



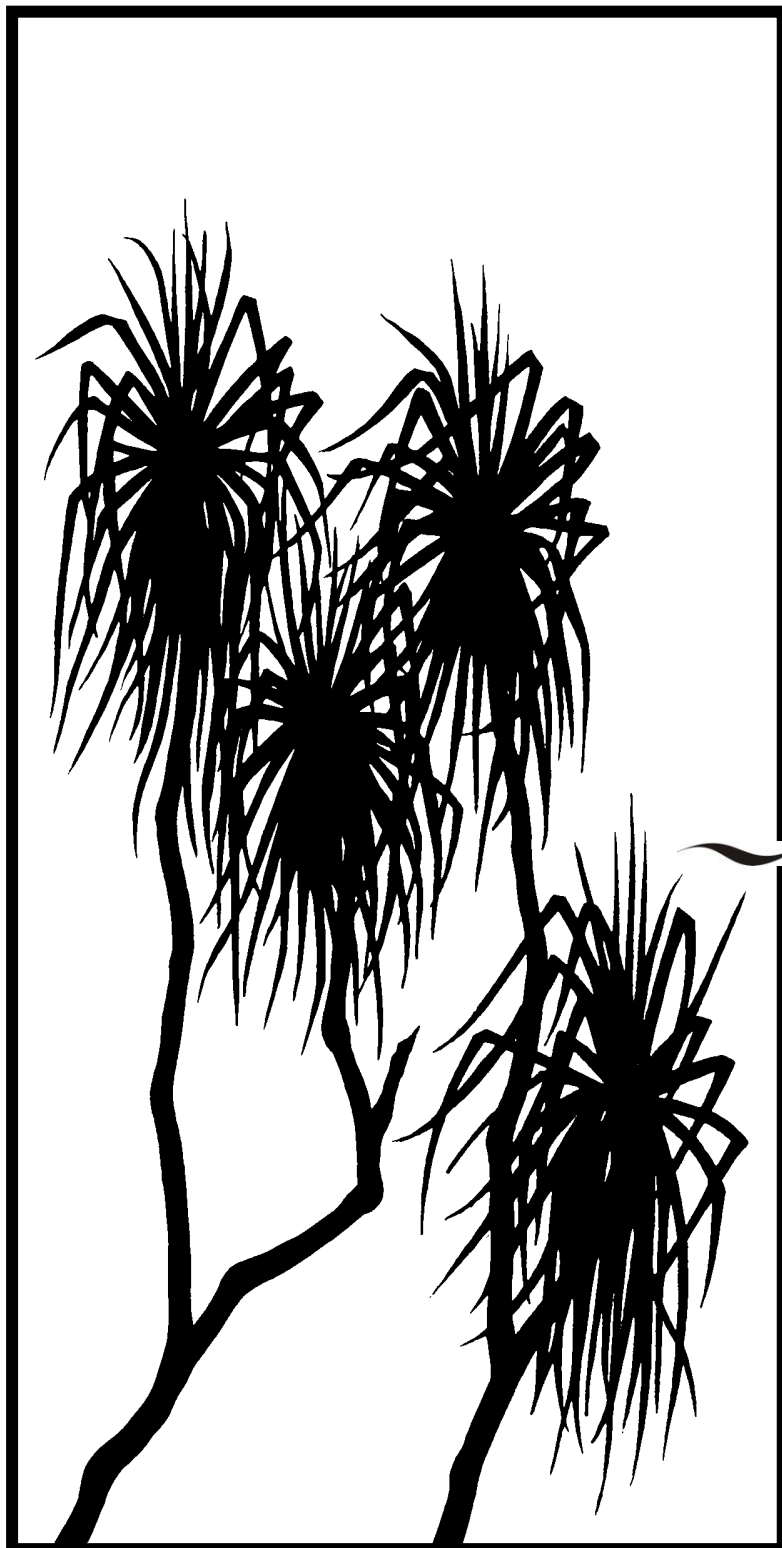
Australian Government

Department of the Environment and Energy

Supervising Scientist

*Internal
Report*

659



**Supervising Scientist
Assessment Report of
2019 Ranger Mine
Closure Plan
Rev #: 1.19.0**

December 2019

Release status — Unrestricted

The Department acknowledges the traditional owners of country throughout Australia and their continuing connection to land, sea and community. We pay our respects to them and their cultures and to their elders both past and present.

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of
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Executive Summary

In October 2019, Energy Resources of Australia Ltd (ERA) submitted its Ranger Mine Closure Plan (RMCP) to the Commonwealth Minister for Resources and Northern Australia and the Northern Territory Minister for Primary Industry and Resources for approval pursuant to Environmental Requirement 9 of the *Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine* (the ERs) attached to ERA's Authority to operate the Ranger uranium mine. The Supervising Scientist is required to advise the Ministers as to whether the implementation of the RMCP is likely to result in achievement of the environmental rehabilitation objectives as set out in the ERs, in particular, the environmental objectives set out in ER 2. This assessment report constitutes the advice of the Supervising Scientist for that purpose.

The ultimate objective of rehabilitation, as stipulated in the ERs, is to prevent long-term impacts to people and the environment surrounding the Ranger Project Area, and to restore the site to a standard that would allow its incorporation into Kakadu National Park. The RMCP provides the key mechanism for ERA to describe, and seek approval for, the rehabilitation strategy. Approval of the technically complex activities will occur independently of the RMCP, by submission of detailed standalone applications for each activity. These standalone applications will be assessed, and once approved, key information from the application should be incorporated into the RMCP. ERA and stakeholders have been working collaboratively to scope and schedule each of the standalone applications, ensuring that each application considers all stakeholder concerns. The Plan must demonstrate that the major rehabilitation activities will achieve the ERs, and to ensure its currency, it is updated and submitted for approval annually.

A significant amount of scientific and technical information has been acquired from research and monitoring undertaken by ERA and the Supervising Scientist over the past 40 years. The RMCP should draw from, and build upon, this knowledge to detail the key risks to the environment, and to present the relevant scientific evidence that justifies the planned approaches to mitigating these risks.

The 2019 version of the RMCP contains significantly more detail compared to the 2018 version. Information from the Ranger Closure Feasibility Study, which was completed in February 2019, has been incorporated, providing refined schedules and costs for specific rehabilitation activities. While the Plan clearly demonstrates that work has been progressing rapidly, there is still a large amount of outstanding information required to address key knowledge gaps. The joint research program developed by ERA and the Supervising Scientist encompasses all of the research required to address the Ranger Key Knowledge Needs and to ensure rehabilitation activities will achieve the ERs. The RMCP presents the studies that will be undertaken by ERA to address the Key Knowledge Needs, and provides clarity around outstanding research requirements. While both organisations are working cooperatively to complete the joint research program in accordance with the current closure schedule, ERA is ultimately accountable for delivering the required outcomes in order to demonstrate that the ERs will be met.

The main area of concern for the Supervising Scientist is in relation to contaminant transport modelling, which is required to assess whether or not the planned rehabilitation activities will prevent future environmental impacts from mine contaminants. To enable assessment, all contaminant sources onsite, including contaminated groundwater and material associated with the Tailings Storage Facility and processing area, must be adequately characterised and appropriately represented in the Ranger conceptual model, and the groundwater and surface water contaminant transport models. At this point in time, the Supervising Scientist does not believe there is sufficient

information provided to support the statements in the RMCP that contaminants from the landform do not pose a risk to the downstream environment.

At this point in time, the Supervising Scientist remains concerned that the work required to complete the contaminant transport modelling may not be completed in time to approve the backfilling of Pit 3 according to the current schedule.

The broad approach to rehabilitation presented in the RMCP demonstrates a reasonable, evidence-based framework for achieving the ERs. ERA and the Supervising Scientist have also been working collaboratively to finalise closure criteria. While a number of criteria are still in draft, significant progress has been made over the last 12 months and it is anticipated that closure criteria will be finalised prior to the next version of the RMCP.

Provided ERA address the comments and recommendations contained in this assessment report, including addressing the Ranger Key Knowledge Needs, the 2019 RMCP satisfies the requirements of ER9.1. The recommendations include the need to complete work required to address the following:

- Detailed contingency plans should be provided for all key activities outlined within the RMCP.
- Further work is required to provide reliable predictions of surface water contaminant concentrations post-closure; including (i) the characterisation of contaminant source terms, including those associated with the Tailings Storage Facility footprint, (ii) verifying the conceptualisation of key groundwater contaminant pathways, and (iii) additional information on the interactions between surface water and groundwater.
- The Revegetation Strategy presented should be expanded to an ecosystem restoration strategy, based on a suitable ecosystem establishment trajectory model which addresses the interdependencies between flora and fauna.
- Additional information is required to give confidence in the ability of the final landform to support vegetation in the long term, particularly concerning soil formation and the establishment of understory species.
- Tailings consolidation modelling should be reviewed to provide greater certainty on consolidation timeframes and the quantity of contaminants which will express into the groundwater. This should consider the heterogeneous nature of the tailings mass and the direction of solute expression. A method to measure tailings consolidation in Pit 3 is required to determine when consolidation is at least 95% complete.
- Further information is required on the rehabilitation of the Tailings Storage Facility, including the extent of contamination within the floor and walls of the dam, the long-term movement of contaminated groundwater from beneath the dam and plans for its remediation, taking into account the potential need to dispose of the contaminated material in Pit 3.
- An assessment of radiation dose to humans and biota from the rehabilitated mine site is required to demonstrate that radiation closure criteria can be met.
- While there is agreement with many of the proposed closure criteria presented in the RMCP, some criteria need further clarification.

1. Introduction

1.1. Requirement

Clause 9.1 of the *Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine* (ERs) states:

9.1 The company must prepare a rehabilitation plan which is approved by the Supervising Authority and the Minister with the advice of the Supervising Scientist, the implementation of which will achieve the major objectives of rehabilitation as set out in subclause 2.2, and provide for progressive rehabilitation.

The initial RMCP was submitted for assessment by ERA in May 2018 in accordance with ER 9.1 and an assessment report was subsequently published by the Supervising Scientist in September 2018 (Supervising Scientist 2018). The current assessment report contains the outcomes of a detailed assessment by the Supervising Scientist of the October 2019 revised RMCP, with the main objective being to determine whether the plan demonstrates a reasonable and evidence-based path for achieving the Environmental Requirements. It constitutes the advice of the Supervising Scientist to the Supervising Authority, being the Northern Territory (NT) Minister for Primary Industry and Resources and the Australian Government Minister for Resources and Northern Australia.

In accordance with Annex B of the Ranger Authorisation (0108) and Section 34 of the NT *Mining Management Act*, the RMCP is required to be updated and submitted for assessment annually on 1 October.

1.2. Statutory Framework

Ranger is subject to both Commonwealth and NT legislation. This is because the Australian Government retains ownership of uranium resources in the NT and because Ranger, like all mining operations in the NT, must satisfy obligations imposed by NT law. The following sections provide an overview of statutory requirements pertaining to the rehabilitation of the Ranger mine.

For the purpose of this report the Australian Government Minister for Resources and Northern Australia will be referred to as the 'Commonwealth Minister', and the Northern Territory Minister for Primary Industry and Resources will be referred to as the 'NT Minister'. Collectively they will be referred to as the regulatory authorities.

1.2.1. Atomic Energy Act 1953

The *Atomic Energy Act 1953* (AEA) reserves ownership of prescribed substances, including uranium, with the Commonwealth in all Commonwealth Territories.

Ranger mine operates under an s41 Authority issued under the AEA. The *Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine* are attached to the s41 Authority.

The initial s41 Authority was entered into on 9 January 1979 and subsequently extended for a further 26 years from 9 January 2000.

Under the current s41 Authority, mining and milling activities on the Ranger Project Area must cease on (or by) 8 January 2021, and rehabilitation works must be completed on (or by) 8 January 2026.

The s41 Authority cannot be further extended without amendment to the AEA.

1.2.2. Commonwealth Environmental Requirements

The *Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine* (ERs), attached to the Ranger Authority issued under s41 of the *Atomic Energy Act 1953*, set out the environmental protection conditions with which the operator must comply. The ERs are also given effect through the Ranger Authorisation issued under the Northern Territory *Mining Management Act* and are attached to and referenced in a number of other agreements.

The Ranger ERs specify the primary and secondary environmental objectives to be achieved during the life of the mine and after closure. The primary environmental objectives focus on maintaining the World Heritage attributes of Kakadu National Park and the ecosystem health of the wetlands for which Kakadu is listed as a Ramsar site, for protecting the health of people living in the region and preventing change to the biological diversity and ecological processes in the region. Impacts within the Ranger Project Area (Figure 1) are to be as low as reasonably achievable.

The primary environmental objectives specifically relating to rehabilitation are, in summary, to establish an environment with habitats and erosion characteristics similar to the adjacent areas of Kakadu National Park and stable radiological conditions with doses that comply with national requirements and are as low as reasonably achievable. Tailings must be placed into the mined-out pits in a way that ensures physical isolation from the environment and prevents any detrimental environmental impacts from contaminants arising from tailings for at least 10,000 years. Moreover, surface or ground waters discharging from the Ranger Project Area during and after rehabilitation must not compromise the achievement of the above primary environmental objectives.

The primary environmental objectives pertaining to the rehabilitation of Ranger mine are detailed in Table 1.

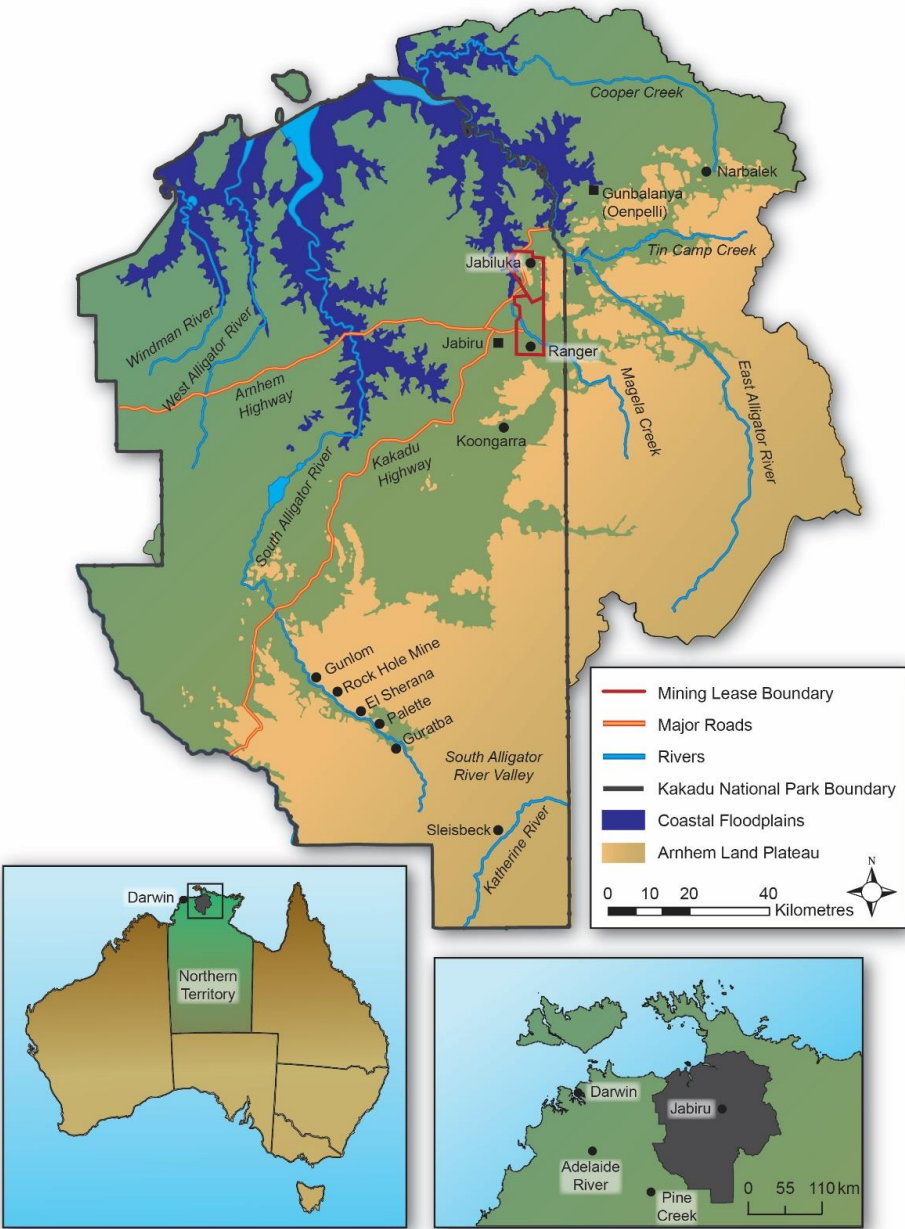


Figure 1. Location of the Ranger Project Area.

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Table 1. Ranger Environmental Requirements that are related to rehabilitation

Clause	Relevant Environmental Requirements
<i>Environmental protection</i>	
1.1	<p>The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:</p> <ul style="list-style-type: none"> (a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list; (b) maintain the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park); (c) protect the health of Aboriginals and other members of the regional community; and (d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes.
1.2	<p>In particular, the company must ensure that operations at Ranger do not result in:</p> <ul style="list-style-type: none"> (a) damage to the attributes for which Kakadu National Park was inscribed on the World Heritage list; (b) damage to the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park); (c) an adverse effect on the health of Aboriginals and other members of the regional community by ensuring that exposure to radiation and chemical pollutants is as low as reasonably achievable and conforms with relevant Australian law, and in particular, in relation to radiological exposure, complies with the most recently published and relevant Australian standards, codes of practice, and guidelines; (d) change to biodiversity, or impairment of ecosystem health, outside of the Ranger Project Area. Such change is to be different and detrimental from that expected from natural biophysical or biological processes operating in the Alligator Rivers Region; and (e) environmental impacts within the Ranger Project Area which are not as low as reasonably achievable, during mining excavation, mineral processing, and subsequently during and after rehabilitation.
<i>Rehabilitation</i>	
2.1	<p>Subject to subclauses 2.2 and 2.3, the company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu National Park, such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu National Park.</p>

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Clause	Relevant Environmental Requirements
2.2	<p>The major objectives of rehabilitation are:</p> <ul style="list-style-type: none"> (a) revegetation of the disturbed sites of the Ranger Project Area using local native plant species similar in density and abundance to those existing in adjacent areas of Kakadu National Park, to form an ecosystem the long-term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park; (b) stable radiological conditions on areas impacted by mining so that, the health risk to members of the public, including traditional owners, is as low as reasonably achievable; members of the public do not receive a radiation dose which exceeds applicable limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines; and there is a minimum of restriction on the use of the area; (c) erosion characteristics which, as far as can reasonably be achieved, do not vary significantly from those of comparable landforms in surrounding undisturbed areas.
2.3	Where all major stakeholders agree, a facility connected with Ranger may remain in the Ranger Project Area following termination of the Authority, provided that adequate provision is made for eventual rehabilitation of the affected area consistent with principles for rehabilitation set out in subclauses 2.1, 2.2 and 3.1.
3.1	The company must not allow either surface or ground waters arising or discharged from the Ranger Project Area during its operation, or during or following rehabilitation, to compromise the achievement of the primary environmental objectives.
9.1	The company must prepare a rehabilitation plan which is approved by the Supervising Authority and the Minister with the advice of the Supervising Scientist, the implementation of which will achieve the major objectives of rehabilitation as set out in subclause 2.2, and provide for progressive rehabilitation.
9.2	All progressive rehabilitation must be approved by the Supervising Authority or the Minister with the advice of the Supervising Scientist and subject to the Northern Land Council agreeing that the aim and objectives for rehabilitation as described in clause 2 are met.
9.3	The company's obligations under clause 9 will cease in respect of any part of the Ranger Project Area over which a close-out certificate is issued by the Supervising Authority subject to the Supervising Scientist and the Northern Land Council agreeing that the specific part of the Ranger Project Area has met the requirements of clause 2.
9.4	Where agreements under subclause 9.2 or 9.3 cannot be reached the Minister will make a determination with the advice of the Supervising Scientist.
11.1	During mining operations and prior to final placement, covering and rehabilitation of the tailings, tailings must be securely contained in a manner approved by the Supervising Authority or the Minister with the advice of the Supervising Scientist which prevents detrimental environmental impact.
11.2	By the end of operations all tailings must be placed in mined-out pits.
11.3	<p>Final tailings disposal of tailings must be undertaken, to the satisfaction of the Minister with the advice of the Supervising Scientist on the basis of the best-available modelling, in such a way to ensure that:</p> <ul style="list-style-type: none"> (i) the tailings are physically isolated from the environment for at least 10,000 years (ii) any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years (iii) radiation doses to members of the public will comply with relevant Australian law and be less than limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines effective at the time of the final tailings disposal.

1.2.3. Environment Protection (Alligator Rivers Region) Act 1978 (Cwlth)

The *Environment Protection (Alligator Rivers Region) Act 1978* establishes the position and duties of the Supervising Scientist for protection of the environment of the Alligator Rivers Region from the effects of uranium mining.

The Supervising Scientist conducts research programs into the environmental effects of uranium mining in the Alligator Rivers Region, develops standards and practices for environmental protection, undertakes environmental monitoring, participates in and oversees the regulatory process and provides advice to regulatory authorities and mine operators. The Supervising Scientist plays a fundamental role in communicating research and monitoring results to assure Governments, and the public, that the environment of the Alligator Rivers Region remains protected from the effects of mining.

The Supervising Scientist Branch sits within the Department of the Environment and Energy, supporting the Minister for the Environment. The Supervising Scientist is required to provide technical advice to the Commonwealth Minister and NT Minister on rehabilitation and closure-related activities at Ranger mine.

The Act also establishes the Alligator Rivers Region Technical Committee (ARRTC) to advise the Minister for the Environment on the quality and relevance of the research conducted by the Supervising Scientist and ERA. The committee comprises a panel of independent scientists recognised for their expertise in relevant fields, and whose current focus is on the various areas of minesite rehabilitation.

1.2.4. Mining Management Act (NT) and Authorisation

The *Mining Management Act* regulates mining in the Northern Territory and ERA undertakes operations and activities at Ranger in accordance with the terms of an Authorisation granted under s35 of the MMA by the NT Minister.

The NT Government is the day-to-day regulator of Ranger but is required to consult with the Australian Government on key matters. The Northern Territory Department of Primary Industry and Resources chairs the Ranger MTC, which also includes the Supervising Scientist, the Northern Land Council, the Gundjehmi Aboriginal Corporation and ERA. The MTC has no decision-making authority or approval powers. Rather, the role of the MTC is to provide a forum where all key stakeholders can remain abreast of current activities and have informed discussions before the regulatory authorities make a determination.

1.2.5. Rehabilitation Approval Responsibilities

Responsibility for the approval of rehabilitation and closure activities at Ranger is generally shared by the Commonwealth and NT Ministers. Both Ministers must approve the RMCP, the final disposal of tailings, and the issue of a close out certificate(s) for the Ranger Project Area (all or part). The regulatory framework also provides for consultation with key stakeholders. In addition, the ERs require Ministers to seek the advice and, where necessary, the agreement of the Supervising Scientist and the Northern Land Council when making these decisions.

Less complex matters are generally decided by the NT Minister alone. For example, the NT Minister generally approves progressive rehabilitation of the Ranger Project Area with the advice of the Supervising Scientist and agreement of the Northern Land Council that the aim and objectives for rehabilitation as described in ER 2 are met (ER 9.2). The NT Minister may also approve the secure containment of tailings, during operations and prior to final disposal, with the advice of the Supervising Scientist (ER 11.1).

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The Commonwealth Minister can make a final determination on specific rehabilitation and closure matters where there is disagreement between the NT Government, Supervising Scientist and Northern Land Council.

The rehabilitation of Ranger mine is not subject to assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Actions that started before the EPBC Act coming into force on 16 July 2000 are exempt from assessment and approval under the EPBC Act, including mining and rehabilitation at Ranger mine which commenced in 1980. The ERs were revised in 1999 and include rehabilitation requirements.

1.2.6. Rehabilitation and Closure Planning Documents

The first RMCP was submitted for assessment by ERA in May 2018 in accordance with ER 9.1 and an assessment report was subsequently published by the Supervising Scientist in September 2018 (Supervising Scientist 2018). The May 2018 RMCP was approved by the NT and Commonwealth Ministers in December 2018.

The regulatory authorities and stakeholders have agreed that some aspects of rehabilitation works would be approved within the plan, while other more complex aspects that require substantial supporting technical information would be subject to a separate assessment and approval process. A summary of the information included in these standalone applications and the outcomes of their assessment would then be included in subsequent updates of the RMCP.

In parallel with the RMCP, ERA submits an Annual Plan of Rehabilitation (APR), prepared in accordance with the requirements of the Ranger Uranium Project Government Agreement between ERA and the Commonwealth Government. The APR is intended to provide the conceptual specifications for rehabilitation works and methodology for an unplanned premature cessation of operations at Ranger mine, along with a supporting cost estimate.

1.2.7. Closure Criteria

ERA's obligation to submit a RMCP will cease when the Commonwealth and NT Ministers issue a close-out certificate the Ranger Project Area, in its entirety (ER 9.3). Prior to taking that decision, Ministers must seek the advice of the Supervising Scientist and the Northern Land Council must agree that that specific part of the Ranger Project Area meets the rehabilitation objectives described in ER 2.

ERA has proposed closure criteria to quantify the rehabilitation objectives within the ERs and provide a clear and objective basis for the Supervising Scientist and the Northern Land Council to determine when the rehabilitation objectives have been met.

Closure criteria require approval by both the NT Minister and the Commonwealth Minister. An assessment of the closure criteria proposed in the RMCP has been included in this assessment report. A commentary is provided in cases where closure criteria require further information.

1.3. Supervising Scientist's Rehabilitation Standards

In accordance with s5c of the *Environment Protection (Alligator Rivers Region) Act 1978*, the Supervising Scientist has developed a series of Rehabilitation Standards for Ranger mine against which the success of rehabilitation can be measured. These standards are advisory only and are available on the Supervising Scientist's website (environment.gov.au/science/supervising-scientist).

The Rehabilitation Standards are based on nearly 40 years of research undertaken by the Supervising Scientist to provide scientific, evidence-based benchmarks that represent the best

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environmental outcomes for the rehabilitation of Ranger mine. The standards are intended to quantify the key rehabilitation objectives stipulated in the ERs and provide measurable targets against which the success of rehabilitation can be assessed. As such, they provide the basis for the Supervising Scientist's assessment of the closure criteria proposed in the RMCP.

A list of the Rehabilitation Standards is provided in Table 2 below.

Table 2 The Supervising Scientist's Rehabilitation Standards

Closure theme	Title of Rehabilitation Standard
Water and Sediment	Magnesium in Surface Water
	Uranium and Manganese in Surface Water
	Ammonia in Surface Water
	Sulfate in Surface Water
	Low-Risk Metals in Surface Water
	Turbidity and Sedimentation (<i>In preparation</i>)
Ecosystem Restoration and Landform	Landform Stability
	Ecosystem Restoration
Radiation	Public Radiation Protection
	Environmental Radiation Protection

1.4. Ranger Key Knowledge Needs

The Ranger KKNs represent the outstanding knowledge required to ensure that the rehabilitation activities proposed by ERA will achieve the environmental objectives and hence satisfy the ERs.

The KKNs are based on the outcomes of a comprehensive screening-level ecological risk assessment conducted on the rehabilitation of Ranger mine. This risk assessment was undertaken in collaboration with ARRTC, ERA, the Northern Land Council, the Gundjeihmi Aboriginal Corporation, CSIRO and other key stakeholders. Regulatory agencies were invited to participate as they saw fit.

The EPARR Act establishes ARRTC to advise the Minister for the Environment on the quality and relevance of the research conducted by the Supervising Scientist and ERA. ARRTC includes a panel of independent scientists, each recognised for their eminent expertise in fields related to the rehabilitation of impacted sites, including minesites. ARRTC formally endorsed the KKNs in November 2016, and these were subsequently published by the Supervising Scientist in 2017 (Supervising Scientist 2017). In early 2018, the Supervising Scientist reviewed and consolidated the KKNs, aligning them more closely with the relevant Ranger ERs. This consolidation process reduced the total number of KKNs from 125 to 32, all the while ensuring that the information from the original KKNs was retained. The revised KKNs are attached to this report at Appendix 2.

Figure 2 provides an overview of the research planning process undertaken by the Supervising Scientist, based on the KKNs, and resulting in a 10-year research plan to inform the rehabilitation of Ranger mine.

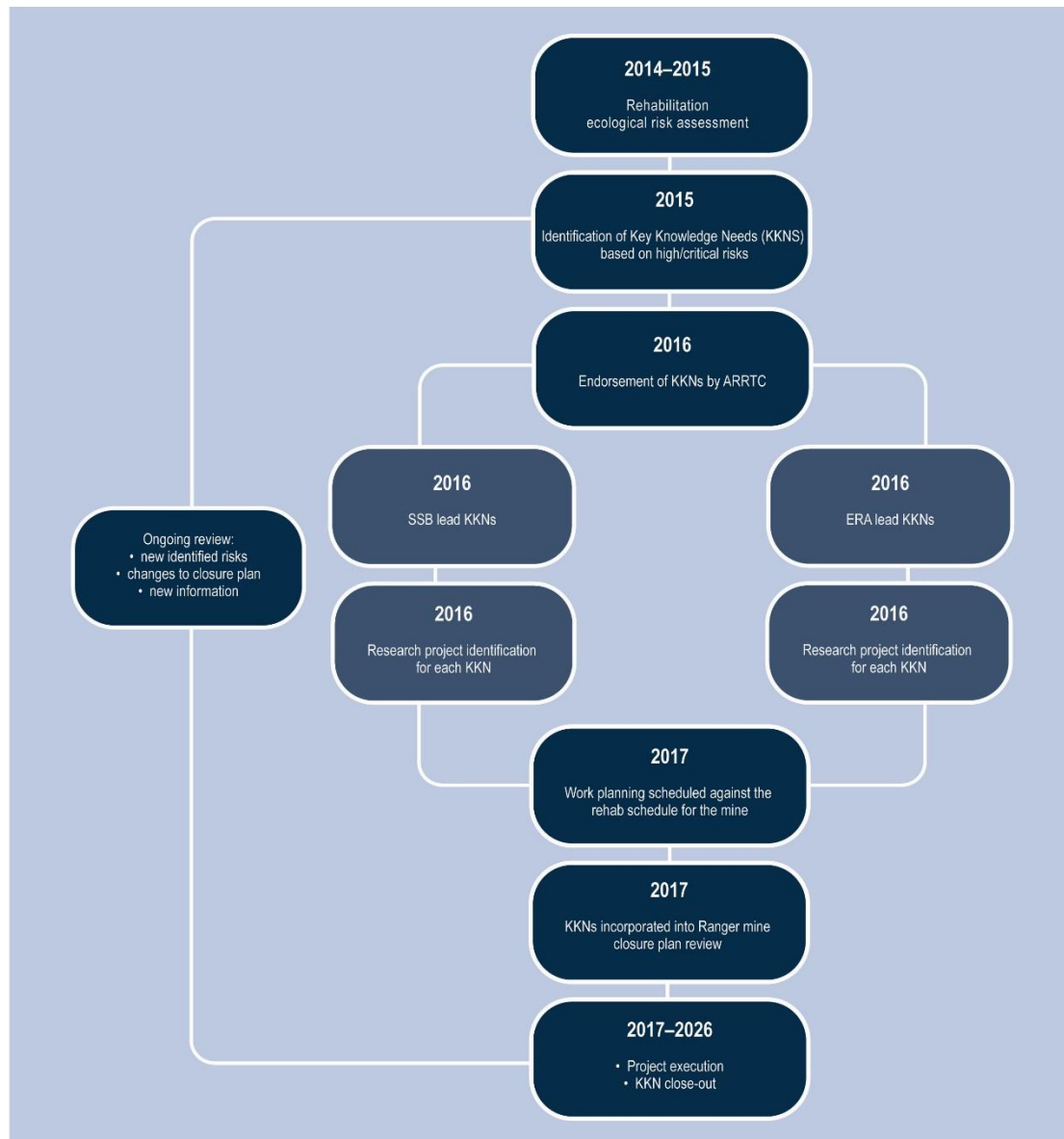


Figure 2. Process for development and review of Supervising Scientist's research program for Ranger mine.

While ultimate responsibility for rehabilitation outcomes at Ranger mine rests with ERA, both ERA and the Supervising Scientist maintain active research programs directed at informing these outcomes. ERA or the Supervising Scientist may either lead a KKN or share responsibility for a KKN. Research projects to be conducted over the next 7 years have been established and are scheduled against the mine rehabilitation schedule. The KKNs have also been acknowledged in the RMCP as the basis of the research program to ensure the adequacy of the proposed rehabilitation activities. To address the KKNs in the timeframe required, it will be important for ERA and the Supervising Scientist to continue to maintain a coordinated and collaborative research program. The Ranger KKNs are presented in Appendix 2 of this report and as they are completed over time (or stakeholders agree that a given KKN is no longer required), this will be reflected in their removal from recommendations provided by the Supervising Scientists in future assessments of the RMCP.

An evidence-based process has been developed to formally modify, close out or add KKNs. Close out of KKNs can occur when (i) the knowledge required by the KKN has been acquired, or (ii)

the KKN is no longer relevant or necessary. Addition of new KKNs may be required where new issues emerge or additional knowledge is required to inform existing issues. The views of both the MTC and ARRTC will be sought before modifying, closing out and adding new KKNs.

The recommendations within this assessment report have been cross-referenced with the KKNs. Where sufficient information has been acquired to fully address a KKN, as detailed and justified in the RMCP, its close out should be proposed. Alternatively, where additional knowledge needs have been identified through this review, a new KKN may be required. As such, the KKNs represent the additional research information required to underpin the RMCP and demonstrate the ERs can be achieved.

1.5. Engagement with ERA

In addition to the formal regulatory and stakeholder engagement processes (i.e. Minesite Technical Committee, ARRAC/ARRTC), substantial consultation occurs between ERA, the Supervising Scientist and other key stakeholders to facilitate the sharing of relevant information and reach agreement on various aspects of the Ranger closure planning process. Some examples of these include:

- Ranger Closure Consultative Forum
- Ecosystem Restoration Working Group
- Monitoring Evaluation and Research Review Group
- Water and Sediment Working Group
- Regular technical meetings between ERA and Supervising Scientist and other key stakeholders.

1.6. Assessment Report Purpose and Structure

This assessment report documents the outcomes of the Supervising Scientist's technical review and assessment of the RMCP. It also includes recommendations for further work required to provide additional information supporting the rehabilitation activities detailed in the RMCP.

This report will be provided to the Ranger MTC and the regulatory authorities as the advice of the Supervising Scientist in accordance with ER 9.

This report assesses whether sufficient information was provided in the RMCP to:

- describe the proposed rehabilitation activities and detail how and when these activities will be conducted, including any environmental protection measures to be implemented while works are underway
- demonstrate that these activities will result in the achievement of the environmental objectives in the ERs
- demonstrate that proposed closure criteria appropriately represent the environmental objectives in the ERs, and are sufficiently clear and measurable to allow for the future determination of their achievement
- demonstrate that appropriate provisions have been made to enable the implementation of effective contingency measures in the event that the rehabilitation works do not occur as planned (e.g. long-term water treatment to manage contamination issues should they occur).

Chapters 3 and 4 consider whether:

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- environmental risks associated with rehabilitation process, and the rehabilitated site, have been identified and adequately assessed and mitigated
- proposed rehabilitation strategies are based on the best available science, including reference to relevant international experience and the principles of BPT.

Chapters 5 to 9 divide the Supervising Scientist's advice on the RMCP according to these closure 'themes':

- Landform
- Water and Sediment
- Radiation
- Soils
- Ecosystem Restoration.

The ERs relevant to each theme have been listed in each chapter, along with an indication of whether sufficient information has been presented in the RMCP to demonstrate that each ER will be achieved.

Chapter 10 details the Supervising Scientist's advice on the proposed closure and post-closure monitoring programs.

The Cultural Criteria presented in the RMCP were not included in the Supervising Scientist's review, and hence are not discussed in this report. Both the Northern Land Council and the Gundjeihmi Aboriginal Corporation will provide advice on the suitability of the Cultural Criteria.

Appendix 3 provides all of the Supervising Scientist's detailed comments on the 2018 RMCP along with ERA's responses. New comments on the 2019 RMCP are summarised in Appendix 4, however these should be read in conjunction with the report.

2. General Observations

The RMCP is a substantial document that provides the necessary overview of the planned approach and key strategies for the rehabilitation and closure of Ranger mine. The 2019 revised RMCP represents a significant improvement on the 2018 plan with an increased level of detail incorporated from ERA's Feasibility Study.

2.1. RMCP Structure and Scope

The RMCP is a generally well-presented document and structured according to the Western Australian guidelines for mining rehabilitation plans. In particular, Chapter 11 presents a good overview of the major rehabilitation activities. The flow of information may be improved by enhancing the cross-referencing between the risk assessment, the supporting studies and the implementation chapters. This would help to link the key risks directly to the closure objectives and end land use, and demonstrate how the planned activities will mitigate these risks.

ERA has made a significant improvement in identifying knowledge gaps in the 2019 RMCP, linking these to relevant Key Knowledge Needs (KKNs) and providing a list of current and planned research projects and investigations to address these. In some cases, it is unclear whether the scope or timing of a given project will provide the required information when it is needed (e.g. to inform a standalone application for a key rehabilitation activity). To ensure that the required information is available when it is needed during the rehabilitation process, this will need to be addressed in the near future via consultation between ERA and relevant stakeholders.

2.2. Key Assumptions

In order to schedule all rehabilitation activities between now and January 2026, many assumptions have been made, particularly with respect to engineering works and modelling. The RMCP would be improved by clearly articulating key assumptions and describing reasonable alternative options should the assumption fail to be achieved.

For example, it is assumed that the material from the Tailings Storage Facility walls and floor, and groundwater beneath the Tailings Storage Facility, may remain in place without any remediation. Evidence has not yet been provided to demonstrate this strategy will not pose a risk to the offsite environment, and no contingencies or alternative options to this approach have been presented in the RMCP. A number of investigations are planned to characterise and quantify the contamination in the wall and floor materials and groundwater. If these investigations and additional modelling work indicate that the material cannot remain in place and needs to be relocated and disposed of in Pit 3, it is likely that this will have significant implications on schedule, costs and potential environmental outcomes.

The site water balance modelling (OPSIM) that is used to predict future volumes of process water requiring treatment is discussed in the RMCP; however, the OPSIM model presented is from August 2018 and is out of date. The OPSIM model necessarily incorporates a number of assumptions around the future implementation and optimisation of water treatment processes. The approval status of these assumptions should be clarified throughout the RMCP, as some of the proposed strategies are yet to be approved (e.g. the use of a High Density Sludge plant to treat process water). Inferring these processes are approved and underway is incorrect and makes it difficult to identify them as assumptions, or potentially non-viable engineering outcomes, that should be accompanied with alternative options and appropriate contingencies.

2.3. Contingencies

The RMCP describes the activities and schedule for the successful rehabilitation of Ranger mine, based on the scenario that the project meets budget and timeline. The plan doesn't adequately address the uncertainty associated with this scenario, and doesn't present sufficient information to demonstrate that contingency options have been developed for failure scenarios for major activities.

The RMCP presents information on some contingency measures for the key approved activities, and it is stated that contingency planning will form part of the BPT and risk analysis assessments for future applications of key activities (i.e. deconstruction of Tailings Storage Facility, deconstruction of processing plant, final landform). Further detail should be provided for each contingency, including the:

- level of confidence in its likely effectiveness
- timing of implementation
- impact on the overall closure schedule, including consequential effects on other related activities.

The RMCP could be improved by incorporating more failure scenarios and demonstrating how contingency measures will mitigate the associated environmental risks (e.g. the impact of multiple above-average rainfall wet seasons and how this excess water will be managed and treated).

2.4. Contaminants

Some uncertainty remains in relation to the nature and extent of potential future contaminant sources on the site. This includes contaminated groundwater plumes in the processing area and Tailings Storage Facility; and contaminated soils in the Land Application Areas, processing areas and Tailings Storage Facility floor and walls. Better understanding of the types and amounts of contaminants present, as well as their potential to move into the offsite environment, is required to enable contaminants to be managed and disposed of in a way that ensures their long-term containment. ERA is currently undertaking a comprehensive suite of site investigations and modelling that aims to identify and measure the type and extent of contaminant sources across the site, and to predict the future behaviour of contaminants during and after rehabilitation.

This information is also critical to ensure that predictions of future contaminant concentrations in Magela and Gulungul Creek at the boundary of the Ranger Project Area are as accurate as possible. These predictions are required to enable assessment of the potential future impacts arising from mine contaminants to the offsite environment, and should account for all major contaminant sources on site, including (but not limited to) tailings, waste rock, contaminated soils and existing contaminated groundwater. This assessment must be undertaken prior to approval and commencement of the Pit 3 backfill.

ERA and the Supervising Scientist have been working collaboratively throughout the development of a suite of models that must be integrated to ensure reliable surface water contaminant predictions. It is recommended that future investigations focus on adequately characterising the nature and extent of contamination across the site, and acquiring sufficient knowledge of surface water/groundwater interactions to ensure appropriate modelling of the spatial and temporal aspects of contaminant migration and dispersion from contaminant source terms into Magela and Gulungul Creeks. This will enhance the understanding of possible contaminant plumes that may impact on the surrounding environment, including their concentrations, arrival time and location.

2.5. Closure Schedule

The RMCP describes the activities required to be undertaken to ensure the successful rehabilitation and closure of the Ranger mine in accordance with the ERs, and based on the principal scenario that all activities can be completed by the deadline of January 2026. This deadline is a key driver for the closure plan and schedule, and an important consideration for ERA in sequencing the different rehabilitation activities. However, it is critical that the deadline does not result in compromises to the long-term environmental outcomes.

While work has been progressing rapidly, there is still a large amount of outstanding information required to ensure that remediation planning is appropriate, to support key assumptions and to complete the contaminant transport modelling. The Supervising Scientist remains concerned that this work may not be completed in time to approve the backfilling of Pit 3 according to the current schedule.

The RMCP would be improved by including more detail about future standalone applications. The RMCP should include a table detailing the application, the expected date for submission, the date approval is required by, a description of the scope of the application and the information it will provide. It is important for ERA and stakeholders continue to work closely together to define and agree on the application requirements and scopes.

2.6. Closure Criteria

Nearly all closure criteria have been finalised amongst stakeholders. However, further information and consultation is needed for some criteria relating to Soils and Ecosystem Restoration:

- Radiation – all finalised
- Landform – all finalised
- Water and Sediment – 2/6 finalised, others in draft
- Soils – all in draft
- Ecosystem Restoration – 2/12 finalised, others in draft

Stakeholder consultation to finalise closure criteria is being undertaken via the Water and Sediment Working Group, the Ecosystem Restoration Group and regular technical engagement meetings being held between the Supervising Scientist and ERA. SSB and ERA are working to ensure that all closure criteria are agreed by the next iteration of the RMCP (i.e. October 2020).

2.7. Closure Monitoring

The information presented in the RMCP on closure monitoring represents a significant improvement to that presented in the 2018 Plan. The RMCP refers to different monitoring phases, i.e. closure monitoring which is underway now and will continue throughout progressive rehabilitation, and post-closure monitoring which will commence after January 2026 and continue until closure criteria have been met (estimated period of 25 years). The RMCP presents clear monitoring objectives, including:

- ensuring adequate data are collected to review, optimise and improve confidence that the proposed progressive rehabilitation will achieve the ERs (enabling an adaptive management approach),
- ensuring adequate data are collected to validate various models, and
- evaluation of performance against closure criteria.

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ERA is working collaboratively with all stakeholders to develop detailed monitoring programs that will ensure the achievement of these objectives. However, under the current legislative framework (Ranger Authorisation under the Atomic Energy Act 1953 - section 41c (5) of the Authority (Nov 1999)) (Section 3.1.2), access to the Ranger Project Area will cease on 8 January 2026. Discussions are currently underway with key stakeholders to ensure that ERA is able to access the site beyond 2026 to undertake the monitoring and maintenance activities described in the RMCP.

3. Risk Assessment

The risk assessment in the RMCP details a range of different risk scenarios which include risks to human health and safety, risks to the natural environment and achievement of the Environmental Requirements, risks to the success of rehabilitation and risks to ERA's reputation and *licence to close*. It appears that the assessment has been conducted following generally accepted methods of risk assessment.

While the Supervising Scientist is satisfied that the significant risks associated with the current Plan have been identified, more detail is required to fully justify the ranking of each of the risk scenarios. It would also be useful if the RMCP made a clear distinction between existing controls and proposed controls, and provided evidence to demonstrate that controls are appropriate to mitigate the identified risks.

While examining risks individually is no longer considered to be best practice as it does not account for the potential interactions between risks, it is noted that ERA and SSB are undertaking a cumulative risk assessment to examine the effects of combined and integrated risks. This risk assessment has been identified as a KKN (CT1). Although it is acknowledged in the RMCP that the outcomes of this work will be used to update the risk assessment, more specific information should be provided in relation to the scope and frequency of these reviews and how they will inform future iterations of the plan. To redress these deficiencies, the risk assessment should include:

- evidence to substantiate the likelihood and consequence rankings, including key assumptions, adequacy and currency of technical information/advice (e.g. based on the latest industry experience) and any uncertainty associated with the information used in this evaluation
- a clear distinction between the existing and proposed controls for the planned closure scenario, along with evidence to support control adequacy and effectiveness, including consideration of control applicability or availability during the three closure phases (i.e. decommissioning, stabilisation and monitoring and post-closure)
- a section that describes the major contingencies that will be implemented should failure of the existing and proposed controls result in unplanned closure scenarios
- a plan to obtain additional information to update the risk assessment over time, as required (i.e. what would trigger an update of the risk assessment?).

3.1. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 4. The table also includes ERA's response to the recommendations, which were provided in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response.

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Table 4. Summary of recommendations pertaining to the risk assessment

Supervising Scientist Recommendation on 2018 RMCP
<p>In the next version of the RMCP provide further information to justify the assignment and ranking of risks, risk classes, controls and control effectiveness, and including the outcomes of an assessment of cumulative risks to the success of rehabilitation and to the protection of the offsite environment (CT1).</p> <p><i>Key Knowledge Needs to be addressed:</i></p> <ul style="list-style-type: none"> CT1. Assessing the cumulative risks to the success of rehabilitation and the protection of the offsite environment.
ERA Response in 2019 RMCP
<p>The 2019 MCP includes further information to justify the assignment and ranking of risks, risk classes and controls. It is acknowledged that further development and refinement will be achieved in the 2020 risk assessment update, and these continual improvements will be included within each MCP update. KKN CT1. <i>Assessing the cumulative risks to the success of rehabilitation on-site and to the protection of the off-site environment/CT1A. What are the cumulative risks to the success of rehabilitation on-site and to the off-site environment?</i> is a joint responsibility for completion between ERA and SSB and is currently 90% complete. Update of results from related projects will be included within the 2020 MCP.</p>
Adequacy of ERA response in 2019 RMCP
<p>The structure of the risk assessment presented in the 2019 RMCP has been updated. It would be improved by including more information to justify the assignment and ranking of risks and risk classes. The controls could be further categorised to delineate between controls (i.e. mitigation measure for the current planned closure scenario) and contingencies (i.e. mitigation measures for alternative unplanned closure scenarios). Controls should be described as existing or proposed, and should all be supported with relevant evidence to demonstrate their likely adequacy and effectiveness.</p>

4. Best Practicable Technology

4.1. Relevant Environmental Requirements

Section 12 of the ERs requires that all aspects of the ERs must be implemented using the best practicable technology (BPT), as shown in Table 5.

The ERs define BPT as the technology relevant to the Ranger Project that produces the maximum environmental benefit that can be reasonably achieved, considering various relevant matters including current world leading practice, available resources, evidence of environmental impacts, location, the ages of equipment and facilities, and social factors. Proposals to undertake rehabilitation activities on the Ranger Project Area must be supported by a BPT analysis, the rigour of which should be commensurate with the potential environmental significance of the proposal.

Table 5. Ranger Environmental Requirements relevant to best practicable technology

Clause	Environmental Requirements
12.1	All aspects of the Ranger Environmental Requirements must be implemented in accordance with BPT.
12.2	Where there is unanimous agreement between the major stakeholders that the primary environmental objectives can be best achieved by the adoption of a proposed action which is contrary to the Environmental Requirements, and which has been determined in accordance with BPT, that proposed action should be adopted. Where agreement cannot be reached the Minister will make a determination with the advice of the Supervising Scientist.
12.3	All environmental matters not covered by these Environmental Requirements must be dealt with by the application of BPT.
12.4	<p>BPT is defined as:</p> <p>That technology from time to time relevant to the Ranger Project which produces the maximum environmental benefit that can be reasonably achieved having regard to all relevant matters including:</p> <ul style="list-style-type: none"> (a) the environmental standards achieved by uranium operations elsewhere in the world with respect to <ul style="list-style-type: none"> (i) level of effluent control achieved (ii) the extent to which environmental degradation is prevented (b) the level of environmental protection to be achieved by the application or adoption of the technology and the resources required to apply or adopt the technology so as to achieve the maximum environmental benefit from the available resources (c) evidence of detriment, or lack of detriment, to the environment (d) the physical location of the Ranger Project (e) the age of equipment and facilities in use on the Ranger Project and their relative effectiveness in reducing environmental pollution and degradation (f) social factors including the views of the regional community and possible adverse effects of introducing alternative technology.

Clause	Environmental Requirements
12.5	Proposals to amend or introduce operational approaches, procedures or mechanisms must be supported by a BPT analysis. The rigour of the BPT analysis must be commensurate with the potential environmental significance of the proposal. The BPT analysis must involve consultation with and having regard to the views of the major stakeholders and copies of the BPT analysis must be provided to each of the major stakeholders.
12.6	A precautionary approach is to be exercised in the application of BPT in order to achieve outcomes consistent with the primary environmental objectives.

4.2. Application of BPT

ERA has a rigorous BPT assessment process that has been reviewed previously and endorsed by all stakeholders. The RMCP includes summaries of the BPT assessments undertaken to date, as well as planned BPT assessments that will be undertaken for proposed rehabilitation activities and submitted for approval as part of standalone applications. All BPT assessments should include a wide range of options, taking into account relevant national and international experience and precedents where they exist.

4.3. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 6. The table also includes ERA's response to the recommendations, which were provided in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response.

Table 6. Summary of recommendations about best practicable technology (BPT)

Supervising Scientist Recommendation on 2018 RMCP
In the next version of the RMCP identify the full range of planned (or potentially required) BPT assessments.
ERA Response in 2019 RMCP
The BPT Section of the MCP has been expanded to make reference to all BPT assessments completed and planned.
Adequacy of ERA Response in 2019 RMCP
While the BPT section has been expanded (Section 9), the RMCP should include a clear rationale for determining which activities will be subject to BPT assessment, and which activities will not.

5. Closure Theme: Landform

5.1. Relevant Environmental Requirements

The Landform closure theme covers the physical aspects of the final landform that ensure long-term stability of the rehabilitated, disturbed footprint of the minesite. Specifically, it includes rehabilitation activities undertaken to ensure (i) the long-term isolation of tailings and geotechnical stability of the final landform, and (ii) minimal erosion and dispersion of sediment to the surrounding environment, that if not met could result in impacts to receiving water ecosystems and human health.

Table 7 provides a summary of the ERs that are relevant to the Landform closure theme (in addition to the primary ERs presented in Table 1). Table 7 also provides the outcomes of the Supervising Scientist's detailed assessment of the RMCP, indicating whether or not the information provided in relation to the Landform closure theme is sufficient to demonstrate that each of the relevant ERs can be met.

Table 7. Ranger Environmental Requirements relevant to the Landform closure theme

Landform aspect	Clause	Environmental Requirements	Does RMCP demonstrate ER can be met?
Landform Physical Properties	2.1	Subject to subclauses 2.2 and 2.3, the company must rehabilitate the Ranger Project Area to establish an environment similar to adjacent areas of Kakadu National Park such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu National Park.	Further information required
Landform Stability	2.2	(c) Erosion characteristics which, as far as can reasonably be achieved, do not vary significantly from those comparable landforms in surrounding undisturbed areas.	Further information required
Tailings Isolation	11.2	By the end of operations all tailings must be placed in the mined-out pits.	Further information required
	11.3	(i) The tailings are physically isolated from the environment for at least 10,000 years.	Further information required
Infrastructure Disposal	2.3	Where all the major stakeholders agree, a facility connected with Ranger may remain in the Ranger Project Area following the termination of the Authority, provided that adequate provision is made for eventual rehabilitation of the affected area consistent with principles for rehabilitation set out in subclauses 2.1, 2.2 and 3.1.	Yes

5.2. Activity Summary

The RMCP proposes that all tailings will be placed in the mine pits, which will then be backfilled with waste rock. The remaining waste rock, including the waste rock used to construct the Tailings Storage Facility walls, will then be progressively distributed across the site to form a final landform which will be progressively revegetated with local native plant species.

These proposed activities broadly comply with the relevant ERs, with the exception of the statement in section 11.4.1.6 of the RMCP that *remnant tailings on the floor under beached equipment* may need to be left in place, which is not in accordance with ER11.2 that 'by the end of operations all tailings must be placed in the mined-out pits'. This issue is currently being discussed by stakeholders.

5.3. Detailed Works Description

5.3.1. Landform Design and Construction Materials

Approval of the final landform design will be subject to assessment of a standalone Final Landform and Revegetation Application. The application is currently scheduled for submission by ERA in 2022.

The RMCP presents and discusses information on the proposed landform design, providing detailed descriptions of the backfill methodology that will be used to fill the mine pits and construct the final landform. In order to reduce the source of radiation and leachable contaminants at the final landform surface, the more mineralised waste rock will be placed beneath the less mineralised waste rock. ERA must also demonstrate that the landform will be able to establish and sustain an ecosystem that is similar to areas adjacent to the Ranger Project Area. This aspect of the final landform is discussed in Chapter 9 of this report.

While the general strategy is supported, more detailed information needs to be provided in the Final Landform and Revegetation application to demonstrate adequate planning and monitoring of material movements, including a basis on which the progress of landform construction can be assessed over time. The landform design must be optimised to ensure its long-term integrity and stability, and to minimise erosion to prevent offsite environmental impacts. Outcomes of iterative erosion and landform evolution modelling undertaken by the Supervising Scientist have been, and will continue to be used to assist with this optimisation process. It is noted that the supporting studies section of the RMCP (section 7.5) includes information on model development being undertaken by the Supervising Scientist that is either out of date or incorrect. Erosion can also be controlled through the use of appropriately designed flow control and sediment containment structures. The Final Landform and Revegetation application needs to contain more information to justify the proposed surface structures, including up to date flood modelling, engineering designs and long-term management plans. Details on the use of ripples also need to be provided, and this should include a detailed BPT assessment that balances the advantages and disadvantages of ripples (e.g. while ripples may reduce erosion, retain fines for soil development and increase plant available water, they may also lead to increased infiltration and seepage of waste rock contaminants) and where possible, account for the interests and views of Traditional Owners.

5.4. Landform Physical Properties (ER 2.1, 2.2c)

The physical properties of the waste rock used to construct the final landform will determine the erosion characteristics, the potential for contaminant leaching, and its ability to support the

establishment of, and sustain into the long-term, a vegetation community similar to the surrounding environment.

The RMCP proposes the use of the trial landform as a reference site to inform the design of the final landform. Importantly, data from the trial landform will be important to understand how waste rock properties have evolved over a 10-year period (e.g. weathering rate, water-holding capacity, plant available water, internal water transport and contaminant availability). In addition to the trial landform, the construction of the final landform on top of the Pit 1 footprint has commenced. The information obtained from monitoring the construction of the landform on Pit 1 will also be useful to enhance understanding of the physical properties of waste rock.

Relevant information from both the trial landform and the Pit 1 landform should be included in the Final Landform and Revegetation application to demonstrate understanding of the physical properties of waste rock, both in the context of erosion and its ability to support a sustainable ecosystem that is similar to adjacent areas.

5.5. Landform Stability (ER 2.1, 2.2c)

5.5.1. Tailings Consolidation

The areas of the final landform located over the mine pits will be susceptible to differential surface settlement as the tailings below the waste rock backfill consolidate over time. Therefore, a detailed understanding of the tailings characteristics and likely consolidation behaviour is required to effectively address risks related to landform stability. This understanding of consolidation behaviour is also necessary to ensure that the contaminants associated with tailings are minimised through the removal and treatment of tailings pore water, or pit tailings flux. This aspect of the tailings consolidation is discussed in Chapter 6 of this report.

The physical consolidation of tailings in Pit 1 has been measured over time using settlement plates, and these measurements have been used to validate the Pit 1 tailings consolidation model. To date, this form of validation has demonstrated that the model has been generating reasonable consolidation estimates. Ongoing monitoring of consolidation is required to continue to ensure that consolidation occurs as predicted.

In April 2019, ERA submitted an application to change the tailings deposition method in Pit 3 in order to address issues with tailings segregation and differential consolidation across the pit. The RMCP states that tailings characterisation studies, and the results of the subaqueous deposition trial, both support the conclusion that the change in tailings deposition method (and consequent maximum tailings level at the end of tailings deposition) will not result in any long-term environmental impacts. The Supervising Scientist undertook a detailed review of the standalone application and concluded that the changes in the deposition strategy are not likely to increase the risk to people or the environment. A number of contingency measures were identified to ensure that the tailings level in Pit 3 does not exceed the approved maximum level of -15 mRL, including reducing the water level in Pit 3 at any time, or physical relocation of tailings after deposition is complete. These contingency measures should be included in the detailed tailings deposition plan, along with a program for monitoring and reporting of tailings level, and various other measurements, in the pit over time. The application indicated the likely formation of a 'sludge layer' on top of the tailings mass. The plan should also consider how this layer will be managed over time and whether or not it will impact on future access to the pit.

There is still significant uncertainty with respect to tailings consolidation modelling. Ongoing updates to the tailings consolidation models for both pits are required. This modelling will not only provide greater confidence in predicted consolidation outcomes and timeframes, but will also

enable assessment of the risk of differential settlement of the landform over the pits and potentially be used to plan material movements accordingly. In particular, ERA must provide an updated tailings consolidation model for Pit 3 that adequately represents the final distribution and properties of tailings in the pit. This information requirement has been identified as a KKN (LAN3).

5.5.2. Erosion Characteristics

The erosion characteristics of the final landform can be determined using indicators of erosion such as denudation rate, incidence of gully formation and measurement of suspended sediment and bedload in waterways surrounding the Ranger Project Area.

Erosion modelling and field observations undertaken by the Supervising Scientist to date indicate that denudation rates on the landform are likely to reduce substantially within the first 100 years, but are unlikely to reach background denudation rates for at least 1000 years (Lowry 2016; Lowry et al. 2017). However, these rates were derived using a low rainfall scenario. Under different scenarios (such as high rainfall), and on different areas of the final landform, it may take significantly longer for the denudation rate to reflect background rates (i.e. >10,000 years). The structures proposed in the RMCP for erosion control (i.e. check-dams, sediment basins) may not be appropriate for such fine sediment, and hence may not adequately mitigate the associated environmental risk. The RMCP should acknowledge the uncertainty in the erosion modelling and ensure that plausible worst-case scenarios are considered in the design of the final landform and surface erosion control structures.

It is accepted that compared to the environmental risks associated with fine suspended sediment transport, the risk from bedload sediment transport is considered to be low. This is because bedload sediment is unlikely to move offsite as it is relatively easy to manage through appropriate controls and mitigation measures, as outlined in the RMCP. To assess the potential impacts associated with bedload transport to Magela and Gulungul creeks, information on background bedload yields is required. The requirement for this information has been identified as a KKN (LAN1).

In addition to understanding and predicting the erosion characteristics of the final landform itself, there is also a requirement to ensure that erosion of the landform does not cause the turbidity (suspended sediment) in surrounding waterways to exceed acceptable levels, both during and immediately following construction. To demonstrate this, suspended sediment transport and deposition should be modelled in the surrounding environment. To assess the potential impacts associated with suspended sediment transport to Magela and Gulungul creeks, information on background suspended sediment yields is required. The requirement for this information has been identified as a KKN (LAN1).

5.6. Tailings Isolation (ER 11.2, 11.3)

5.6.1. Gully Erosion

Gully erosion is the key mechanism that may lead to tailings exposure and where practicable, the final landform design should be optimised in a way that prevents gully formation over the buried tailings in both Pit 1 and Pit 3. The landform evolution modelling being undertaken by the Supervising Scientist will provide an indication of the possible locations and sizes of gullies that may form on the final landform over a 10,000-year period. This modelling will be used to assess the final landform design, and if the modelling indicates that significant gullies are likely to form over the top of the buried tailings, the landform design should be amended. Additionally, surface

erosion control structures (e.g. rock armouring) can be used to help prevent and manage gully formation. The most recent version of the final landform design (FLv6.2) that has been provided by ERA is currently being assessed by the Supervising Scientist. Findings will be provided to ERA as they become available. However, as acknowledged in the RMCP, the landform erosion modelling results are only indicative and should not be used or referenced as providing precise locations or absolute depths of potential gully formation on the final landform.

The Final Landform and Revegetation application should demonstrate that gully formation is not likely to expose tailings over the long-term (10,000 years), and should include any other information and evidence to demonstrate adequacy of the final landform design.

5.6.2. Extreme Events and Landscape-scale Processes

The potential for extreme events and landscape-scale processes, such as flood events in Magela Creek, to impact on the stability of the final landform has been considered in the RMCP. The landform flood study presented in the RMCP could be improved by taking into consideration the impacts of major flood events on long-term landform stability. The flood study could also be improved by incorporating the synthetic rainfall datasets that have been supplied to ERA by the Supervising Scientist. Additional information is required to ensure that risks associated with landscape-scale processes incorporate, where appropriate, potential future climate change. This information has been identified as a KKN (LAN2).

5.7. Closure Criteria

Closure criteria proposed in the RMCP pertaining to the final landform have been assessed and the outcome is described as being either a) Accepted or requiring b) Further Information (Table 8). For criteria that require further information (or clarification), comments are provided in the table. It is intended, through ongoing engagement amongst stakeholders, that all Landform closure criteria will be agreed in time for inclusion in the 2020 RMCP. The Supervising Scientist is currently reviewing its Landform Rehabilitation Standard, which will provide ERA with updated advice on the approach to assessing the achievement of ERs related to landform stability and erosion characteristics.

Of note, closure criteria L3 and L4, both related to the physical isolation of tailings for 10,000 years, were proposed in the 2018 RMCP but they have been removed from the 2019 RMCP. It is recommended that these aspects of the closure criteria be retained, or that justification is provided to support their removal.

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Table 8. Supervising Scientist position on proposed Landform closure criteria

RMCP reference	Proposed Landform closure criteria	Assessment Outcome	Supervising Scientist Comment
L1	DEM A high-resolution digital elevation model of the constructed landform matches the approved landform design, within applicable construction standards.	Accepted	
L2	Landform evolution model (LEM) predictions of gully erosion Modelling of erosion on the constructed landform matches results of erosion modelling conducted on the approved landform design and confirms tailings will not be exposed for 10,000 years.	Accepted	
L3	Gully erosion Annual inspections show that there is no gully formation occurring above the buried tailings.	Accepted	
L4	LEM model predictions of denudation rate Modelling of erosion on the constructed landform predicts that the denudation rate will approach 0.04 mm/year.	Accepted	While accepted, it is noted that the clarifying text <i>averaged over the entire landform</i> that was proposed in the 2018 RMCP (i.e. previously L5) has been removed in the 2019 RMCP. This text allowed for some degree of variation across the landform, and it is suggested that it is reincorporated into L4.
L5	Bedload Annual inspections show that no bedload is being carried away from the constructed landform, in the absence of active management.	Accepted	
L6	Turbidity Event-based fine suspended sediment loads, measured in Magela and Gulungul creeks at the downstream boundary of the Ranger Project Area, are approaching background values.	Accepted	

5.8. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 9. The table also includes ERA's response to the recommendations, which were provided in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response. It is noted that the Landform KKNs have been revised since the 2018 RMCP and have been updated in the table.

Table 9 Landform recommendations

Supervising Scientist Recommendation on 2018 RMCP
<p>Before commencing construction of the final landform (other than over Pit 1) ERA must address the listed KKNs, and demonstrate that the final landform design minimises erosion to the greatest extent possible (LAN3), considering the baseline erosion and sediment transport characteristics (LAN1) and in consideration of landscape-scale process and extreme events (LAN2).</p> <p><i>Key Knowledge Needs to be addressed:</i></p> <ul style="list-style-type: none"> • LAN1: Determining baseline erosion and sediment transport characteristics in areas surrounding the RPA • LAN2: Understanding the landscape-scale processes and extreme events affecting landform stability • LAN3: Predicting erosion of the rehabilitated landform (excluding LAN3.A and LAN3.D)
ERA Response
<p>It is intended that the listed KKNs will be addressed through ongoing studies prior to the construction of the final landform. LAN1 has been removed from the KKNs. Applications to undertake these activities are planned to be submitted in Q3 2022 (Final Landform) and will provide additional information which will be incorporated into following MCP updates.</p>
Adequacy of ERA Response in 2019 RMCP
<p>ERA response is acknowledged, noting that the statement 'LAN1 has been removed from the KKNs' is incorrect. It is also noted that the Supervising Scientist is responsible for completing a substantial proportion of the research work to address these KKNs, with findings to be provided to ERA in time for the Final Landform Application.</p>
Supervising Scientist Recommendation on 2018 RMCP
<p>In accordance with the previous recommendations of the Supervising Scientist; before the placement of the grade 1s waste rock cap on Pit 1 ERA must address the listed KKNs, and provide a digital elevation model (DEM) of the final landform design that has been demonstrated, using erosion modelling, to minimise erosion to the greatest extent possible (LAN3.A and LAN3.D).</p> <p><i>Key Knowledge Needs to be addressed:</i></p> <ul style="list-style-type: none"> • LAN3.A: What is the optimal landform shape and surface (e.g. ripples, substrate characteristics) that will minimise erosion? • LAN3.D: What are erosion characteristics of the final landform under a range of modelling scenarios (e.g. location, extent, time frame, groundwater expression and effectiveness of mitigations)?
ERA Response
<p>Information on PSD and PAW modelling, plant rooting depth, sub-surface consolidated layer, and more has been added. Consistent with information previously provided as part of 2019 App. 3 to Pit 1 Application - Ref: Lu P, Meek I, Skinner R. 2019. Supporting Information on Revegetation Growth Substrates at Ranger for Pit 1 Application. Energy Resources of Australia Ltd report, Feb. 2019</p>
Adequacy of ERA Response in 2019 RMCP
<p>The ERA response appears to have been placed in the wrong location.</p>

6. Closure Theme: Water and Sediment

6.1. Relevant Environmental Requirements

The Water and Sediment closure theme covers the rehabilitation activities undertaken to minimise the release of contaminants (i.e. radiological¹, chemical and physical) and prevent changes to water and/or sediment quality in the receiving environment that might result in impacts to ecosystems and/or human health.

Table 10 provides a summary of the ERs that are relevant to the Water and Sediment closure theme (in addition to the primary ERs presented in Table 1). Table 10 also provides the outcomes of the Supervising Scientist's detailed assessment of the RMCP, indicating whether or not the information provided in relation to the Water and Sediment closure theme is sufficient to demonstrate that each of the relevant ERs can be met.

Table 10. Ranger Environmental Requirements relevant to the Water and Sediment closure theme

Water or sediment aspect	Clause	Environmental Requirement	Does RMCP demonstrate ER can be met?
Water/ Sediment Quality	3.1	The company must not allow either surface or ground waters arising or discharged from the Ranger Project Area during its operation, or during or following rehabilitation, to compromise the achievement of the primary environmental objectives.	Further information required
Protection of Ecosystems	1.1	<p>The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:</p> <ul style="list-style-type: none"> (a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage List (b) maintain the health of wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park) (d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes. 	Further information required

¹ Note that although radiation can be considered as a contaminant in water and/or sediments, this is considered as a specific closure theme in Chapter 7 of this report.

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Water or sediment aspect	Clause	Environmental Requirement	Does RMCP demonstrate ER can be met?
	1.2	<p>In particular, the company must ensure that operations at Ranger do not result in:</p> <ul style="list-style-type: none"> (a) damage to the attributes for which Kakadu National Park was inscribed on the World Heritage List (b) damage to the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park) (d) change to biodiversity, or impairment of ecosystem health, outside of the Ranger Project Area. Such change is to be different and detrimental from that expected from natural biophysical or biological processes operating in the Alligator Rivers Region (e) environmental impacts within the Ranger Project Area which are not as low as reasonably achievable, during mining excavation, mineral processing, and subsequently during and after rehabilitation. 	Further information required
	10.1	<p>All operations should be managed to minimise, to the maximum extent practicable, and to the satisfaction of the Supervising Authority or the Minister with the advice of the Supervising Scientist:</p> <ul style="list-style-type: none"> (c) the risk to fauna as a result of drinking contaminated water. 	Further information required
	11.3	<p>Final disposal of tailings must be undertaken, to the satisfaction of the Minister with the advice of the Supervising Scientist on the basis of best-available modelling, in such a way as to ensure that:</p> <ul style="list-style-type: none"> (ii) any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years. 	Further information required
Protection of Human Health	1.1	<p>The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:</p> <ul style="list-style-type: none"> (c) protect the health of Aboriginals and other members of the regional community. 	Further information required

Water or sediment aspect	Clause	Environmental Requirement	Does RMCP demonstrate ER can be met?
	1.2	<p>In particular, the company must ensure that operations at Ranger do not result in:</p> <p>(c) an adverse effect on the health of Aboriginals and other members of the regional community by ensuring that exposure to radiation and chemical pollutants is as low as reasonably achievable and conforms with relevant Australian law, and in particular, in relation to radiological exposure, complies with the most recently published and relevant Australian standards, codes of practice, and guidelines.</p>	Further information required

6.2. Activity Summary

The RMCP proposes a number of activities that relate to the management, treatment and disposal of contaminated water and sediment, to minimise environmental impacts on the minesite and to prevent environmental impacts offsite. These activities all relate to the reduction and containment of mine-related contaminants and include:

- management, storage and treatment of contaminated water and sediments
- management and disposal of tailings, brines and other contaminate waste
- management and remediation of contaminated sites, including contaminated soils and groundwater.

While these proposed activities are broadly in line with the relevant ERs, additional information is required to enable assessment of the activities against the requirement to prevent future offsite environmental impacts.

6.3. Detailed Works Description

Approval of future water management and treatment processes, and the backfilling of Pit 3, will be subject to assessment of a number of standalone applications. The proposed applications include the Integrated Water Treatment Strategy Application, the Tailings Storage Facility Floor Contaminated Material Management Application and the Pit 3 Closure Application. All of these applications are currently scheduled for submission by ERA in 2020. Given the significant amount of work required to be completed by October 2020 to support the Pit 3 Closure application there is a risk that the application, and subsequent works in Pit 3, could be delayed. Additionally, further work may be required should the revised water quality modelling predict that contaminant concentrations in surface water will be higher than expected.

6.3.1. Contaminated Water Management and Treatment

The RMCP presents the proposed strategy for the management, storage, treatment and disposal of tailings, contaminated water, brine (the by-product of water treatment) and other contaminant sources (e.g. soils, infrastructure, equipment). The time for which contaminated water will require active management and treatment to ensure achievement of the ERs will depend on the success of

this strategy. The RMCP currently indicates that all contaminated water can be treated by January 2026, and that all brine and other wastes generated from water treatment processes can be stored effectively in the designated void space in Pit 3. Future contaminated water management, storage and treatment requirements are based on predictive modelling (OPSIM), which estimates annual volumes of contaminated water produced over time, as well associated volumes of brine produced through treatment of the contaminated water. This modelling includes a number of significant assumptions, such as seasonal rainfall, water treatment capacity and efficiency over time and volume of contaminated water generated by the process of tailings consolidation in Pit 1 and Pit 3. The veracity of these assumptions remains under review by ERA and stakeholders. However, there is no indication of model uncertainty based on the likely variability in these assumptions over time. Further information should be included in the Integrated Water Treatment Strategy application and the Pit 3 Closure application to enable a detailed assessment of likely success of the proposed water treatment strategies.

It is also acknowledged in the RMCP that a final rehabilitation plan for many water management areas has not been completed and associated contingency plans are yet to be developed. This information should be included in subsequent updates of the RMCP.

6.3.2. Contaminated Waste Management and Disposal

The current works schedule states that the Tailings Storage Facility will be required for process water storage until late 2024, and that backfill of Pit 3 will be completed by 2025. This does not allow for the possible disposal of contaminated material from the Tailings Storage Facility in the lower levels of Pit 3, given that the pit backfill would be close to completion. Backfill of Pit 3 should not commence until it has been demonstrated that the placement of material from the TSF into Pit 3 is not required.

More information is required on the disposal of contaminated soils, site infrastructure and other materials. This should include the effect that in-pit disposal may have on tailings consolidation, as well as an assessment of the potential environmental risks and information on how they will be mitigated. Currently, there is insufficient detail to enable assessment of the planned waste disposal.

6.3.3. Contaminant Transport Modelling

The RMCP presents results of initial contaminant transport modelling that is being used to predict post-closure concentrations of mine-derived contaminants in the offsite environment. In the case of tailings-derived contaminants, this modelling predicts concentrations over a 10,000-year period. These predictions rely on the integration of a number of different models, in particular those that link the contaminant sources to the groundwater system, and subsequently the groundwater system to surface water system. Key models include the tailings consolidation model, groundwater flow model, ground contaminant transport model and surface water contaminant transport model. To ensure integration across all models, from source to receptor, each model needs to generate outputs that become suitable and appropriate inputs to subsequent models. The ultimate outcome is the prediction of surface water concentrations of key contaminants at the Ranger Project Area boundary over time to enable assessment of the potential future impacts from mine contaminants to the offsite environment.

There is still uncertainty associated with each of these models, and the approach to integrating them has not been fully assessed, nor agreed to by stakeholders. In particular, it is broadly accepted that there are insufficient groundwater data available to adequately identify key groundwater/surface water interactions, which are critical to understanding how groundwater contaminants are potentially delivered to the surrounding surface water system.

Until these issues and those discussed in more detail below are resolved, the predicted contaminant concentrations in surface waters surrounding the mine site remain unreliable. As such, assessment of the rehabilitation plan against the requirement to protect the surrounding environment in the long-term cannot be undertaken at this stage. ERA is currently working on the comprehensive suite of investigative work and modelling to improve confidence in the predictions of contaminant behaviour during and after rehabilitation. This modelling will need to be completed and presented in the Pit 3 Closure application, and should focus on:

- the development of a surface water flow and contaminant transport model that incorporates an improved understanding of the groundwater/surface water interactions that control the location and timing of delivery of contaminated groundwater to the surface water system, enabling the model to predict the spatial and temporal aspects of contaminant migration and dispersion from source terms on the mine site into Magela and Gulungul creeks
- assessment of confidence in modelled outputs using statistical, sensitivity and uncertainty analyses for each model, as well as consideration of cumulative uncertainty where multiple models are interconnected.

6.4. Water and Sediment Quality (ER 3.1–3.4)

6.4.1. Water Storage, Management and Treatment

6.4.1.1. Process Water and Brine

During rehabilitation the key process water storage locations will be the Tailings Storage Facility, Pit 3 and RP6. ERA has acknowledged that further assessment is required to determine if the Tailings Storage Facility can be used as a process water storage beyond 2020. Until these assessments have been completed, relevant contingency options should be identified and included in the RMCP.

The site water balance model presented in the RMCP is out of date, being based on total dissolved solids concentrations in process water from August 2018, and assuming that brine injection has been operational for 80% of the time since January 2019. The brine injection system has been offline since late 2016 (due to issues with the underdrain water recovery system) and during this period the brine has been recirculated through the process water circuit, which would increase the process water total dissolved solids concentration compared to the that measured in August 2018. Because of this, the forecast total dissolved solids concentrations in process water may be underestimated, which may in turn impact on the future efficiency of the brine concentrator and ERA's ability to treat process water within the desired timeframe. The model also assumed that High Density Sludge process water treatment has been underway throughout 2019, which is also not the case. It is important that the OPSIM site water balance model is rerun to account for more recent process water total dissolved solids concentrations, and to update any outdated assumptions.

A schedule is included in the RMCP for water treatment. While brine concentration will remain the preferred option for process water treatment during rehabilitation, operational improvements are planned to increase treatment capacity more broadly. These include the use of a high-density sludge treatment plant to treat process water and a brine squeezer treatment plant to retreat pond water brine. The timing and effectiveness of each operational improvement are currently based on a number of assumptions, which all underpin the site water balance model. ERA routinely report these assumptions to stakeholders and the progress of work being undertaken to achieve them. The Supervising Scientist supports the approach to assessing multiple integrated options to ensure

sufficient capacity to treat all process water on site. However, until all assumptions and possible options are tested and realised, there remains uncertainty around ERA's ability to reach the desired timeframe for water treatment (mid-2025). Information supporting this integrated approach to water treatment should be included in the Integrated Water Treatment Strategy Application.

Given the uncertainty associated with the predicted process water volumes up to 2025, it is critical that ERA is able to fulfil its identified contingency to continue water treatment and disposal of all process water (including expressed tailings pore water) for as long as necessary. As the process water treatment predictions are further refined, this may also have implications for the disposal of brine in Pit 3. Additional information should be provided in the RMCP, including:

- results of investigations undertaken in order to reinstate the Pit 3 underdrain extraction bore
- evidence to demonstrate the longevity of the brine injection wells and factors that may affect this.

6.4.1.2. Pond Water

It is acknowledged in the RMCP that further assessment is required to demonstrate there are sufficient disposal options for treated pond water throughout rehabilitation. This assessment will need to include consideration of the future capacity of the remnant Land Application Areas, and whether or not there will be an increase in associated environmental risks (e.g. waterlogging, unseasonal runoff, and alteration to groundwater levels). This information, along with any additional information that supports the long-term strategy for treating process water should be presented in the Integrated Water Treatment Management Strategy application.

6.4.1.3. Release Water

As catchment areas are progressively rehabilitated, process and pond water catchments will gradually be converted into release water catchments. As this occurs, relevant monitoring programs will need to be established to demonstrate that water from these converted catchments is suitable for release. In relation to this, the RMCP presents water quality monitoring data from the trial landform that show concentrations of contaminants in surface runoff from waste rock are generally low. However, during progressive rehabilitation and construction of the final landform, there may be an increase in suspended sediment concentration in surface runoff from the site, which may increase the risk of sediment-related impacts to the offsite environment. ERA is currently developing a surface water model to predict the concentrations of suspended sediment in the creeks surrounding the Ranger Project Area. This modelling should also consider the deposition of sediment throughout surrounding catchments, particularly to assess the risk of infilling of nearby billabongs. The modelling should be used to inform the types of erosion management measures that will be required during rehabilitation, and it is expected that more specific designs and management plans for erosion and sediment controls will be presented in the RMCP, or relevant stand-alone applications, before the commencement of major rehabilitation works onsite. This should include information on the timeframes for which these structures are expected to remain in place (i.e. criteria for removal) as well as a schedule for routine maintenance to ensure their effectiveness over time (e.g. sediment removal and disposal locations).

6.4.2. Ranger Conceptual Model

The hydrogeological and groundwater quality information presented in the RMCP is largely based on the Ranger Conceptual Model (INTERA 2016, 2019). The original Ranger Conceptual Model was developed in 2016 (INTERA 2016) and is subject to ongoing updates and refinement. It is

important that the conceptual model retains sufficient complexity at a relevant scale as it provides the foundation for analytical and numerical models that need to adequately simulate the groundwater flow system to the degree necessary to satisfy the objectives of the contaminant transport modelling. Accordingly, the conceptual model was updated in early 2019 (INTERA 2019). The Supervising Scientist reviewed the updated model and found it to be a significant improvement over the previous version.

Although the updated 2019 Ranger Conceptual Model is an improvement on previous models, it should be continually updated with new data and information that become available over time, providing ongoing refinement of:

- key hydrolithological units, aquifers and groundwater flows, particularly in regions in the vicinity of Pit 1, Pit 3 and the Tailing Storage Facility that are high-risk areas for contaminant transport (e.g. the Magela Creek bed, the Djalkmarra sands, and the MBL zone)
- surface water and groundwater interactions
- knowledge of existing contaminated groundwater (e.g. under the Tailings Storage Facility) and contaminated areas (e.g. Land Application Areas, Processing Area, Pit 3 North Ramp Hazardous Waste Disposal Area, etc.).

The RMCP should detail future hydrogeological work that will be undertaken to refine the Ranger Conceptual Model and explain how this will feed into the contaminant transport modelling and rehabilitation planning. The information requirements pertaining to the prediction of contaminant transport in groundwater and gaining a better understanding of surface-groundwater interactions have been identified in KKNs WS2 and WS3.

6.4.3. Contaminant Sources

Further work is required to quantify contaminant source terms (including radionuclides) and the factors that influence their mobilisation on a whole-of-site basis. This includes quantifying existing groundwater contamination and contaminants that are predicted to arise from the waste rock landform, the buried tailings and brines and contaminated soils and sediments disturbed during rehabilitation. These information requirements have been identified as a KKN (WS1). Additional information should be presented in the Pit 3 Closure application to demonstrate that all contaminant sources onsite, including contaminated groundwater and material associated with the Tailings Storage Facility and processing area, has been well characterised, is adequately represented in contaminant transport modelling and will not result in environmental impacts.

6.4.3.1. Waste Rock

The rate of rainfall infiltration through the waste rock landform is a key factor that will drive the geochemical reactions that lead to the dissolution of contaminants from the waste rock, which is agreed to be the most significant post-closure source of contaminants. The RMCP indicates that waste rock infiltration rates will be between 1 and 10 mm per hour, and based on this it has been assumed that 10% of total rainfall will infiltrate the final landform. This value has been used in modelling to predict concentrations of contaminants that could enter shallow groundwater via seepage through the waste rock landform. ERA has recently acknowledged that this rate is too low and the actual rate is likely to be substantially higher, which aligns with some recent field observations made by the Supervising Scientist. ERA is currently reviewing the waste rock source term and the information will be incorporated in the updated contaminant transport modelling. Relevant geochemical information underpinning the seepage estimates should also be provided,

including the quantification of sulfide minerals present in waste rock, and assessing potential solute release subsequent to the consumption of sulfide minerals.

6.4.3.2. Tailings and Pore Water

Tailings pore water (process water) will express from the tailings in Pit 1 and Pit 3 as they consolidate over time. To minimise this contaminant source post-closure, ERA has committed to capturing and treating pore water until the tailings in the pits have reached at least 95% consolidation, leaving only a small proportion of residual tailings pore water in the pits post-closure. To meet this commitment, the tailings in the pits will need to reach at least 95% consolidation before January 2025, which is when the process water treatment plant will be decommissioned. Tailings consolidation modelling has been used to demonstrate that this target is achievable.

To date, surface settlement data have been used to demonstrate consolidation of tailings in Pit 1 has occurred as expected, based on modelled estimates. The RMCP indicates that the model predicts that more than 99% of the tailings pore water will be removed by January 2026. The Supervising Scientist accepts the tailings consolidation modelling for Pit 1 with respect to predicted settlement over time. However, there is less certainty around the removal of tailings pore water. While contaminated water from the pit has been captured and treated throughout the consolidation process, it is difficult to determine whether this water was from the tailings pore spaces, or from other sources such as rainfall or surrounding groundwater, which both express into the pit void.

In contrast, no details have been provided to describe how consolidation of tailings in Pit 3 will be measured over time, nor how achievement of the 95% consolidation target will be verified. Ongoing monitoring and reporting of tailings deposition and consolidation over time will be critical for providing assurance that deposition activities are progressing as planned. To improve estimates of the volume and timing of contaminated water expression during tailings consolidation the consolidation model should be updated with the most recent data on the characteristics and distribution of tailings in the pit. This is particularly important where the outcomes of tailings consolidation modelling underpin key inputs or assumptions of the contaminant transport modelling, which is the case for the predicted final tailings level and the volume of residual tailings pore water after consolidation is complete.

Currently, the tailings consolidation modelling predicts an average final level of -19.7mRL, with only a small proportion (30,000m³) reaching -15mRL (against the south-eastern wall of the pit). If the tailings do not consolidate as predicted, the final tailings level may be higher than expected and this may lead to the potential for greater interaction between the tailings and the surrounding groundwater system. The modelling also predicts that consolidation will be 95% complete by June 2025, in which case process water treatment facilities will be available to treat expressed tailings pore water. However, if the consolidation takes longer than expected, water treatment will be required for longer than expected and the decommissioning of the process water treatment plant may need to be postponed.

ERA is also planning to undertake sensitivity testing of the Pit 3 tailings consolidation model to help determine how the fine to coarse tailings ratio of the deposited tailings, which have segregated, will affect the model outputs. This sensitivity testing is important to understand how the heterogeneous nature of the tailings in the pits might affect the quantity of contaminants mobilised from tailings and the timing, direction and rate of solute expression.

6.4.3.3. Contaminated Groundwater and Soil

Work to characterise the nature and extent of the existing groundwater and soil contamination across the site is ongoing. It is currently unclear what active management activities will be

undertaken during rehabilitation to manage contaminants associated with groundwater and soils. It is also unclear which areas will be remediated in order to reduce the potential future contaminant source terms.

It has been assumed that levels of contamination in the groundwater and soil associated with the Tailings Storage Facility will be low enough for this material to remain in place, as opposed to pumping and treating groundwater and disposal of contaminated soils in Pit 3. The RMCP states that *currently, natural attenuation will be the proposed method for management of these plumes* and that *impacts to groundwater after site closure from the reclaimed TSF will be less than those observed during the operational period*. However, there is no evidence provided to support these assumptions. The groundwater beneath the Tailings Storage Facility and material in the walls and floor need to be assessed to determine the level of contamination and to verify these assumptions. This work is currently underway, and is expected to be presented in the standalone Tailings Storage Facility Floor Contaminated Material Management application.

In relation to the processing area, the RMCP presents some inconsistent information on groundwater contamination. The RMCP states that there is a *lack of impact to nearby downgradient bores* from the processing area, but also discusses the migration of contaminants in groundwater towards Corridor Creek. The RMCP also discusses the lack of recent groundwater quality data in and around this area. Ongoing groundwater assessment and monitoring in vicinity of the processing area is critical to inform any proposed remediation activities.

Other areas of the site that require further consideration include the Land Application Areas, the Pit 3 North Wall Hazardous Waste Disposal area and the onsite billabongs. It is acknowledged in the RMCP that the potential risks associated with the generation of mine-induced acid sulfate sediments needs to be assessed in more detail, particularly in Coonjimba, Georgetown and Gulungul billabongs. This assessment will need to consider the potential associated impacts on water quality in Magela Creek. These information requirements have been identified as KKNs (WS5).

In general, further information is required to support the approach to remediating contaminated groundwater and soils across the site. This information should include the nature and extent of the existing contaminated groundwater and soil, the proposed management and remediation activities that will be undertaken to reduce the risks associated the contaminants during and after rehabilitation and an indication of the likely fate of any residual contaminants. These studies should be focussed on ensuring that the:

- level of contamination has been adequately measured (i.e. that samples are representative)
- volumes of contaminated material have been reliably estimated
- environmental risk associated with leaving the contaminated material in place has been assessed, and where necessary, compared against the risk of remediation and disposal of the material in the upper levels Pit 3 during the late stages of waste rock backfill (which according to the current schedule is when much of the material will be placed in the pit).

The Ranger Conceptual Model and contaminant transport models should then be updated based on the above, to ensure these important post-closure contaminant source terms are accurately reflected. Importantly, neither the Tailings Storage Facility nor the processing area have been characterised or included as contaminant source terms for the contaminant transport modelling. Given that the RMCP states that *all material with the potential for environmental impact* will be placed at the *bottom of the mined-out pits*, this information will be required to assess the Pit 3 Closure application, which should include consideration of whether or not the closure schedule needs to be modified to allow for the disposal of contaminated material in the lower levels of Pit 3.

6.4.4. Contaminant Transport Modelling

The RMCP provides a modelling plan that illustrates the various models that will be used to predict the transport and fate of contaminants, including groundwater and surface water flow and contaminant transport models. When completed and integrated, these models will provide post-closure surface water contaminant concentrations in the creeks surrounding Ranger mine. These concentrations will then be assessed to determine whether or not mine-derived contaminants are likely to result in impacts to the offsite environment and the expected impacts on the on-site environment

The RMCP presents a variety of different groundwater models, each of which have been developed to address a specific issue with respect to the future migration of contaminants from key contaminant sources to the offsite environment (e.g. the Pit 1 solute egress modelling, the Pit 3 solute transport modelling, the assessment of post-closure Mg loading to Magela Creek from Pit 3 tailings, etc.). The contaminant transport modelling for the Pit 1 and Pit 3 was considered suitable to predict the average peak annual contaminant loads delivered to downstream surface waters (i.e. Corridor and Magela creeks) over 10,000 years. The loads presented in the RMCP do not consider the likely future contribution of contaminants from other key contaminant sources on the site, including the Tailings Storage Facility and processing area. The predicted, combined loads also have not yet been integrated into an acceptable surface water model to enable predictions of contaminant concentrations in surface waters surrounding the mine. This is key to the assessment of long-term environmental effects.

To help understand how the groundwater system will change during and after closure, and how this will affect the migration of contaminants offsite, ERA recently developed a post-closure groundwater flow model. This transient model was developed by modifying the calibrated groundwater flow model to represent post-closure conditions onsite, with the pits backfilled and the landform constructed, and the time scale of post-closure hydrogeologic conditions. This model is currently under review by the Supervising Scientist.

The surface water modelling presented in the RMCP is considered to be rudimentary. The contaminant concentrations predicted in receiving surface waters are not yet reliable enough to demonstrate that there will not be detrimental impacts to the surrounding environment. Because of this, the predicted concentrations of contaminants in surface waters that are presented in the RMCP are not supported by the Supervising Scientist. Additional work is currently underway by ERA to update and refine the model and provide more reliable predictions of contaminant concentrations in surface waters. It is critical that the model is supported by an evidence-based understanding of the spatial and temporal (seasonal) interactions between groundwater and surface water. In particular, the model must reliably represent contaminant delivery from ground water to surface water, accounting for variable surface flow conditions with a focus on periods of low surface flow, either during intermonsoonal periods or towards the end of the annual wet season. During these periods groundwater input may contribute a higher proportion of stream flow, and there is less dilution capacity in the creeks which may result in higher concentrations of groundwater-derived contaminants. This work is required as a priority and must be included in the Pit 3 Closure Application to support the backfill of Pit 3.

In addition to this, there is no uncertainty analysis provided for the concentrations presented in the RMCP. To ensure that the assessment of potential future environmental impacts is possible, uncertainty in the estimated concentrations must be quantified and understood. This will require a robust analysis of model uncertainty that needs to capture both parameter uncertainty associated with the calibrated flow models (e.g., K, S, R, ET, GHB conductance etc.), as well as prediction uncertainty that also incorporates errors in prescribed source terms.

These information requirements have been identified as KKNs (WS2, WS3), and until this work has been completed and assessed, the Supervising Scientist cannot accept the statements in the RMCP that claim *contaminants from the landform do not pose a risk to the surrounding environment and stream flow within Magela Creek will be sufficient to dilute the post-closure mine inputs of contaminants of potential concern to low background concentrations downstream of the Gulgul Creek confluence.*

6.5. Protection of Ecosystems (ER 1.1, 1.2, 7.1, 11.3) and Protection of Human Health (ER 1.1c, 1.2c)

6.5.1. Baseline Aquatic Biodiversity

To date, most of the aquatic biodiversity surveys in the Magela Creek catchment have been undertaken during the wet season recessional flow period, at a consistent stage of creek flow. While current water quality guideline values (and closure criteria) are based on a range of aquatic organism types, it is possible that there may be key groups (e.g. flow-dependent insects, hyporheic biota and stygofauna) that have not been represented in laboratory and field toxicity assessments. Organism assemblages for all stages of creek flow should be characterised and assessed for their sensitivity to contaminants. The potential contribution of subterranean fauna in Magela Creek sand beds to ecological processes and the biodiversity of the Alligator Rivers Region also needs to be determined. This information requirement has been identified as a KKNs (WS4).

6.5.2. Key Risks to Aquatic Ecosystems

6.5.2.1. Suspended Sediments

While significant consideration has been given to contaminants in surface water, more information needs to be provided to understand the potential risks associated with suspended sediment. This should include estimates of future concentrations of suspended sediments in billabongs and creeks, the likelihood of sedimentation and infilling of these waterways, as well as an indication as to whether or not contaminants bound to the suspended sediment pose a risk to the receiving environment. The Supervising Scientist is also currently developing a Turbidity and Sedimentation Rehabilitation Standard. The need to assess the potential for impacts associated with mobilisation and accumulation of uranium and other contaminants in suspended sediments transported offsite has been acknowledged by ERA, which will be informed by surface water modelling. These information requirements have been identified as KKNs (WS3, WS5 and WS8).

6.5.2.2. Contaminants

Toxicological effects

There is a significant body of knowledge around the key contaminants of potential concern (referred to as CoPCs) for Ranger mine, and their toxicological effects on local aquatic biota. While not highly likely, it is possible that contaminants other than those currently identified as CoPCs may need to be considered in the post-closure risk assessment and contaminant transport modelling. This is because the current list of CoPCs were identified based on the risk they posed to the offsite environment during operations, when active water treatment and management ensured that the majority of mine-derived contaminants were not released from the site. However post-closure, active water management will have ceased, changing the risk profile. For example, a range of interception systems are currently in place to manage contaminated groundwater. Without these systems in place, it may be possible that a broader suite of mine-derived contaminants could reach the offsite environment. ERA is reviewing the current list of CoPCs, which will be informed by contaminated site studies once they have been completed. Any new CoPCs that are identified

as posing a risk to the offsite environment post-closure should be included in the contaminant transport modelling. Provision should also be made for a periodic review of the contaminants measured in the post-closure monitoring program outlined in the RMCP, and if required closure criteria developed accordingly. This information requirement has been identified as a KKN (WS7). It is likely that post-closure, mine-derived contaminants will co-occur in receiving surface waters, and synergistic interactions and other modifying factors (e.g. increased pH is known to increase ammonia toxicity) may modify their toxicity. This information requirement has been identified as a KKN (WS7).

The potential impact of contaminants to subterranean fauna in Magela Creek sand beds should be determined. This information requirement has been identified as a KKN (WS7).

Eutrophication

The potential risk of eutrophication as a result of nutrients emanating from the rehabilitated minesite is acknowledged in the RMCP, and will be assessed when water quality modelling data predicting nutrient concentrations become available. Further discussion on nutrients in the context of eutrophication risks and closure criteria is provided below. These information requirements have been identified as a KKN (WS6).

Interruption to Fish Migration

The potential risk that a contaminant plume in creek channels could form a barrier that inhibits organism migration and connectivity (e.g. fish migration, invertebrate drift, gene flow) is not considered in the RMCP. This information requirement has been identified as a KKN (WS7).

Acid sulfate sediments

The generation of acidity due to the presence of acid sulfate sediments has the potential to significantly impact aquatic ecosystems. The issue of acid sulfate sediments is acknowledged in the RMCP and the Supervising Scientist's sulfate standard has been adopted, which aims to prevent the occurrence of acid sulfate sediments in billabongs. However, knowledge is needed to assess the current extent of acid sulfate sediments and to predict the risk of acid sulfate sediments impacting billabongs in the future. This includes modelling to predict the pathways and concentrations of sulfate in the billabongs, and sediment sampling to measure the current occurrence on-site and off-site. This information will be required for the Pit 3 backfill application and is included in KKN WS5A as well as other KKNs related to contaminant sources (WS1) and pathways (WS2).

6.6. Closure Criteria

The draft closure criteria proposed in the RMCP pertaining to water and sediment have been assessed and the outcome is described as being either a) Accepted or b) Require Further Information (Table 11). For criteria that require further information (or clarification), comments are provided in the table. It is intended, through ongoing engagement via the Water and Sediment Working Group, that the all Water and Sediment closure criteria will be agreed in time to be included in the 2020 RMCP. The Supervising Scientist is currently reviewing its Water and Sediment Rehabilitation Standards, which will provide ERA with updated advice on the approach to assessing the achievement of ERs related to offsite impacts to ecosystems.

Most of the proposed draft closure criteria for protection of ecosystem health are in accordance with relevant Supervising Scientist's Rehabilitation Standards, noting that the Low Risk Metals in Surface Water Standard is currently under review and the Turbidity and Sedimentation Standard is under preparation. In accordance with the ERs, surface water criteria should be applied at, or inside, the RPA boundary downstream of the mine site.

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Table 11. Supervising Scientist position on proposed Water and Sediment closure criteria

RMCP reference	Water and Sediment criteria	Assessment outcome	Supervising Scientist Comment
W1	<p>Water quality: human health</p> <p><u>Drinking water</u></p> <p>Drinking water quality in designated drinking water resources meets the national drinking water health guidelines.</p> <p>SO₄²⁻ 500 mg/L, Mn 500 µg/L, NO₃ 50 mg/L, NO₂ 3 mg/L, U 17 µg/L (NHMRC & NRMCC, 2011; v3.5 updated 2018).</p> <p><u>Diet</u></p> <p>Local diet model demonstrates that ingestion of mine derived CoPC via aquatic bush foods and drinking water does not cause annual intakes to exceed any relevant national/international tolerable intake levels.</p> <p><i>Parameter(s) - TBA</i></p>	Further information	The term 'designated drinking water' should be clarified. Closure criteria for diet are yet to be established for individual parameters.
W2	<p>Water quality: amenity and recreation</p> <p>Water quality at sites designated for recreational use meets the national recreational guidelines for secondary contact.</p> <p><u>Toxic or irritant chemicals</u></p> <p>NO₃ 500 mg/L, NO₂ 30 mg/L, U 170 µg/L (i.e., drinking water CoPC x 10: NHRMC, 2008)</p> <p>SO₄²⁻ 400 mg/L, Mn 100 µg/L (ANZECC & ARMCANZ, 2000 irritants, no guidelines for irritants/toxicants in NHMRC, 2008).</p> <p><u>Visual clarity and surface films</u></p> <p>No mine-related change to water quality in Magela and Gulungul creeks causes turbidity to be significantly increased over natural background values. Oil and petrochemicals not to be noticeable as a visible film on the water or be detectable by odour.</p>	Accepted	

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RMCP reference	Water and Sediment criteria	Assessment outcome	Supervising Scientist Comment
W3	<p>Water quality: ecosystem health</p> <p><u>Contaminants</u></p> <p>SSB Rehabilitation Standards are met in Magela and Gulungul creeks at the boundary of the Ranger Project Area, downstream of the Ranger Mine:</p> <p>Dissolved aluminium; 27 µg/L (seasonal median)</p> <p>Dissolved cadmium; 0.06 µg/L (72-hour moving average)</p> <p>Dissolved chromium total; 0.2 µg/L (seasonal median)</p> <p>Dissolved chromium VI; 0.01 µg/L (72-hour moving average)</p> <p>Dissolved copper; 0.2 µg/L (seasonal median)</p> <p>Dissolved iron; 430 µg/L (72-hour moving average)</p> <p>Dissolved lead; 1.0 µg/L (72-hour moving average)</p> <p>Dissolved vanadium; 0.25 µg/L interim (seasonal median)</p> <p>Dissolved zinc; 2.4 µg/L (72-hour moving average)</p> <p>Dissolved total ammonia nitrogen; 0.4 mg/L (pH and temperature dependant)</p> <p>Dissolved magnesium; 2.9 mg/L</p> <p>Dissolved magnesium to calcium (Mg:Ca) mass ratio; no greater than 3.5:1</p> <p>Dissolved sulfate; 10 mg/L (seasonal average)</p> <p>Dissolved uranium; 2.8 µg/L (72-hour moving average)</p> <p>Dissolved manganese; 75 µg/L (72-hour moving average)</p> <p><u>Nutrients</u></p> <p>Loads of N and P leaving site are less than the site-specific Annual Additional Load Limits for PO₄-P and NO₃-N, and equivalently derived NH₃-N load:</p> <p>PO₄-P 2.8 t/y; NO₃-N 4.4 t/yr; NH₃-N (<i>to be derived</i>)</p> <p><u>Sedimentation</u></p> <p>Mine derived erosion products do not cause sedimentation in offsite billabongs to exceed the site-specific guideline (<i>SSB rehabilitation standard pending</i>).</p>	Further information	<p>The effect of contaminant mixtures is currently being assessed, including additive and synergistic interactions and how influences from other modifying factors (e.g. increased pH is known to increase ammonia toxicity) may increase toxicity. It will need to be demonstrated that the proposed criteria are applicable in water quality situations relevant to closure.</p> <p>The risk of eutrophication should be reassessed and placed in the context of both baseline conditions and predicted post-closure surface water concentrations.</p>

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RMCP reference	Water and Sediment criteria	Assessment outcome	Supervising Scientist Comment
W4	<p>Sediment quality: metals and sulfate</p> <p><u>Contaminants</u></p> <p>Uranium; SSB rehabilitation standard for dissolved U in water is met, providing protection against accumulation and toxicity in sediments. (Section 8.3.3.5)</p> <p>Metals (mg/kg dry weight; <2mm; nitric perchloric digest Total acid extractable metals):</p> <p>Antimony; 2.0</p> <p>Cadmium; 1.5</p> <p>Chromium; 80</p> <p>Copper; 65</p> <p>Lead; 50</p> <p>Mercury; 0.15</p> <p>Nickel; 21</p> <p>Silver; 1.0</p> <p>Zinc; 200</p> <p>Arsenic; 20</p> <p><u>Sulfate: TBC</u></p>	Further information	Provide details of the rationale for proposed metals and sulfate in sediments closure criteria.
W5	<p>Water and sediment quality on the RPA</p> <p>Chosen management options result in water quality in the creeks and billabongs and sedimentation in the billabongs on the RPA that are ALARA. Accumulation of erosion products in Coonjimba and Georgetown Billabong (TBC –Section 8.3.3.8)</p>	Further information	<p>It is acknowledged in the RMCP that a closure criterion is to be developed for sedimentation in offsite billabongs. The Supervising Scientist's Turbidity and Sedimentation Rehabilitation Standard will support this.</p> <p>It is recommended that ERA update closure criteria that refer to ALARA with quantitative values that reflect ALARA.</p>
W6	<p>World heritage and Ramsar values</p> <p>Will be protected to the extent that the site could be incorporated into Kakadu NP.</p> <p><i>TBC. Biodiversity GVs above should be protective of this management outcome.</i></p>	Accepted	

6.6.1. Assessment Approach

The RMCP provides a useful and updated framework for water quality assessment based on the revised Australian and New Zealand water quality guidelines (ANZG 2018). Key elements of this framework assess actual or predicted water quality against local water quality guidelines. If actual/predicted concentrations exceed the guidelines, management options include either modification of the guideline values based on detailed site-specific information, and/or consideration and adoption of alternative management strategies (e.g. water treatment). The method for assessing the risk of metals in tailings and brines is currently being reconsidered for the metals that have limited ecotoxicological datasets. The primary focus of assessing exceedance of water quality guidelines in the RMCP is for the on-site environment for which a risk-based vulnerability assessment framework has been developed, that may be used in both ALARA and BPT assessments.

Potential for water quality criteria exceedances for the offsite environment is also acknowledged in the RMCP. It is uncertain as yet, however, whether the same process to that described above for the onsite environment would be applied to assess offsite risks. Even so, ERA is interpreting the relevant ER for the offsite environment differently to the interpretation of other stakeholders. Thus, ERA provides an interpretation of ER 1.2(d) in the second outcome of the Water and Sediment Objectives 2 (RMCP: Table 8-2) that contaminants off the RPA *do not cause detrimental impact to the ecosystem health of the Alligators River Region* which would imply an effect to be *regional* in nature to be considered detrimental. Rather, ER 1.2(d) states that to be considered detrimental a change must be in excess of that observed naturally in the region, which the Supervising Scientist interprets as outside the range of natural variability, not that changes must be regional in nature.

The closure criteria for key mine-derived sediment contaminants, i.e. uranium and sulfate, could be assessed through ensuring surface water quality concentrations remain below the rehabilitation standard values. For example, the potential uranium accumulation in sediments post-closure can be based on the results of uranium partition modelling to predict if sediment quality closure criteria will be met over the long-term. ERA has acknowledged this recommendation and has committed to undertaking the necessary work and incorporating it into a future revision of the RMCP. Similarly for sulfate, the rehabilitation standard aims to prevent ASS by keeping sulfate below concentrations where ASS has been observed to occur. There are few data regarding the toxicity of other metals in sediments, especially in tropical conditions and closure criteria may not be needed for these (e.g. Cu, Zn, Cr, etc). A contemporary sediment sampling program would indicate if any of these metal concentrations are increasing over concentration measured in previous years and against national guideline values. This assessment, together with an ongoing commitment ERA has made to sediment sampling as a result of the Independent Surface Water Working Group (ISWWG) review, would indicate if further attention is required.

For now, it is noted that there has been no agreement reached amongst stakeholders on an acceptable level of biological effects outside of the Ranger Project Area. Throughout mine operations, the Supervising Scientist has adhered to the concept of no observable change in biodiversity compared to that measured in reference ecosystems. The Mirrar Traditional Owners have been clear in stating that they consider any mine-derived change to biodiversity outside of the Ranger Project Area to be detrimental.

6.7. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 12. The table also includes ERA's response to the recommendations, which were provided

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in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response.

Table 12. Water and Sediment recommendations

Recommendation on 2018 RMCP
<p>Before commencing backfill of Pit 3 or construction of the final landform ERA must address the listed KKNs, and demonstrate that the environment surrounding the minesite (WS4) will not be impacted (WS5, WS6, WS7, and WS8) by contaminants arising from the rehabilitated minesite (WS1, WS2 and WS3).</p> <p>Key Knowledge Needs to be addressed:</p> <ul style="list-style-type: none"> • WS1 — Characterising contaminant sources on the Ranger Project Area • WS2 — Predicting transport of contaminants in groundwater • WS3 — Predicting transport of contaminants in surface water • WS4 — Characterising baseline aquatic biodiversity and ecosystem health • WS5 — Determining the impact of contaminated sediments on aquatic biodiversity and ecosystem health • WS6 — Determining the impact of nutrients in surface water on aquatic biodiversity and ecosystem health • WS7 — Determining the impact of contaminants in surface and groundwater on aquatic biodiversity and ecosystem health • WS8 — Determining the impact of suspended sediment on aquatic biodiversity and ecosystem health
ERA Response in 2019 RMCP
<p>It is intended that the listed KKNs will be addressed through ongoing studies prior to the backfilling of Pit 3 and construction of the final landform. Several KKNs require input from SSB. Applications to undertake these activities are planned to be submitted in Q4 2020 (Pit 3 Backfill) and Q3 2022 (Final Landform) and will provide additional information. Refer to Appendix 7.1 for description of studies to address these KKNs.</p>
Adequacy of ERA response in 2019 RMCP
<p>ERA response is accepted, and it is agreed that all of the WS KKNs will need to be adequately addressed prior to the backfilling of Pit 3 to ensure that potential future impacts from mine contaminants can be assessed. ERA is solely responsible for completing research to address WS1, WS2 and WS3 and the Supervising Scientist is responsible for completing a significant proportion of research to address the remaining KKNs. Research outputs will be delivered to ERA according to the current closure schedule.</p>

7. Closure Theme: Radiation

7.1. Relevant Environmental Requirements

The Radiation closure theme covers the radiological aspects of the rehabilitated minesite, and the rehabilitation activities undertaken to understand and minimise the level of radiation exposure and impacts to ecosystems and human health.

Table 12 provides a summary of the ERs that are relevant to the Radiation closure theme (in addition to the primary ERs presented in Table 1) and provides the outcome of the Supervising Scientist's detailed assessment of the RMCP against these ERs. The assessment evaluated whether the information provided in the RMCP was sufficient to demonstrate that each of the relevant ERs can be met.

Table 12. Ranger Environmental Requirements relevant to the Radiation closure theme

Radiation aspect	Environmental Requirement		Does RMCP demonstrate ER can be met?
Human health	1.1	The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives: (c) protect the health of Aboriginals and other members of the regional community.	Further information required
	1.2	In particular, the company must ensure that operations at Ranger do not result in: (c) An adverse effect on the health of Aboriginals and other members of the regional community by ensuring that exposure to radiation and chemical pollutants is as low as reasonably achievable and conforms with relevant Australian law, and in particular, in relation to radiological exposure, complies with the most recently published and relevant Australian standards, codes of practice, and guidelines.	Further information required
	2.2	(b) stable radiological conditions on areas impacted by mining so that, the health risk to members of the public, including traditional owners, is as low as reasonably achievable; members of the public do not receive a radiation dose which exceeds applicable limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines; and there is a minimum of restrictions on the use of the area.	Further information required

Radiation aspect	Environmental Requirement		Does RMCP demonstrate ER can be met?
Ecosystem health	1.1	<p>The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:</p> <ul style="list-style-type: none"> (a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list (b) maintain the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park) (d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes. 	Further information required

7.2. Activity Summary

The RMCP proposes to minimise radiation exposure to both the public and the environment by:

- disposing of tailings in the pit voids and capping the tailings with waste rock
- using low-grade waste rock on the surface of the final landform.

While the proposed plan should help to minimise the levels of radiation to which the public and the environment are potentially exposed after rehabilitation, they do not in themselves provide assurance that the closure criteria and ERs relevant to the Radiation closure theme will be met.

7.3. Detailed Works Description

Approval of the radiation dose assessment, which will incorporate doses received from both tailings and waste rock, will be subject to assessment of a standalone application, which at this point in time includes the Final Landform and Revegetation Application. This application is currently scheduled for submission by ERA in 2022.

7.3.1. Tailings Disposal

The RMCP presents the proposed strategy for disposing of radioactive tailings, which is to deposit them in the pit voids and then cover them with waste rock. Radionuclides in the tailings could potentially move through groundwater into surface water systems surrounding the minesite. Elevated radionuclide activity concentrations in surface waters may increase radiation exposure to the public and the environment along various pathways. To inform the risk to people and ecosystems from radiation, radionuclide activity concentrations in surface waters will be predicted by multiplying the ratio of (modelled) surface water to (measured) tailings magnesium concentrations by the activity concentration of the radionuclide in tailings. This approach assumes that radionuclides will be transported in an identical manner to magnesium, and is likely to lead to overestimates of surface water radionuclide activity concentrations. Further to this, the approach requires knowledge of radionuclide activity concentrations in tailings, for which no information has been presented in the RMCP.

The need to characterise radionuclide activity concentrations in tailings has been identified as a KKN (RAD1), and the need to determine radionuclide activity concentrations in surface water has

been identified as a KKN (RAD2). Both of these KKNs will need to be completed to inform the Pit 3 Closure application.

7.3.2. Landform Surface

After construction is complete, the waste rock on the surface of the final landform will be the primary source of radiation and the magnitude of potential exposure along each of the exposure pathways will depend on the uranium activity concentration of the waste rock. In order to reduce the source of radiation at the final landform surface, the more mineralised waste rock will be placed underneath the less mineralised waste rock. While the RMCP indicates that the waste rock surface will have an average uranium activity concentration of approximately 0.8 Becquerels per gram, the data and analyses used to derive this value have not been presented. To enable assessment of this critical value, and to ensure confidence in the future dose estimates, the derivation of the value should be detailed in the RMCP.

7.4. Protection of Human Health (ER 1.1, 1.2, 2.2, 5.1–5.3.)

The RMCP outlines the process for assessing radiation doses to the public from the final landform and presents information on the baseline radiological condition of the mine site as determined by Bollhöfer et al. (2014).

The RMCP presents information on baseline radium-226 activity concentrations in Magela Creek water, determined from routine water quality monitoring at the Magela Creek upstream location for the 2010 to 2013 wet seasons. However, water quality monitoring at this location has occurred over an extended period, and it is unclear why the baseline conditions were derived from a small subset of the monitoring data, rather than from all available data. Information should be presented to support the use of this subset of data for deriving baseline conditions, otherwise all available data should be used.

The RMCP presents baseline activity concentrations of uranium-238, radium-226 and lead-210 in bush foods, with the information compiled from several studies conducted by the Supervising Scientist. However, the RMCP does not present baseline activity concentrations for polonium-210, which is the radionuclide with the highest ingestion dose coefficient. Furthermore, a complete compilation of all Supervising Scientist bush food radionuclide data were published in 2016 (Doering & Bollhöfer 2016), which has not been used, nor referred to, in the RMCP for the determination of baseline values.

The 2018 RMCP identified the representative person as an Indigenous person using the final landform and surrounding environment for traditional activities including transient camping and the gathering of traditional bush foods for consumption. The probable visitation scenarios of traditional owners to the RPA were identified based on information documented in Garde (2015) after consultation with the Mirarr traditional owners. This information is critical for informing the dose assessment, however it appears to have been removed from the 2019 RMCP and it is unclear why.

While the RMCP identifies the potential radiation exposure pathways to the public from the final landform, it does not present a dose assessment which compiles data to parameterise the radiation exposure pathways so that radiation doses received from each pathway can be estimated. The absence of a radiation dose assessment in the RMCP means that there is currently insufficient information to demonstrate that the ERs relevant to radiation protection of the public can be met.

The plan indicates that a dose assessment will be undertaken and presented in a standalone application for the Final Landform, scheduled for submission in 2022. The need to compile data

for parameterising the various radiation exposure pathways has been identified as KKNs RAD3 and RAD5. The need to assess radiation doses to the public and to undertake a sensitivity analysis of radiation dose modelling has also been identified as a KKN (RAD7).

7.5. Protection of Ecosystem Health (ER 1.1, 5.1)

The RMCP acknowledges the need to assess radiation risks to the environment in line with leading practice standards for radiation protection and commits to undertake such an assessment using the ERICA Tool. The RMCP should present information on the parameter values (e.g. tissue conversion factors and whole-organism concentration ratios) that will be used in this assessment. The lack of a radiation dose assessment for wildlife in the RMCP means that there is currently insufficient information to demonstrate that the ERs relevant to radiation protection of the environment can be met. The need for this information has been identified as a KKN (RAD6) and it is acknowledged in the plan that the required research is being undertaken to address this.

7.6. Closure Criteria

Closure criteria proposed in the RMCP pertaining to radiation have been assessed and all proposed criteria have been accepted (Table 14).

Table 14. Supervising Scientist position on proposed Radiation closure criteria

RMCP reference	Radiation criteria	Assessment outcome
R1	Using the agreed restrictions on land use the total above-baseline radiation dose from external gamma exposure, inhalation of radon decay products (RDP), inhalation of dust and ingestion of bush food (including water), (shall not exceed) 0.3 mSv per year.	Accepted
R2	Should land use restrictions fail the total above-baseline radiation dose from external gamma exposure, inhalation of RDP, inhalation of dust and ingestion of bush food (including water), (shall not exceed) 1 mSv per year.	Accepted
R3	Total above-baseline radiation dose rate to terrestrial plants and animals from internal and external exposures (shall not exceed) 100 $\mu\text{Gy h}^{-1}$ to the most highly exposed terrestrial species.	Accepted
R4	Total above-baseline radiation dose rate to aquatic plants and animals from internal and external exposures (shall not exceed) 400 $\mu\text{Gy h}^{-1}$ to the most highly exposed aquatic species.	Accepted

7.7. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 15. The table also includes ERA's response to the recommendations, which were provided in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response.

Table 15. Radiation recommendations

Recommendation on 2018 RMCP
<p>Before commencing construction of the final landform ERA must address the listed KKNs, and complete an assessment of radiation dose to wildlife and humans from both tailings and waste rock sources (RAD7 and RAD8), using all relevant data and knowledge on radionuclide activity concentrations (RAD1, RAD2 and RAD3) and relevant exposure pathways (RAD3 and RAD5).</p> <p><i>Key Knowledge Needs to be addressed:</i></p> <ul style="list-style-type: none"> • RAD1 — Radionuclides in the rehabilitated site • RAD2 — Radionuclides in aquatic ecosystems • RAD3 — Radon progeny in air • RAD5 — Radionuclides in bushfoods • RAD6 — Radiation dose to wildlife • RAD7 — Radiation dose to the public • RAD8 — Impacts of contaminants on wildlife • RAD9 — Impacts of contaminants on human health
ERA response in 2019 RMCP
<p>Agreed - It is intended that the listed KKNs will be addressed through ongoing studies before construction of the final landform. RAD 4 & 5 have been removed from the KKNs. Additional information which will be incorporated into following MCP updates.</p>
Adequacy of ERA response in 2019 RMCP
<p>ERA response is accepted but before RAD5 can be closed-out, research into the U-235 decay series must first be completed, which is being undertaken by the Supervising Scientist,. It is also noted that the Supervising Scientist is responsible for completing a proportion of the research to address all other radiation KKNs. Research outputs will be delivered to ERA according to the current closure schedule.</p>

8. Closure Theme: Soils

8.1. Relevant Environmental Requirements

The Soils closure theme covers the rehabilitation activities undertaken to minimise the release of contaminated soils, and contaminants from these soils, to prevent changes to water and/or sediment quality in the receiving environment and related impacts to ecosystems and/or human health.

In the RMCP, the only ER listed as being relevant to soils is 1.2 (e), which pertains to environmental impacts within the Ranger Project Area being ALARA. However, ER 1.2(c) is also considered to be relevant as it requires that the company prevent *an adverse effect on the health of Aboriginals and other members of the regional community by ensuring that exposure to radiation and chemical pollutants is as low as reasonably achievable and conforms with relevant Australian law*. Similarly, all of the primary ERs should also be referenced in the RMCP as they are all relevant to soils unless it can be demonstrated that contaminated soils within the Ranger Project Area do not pose a risk to the environment outside the Ranger Project Area.

8.2. Activity Summary

The RMCP states that contaminated site assessments will be used to define the nature and extent of existing soil contamination within the Ranger Project Area and where remediation is required, the contaminated soil will be recovered and disposed of in Pit 3. This is in line with the relevant ERs.

8.3. Detailed Works Description

8.3.1. Delineation of Contaminated Soils

The RMCP identifies the Land Application Areas (LAAs), processing plant, Tailings Storage Facility and landfills as the areas on-site with known or potential soil contamination. The RMCP also states that additional studies are currently underway to improve understanding of the nature and extent of contaminated soils across the site, and to confirm whether or not remediation is required.

It is stated in the RMCP that the LAAs pose a low risk because contaminated runoff from these areas is *diluted to very low levels*, however more information is required to enable assessment of the environmental risk from LAAs soils if they are left in place, or disturbed during rehabilitation activities. Although the RMCP states that *shallow contaminated soils in the processing plant area will be removed during decommissioning*, no data are presented to indicate the types of contaminants present, nor the extent of contaminated soil in this area.

The RMCP needs to indicate the volumes of contaminated soil and should be updated with a detailed plan and timeline for undertaking a whole-of-site contaminated soil site assessment. Additional information should be provided on any other areas on the Ranger Project Area where there is or might be contaminated soil.

This is discussed in more detail in this assessment report under the Water and Sediments closure theme, in the context of delineation of contaminant sources (refer section 6.4.3).

8.3.2. Remediation and Disposal of Contaminated Soils

Approval of the final plan for remediation and disposal of contaminated soils will be subject to assessment of a number of standalone applications, which at this point in time includes the Tailings Storage Facility Floor Contaminated Material Management Application. This application is currently scheduled for submission by ERA in 2020.

The RMCP does not clearly demonstrate that there is no risk to the offsite environment from contaminated soils within the Ranger Project Area, nor that contamination within the Ranger Project Area will be reduced to levels that are ALARA. To achieve this, the information obtained from contaminated site assessments should be compared with appropriate standards. It is stated in the RMCP that if soil contaminant concentrations are shown to be below either local background concentrations or the *published investigation levels* (i.e. health investigation level and/or ecological investigation level), then no further assessment or remediation will be required. Health and/or ecological investigation levels for contaminants that are not currently listed in the published investigation levels, including uranium, need to be developed (identified in KKNs RAD8 and RAD9). Consideration should also be given to guidance provided by the Environmental Health Standing Committee (EnHealth) in assessing the risk of contaminants to human health.

Once the risk from contaminated soils across the site is understood, detailed action plans and timelines for remediation should be prepared for high risk areas and included in the RMCP. These plans should include volumes of contaminated material that need to be recovered and locations for disposal.

The RMCP indicates that the Tailings Storage Facility is likely to be a source of contamination after rehabilitation. However, there are no details provided on the nature or extent of contamination (i.e. soils or sediments below the facility or within the walls), or how this area will be rehabilitated to minimise the risk to the environment and human health. ERA is currently undertaking investigations to determine the best method for remediation of the Tailings Storage Facility, and a standalone application will be submitted for assessment.

8.4. Closure Criteria

Closure criteria proposed in the RMCP pertaining to soils have been assessed and the outcome is described as being either a) Accepted or b) Require Further Information (Table 16). For criteria that require further information (or clarification), comments are provided in the table.

Table 16. Supervising Scientist position on proposed Soil closure criteria

RMCP reference	Soil criteria	Assessment outcome	Supervising Scientist Comment
S1	Contaminated soil assessment for uranium and manganese in Land Application Area: demonstrate risk is ALARA	Further information	The assessment of ALARA requires a detailed understanding of the potential impacts to human health and the environment such that these can be balanced against the cost and practicality of remediation options.
S2	Contaminated assessment of identified CoPCs for other soils identified as not being part of the larger decommissioning works: demonstrate risk is ALARA	Further information	If current investigations indicate that contaminated soils on the Ranger Project Area do pose a risk to the offsite environment, there may be a requirement in future to develop soil closure criteria with specific concentrations for key contaminants.

8.5. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 17. The table also includes ERA's response to the recommendations, which were provided in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response.

Table 17. Soils recommendations

Recommendation on 2018 RMCP
<p>Before commencing backfill of Pit 3 ERA must address the listed KKNs, and complete a whole-of-site contaminated site assessment to inform the requirement for soil remediation (WS1 and RAD1), including within the walls of the Tailings Storage Facility.</p> <p>Key Knowledge Needs to be addressed:</p> <ul style="list-style-type: none"> • WS1 - Characterising contaminant sources on the Ranger Project Area • RAD1 - Radionuclides in the rehabilitated site
ERA Response in 2019 RMCP
<p>Prior to commencing backfill of Pit 3 the listed KKNs will be addressed and a whole-of-site contaminated site assessment will be completed to inform soil remediation. This includes contamination assessment within the walls for the Tailings Storage Facility. Drilling is currently scheduled to undertake samples of the Tailings Storage Facility walls. An application to decommission the Tailings Storage Facility will include further details on the strategy for remediation based on the outcomes of drilling and contamination assessment.</p>
Adequacy of ERA response in 2019 RMCP
<p>ERA response is accepted.</p>

9. Closure Theme: Ecosystem Restoration

9.1. Relevant Environmental Requirements

The Ecosystem Restoration closure theme covers the restoration of flora and fauna communities on the final landform, aiming to ensure they are sustainable and similar to those in the adjacent areas of Kakadu National Park.

Table 18 provides a summary of the ERs that are relevant to the Ecosystem Restoration closure theme (in addition to the primary ERs presented in Table 1) and whether or not the information provided is sufficient to demonstrate that each of the relevant ERs can be met.

Table 18. Ranger Environmental Requirements relevant to the Ecosystem Restoration closure theme

Ecosystem aspect	Clause	Environmental Requirements	Does RMCP demonstrate ER can be met?
Ecosystem Restoration	2.1	Subject to subclauses 2.2 and 2.3, the company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu National Park such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu National Park.	Further information required
	2.2	The major objectives of rehabilitation are: (a) revegetation of the disturbed sites of the Ranger Project Area using local native plant species similar in density and abundance to those existing in adjacent areas of Kakadu National Park, to form an ecosystem the long-term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park.	Further information required
Ecosystem Protection	10.2	The company must ensure that the operations at Ranger will not result in any adverse impact on Kakadu National Park through the introduction of exotic fauna or flora.	Further information required

9.2. Activity Summary

The RMCP provides a high-level overview of the proposed ecological restoration process for 1190 hectares of disturbed land on the Ranger Project Area, which will be achieved by progressively revegetating the area with local species and undertaking ongoing monitoring and maintenance activities, including irrigation, fire management, weed control and infill planting.

These proposed activities are broadly in line with the relevant ERs.

9.3. Detailed Works Description

The RMCP provides a high-level plan to revegetate the final landform with local species to establish a sustainable vegetation community that is similar to adjacent areas of Kakadu National Park. The RMCP details three broad components: 1) site preparation; 2) revegetation; and 3) maintenance and monitoring.

Further information is required to demonstrate that the relevant ERs can be achieved. It is understood that this will be provided in a standalone application for the Final Landform and Revegetation scheduled for submission in 2022, which should include a detailed description of the works to be undertaken.

These information requirements have been identified as KKNs (ESR2, ESR3 and ESR4).

9.3.1. Revegetation Strategy

An overarching Revegetation Strategy will be used to guide the revegetation process (provided as Appendix 11.4 of the RMCP). The Strategy has been revised significantly since the 2018 RMCP, and includes details of a two-staged approach where framework overstorey species and a sub-set of suitable midstorey and understorey species will be established initially, followed by the introduction of additional species at a later date (possibly five or more years after initial planting). This approach is intended to harnesses ecological processes such as vegetation community and soil development, and species-specific environmental preferences, to underpin the success of revegetation.

It is suggested the Revegetation Strategy be expanded to an 'Ecosystem Restoration Strategy' in recognition of the intention of the ERs, and key linkages between flora and fauna and broader ecosystem processes. The Ecosystem Restoration Strategy should be built on a detailed ecosystem establishment trajectory model. The information drawn from previous and current/planned revegetation studies should be used in the development of the trajectory model. The model should consider scenarios that capture the key aspects of, and influences on, ecosystem establishment, and be used to identify and plan for management of risks, and provide the basis for a targeted monitoring program. There is a need to monitor the revegetation against closure criteria until the closure objective has been met, or until milestones within an appropriately modelled trajectory (or trajectories) have been achieved and sufficient confidence is gained that the desired end state will be achieved.

Trajectories of possible change will need to be documented and management strategies to reach desired end states clearly articulated. The trajectory model needs to include the uncertainty associated with the possible end states and management interventions. ERA has acknowledged the requirement for information in relation to key sustainability indicators and establishment trajectories to measure revegetation success. These have been identified as a KKN (ESR5).

It is likely that revegetation infill planting will be required to address plant mortality following initial revegetation and, possibly in the long-term if the revegetation deviates from expected trajectories (e.g. due to fire, extreme climatic events). There is a need to refine the vegetation mortality contingencies to consider mortality, both in the short- and long-term, and the potential for mortality to vary between species and locations. ERA has acknowledged that this information will be addressed through ongoing revegetation trials.

9.3.2. Revegetation Trials

The proposed Revegetation Strategy presented in the RMCP is based on a substantial body of work conducted on revegetation at Ranger mine over many years. However, many of the trials have been conducted over relatively short timeframes and at spatial scales that are small compared to the final landform. Therefore, evidence to support the potential for long-term sustainability of revegetation at Ranger mine is currently limited. Recently ERA has developed a range of revegetation trials, and of particular note is the commencement of progressive revegetation of the Pit 1 area. It is also understood that ERA is conducting seed germination and other nursery trials to assist with assessing which species are able to be grown from seed, and which are not able to be successfully propagated.

It is possible that some species in the surrounding environment may not be able to establish, or persist, on the waste rock landform. Where this is the case ERA must provide evidence to demonstrate the reasons why establishment is not possible. This information requirement has been identified as a KKN (ESR7). There is broad agreement amongst stakeholders with respect to ERA's approach to the proposed trials, and the information obtained from these trials will be critical for further informing the revegetation strategy. Should ERA identify that certain aspects of the ERs cannot be met, a substantial body of evidence must be provided to demonstrate that what is being proposed constitutes BPT. These information requirements have been identified as KKNs (ESR1, ESR2, ESR3 and ESR4).

9.4. Ecosystem Restoration (ER 2.1, 2.2)

9.4.1. Similarity

9.4.1.1. Reference Sites

The Supervising Scientist is currently working with ERA to progress the establishment of an agreed conceptual reference ecosystem that is representative of ecosystems in areas surrounding the mine site, and on which the revegetation strategy should be based. The reference ecosystem will comprise a combination of data describing the vegetation in natural areas within, and surrounding the Ranger Project Area, measured using a number of different methods and at different scales. Research undertaken by the Supervising Scientist to date shows that the vegetation community type on which ERA has based current revegetation targets is not common in adjacent areas of Kakadu National Park. The dataset used by ERA to represent the vegetation community is also not considered to be statistically-robust. The Supervising Scientist is working to quantify the occurrence of this vegetation community in adjacent areas, and continues to work with ERA to appropriately characterise the conceptual reference ecosystem for closure. A KKN related to the scale and temporal variability of terrestrial ecosystems in areas surrounding the Ranger Project Area has been identified (ESR1).

Grasses and understorey are critical to savanna structure and function, including creating the conditions required for the colonisation and survival of soil biota (e.g. Scholes & Archer 1997; Hutley et al. 2001; Ludwig et al. 2004; Hutley & Setterfield 2008). The RMCP indicates that understorey species will be planted as part of the revegetation strategy. Nevertheless, the ability for the final landform to support understorey remains a key unknown and to date, there has been limited demonstration of success in establishing understorey species on Ranger mine waste rock. To address this knowledge need, ERA has recently commenced trials for introducing understorey species on the trial landform. It is understood that ERA is also planning to trial direct seeding of understorey species during the progressive revegetation of Pit 1. Further detail should also be provided on species selection, including consideration of faunal requirements such as habitat use

and diet. The results of these studies should be used to support the ongoing refinement of the revegetation strategy.

Information requirements pertaining to understorey propagation and establishment on waste rock have been identified as KKN ESR3 and habitat requirements for fauna establishment are identified as KKN ESR2.

ERA has acknowledged the need to provide further information in relation to the relevant closure criteria, in consultation with the Supervising Scientist, and has committed to providing this in future updates of the RMCP.

It is suggested in the RMCP (section 8.6.1.2) that rock would be included in assessments of understorey cover. Although rocks may assist in erosion control, they should not be included in the assessment of whether understorey cover on the rehabilitated site is similar to reference/analogue ecosystems.

Further refinement and consensus are required on the revegetation species list (including both over- and understorey species), including the rationale for selection of framework species. ERA has committed to finalising this for the 2020 RMCP.

The information requirement concerning the development of appropriate structural indicators to measure revegetation success has been identified as a KKN (ESR1).

9.4.1.2. Fauna

In summarising findings from studies within the Ranger Project Area, it is stated in the RMCP that there is evidence of fauna colonisation across the trial landform and other revegetated sites.

Further information is needed to determine what habitats should be provided on the rehabilitated site to ensure the recolonisation of fauna (particularly including threatened species). The creation of this habitat should be a key focus of the Ecosystem Restoration Strategy, describing the establishment of key plant species and any installation of constructed habitat. This information requirement has been identified as a KKN (ESR2). There is also a need to assess the threat of introduced animals to faunal colonisation of the rehabilitated site. Information pertaining to the abundance of introduced animals in areas adjacent to the Ranger Project Area is limited (viz KKN ESR4).

9.4.2. Sustainability

9.4.2.1. Plant Available Water

Determining if the waste rock landform will contain sufficient water to support a mature vegetation community through the dry season is a key aspect of ecosystem sustainability. This requires both an understanding of total plant water use and the amount of plant available water within the landform. The Supervising Scientist has undertaken a detailed review of ERA's work to quantify water usage requirements of the adjacent natural vegetation communities, and to estimate the plant available water within the final landform.

The modelling undertaken to predict plant available water in the final landform should be tested by the ongoing collection of relevant data and information throughout progressive rehabilitation. Confidence can also be significantly enhanced by including uncertainty analysis in the model, particularly because the current model simulations predict there may be insufficient plant available water during some years. It is noted that further work will be undertaken by ERA as part of the planned Pit 1 revegetation trials.

In the RMCP, plant evapotranspiration is used as an indicator to demonstrate that there is sufficient plant available water in the rehabilitated landform, with the assumption that overstorey species are the main component of evapotranspiration during the dry season. This does not include midstorey species that may account for a moderate to high proportion of the total cover. Dry season water use by evergreen midstorey species (e.g. *Acacia mimula*) is currently unknown, leading to a potential under estimate of total plant water usage.

Further information on the internal properties in each area of the final landform (e.g. nature, depth and extent of material) should be provided, to allow assessment of the degree to which the assumed properties used in the WAVES modelling will occur in the final landform.

The WAVES model should be periodically updated as further information is gained, both from revegetation trials and from natural vegetation communities.

The need to gain a better understanding of plant available water in the rehabilitated landform has been identified as KKN ESR7.

9.4.2.2. Soil Development and Nutrients

It has been assumed that rock material will weather rapidly to form rudimentary soil materials. However, studies cited in relation to this assumption were conducted on waste rock originating from the upper levels of Pit 1 alone, which has different geochemical properties to waste rock from Pit 3. Given that the majority of the final landform will comprise waste rock from Pit 3, the information referenced may not be representative of the whole landform. Field observations undertaken by the Supervising Scientist on the trial landform indicate that not all rock types will weather rapidly. Additional information is required to quantify how quickly the waste rock substrate will develop into a soil suitable to support a vegetation community similar to the surrounding area. ERA has acknowledged that this information will be provided in the 2020 and subsequent updates of the RMCP as relevant studies are completed. These information requirements have been identified as KKN ESR7.

There are likely to be substantial differences between waste rock and natural soils in terms of nutrients (e.g. P, N, Mg, exchangeable K and S) and rhizobia/mycorrhizal fungi available to plants, and there is a possibility that some contaminants may affect plant growth (KKN ESR6). The revegetation strategy should identify the requirements necessary for the commencement of nutrient cycling on the landform, in particular, the colonisation and survival of key soil biota and invertebrates. The RMCP presents information that is available to date on nutrient cycling in the rehabilitated landform (e.g. 2018 study on the trial landform). The need to gain a better understanding of nutrient cycling is acknowledged in the RMCP and has been identified as a KKN (ESR7). ERA has outlined planned studies and committed to provision of a summary of this information in the 2020 RMCP update, following their completion.

9.4.2.3. Spatial and Temporal Scale of Landscape Factors

Information on spatial and temporal considerations for assessing the influence of landscape-scale factors on revegetation success is partially addressed in the RMCP. This information is important to identify mitigations to address integrated landscape risks, such as extreme weather events (e.g. cyclones, extreme rainfall, prolonged dry season). The need to gain a better understanding of the landscape-scale processes and extreme events on landform stability has been identified as a KKN (LAN2) and ERA has acknowledged that as planned studies are completed, these will be included within the Ecosystem Restoration Strategy.

9.4.2.4. Fire

Although identified as a risk to revegetation success, there is very limited contemporary information from the region presented in the RMCP to demonstrate the resilience of revegetation to fire. There are numerous relevant published studies on fire and plant survivability in the region (e.g. Setterfield 1997; Williams et al. 1999; Setterfield 2002; Russell-Smith et al. 2003; Werner 2005; Werner & Prior 2013) that could be used to strengthen the information presented in the RMCP and provide stronger criteria for vegetation success.

The RMCP makes only a brief reference to the effect of fire regimes on fauna (from a protection of wildlife perspective), therefore it is unclear what the most appropriate fire regime may be to allow faunal colonisation and persistence on the rehabilitated minesite.

The requirement to determine the most appropriate fire management regime to ensure a fire resilient ecosystem on the rehabilitated site has been identified as a KKN (ESR8).

9.4.2.5. Introduced Species

Information on the composition and abundance of introduced species in areas adjacent to the rehabilitated site is required, both to assess the risk that these ecological stressors may pose to successful ecosystem restoration and to demonstrate that their presence on the site is not higher than in adjacent areas. This information will be required throughout the rehabilitation process (e.g. early detection of pests or weeds may allow for ready cost-effective eradications) and close to the completion of rehabilitation to assess whether active mitigation measures will be needed. This has been identified as a KKN (ESR4).

9.5. Closure Criteria

Closure criteria proposed in the RMCP pertaining to ecosystem restoration have been assessed and the outcome is described as being either a) Accepted or b) Requiring Further Information (Table 19). For criteria that require further information (or clarification), comments are provided in the table. The Supervising Scientist's Rehabilitation Standard for ecosystem restoration is still under development. However, it currently includes recommended indicators of similarity to surrounding areas of Kakadu National Park and demonstration of long-term ecosystem sustainability. ERA and the Supervising Scientist continue to work closely together to ensure that the Ecosystem Restoration closure criteria and elements of the Rehabilitation Standard align.

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Table 19. Supervising Scientist position on proposed Ecosystem Restoration closure criteria

RMCP reference	Proposed criteria	Assessment outcome	Supervising Scientist Comment
F1	Provenance: Revegetation has used local native species from within Kakadu National Park.	Accepted	
F2	Species composition (tree and shrubs) and relative abundance: Bray–Curtis similarity index $\geq 25\%$ Total species richness 90% of midstorey and overstorey framework species.	Further information	For overstorey species, the RMCP proposes a Bray–Curtis similarity of $\geq 25\%$ as a closure criterion for revegetation (Criterion F2) together with a proposed total species richness criterion of 90 % of midstorey and overstorey framework species. The Supervising Scientist does not support the numbers as currently presented, noting that both these metrics depend on the spatial scale of measurement, include no measures of variability and no understorey metrics are provided. Species number criteria should also incorporate the structural components of vegetation communities (i.e. understorey and overstorey), to ensure that none of these is over or under-represented. Recent technical advice provided by the Supervising Scientist to ERA from survey data in the surrounding environment indicates a total species number of around 290, based on overstorey and understorey vegetation in a 12 hectare area.
F3	Canopy architecture: Presence of multistrata. Presence of understorey shrubs and grasses developed appropriate to the substrate.	Further information	For the closure criterion proposed for canopy architecture (Criterion F3), presence alone is not sufficient to demonstrate that revegetation communities are representative of adjacent areas of Kakadu. Criteria should be presented as ranges relative to reference sites and broken down into an appropriate classification of strata. Also, the establishment of understorey species that are appropriate to substrate is not consistent with the ERs that state that vegetation should be comparable to surrounding areas.
F4	Canopy cover index, groundcover index Comparable to appropriate reference sites.	Further information	For the closure criterion proposed for canopy and groundcover (Criterion F4), clarification is required on what is meant by canopy/groundcover index. Foliage projective cover would generally be considered as an appropriate measure to assess vegetation cover.
F5	Tree distribution Trees are planted in a manner to appear 'natural'.	Further information	Whilst the objective is supported, it should be supported with some form of metric by which success can be judged.

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RMCP reference	Proposed criteria	Assessment outcome	Supervising Scientist Comment
F6	Reproduction (flowering and seeding) Evidence of flowering and fruiting of 100 percent of framework species or characteristic species (based on species present).	Further information	The plant reproduction closure criterion (Criterion F6) should be updated to include consideration of the amount and periodicity of flower, fruit and seed resources provided in the revegetated site, rather than simply whether there is any evidence of any flowering or fruiting.
F7	Recruitment / regeneration Presence of seedlings and/or 'suckers' of 80 percent of framework species or characteristic species (based on species present).	Further information	The closure criterion for recruitment and regeneration (Criterion F7) does not yet adequately capture the process of vegetation recruitment. A seedling may be present but not survive the dry season and hence is not recruited into the population (i.e. recruitment has not occurred). This criterion should capture seedling germination/sucker emergence, survivorship and growth. While understood as a general term, framework species should be clearly defined to avoid confusion.
F8	Nutrient cycling Accumulation of litter and organic matter. Evidence of decomposition of litter. Presence of soil animals and saprophytic fungi. The above criteria occur in 90 percent of the survey plots.	Further information	The closure criterion for nutrient cycling (Criterion F8) should be expanded to link it more closely with processes occurring in the surrounding undisturbed environment.
F9	Fire resilience Following a recent fire (within previous five years), all other closure criteria must be shown to have been met, demonstrating recovery	Further information	The closure criterion proposed for fire resilience (Criterion F9) has been updated since the 2018 RMCP, with reference to the achievement of all other relevant closure criteria following a recent fire.
F10	Resilient to wind and drought Woodland ecosystem demonstrates survival under natural conditions, similar appropriate reference sites.	Accepted	
F12	Weed composition and abundance No Class A weeds. Class B weeds similar to surrounding Kakadu NP. Presence of other introduced species would not require a maintenance regime significantly different from that appropriate to adjacent areas of Kakadu NP.	Accepted	

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RMCP reference	Proposed criteria	Assessment outcome	Supervising Scientist Comment
F13	<p>Native fauna</p> <p>Development of habitat suitable for native fauna species that utilise appropriate reference sites: The following habitat features must be present: multi-strata layers; coarse woody debris (10 cm in diameter), trending towards development of hollows, rock features.</p> <p>Local native mammals, birds, reptiles & invertebrates using the site (or likely to).</p> <p>An effective termite decomposer fauna has developed: Recent termite constructs (mounds, arboreal nests, earthen workings in litter, on wood and on tree stems) are present, and there is evidence of termite-mediated decomposition of woody and other plant materials.</p> <p>Exotic fauna</p> <p>Feral animals (specifically buffalo, horses and pigs) are similar in density on the RPA compared to the adjacent areas of Kakadu NP.</p>	Further information	<p>Fauna closure criteria (F13) have been updated since the 2018 RMCP, with the inclusion of criteria for native fauna habitat and the presence of fauna, including termite decomposers in particular. The previous criterion in relation to the presence of major functional groups (vertebrate and invertebrate) has been removed.</p> <p>While the additional criteria are supported, these should include standard quantitative biodiversity indices (e.g. species richness and abundance) that allow assessment of whether terrestrial fauna communities on the rehabilitated site are comparable (or on a trajectory to be comparable) with those in adjacent areas of Kakadu National Park. Evidence is required to support the assumption that fauna will colonise the rehabilitated site once suitable habitat has established. The requirement for information to assess the suitability of habitats on the rehabilitated site (and inform its design) for fauna colonisation has been identified as a KKN (ESR2) and should be a key aspect of the Ecosystem Restoration Strategy.</p> <p>Criterion F13 should be reworded to introduced animal densities 'not greater than' those in surrounding areas, as opposed to similar to those in surrounding areas.</p>

9.5.1. Criteria Terminology

In the Ecosystem Restoration (flora and fauna) closure criteria explanatory text presented in the RMCP, there is a distinction made between *critical standalone* criteria and others that may be assessed *collectively*, or *within the context of meeting the overall closure criteria as a whole*. It is stated in the RMCP that this approach has been recommended by DPIR but the rationale should be detailed in the plan. For example, it is not clear why some criteria would be seen as more critical than others, as all relate to meeting the ERs and if criteria were assessed collectively, the important detail would likely be lost.

To ensure that closure criteria for ecosystem restoration are specific and measurable, terminology should be consistent and clearly defined, such as:

- *comparable to*
- *similar to*
- *to appear*
- *under natural conditions*
- *adjacent areas of KNP and surrounding KNP.*

9.5.2. Revegetation Establishment Trajectories

Trajectories are applicable to any closure criteria that are expected to be reached after an extended period of time from the initial establishment, which is the case for ecosystem establishment. This requires the selection of points within the desired trajectory that represent milestones for closure criteria, which once met give confidence that the desired end state will be achieved.

9.6. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 20. The table also includes ERA's response to the recommendations, which were provided in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response. It is noted that the Ecosystem Restoration KKNs have been updated since the 2018 RMCP and have been updated in the table.

Table 20 Ecosystem Restoration recommendations

Recommendation on 2018 RMCP
<p>Before commencement of revegetation activities on the final landform ERA must address the listed KKNs, and develop an ecosystem restoration strategy which includes consideration of both flora and fauna (ESR1, ESR2, ESR3 and ESR4), and is based upon an appropriate trajectory model (ESR5) that accounts for key influences on revegetation establishment (ESR6, ESR7 and ESR8).</p> <p><i>Key Knowledge Needs to be addressed:</i></p> <ul style="list-style-type: none"> • ESR1 — Determining the requirements and characteristics of terrestrial vegetation in natural ecosystems adjacent to the mine site, including Kakadu National Park. • ESR2 — Determining the requirements and characteristics of a terrestrial faunal community similar to natural ecosystems adjacent to the mine site, including Kakadu National Park. • ESR3 — Understanding how to establish native terrestrial vegetation, including understory species. • ESR4 — Determine the incidence and abundance of introduced species in natural ecosystems adjacent to the mine site, including Kakadu National Park, and their potential to impact on the successful rehabilitation of Ranger mine. • ESR5. Develop a restoration trajectory for Ranger mine. • ESR6 — Understanding the impact of contaminants on vegetation establishment and sustainability. • ESR7 — Understanding the effect of waste rock properties on ecosystem establishment and sustainability (excluding ESR7.B). • ESR8 — Understanding fire resilience and management in ecosystem restoration.
ERA Response in 2019 RMCP
<p>This recommendation is the intent of ERA. The KKNs will be addressed and studies information utilised in the final RPA landform revegetation plan.</p>
Adequacy of ERA response in 2019 RMCP
<p>ERA response accepted. It is noted that some of the projects listed in Appendix 7.1 of the RMCP don't yet have sufficient detail on planned outputs to demonstrate that they will address the KKNs.</p>
Recommendation on 2018 RMCP
<p>In accordance with the previous recommendations of the Supervising Scientist; before the placement of the grade 1s waste rock cap on Pit 1 ERA must address the listed KKNs, and demonstrate that the waste rock landform will provide sufficient plant available water to support a mature vegetation community (ESR7.B).</p> <p><i>Key Knowledge Needs to be addressed:</i></p> <ul style="list-style-type: none"> • ESR7.B — Will sufficient plant available water be available in the final landform to support a mature vegetation community?
ERA Response in 2019 RMCP
<p>The results of the completed KKN are summarised within Section 7.3.5 of the updated MCP. Demonstrated that 4-6 m of waste rock landform with various levels of rock contents can maintain a positive PAW water balance while supporting a vegetation similar to one of the reference sites.</p>
Adequacy of ERA response in 2019 RMCP
<p>While further information is provided the RMCP to gain a better understanding of the extent to which plant available water is likely to be an issue for revegetation, the KKN has not yet been completed. Further work is required against KKN ESR7B, <i>Validation of the WAVES model on the pit 1.</i></p>

10. Monitoring

10.1. Relevant Environmental Requirements

Under the ERs monitoring is required until site closure (Table 21). Monitoring programs must be implemented:

- while undertaking rehabilitation activities to ensure continued protection of the offsite environment and to inform the progressive rehabilitation process
- after the completion of rehabilitation activities to assess and demonstrate achievement of the rehabilitation objectives.

Table 21. Ranger Environmental Requirements relevant to Monitoring

Monitoring aspect	Clause	Environmental Requirement	Does RMCP demonstrate ER can be met?
Monitoring for Environment Protection	13.3	The company must carry out a monitoring program approved by the Supervising Authority or the Minister with the advice of the Supervising Scientist following cessation of operations until such time as a relevant close-out certificate is issued under clause 9.3.	Further information required

10.2. Activity Summary

The RMCP provides a section on monitoring which covers each of the six closure themes over two periods; a) closure (i.e. during rehabilitation until 2026) and b) post-closure (i.e. after the completion of rehabilitation, beyond 2026). This section of the RMCP has been expanded since the 2018 plan and is a significant improvement. The proposed closure monitoring programs build on the existing operational monitoring programs currently undertaken by ERA. The proposed post-closure monitoring programs will continue until the monitoring results demonstrate that the site has met the required closure objectives. It is accepted that monitoring effort is likely to reduce over time, in line with reducing environmental risk. However, this should be justified with data rather than being based on a predetermined timeframe. ERA has assumed that post-closure monitoring will be necessary for at least 25 years. While this may be a reasonable estimate, in accordance with ER 13.3 monitoring will need to continue until closure has been achieved, which may take longer than 25 years, particularly for ecosystem restoration.

During both the closure and post-closure phases, monitoring results will be essential for assessing the success of rehabilitation activities, informing the KKNs and enabling effective implementation of an adaptive management approach to ensure the successful transition of the site from operational mining, through progressive rehabilitation and to final closure. The RMCP also acknowledges that both monitoring programs (and closure criteria for which they are intended to assess) are subject to review, as new information becomes available and stakeholder feedback is provided.

The RMCP presents a *Pit 1 Progressive Closure Monitoring Framework*, which will form the basis of more detailed monitoring programs. These will be developed via a Monitoring Evaluation and Research Review Group, established in recognition of the interrelationship between closure-related studies being undertaken by both ERA and the Supervising Scientist. The Group is represented by

staff from both organisations, and subject matter experts as required, to develop monitoring and research programs during the progressive rehabilitation period.

The Supervising Scientist supports the use of the ‘trigger action response plan’ (TARP) methodology for implementing adaptive management activities. It is noted that this approach will only be useful in situations where effects are likely to be observed within a relatively short timeframe, as opposed to effects which may appear after hundreds or thousands of years. This approach could be improved by:

- ensuring that triggers are specific, measurable and readily linked to management actions
- ensuring that actions are specific and avoid the use of generic responses such as *monitor trends and develop site-specific action plans as required*
- using a ‘tiered’ risk approach.

Examples of the tiered risk approach include:

- ‘first tier’ triggers that identify opportunities for closer monitoring or early intervention that may mitigate potential impacts before significant impact to rehabilitation success, or the environment, occurs
- ‘second tier’ triggers that identify when indicators have reached a threshold that requires more substantive or widespread remedial actions to prevent rehabilitation failure or mitigate environmental impacts.

The RMCP describes the proposed closure monitoring programs at an appropriate level for this point in time. It is expected that more detailed monitoring plans will be submitted to stakeholders for review as they are developed and included in future revisions of the RMCP or other relevant statutory documents, as appropriate. It will also be critical to ensure that the methods and techniques used for monitoring are reviewed regularly to ensure that they are continually optimised, aligning with technological advancement and current leading practices. Generally, each monitoring program should also include additional information on reporting of monitoring results, including commitments to report to stakeholders at appropriate reporting frequencies, noting that annual reporting of surface water quality monitoring results post-closure is not likely to be frequent enough.

Specific comments on the monitoring programs according to closure themes are provided in the following sections.

10.2.1. Landform Monitoring

The RMCP needs to include further details on monitoring methods to demonstrate how information will be collected to assess landform performance over time, including:

- how gully formation will be measured on the revegetated landform
- details of monitoring data required for ongoing validation of erosion modelling
- water quality monitoring methods to be used for assessing landform erosion (e.g. turbidity as a surrogate for suspended sediment in surface water).

It is stated in the RMCP that the final landform topography will be documented after completion using ground-based LiDAR survey techniques, and that specific details are yet to be determined. The Supervising Scientist is currently developing airborne LiDAR platforms which may be more suited to this task.

Monitoring of tailings consolidation in Pit 1 has been undertaken using settlement plates installed at the interface between the top of tailings the tailings surface and the overlying waste rock backfill. It is understood from consultation with ERA that it may not be possible to utilise this monitoring method for Pit 3. The RMCP mentions the use of vibrating piezometers to monitor excess pore pressures within tailings but it is not clear whether, nor how, they may be used to inform tailings consolidation in the final landform. This is a critical issue as the current target of 95% tailings consolidation before 2026 is a key assumption in the contaminant transport modelling, and the OPSIM site water balance model (which include predictions of process water volumes requiring treatment prior to 2026). It will not be possible to determine when this target has been met without a suitable method to monitor tailings consolidation over time.

ERA has acknowledged these information requirements, which have been identified as a KKN (LAN3).

10.2.2. Water and Sediment

10.2.2.1. Surface Water

The monitoring section of the RMCP outlines a proposed program consisting of continuous, monthly grab and event-based sampling of water quality and sediments to assess compliance with closure criteria. The monitoring program is likely to be refined and agreed between ERA and the Supervising Scientist via the Water and Sediment Working Group.

It is noted that the proposed water quality monitoring program includes sulfate as a parameter at key monitoring sites on Magela and Gulungul Creeks. Given the risk of acid sulfate soil development on the Ranger Project Area and the Supervising Scientist's rehabilitation standard for this parameter, it should also be monitored at RP1 (and other onsite waterbodies, while they are present) and Georgetown and Gulungul Billabongs.

10.2.2.2. Groundwater

The groundwater monitoring program presented in the RMCP should be revised to clearly demonstrate that monitoring will be undertaken at an appropriate spatial and temporal scale to:

- observe trends in groundwater level recovery and contaminant transport post-closure that can be used to validate groundwater models, and recalibrate if necessary
- detect significant increases in contaminant concentrations in aquifers surrounding Pit 1, Pit 3 and the Tailing Storage Facility, to enable downstream mitigation of impacts if required (i.e. groundwater interception or abstraction).

The RMCP incorrectly states that a groundwater monitoring program for Pit 1 was approved in the application of the final tailings level. This is not the case, rather a key recommendation made as part of the approval of the final tailings level in Pit 1 was that the monitoring program approved in the 2005 application to deposit tailings in Pit 1 must be continued until a new, more appropriate monitoring program was developed and approved. This has not yet been done, however ERA and the Supervising Scientist are currently discussing this issue.

The RMCP indicates that the site-wide post-closure groundwater monitoring network will be based on the existing network as outlined in the 2017/18 Annual Ground Water Report (ERM 2018) and amended over time, if required. Additional information obtained from ongoing post-closure solute transport modelling or new monitoring bores, including those planned to be installed in vicinity of Pit 1 and Pit 3 during 2019, should be used to refine and optimise the long-term groundwater monitoring plan.

10.2.3. Radiation

The RMCP includes a proposed radiation monitoring program after rehabilitation of the mine site. The proposed monitoring program includes atmospheric monitoring, surface water monitoring, surface radiation monitoring and bioaccumulation monitoring. More information is required in relation to the bioaccumulation monitoring. It is currently unclear what terrestrial bush foods will be targeted for sampling, and it appears that bioaccumulation monitoring of radionuclides in aquatic bush foods is not proposed. This would mean that the potential radiation dose to the public from ingestion of aquatic bush foods could only be assessed using water radionuclide monitoring results and concentration ratios, rather than actual activity concentrations in the bush foods.

10.2.4. Ecosystem Restoration

It is stated in the RMCP that a long-term vegetation and fauna monitoring program has commenced at 17 sites to document the condition and seasonal variation of reference sites in adjacent areas of Kakadu and undisturbed areas of the Ranger Project Area. It is intended that information collected from these reference sites will be used in the development of closure criteria and to assess future rehabilitation success. The RMCP should provide detailed information about:

- justification for site selection
- survey methods (including plot size) and quantitative metrics being used to assess *condition* and *natural variability*
- how the data from these surveys are being used to derive or update closure criteria.

The monitoring program should be further developed based on the risks and mitigations identified through a trajectory model, and include monitoring of the progressive rehabilitation activities which have already commenced. ERA has acknowledged the need for this, with the State-and-Transition Model for Ranger Mine revegetation that is under development (collaboration between ERA, the Supervising Scientist and CSIRO) to inform a KKN (ESR5). The outcomes of this work will enable the revegetation objectives (including the conceptual reference ecosystem), pathways, risks, contingencies and monitoring to be more clearly articulated.

10.3. Recommendations

The Supervising Scientist's recommendations on the previous version of the RMCP are provided in Table 22. The table also includes ERA's response to the recommendations, which were provided in the 2019 RMCP, along with the Supervising Scientist's comment on the adequacy of the response.

Table 22. Summary of recommendations pertaining to monitoring

Recommendations on 2018 RMCP
<p>Develop detailed monitoring plans that cover and distinguish between all the necessary types and periods of monitoring, including:</p> <ul style="list-style-type: none"> • ‘operational’ monitoring to detect potential impacts during the implementation phase of rehabilitation • progressive closure monitoring to confirm that rehabilitated areas are performing as expected and, if necessary, inform future rehabilitation activities • monitoring to verify surface and groundwater modelling predictions • post-2026 stabilisation and maintenance phase monitoring. • resources required to fulfil monitoring requirements • any other project specific assumptions or information which would be required to conduct a detailed assessment of the appropriateness of the monitoring programs.
ERA Response in 2019 RMCP
<p>Additional information on monitoring has been provided in the Closure monitoring and maintenance Section. This will continue to be developed in subsequent iterations of the MCP as further information becomes available.</p>
Adequacy of ERA Response in 2019 RMCP
<p>The RMCP describes the proposed closure monitoring programs at an appropriate level for this point in time. It is expected that more detailed monitoring plans will be submitted to stakeholders for review as they are developed and included in future revision of the RMCP or other relevant statutory documents, as appropriate.</p>

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Appendix 1 — List of Acronyms

AALL	annual additional load limits
Ac	actinium
ALARA	as low as reasonably achievable
APR	Annual Plan of Rehabilitation
ARR	Alligator Rivers Region
ARRAC	Alligator Rivers Region Advisory Committee
ARRTC	Alligator Rivers Region Technical Committee
BPT	best practicable technology
COPC	contaminants of potential concern
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPIR	Department of Primary Industry and Resources
DEM	digital elevation model
EIL	ecological investigation level
ER	Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine, attached to the Ranger Authority issued under s 41 of the Atomic Energy Act 1953
ERA	Energy Resources of Australia Ltd
GCH	Gulungul Creek at Arnhem Highway
GCMBL	Georgetown Creek median bund level-line
GCT2	Gulungul Creek Tributary 2
KKN	Key Knowledge Need
LEM	landform evolution model
LAA	land application area
MTC	Minesite Technical Committee
NTU	nephelometric turbidity unit
PAW	plant available water
Ramsar	The Ramsar Convention on Wetlands, an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources
RMCP	Ranger Mine Closure Plan
RP1/RP2/RP3/RP6	Retention Pond 1/Retention Pond 2/Retention Pond 3/Retention Pond 6
RPA	Ranger Project Area
SSB	Supervising Scientist Branch
TARP	trigger action response plan
TSF	Tailings Storage Facility (dam)
U	uranium

Appendix 2 – The Ranger Key Knowledge Needs

Note: KKN questions shown in greyed-out text have been closed out (i.e. required information has been attained) or removed (i.e. clearly no longer required, or covered in other KKNs)

LANDFORM REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
LAN1	Erosion	Baseline	LAN1. Determining baseline erosion and sediment transport characteristics in areas surrounding the RPA	LAN1A. What are the baseline rates of gully formation for areas surrounding the RPA?	Baseline information on gully characteristics and formation (e.g. extent/occurrence and distribution of gullies of differing size and complexity, rate of 'knick-point' retreat) in natural landforms is needed. This information can be obtained from appropriate imagery and will be used to assess whether the extent, rate and magnitude of gully formation predicted for the rehabilitated site will vary significantly from those observed in comparable non-mine disturbed landforms in adjacent areas.	SSB
				LAN1B. What are the baseline rates of sediment transport and deposition in creeks and billabongs?	The risk of bedload sediment transport from the rehabilitated site is generally considered to be low because of the ability to manage it through appropriate mitigation measures (e.g. sedimentation basins). However, information on natural bedload yields in Magela and Gulungul creeks is needed to distinguish mine-derived bedload from natural yields and monitor the effectiveness of mitigation measures. If the mitigation measures are not effective, this information would also be used to assess potential impacts to aquatic ecosystems.	BOTH
LAN2	Erosion	Baseline	LAN2. Understanding the landscape-scale processes and extreme events affecting landform stability	LAN2A. What major landscape-scale processes could impact the stability of the rehabilitated landform (e.g. fire, extreme events, climate)?	Identification of major landscape-scale processes or extreme events that could adversely affect the stability of the rehabilitated landform is needed to assess whether there are any potential risks associated with these processes that could result in mass failure and containment of tailings for at least 10,000 years. This information is likely to be available in existing reports and will be used to assess potential impacts on landform stability (see LAN2B).	SSB
				LAN2B. How will these landscape-scale processes impact the stability of the rehabilitated landform (e.g. mass failure, subsidence)?	Information to assess the degree to which major landscape-scale processes or extreme events could affect the stability of the rehabilitated landform is being addressed and will be further sought from the available literature.	BOTH

LANDFORM REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
LAN3	Erosion	Predicting	LAN3. Predicting erosion of the rehabilitated landform	LAN3A. What is the optimal landform shape and surface (e.g. riplines, substrate characteristics) that will minimise erosion?	The shape (e.g. slope) and surface characteristics (e.g. particle size, roughness, riplines, drainage) of the rehabilitated landform will influence erosion rates. These characteristics and their effect on erosion rates can be assessed through an iterative modelling approach using CAESAR-Lisflood. Information on proposed landform characteristics should be used to optimise landform design. This could include using 'geomorphic reclamation' processes, which are the characteristics (e.g. slope curvature/length) of the pre-mining or adjacent landscape. These will be calculated and used to inform the design of the final landform.	ERA
				LAN3B. Where, when and how much consolidation will occur on the landform?	The degree of subsidence within the rehabilitated landform (e.g. over Pits 1 and 3 associated with tailings consolidation) may influence erosional processes. Determining these rates will require some knowledge of predicted location and extent of consolidation over the pits.	ERA
				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)?	<p>Some input parameters for the landform evolution model may be influenced by local conditions and these need to be understood to maximise the accuracy of the model predictions. Examples of parameters include:</p> <ul style="list-style-type: none"> • sediment settling velocity, • shear stress and roughness, • rate of weathering for waste rock, • effect of vegetation succession and fire on suspended sediment transport, and • impact of extreme rainfall events and scenarios over time on suspended sediment transport. <p>Validation of bedload predictions could be undertaken by comparing measured parameters from the trial landform and the rehabilitated Pit 1 landform (e.g. bedload, suspended sediments) with the model outputs at both plot and catchment scale.</p>	SSB

LANDFORM REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				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)?	In order to assess the effectiveness of the final landform design (including any integral control structures), it will be necessary to identify and understand the erosion characteristics (extent and magnitude of gully formation; denudation and erosion rate; potential for groundwater expression) that may result under the different model scenarios.	SSB
				LAN3E. How much suspended sediment will be transported from the rehabilitated site (including land application areas) by surface water?	Suspended sediment has the potential to impact on aquatic ecosystems downstream of the rehabilitated site. Turbidity/suspended sediment should be monitored on the constructed Pit 1 final landform to determine what loads are likely to be released from the mine site and to assist with the calibration/validation of model predictions of suspended sediment transport at the catchment scale. The significance of suspended sediment that may be transported from land application areas will also need to be assessed. This assessment is commensurate with the level of soil disturbance associated with remediation of these areas.	BOTH

WATER AND SEDIMENT REHABILITATION THEME

KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
WS1	Biodiversity and ecosystem health	Source	WS1. Characterising contaminant sources on the RPA	WS1A. What contaminants (including nutrients) are present on the rehabilitated site (e.g. contaminated soils, sediments and groundwater; tailings and waste rock)?	A comparative assessment of contaminants of potential concern (COPCs) and their respective source(s) (e.g. waste rock, tailings/pore water, groundwater, soils) is needed, including consideration of any 'hotspots' that may be present on the rehabilitated site (e.g. groundwater under the plant area, GCT2 area, LAAs, billabong/stream sediments). This information contributes to whole-of-site contaminant transport modelling to predict post-closure water quality and will inform the rehabilitation and risk management of the site.	ERA
				WS1B. What factors are likely to be present that influence the mobilisation of contaminants from their source(s)?	For each contaminant source present on the rehabilitated site, physical, chemical and other factors that affect, or interact to affect, contaminant mobilisation need to be identified and assessed. This information contributes to whole-of-site contaminant transport modelling to predict post-closure water quality and will inform the rehabilitation and risk management of the site.	ERA
WS2	Biodiversity and ecosystem health	Pathway	WS2. Predicting transport of contaminants in groundwater	WS2A. What is the nature and extent of groundwater movement, now and over the long-term?	Knowledge of current and post-closure groundwater movement is required, both within the rehabilitated site and to the off-site environment. This is being achieved through numerical model predictions that consider the implications of changes to the groundwater movement due to the mine closure and recovery, i.e. the return to a stable state of levels, contaminant concentrations, flow paths and the influence of sea-level rise on groundwater flow, after rehabilitation. The most appropriate monitoring locations for calibration and verification of models needs consideration. This information contributes to whole-of-site contaminant transport modelling to predict post-closure water quality and will inform the rehabilitation and risk management of the site.	ERA
				WS2B. What factors are likely to be present that influence contaminant (including nutrients) transport in the groundwater pathway?	There is a need to determine whether conservative modelling or reactive modelling provides a worse-case for contaminant transport within the groundwater pathway. Reactive modelling examines physical and chemical factors that influence contaminant transport within the groundwater pathway (e.g. pH, redox conditions) and interactions amongst these (e.g. COPC mixtures). Identification of these factors (and their significance) informs contaminant transport modelling to predict the downstream concentrations of COPCs.	ERA

WATER AND SEDIMENT REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				WS2C. What are predicted contaminant (including nutrients) concentrations in groundwater over time?	The contaminant concentration in the groundwater system will vary with time due to the development of geochemical reactions at the source and movement of contaminants through the groundwater. Understanding of the variation of contaminant concentration will be used to determine the timing and amount of contaminant that may reach a receptor affecting the health of the ecosystem. Knowledge of the concentrations of COPCs in groundwater informs contaminant transport modelling used to predict the downstream concentrations of COPCs and inform rehabilitation and risk mitigation strategies.	ERA
WS3	Biodiversity and ecosystem health	Pathway	WS3. Predicting transport of contaminants in surface water	WS3A. What is the nature and extent of surface water movement, now and over the long-term?	Detailed information on current and future hydrological conditions for catchments both within the RPA and adjacent/downstream areas is required. The effect of sea-level rise on the surface waters flow also needs consideration. The timing and magnitude of surface water flows informs contaminant transport modelling used to predict the on-site and downstream concentrations of COPCs.	ERA
				WS3B. What concentrations of contaminants from the rehabilitated site will aquatic (surface and groundwater dependent) ecosystems be exposed to?	Determination of the concentrations of COPCs that aquatic ecosystems (including riparian vegetation) will be exposed to from the rehabilitated site needs to be based on the integration of modelling predictions for both groundwater (WS2) and surface water (WS3). Predicted COPC concentrations in surface and groundwaters can then be compared against water quality guideline values or other locally-derived biological effects information (for groundwater dependant species) in order to assess whether aquatic biodiversity and ecosystem health are exposed to risk following rehabilitation. (To address this KKN, information from WS3D is first required.)	ERA
				WS3C. What factors are likely to be present that influence contaminant (including nutrients) transport in the surface water pathway?	There is a need to determine whether conservative modelling or reactive modelling provides a worse-case for contaminant transport in the surface water pathway. Reactive modelling examines physical and chemical factors that will influence contaminant transport and toxicity (e.g. pH) and interactions amongst these (e.g. COPC mixtures). Identification of these factors (and their significance) informs contaminant transport modelling used to predict the downstream concentrations of COPCs.	ERA

WATER AND SEDIMENT REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				WS3D. Where and when does groundwater discharge to surface water?	Information on the locations and timing of groundwater discharge to surface water is required to assess the significance of this contaminant transport pathway. Improved understanding of groundwater/surface water interactions informs contaminant transport modelling used to predict the downstream concentrations of COPCs.	BOTH
				WS3E. What factors are likely to be present that influence contaminant transport (including nutrients) between groundwater and surface water?	Factors that could influence movement of contaminants, and limit or increase their concentration from groundwater to surface water, include geology, topography, aquifer geometry and hydraulic characteristics. Identification of these factors (and their significance) informs contaminant transport modelling to predict the downstream concentrations of COPCs.	ERA
				WS3F. What are the predicted concentrations of suspended sediment and contaminants (including nutrients) bound to suspended sediments in surface waters over time?	When suspended sediments are transported from the rehabilitated site, they could affect aquatic ecosystem health directly (e.g. habitats/biota effects) and/or indirectly (e.g. transport of bound contaminants). Knowledge of the concentrations of suspended sediments and associated contaminants informs contaminant transport modelling to predict the downstream concentrations of COPCs.	BOTH
				WS3G. To what extent will the interaction of contaminants between sediment and surface water affect their respective qualities?	Contaminants in surface water may accumulate in sediments to concentrations above those at which biological effects could be expected. Conversely, contaminants in sediments may resuspend into the water column and reduce water quality. An understanding of the factors affecting the flux of contaminants between surface waters and sediments is required to determine if closure criteria will protect both environmental compartments.	BOTH
				WS3H. Where and when will suspended sediments and associated contaminants accumulate downstream?	If contaminants from the rehabilitated site accumulate in downstream sediments, it is possible that they could affect aquatic ecosystem health directly and in the short term (e.g. to benthic biota) and/or in future through re-mobilisation of deposited contaminants. Knowledge of locations and likely timing for deposition of suspended sediments and associated contaminants informs the assessment of risk to aquatic ecosystems.	ERA

WATER AND SEDIMENT REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
WS4	Biodiversity and ecosystem health	Receptor	WS4. Characterising baseline aquatic biodiversity and ecosystem health	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?	<p>Although there is currently substantial knowledge on baseline water quality and biodiversity in surface waters during early dry season (recessional) flow periods, information on water quality and biota for other periods of surface water flow and inundation (i.e. both wet and dry seasons, stream channels and billabongs) is limited. More complete information will allow a more comprehensive assessment of whether predicted (modelled) concentrations of COPCs transported from the rehabilitated site are likely to impact on downstream aquatic ecosystem health.</p> <p>Hyporheic and stygofauna communities in the Magela Creek sand beds are poorly understood and the significance of their contribution to ecological processes to the biodiversity of the ARR is unknown. The environmental conditions sustaining these (e.g. water quality, flow), and other groundwater dependent ecosystems (e.g. dry season water sources for riparian vegetation) are also unknown. If these communities are ecologically important, their potential sensitivity to increased solute loads needs to be assessed (WS7C). This information helps determine if specific closure criteria are needed to protect these communities.</p>	SSB
WS5	Biodiversity and ecosystem health	Receptor	WS5. Determining the impact of contaminated sediments on aquatic biodiversity and ecosystem health	WS5A. Will contaminants in sediments result in biological impacts, including the effects of acid sulfate sediments?	<p>Some COPCs transported from the rehabilitated site, e.g. uranium and sulfate, will bind to organic matter and benthic sediments in downstream ecosystems, in particular, the shallow lowland billabongs. The long-term risk of accumulation of these COPCs in sediment to biodiversity or ecological processes needs to be assessed for both the creek and billabongs. This information will inform management of the rehabilitated site and, in relation to sulfate in particular, any ongoing need to manage this COPC in surface and groundwater. Such a risk assessment would include analyses of the temporal trends in COPC concentrations in the sediments and, for sulfate, the predicted budget for billabongs (i.e. Coonjimba, Georgetown, Gulungul) to assess the risk of acid sulfate sediment formation and associated potential impacts on aquatic biodiversity and ecosystem health.</p>	BOTH

WATER AND SEDIMENT REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				WS5B. What are the factors that influence the bioavailability and toxicity of contaminants in sediment?	Closure criteria for U in sediments were derived using sediments from Gulungul Billabong, as they are representative of the major depositional zones in and outside of the RPA (i.e. shallow backflow billabongs). However, if physico-chemical conditions (e.g. pH, TOC) of sediments differ from those in Gulungul Billabong, this may affect the toxicity of COPCs, and the closure criteria may not be appropriate. Knowledge of the influence of bioavailability and toxicity modifying factors in sediments helps derive closure criteria specific for different sediment conditions.	SSB
				WS5C. What would be the impact of contaminated sediments to surface aquatic ecosystems?	If predicted COPC concentrations in sediments are likely to reach a threshold where there is a risk that they could be mobilised into surface waters, the potential impacts to these aquatic ecosystems need to be assessed.	<i>Removed November 2019</i>
WS6	Biodiversity and ecosystem health	Receptor	WS6. Determining the impact of nutrients in surface water on aquatic biodiversity and ecosystem health	WS6A. What is the toxicity of ammonia to local aquatic species, considering varying local conditions (e.g. pH and temperature)?	The effects of ammonia on local species under local conditions need to be quantified. The toxicity of ammonia is highly influenced by pH and temperature, which can vary substantially between billabongs and streams, and seasonally. This research also needs to include assessment of toxicity to freshwater mussels, which have been reported as particularly sensitive to ammonia, an important component of the local aquatic ecosystem and a highly-valued food source for traditional owners. This information assists in deriving site-specific closure criteria for ammonia.	SSB
				WS6B. Can Annual Additional Load Limits (AALL) be used to inform ammonia closure criteria?	A review of the literature supporting AALLs is needed to understand their continuing relevance. It needs to be determined whether ammonia loads could be considered in the same context as the AALLs.	ERA
				WS6C. Will the total loads of nutrients (N and P) to surface waters cause eutrophication?	Contaminant transport modelling will predict loads of nutrients that downstream surface waters are likely to receive from the rehabilitated site. This information should be used to assess if there is a risk of eutrophication to downstream surface waters.	ERA
WS7	Biodiversity and ecosystem health	Receptor	WS7. Determining the impact of contaminants in surface and groundwater on	WS7A. Are current guideline values appropriate given the potential for variability in toxicity due to mixtures, modifying factors and different exposure scenarios?	Water quality limits that have been derived for individual toxicants do not incorporate potential interactive (e.g. additive, synergistic, antagonistic) effects of toxicant mixtures or other modifying effects occurring in the field (e.g. pH, temperature, DOC). This knowledge informs the development and application of closure criteria for COPCs.	SSB

WATER AND SEDIMENT REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
			aquatic biodiversity and ecosystem health	WS7B. What is the risk associated with emerging contaminants?	Contaminant research has been prioritised on a risk basis, but the continued gathering of contaminant knowledge before and during the mine's transition into a rehabilitated site may result in the identification of new or emerging contaminants of potential concern (e.g. contaminated sites studies and where the risk profile of a contaminant changes through increased knowledge of effects or exposure). Where such contaminants are identified, they need to be assessed using a tiered, risk-based approach.	BOTH
				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)?	Current guideline values are derived from a limited suite of laboratory tests and, where possible, validated using field-effects data. Some (sandy) stream-dwelling species, which have been reported as sensitive to contaminants, are not represented in these data sets and their sensitivity to COPCs are unknown. This knowledge will indicate if closure criteria are protective of these taxa and identify any phase of the hydrograph of receiving stream environments that represents greater risks to stream biota than other phases.	SSB
				WS7D. How do acidification events impact upon, or influence the toxicity of contaminants to, aquatic biota?	Acidification events, and associated increases in dissolved metal concentrations, have been observed in on-site waterbodies (e.g. Coonjimba Billabong, RP1) as a result of acid sulfate soil formation associated with elevated sulfate concentrations from the mine. These events typically occur during re-wetting events in the early wet season and in most cases are short-lived (days, weeks). In order to fully inform management actions for sulfate in surface and groundwaters (see WS5A), biological-effects studies of the impacts to such receiving waters should be undertaken to examine short (during events) and longer-term (seasonal, interannual) changes to biodiversity and ecological processes.	<i>Removed November 2019</i>
				WS7E. How will Mg:Ca ratios influence Mg toxicity?	An understanding of the Mg:Ca ratio of seepage water from various sources and how this affects toxicity is required. The gathering of field (or semi-field) effects data for mine released waters (including groundwater sources) mixed with receiving waters would provide supporting evidence.	SSB

WATER AND SEDIMENT REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				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)?	Previous studies in Magela Creek have demonstrated avoidance by fish of mine wastewater discharges, indicating potential reduced recruitment to upstream sites. Information on seasonal movement and dispersal of organisms needs to be considered and combined with groundwater contaminant modelling data, in order to assess potential for impaired movement and connectivity in streams.	SSB
				WS7G. What concentrations of contaminants will be detrimental to the health of (non-riparian) aquatic vegetation?	The guideline values for COPCs were derived using a limited species range that included one aquatic macrophyte (<i>Lemna</i>) with a relatively short exposure duration (4 days). Apart from their inherent biodiversity and conservation values, the diverse aquatic plant communities in billabongs and along littoral portions of the creeks constitute critical habitat for other biota, and for this reason are deserving of more detailed investigation than just the limited laboratory information available for the single species. Laboratory and field studies under a range of realistic exposure scenarios or across existing contaminant gradients in onsite waterbodies should be undertaken to assess the potential sub-lethal impacts of COPCs on aquatic vegetation in these aquatic ecosystems and thereby determine if healthy aquatic habitats can be maintained following rehabilitation.	BOTH
				WS7H. What concentrations of contaminants will be detrimental to the health of riparian vegetation?	Riparian vegetation, particularly that growing along the banks of the major drainage lines (Magela and Gulungul creeks) may be seasonally exposed to elevated concentrations of contaminants in shallow groundwater after minesite rehabilitation. An assessment of the potential sub-lethal impacts of COPCs on germination and early growth of representative species (e.g. through pot trials) will assist in determining if healthy riparian habitats can be maintained following rehabilitation.	SSB

WATER AND SEDIMENT REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
WS8	Biodiversity and ecosystem health	Receptor	WS8. Determining the impact of suspended sediment on aquatic biodiversity and ecosystem health	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)?	Suspended sediments can have various physical effects on aquatic ecosystems, such as habitat alteration (e.g. deposition), light attenuation and subsequent influence on primary productivity and physiological effects on organisms (e.g. inhibition of reproduction/growth, fish gill function). The magnitude of the effects of suspended sediments can vary according to their characteristics. For example, larger particle sizes are more likely to result in impacts associated with deposition (e.g. smothering of habitat), whereas smaller particle sizes are more likely to result in impacts upon filter feeding organisms. An assessment of potential impacts of suspended sediment on aquatic biodiversity should be based on predicted characteristics of sediments that may be transported from the rehabilitated site.	SSB
				WS8B. To what extent does salinity affect suspended particulates, and what are the ecological impacts of this?	Salinity can affect behaviour of suspended particles by processes such as flocculation and may affect the rate at which the particles settle from the water column. The potential for high-salinity waters associated with the rehabilitated site (e.g. evapo-concentration in billabongs during the dry season) to affect behaviour of suspended particulates (e.g. increased deposition rates) and subsequent ecological impacts (e.g. infilling of billabongs) needs to be assessed.	SSB

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
RAD1	Human and ecosystem health	Source	RAD1. Radionuclides in the rehabilitated site	RAD1A. What are the activity concentrations of uranium and actinium series radionuclides in the rehabilitated site, including waste rock, tailings and land application areas?	Waste rock, buried tailings and contaminated soils on land application areas represent potential sources of radionuclides to the environment from the rehabilitated site. The radionuclides of concern are those of the uranium and actinium decay series because they occur at elevated concentrations in the source materials. Radionuclides of the thorium decay series are not of concern, as they do not occur at elevated levels in the source materials. Knowledge of the activity concentrations of uranium and actinium decay series radionuclides in waste rock, tailings and land application area soils is needed to model activity concentrations in the environment post-rehabilitation, which in turn are needed to estimate radiation doses to the public and wildlife. The knowledge could be acquired through radionuclide measurements on existing waste rock, tailings and land application area soils.	ERA
RAD2	Human and ecosystem health	Pathway	RAD2. Radionuclides in aquatic ecosystems	RAD2A. What are the above-background activity concentrations of uranium and actinium series radionuclides in surface water and sediment?	<p>Increased radionuclide activity concentrations in surface water and sediment due to contaminated water arising from the rehabilitated site could result in radiation doses above natural background to the public and wildlife. Knowledge of the increases in activity concentrations of uranium and actinium decay series radionuclides in surface water and sediment is needed to estimate these doses. The knowledge could be acquired through modelling of:</p> <ul style="list-style-type: none"> • radionuclide releases to surface water via runoff and groundwater pathways from the rehabilitated site • the mixing of released radionuclides in surface water • radionuclide partitioning between sediment and water. <p>Furthermore, the modelling of radionuclide releases could be based on an element with high solubility to provide conservative estimates of activity concentrations.</p>	ERA

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
RAD3	Human and ecosystem health	Pathway	RAD3. Radon progeny in air	RAD3A. What is the above-background concentration of radon and radon progeny in air from the rehabilitated site?	<p>Radon (a radioactive gas) will be emitted to the atmosphere from the rehabilitated site due to the decay of radium-226 in surface waste rock. The inhalation of radon progeny radionuclides produced through the decay of emitted radon could result in radiation doses above natural background to the public. Knowledge of radon and/or radon progeny concentrations in air is needed to estimate these doses. This knowledge could be acquired by modelling the atmospheric dispersion of radon from the rehabilitated site, using site-specific data (as necessary) for parameters such as:</p> <ul style="list-style-type: none"> • radium-226 activity concentrations in surface waste rock (RAD1A) • radon exhalation rates for waste rock • dry and wet season meteorological conditions. 	SSB
				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?	If the modelling under RAD3A gives radon concentrations in air, then knowledge of the equilibrium factor between radon progeny and radon will be needed to obtain radon progeny concentrations for dose modelling. If needed, site-specific knowledge on equilibrium factors could potentially be acquired through simultaneous measurements of radon and radon progeny concentrations in ambient air off-site of the operating mine.	<i>Removed November 2019</i>
				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?	The dose coefficient for radon progeny depends on the proportion of radon progeny attached and unattached to aerosols. If needed, site-specific knowledge on the unattached fraction could be acquired through simultaneous measurements of radon progeny attached and unattached to aerosols in ambient air at locations off-site of the operating mine.	<i>Removed November 2019</i>
RAD4	Human and ecosystem health	Pathway	RAD4. Radionuclides in dust	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?	If the modelling under RAD4B uses a resuspension factor approach to estimate the release of radionuclides in dust from the rehabilitated site to the atmosphere, then site-specific knowledge of dust resuspension factors or emission rates may be needed. If needed, this knowledge could be acquired through measurements of radionuclide activity loadings in dust and activity concentrations in ambient air.	<i>Removed November 2019</i>

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				<p>RAD4B. What is the above-background activity concentration in air of long-lived alpha-emitting radionuclides in dust emitted from the final landform?</p>	<p>The inhalation of radionuclides in dust emitted to the atmosphere from the rehabilitated site could result in radiation doses above natural background to the public. Knowledge of airborne activity concentrations of radionuclides in dust is needed to estimate these doses. This knowledge could be acquired by modelling the atmospheric dispersion of radionuclides in dust from the rehabilitated site, using site-specific data (as necessary) for parameters such as:</p> <ul style="list-style-type: none"> activity concentrations of uranium and actinium decay series radionuclides in surface waste rock (RAD1A) resuspension factors (or emission rates) of radionuclides in dust from waste rock dry and wet season meteorological conditions. 	<p><i>Closed out November 2019</i></p>
				<p>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?</p>	<p>The dose coefficient for radionuclides in dust depends on the activity median aerodynamic diameter (i.e. size) of the aerosol. If needed, site-specific knowledge on activity median aerodynamic diameter could be acquired through radionuclide measurement of size fractionated dust samples collected using cascade impactors.</p>	<p><i>Removed November 2019</i></p>

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
RAD5	Human and ecosystem health	Pathway	RAD5. Radionuclides in bushfoods	RAD5A. What are the concentration ratios of actinium-227 and protactinium-231 in bush foods?	The ingestion of uranium and actinium decay series radionuclides bioaccumulated in bush foods could result in radiation doses above natural background to the public. Radiation dose assessments for the human food chain use concentration ratios to predict radionuclide activity concentrations in food items from those in the surrounding soil or water. A sizeable body of knowledge exists on concentration ratios for uranium decay series radionuclides. However, there is effectively no knowledge (site-specific or otherwise) on concentration ratios for actinium decay series radionuclides. The actinium decay series radionuclides of potential concern include actinium-227 and protactinium-231, which have relatively high ingestion dose coefficients. Knowledge on concentration ratios for these radionuclides could potentially be acquired through sampling and measurement on bush foods and associated soils and waters after development of radiochemistry separation and measurement techniques for actinium-227 and protactinium-231.	SSB
RAD6	Human and ecosystem health	Receptor	RAD6. Radiation dose to wildlife	RAD6A. What are the representative organism groups that should be used in wildlife dose assessments for the rehabilitated site?	Wildlife dose assessments are generally based on a small number of organism groups representative of the broad variety of species present in the environment. This is because it is not usually practical to sample and perform radionuclide analyses on all species present. Knowledge of representative organism groups could potentially be acquired from reviewing ecological information about the species present in the local environment and generalising them up to a small number of representative organism groups. Alternatively, broad wildlife groups defined by international bodies (e.g. International Atomic Energy Agency) or within wildlife dose assessment tools (e.g. ERICA) could potentially be used. When selecting representative organism groups, consideration should be given to any rare, threatened or culturally significant species that may be present in the local environment.	<i>Closed out November 2019</i>

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				RAD6B. What are the whole-organism concentration ratios of uranium and actinium series radionuclides in wildlife represented by the representative organism groups?	<p>The bioaccumulation of uranium and actinium decay series radionuclides in wildlife could result in radiation doses above natural background to those wildlife. Standard dose assessment tools for wildlife use whole organism concentration ratios to predict radionuclide activity concentrations in wildlife from those in the surrounding soil or water. Whole organism concentration ratios of uranium decay series radionuclides have been derived for some (but not all) types of wildlife using site-specific data. There is effectively no data (site-specific or otherwise) for deriving whole organism concentration ratios for actinium decay series radionuclides, specifically actinium-227 and protactinium-231. Knowledge of whole organism concentration ratios for uranium and actinium decay series radionuclides could potentially be acquired by one or more of the following methods:</p> <ul style="list-style-type: none"> • sampling and radionuclide measurements on organisms and associated soil or water to derive additional site-specific values • review and analysis of international databases (e.g. Wildlife Transfer Database) and publications to fill gaps in site-specific values • use of surrogate organism and analogue element approaches to fill gaps in site-specific values. 	SSB

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				RAD6C. What are the tissue to whole organism conversion factors for uranium and actinium series radionuclides for wildlife represented by the representative organism groups?	<p>Standard dose assessment tools for wildlife use whole organism concentration ratios to predict radionuclide activity concentrations in wildlife from those in the surrounding soil or water. Most site-specific data on radionuclide activity concentrations in wildlife is tissue-specific, as it was originally collected to support human food chain dose assessments. The data need to be converted to whole organism values to be useful in wildlife dose assessments. Knowledge on tissue to whole organism conversion factors could be acquired by one or more of the following methods:</p> <ul style="list-style-type: none"> • review and analysis of existing site-specific data to reconstruct whole organisms from individual tissues using a mass balance approach • sampling and radionuclide measurements on the individual tissues comprising whole organisms • review and analysis of international databases and publications • use of surrogate organism and analogue element approaches to fill knowledge gaps. 	SSB

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				RAD6D. What are the dose-effect relationships for wildlife represented by the representative organism groups?	<p>The potential radiation risk to wildlife can be evaluated by comparing whole organism dose rates to environmental reference levels, which generally represent the dose rates at which radiation effects in organisms may begin to occur. Environmental reference levels derived by international bodies are currently used within the rehabilitation standard for radiation protection of the environment. If needed, dose-effect relationships for specific organism groups could be derived by one or more of the following methods:</p> <ul style="list-style-type: none"> laboratory studies within which aquatic and terrestrial organisms are chronically exposed to known activities of radionuclides and the effects on key biological endpoints (i.e. mortality, morbidity, reproduction and genetic mutations) observed review of international databases (e.g. FREDERICA) and publications. 	SSB
				RAD6E. What is the sensitivity of model parameters on the assessed radiation doses to wildlife?	<p>Radiation dose modelling for wildlife uses a large number of parameters. The potential variability in parameter values used in the modelling can cause variability in the estimate of the dose to wildlife. Sensitivity analysis is a standard method that can be used to identify key parameters causing variability in modelling results. Understanding the variability in dose modelling results due to each input parameter is important so that research to acquire additional site-specific knowledge (if needed) can be appropriately prioritised and targeted.</p>	ERA

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
RAD7	Human and ecosystem health	Receptor	RAD7. Radiation dose to the public	RAD7A. What is the above-background radiation dose to the public from all exposure pathways traceable to the rehabilitated site?	<p>The pathways through which the public can be exposed to radiation due to the rehabilitated site are:</p> <ul style="list-style-type: none"> • inhalation of radon progeny and radionuclides in dust • ingestion of bush foods and drinking water • external gamma <p>The statutory limit on radiation dose to the public applies to the dose above natural background from all sources and exposure pathways summed. The assessment of radiation dose to the public due to the rehabilitated site requires an analysis of each exposure pathway for a clearly defined scenario of future land use. Parameterisation of exposure pathways can be made using existing knowledge and that acquired under RAD1A, RAD2A, RAD3A, RAD3B, RAD3C, RAD4A, RAD4B, RAD4C and RAD5A. Knowledge on future land use to develop a quantitative scenario against which radiation doses can be assessed can potentially be acquired by :</p> <ul style="list-style-type: none"> • consultation with traditional owners • review of the literature or other records for information on historic use of the area 	ERA
				RAD7B. What is the sensitivity of model parameters on the assessed doses to the public?	Radiation dose modelling uses a large number of parameters to estimate doses to the public. The potential variability in parameter values used in the modelling can cause variability in the estimate of the dose. Sensitivity analysis is a standard method that can be used to identify key parameters causing variability in modelling results. Understanding the potential variability in the estimated dose due to each input parameter is important so that research to acquire additional site-specific knowledge (if needed) can be appropriately prioritised and targeted.	ERA

HEALTH IMPACTS OF RADIATION AND CONTAMINANTS REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
RAD8	Ecosystem health	Receptor	RAD8. Impacts of contaminants on wildlife	RAD8A. Will contaminant concentrations in surface water (including creeks, billabongs and seeps) pose a risk of chronic or acute impacts to terrestrial wildlife?	Wildlife may drink water from waterbodies affected by the mine but their intake profile from these sources is not aligned with the models of intake on which livestock drinking water guidelines are based (e.g. infrequent, occasional use versus longer-term frequent use). Livestock drinking guidelines are probably not appropriate for small wildlife or taxa such as reptiles. An assessment of the risks associated with both chronic and acute impacts to all large and small terrestrial wildlife needs to take into account how much of an animal's consumption is likely to come from poor quality sources associated with the rehabilitated site. This information will determine if specific water quality closure criteria are required to protect large and small terrestrial wildlife.	SSB
RAD9	Human health	Receptor	RAD9. Impacts of contaminants on human health	RAD9A. What are the contaminants of potential concern to human health from the rehabilitated site?	Identification of the COPCs that may be elevated in soil (e.g. landform and LAAs) or water (e.g. creeks and billabongs) is a key first step in assessing potential risks to human health. A screening approach to identify those COPCs with higher toxicity (from relevant drinking water guidelines) and which may also be present in the environment due to the rehabilitated site should be undertaken. This will inform whether closure criteria for human health are required.	ERA
				RAD9B. What are the concentration factors for contaminants in bush foods?	Human food-chain assessments of COPC exposure use concentration factors to quantify transfer from the environment (e.g. soil and water) to food items. This is particularly the case for prospective assessments, where exposure estimates are made from predicted soil or water COPC concentrations using concentration factors.	SSB
				RAD9C. What are the concentrations of contaminants in drinking water sources?	Dietary exposure to COPCs in drinking water will be proportional to the COPC concentrations in the water and the amount consumed.	ERA
				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?	The total dietary intake of each COPC needs to be assessed and compared to relevant guideline values to determine the acceptability of the exposure in a human health context.	ERA

ECOSYSTEM RESTORATION REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
ESR1	Ecosystem similarity	Ecosystem similarity	ESR1. Determining the requirements and characteristics of terrestrial vegetation in natural ecosystems adjacent to the mine site, including Kakadu National Park.	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?	Baseline information on terrestrial vegetation composition and structure at scales that adequately capture and explain heterogeneity in natural ecosystems is required. This information, historical or new, will be used in the development of closure criteria and to assess whether vegetation growing on the rehabilitated site is similar to reference sites observed in non-mine disturbed ecosystems in adjacent areas. Examples of compositional and structural characteristics of vegetation include species abundance, and density, number of species, size class distribution of trees and shrubs, vegetation strata (e.g. canopy or ground cover) and hollow abundance. Such information would ideally be based on large-scale survey methods (e.g. remote sensing) that will better capture the spatial and temporal variation than the historical smaller scale ground-based surveys. Accompanying environmental measurements are also required in order to identify factors accounting for the variations in vegetation. Identifying factors responsible for observed ecological patterns may assist in revegetation planning and establishment.	SSB
				ESR1B. Which indicators of similarity should be used to assess revegetation success?	The proposed vegetation similarity indicators have been drawn from the National Restoration Standards (Standards Reference Group SERA 2016) and include species composition, number of species, vegetation strata, tree/shrub class size distribution and vegetation distribution ('naturalness'). Closure criteria will be developed for these indicators and applied for each of these to assess the degree of similarity between vegetation growing on the rehabilitated site and that observed in non-mine disturbed ecosystems in adjacent areas. Indicators will be developed for both understorey and overstorey vegetation.	<i>Closed out November 2019</i>

ECOSYSTEM RESTORATION REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				ESR1C. What values should be prescribed to each indicator of similarity to demonstrate revegetation success?	Once appropriate similarity indicators have been identified, specific value(s) for each need to be established that account for the expected range in natural spatial and temporal variability (i.e. avoidance of single numbers). This information will be used in the development of closure criteria and to assess whether vegetation growing on the rehabilitated site is progressing acceptably towards that observed in non-mine disturbed ecosystems in adjacent areas, the extent of such progress, and whether it has achieved an agreed level of similarity. The indicator values may vary according to the spatial scale at which they are derived and this dependence needs to be understood for future applications.	BOTH
ESR2	Ecosystem similarity	Ecosystem similarity	ESR2. Determining the requirements and characteristics of a terrestrial faunal community similar to natural ecosystems adjacent to the mine site, including Kakadu National Park	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?	Much baseline information on terrestrial fauna community structure in natural ecosystems adjacent to the mine site is already available, but additional information may be required. This reference information will be used to characterise fauna communities in natural ecosystems adjacent to the mine site, the extent of variation in the fauna and the factors that influence such variation. This context will be used in the development of faunal community closure criteria and to measure and interpret progress of fauna communities in the rehabilitated site towards those in adjacent suitable reference locations. For vertebrates, such information would ideally be based on contemporary fauna survey methods (e.g. camera trapping) that will better capture the spatial and temporal variation than the historical survey techniques.	BOTH
				ESR2B. What habitat, including enhancements, should be provided on the rehabilitated site to ensure or expedite the colonisation of fauna, including threatened species?	The establishment of vegetation does not guarantee that suitable habitats for terrestrial fauna colonisation are available, particularly early in the ecosystem restoration process. Information is needed on the time that it may take before the rehabilitated site can be expected to naturally develop key fauna habitat features (e.g. tree hollows); if this is likely to be many years, options for habitat enhancements will need to be examined (e.g. nesting boxes, rock piles).	BOTH

ECOSYSTEM RESTORATION REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				ESR2C. What is the risk of introduced animals (e.g. cats and dogs) to faunal colonisation and long-term sustainability?	The risk that introduced animals could impede the re-establishment of fauna and the long-term sustainability of faunal communities needs to be assessed. This is likely to be particularly important early in the ecosystem restoration process, when the rehabilitated landscape could provide optimal habitat for introduced animals (e.g. ideal conditions for predators) and before suitable habitats for native fauna are established (e.g. fallen logs, tree hollows for refuge). This information will inform the need for mitigation measures, such as active management of introduced animals and/or establishment of habitat enhancements that favour native fauna.	BOTH
ESR3	Ecosystem similarity	Ecosystem similarity	ESR3. Understanding how to establish native terrestrial vegetation, including understory species.	ESR3A. How do we successfully establish terrestrial vegetation, including understory (e.g. seed supply, seed treatment and timing of planting)?	The ability to establish the full range (or an appropriate complement) of native vegetation species from the reference ecosystem needs to be demonstrated. While this has been shown in initial trials for over 35 framework species, there is far less available evidence for the successful establishment of a diverse suite of understorey species. This information will be sought from the literature, and from ongoing research including trials on the Ranger Trial Landform and, in future, on the Pit 1 rehabilitated site. The information will provide necessary assurance that it is possible to establish vegetation communities on the rehabilitated site that will be similar to adjacent non-mine disturbed ecosystems.	ERA
ESR4	Ecosystem similarity	Ecosystem similarity	ESR4. Determine the incidence and abundance of introduced species in natural ecosystems adjacent to the mine site, including Kakadu National Park, and their potential to impact on the successful rehabilitation of Ranger mine	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?	Information on the composition and abundance of introduced species in areas adjacent to the rehabilitated site is required, both to assess the risk that these ecological stressors may pose to successful ecosystem restoration and to demonstrate that their presence on the site is not higher than in adjacent areas. This information will be required throughout the restoration process to inform trigger points for implementing mitigation strategies (e.g. early detection of pests or weeds may allow for ready cost-effective eradications). Further research may be required to inform management options that (i) result in control of pests and weeds but (ii) do not prevent the successful restoration of native species and communities.	SSB

ECOSYSTEM RESTORATION REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
ESR5	Long term viability	Ecosystem Sustainability	ESR5. Develop a restoration trajectory for Ranger mine	ESR5A. What are the key sustainability indicators that should be used to measure restoration success?	The proposed indicators of long-term viability and ecosystem function (sustainability) of the restored ecosystem have been drawn from the National Restoration Standards (e.g. Standards Reference Group SERA 2016). These indicators include recruitment of revegetation, nutrient cycling, faunal usage, habitat availability, resilience to fire, extreme weather events, pests and diseases. Other attributes to be considered are external exchanges (e.g. habitat connectivity, physical conditions (e.g. nutrient availability), and absence of threats (e.g. weeds). This information will be used in the development of closure criteria and to assess whether ecosystems established on the rehabilitated site will be similar to those observed in natural non-mine disturbed ecosystems in adjacent areas.	BOTH
				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?	Restoration trajectories will be required to assess the achievement of closure criteria that are expected to be reached after a period of time (e.g. decades) from the initial establishment. The trajectory approach outlined in the National Ecological Restoration Standards is based on modelling of a desired and/or expected trajectory pathway, distinguishing the desired pathway from possible undesired states, and selecting points within the desired trajectory that represent milestones leading to agreed closure. This should be based on previous regional revegetation studies, either at Ranger or elsewhere, and response of the savanna ecosystems to disturbance. The model should also consider scenarios (e.g. fire and weeds) that capture key aspects of revegetation establishment and natural disturbances. This information should also be used to identify and plan for management of risks and should form the basis for design and assessment of monitoring programs and results.	BOTH

ECOSYSTEM RESTORATION REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
ESR6	Long term viability	Ecosystem Sustainability	ESR6. Understanding the impact of contaminants on vegetation establishment and sustainability	ESR6A. What concentrations of contaminants from the rehabilitated site may be available for uptake by terrestrial plants?	Exposure of vegetation (both revegetation and existing native vegetation) to contaminants could occur from a number of sources on the rehabilitated site, such as waste rock, contaminated soils and groundwater. Integrated surface and groundwater modelling should identify areas of the rehabilitated site that may act as potential hotspots for increased concentrations of contaminants (see KKN WS1A), such as magnesium sulfate. The concentrations of contaminants available for uptake by terrestrial plants needs to be understood in order to assess whether there may be a risk to vegetation establishment and long term sustainability. For waste rock, which represents an unnatural substrate and plant medium, the assessment is conducted separately through KKN ESR7D.	BOTH
				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?	Contaminants and/or other stressors associated with the operation of Land Application Areas have altered and impaired the structure and health of vegetation. While the presence of multiple stressors confounds the ability to isolate specific causes of impaired plant health, the identification of plants tolerant to multiple stressors (including contaminants) may assist in revegetation planning and establishment (e.g. selection of species best suited to locations of contaminant build-up and/or water-logging) and in assessing plant health, over the longer-term).	ERA

ECOSYSTEM RESTORATION REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
ESR7	Long term viability	Ecosystem sustainability	ESR7. Understanding the effect of waste rock properties on ecosystem establishment and sustainability	ESR7A. What is the potential for plant available nutrients (e.g. nitrogen and phosphorus) to be a limiting factor for sustainable nutrient cycling in waste rock?	There are likely to be substantial differences between waste rock and natural soils in nutrient concentrations (e.g. P, N, Mg, exchangeable K and S) and rhizobia/mycorrhizal fungi available to plants. Combined with a potential lag in the timing at which effective nutrient cycling processes develop in the waste rock, nutrient deficiency may impair the establishment and sustainability of healthy vegetation communities. Targeted monitoring of processes, including soil available nutrient levels and plant nutrient status in established vegetation, compared to levels in soils and plants in reference sites, can provide evidence (i.e. empirical data) of progression to a self-sustaining nutrient cycle. This information will assist in determining whether an active nutrient maintenance regime may be required for a period of time following rehabilitation.	ERA
				ESR7B. Will sufficient plant available water be available in the final landform to support a mature vegetation community?	<p>Plant available water in waste rock substrate may be limited. Studies on the trial landform have demonstrated water holding capacity of the landform is comparable to the natural reference system. Despite uncertainties in measurements and modelling, the trial landform studies indicate that the waste rock of 4 m thickness may support mature vegetation similar to adjacent areas over short dry seasons but possibly not during longer dry seasons. Further information is needed to determine the availability of water in the waste rock substrate, such as:</p> <ul style="list-style-type: none"> influence of waste rock depth on water holding capacity water availability at greater depths (e.g. 4-8 m) and ability of plants to access this (e.g. maximum rooting depths) influence of waste rock particle size and pore spaces contribution of understorey to evapotranspiration rates uncertainty associated with water balance models and sensitivity of input parameters. <p>These factors will need to take into account location (e.g. elevation and aspect) on the final landform.</p>	ERA

ECOSYSTEM RESTORATION REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	Responsibility (SSB/ERA/BOTH)
				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?	There is uncertainty about whether key ecological processes required to support sustainable vegetation communities will occur on the rehabilitated landform. It has also been assumed that rapid weathering of waste rock will occur to form rudimentary soil materials but there is little information to demonstrate that this will be applicable across the rehabilitated site (i.e. all types of waste rock materials). This information can be used to determine whether specific mitigations may be needed (e.g. addition of fines, mulch).	ERA
				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?	Apart from plant available water and nutrients, other factors need to be identified in the event that ecosystem establishment and sustainability are impaired. These factors may include, for example, sub-optimal light conditions for tubestock or water-logging of the landform at initial planting.	ERA
ESR8	Long term viability	Ecosystem Sustainability	ESR8. Understanding fire resilience and management in ecosystem restoration	ESR8A. What is the most appropriate fire management regime to ensure a fire resilient ecosystem on the rehabilitated site?	Fire can present a significant risk to long term sustainability of restored ecosystems. The current strategy is to exclude fire from revegetation areas for the first 5-7 years following initial planting, followed by the gradual introduction of fire to rehabilitated areas. With the large spatial extent of fires in the region, management of fires is a cross-jurisdictional issue and needs to be managed for ecosystem restoration success at multiple scales. More specific information is needed to determine the most appropriate fire management regime over time, from initial introduction to a regime that is similar to surrounding areas, including consideration of sensitive plant and animal species. Recent research in Kakadu National Park that modelled the effects of fire regimes on overstorey population dynamics would be particularly relevant to this knowledge need.	ERA

CROSS-THEME REHABILITATION THEME						
KKN No.	ER Link	Category	Title	Questions	Description	
CT1	Biodiversity and Ecosystem Health	Risk	CT1. Assessing the cumulative risks to the success of rehabilitation on-site and to the protection of the off-site environment.	CT1A. What are the cumulative risks to the success of rehabilitation on-site and to the off-site environment?	It is important to assess cumulative risk as examining risks individually does not address the interaction between risks and their iterative effects. An integrated conceptual model will capture the interactions between multiple risks (e.g. landform stability, revegetation and contaminant exposure) and assessment endpoints (receptors). The integrated model and assessment will be continually tested and improved as part of best practice and include outputs from all other KKNs.	BOTH
CT2	World Heritage values	Heritage Values	CT2. Characterising World Heritage values of the Ranger Project Area	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?	There are areas within the Ranger Project Area that exhibit World Heritage Values for which Kakadu is listed, and documentation of these may assist decision-makers in incorporating the site into Kakadu National Park once closure has been achieved.	BOTH

Appendix 3 – Assessment of responses to comments on 2018 RMCP

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
Executive summary	<p>Tailings consolidation modelling should be reviewed to provide greater certainty on consolidation time frames, the volume of contaminants which will express into the groundwater and the ability to capture and treat 99% of the expressed pore water. This should consider the heterogeneous nature of the tailings mass and the direction of solute expression</p>	<p>Consolidation model for Pit 1 was reviewed in 2012 and 2015. The 2015 model has been and is being validated with settlement plates data installed in Pit 3. It is demonstrated that the average tailing settlement predicted by the model is in close agreement with the measured average settlement, as shown in Figure 7-5 in the MCP. The consolidation model for Pit 3 was reviewed in 2019 with cone penetration test data. It was noted that the measured porewater pressure profiles within the tailings closed matched with those predicted by the consolidation model. A typical pore pressure profile comparison is given in Figure 7-7 of the MCP. It is planned to conduct the next cone penetration test, to review the Pit 3 consolidation model, in the last quarter of 2019. The impact of the expressed tailings pore water, from the revised consolidation model, will be assessed within the groundwater solute transport modelling by INTERA. Refer to Sections 7.1.2 and 7.1.3.</p>	<p><i>Acknowledged</i></p> <p>Tailings permeability estimates have been updated from heterogenous tailings characteristics and used to inform solute transport modelling for Magnesium only. Other contaminants predictions are yet to occur.</p>
	<p>An assessment of radiation dose to humans and biota from the rehabilitated minesite is required to demonstrate that radiation closure criteria can be met. Additional information on the radiological properties of the rock to be used on the surface of the landform is required to inform the dose assessment.</p>	<p>ERA are currently modelling the predicted radiation doses to members of the public and wildlife from the final landform. The dose assessment will incorporate potential exposure to radiation from both the U-238 and U-235 series. See 7.10.1 & 7.10.3 for further detail.</p> <p>ERA will undertake gamma and radon flux surveys on the Pit 1 final landform to confirm average surface waste rock uranium content. This can be extrapolated to the extent of the final landform based on ERA's knowledge of uranium content of the stockpiles. See Section 7.10.4 for further detail.</p>	<p><i>Acknowledged</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Further information is required on the rehabilitation of the Tailings Storage Facility, including on the extent of contamination within the walls of the dam and the long-term movement of contaminated groundwater from beneath the dam.	This information will become available following submission of relevant applications to address Tailings Storage Facility contaminated material and Tailings Storage Facility deconstruction. A drilling program is currently being undertaken to assess the extent of contamination within the Tailings Storage Facility walls in order to inform the appropriate strategy. Groundwater monitoring for contamination is ongoing.	<p><i>Acknowledged</i></p> <p>Further comments on the importance of this information in relation to sequencing of closure of Pit 3 are provided in the 2019 SSB Assessment Report.</p>
	Further work is required to provide reliable predictions of surface water contaminant concentrations post-rehabilitation; including (i) the characterisation of contaminant source terms, (ii) verifying the conceptualisation of key groundwater contaminant pathways, (iii) additional information on the interactions between surface water and groundwater, and (iv) more detailed ground and surface water modelling.	<p>Progress on each of these areas has been made and described in the section 7 Supporting studies. It is agreed that further work is required, and work on each of the relevant KKNs is progressing.</p> <p>Updates to the surface water monitoring are currently underway by Water Solutions, and is described in future studies in section 7.</p>	<p><i>Acknowledged</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>While there is agreement with many of the proposed closure criteria presented in the RMCP, some criteria need further clarification. All closure criteria should be quantified and accompanied by a suitable monitoring program. In the absence of agreement on an acceptable level of environmental effect outside of the Ranger Project Area, closure criteria should aim to prevent any mine-derived change to biodiversity and be applied at the boundary of the Ranger Project Area.</p>	<p>Further clarification has been provided to the closure criteria, noting that some are still under development with input from stakeholders. These have been linked to suitable monitoring programs with quantifiable outputs as far as practicable. This will be further developed in the 2020 MCP with further progression is achieved on finalisation of criteria. The approach to developing water criteria has changed to align with the national water quality management framework approach to setting water quality objectives. A stakeholder water quality working group is being reformed. This group will work on progressing water and sediment closure criteria and the associated monitoring program once criteria are agreed. This is acknowledged in the relevant sections on criteria development and monitoring. The existing compliance points on Magela and Gulungul creeks (MG009 and GCLB) are proposed for assessing ecosystem protection off the RPA.</p>	<p><i>Acknowledged</i></p>
	<p>As acknowledged within the RCMP, all rehabilitation activities will need to be supported by best practicable technology (BPT) analyses.</p>	<p>BPT is a review to select the best practical technology and, as such, will not be appropriate for activities. Operations, such as the run according to best practice and under the Nursery Association national guidelines. The list of planned BPTs within the Section 9 are those dictated by the Authority and any additional requirements for planned applications.</p>	<p><i>Acknowledged</i></p> <p>The BPT assessments to date are adequately detailed and a list of future BPT assessments described. All BPT assessments should include a wide range of options, taking into account relevant national and international experience and precedents where they exist.</p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
Executive Summary	Additional information is required to give confidence in the ability of the final landform to support vegetation in the long term, particularly concerning plant available water, soil formation and the establishment of understorey species.	See specific comments	<i>Acknowledged</i>
	The Revegetation Strategy presented should be expanded to an ecosystem restoration strategy, based upon a suitable ecosystem trajectory model which addresses the interdependencies between flora and fauna.	Additional studies in regard to fauna recolonisation on rehabilitation sites at Ranger Mine are continuing, as is the KKN studies in regard to development of a rehabilitation trajectory. The ecosystem rehabilitation strategy will be finalised when this additional information is available.	<i>Acknowledged</i>
2.4 General Observations	<p>A thematic report structure is recommended, and may include:</p> <ul style="list-style-type: none"> • a description of the proposed activity • a schedule for undertaking the proposed activity, including clear milestones • supporting evidence to demonstrate that the activity will result in achievement of the relevant ERs • an associated closure criteria that will be used to assess the success of the activity • associated monitoring program(s). 	The restructured MCP is a standardised industry structure that follows both the WA MCP guidelines and the recommendations in the Authority (Annex B7)	<i>Accepted</i>
	In the next version of the RMCP include detailed contingency plans for all key activities.	Contingency plans have been included within the MCP for the key activities that have been approved to date. Contingency planning will form part of the BPT and risk analysis assessments for future applications of key activities (i.e. deconstruction of Tailings Storage Facility, deconstruction of processing plant, final landform).	<i>Acknowledged</i> Refer to further comments on contingencies within body of report, below and in Appendix 4.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
3.1 Risk Assessment	<p>To justify the assignment and ranking of risks, risk classes, controls and control effectiveness, the risk assessment should include:</p> <ul style="list-style-type: none"> • evidence to justify the likelihood and consequence rankings, including key assumptions and the level of certainty associated with the information informing this evaluation • a clear distinction between existing and proposed controls, and evidence to support control effectiveness rankings including consideration of control applicability or availability during the three closure phases (i.e. decommissioning, stabilisation and monitoring and post-closure) • a clear plan to obtain additional information to inform the assessment of each risk, to improve the control effectiveness, or to identify new risks as further information is obtained, where required. 	<p>The 2019 MCP includes further information to justify the assignment and ranking of risks, risk classes and controls. It is acknowledged that further development and refinement will be achieved in the 2020 risk assessment update, and these continual improvements will be included within each MCP update.</p>	<p><i>Acknowledged</i></p> <p>Noted that the 2019 MCP does not appear to include further information to justify assignment and ranking of risks, classes and controls.</p>
	<p>Terms and definitions should be simplified and standardised.</p>	<p>No response</p>	<p><i>Not addressed</i></p>
	<p>The likelihood classifications may need to be reconsidered given the long timeframe for the life of the project (10,000 years).</p>	<p>No response</p>	<p><i>Acknowledged</i></p> <p>Timeframes have been added to the likelihood classifications, although it is not clear how these were considered in the risk assessment scoring.</p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Additional discussion around control effectiveness and contingencies should be provided for existing controls that: <ul style="list-style-type: none"> might be removed during decommissioning are known to be ineffective at the time of reporting. 	No response	<i>Not addressed</i>
	Table 9-6 should include: <ul style="list-style-type: none"> reference to the existing controls the phase of closure for which the risk is being assessed risk <i>TC4-03: Delays to rehabilitation and/or closure activities extending beyond 2026</i> in the Aquatic Ecosystem risk category (TA), as well as the People risk category (TC). 	No response	<i>Not addressed</i> Table 10-5 includes reference to controls noting that there is no distinction between existing/potential controls, or the relevant closure phase.
	Risks that are present at more than one location across the site should be standardised.	No response	<i>Accepted</i> The risk assessment has been re-structured to address this comment.
4.3 Best Practicable Technology (BPT)	In the next version of the RMCP identify the full range of planned (or potentially required) BPT assessments.	The BPT Section of the MCP has been expanded to make reference to all BPT assessments completed and planned.	<i>Acknowledged</i> The BPT assessments to date are adequately detailed and a list of future BPT assessments described. All BPT assessments should include a wide range of options, taking into account relevant national and international experience and precedents where they exist.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
5.3.2 Landform: Construction Material	It is noted that the material movement areas shown in Figure 10-31 do not include the area to the north-west of the Tailings Storage Facility surrounding the trial landform and RP1 as shown in Figure 10-36. This should be clarified.	Figure 10.31 in the 2018 MCP illustrated reclamation areas, which are described in the 2019 MCP as closure domains. Notwithstanding the change in terminology, and update of figures, the 2018 Figure 10.31 demonstrates the four areas that will require cut/fill to construct the final landform (with volumes summarised in 2018 Table 10-12). However, the 2018 Figure 10-36 covers the categories of backfill techniques, with the Tailings Storage Facility considered Category B. The two figures are not meant to be an exact match. The TLF and the RP1 will not be covered with waste.	<i>Accepted</i>
5.7.2 Landform: Exploration Decline	<p>A standalone application for the rehabilitation of the Ranger 3 Deeps exploration decline was submitted for assessment in July 2018 and is currently under review. This application does not propose the complete backfill of the decline. The information contained within the application should be incorporated into (or appended to) future versions of the RMCP.</p> <p>The exploration decline should be included in Table 10-1: Current schedule of closure tasks.</p> <p>Figure 10-14: 2025 closure summary shows contaminated material being placed in the exploration decline. This is not currently reflected in the standalone application or other sections of the RMCP. This needs to be clarified.</p>	Information within the 2019 MCP has been updated to reflect that within the Ranger 3 Deeps approval. No contaminated material will be disposed of within the decline.	<i>Accepted</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
5.10 Landform: Detailed Activity Description	<p>Provide additional information, including:</p> <ul style="list-style-type: none"> • detailed construction plans and timelines • engineering designs, construction tolerances and a digital elevation model • material movement and balances (including reference to consolidation models) • assumed availability rates/capacities of key equipment • mapped locations of material grades • quality control procedures to be employed during construction • a schedule showing material movements as the landform is constructed. 	<p>This additional information will be provided within the MTC application (final landform and revegetation) due for submission in 2022.</p>	<p><i>Acknowledged</i></p> <p>In addition to the previously-listed information, the following should also be provided:</p> <ul style="list-style-type: none"> • plans/designs for the distribution/extent of the different surface materials (waste rock, rock armour, ripping, natural surfaces) on the final landform • engineering designs and long-term management plans for proposed sediment and erosion control structures on the final landform • up to date flood modelling
	<p>Update the RMCP to reflect that tailings deposition into Pit 3 has generally been onto either a small beach or down the pit wall and directly into the water.</p>	<p>The 2019 MCP has incorporated the details of the approved Pit 3 Tailings Deposition Application (July 2019) which covers this topic in detail.</p>	<p><i>Accepted</i></p>
	<p>Clarify if <i>finished surface level</i> is the surface of the waste rock landform, and therefore much of the infrastructure would remain in situ and simply be buried.</p>	<p>The underground services/buried items will be demolished (which involves breaking up infrastructure) and relocated to be buried on-site at 8m level deep below the final landform (Pit 3).</p>	<p><i>Accepted</i></p>
	<p>Include discussion on the placement of contaminated material from RP2 and RP3 in the Exploration Decline, as indicated in Figure 10-14.</p>	<p>This action is no longer proposed. All contaminated material will be directed to Pit 3. No contaminated material is planned to be transferred to R3D. The figure has been updated.</p>	<p><i>Accepted</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Improve the scheduling for disposal of contaminated material into the pits, including the 4.6 million tonnes of mineralised material from the northern wall of the Tailing Storage Facility that will be placed in Pit 3 in 2025, and the other <i>mineralised</i> material that will be placed in the lower sections of the pits. It should be clarified how this material will be placed below the <i>low-grade 2 rock cap</i> .	Current implementation plans are summarised within the implementation Section 11. The Tailings Storage Facility deconstruction will be subject to an application proposed to be submitted in October 2021. Detailed quantities and scheduling will be included within this application.	<i>Acknowledged</i>
	Further detail is required to support the deliberate introduction of weeds on the final landform.	The MCP has been updated to confirm that there will be no introduction of exotic species into the RPA. Occurrence of weed species will be actively managed during closure. The use of the term "weed" was in error and has been removed.	<i>Accepted</i>
5.10 Landform: Landform Physical Properties	Provide details on how predicted maximum final landform slopes were calculated.	The methodology of calculation of maximum landform slopes was via a GIS package to extract the long section from the provided final landform topography (which was generated from the landscape evolution modelling). The slopes can also be calculated from a contour plan of the same final topography.	<i>Accepted</i>
	Assess the adequacy of existing monitoring data from historical revegetation trials and analogue sites to inform recommendation and future work. If existing data are insufficient or inappropriate, further data should be collected from the trial landform or relevant reference sites.	Assessment has been made of the existing monitoring data of revegetation trials on the trial landform (historic and current) and for reference sites taking into consideration the suite of species and growth medium properties. Knowledge gaps identified were used to inform further trials. Monitoring of the trial landform and Pit 1 will provide confidence in the revegetation program.	<i>Accepted</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
5.10 Landform: Landform Stability	Develop a water balance for Pit 1 to support the statement that > 99% of the process water expressed by consolidation will be recovered for treatment by January 2026.	Solute and volume balance studies conducted on Pit 1 from January 2017 to December 2018 indicate that all tailings consolidation flux is being recovered by the decant structures. Recovery of all the tailings consolidation flux is expected to continue while Pit 1 decant structures are operated. Refer to Section 7.1.2.	<i>Acknowledged</i> Further comments are provided in the 2019 RMCP Assessment Report in relation to tailings consolidation vs process water removal.
	Information on the new tailings deposition strategy in Pit 3 should be included in future versions of the RMCP, including the consolidation time frames, and any differential settlement predicted using the updated Pit 3 consolidation model.	Information is included within updated Section 7.1.3.	<i>Accepted</i>
	It should be acknowledged that landform erosion modelling results are dependent on the specific scenario modelled, and are indicative only (e.g. not to be referenced as providing precise locations or depths of potential gully formation on the final landform).	This was noted on page 7-78 of the 2018 MCP: "Supervising Scientist have advised ERA that landform erosion modelling results are indicative only and should not be used to provide precise locations or depths of potential gully erosion, as such this information has only been used to guide the development of the final landform. However, as outlined in Chapter 6, Section 6.2.1.3, tailings will be below the natural landscape, and are not expected to be exposed (Supervising Scientist, 2017a)."	<i>Accepted</i>
	Provide the following information on the proposed flow and sediment control structures, including: <ul style="list-style-type: none"> the design a program of maintenance the volume of bedload requiring disposal potential impacts and planned mitigation measures that the structures are ineffective. 	Design features are provided in Section 11. The maintenance is included within Section 12 - Monitoring and maintenance.	<i>Acknowledged</i> Most information has been provided, except volumes of sediment requiring disposal.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Provide information on the background bedload yields, to assess the potential impacts associated with bedload transport to Magela and Gulungul creeks (should this occur).	This KKN is planned to be completed in 2020, and the results will be incorporated into the next MCP update, and will supply the details requested in the comment.	<i>Acknowledged</i> Note that the primary relevant KKN is LAN1B.
	Assess the potential risks of extreme events and landscape-scale processes on landform stability.	These risks were considered under Category B, C & D of the August 2019 Risk Assessment. This also included consideration of greater than expected rainfall events, variation of predicted Pit 1 & 3 consolidation, excessive erosion impacting landform stability and the potential effects of large scale fire or cyclone events.	<i>Acknowledged</i> This will be addressed with completion of relevant ERA/SSB projects allocated to KKN LAN2.
	Use synthetic rainfall datasets in flood modelling.	The LEM (landform evolution model) does utilise a synthetic rainfall data set for 10,000 years, and also considers climate change scenarios.	<i>Not addressed</i> The comment was in relation to use of synthetic rainfall data in flood modelling, not LEM modelling.
5.10 Landform: Tailings Isolation	The final landform design should be revised to avoid gully formation over tailings for both Pit 1 and Pit 3.	The landform model - FLv6.2 - was provided to SSB at the completion of FS study.	<i>Acknowledged</i> SSB is currently assessing FLv6.2.
	Given the tailings deposition method is currently under review the control effectiveness rating of C1 for the tailings consolidation risk should be reconsidered.	The risk assessment was updated with the risk assessment in August 2019, after the part approval was received for the Pit 3 modification to deposition application. The risk is to be managed as a class III risk.	<i>Accepted</i> Noted that assessment of control effectiveness has been removed from 2019 RMCP. This is discussed in other SSB comments on risk assessment.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
5.10 Landform: Infrastructure Disposal	Provide a detailed backfill plan for Pit 3 including: <ul style="list-style-type: none"> types and volumes of contaminated material that will require disposal (e.g. hydrocarbons, soil, waste from HDS plant) plans for material segregation (if required) disposal methods to be used (e.g. mixing with waste rock, layering, cells, etc.) schedule for plant demolition and disposal. 	This information will be received in the Pit 3 backfill application due to be submitted in October 2020, and will therefore appear in the 2021 MCP update.	<i>Acknowledged</i>
	Section 7.5.1 states that <i>all material with the potential for environmental impact</i> will be placed at the bottom of the mined-out pits. It is suggested this statement is removed from the plan as it is not readily achievable given grade 1 waste rock has the potential for environmental impact.	<i>No response</i>	<i>Not addressed</i> It is noted that this comment was in the text but not specifically included in the relevant summary table of comments/recommendations in SSB's 2018 Assessment Report.
	Incorporate a summary of the standalone application for rehabilitation of the Ranger 3 Deeps exploration decline into future versions of the RMCP.	This is incorporated into the implementation Section 11.	<i>Accepted</i>
5.10 Landform: Closure Criteria	The <i>probable worst-case scenario</i> should be retained in the closure criteria and clearly defined, in consultation with the Supervising Scientist.	Finalisation of the completion criteria is aimed for the inclusion into the 2020 MCP, and this will done in consultation with the SSB.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Quantify closure criteria L7 and L8.	Additional studies have been conducted and information included in Section 7 regarding the landform theme, these include an updated DEM, tailings consolidation modelling. The outcomes of these works provide further validation to the closure criteria developed for the landform. The outcomes of on-going and future studies (Section 7.10) will be considered in future reviews of the criteria.	<i>Accepted</i> Noted that criteria L7 and L8 have been removed in the 2019 RMCP update.
	Use the BACIP method described by Moliere and Evans (2010) to assess suspended sediment loads in closure criteria L11.	The BACIP method is utilised for TSS as described in Section 8.2 and Section 12.4. It is intended that all methodologies will be assessed and selected accordingly for TSS, and other monitoring requirements, and will be specified within the MCP monitoring section as decisions are finalised.	<i>Acknowledged</i> Noted that SSB is currently reviewing the Landform Rehabilitation Standard, which will provide ERA updated advice on the approach to assessing suspended sediments.
5.10 Landform: Monitoring	<p>Provide further details to on monitoring method to demonstrate how relevant information will be collected to assess landform performance over time, including:</p> <ul style="list-style-type: none"> • how gully formation will be measured on the revegetated landform • details of monitoring data required for ongoing validation of erosion modelling • water quality monitoring methods to be used for assessing landform erosion (e.g. turbidity as a surrogate for suspended sediment in surface water). 	Suspended sediment/turbidity will be monitored on the constructed Pit 1 landform to assist in the calibration/validation of future model predictions of suspended sediment transport. Thus the KKN LAN3E. <i>How much suspended sediment will be transported from the rehabilitated site (including land application areas) by surface water?</i> will be finalised in 2020 to provide the requested information to be included in the MCP update when available. LAN 4 & 5 are SSB KKNs.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
6.8 Water and Sediment: Detailed Works Description	<p>Additional information should be provided to support the site wide water balance model, including:</p> <ul style="list-style-type: none"> • detailed plans and timelines for all activities related to water management, storage and treatment and brine disposal • availability, rates, capacities of key plant and equipment (e.g. water treatment plants, brine injection bores, etc.) • updated modelling assumptions and modelling uncertainty analyses. 	<p>Additional information regarding the Water Balance Model are routinely provided to stakeholders at MTC meetings/stakeholder forums. Detailed information is now available within the Ranger Water Management Plan. The scope of the MCP is to describe the broader process by which the model is maintained and validated. The predominant uncertainty with respect to the water model is rainfall variance. This is captured in model outputs which show the range of possible outcomes consequence of input of rainfall datasets representing increments from the range of historical data. Whilst additional uncertainty analysis is employed for example to compare alternate strategies and understand contingency requirements, such analysis is outside of the scope for the MCP. An Integrated Water Treatment Strategy application will be submitted in January 2020 and this information will be provided in updated MCPs.</p>	<i>Acknowledged</i>
6.8 Water and Sediment: Water Management	<p>Include a detailed schedule that outlines the predicted process water volume and intended storage locations over time.</p>	<p>Forecasts of process water volumes over time are provided in Figure 2-10. In the operational phase ahead of closure, free process water will be stored between the Tailings Storage Facility and Pit 3, with the balance between the two storages varied to suit the operational requirements of the dredge and Pit 3 deposition and process water return infrastructure. Additional detail to describe the schedule is provided in Section 11.</p>	<i>Accepted</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Demonstrate that the Tailings Storage Facility is able to be used as a process water storage post-2020, and provide relevant contingencies options for the event the Tailings Storage Facility is determined to be unsuitable for water storage.	Further studies are required to demonstrate that the Tailings Storage Facility will be suitable for use as a water storage facility. Relevant contingency options will be considered in the event that the studies demonstrate that the Tailings Storage Facility is unsuitable for water storage.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>A schedule should also be included for water treatment, indicating the planned options for process water treatment and demonstrating that these options will be sufficient to treat the predicted process water volumes.</p>	<p>A schedule for water treatment has been included. Three active process water treatment routes are planned:</p> <ul style="list-style-type: none"> • Treatment using the existing Brine Concentrator. The Brine Concentrator will be the principal path for active process water treatment, with its feed water stream drawn from the bulk process water inventory – which is typically the highest. A feasibility study is underway to incrementally expand the distillate production capacity of the Brine Concentrator through an upgrade of the vapour recompression fan in unit three. Under the median forecast, the Brine Concentrator will be decommissioned in June 2025 – after all sources of process water have ceased. • Treatment using the HDS plant. This plant will treat an intermediate range of process water in terms of salt concentration, to minimise treatment cost and maximise plant throughput. HDS plant operation is planned from 2019 through to the end of 2021. • Treatment using reverse osmosis technology, of similar nature to (and perhaps using) the Brine Squeezer. This treatment process will target sources of process water with lower salt concentration, and is expected to run through to the middle of 2025. The contributions of the three active process water treatment routes are shown in Figure 11-29. 	<p><i>Acknowledged</i></p> <p>Given the uncertainty associated with the predicted process water volumes up to 2025, it is critical that ERA is able to fulfil its identified contingency to continue water treatment and disposal of all process water (including expressed tailings pore water) for as long as necessary. As the process water treatment predictions are further refined, this may also have implications for the disposal of brine in Pit 3. Additional information should be provided in the RMCP, including:</p> <ul style="list-style-type: none"> • results of investigations undertaken in order to reinstate the Pit 3 underdrain extraction bore • evidence to demonstrate the longevity of the brine injection wells and factors that may affect this.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>Clarify why tailings pore water expression during deposition has increased by more than 30% in consolidation modelling results between 2014 and 2016.</p>	<p>Further explanation has been included within Section 7.1.3.</p>	<p><i>Not addressed</i></p> <p>In 7.1.3 it is stated that:</p> <p>'The increase in expressed water (for the 2016 case) during deposition is due to thickening after Year 1 in the 2014 case.'</p> <p>However, the latest 2018 modelling shows that expression is now more consistent with the 2014 case (rather than 2016), which assumed thickened tailings.</p>
	<p>It is critical that ERA fulfil its commitment continue water treatment for as long as necessary to treat and dispose of all process water (including expressed tailings pore water) onsite. This commitment is fully supported by the Supervising Scientist, along with the intention to increase the capacity of process water treatment over time, which will be necessary to achieve treatment of all process water by 2025. This commitment should be included as a contingency in section 10.9.1.</p>	<p>ERA is committed to continuing to treat water until such time as inventories are eliminated. The current plan facilitates this outcome within the legislated timeframe for average rainfall scenarios.</p> <p>However ERA continues to investigate opportunities to increase process water treatment capacity, whilst monitoring progress of existing facilities and inventories as influenced by external factors (e.g. rainfall). Decisions to implement such initiatives will be dependent on ongoing assessment of business case, risk and contingency and BPT analysis as may be appropriate for identified technologies.</p>	<p><i>Acknowledged</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>Further details the Pit 3 brine injection system should be provided in the RMCP, including:</p> <ul style="list-style-type: none"> the expected lifespan of brine injection bores and factors that may affect this time frames and potential issues associated with the construction of additional brine injection bores, should they be required any other brine disposal methods that might be used in the case that the brine injection system fails (i.e. failure of all bores, or the underbed drain extraction system). 	<p>Five brine injection bores have been installed to enable brine concentrator brine to be injected into the underfill layer in the base of Pit 3. It is not possible to definitively estimate the lifespan of injection wells as the system has yet to be operated since the substantial improvement in brine concentrator utilisation from 2017 to the present. However the four remaining wells are thought to be adequate. Noting the critical role of this system, contingency wells have been included in the budget for rehabilitation. A trial has been conducted for the necessary directional drilling method required for installation of such wells from the exterior of Pit 3. There is sufficient time to construct these contingency wells as the existing wells are intended to be used sequentially. Alternate brine disposal methods have been considered at a concept level, as have a range of options for restoration of the underdrain bore system. These will be further developed in the very unlikely circumstances require.</p>	<p><i>Acknowledged</i></p>
	<p>Provide further information to demonstrate that there are sufficient appropriate disposal options for treated water throughout the rehabilitation process, as irrigation areas are decommissioned.</p>	<p>Further assessment is required to demonstrate that there are sufficient appropriate disposal options for treated water throughout the rehabilitation process. This will require assessing the capacity within release storages, expected evaporative losses from storage surfaces, capacity in the remnant application areas, rehabilitation requirements and turbomister capacity. This information will be updated in future iterations of the MCP. An integrated water treatment strategy application is planned to be submitted to regulators in early 2020.</p>	<p><i>Acknowledged</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>Provide further detail on time frames that sediment control infrastructure is expected to remain in place (i.e. criteria for removal) and any ongoing maintenance requirements (e.g. sediment removal and disposal locations).</p>	<p>Further planning is required to assess the option to retain sediment control infrastructure as permanent. This involves assessing the impacts of re-disturbing areas for removal. The Water Solutions (2017) Preliminary Flood Modelling and Hydraulic Design report suggests that "once the monitoring program identifies that the vegetation on the site has been well established and that erosion processes have been reduced to acceptable levels, the temporary erosion protection measures may be decommissioned...Attempts to remove these erosion limitation features would likely re-disturb the environment, which is undesirable. It is recommended that these features remain in place."</p>	<p><i>Acknowledged</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
<p>6.8 Water and Sediment:</p> <p>Site Conceptual Models</p>	<p>The RMCP should detail future hydrogeological work that will be undertaken to refine the Ranger Conceptual Model, and explain how this will further inform rehabilitation planning, particularly with regard to:</p> <ul style="list-style-type: none"> • further refinement and characterisation of key hydrogeological units, aquifers and groundwater flows in high-risk areas for contaminant transport (around Pit1, Pit 3 and the Tailings Storage Facility) • further information on surface water/groundwater interactions • improved characterisation of existing contaminated groundwater (e.g. under the Tailings Storage Facility) and contaminated sites (e.g. Land Application Areas). 	<p>Work has been undertaken by ERA and INTERA in the last 12 months to update the Ranger Conceptual Model. Groundwater monitoring, specifically to support closure criteria, is detailed within Section 12.5.2. This monitoring has been designed to support further refinement of key hydrogeological units, and groundwater / surface water interaction via collection of groundwater quality and high resolution water level data via dataloggers. All monitoring data collected for both operational requirements and specific studies is used to support ongoing updates to the Ranger Conceptual Model. The updated Ranger Conceptual Model (INTERA 2019) details all refinements made to the characterisation of all hydrogeological units within the model domain, which includes all high risk areas. Project planning and scoping is underway to support future studies specifically to quantify the contamination below the Tailings Storage Facility and Processing Area. These studies will support the development of the remediation plan. The Tailings Storage Facility contaminated materials application will specifically address contamination as a result of operation of the Tailings Storage Facility. KKN WS2 and WS3 are to address surface water and groundwater interactions.</p>	<p><i>Acknowledged</i></p> <p>The conceptual model will need to be updated as this information becomes available and the RMCP should detail future hydrogeological work that will be undertaken to refine the model and explain how this will feed into the contaminant transport modelling and rehabilitation planning. Additional comments are provided in the 2019 RMCP Assessment Report.</p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
6.8 Water and Sediment: Contaminant Source Terms	Further work is required to quantify contaminant source terms and factors that influence their mobilisation on a whole-of-site basis, including existing groundwater contamination and contaminants predicted to arise from the waste rock landform, the buried tailings and contaminated soils and sediments disturbed during rehabilitation.	ERA has numerous projects underway to address this. Refer to the summary of activities against KKN WS1A <i>What contaminants (including nutrients) are present on the rehabilitated site (e.g. contaminated soils, sediments and groundwater; tailings and waste rock)?</i>	<i>Acknowledged</i> Additional information should be presented in the Pit 3 Closure application to demonstrate that all contaminant sources onsite, including contaminated groundwater and material associated with the Tailings Storage Facility and processing area, has been well characterised, is adequately represented in contaminant transport modelling and will not result in environmental impacts.
	<ul style="list-style-type: none"> For the waste rock source term: <ul style="list-style-type: none"> ensure that an appropriate infiltration rate is used to understand vadose zone behaviour and to determine the concentrations of contaminants in waste rock seepage, and update contaminant transport modelling accordingly improve the estimate of sulfide minerals and associated oxidation potential in the waste rock landform improved assessment of solute release subsequent to the consumption of all of the sulfide minerals. 	ERA has numerous projects underway to address this. Refer to the summary of activities against KKN WS1A <i>What contaminants (including nutrients) are present on the rehabilitated site (e.g. contaminated soils, sediments and groundwater; tailings and waste rock)?</i>	<i>Acknowledged</i>

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	<p>For the tailings and pore water source term:</p> <ul style="list-style-type: none"> • additional data are required to update the tailings consolidation modelling and water balance accounting for both pits, taking into account the heterogenous nature of the tailings in the pits, and the effect this may have on the amount of contaminants mobilised from tailings and the direction and rate of solute expression 	<p>Model was updated in 2015 by Fitton (Figure 7-5). Ongoing measurements of tailings settlement have been undertaken on a monthly basis to confirm the model is still valid. Available measurements relevant to flows in and out of the waste rock cap on top of Pit 1 have been used to construct a solute mass balance, using magnesium as the representative solute, and a water (volume) balance. The solute balance indicates that the measured mass of solute recovered through the decant towers matches the mass of solute estimated to have been expressed from tailings (Figure 7-6). The consolidation model for Pit 3 has recently been reviewed with the results obtained from the cone penetration test (CPT) by Fitton (2019a). It was noted that the pore pressure profiles measured in the last CPTs closely agree with those predicted by the consolidation model. Expression of tailings pore water with respect to local scale and regional scale ground water impacts is to be assessed within the groundwater solute transport modelling being undertaken by INTERA.</p>	<p><i>Acknowledged</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>For the groundwater source term:</p> <ul style="list-style-type: none"> • characterisation the existing groundwater contamination onsite, including beneath the Tailings Storage Facility, and update the Ranger Conceptual Model and contaminant transport models accordingly • proposed remediation and active management options for groundwater during and after the rehabilitation of contaminated sites (e.g. the processing area, stockpiles and the Tailings Storage Facility) • to demonstrate that Land Application Areas will not result in a significant groundwater contamination source, include data from bores representing all aquifers and areas of the Ranger Project Area that could be impacted (i.e. Aquifer 1 and Aquifer 2). 	<p>No additional characterisation of groundwater contamination has occurred within the last 12 months. Project planning and scoping is underway to support future studies specifically to quantify the contamination below the Tailings Storage Facility and processing area. These studies will support the development of the remediation plan and will be detailed in future MCP updates. The Tailings Storage Facility contaminated materials application will specifically address contamination as a result of operation of the Tailings Storage Facility. Section 7.10.9 identifies planned future studies relating to contaminated sites.</p>	<p><i>Acknowledged</i></p>
	<p>The potential risks associated with the generation of acid sulfate sediments due to mine-derived sulfate needs to be assessed, particularly in Coonjimba, Georgetown and Gulungul billabongs.</p>	<p>The 2018 MCP addresses acid sulfate soil risk assessment that was undertaken with regard to the Coonjimba Billabong. Further assessments are planned to be carried out for the Georgetown and Gulungul billabongs (2020). It was planned that EcOZ undertake assessments in 2018, however this was deferred until the ERM Conceptual model has been finalised.</p>	<p><i>Acknowledged</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
6.8 Water and Sediment: Contaminant Transport Modelling	<p>All numerical modelling should be based on:</p> <ul style="list-style-type: none"> the data-driven Ranger Conceptual Model, which needs to include sufficient detail and confidence for high-risk areas (e.g. the Magela Creek bed, the Djalkmarra sands and the MBL zone) detailed and reliable quantification of all potential contaminant source terms onsite, including existing groundwater contamination on the minesite a calibration period that is sufficient to stress the model to the extent that its behaviour during pre-mining, operational and post-mining conditions can be assessed, including mine-impacted and baseline variability in groundwater levels, stream flow and associated processes all available data, including pre-mine data if available, with clear justification for the exclusion of data not used surface water and groundwater interactions at a temporal scale appropriate for the baseline variation in groundwater levels and surface water flow. 	<p>ERA agrees that all numerical modelling should be based on the points identified. ERA has committed to the development and update of the sitewide groundwater model to predict post-closure solute loading to creeks from all sources using uncertainty analysis. A detailed update on the progress of modelling to date was provided by INTERA at ARRTC41. A subsequent update on the completed conceptual model was provided at ARRTC42.</p>	<p><i>Acknowledged</i></p> <p>Further comments on contaminant transport modelling are provided in the 2019 RMCP Assessment Report.</p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>To enable more reliable predictions of contaminant concentrations in surface water, the contaminant transport modelling, particularly the surface water model, needs to be refined using more relevant and appropriate data and assumptions, including:</p> <ul style="list-style-type: none"> • undertaking contaminant transport modelling at increased temporal and spatial resolution (particularly around the period of peak solute delivery to the surface water system) • developing better understanding of groundwater/surface water interactions that will control the location and timing of delivery of contaminated groundwater to the surface water system • implications of groundwater recovery as groundwater levels return to a stable state after rehabilitation • improved understanding of the role of groundwater/surface water interactions in solute migration • assessment of confidence in modelled outputs using statistical, sensitivity and uncertainty analyses for each model, as well as analysis of cumulative uncertainty where multiple models are interconnected. 	<p>The surface water contaminant transport modelling is currently being updated and refined to improve outputs with consideration of the relevance and appropriateness of data and assumptions. Updated information will be provided within the future update of the MCP.</p>	<p><i>Acknowledged</i></p> <p>Further comments on contaminant transport modelling are provided in the 2019 RMCP Assessment Report.</p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	<p>Develop an understanding of the spatial and temporal (seasonal) interactions between groundwater and surface water. This work is required as a priority, particularly in light of the significant concerns related to water quality in Magela Creek raised in Appendix 8.1 of the RMCP (2011–12 ITWC PFS BPT Assessment).</p>	<p>The updated monitoring section discusses closure monitoring, which has been designed to support further refinement of key hydrogeological units and groundwater / surface water interaction via collection of groundwater quality and high resolution water level data using dataloggers.</p>	<p><i>Acknowledged</i></p> <p>It is noted that ERA are currently developing a finer resolution temporal model to inform knowledge on groundwater delivery to the surface water.</p>
	<p>Reactive transport modelling is required for calcium so that its effect on magnesium toxicity in the receiving surface waters can be understood (calcium has been shown to ameliorate magnesium toxicity).</p>	<p>ERA project 1260-02 - <i>Mg:Ca input into Surface Water Model</i> - is underway to address this. Outcomes will be reported in the next MCP and inform inputs to the surface water model. This project is listed project against KKN WS3C. <i>What factors are likely to be present that influence contaminant (including nutrients) transport in the surface water pathway?</i></p>	<p><i>Acknowledged</i></p>
	<p>A robust analysis of model uncertainty will need to be undertaken to quantify and understand the level of uncertainty associated with the modelled outputs.</p>	<p>The Ranger Mine sitewide modelling process complies with the guiding principles from the Australian Groundwater Modelling Guidelines. The Ranger Mine groundwater calibrated model will meet all indicators for the Level 3 confidence level (highest confidence level) after completion of the planned peer review by an independent hydrogeologist with modelling experience. Furthermore, ERA have made a commitment to have INTERA update minor sections of the report to address comments made by SSB. The outstanding concerns relate to development of a formal uncertainty analysis which ERA has committed to undertake (and will be included in future MCP when complete).</p>	<p><i>Acknowledged</i></p> <p>It is noted that uncertainty analysis will also need to be undertaken for the surface water model.</p>

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6.8 Water and Sediment: Protection of Ecosystems	Organism assemblages for all stages of creek flow should be characterised and assessed for their sensitivity to contaminants	KKN WS7c addresses this issue and is assigned to SSB. The SSB project 'Seasonal sensitivity' (to Mg) profile for organisms in the Magela creek channel' commenced in July 2018 and is due for completion in late 2019.	<i>Acknowledged</i>
	Assess the potential contribution of subterranean fauna in Magela Creek sand beds to ecological processes and the biodiversity of the ARR and if significant, then determine the potential impact of contaminants on these communities.	As per the KKN, ERA is responsible for assessing contaminants on ecological communities and processes. This requires input from SSB to establish contribution of subterranean fauna in order to determine potential impacts. The MCP will be updated as information becomes available.	<i>Acknowledged</i>
	Provide information on concentrations of suspended sediments and contaminants (including nutrients) bound to sediments, including: <ul style="list-style-type: none"> • effects of sediment mobilisation on surface water quality • physical effects of suspended sediment on aquatic biodiversity • where, when and to what extent contaminants may accumulate in downstream sediments • monitoring methods. 	Suspended sediment transport and accumulation will be predicted by the surface water model. Several projects to assess the biological impacts of contaminated sediments are listed against KKN WS5A. SSB has developed a rehabilitation standard to protect aquatic biodiversity from the effects of sedimentation. Information on these projects and agreement on monitoring approaches will be included in the next MCP update.	<i>Acknowledged</i> The Supervising Scientist's Turbidity and Sedimentation Rehabilitation Standard is currently being developed.
	Provide additional details on remediation of onsite waterbodies.	Results of surface water modelling and the numerous assessments based on those results, including ERA project 1221-09 - <i>Surface Water Pathway Risk Assessments (release pathways onsite)</i> , is scheduled for 2020. This will assess the risks related to onsite water bodies and inform BPT and ALARA assessments of water management options, including remediation of off-site water bodies.	<i>Acknowledged</i>

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	Assess the risk of eutrophication to on and offsite waterbodies when surface water model results predicting nutrient concentrations become available.	A project has been scheduled to address this. Refer to details included within ERA project 1260-04 Eutrophication Risk Study listed against KKN WS6C.	<i>Acknowledged</i>
	Provision should be made for a periodic review of contaminants measured in the post-closure monitoring program outlined in the RMCP, and closure criteria developed where required in the future.	CoPC are discussed in 8.4.3.3 Step 3. Define relevant indicators. In that section it is noted that a review of CoPC for all sources on the Ranger Mine is being conducted by ERM Ltd as part of the background concentrations of CoPC in groundwater project (refer Section 7 Supporting Studies). A project to review CoPCs again following sampling of contaminated sites is scheduled and listed against KKN WS1. Further detail has been provided within the Pit 3 Tailings Application (Iles & Humphrey 2014 Draft Water Quality Closure Criteria). A discussion paper was also submitted to the MTC water and sediment working group.	<i>Acknowledged</i>
	Assess the risk of contaminated groundwater on riparian and aquatic vegetation.	SSB is assessing this through their project Ecohydrology and Sensitivity of Riparian Vegetation. Field work commenced in late 2018 and pot trials to determine possible toxicity of magnesium to riparian tree species commenced in shade-house facilities at CDU in April 2019. A SSB groundwater project has also been linked to this study. ERA has provided advice and information to inform future assessments.	<i>Acknowledged</i>

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	Assess the potential risk of contaminant plumes in creek channels forming a barrier that inhibits organism migration and connectivity.	This KKN is assigned to SSB. SSB are conducting a collaborative project with Charles Darwin University and the National Environmental Science Program (NESP). The project effects of surface and groundwater egress of mining-related solutes on aquatic ecological connectivity, Magela Creek, commenced in November 2018. Completion is expected in mid-2020. Updates will be incorporated into the next MCP.	<i>Acknowledged</i>
	Assess whether there are additional key aquatic organisms for which water quality guidelines need to be developed (e.g. flow-dependent insects, hyporheic biota and stygofauna).	This KKN is assigned to SSB (KKN WS7c). SSB have two projects listed against this in their project description paper submitted to ARRTC May 2019.	<i>Acknowledged</i>
6.8 Water and Sediment: Closure Criteria	Define the process for ALARA in the context of closure criteria and provide examples of water and sediment criteria that are ALARA.	The MCP has been updated to clarify use of ALARA, as a process, in respect to closure criteria. ANZG (2018) supports the use of narrative statements for guideline values and water quality objectives. Several examples of narrative draft water quality objectives are used in Table 6-3, eg demonstrating what water quality is ALARA, and for aesthetic water values.	<i>Acknowledged</i> It is noted that there don't appear to be any examples, or a Table 6-3.

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	<p>It is incorrectly asserted that the ERs require an effect to be regional in nature to be considered detrimental. ER1.2(d) states that to be considered detrimental a change must be in excess of that observed naturally in the region (i.e. outside the range of natural variability), not that changes must be regional in nature.</p>	<p>ER1.2d states: "...the company must ensure that operations at Ranger (Mine) do not result in: change to biodiversity or impairment of ecosystem health outside of the Ranger Project Area. Such change is to be different and detrimental from that expected from natural biophysical or biological processes operating in the Alligator Rivers Region." So it is considered there is no conflict in ERA's assumptions. ERA does consider the scale of change as an important issue, and this is recognised in the project on ecosystem vulnerability. The two outcomes for the water and sediment management objective are stated as: First outcome - mine derived sedimentation or analytes from surface or ground waters discharged to surface waters off the RPA do not cause detrimental impact to the ecosystem health of the Alligators River Region, and that there will be no detrimental environmental impact off the RPA from tailings contaminants for at least 10,000 years.</p>	<p><i>Not addressed</i></p> <p>Further clarification of this comment is provided in the 2019 RMCP Assessment Report.</p>
	<p>To enable assessment of the ecological implications of an exceedance of a water quality closure criterion, the closure criteria need to be numerical values and should be applied at the boundary of the Ranger Project Area until such time as there is agreement on an acceptable level of detriment for areas outside of the Ranger Project Area.</p>	<p>The approach to developing water criteria has changed to align with the national water quality management framework approach to setting water quality objectives. The closure criteria has been revised to establish numerical values and will be applied to the boundary of the RPA.</p>	<p><i>Accepted</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Determine potential levels of exposure of humans to contaminants from drinking water from onsite waterbodies (i.e. consumption rates, locations, concentrations) and assess the risk to human health.	Concentrations of contaminants in surface water will be predicted by the surface water model. The human health risk associated with this is Addressed by KKN RAD9D. <i>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?</i> ERA has an initial assessment project 1260-08 Bush tucker Diet Assessments and two update projects (1260-09 and 1260-10) scheduled to address this KKN.	<i>Acknowledged</i>
	Propose closure criteria for sulfate, specifically in relation to the risk of acid sulfate sediment generation for billabongs.	A guideline criteria for this has been proposed based on the SSB rehabilitation standard for sulfate.	<i>Accepted</i>
	Acknowledge that there may be a requirement in future to consider the reintroduction of a closure criterion for pH, depending on the outcome of acid sulfate soil investigations.	This is acknowledged within this section. It is stated that SSB is also investigating the need for a pH standard.	<i>Acknowledged</i>
	Provide evidence that the proposed closure criteria are applicable to contaminant mixtures.	KKN WS7A assigned to SSB and is being addressed by their project Assessing the toxicity of mine water mixtures for operational and closure scenarios.	<i>Acknowledged</i>
	Undertake modelling of the potential contaminant accumulation in sediments post-closure, based on the results of surface water contaminant modelling, to demonstrate that sediment closure criteria are likely to be met.	Surface water contaminant modelling is currently being developed. This will inform modelling of the potential accumulation of contaminants in sediments and likelihood of achieving sediment closure criteria. ERA has several projects assessing the risk associated with sediment contamination. The section of the MCP will be updated when results become available.	<i>Acknowledged</i>

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	Assess the potential for offsite impacts associated with mobilisation and accumulation of contaminants via transport of suspended sediments.	Sediment transport and accumulation will be predicted by the surface water model. ERA has several projects assessing the risk associated with sediment contamination. Refer to projects listed against KKN WS5A. <i>Will contaminants in sediments result in biological impacts, including the effects of acid sulfate sediments?</i>	<i>Acknowledged</i> Noted that the current surface water modelling being undertaken by ERA may not predict concentrations of suspended sediments.
	Reassess closure criteria for nutrients, as the currently proposed criteria are less than baseline water quality values.	The concentration criteria for nutrients have been removed. The annual additional load limits are proposed instead (Table 8-3). These have applied at the Ranger Mine for several decades and are based on natural distributions of nitrate and phosphate. Work to assess the same approach for ammonia is scheduled. See projects listed against KKN WS6B. <i>Can Annual Additional Load Limits (AALL) be used to inform ammonia closure criteria?</i>	<i>Acknowledged</i>
	Develop a sedimentation closure criterion for aquatic ecosystem protection in billabongs.	The development of a sediment closure criterion for aquatic ecosystem protection is dependent on further studies. There is a KKN dedicated to effects of sedimentation on ecosystem health (KKN WS5). In addition, SSB have published a rehabilitation standard for sedimentation. This section of the MCP will be updated when information becomes available.	<i>Acknowledged</i> The Supervising Scientist's Turbidity and Sedimentation Rehabilitation Standard is currently under preparation.

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	<p>For parameters/locations where criteria are proposed for multiple outcomes (e.g. human health, recreation, ecosystem protection), state that the most conservative criterion across the outcomes applies.</p>	<p>This was stated in the 2018 MCP. Separate draft criteria were proposed for each protection objective so achievement could be measured. It was stated that:</p> <p><i>In some instances, the same parameter appears against several objectives. In most cases the ecosystem protection criteria are more stringent than, for example, human health criteria. Criteria values for each outcome are given so compliance with each particular outcome and objective can be assessed.</i></p>	<p><i>Accepted</i></p>
<p>6.8 Water and Sediment: Monitoring</p>	<p>The surface water monitoring program should include:</p> <ul style="list-style-type: none"> • acknowledgment that additional contaminants that have not been previously identified as a risk may need to be considered in future (e.g. findings from contaminated site investigations) and include provision in the post-closure monitoring program for periodic review of contaminants • key sites on the Ranger Project Area (e.g. Georgetown Billabong, Coonjimba Billabong, RP1 and other onsite waterbodies, while they are present) for demonstration that concentrations of contaminants are as low as reasonably achievable • acknowledgment that grab sampling may need to be conducted more frequently than monthly in the initial period after completion of rehabilitation works • sampling for Ra-226. 	<p>These sites are included in the revised monitoring program and the potential use of event triggered monitoring is discussed in addition to monthly grab sampling. The CoPC list is currently being reviewed and a project to review again following contaminated sites sampling is scheduled. Project 1221-07 <i>Acid Sulfate Sediments Conceptual Model</i> is underway to address this. Previous studies have also addressed this.</p>	<p><i>Acknowledged</i></p> <p>The monitoring program should be refined and agreed between ERA and the Supervising Scientist via the Water and Sediment Quality Working Group.</p>

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	<p>Revise the proposed groundwater monitoring plan to clearly demonstrate that monitoring will be undertaken at an appropriate spatial and temporal scale to:</p> <ul style="list-style-type: none"> observe trends in groundwater level recovery and contaminant transport post-closure that can be used to validate groundwater models, and recalibrate if necessary detect significant increases in contaminant concentrations in aquifers surrounding Pit 1, Pit 3 and the Tailings Storage Facility, to enable downstream mitigation of impacts if required (i.e. groundwater interception or abstraction). 	<p>The post-closure solute transport modelling being undertaken by INTERA will inform the development of specific long term groundwater monitoring beyond that currently detailed in Section 12.5.2. Updates on the development of a site wide groundwater monitoring plan will be included in future MCP updates.</p>	<i>Acknowledged</i>
7.8 Radiation Baseline conditions	<p>Use monitoring data collected over all years to derive statistical results for baseline water radionuclide concentrations at Magela Creek upstream or otherwise explain why only the data from 2010 to 2013 have been used.</p>	<p>Table 7-15 will be updated in the 2020 MCP. Please refer to Table 7-18 which includes baseline values for Ra226 and U as part of the surface water quality analysis. The concentrations provided in Table 7-18 were derived from ERA sampling undertaken between 1992 and 2018.</p>	<i>Acknowledged</i>
7.8 Radiation Radiation Sources	<p>Reconsider the view that the waste rock on the surface of the landform (with estimated uranium activity concentration of 0.8 Bq/g) is not radioactive.</p>	<p>Agreed. This sentence has been removed.</p>	<i>Accepted</i>
	<p>Include data and analyses to demonstrate what the average uranium activity concentration across the landform surface will be.</p>	<p>This will be included in the 2020 MCP following results of the gamma and radon flux surveys undertaken at the completion of the construction of the Pit 1 final landform (Section 7.10.4).</p>	<i>Acknowledged</i>

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	Include data and analyses to demonstrate what the radionuclide activity concentration of the tailings will be.	Radionuclide concentrations in tailings will be quantified as part of the future studies to define solute transfer source terms for the Ranger Mine conceptual model. See section 7.7.2 and box 6 of Figure 7-74.	<i>Acknowledged</i>
7.8 Radiation Human health	Provide estimates of radionuclide activity concentrations in surface water surrounding the minesite.	Radionuclide concentrations in surface water are predicted within the surface water model (Section 7.8). ERA are in the process of updating the surface water model, the results of which will be available in the 2020 MCP.	<i>Acknowledged</i>
	Provide information on radon and radon progeny concentrations in the air due to the final landform.	Radiological parameters required for the radiation dose assessment will be outlined in future iterations of the MCP and provided in detail within ERA's application for approval to construct the final landform. See Section 7.10.1 for further detail.	<i>Acknowledged</i>
	Provide information on the activity concentration of radionuclides in dust due to the final landform.	Radiological parameters required for the radiation dose assessment will be outlined in future iterations of the MCP and provided in detail within ERA's application for approval to construct the final landform. See Section 7.10.1 for further detail.	<i>Acknowledged</i>
	Provide information on gamma dose rates on the final landform.	Radiological parameters required for the radiation dose assessment will be outlined in future iterations of the MCP and provided in detail within ERA's application for approval to construct the final landform. See Section 7.10.1 for further detail.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Provide information on concentration ratios for uranium and actinium decay series radionuclides in bush foods.	Radiological parameters required for the radiation dose assessment within ERA's application for approval to construct the final landform due for submission in 2022. See Section 7.10.1 for further detail.	<i>Acknowledged</i>
	Provide an estimate of radiation doses to the public from the final landform.	The radiation dose assessment is contingent upon the completion of current and future closure studies. The completed dose assessment will be included in future iterations of the MCP. See Section 7.10.1 for further detail	<i>Acknowledged</i>
7.8 Radiation Ecosystem health	Identify the representative organisms upon which the radiation dose assessment for wildlife will be based.	The Identification of the representative organisms upon which the radiation dose assessment for wildlife will be based, is one of the studies underway to fulfil the overarching radiation dose assessment. The species list will be included in future iterations of the MCP.	<i>Acknowledged</i>
	Provide whole-organism concentration ratios for the representative organisms.	The prediction of radiation dose to wildlife forms part of the radiation dose assessment. This study is underway and will be included in future iterations of the MCP. See Section 7.10.1 for further detail.	<i>Acknowledged</i>
	Provide tissue to whole-organism conversion factors for converting tissue-specific activity concentrations to whole-organism activity concentrations.	The prediction of radiation dose to wildlife forms part of the radiation dose assessment. This study is underway and will be included in future iterations of the MCP. See Section 7.10.1 for further detail.	<i>Acknowledged</i>
	Provide an estimate of radiation dose rates to wildlife from the final landform.	The prediction of radiation dose to wildlife forms part of the radiation dose assessment. This study is underway and will be included in future iterations of the MCP. See Section 7.10.1 for further detail.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
7.8 Radiation Rehabilitation monitoring	Include bioaccumulation monitoring of radionuclides in bush foods within the radiation monitoring program.	<p>Post-closure monitoring of radionuclides in bushfoods is now included in Table 12-9.</p> <p>Monitoring during the closure and post-closure phases will continue to be refined as relevant studies are completed. Changes and additional detail regarding radionuclide monitoring in bushfoods will be incorporated into future iterations of the MCP.</p>	<i>Accepted</i>
	Include soil radionuclide monitoring within the radiation monitoring program.	<p>Post-closure monitoring of radionuclides in soil is now included in Table 12-9.</p> <p>Monitoring during the closure and post-closure phases will continue to be refined as relevant studies are completed. Changes and additional detail regarding soil radionuclide monitoring will be incorporated into future iterations of the MCP.</p>	<i>Accepted</i>
	Include groundwater radionuclide monitoring within the radiation monitoring program.	<p>Post-closure monitoring of radionuclides in groundwater is now included in Table 12-9. Radionuclides are also included in Table 12-7 of the groundwater monitoring program discussed in Section 12.</p> <p>Monitoring during the closure and post-closure phases will continue to be refined as relevant studies are completed. Changes and additional detail regarding groundwater radionuclide monitoring will be incorporated into future iterations of the MCP and the Annual Ranger Water Management Plan.</p>	<p><i>Not addressed</i></p> <p>Post-closure monitoring of radionuclides in groundwater is not included in Table 12-9. Also noted that radionuclides specified in Table 12-7 are background data, not proposed monitoring.</p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
8.4 Soils: Delineation of contaminated soils	Although the RMCP acknowledges that soils in the processing plant area will require remediation, no data indicating the extent (e.g. depth and surface area/volume) of contaminated soil in this area are presented, or referenced. The RMCP needs to indicate the volume of contaminated soil, as well as the proposed method for recovery and placement of this soil into the Pit.	Data including depth, surface area and volume of contaminated soil will be provided following the contaminated soil assessment of the processing area. When completed, this information will be included in future updates of the MCP.	<i>Acknowledged</i>
8.6 Soils Closure Criteria	Assess the risk of contaminated soils within the Ranger Project Area impacting the environment outside the Ranger Project Area.	A risk review was held as part of the Feasibility study to identify further work required to scope and assess potentially contaminated sites to the correct level to satisfy the closure objectives and relevant legislation. The Contaminated Site Register was updated throughout 2018 and has been reviewed to identify contamination volume, clean up requirements, and the potential impact of the contamination outside of the Ranger Project Area. (Refer to Section 7.10.9)	<i>Not addressed</i> It is not clear how the contaminated sites assessment will inform off-site risks, or demonstrate that on-site risks are ALARA. Information on contamination volumes, clean up requirements and potential off-site impacts should be included in the RMCP – the section referenced in ERA's response does not exist in the document.
	Develop a site-specific EIL for uranium and any other contaminants that are not covered by National Environmental Protection Measure guidelines.	This is planned to be developed as part of soil monitoring for contamination.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
8.6 Soils Risk Assessment	To support the risk assessment that soils in the Land Application Areas pose a low risk as a source of potential contamination, information should be presented on relevant contaminants and suspended sediments (e.g. if soils are disturbed as part of any required remediation).	Additional information will be provided within future updates to the MCP.	<i>Acknowledged</i>
9.7 Ecosystem Restoration: Detailed Activity Description	<p>Additional information on the works proposed in the revegetation application should include:</p> <ul style="list-style-type: none"> • detailed action plans and timelines, including methods (i.e. planting, irrigation) • seed availability and collection plan • nursery details and propagation studies • target and planned planting densities and methods (e.g. final target density for each species) • habitat to be installed (e.g. nesting boxes, rock piles) • ongoing management activities, including weed control and infill planting • any other project specific assumptions or information which would be required to conduct a detailed assessment of the activity. 	The MCP cannot include this level of detail until further revegetation trials have progressed, and relevant KKNs completed. Thus, the revegetation strategy will remain at the current high level of detail in the 2019 MCP. Further detail will be added into each MCP update, with the ERA Ranger Revegetation Implementation Plan to be developed with the full detail in preparation for execution, and with adequate timing for review.	<p><i>Acknowledged</i></p> <p>Note that this comment was made in relation to detail that should be included in the Final Landform and Revegetation application, not the RMCP.</p>
	Expand the Revegetation Strategy to an ecosystem restoration strategy.	The rehabilitation of the RPA will consider ecosystem establishment, and not simply the revegetation of the site. An ecosystem rehabilitation strategy will be developed, incorporating relevant KKN information, when complete, and be included within future MCP updates.	<i>Not addressed</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Key findings and knowledge gaps should be synthesised from all previous work, and based on this a monitoring program should commence on the trial landform to inform the Ecosystem Restoration Strategy.	TLF monitoring results have been updated within the 2019 MCP, along with updated summaries of previous studies. The monitoring section update within the MCP has utilised these results. Similarly, Ongoing and planned studies on the TLF will be monitored accordingly, to inform the finalisation of the ecosystem rehabilitation strategy.	<i>Accepted</i>
9.7 Ecosystem Restoration: Revegetation Trials	Information and data from previous revegetation studies need to be collated and incorporated into the Ecosystem Restoration Strategy, including: <ul style="list-style-type: none"> • up-to-date monitoring results for the trial landform, including monitoring of grasses and groundcover species • findings and recommendations from revegetation studies conducted at Ranger that pre-date the trial landform • a synthesis of key findings and knowledge gaps. 	Agreed - refer to Appendix 11.2 Revegetation Strategy.	<i>Accepted</i>
	Provide information demonstrating that waste rock can maintain long-term species diversity through recruitment and regeneration and whether there are factors that could be manipulated to facilitate this.	Revegetation monitoring does include recruitment and regeneration post-fire. Future trials are planned to investigate potential factors to be modified for benefit in longterm ecosystem self-sustainability.	<i>Acknowledged</i> Further comments on the application of information obtained from revegetation trials are provided in the 2019 RMCP Assessment Report.
9.7 Ecosystem Restoration: Reference Sites	Provide the survey methods used for the regional vegetation survey program.	ERA is committed to longterm monitoring of reference sites, and review and refinement of methodology and site selection is ongoing with regulators.	<i>Acknowledged</i> Current monitoring methods could be included in the RMCP.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
9.7 Ecosystem Restoration: Ecosystem Restoration	Provide further information to demonstrate that sufficient seed can be sourced to complete revegetation in the time frame required and reach the desired end state (including the amount of seed and resulting tube stock for each species), and consider classifying seed availability as a Class 3 risk.	Seed availability in the 2019 MCP risk assessment is rated as a Class III risk, but is managed as a class IV risk due to the risk rating for the project schedule. The collection of seed has commenced with back-up air conditioning provided within the new seed storage facility at the nursery. The determination of quantity and type of seed required for rehabilitation plans of the RPA and a schedule for seed requirements are complete and a seed matrix is updated monthly for internal reporting.	<i>Acknowledged</i>
	Provide information on which species are currently able to be grown from seed, and which are not able to be successfully propagated.	As nursery trials continue, this information will be compiled indicating any seed requiring pretreatment for assisted germination rates. Soil ameliorants (that are applicable for tube stock) will also be investigated. Recalcitrant species will also be identified. 100% species diversity return in the short term is not a realistic goal for rehabilitation on a waste rock landform.	<i>Acknowledged</i>
	Provide information on soil formation properties for each type of waste rock to be used in landform construction, including: <ul style="list-style-type: none"> • weathering rates • soil texture information for the entire waste rock substrate (i.e. not just < 2mm fraction). 	The associated KKN study will be progressed, and the PSD investigation will be reported on within the 2020 MCP update.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Provide uncertainty analysis for all modelling undertaken in relation to demonstrating that there will be sufficient plant available water in the final landform.	<p>Information on PSD and PAW modelling, plant rooting depth, subsurface consolidated layer, and more has been added to the 2019 MCP.</p> <p>Consistent with information previously provided as part of 2019 App. 3 to Pit 1 Application. Supporting information available within the reference</p> <p>Lu P, Meek I, Skinner R. 2019. Supporting Information on Revegetation Growth Substrates at Ranger for Pit 1 Application. Energy Resources of Australia Ltd report, Feb. 2019</p>	<p><i>Not addressed</i></p> <p>No additional uncertainty analysis has been provided in the 2019 RMCP.</p>
	Provide information to demonstrate that plant roots will be able to penetrate a waste rock substrate to a sufficient depth to address plant available water requirements, including understory species and accounting for macropores.	Summary of 2019 root excavation trial has been added to the Supporting Studies Section. Plant roots are able to penetrate the waste rock substrate.	<p><i>Accepted</i></p>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Provide further evidence to support the assumption that understorey is a minor component of evapotranspiration.	During the dry season, understorey evapotranspiration is a minor component of the total system evapotranspiration. This is supported by the additional information within the 2019 MCP Supporting Studies Section. In particular, the figure relating to soil water dynamics at the analogue area which shows that during the dry season soil water is almost completely depleted in the top 1 m. This is where the understorey plants extract water from. Hutley et al 2000, showed that dry season understorey evapotranspiration is a minor component of the total evapotranspiration. Despite this, the CDU/ERA modelling included the simulated understorey evapotranspiration. REF: L. B. HUTLEY, A. P. O'GRADY and D. EAMUS 2000. Evapotranspiration from Eucalypt open-forest savanna of Northern Australia, Functional Ecology , 14, 183–194	<i>Acknowledged</i> Further comments are provided in the 2019 RMCP in relation to the contribution of midstorey to evapotranspiration.
	Provide evidence to demonstrate that compaction layers: <ul style="list-style-type: none"> • will improve the water-holding capacity of the waste rock • will not lead to other issues affecting plant growth (e.g. physical restriction of roots, formation of perched water tables) 	The results of the completed KKN are summarised within Section 7.3.5 of the updated MCP. Demonstrated that 4-6 m of waste rock landform with various levels of rock contents can maintain a positive PAW water balance while supporting a vegetation similar to one of the reference sites.	<i>Acknowledged</i> Any reference to compaction layers appears to have been removed from the 2019 RMCP, with no explanation provided for this.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Provide further information on the internal properties of the final landform (e.g. nature, depth and extent of compacted layers), in conjunction with a conceptual model and water balance (under a range of rainfall scenarios) to demonstrate that there will be sufficient water available for revegetation.	The results of the completed KKN are summarised within Section 7.3.5 of the updated MCP. Demonstrated that 4-6 m of waste rock landform with various levels of rock contents can maintain a positive PAW water balance while supporting a vegetation similar to one of the reference sites.	<i>Acknowledged</i> While the reference to compaction layers appears to have been removed from the 2019 RMCP and a water balance has been conducted, further information on the internal properties of the final landform is still required.
	The lack of a seasonal trend in radon exhalation rates on the waste rock-only section of the trial landform should be investigated in the context of the ability of the waste rock substrate to retain water.	Bollhöfer, A., Doering, C., 2016. Long-term temporal variability of the radon-222 exhalation flux from a landform covered by low uranium grade waste rock. J. Environ. Radioact. 151, 593–600. has discussed the effect of the soil moisture on the radon emission.	<i>Not addressed</i> The cited reference reports on seasonal trends in radon exhalation flux from waste rock. However, ERA has not integrated this information (in particular that seasonal variations in radon exhalation from waste rock begin to occur 2+ years after landform construction) into Section 7.3.3 of the MCP.
	Include more relevant information on fire and plant survivability in the region, including reference to fire severity and intensity, and survivability of specific species.	Reporting on the completed Project 1240-30 (Trial landform fire report) will be presented in the 2020 MCP update. Monitoring of fire response will continue.	<i>Acknowledged</i>
	Determine the most appropriate fire management regime to ensure a fire resilient ecosystem on the rehabilitated site, including reference to faunal colonisation.	Information on fire management in the Maintenance and Monitoring Section has been updated. The fire management strategy will be continually developed as knowledge increases with ongoing monitoring. Reporting on the completed Project 1240-30 (Trial landform fire report) will be presented in the 2020 MCP update.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Further information should be provided to explain why fire was not classified as a class III risk.	In the updated MCP risk assessment, fire is classified as a Class III risk. Evaluation based on meeting rehabilitation requirements by Jan 2026, and if a cyclone or bushfire event destroyed large areas of RPA rehabilitation.	<i>Accepted</i>
	Provide details on which species would be included in the understorey (in consideration of requirements for faunal colonisation), and evidence to support the assumption that direct seeding is the best option for the establishment of such species.	Planned trials on rehabilitation understorey species are described in Section 7.6.3. It is not assumed that these species will be direct seeded, but predominantly introduced via tubestock. Habitat requirements for fauna return will be considered under KKN ESR2B, and will be reported on in the 2020 MCP	<i>Acknowledged</i>
	Provide evidence to demonstrate that appropriate measures will be taken to ensure fauna colonisation of the rehabilitated site.	Work on fauna return strategies is ongoing and updates may be expected in 2020 MCP. Studies related to KKN ESR2 are underway.	<i>Acknowledged</i>
	Quantify the magnitude of potential sources of feral animals (i.e. no. of animals per unit area), to allow comparison of densities between areas inside the Ranger Project Area and adjacent areas of Kakadu National Park.	Studies are underway and will be reported on in the 2020 MCP The KKN for fauna outside the RPA has been assigned to SSB.	<i>Acknowledged</i>
	Assess the risk of feral animals impacting on faunal colonisation of the rehabilitated site.	Studies are underway and will be reported on in the 2020 MCP The KKN for fauna outside the RPA has been assigned to SSB.	<i>Acknowledged</i>
	Refine the vegetation mortality contingencies to consider mortality beyond the first 6 months and the potential for mortality to vary between species and locations.	Ongoing revegetation trials (described in Section 7.3.4) will address these queries.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
9.7 Ecosystem Restoration: Ecosystem Restoration Risks Not Assessed	Assess the risk of potential impacts of contaminants leached from waste rock on revegetation and fauna, including details on how this would be avoided or mitigated.	SSB are undertaking KKN ESR6A. <i>What concentrations of contaminants from the rehabilitated site may be available for uptake by terrestrial plants?</i> ESR6B will be completed and reported on in updated MCP.	<i>Acknowledged</i> Noted that the need for KKN ESR6A (i.e. impact of contaminants on vegetation) is currently subject to discussion between SSB, ERA and ARRTC. Noted that the need to assess risk of contaminants to fauna is identified in KKN RAD8.
	Provide information to assess how vegetation community development may be affected by landform stability, including re-contouring the landform surface.	Landform stability is considered in the final landform design, and follow up monitoring. Refer to updated MCP relevant sections (7.5). The predicted date for completion of KKN LAN3 - will be the end of 2020, and thus results will be discussed in the 2021 updated MCP.	<i>Acknowledged</i> Noted that it is not clear if the results discussed in section 7.5 of the RMCP from the analysis of the FLV5.2 landform are the same as those from the FLV6.2 landform.
	Provide information on nitrogen dynamics in the rehabilitated landform, including an assessment of the potential for nitrogen to be a limiting factor for nutrient cycling, and nutrient availability and presence of soil biota to assist in plant growth.	KKN ESR7 A, C & D studies with provide information on this query, and a summary of study findings will be summarised in the 2020 MCP update.	<i>Acknowledged</i>
	Acknowledge that comprehensive surveys to inform the status of weeds and feral animals will be required before and during the rehabilitation process, including the entire Ranger Project Area and surrounding areas.	Studies are underway and will be reported on in the 2020 MCP update. The KKN for fauna outside the RPA has been assigned to SSB.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Provide the rationale for the nominated 200 m weed buffer zone.	This nominated zone has been changed to the following: During revegetation establishment and early development a 'weed and fire buffer zone' will be maintained to reduce the risk of fire and weedy plant species (potentially including some natives) impacting on the revegetated areas. As the resilience of the revegetated ecosystems increases, this effort will gradually be diminished (considerate of Ongoing risk) until the management effort required to sustain the revegetation are aligned to those of Kakadu National Park.	<i>Accepted</i>
	Mitigations to address integrated landscape risks, such as weather, should be addressed in the Ecosystem Restoration Strategy.	When further studies are completed, these mitigations will be included within the ecosystem rehabilitation strategy.	<i>Acknowledged</i>
9.7 Ecosystem Restoration: Closure Criteria	Clearly justify why some closure criteria would be more important than others, in relation to the Environmental Requirements.	Some criteria, such as canopy architecture and ground cover index, are not independent of each other and should be considered collectively, or within the context of meeting the overall closure objective as a whole. This approach was recommended by DPIR as part of their initial assessment of the Ranger Mine closure criteria and ERA agrees with this recommendation.	<i>Acknowledged</i> SSB will seek clarification from ERA on this response.
	Ensure that the closure criteria for ecosystem restoration use consistent and clearly defined terminology.	Updating the content within the Closure Criteria and Supporting Studies sections has addressed these inconsistencies.	<i>Acknowledged</i> SSB will seek clarification from ERA on this response.

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Include a defined trajectory (or trajectories) in relation to vegetation community establishment, using site-specific indicators relating to ecosystem composition, structure and function.	This information has been identified as a KKN and thus studies will be conducted to enable the formulation of such defined rehabilitation trajectories, to be utilised in monitoring, assessment of rehabilitation success against completion criteria, and the potential for requirement for further works if the ecosystem re-establishment is not on track of this defined trajectory. The KKN ESR5 studies are progressing, and an update will be provided in the 2020 updated MCP.	<i>Acknowledged</i>
	Provide information to justify the $\geq 15\text{--}30\%$ similarity as the closure criterion for species composition and relative abundance.	ERA and SSB continue to work on reference site selection, data analysis and assessment metrics. Meanwhile, some criteria (including ground cover) are awaiting further consideration. Information to justify the similarity percentage range for species composition and relative abundance will be provided in updated MCPs following outcomes of ongoing studies.	<i>Acknowledged</i>
	Provide information to justify the proposed total species number closure criterion of ≥ 35 .	This information is pending finalisation of reference sites. This criterion will be updated when this information becomes available.	<i>Acknowledged</i>
	The canopy architecture criterion (F3) should not be expressed as presence/absence, rather should be presented as ranges and broken down into an appropriate classification of strata.	The points made in the comment are noted. The finalisation of completion criteria will occur after further studies relating to KKNs are completed. ERA and SSB continue to liaise and discuss reference site selection, data analysis and assessment metrics.	<i>Acknowledged</i>
	Clarify what is meant by <i>canopy/groundcover index</i> in relation to criterion F4 and do not include rocks in the assessment of understorey cover.	ERA and SSB continue to work on reference site selection, data analysis and assessment metrics. Meanwhile, some criteria (including ground cover) are awaiting further consideration.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	A proposed revegetation species list (including both over- and understorey species) should be provided.	Overstorey and midstorey performance (Section 7.3.4.3) and understorey establishment (Section 7.3.4.4) have been added to the 2019 MCP. Outcomes of ongoing studies will inform this list and this will be updated accordingly. A preliminary species list (including understorey species) was presented at the Ranger Consultative Closure Group (August 2019). The list is likely to be finalised and presented in the 2020 MCP.	<i>Acknowledged</i>
	Update terrestrial fauna closure criteria using data gathered with contemporary fauna sampling methodologies.	It is intended that the fauna completion criteria will be finalised (with stakeholder input) after studies to address relevant KKNs have been completed. The MCP will be updated with this information, as appropriate.	<i>Acknowledged</i> SSB and ERA will need to consult on the development of appropriate fauna closure criteria.
	Include standard quantitative biodiversity indices (e.g. species richness and abundance) for fauna that allow assessment of whether terrestrial fauna communities on the rehabilitated site are comparable (or on a trajectory to be comparable) with those in adjacent areas of Kakadu National Park.	The development of quantitative biodiversity indices is pending further studies. This will be updated once information becomes available (there are a number of KKNs that are being Addressed by both ERA and SSB on this topic). Future MCPs will incorporate this information when available.	<i>Acknowledged</i> SSB and ERA will need to consult on the development of appropriate fauna closure criteria.
	Provide evidence to support the assumption that fauna will colonise the rehabilitated site, once suitable habitat has established.	Work on fauna return strategies is ongoing (including relevant KKNs) and updates may be expected in the 2020 MCP.	<i>Acknowledged</i>
	Provide information to justify the proposed plant reproduction closure criterion of evidence of flowering and fruiting in 80% of species, including consideration of the amount and periodicity of flower, fruit and seed resources provided in the revegetated site.	Information to justify this criteria is pending further studies and finalisation of the reference sites. This will be updated when suitable information is available. At present, woody species are being assessed and of these evidence has demonstrated that only a single species has not reproduced on site trials.	<i>Acknowledged</i> Criteria will need to take into account that there is a key difference between flowering/fruiting and successful reproduction (i.e. new individuals established and surviving).

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Criterion F7 should capture seedling germination/sucker emergence, survivorship and growth, and the term <i>framework species</i> should be clearly defined.	A review of this criterion is pending further research and finalisation of reference sites. Monitoring against closure criteria is an ongoing process, and effective recruitment over time will be assessed, through repeated surveys for flowering/fruitlet, and presence and development of recruits.	<i>Acknowledged</i>
	Criterion F13 should be reworded to; feral animal densities 'not greater than' those in surrounding areas, as opposed to <i>similar</i> to those in surrounding areas.	This criterion has been reworded in terms of weeds and feral animals to "not greater than" the surrounding areas. Note - Previous wording was used to align with the KKN. Work on fauna return strategies (including criteria / monitoring approaches) is ongoing and updates may be expected in 2020 MCP.	<i>Not addressed</i> Criterion F13 in Table 8-5 of the RMCP has not been reworded as per the ERA response.
	Criterion F7 should capture seedling germination/sucker emergence, survivorship and growth, and the term framework species should be clearly defined.	A review of this criterion is pending further research and finalisation of reference sites. Monitoring against closure criteria is an ongoing process, and effective recruitment over time will be assessed, through repeated surveys for flowering/fruitlet, and presence and development of recruits.	<i>Acknowledged</i>
	Criteria for nutrient cycling (F8) should be expanded to include a more detailed assessment of nutrient cycling, including: <ul style="list-style-type: none"> • quantification of nutrients present • relative abundance for soil biota • appropriate spatial scales. 	This criterion will be further developed when the relevant studies (for the associated KKNs) are complete. This information will be included in the updates of the 2020 MCP.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	The criterion proposed for fire resilience should clearly detail how <i>resilience</i> would be assessed and what an acceptable value for resilience is. Consideration should also be given to how the restored vegetation community responds to fire regimes that are characteristic of the surrounding area, rather than how it may respond to a single fire.	The criteria proposed for fire resilience has been improved to detail how resilience would be assessed and to establish an acceptable measure of this. Trials are being carried out to assess behaviour and responses of vegetation to fire regimes. There are specific KKNs to address this.	<i>Acknowledged</i>
	Criterion F11 (plant available water) should incorporate sustainability of a mature plant community.	Information on PSD and PAW modelling, plant rooting depth, sub- surface consolidated layer, and more has been added. Consistent with information previously provided as part of 2019 App. 3 to Pit 1 Application - Ref: Lu P, Meek I, Skinner R. 2019. Supporting Information on Revegetation Growth Substrates at Ranger for Pit 1 Application. Energy Resources of Australia Ltd report, Feb. 2019	<i>Accepted</i> Criterion F11 has been removed from the RMCP.
9.7 Ecosystem Restoration: Closure Monitoring	The vegetation and fauna monitoring program should include detailed information about: <ul style="list-style-type: none"> • justification for site selection • survey methods and quantitative metrics being to assess <i>condition</i> and <i>natural variability</i> • how the data from these surveys are being used to derive or update closure criteria. 	Information derived from KKN studies will be used to further develop the monitoring programmes which will be updated in the 2020 MCP with information available. Site selection of 'reference' or analogue sites is still under discussion with SSB. Monitoring programmes cannot be finalised until the reference sites and completion criteria are further developed.	<i>Acknowledged</i>

2018 SSB Assessment Report Section	SSB Comments in 2018 RMCP Assessment Report	ERA Response in 2019 RMCP	SSB Assessment of ERA Response Adequacy
	Revise the proposed monitoring methods and frequency based upon the risks and mitigations identified through a trajectory model.	A State-and-Transition Model for Ranger Mine revegetation is under development (in collaboration with ERA, SSB and CSIRO) and will enable the revegetation objectives (including the conceptual model), pathways, risks, contingencies and monitoring to be more clearly articulated in the 2020 MCP.	<i>Acknowledged</i>
	Weed monitoring and weed control, at some frequency, will need to continue until closure.	Additional information on weed management and monitoring has been provided in Section 12.	<i>Accepted</i>
10.5 Monitoring	Update the TARP.	This section will be continually improved with each update of the MCP and with further monitoring information available.	<i>Acknowledged</i>

Appendix 4 — New comments on 2019 RMCP

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
Landform	Landform design and construction materials	7.5	This section includes information on model development being undertaken by the Supervising Scientist that is either out of date or incorrect. For example, the Supervising Scientist is not integrating a dynamic vegetation model linking soil moisture to biomass growth.	Ensure that information on landform modelling being undertaken by the Supervising Scientist is correct and up to date.
			There is insufficient information on planning/ monitoring of material movements and proposed surface structures.	Provide more detailed information to demonstrate adequate planning and monitoring of material movements, including a basis on which the progress of landform construction can be assessed over time.
				Provide more detailed information to justify the proposed surface structures, including up to date flood modelling, engineering designs and long-term management plans.
	Landform flood study	7.5.2	The landform flood study does not take into consideration the impacts of major flood events on long-term landform stability and could be improved by incorporating the synthetic rainfall datasets that have been supplied to ERA by the Supervising Scientist.	Consider the impacts of major flood events on long-term landform stability and incorporate the synthetic rainfall datasets in landform flood modelling.
	Closure criteria	8.2, Table 8-1	Closure criteria related to the physical isolation of tailings for 10,000 years that were proposed in the 2018 RMCP (i.e. previously L3 and L4) have been removed in the 2019 RMCP, without justification.	Re-instate the closure criteria to demonstrate that tailings will be isolated for at least 10,000 years, or provide justification for their removal.

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
		8.2, Table 8-1 (L4)	<p>While the closure criterion related to denudation rate (L4) has been proposed in accordance with the Landform Rehabilitation Standard, it is noted that the clarifying text <i>averaged over the entire landform</i> that was proposed in the 2018 RMCP (i.e. previously L5) has been removed in the 2019 RMCP.</p> <p>The previous text allowed for some degree of variation across the landform.</p>	Reconsider the requirements for denudation rate.
	Tailings disposal in pits	11.4.1.6	<p><i>This will, in turn, mean that remnant tailings on the floor under beached equipment would not be able to be removed.</i></p> <p>This is not in accordance with the environmental requirement ER11.2</p>	Consult with stakeholders regarding the proposal for some remnant tailings, which is not in accordance with the environmental requirements.
	Denudation rates	11.16.6	Although denudation rates on the landform are unlikely to reach background denudation rates for at least 1000 years, under higher rainfall scenarios and on different areas of the final landform, it may take significantly longer for the denudation rate to reflect background rates (i.e. >10,000 years).	Acknowledge the uncertainty in the erosion modelling and ensure that plausible worst-case scenarios are considered in the design of the final landform and surface erosion control structures.
	Tailings consolidation monitoring	12.4	The RMCP mentions the use of vibrating piezometers to monitor excess pore pressures within tailings but it is not clear whether or how they may be used to inform tailings consolidation in the final landform. It is understood from consultation with ERA that it may not be possible to utilise the settlement plate method (i.e. as used in Pit 1) in Pit 3.	Provide further information on tailings consolidation monitoring, including Pit 3 and during the post-closure phase.

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
	Surface ripping	11.16.6.1, Appendix 11.4	<p><i>...ripping to 0.5 m deep along the contour at four metre intervals, creating rough contour banks which will slow runoff and encourage infiltration in areas of identified higher erosion potential...</i></p> <p>Further consultation with Traditional Owners and assessment or ripping benefits versus impacts will be undertaken prior to finalising the ripping design for the remainder of the landform. The ripping design in the feasibility study was to minimise erosion only...</p> <p>Surface ripping has been identified as critical to early erosion control and subsequent vegetation establishment and soil development (Saynor et al 2019). Rip lines of 0.5 m depth will be installed at 4 m intervals across the entire surface of the waste rock landform.</p> <p>It is unclear how the areas of higher erosion potential have been identified and on what basis have been used to determine areas that require ripping</p>	Present a consistent and justified approach to surface ripping of the final landform that considers requirements for erosion control, infiltration (i.e. ecosystem establishment vs contaminant transport) and the views of Traditional Owners.
Radiation	Radionuclide monitoring of terrestrial bushfoods	12.6.2, Table 12-9	In addition to Ra-226, studies by SSB suggest that Po-210 and Pb-210 are important dose-forming radionuclides in terrestrial bushfoods.	Consider including Po-210 and Pb-210 in the post-closure monitoring of radionuclides in terrestrial bushfoods.
			The gamma spectrometry method specified is unlikely to have the requisite sensitivity for measuring radionuclides in terrestrial bushfoods.	Consider alpha spectrometry as the analysis method for Ra-226, Po-210 and Pb-210 (via Po-210 ingrowth) and ICP-MS as the analysis method for U.

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
			Information currently provided in Table 12-9 suggests that the only terrestrial bushfood group to be monitored for radionuclides is fruit. There are several other terrestrial bushfood groups in the model diet (e.g. buffalo, pig, wallaby, goanna and yam) through which radionuclides can be ingested.	Provide a list of the terrestrial bushfood groups to be targeted for post-closure monitoring of radionuclides or if fruit is the only group to be targeted, then justification for this needs to be provided.
	Radionuclide monitoring of aquatic bushfoods		Table 12-9 indicates that there will be no post-closure monitoring of radionuclides in aquatic bushfoods (i.e. only water).	Consider the inclusion of monitoring of radionuclides in aquatic bushfood, especially for on-site waterbodies potentially contaminated by mining operations (e.g. Georgetown Billabong), to confirm dose estimates based on water radionuclide measurements.
			Po-210, in addition to Ra-226, is an important dose-forming radionuclide in aquatic bushfoods.	Consider including Po-210 in the post-closure monitoring of radionuclides in water for the purpose of estimating ingestion doses from aquatic bushfoods.
			The gamma spectrometry method specified is unlikely to have the requisite sensitivity for measuring radionuclides in water.	Consider alpha spectrometry as the analysis method for Ra-226 and Po-210 in water and ICP-MS as the analysis method for U in water.
	Radon exhalation	7.3.3	<p><i>...there was no obvious seasonal trend observed for radon exhalation fluxes from waste rock only.</i></p> <p>The most up-to-date information on radon exhalation characteristics for waste rock has not been referenced. A study by SSB indicates that seasonal variations in radon exhalation fluxes from waste rock begin about 2+ years after landform construction:</p> <p>Bollhöfer, A., Doering, C., 2016. Long-term temporal variability of the radon-222 exhalation flux from a landform covered by low uranium grade waste rock. J. Environ. Radioact. 151, 593–600.</p>	Reference the most up-to-date studies and their findings for radon exhalation characteristics from waste rock.

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
	Bushfood radiation baseline	7.4.1.3 (including Table 7-16)	<p>The most up-to-date information on radionuclide activity concentrations and concentration ratios in bushfoods has not been referenced. The most up-to-date information is available in:</p> <p>Doering and Bollhöfer, 2016. A database of radionuclide and metal concentrations for the Alligator Rivers Region uranium province. Journal of Environmental radioactivity 162-163, 154-159.</p> <p>Doering et al., 2017. Estimating doses from Aboriginal bush foods post-remediation of a uranium mine. Journal of Environmental Radioactivity 172, 74-80.</p>	Consider revising this section with the most up-to-date information on radionuclides in bushfoods.
Water and Sediment	Site water model (OPSIM)	2.2.9.7, 11.5.1	<p>The summary of the site water model is based on August 2018 results. Given that it is such an integral aspect of the site closure planning, the most up to date results and assumptions should be presented in the RMCP (e.g. as an Appendix).</p> <p>The approval status of assumptions for future water treatment processes is unclear, as some strategies are yet to receive regulatory approval.</p>	Present results of the most up to date site water model and assumptions and ensure the approval status of potential or proposed future water treatment processes is clearly stated.
			<p>This modelling includes a number of significant assumptions, such as seasonal rainfall, water treatment capacity and efficiency over time and volume of contaminated water generated by the process of tailings consolidation in Pit 1 and Pit 3. However, there is no indication of model uncertainty based on the likely variability in these assumptions over time.</p>	Provide information on surface water model uncertainty relating to variability in model assumptions over time, to enable a detailed assessment of likely success of the proposed water treatment strategies.

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
	Pit 1 solute balance	7.1.2	<p>The solute balance indicates that the measured mass of solute recovered through the decant towers matches the mass of solute estimated to have been expressed from tailings (Figure 7-6).</p> <p>The volume balance indicates that the decant structures are recovering additional volume from the waste rock cap.</p> <p>Figure 7-6 actually shows the solute expression profiles are similar but in fact the predicted mass of solute is consistently underestimated by the model by up to 20% and is fairly consistent.</p>	Provide evidence or discussion to support the assumption this consistent difference is simply attributed to waste rock as a source term and not an inherent underestimation from the source term assessment or consolidation model outputs.
	Removal and treatment of tailings pore water – Pit 3	10.3	<p><i>Process water treatment required beyond closure date to treat process water to achieve 95% consolidation for Pit 3.</i></p> <p>No details have been provided to describe how consolidation of tailings in Pit 3 will be measured over time, nor how achievement of the 95% consolidation target will be verified.</p>	Detail how consolidation of tailings in Pit 3 will be measured over time and how achievement of the 95% consolidation target will be verified.
	Groundwater contaminant plumes	7.4.3.6	Further information is required to support the approach to remediating contaminated groundwater and soils across the site.	<p>Provide more detailed information on the nature and extent of the existing contaminated groundwater and soil, demonstrating that the:</p> <ul style="list-style-type: none"> • level of contamination has been adequately measured (i.e. that samples are representative) • volumes of contaminated material have been reliably estimated • environmental risk associated with leaving the contaminated material in place has been assessed, and where necessary, compared against the risk of remediation and disposal of the material in the upper levels Pit 3 during the late stages of waste rock backfill (which according to the current schedule is when much of the material will be placed in the pit)

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
		7.9.9.1	<p><i>This lack of impact to nearby downgradient bores suggests that migration of contaminants from the processing plant area is extremely slow....</i></p> <p><i>...The contaminant plume that is present in the processing plant area has migrated to the south and south east, towards Corridor Creek, consistent with local groundwater flow directions.</i></p> <p><i>However, the lack of recent water quality data throughout much of the processing plant area leaves uncertainty about current groundwater conditions.</i></p> <p>These statements appear to be inconsistent and there has been impact identified in downgradient bores, as identified through recent groundwater reports.</p>	Remove inconsistencies in relation to groundwater contamination in the processing area and update to reflect what the latest groundwater monitoring has identified in terms of downgradient groundwater impacts.
	Contaminated site remediation – Tailings Storage Facility groundwater	7.9.9	<p><i>(Table 7-39) Once tailings are removed, assumption that no remediation is required</i></p> <p><i>(p 7-210) Natural attenuation is assumed to allow for plume remediation</i></p> <p>These statements appear to be out of date, when INTERA's current body of work is already assessing what to do with contaminated materials below the Tailings Storage Facility.</p>	Ensure statements in relation to remediation of Tailings Storage Facility contaminated groundwater are consistent with current knowledge and planned work.
	Contaminated site remediation – processing area groundwater	7.9.9.1	<p><i>Reclamation is expected to remove much of the CoPC sources in the shallow soil, so groundwater concentrations are expected to decrease over time</i></p> <p>While it is agreed that source removal will eventually result in lower concentrations in groundwater, it is unclear over what period of time this might occur, or the fate and transport of the CoPC that remain in the soil and groundwater.</p>	Provide further information to demonstrate how removal of soil contamination in the processing area will address groundwater long term contamination (i.e. predicted concentrations, timeframe, fate of residual soil/groundwater contamination).

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
	Water management - LAAs	11.9.1.2	Although it is acknowledged in the RMCP that further assessment is required to demonstrate there are sufficient disposal options for treated pond water throughout rehabilitation, further consideration is needed of the future capacity of the remnant Land Application Areas, and whether or not there will be an increase in associated environmental risks (e.g. waterlogging, unseasonal runoff, and alteration to groundwater levels).	Provide further information on the future capacity of the remnant Land Application Areas, and whether or not there will be an increase in associated environmental risks (e.g. waterlogging, unseasonal runoff, and alteration to groundwater levels).
	Water management – suspended sediments	11.9	During progressive rehabilitation and construction of the final landform, there may be an increase in suspended sediment concentration in surface runoff from the site, which may increase the risk of sediment-related impacts to the offsite environment.	Surface water modelling being conducted to predict the concentrations of suspended sediment in the creeks surrounding the Ranger Project Area should consider the deposition of sediment throughout surrounding catchments, particularly to assess the risk of infilling of nearby billabongs.
	Waste and hazardous materials management	11.10	The current works schedule states that the Tailings Storage Facility will be required for process water storage until late 2024, and that backfill of Pit 3 will be completed by 2025. This does not allow for the possible disposal of contaminated material from the Tailings Storage Facility in the lower levels of Pit 3, given that the pit backfill would be close to completion.	Backfill of Pit 3 should not commence until it has been demonstrated that the placement of material from the TSF into Pit 3 is not required.
			Insufficient information is provided on the disposal of contaminated soils, site infrastructure and other materials to enable assessment of the planned waste disposal.	Provide further information on the disposal of contaminated soils, site infrastructure and other materials, including the effect that in-pit disposal may have on tailings consolidation, and an assessment of the potential environmental risks and information on how they will be mitigated.
	Closure criteria – sediment quality	8.3.2, Table 8-2	The rationale for proposed metals and sulfate in sediments closure criteria is not detailed.	Provide the rationale for proposed metals and sulfate in sediments closure criteria.

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
Water and Sediment	Surface water modelling	7.8.3	<p><i>Based on the predicted downstream solute concentrations, and the magnesium-calcium ratios, the post-closure final landform does not pose a risk to the downstream environment.</i></p> <p>There is currently insufficient information to support this statement and ERA is currently updating the surface water modelling to assess the risk of downstream impacts associated with contaminants from the post-closure landform.</p>	Until it can be demonstrated otherwise, remove any statements within the RMCP suggesting that the post-closure final landform does not pose a risk to the downstream environment.
	Water and sediment monitoring – surface water	12.5.1	The proposed surface water quality monitoring program includes sulfate as a parameter at key monitoring sites on Magela and Gulungul Creeks. Given the risk of acid sulfate soil development on the Ranger Project Area and the Supervising Scientist's rehabilitation standard for this parameter, it should also be monitored at RP1 (and other onsite waterbodies, while they are present) and Georgetown and Gulungul Billabongs.	Include sulfate as a water quality monitoring parameter at RP1 (and other onsite waterbodies, while they are present) and Georgetown and Gulungul Billabongs.

Closure Theme	Topic	RMCP Reference	Comment	Recommendation
	Water and sediment monitoring – groundwater	12.5.2	The proposed groundwater monitoring program does not clearly demonstrate that it will facilitate validation of groundwater models, or detect significant increases in contaminant concentrations in aquifers surrounding Pit 1, Pit 3 and the Tailing Storage Facility.	<p>Revise the groundwater monitoring program to clearly demonstrate that monitoring will be undertaken at an appropriate spatial and temporal scale to:</p> <ul style="list-style-type: none"> observe trends in groundwater level recovery and contaminant transport post-closure that can be used to validate groundwater models, and recalibrate if necessary detect significant increases in contaminant concentrations in aquifers surrounding Pit 1, Pit 3 and the Tailing Storage Facility, to enable downstream mitigation of impacts if required (i.e. groundwater interception or abstraction). <p>Additional information obtained from ongoing post-closure solute transport modelling or new monitoring bores (including those planned to be installed in vicinity of Pit 1 and Pit 3 during 2019), should be used to refine and optimise the long-term groundwater monitoring plan</p>
Ecosystem restoration	Plant available water modelling	7.3.5.3	The transpiration rate input to the WAVES modelling is based on a subset of key overstorey tree species but does not capture the midstorey species that may account for a moderate to high proportion of the total cover.	Provide an estimation of the contribution of midstorey species (including evergreen species) to transpiration rates in the WAVES modelling.

All	Contingencies	11	<p>Pit 1 (11.2.3) – states that <i>no contingency plans are required</i> i.e. missing contingencies for potential issues such as differential tailings consolidation, revegetation success, higher seepage rates, etc.</p> <p>Pit 3 (11.3.3) - only includes contingencies for the risk of tailings rising above -15 mRL i.e. missing contingencies for potential issues such as tailings consolidation taking longer than expected (e.g. extended water treatment as identified in BPT section 9.2.7.4), differential tailings consolidation, revegetation success, higher seepage rates, etc.</p> <p>Tailings Storage Facility (11.4.3) - only includes contingencies for the risk of dredge disposal i.e. missing contingencies for risks for potential issues such as Tailings Storage Facility wall breach while still in use, management of contaminated materials (i.e. residual tailings on inside walls, floor, clay core, rip rap), and the contaminated groundwater plume.</p> <p>Water treatment (11.5.4) and Water management (11.9.3) - only includes contingencies for treatment of process water i.e. missing contingencies for treatment of pond water and risks associated with water quality closure criteria not being met (i.e. ongoing treatment).</p> <p>Waste and hazardous material (no section) and Contaminated sites (11.5.3) - no contingencies included, noting it is acknowledged in 11.5.3 that contingencies for contaminated sites will be identified by future BPT assessments.</p> <p>Ecosystem restoration (no section) – no contingencies included for the potential failure of the rehabilitated landform to become a self-sustaining ecosystem, which are also not included in the RMCP risk assessment (i.e. states <i>Ping to Add</i>).</p>	<p>Ensure that all contingencies associated with risks listed in the Ranger Closure Risk Assessment (Appendix 10.1) are included or referenced within the relevant areas within Section 11.</p> <p>Further detail should be provided for each contingency, including:</p> <ul style="list-style-type: none"> • level of confidence in its likely effectiveness • timing of implementation • impact on the overall closure schedule, including consequential effects on other related activities <p>Include contingencies for the potential failure of ecosystem restoration (i.e. rehabilitated landform does not become a self-sustaining ecosystem).</p>
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Closure Theme	Topic	RMCP Reference	Comment	Recommendation
All	Risk Assessment	10.3	The ongoing review process for the closure-related risks is not clear in terms of frequency, scope and how it informs future iterations of the RMCP.	Detail the ongoing risk assessment review process, including a plan to obtain additional information to update the risk assessment over time, and what would trigger an update of the risk assessment.
		Appendix 10.1	To obtain the risk ranking, the controls are considered but those listed are a combination of existing controls, planned controls and contingencies (potential controls). If all of these elements are considered together, this may result in an artificial reduction in risk level by considering controls that aren't necessarily in place, or have a low level of effectiveness.	Clearly distinguish between the existing and proposed controls for the planned closure scenario, along with evidence to support control adequacy and effectiveness, including consideration of control applicability or availability during the three closure phases (i.e. decommissioning, stabilisation and monitoring and post-closure)
All	Applications	N/A	Insufficient details on future applications was provided.	The RMCP should include a table detailing the application, the expected date for submission, the date approval is required by, a description of the scope of the application and the information it will provide.