ERA Energy Resources of Australia Ltd

8 Post-mining land use, closure objectives & closure criteria

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Cover photograph: Wasp nest (*Polistes* sp.) on Scarlet Gum (*Eucalyptus phoenicea*) on Trial Landform

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GLOSSARY

Below are key terms that are used in this section.

Key term	Definition
Benchmark dose rate	Also referred to as environmental reference level, a chronic radiation dose rate received by the most highly exposed individuals of non-human biota that would be unlikely to have significant effects on terrestrial or aquatic populations
Bininj	Bininj means many things depending on context: 1. Bininj means 'Aboriginal person' as opposed to a non-Aboriginal person. 2. Bininj means a speaker of Bininj Kunwok languages and a person of local Aboriginal descent (as opposed to say, a Yolngu person from NE Arnhem Land or 'Mungguy' which is the Jawoyn language equivalent) 3. Bininj means a man as opposed to a daluk (a woman). 4. Bininj means a human being as opposed to a non-human animal. In the context of the mine closure Bininj means a speaker of Bininj Kunwok languages and a person of local Aboriginal descent.
Closure criteria	performance criteria and will be used to measure the achievement of the rehabilitation closure objectives
Constituents of potential concern	Chemical elements identified by the Supervising Scientist Division as being of potential concern to the receiving environment
Environmental Requirement	The Ranger Environmental Requirements are attached to the s.41 Authority and set out Primary and Secondary Environmental Objectives which establish the principles by which the Ranger operation is to be conducted, closed and rehabilitated and the standards that are to be achieved.
Ranger Project Area	Abbreviated to RPA. The Ranger Project Area means the land described in Schedule 2 to the Commonwealth *Aboriginal Land Rights (Northern Territory) Act 1976.*

ABBREVIATIONS AND ACRONYMS

Below are abbreviations and acronyms that are used in this section.

Abbreviation/ Acronym	Description
AALL	Annual Additional Load Limits
ALARA	As Low As Reasonably Achievable
ANZEEC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BACIP	Before-After-Control-Impact Paired sampling
BPT	Best Practicable Technology
CCWG	Closure Criteria Working Group
COPC/COPCs	Constituent of Potential Concern / Constituents of Potential Concern

Abbreviation/ Acronym	Description
DEM	Digital Elevation Model
EIL	Environment Investigation Levels
ER	Environmental Requirements
ERA	Energy Resources of Australia
ERM	Environmental Resources Management
ERISS	Environmental Research Institute of the Supervising Scientist
GAC	Gundjeihmi Aboriginal Corporation
GV	Guideline Values
HIL	Health Investigation Level
IAEA	International Atomic Energy Agency
ICRP	International Commission of Radiological Protection
IMAP	Inventory Multi-tiered Assessment and Prioritisation
KKN	Key Knowledge Needs
MCP	Mine Closure Plan
MTC	Minesite Technical Committee
LAA	Land Application Area
LEM	Landform Evolution Model
NEPM	National Environment Protection Measure
NLC	Northern Land Council
NOHSC	National Occupational Health and Safety Commission
NP	National Park
RPA	Ranger Project Area
SSB	Supervising Scientist Branch
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WoNS	Weeds of National Significance
WQMF	Water Quality Management Framework
W/SQO	Water or Sediment Quality Objectives

8 POST-MINING LAND USE, CLOSURE OBJECTIVES AND CLOSURE CRITERIA

8.1 Post-mining land use

The post-mining land use needs to be clearly articulated to allow for the development of specific closure objectives, which are used in the development and formalisation of closure criteria. In accordance with industry guidance (DMIRS 2020), the proposed post-mining land use should be:

- relevant to the wider regional environment.
- achievable in the context of post-mining land capability.
- acceptable to Energy Resources of Australia (ERA) stakeholders.
- ecologically sustainable in the context of the local and regional environment.

The Environmental Requirements (ERs) (refer MCP Section 3) specify that the Ranger Project Area (RPA) must be rehabilitated

> *…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.*

It should be noted that any decision on the actual incorporation of the RPA to Kakadu National Park (Kakadu NP) will be made by the relevant authority and may not eventuate until sometime after closure, if at all.

Thus, the predetermined post-mining land use of the rehabilitated RPA is the “potential incorporation into the Kakadu NP”. To meet this land use, the closure of the Ranger Mine is required to meet a number of closure objectives, which are discussed below (Section 8.2).

Whether the RPA is incorporated into Kakadu NP, or not, the rehabilitated site will most likely be utilised for both recreational and cultural use by the local Aboriginal people. ERA has a long history of stakeholder engagement with the Mirarr people through consultation with the Northern Land Council (NLC) and Gundjeihmi Aboriginal Corporation (GAC). In 2014, ERA formalised this engagement regarding post-mining land use and closure criteria development with extensive consultation with Traditional Owners, through the consulting linguist and anthropologist Murray Garde (Garde, 2015). This report was summarised and refined for habitation, use of traditional plants and animals and the assumed post closure bush food diet (Paulka, 2016).

8.1.1 Future occupancy intentions

Consultation with Bininj, Aboriginal people of the West Arnhem region, including the Mirrar, has established that there is an enthusiastic intention to continue visitation post-rehabilitation on the condition that Bininj are satisfied that the area is safe to enter and occupy (Garde, 2015). Over the past 35 years there have been restrictions on visitation to this significant area of the Mirarr clan's estate and people are keen to reconnect with the country and the places of cultural significance to them. Intended visitation can be organised into the following purposes:

- hunting, fishing, bush food gathering
- recreation
- land management activities
- cultural site visitation, ritual responsibilities

The following sections outline the intentions to occupy or visit the rehabilitated RPA in terms of average number of days per person per year. These are estimates based on consultations with Bininj combined with knowledge about current occupation patterns for each of the four visitation purposes. It is highly likely that these four categories will not be discrete or mutually exclusive. For example, hunting may occur during visits originally associated with a different purpose e.g. a monitoring or management visit.

Based on this information ERA has estimated occupancies at various locations to enable the calculation of radiation doses post closure and the development of appropriate closure criteria. A summary of the estimated occupancy times for the various activities are provided in Table 8-1 with an estimate of the typical locations expected to be occupied shown in Figure 8-1.

The table of estimated occupancies contains the original Garde estimated days per activity and a breakdown over various locations. The table also provides an estimate of percentage of time for each location and an estimate of hours per year.

As can be seen in both the figure and table, the majority of area estimated to be occupied will be in the Magela riparian zones. With the exception of land management and monitoring, Garde details that occupancies will be centred on the Magela creek and site billabongs (Georgetown and Coonjimba). It is expected that hunting and gathering (and to a lesser extend other activities) will also extend into the previously disturbed water management areas, including the old Retention Pond 1 (RP1) area, Land Application Areas (LAAs) and Corridor Creek. As the landform evolves into an ecosystem, drainage lines will reform and fauna will reinhabit the landform. It is at these locations that it is estimated that occupancy, mainly in the form of hunting and food gathering, will occur (refer Figure 8-1). It is likely that shorter, infrequent hunting will occur on the remainder of the landform, however this has been estimated to be minimal. The fauna detailed by Garde are either aquatic based or likely to gather in the riparian areas around water and food sources.

Table 8-1: Estimates of occupancy periods at various locations on the rehabilitated RPA

Purpose of visit	Estimated time[1]	Location	%	Estimated hours per year
Hunting and food gathering (day trips)	30 days per person per year[2]	Magela riparian zones (undisturbed)	70	126
		LAA, RP1,water management areas and site billabongs	20	36
		Landform waste rock	10	18
Seasonal camping (extended camping)	20 days per person per year[3]	Magela riparian zones (undisturbed	75	360
		Site billabongs	20	96
		LAA, RP1 & water management areas	3	14
		Landform waste rock	2	10
Recreation	10 days per person per year[3]	Magela riparian zones (undisturbed	90	216
		Site billabongs	7	17
		LAA, RP1 & water management areas	2	5
		Landform waste rock	1	2
Land management and monitoring	10 days per person per year[4]	Site billabongs	25	20
		LAA, RP1 & water management areas	25	20
		Landform waste rock	50	40
Ritual	5 days per year[5]	Magela riparian zones (undisturbed	90	54
		Site billabongs	5	3
		LAA, RP1 & water management areas	5	3

1 – Estimated time from Garde 2015

2 – A 6 hour day has been assumed (Garde estimated both half and full day trips)

3 – Full 24 hour day assumed (conservatively assume camping overnight for bush walks)

4 – Land management assumed to be conducted on an 8 hour day

5 – Rituals assumed to last for 12 hours on average (some may be overnight, some very short)

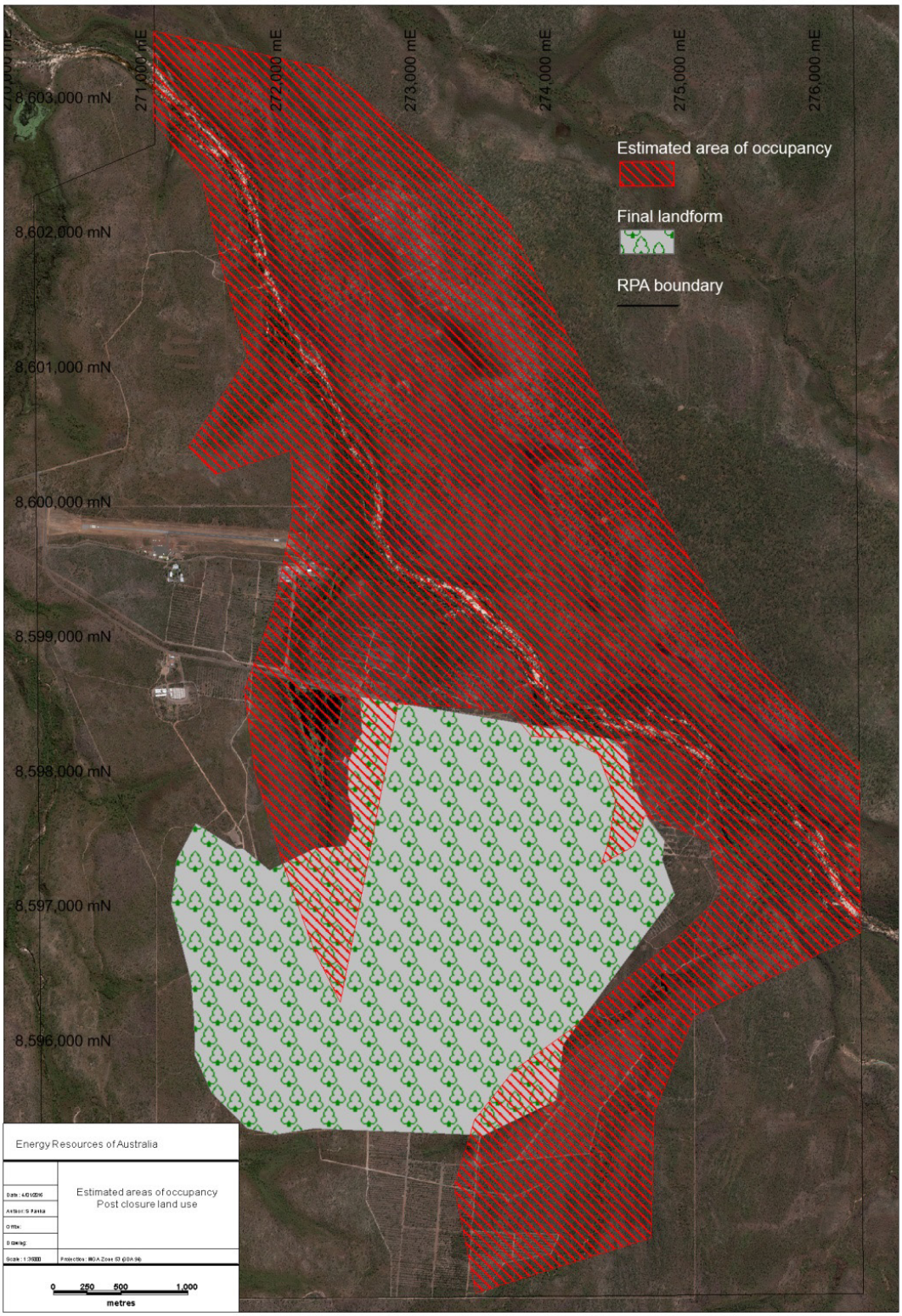

Figure 8-1: Estimated location for occupancy post closure

8.1.1.1 Hunting and gathering

Customary harvesting by local people of terrestrial bush foods from former mine impacted areas is ultimately likely to become more prevalent following the rehabilitation of the RPA.

Garde (2015) notes that the most popular of excursions usually involve fishing in Magela Creek but he is also aware that Bininj regularly hunt macropods, pigs, buffalo, water fowl (mostly magpie geese) and emus, mostly with guns. His estimates of potential visitation periods for hunting, fishing and food collection purposes are based on the following observations:

- Hunting visitation is likely to be more frequent on weekends as people combine hunting/food collection with recreational purposes.
- Hunting and gathering visits are frequently day trips (that extend for either a half-day or the full duration of the day).
- Hunting and gathering trips usually depend on the availability of transport (4WD vehicle), a firearm, seasonal access conditions (i.e. road not inundated) and the seasonal availability of the intended resource.
- Seasonal camping or extended occupation for seasonal resource exploitation is also highly likely.

Extended seasonal camps are common in the region and the concentration of food resources at various times, such as the late dry/early wet season, for water fowl such as magpie geese, ducks and other bird life. These resources will mostly attract Bininj from Jabiru to places such as Georgetown Billabong, Coonjimba billabong and the rehabilitated RP1 area and Magela Creek mainly from MAG009 and upstream as far as the Magela Falls region.

Estimate of time spent on hunting and gathering, day trips:

Average of three times a month (less lack of access in wet season) = 30 days per year.

Estimate of time spent on hunting and gathering, extended seasonal camping:

= 20 days

Notional estimate of number of people accessing the rehabilitated RPA:

50 people— mostly from local resident areas.

8.1.1.2 Recreation

Bininj consulted in relation to intended recreational activities listed a number of possibilities. These include the following:

- intergenerational knowledge transfer visits
- residential college and school trips
- camping trips along Magela Creek

- bushwalking trips along traditional walking routes
- weekend swimming, 'get out of town picnics'

Some Bininj consulted said they would like young people (Bininj) to become familiar with certain cultural sites on the RPA post-rehabilitation. Estimates of such activities are about 2 days per person per year. These may be either sponsored by one of the Bininj organisations or they could be private trips e.g. a family outing.

Other Bininj said that if they could be assured that it was safe to do so, they would consider camping at traditional or well-known camping places. Examples would include various billabongs along the Magela and associated tributaries. There is also an historical precedent for some long term residence at sites along the Magela, for example 009 camp, where Bininj have spent some years in residence. The area at 009 on the Magela remains a popular recreational site where weekend visits are still popular. In recent years however, the increase in the crocodile population has meant that people are only swimming there in isolated waterholes that appear in the late dry season.

The advent of a local rangers is likely to see a program of bush walking and other site visits as the young rangers become familiar with places that have been closed or difficult to access due to mining over the past 35 years. There are plans to include these bushwalks as annual or biannual events which will form part of a land management program on the Mirarr estate. These will follow the traditional Aboriginal walking routes. Further documentation of these routes took place in 2013 with assistance of the indigenous Heritage Program and the results have been archived on an online content management database. Robert Layton documented traditional walking routes on the RPA and Magela Creek area in his report of 1981. Whilst they have a recreational aspect to them, bushwalking programs by indigenous ranger groups are also considered as important activities. This is discussed in the next section; land management and monitoring.

Estimate of time spent on or transit through rehabilitated RPA for recreation:

10 days average per person per year.

Locations:

Gulungul Creek road crossing, Georgetown Billabong, Coonjimba Billabong and the rehabilitated RP1 area and Magela Creek mainly from Mudginberri to MG009 and then upstream in the area just north of Georgetown Billabong.

8.1.1.3 Land management and monitoring

An ongoing program of monitoring and management in relation to cultural criteria for closure will be required following the rehabilitation of the RPA. In the early days of rehabilitation, it is envisaged that indigenous rangers will make periodic visits to undertake assessment of the cultural criteria associated with closure of the Ranger mine. It is difficult to fix the frequency of these visits at this early stage. Notionally, annual visits would be undertaken.

Fire and weed management will result in regular visits to the site once vegetation has matured. The time needed to conduct site monitoring and management is estimated to be 10 days per person each year. Specific locations requiring the majority of effort are currently difficult to determine.

8.1.1.4 Rituals

Many traditional ceremonies are no longer performed in Kakadu National Park; in the midst of a national park full of tourists and inquisitive non-indigenous people. Garde (2015) outlines some of the historic major and public ceremonies that still occur in Arnhem land.

Bininj in Jabiru and Kakadu are required to undertake certain rituals associated with the recent death of a family member. An example is the painting of ochre on trees, buildings and vehicles with which the recently deceased person has been associated. This ritual also involves visits by the family to sites in the country of the deceased so that the ochre can be placed on trees at important camping places. Bininj may need to access the rehabilitated area for this purpose. The time needed to conduct such activity is estimated to be 1 day per person each year. Locations would be established seasonal camps and other sites of frequent visitation (e.g. favourite fishing places or goose hunting places near billabongs).

Bininj also have the responsibility in this region to perform increase rituals at certain key sites, especially sacred sites that are totemic centres for particular natural species. These kinds of rituals are performed throughout Australia and are well documented in anthropological literature. The rituals are performed within a matter of minutes and in some cases (depending on the site) they can take longer. A half day or day trip to the relevant area would be typical to 'throw the dreaming totem'. The sacred sites on the RPA may be locations where such rituals might be carried out in the future as Bininj attempt to reconnect with the rehabilitated land. It is estimated that one day per person per year could be dedicated for this purpose.

Locations:

The recorded sacred sites but possibly also at any of the archaeological scatters.

Bininj in the Kakadu and West Arnhem Land region can also visit sites to introduce new visitors or young people (Bininj) to such places. They may also wish to communicate with the spirits of deceased kin at certain sites. It is difficult to know how frequently site visits for this purpose may be planned. Two or three days per year is assumed.

Locations:

Mostly along the Magela Creek but possibly also at the gravesite and the other recorded sacred sites.

8.1.2 Bush food diet

Establishing how much bush food is consumed by Bininj in the northern region of Kakadu NP is important as part of the post rehabilitation radiological dose assessment. Sources for bush meat fall largely into three categories - that hunted by Bininj themselves in Kakadu; that delivered as a community service by other agencies or non-indigenous individuals; and that shared by more distant kin e.g. relatives visiting from Gunbalanya or Western Arnhem Land outstations.

A more exact study based on detailed quantitative analysis from fieldwork is now deemed impractical, not only for the diverse Aboriginal communities and residences within Kakadu NP, but probably for anywhere in Australia. Measuring the weights of all bush meats and plant foods consumed across the dozen or so communities/outstations/ranger stations in northern Kakadu where bush foods still are a significant element of the diet would require a large number of teams to record everything harvested over an annual cycle. This would require an unacceptable intrusion into the lives of bush food consumers and be beyond the resources of any research agency. This impracticality was confirmed by economic anthropologists discussing this issue at an Australian National University conference (September 2014) and based on the work of the anthropologist Jon Altman.

Altman's work (1987) is one of only two studies in Australia that have focused on the quantitative collection of nutrition data for Aboriginal people living in remote areas on their own estates, the other being Betty Meehan's work with the coastal Burarra people near the mouth of the Blyth River near Milingimbi (Meehan, 1982). As part of his doctoral research in the late 1970s, Altman resided for about 18 months at Mumeka outstation on the Mann River south of Maningrida. During a ten month period of that time, he collected daily data on returns for this outstation community from hunting and gathering (as well as market goods delivered by the store) and employed Bininj assistants to do the same if there was more than one production team away from the camp on any one day. Altman's data is represented in kilocalories and protein rather than pure weight of food resources collected. However, in 1980 he calculated that per capita forty-six per cent of total kilocalorie, and eighty-one percent of total proteins came from bush foods for this remote western Arnhem Land community (Altman, 1987, p.37). Comparisons with contemporary northern Kakadu 35 years later would be difficult. Bininj in the Kakadu region have greater access to market foods (and higher cash incomes to spend on such foods) throughout the seasonal cycle, but bush foods still represent a significant economic, nutritional and cultural element of diets.

As an absolute quantitative measurement of bush food consumption cannot be undertaken, an estimate has been made based on long term and extensive data collection by survey and interview. This is the methodology undertaken by the Supervising Scientist Branch (SSB) (Ryan *et al.*., 2011) and has been used for the proposed post closure diet.

The estimated annual intake of bushfood by local Aboriginal people, living in northern Kakadu NP has been provided in Table 8-2. This diet has been adapted from that compiled by Ryan *et al.* (2011). The Gundjeihmi names for these foods have been added and there have been some additions of missing items. Anecdotal evidence based on recent interviews with residents from Bininj communities in northern Kakadu and long term participant observation of food

collection trips by Murray Garde since 2003, indicate that there is a high probability that the Supervising Scientist data is still accurate. Specific differences from that diet to today are described below.

- Emu (they are periodically hunted in the area south of the RPA)
- Flying fox (consumed regularly in some communities, occasionally or never in others) Those communities that consume flying fox suggested they did so about every one to two months and an average take would be about a dozen animals (by shotgun). Sometimes flying fox have been supplied to Bininj by other agencies/individuals, for example Dave Lindner.
- Various water fowl including plumed whistle ducks, wandering whistle duck, Radjah shelduck, white ibis and straw-necked ibis and less frequently brolga and the black-necked stork. Consumption of other birds such as sulphur-crested cockatoos and corellas is rare.
- In relation to crocodiles, typical consumption is approximately 5 or 6 crocodiles (combined fresh and salt water). This suggests that the ERISS 2 kg per person figure is low and has been slightly adjusted up to 3 kg.
- The figure for goanna consumption should include consumption of frilled neck lizards. Their consumption is not infrequent as they are now more commonly eaten than goanna. Their populations have not been affected by cane toads to the same extent as have those of goannas. The figure of 2kg/year per person still seems reasonable.

Although there is no direct quantifiable evidence, except comparison in the general Australian population, the figure for buffalo consumption in the SSB diet seems possibly over-estimated at 146 kg per person per year. Agricultural commodity statistics (2013, Australian Bureau of Agricultural and Resource Economics and Sciences) indicate per capita consumption of meats in the general Australian population total approximately 100 kg per year, with beef/veal being only 32.2 kg.

The Supervising Scientist proposed value was not updated during the Garde review; however, the values presented in Table 8-2 represents bush food consumed over the full year in Northern Kakadu. The buffalo consumed as a bush food in Northern Kakadu often comes from Anbarrawarrgu, (the Buffalo Farm), as such this would not be included in the diet consumed on the RPA. Buffalo consumption on the RPA has been reduced to 5 kg per year per person. This has been based on an assumption that Buffalo will be hunted and shot 5 times during the year, that a single person will not consume more than 0.5 kg of Buffalo in a single sitting and that the Buffalo meat will last for 2 days, being shared among the community (i.e. 1kg meat per Buffalo per person). The weight of organs consumed has been reduced accordingly to 0.5 kg of each.

Table 8-2: Estimate of annual intake of bushfood of local Aboriginal people in northern Kakadu

Food item	Flesh eaten	Organs eaten	kg/yr per person
Buffalo flesh	X		146
Buffalo kidney		X	18
Buffalo liver		X	18
Wallaby	X	X	20
Pig	X		25
Magpie goose	X	X	20
Other water fowl	X	X	3
Fish group 1	X	X	10
Fish group 2	X		20
Mussels	X		4
Turtle flesh (3 species, pig nose, long neck and snapping)	X		5
Turtle liver (long neck only)		X	0.5
Filesnake	X		3
Crocodile flesh	X		3
Goanna	X	X	2
Yams	X		20
Fruit	X		3
Water Lilly	X		3
Flying fox	X		5
Emu	X	X	2
Food total			*330.5*

Significant variables include the fact that some communities engage in hunting and bush food collection more often than others and some people consume certain bush foods that others do not. There are also seasonal variables that affect the availability and access to certain species. Certain foods may be favoured by particular age groups e.g. internal organs of some animals are favoured by the elderly and flying fox is not always eaten by some younger people.

Organs of certain animals are still regularly eaten. The most frequently consumed are those of buffalo (liver, kidneys, tongue), magpie geese (most organs), macropods (liver, kidneys) and long-neck turtle (liver). The organs of these animals have cultural significance in terms of the preparation of a meal. Bininj usually spend considerable time hunting these animals and the organs are removed quickly and eaten as an entrée dish whilst the main parts of the animal

are then prepared for the longer cooking process. Organs such as liver are also considered important food for the elderly.

8.1.3 Culturally important flora and fauna

There are various criteria for establishing the cultural importance of a plant. The widest framework is linguistic reference. If it has a name and can be referred to, it must have some significance in the cultural life of Aboriginal people. A further criterion is utility. If it is used as some form of resource (e.g. food, medicinal, aesthetic, material culture, ritual) it is culturally important. On a number of occasions Bininj have indicated that culturally significant plants also include those that link animals together with other animals (including people). Plants that have flowers, seeds or fruit that attract birds and other animals are important for rehabilitation because they encourage the rapid re-establishment of biodiversity for example Owenia trees (*Owenia vernicosa*). Although Owenia seeds can take up to 5 years to germinate, they will grow in very rocky habitats, even in cracks of bare sandstone, their fruit is favoured by black cockatoos and emus and the sap is eaten by sugar gliders. People use the crushed leaves as an ichthycide (fish poison).

It may not be possible for all the floristic species identified in the Garde report to be sourced, propagated and established, or suitable for the Ranger site (for example some rainforest species); if this is the case a justification will be provided for exclusion. The plants listed are those found across the three relevant ecological zones of the RPA - watercourses and billabongs, riparian margins and savannah woodland.

8.2 Closure objectives

Closure objectives set out the long-term goals for closure and should be based on the post-mining land form and use (DIIS 2016). Closure objectives are an essential component of the rehabilitation process, providing transparency for stakeholders as to what the proponent commits to achieve at Authorisation relinquishment. Development of closure objectives should consider each of the environmental factors impacted by the operation (DMIRS 2020).

The environmental obligations, termed Environmental Requirements (ERs), of the section 41 Authority, issued under the *Atomic Energy Act,* and now annexed to the Ranger Authorisation issued under the *Mining Management Act*, also provide specific closure objectives that align to the post-closure land use already discussed. A table of these ERs as closure objectives is provided as Table 8-3. These objectives were developed at the time of the authorisation of mining with the post-mining land use in mind. The objectives have been reviewed with stakeholders throughout the project and have been agreed to as being appropriate for the project impacts and proposed land use.

The guidelines for preparing mine closure plans (DMIRS 2020) provides a planning framework for mine closure. The framework is similarly reflected in other industry guidance documents (AusIMM 2018) and details the process for collating project details, stakeholder input, baseline environmental information, risk and uncertainties to determine appropriate post-mining land use(s) and closure objectives. Closure objectives require the development of relevant and measurable criteria, to demonstrate and determine when the objectives and successful

rehabilitation have been achieved. Section 8.3 presents the current status of closure criteria, as informed by the project impacts, supporting studies and stakeholder engagement.

Table 8-3: Closure objectives

Closure objective	ER reference
Landform	
The tailings are physically isolated from the environment for at least 10,000 years.	11.3 (i)
Erosion characteristics which, as far as can reasonably be achieved, do not vary significantly from comparable landforms in surrounding undisturbed areas.	2.2 (c)
Radiation	
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.	2.2 (b) and 11.3 (iii)
In particular, the company must ensure that operations at Ranger 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; and • 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.	1.2 (d, e)
Water and sediment	
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. The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives: • Protect the health of Aboriginals and other members of the regional community. The company must ensure that operations at Ranger do not result in: • 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.	3.1, 1.1(c) and 1.2(c)

Closure objective	ER reference
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. The company must ensure that operations at Ranger 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. • 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: • any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years.	3.1, 1.2(d) and 11.3 (ii)
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. The company must ensure that operations at Ranger do not result in: • 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.	3.1 and 1.2(e)
Flora and fauna	
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 NP, 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.	2.2 (a)
Soil	
The company must ensure that operations at Ranger do not result in: • 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.	1.2 (e)
Cultural	
The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives: • maintain the attributes for which Kakadu NP was inscribed on the World Heritage list.	1.1 (a)
The company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu NP such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu NP.	2.1

*Ecosystem health means the ability to support and maintain a balanced, integrative, adaptive community of organisms having a species composition, diversity and functional organisation comparable to that of the natural habitat of the region

8.3 Closure criteria

A key component of closure planning for the Ranger Mine is the development of closure criteria, which form the performance criteria and will be used to measure the achievement of the rehabilitation closure objectives. These criteria are to represent direct measurable and quantifiable values, or tiered assessment processes based on industry best practice frameworks, such as the International Commission of Radiological Protection (ICRP), Inventory Multi-tiered Assessment and Prioritisation (IMAP) and National Environment Protection Measure (NEPM). Closure criteria will be used as the basis for determining the successful fulfilment of closure objectives to enable issuance of close-out certificates. It is acknowledged that further work is required to define quantifiable monitoring parameters necessary to confirm closure criteria have been met.

The mechanisms and processes by which closure criteria are developed are outlined in the Terms of Reference for the Closure Criteria Working Group (CCWG) (Paulka 2012) and shown in Figure 8-3. The closure criteria address the broader objectives described in the ERs and Ranger Authorisation. Figure 8-3 has been updated to reflect the current status of closure criteria planning and shows the five-stage pathway for the development, refinement and approval of these criteria.

As described in Section 8.2, the Ranger ERs contain a number of objectives for the rehabilitation and closure of Ranger Mine. The overall objective for rehabilitation and closure has been based on the rehabilitation goals outlined in the Ranger Authorisation and the ERs (ERA 2014). It is recognised in the wording of Primary Environmental Objectives that the environment established on the rehabilitated Ranger Project Area must be similar to the adjacent Kakadu National Park and any impacts within the RPA must be as low as reasonably achievable (ALARA). These objectives are reflected within the closure criteria. The assessment of what is ALARA is discussed in Section 6.

To identify closure criteria, key themes were developed by the CCWG (Stage 2), which include: landform, radiation, water and sediment, flora and fauna, soils, and cultural. More recently the flora and fauna theme has been renamed to ecosystem. The topics for cultural closure criteria closely align with each of the closure criteria themes. In this MCP, cultural criteria have been presented as a separate section with links provided via a numbering system to show the relationships.

The closure criteria for each theme are based on stakeholder consultation (Section 4), substantial research and studies (Section 5), Best Practicable Technology (including ALARA approach) (Section 6) and risk assessments (Section 7) over the life of the mine.

The closure criteria presented in this MCP have been divided into two categories; proposed criteria for minister approval, and draft criteria for further review. These have been divided into separate tables in order to clearly identify those that have been agreed between stakeholder groups and are ready for finalisation with ministerial approval and those that require further review and consultation.

The draft closure criteria will continue to undergo review and refinement, based on studies and consultation with MTC members with a plan to finalise all criteria for the 2021 MCP.

Each closure theme is presented in a separate section below with the following information:

- summary of relevant objectives and outcomes
- closure criteria summary table
- justification for outcome, parameter, criteria and method to assess achievement

Figure 8-2: Fungi on Trial Landform

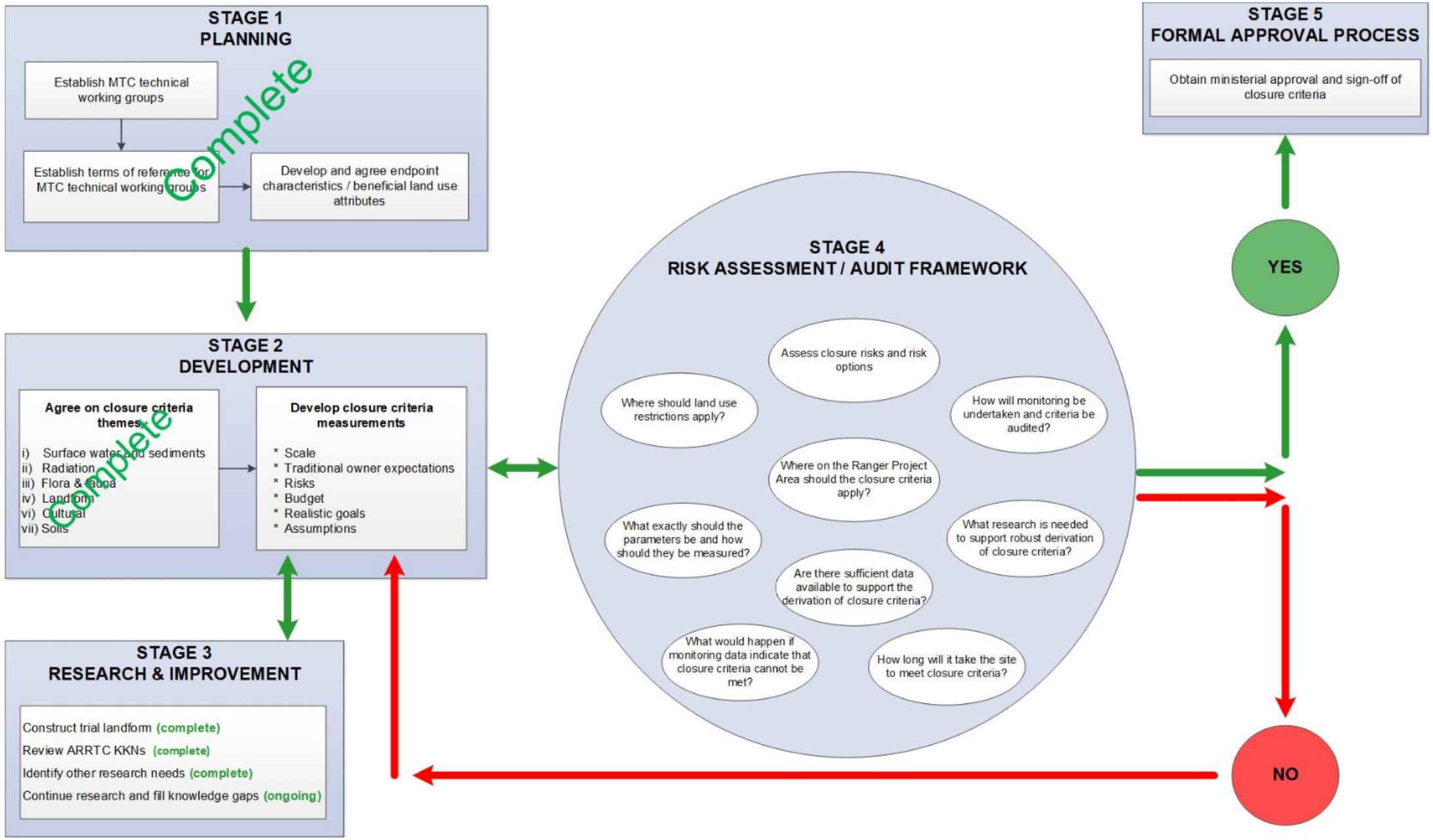

Figure 8-3: Framework for the closure criteria working group, and subsequent closure criteria development and approvals pathway

8.3.1 Landform

There are two objectives derived from the ERs relating to the landform theme (Table 8-3). Each objective, the outcome derived from that objective and explanation are summarised below.

Landform Objective 1:

The first objective comes from ER 11.3 (i) and relates to the isolation of tailings:

The tailings are physically isolated from the environment for at least 10,000 years.

As it will not be physically possible to monitor and measure this over the defined period of 10,000 years, a model will be required to show that this can be achieved. The outcome derived is based on best available modelling demonstrating that the tailings remain isolated.

Any modelling predictions should be conservative to give confidence that the objective will be achieved, however any worst-case scenarios developed will need to be realistic and reasonable.

Landform Objective 2:

The second objective comes from ER 2.2 (c) and relates to erosion of the landform:

Erosion characteristics of the rehabilitated landform, as far as can reasonably be achieved, do not vary significantly from comparable landforms in surrounding undisturbed areas.

Three outcomes have been derived from this objective.

First outcome - derived directly from the objective relating to erosion rates being comparable to natural landscapes. It is expected the erosion rates will be initially high then trend slowly towards the natural rates. As these timeframes are expected to be quite long best available modelling will be used to demonstrate that the erosion characteristics of the final landform will eventually be comparable to natural landscapes.

Second outcome - to ensure sediments created through erosion of the landform do not cause sand to infill Magela and Gulungul creeks and associated billabongs. Whilst this outcome does not directly relate to the objective for erosion characteristics, it was considered an important environmental protection outcome that relates to erosion.

Third outcome - applies the concept that turbidity can be used as an indicator of site-scale erosion characteristics. Moliere *et al.*. (2004) have shown that turbidity measures are highly correlated to total suspended sediment loads taken as a cumulative total over the wet season. The total suspended sediment can be captured at sites upstream and downstream in a paired before-after-control-impact design (BACIP) to demonstrate landscape stability and the trajectory of sediment fluxes on the rehabilitated landscape towards those of analogue landscapes. This method is further described in Moliere & Evans (2010).`

The proposed landform closure objectives, outcomes and parameters are set out in Table 8-4 and Table 8-5 with the former providing a summary of the proposed closure criteria for ministerial approval and the latter those that remain in draft for further review. Some criteria also have linkages to cultural criteria. Where this occurs, reference has been made to the cultural criteria section for more details.

Section 8.3.1.1 provides justification the outcomes, parameters and closure criteria that were derived for each of the key elements of the landform theme: infrastructure, isolation of tailings, and erosion characteristics.

Figure 8-4: Typical rocky surface of the Trial Landform (2019)

Table 8-4: Final Closure criteria – Landform

ER	Objective	Outcome	Parameter	Summary of criteria[2] for Minister Approval	ID	Cultural link
11.3 (i)	The tailings are physically isolated from the environment for at least 10,000 years	Best available modelling demonstrates that tailings will remain isolated for at least 10,000 years	Digital elevation model (DEM)	A high-resolution digital elevation model of the constructed landform matches the approved landform design, within applicable construction standards.	L1	
			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.	L2	
			Gully erosion	Gully formation will not expose buried tailings.	L3	C2
2.2 (c)	Erosion characteristics of the rehabilitated landform, as far as can reasonably be achieved, do not vary significantly from comparable landforms in surrounding undisturbed areas	Best available modelling demonstrates that erosion rates return to that of comparable natural landscapes	LEM model predictions of denudation rate	Modelling of erosion on the constructed landform predicts that the denudation rate will be on a trajectory towards 0.04 mm/year.	L4	C2 C3
		Sediments from erosion of the landform do not cause sand to infill in Magela and Gulungul creeks and associated billabongs	Bedload	Bedload is not being carried away from the constructed landform, in the absence of active management.	L5	C6

Table 8-5: Draft closure criteria - Landform

ER	Objective	Outcome	Parameter	Draft criteria for review 2	ID	Cultural link
2.2 (c)	Erosion characteristics of the rehabilitated landform, as far as can reasonably be achieved, do not vary significantly from comparable landforms in surrounding undisturbed areas	Sediments from erosion of the landform do not cause sand to infill in Magela and Gulungul creeks and associated billabongs	Sedimentation	Accumulation of erosion products in Coonjimba and Georgetown Billabong will be ALARA.	L7	C6
		Suspended sediment loads in Magela and Gulungul creeks will be approaching background	Suspended Sediment	Event-based fine suspended sediment loads, evaluated across the wet season, to Magela and Gulungul creeks, are on a trajectory towards background loads.	L6	C7

[2] Criteria to be read in conjunction with the closure criteria details provided in Mine Closure Plan Section 8.3.1.

8.3.1.1 Justification for outcome, parameter and criteria

The following subsections justify how the outcomes of closure were derived from the objectives, the parameters used to measure outcomes, and the proposed closure criteria for each of the key elements of the landform theme (infrastructure, isolation of tailings and erosion characteristics). Confidential

Isolation of tailings

The method used to demonstrate achievement of tailings isolation criteria will be based on the Landform Evolution Model (LEM) predictions, using the CEASER-Lisflood landform evolution model. The criteria will be achieved if the model demonstrates tailings will not be exposed. The modelling of climate change scenarios and the inbuilt conservatism will mean there is no tolerance assigned to the output and therefore it will confirm the criteria either has or has not been achieved.

Once constructed, the as built topography will be compared to design to confirm it is within the construction tolerances expected. These are currently expected to be in the order of +/- 0.5 m at drainage boundaries and +/- 1 m elsewhere (Section 9.4.5.).

The appropriate design of the landform, erosion mitigations and drainage channels should minimise development of gully erosion. Post wet season inspections will be undertaken to determine the presence or absence of unplanned gully erosion. Significant erosion such as gully erosion is more likely to occur in the initial stages of the life of the landform. Following the initial settling of the landform, significant unplanned erosion should not occur. Gully erosion detected over Pit 1 and 3 will be remediated prior to the following wet season. It is expected that after the first five years the landform will stabilise, and less erosion will occur. This criterion is considered to be achieved when no gully erosion, beyond that would ordinarily occur in the region, could expose tailings occurs after this period.

Erosion characteristics

Denudation rate is the measure of the weathering or erosion of a landform surface by forces such as water and wind and expressed in terms of millimetres per year. This parameter is considered the most suitable parameter for comparing erosion characteristics of landscapes over time. The denudation rate of the waste rock landform is unlikely to be comparable to natural landscapes in the short term; therefore, a LEM will be used to predict denudation rates. The model needs to demonstrate that the long-term predictions of denudation rate from the designed landform are on a trajectory towards background rates (reported by the SSB in their rehabilitation standard to be 0.04 mm per year).

Sediments from erosion of the landform should cause sand to infill in Magela and Gulungul creeks and associated billabongs. This will be measured through both course sediment (bedload) and finer sediment (sedimentation). The criteria will be to make sure that Bedload is not being carried away from the constructed landform, in the absence of active management, and over time accumulation of erosion products in Coonjimba and Georgetown Billabong will be ALARA.

Event based suspended sediment loads, evaluated across an entire wet season, is considered the most suitable parameter for measurement of site-scale erosion characteristics. Suspended sediment loads from the rehabilitated landform to Magela and Gulungul creeks are expected to be high initially, and then trend progressively towards background (analogue) suspended sediment loads. Work completed by the SSB has demonstrated that turbidity can be used as an indicator for suspended sediment (Moliere & Evans 2010).

The suspended sediment load leaving the landform and entering Magela or Gulungul Creek will be measured through turbidity monitoring up and downstream of the RPA. Event-based sediment loads leaving the site will be tracked across a wet season and compared to background (analogue) loads, based on the method described in Moliere and Evans (2010). It is expected that it will take some time for these loads to return to background levels; therefore, achievement of this criterion will be based on the trajectory towards the analogue, which is expected to be between five and ten years.

8.3.2 Water and sediment

8.3.2.1 Water quality management framework

The recently revised *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) provide a stepwise Water Quality Management Framework (WQMF) for developing agreed water and sediment quality objectives.

The language of the WQMF differs from that used by ERA and stakeholders in closure criteria discussions (reflected throughout this section). In this section both sets of terms are used in places. Where this occurs, terms from the WQMF are italicised in brackets.

An important distinction is the term “objective”. Throughout the MCP “objective” is used to imply a management goal whereas the WQMF refers to water or sediment quality objectives (W/SQO). As explained in Section 8.3.2.2 water/sediment quality guideline values (GVs) are identified for each management goal. The most stringent of these GVs is then chosen as the draft W/SQO.

The setting of the water quality objectives is currently at Step 5 of the process “Define draft water/sediment quality objectives” (Section 8.3.2.3). For this reason, ERA will be requesting minister approval of Draft Water Quality Objectives not final criteria as in the other themes. The proposed water and sediment management objectives and outcomes (*management goals*) and parameters (*indicators*) are set out in Table 8-6 and Table 8-7 with the former providing a summary of the stakeholder agreed draft Water Quality Objectives for ministerial approval, and the latter being those proposed, that are undergoing further review with stakeholders.

The same indicator appears against several management outcomes but with different GVs (e.g. a higher GV value for drinking water than for ecosystem protection for a given indicator). In most cases the ecosystem protection GVs are more stringent than GVs for other management objectives. The GVs for ecosystem protection are therefore proposed as the draft W/SQO. This is indicated in Table 8-6 by underlined italicised type. This reflects progress

against steps one to five in the WQMF. Steps six to ten in the WQMF provide a framework for assessing if draft W/SQO can be met, gathering more information, revising the draft W/SQO if appropriate, and eventual agreeing on final W/SQO. This process is important to derive and agree on final W/SQO for waterbodies on the RPA where impacts are to be as low as reasonably achievable (ALARA).

8.3.2.2 Management objectives and outcomes

There are three management objectives derived from the ERs that relate to the water and sediment theme (Table 8-3). These objectives are discussed below and captured in Table 8-5 and Table 8-6. Stakeholder discussions may identify additional goals. Some work has progressed on identifying community values for different water types on and off the RPA. This and other information will be discussed further with stakeholders.

The ER 3.1 is central to the first three management objectives:

> *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.*

This ER directs ERA to ensure that the primary environmental objectives must apply off the RPA to the period following rehabilitation for any surface or ground waters discharged from the RPA. The various primary environmental objectives are then separated into the separate closure management objectives for this closure criteria theme.

Water and sediment management objective (*management goal*) 1:

The first management objective groups ER 1.1(c) and 1.2(c) as both relate to human health:

> *The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:*
>
> *1.1(c) Protect the health of Aboriginals and other members of the regional community*
>
> *The company must ensure that operations at Ranger do not result in:*
>
> *1.2(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.*

Two pathways were identified for the assessment of the potential risk to human health from chemical pollutants in water (radiation is addressed separately in the radiation theme):

- Pathway 1: through ingestion of water and bush food that has bio-accumulated mine derived analytes. The management outcome is that diet consumption limits are not exceeded as a result of mine derived contamination.

- Pathway 2: through recreational activities. The management outcome is that recreational water resources remain safe for their designated use.

Water and sediment management objective (*management goal*) 2:

The second management objective is derived from ER 1.1 (d), ER 1.2(d) and 11.3(ii) and relates to protection of the Alligator Rivers Region and protection of the environment from tailings contaminants for 10,000 years:

1.1 The company must ensure that operations at Ranger are undertaken is such a way as to …:

> *(d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes*

1.2 The company must ensure that operations at Ranger do not result in:

> *(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.*

11.3 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:

> *ii. any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years.*

Two management outcomes have been derived from this management objective:

First outcome - mine derived 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.

Second outcome - mine sourced solutes do not increase contaminants in sediments off the RPA to levels that would be detrimental to ecosystem health of the region.

These two outcomes cover the three pathways for contaminant transport for this theme, groundwater, surface water and sediments.

Water and sediment management objective (*management goal*) 3:

The third management objective is from ER 1.2 (e) and ER 2.1:

ER 1.2 (e) relates to protection inside the RPA, focusing on impacts to be as low as reasonably achievable

The company must ensure that operations at Ranger do not result in:

> *(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.*

ER 2.1 relates to incorporating the rehabilitated site into Kakadu NP.

> *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.*

The management outcome for this objective is that impacts on the RPA (water and sediment quality) will be as low as reasonably achievable (ALARA).

8.3.2.3 Justification for outcome, parameter and criteria

ERA is following the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) Water Quality Management Framework (WQMF) to provide a process for stakeholders to develop agreed water quality objectives that apply both on and off the RPA.

The WQMF provides a sequential stepwise approach (Figure 8-5) to setting management goals through to assessing, refining and deriving water and sediment quality objectives (W/SQO).

It is important to note that Traditional Owners have reported concerns about trying to integrate cultural values with the 'scientific, legal and technical domains of a process that will take place within a framework controlled by those from the dominant non-Indigenous culture' (Garde 2015). The application of this framework has been and will continue to be discussed with stakeholders, including the representatives of the Traditional Owners through working groups and consultative forums.

The following sections describe the ten-step framework, and a high-level description of information available, for developing a water management plan. These same steps can be applied to assessing a remediation strategy. Both are relevant to deriving closure criteria.

Table 8-6: Agreed draft water and sediment quality objectives for minister approval – water and sediment

ER	Objective	Outcome (Management Goal - WQMF)	Parameter (Indicator – WQMF)	Guideline Values & Draft Water Quality Objectives for Minister Approval[3] [4]	ID	Cultural link
3.1 and 1.1(c) and 1.2 (c)	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. 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 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.	Mine derived analytes will not cause dietary intake of bush food and water to exceed human consumption limits.	Drinking water: Mn, NO_3, NO_2, SO_4^{2-}, U	Water quality off the RPA meets the national drinking water health guidelines (at times when they would be met in non-mine effected local creeks) • SO_4^{2-} 500 mg/L, Mn 500 µg/L, NO_3 50 mg/L, *NO_2 3 mg/L*, U 17 µg/L (NHMRC & NRMMC, 2011; v3.5 updated 2018).	W1	-
		Mine derived hazards will not cause unacceptable visual amenity or water quality to exceed recreational guideline values for secondary contact at sites identified for recreational value.	Toxic or irritant chemicals: NO^3, NO_2, U, SO_4, Mn	Water quality off the RPA meets the national recreational guidelines for secondary contact (at times when they would be met in non-mine effected local creeks) • NO_3 500 mg/L, NO_2 30 mg/L, U 170 µg/L, Mn 5 mg/L (i.e., drinking water COPC x 10: NHRMC, 2008) • SO_4^{2-} 400 mg/L (ANZECC & ARMCANZ, 2000 irritants, no guidelines for irritants/toxicants in NHMRC, 2008).	W2	C7
			Visual clarity and surface films	No mine related change causes turbidity to be statistically 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.	W6	C7
3.1 and 1.2(d) 11.3 (ii)	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. 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. 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: ii. any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years.	Mine derived 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.	Turbidity, ammonia, manganese, uranium, magnesium, (magnesium: calcium mass ratio) & sulfate.	SSB Rehabilitation Standards are met in Magela and Gulungul creeks off the RPA: *Dissolved total ammonia nitrogen; 0.4 mg/L (pH and temperature dependant)* *Dissolved magnesium; 2.9 mg/L (72-hour moving average)* *Dissolved magnesium to calcium (Mg:Ca) mass ratio; no greater than 9:1* *Dissolved sulfate; 10 mg/L (seasonal average)* *Dissolved uranium; 2.8 µg/L (72-hour moving average)* *Dissolved manganese; 75 µg/L (72-hour moving average)* *Turbidity: no statistically significant increase over natural turbidity*	W3	C7

[3] Criteria to be read in conjunction with the closure criteria details provided in Mine Closure Plan Section 8.3.2.

[4] Most stringent GV are taken as the draft W/SQO. These have been underlined.

Table 8-7: Draft water and sediment quality objectives under review

ER	Objective	Outcome	Parameter	Draft criteria for review [5]	ID	Cultural link[6]
3.1 and 1.1(c) and 1.2 (c)	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. 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 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.	Mine derived analytes will not cause dietary intake of bush food and water to exceed human consumption limits.	Diet parameters TBC with expert opinion	Local diet model demonstrates that ingestion of mine derived constituents of potential concern (COPC) via aquatic and terrestrial bush foods and drinking water does not cause annual intakes to exceed any relevant national/international tolerable intake levels.	W7	-
3.1 and 1.2(d) 11.3 (ii)	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. 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. 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: ii. any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years.	Mine derived 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.	copper and zinc	SSB Rehabilitation Standards are met in Magela and Gulungul creeks at the boundary of the Ranger Project Area, downstream of the Ranger Mine: Values TBC following development of local site specific guideline value	W3	C7
3.1 and 1.2(d) 11.3 (ii)	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. 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. 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: ii. any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years.	Mine sourced solutes do not increase U in sediments off the RPA to levels that would be detrimental to ecosystem health of the region.	Uranium in sediments	Uranium in sediments does not exceed 100 mg/kg dry weight (whole sediment; weak acid extactable digestion method)	W4	-

[5] Criteria to be read in conjunction with the closure criteria details provided in Mine Closure Plan Section 8.3.2.

[6] All cultural criteria will be considered as part of the ALARA process

ER	Objective	Outcome	Parameter	Draft criteria for review [5]	ID	Cultural link[6]
3.1, 1.2(e) and 2.1	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. The company must ensure that operations at Ranger do not result in: (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. The company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu NP such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu NP.	Surface water and sediment quality on the RPA is demonstrated to be as low as reasonably achievable.	As for off the RPA listed above.	Impacts on the RPA are ALARA	W5	-

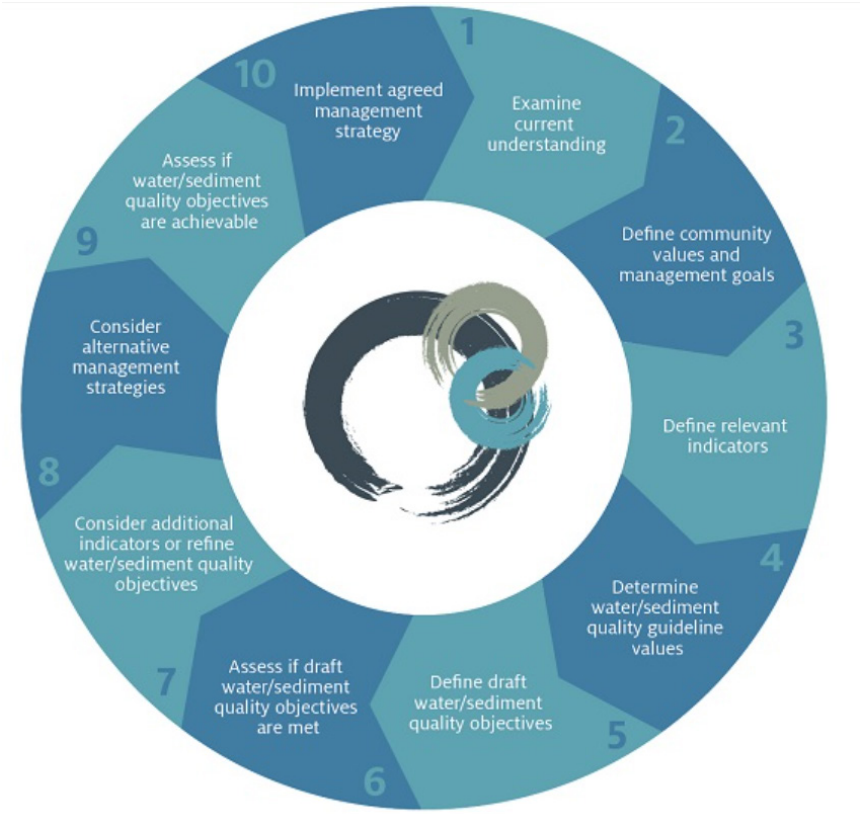

Figure 8-5: The Water Quality Management Framework (ANZG 2018)

Step 1. Examine current understanding

To inform decisions at subsequent steps, develop conceptual models of how the waterway systems work, the issues they face and how to manage them.

The understanding of how the Magela Creek system works and mine related issues is well advanced after almost 40 years of research and monitoring related to the Ranger Mine and surrounds (refer to studies listed in the SSB bibliography[7] and throughout this document).

Several key risk assessments and conceptual models relevant to the closure phase for water and sediment were considered. For example:

- revised Key Knowledge Needs (KKN) for closure (Supervising Scientist 2017a) have been based on environmental risk assessments of the Ranger Mine (Pollino *et al*. 2013, Pollino 2014, Bartolo *et al.* 2013). The knowledge base is updated as progress against the KKNs is reported (Section 5).
- an assessment of important ecological processes in the Alligator Rivers Region, to inform an ecological risk assessment (Bartolo *et al*. 2018)

[7] https://www.environment.gov.au/science/supervising-scientist/publications#bibliography

- peer reviewed groundwater and surface water conceptual models (INTERA 2019 and Water Solutions 2018)
- linkages between hydrological processes and ecosystem dynamics (BMT 2018)
- discussions of Indigenous worldviews on the environment, including water (Garde 2015).

Step 2. Define community values and management goal

Define community values and establish or refine more-specific management goals (including level of protection) for the relevant waterways at stakeholder involvement workshops.

Environmental requirements specific to the protection of water quality and decommissioning strategies specify:

- waters leaving the RPA do not compromise the achievement of the primary environmental objectives (ER 3.1) related to protection of the people, ecosystem (biodiversity and ecological processes), and World Heritage and Ramsar values of the surrounds (ER 1 and 2)
- impacts on the RPA are as low as reasonably achievable (ALARA) (ER 1.2e)
- all aspects of the Ranger Environmental Requirements and those environmental matters not covered by the Environmental Requirements must use Best Practicable Technology (BPT) (ER 12)
- the RPA must be rehabilitated to a state to allow incorporation into Kakadu NP (ER 2.1).

These Environmental Requirements provide high-level management goals for rehabilitation of the minesite. Water quality guideline values have been set for some of these goals (Table 8-5).

Additional management goals for water and sediment have been identified that need to be considered by stakeholders. For example:

- Garde (2015) describes the community's cultural expectations and expected uses of the rehabilitated mine. Hunting, cultural and recreational use of water is included.
- Garde (2015) states the waters contained within all riparian corridors, (i.e. rivers and billabongs), must be of a quality that is commensurate with non-affected riverine systems and health standards. The principle of 'as low as reasonably achievable' should not apply to these areas. Instead, the standard of rehabilitation must be as high as is technically possible and level of contamination must be as low as technically possible.
- The Northern Land Council (NLC) and Gunjeihmi Aboriginal Coroporation (GAC) reiterated this and provided additional (draft) information on their position on ALARA for onsite water bodies (email from Chris Brady 8/4/2020).

- In the response to the 2019 Mine Closure Plan draft, the Traditional Owner representatives emphasise the importance of waterways on the RPA to Traditional Owners. These areas were previously, and should again be, a focus of activity for Traditional Owners. The main focus of activity is likely to be focussed on Georgetown and Coonjimba Billabongs and the Magela Creek channel.
- The principle of “as low as reasonably achievable” therefore should not apply to these areas. Instead, the standard of rehabilitation must be as high as is technically possible and the level of contamination must be as low as technically possible.
- In recognition of this, the BPT process established by ERA for determining water quality of these key waterbodies is adjusted such that cost is not considered, whilst the weighting of cultural value is doubled.
- Additionally, to ensure that the aim is for these key waterways to be utilised by Traditional Owners, for example as seasonal camping area where people fish and come into contact with the water, the water quality at an absolute minimum, will not exceed the Australian recreation water quality guidelines as a result of mine related activities.
- In other water bodies (e.g. sumps, minor drainage lines) Traditional Owners expect that management during the monitoring and maintenance period pending final rehabilitation will be such that they do not pose a credible risk to people or wildlife.
- The final NLC/GAC position paper is discussed in Section 6.

- A stakeholder workshop identified the water types on and surrounding the RPA and the environmental values for each water type based on the environmental requirements and stakeholder expectations (BMT WBM 2017).
- The Traditional Owners and the SSB have indicated that a goal of no change to biodiversity on the RPA is preferred.

Step 3. Define relevant indicators

Select indicators for relevant pressures identified for the system, the associated stressors and the anticipated ecosystem receptors.

Indicators have been identified for the operational phase of the mine through many years of research, monitoring and application of the ANZEEC and ARMCANZ water quality guidelines. (e.g. Brown *et al.* 1985, Turner & Jones 2010, Frostick *et al*. 2012).

Iles and Humphrey (2014) reviewed the literature on release standards for constituents of potential concern (COPC) present in ore, process water and waste rock sources, and identified those needing a hazard assessment and/or requiring closure criteria. After further review, the

SSB developed rehabilitation standards[8] in the water and sediment theme for key chemical contaminants (ammonia, manganese, uranium, magnesium, (magnesium:calcium ratio), sulfate, aluminium, cadmium, chromium, copper, iron, lead, vanadium and zinc, turbidity and sedimentation[9]. Several metals were later removed from this list based on a hazard assessment undertaken by the SSB and reported to several stakeholder fora (eg; the Water and Sediment Working Group, ARRTC, Ranger MTC). The scientific basis for the SSB standards is described in each standard.

Other work relevant to selecting indicators for closure water quality management are as follows:

- the development of endpoints and indicators for the protection of biodiversity (Supervising Scientist 2002) and that reflect the environmental values of water bodies both on and off the Ranger Project Area. These include indicators for health and cultural uses and the Ramsar and Kakadu NP World Heritage values (BMT WBM 2017).
- the review of conceptual model endpoints and important ecological processes (Bartolo et al. 2018).
- the definition of key ecological components underpinning the environmental requirements of the Ranger Project Area and surrounds and the interactions with underpinning processes (BMT 2018)
- the development, in consultation with Traditional Owners, of indicators for cultural closure criteria, including some for water (Section 8.3.6)
- the identification of uranium as the COPC in reports on accumulation of metals in contaminated sediments on the minesite. Other metals showed limited enrichment even in the sediments of the waste water treatment wetlands (Iles et al.. 2010, Parry 2016, Esslemont and Iles 2017)
- the selection of indicators for drinking water and recreation from NHMRC & NRMMC (2011; v3.5 updated 2018) and NHMRC (2008) based on the surface water COPCs identified by Frostick et al.. (2012)
- a review of current load limits for nutrients and a risk assessment of eutrophication that indicated a low risk from nutrients following closure. Nutrients have therefore been removed from the closure criteria list. Nutrients will be monitored during and following

[8] https://www.environment.gov.au/science/supervising-scientist/publications/ss-rehabilitation-standards

[9] Management goals and criteria for sedimentation are captured in the Landform and Cultural themes

closure and the risk reviewed with updated predictions of post closure contaminant discharges (Section 5.5.2.1.5)

- expert advice will be sought on indicators relevant to a diet assessment. This will include an expert review of the indicators and GVs for drinking water

A review of COPC for all sources on the Ranger Mine was conducted by ERM Ltd as part of the *Background concentrations of COPC in groundwater* project. No new COPCs have been added to the closure criteria list as a result of this review. COPCs will be reviewed again as a component of the contaminated sites sampling campaign. The list of indicators for W/SQO will be reviewed when outcomes from this project are available.

Radionuclides are discussed in Section 8.3.3.

Step 4. Determine water/sediment quality guideline values

Determine the water/sediment quality guideline values for each of the relevant indicators required to provide the desired level of protection (if applicable) for the management goals for relevant waterways.

Ecosystem protection

Guideline values (GV) for high-level ecosystem protection have been derived by the SSB and reported in their Rehabilitation Standard Series[10]. These are identified as being applicable at the lease boundary in Magela and Gulungul creeks. Meeting these GVs at the lease boundary provides an assurance that no change will occur to the offsite biodiversity.

The GV for uranium in surface water was found to protect against sediment toxicity effects considering the potential for accumulation and de-adsorption from sediment back to surface waters at unacceptable concentrations. This could negate the need for an uranium GV for sediment (SSB 2019). A narrative guideline was used for sediments referring to meeting the GV for U in water in the 2019 MCP. Due to ongoing discussions with the Alligator Rivers Region Technical Committee (ARRTC) this criteria remains in the draft table with the value being the rounded up value of the interim sediment quality criteria derived by the SSB. The SSB are finalising their advice on the guideline value for uranium in sediment

GVs based on ecotoxicity studies of the SSB are available for species protection levels of 99, 95, 90 and 85 %. The closure objective for water quality in the Ranger Project Area (ERA 2018), reflecting ER 1.2e was stated as *'Surface water quality on the RPA [Ranger Project Area] meets the highest ecosystem protection level that is demonstrated to be reasonably achievable.'* Stakeholder feedback indicated that a process was needed to determine what water quality was ALARA and recommended that quantifiable numeric values are derived to reflect ALARA values. This is addressed in Step 8.

[10] https://www.environment.gov.au/science/supervising-scientist/publications/ss-rehabilitation-standards

Management goals differ for on and off the RPA, and therefore GVs would also be expected to differ. However, the same GVs can be used for on and off the RPA at this step. Subsequent steps will enable refinement of GVs and W/SQO for on and off the RPA.

Diet and recreation

Guideline values for drinking water are from the Australian drinking water guidelines NHMRC & NRMMC (2011; v3.5 updated 2018)

In addition to comparing predicted COPC concentrations to these guideline values, an assessment of risk from water quality to the traditional diet, including drinking water, will be undertaken by a specialist. This assessment will be based on the water quality predictions from the surface water model.

The Australian recreation guidelines (NHMRC 2008) provide recreation water quality guidelines for chemical hazards, pH and dissolved oxygen, and suggest using ten times the drinking water guidelines as a simple screening approach to identify COPC that may merit further consideration where waters might be swallowed during recreation. NHMRC (2008) also says *"… waters contaminated with chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreational purposes…"* However the NHMRC (2008) guidelines do not provide a list of irritants or guideline values for such chemicals, whereas ANZECC & ARMCANZ (2000) do. The GV for sulfate was therefore taken from ANZECC & ARMCANZ (2000).

The same parameters identified for drinking water are used as suggested above. I should be noted that the irritant guideline values for sulfate is more restrictive than using the drinking water times ten approach.

The lower range in Magela Creek is less than the pH guideline suggested for poorly buffered low ionic strength waters by NHMRC (2008). Turner *et al.* (2015) demonstrated that the natural range of pH in Magela Creek is 4.7 to 7.9 and highly variable and considered it *"highly unlikely that a quantity of mine derived water sufficient to significantly alter the pH in Magela and Gulungul creeks could be released"* and removed pH from the list of compliance parameters. Considering this, pH is not considered a parameter that requires a GV for recreation purposes. Should future acid sulfate soils studies indicate a potential risk, consideration will be given to the inclusion of a GV for pH.

Dissolved oxygen is also highly variable in the seasonal waterbodies on and off the RPA and there has been no requirement for compliance monitoring of dissolved oxygen for several decades at Ranger Mine. Dissolved oxygen is also not considered a parameter that requires a GV for recreation purposes.

Step 5. Define draft water/sediment quality objectives

Use the guideline values or narrative statements chosen for each selected indicator as draft water/sediment quality objectives to ensure the protection of all identified community values and their management goals (ANZG 2018).

Choose the most stringent of the guideline values for the water/sediment quality objectives (ANZG 2018).

- For water, the same indicator appears against several management objectives in Table 8-6. The ecosystem protection GV are more stringent than GVs for the same parameter for other management objectives. The most stringent of the GVs for each indicator is underlined. These are the GVs that are adopted as draft W/SQO at this step.
- ANZG (2018) supports narrative statements (as opposed to numeric values) as GVs and W/SQO. Several examples of narrative draft W/SQO are used in Tables 8-6 and 8-7, e.g. demonstrating what water quality is ALARA and for aesthetic water values.

Step 6. Assess whether draft water/sediment quality objectives are met

Use measurements from the monitoring of each relevant indicator to assess whether current water/sediment quality meets the draft water/sediment quality objectives (ANZG 2018).

- ERA has engaged consultants to use numerical models to predict the concentration and loads of a range of contaminants in surface water on, and downstream of, the Ranger Mine after mine closure (Section 5.5.2.11). Initial predictions have been provided and are being compared to the draft W/SQOs. Improvements are being made to the suite of models used with updated outputs to be available in late 2020. The predicted concentrations of these COPC will be compared to the draft W/SQO and the following steps of the WQMF implemented as appropriate. The outcomes will form part of the Pit 3 closure application process.

Step 7. Consider additional indicators or refine the water/sediment quality objectives

Assess the need to revise or add to the lines of evidence or indicators and the water/sediment quality guideline values (ANZG 2018).

It is likely that concentrations higher than the draft W/SQO will be predicted for some locations/times on the disturbed mine footprint in the RPA. Less likely, though still possible, is the potential that predicted concentrations exceed the draft W/SQO in small areas close to the RPA lease under certain (low) flow conditions.

If concentrations do exceed the draft W/SQO, this does not necessarily imply that impacts will occur. Further assessment is required to understand the implications; this type of tiered assessment is common to many guideline frameworks (eg EnHealth 2012, NHMRC 2008, NHMRC & NRMMC 2011).

Assessing the need to revise the GVs or add additional indicators and lines of evidence will be done by the stakeholder working group. The approach would depend on the nature (extent, duration, intensity, location etc.) of any predicted exceedance.

The draft W/SQO is for high-level ecosystem protection. On the RPA the goal is for impacts that are ALARA so the need to revise the GV for application to the RPA is not unexpected. Step six will indicate which COPC GVs need to be revised.

Some progress on alternative GVs and additional indicators and lines of evidence has been made.

- GVs are available from the ecotoxicity studies of the SSB and ANZG (2018) for alternative levels of species protection for most COPC.
- BMT Ltd has been working with ERA and stakeholders since 2017 in a three-phase project to:
    - identify preliminary ecological and cultural endpoints for each of the primary environmental objectives (BMT WBM 2017)
    - map environmental values for different water types on and off the RPA (BMT 2018)
    - to develop a risk-based vulnerability assessment framework considering impact components such as duration, geographic extent and resilience, to determine how different concentrations of magnesium—potentially the most restrictive contaminant of concern—might affect these endpoints. This involves considering direct sensitivity to magnesium concentrations and indirect sensitivity via other factors affecting vulnerability, such as habitat, diet, reproduction and dispersion. (Section 5.5.2.16 provides a description of the project).

Step 8. Consider alternative management strategies

Evaluate the effectiveness of current management strategies to address the identified water quality issues and recommend possible improvements. Improved or alternative management strategies are to be formulated, assessed and prioritised.

Consideration of alternative management options, community, environmental and cost aspects are common to both ALARA and BPT assessments. Impacts on the RPA must be ALARA and closure options must undergo a BPT assessment.

The BPT assessment process compares different management options and ranks them against each other based on scores for each of the BPT criteria. This includes criteria categories for water quality and environment protection. All scores are combined to form a single value, and the different options are ranked. The option with the best score is deemed the best practicable technology.

ERA has identified a process that combines options assessments with a risk management framework to demonstrate that the chosen closure strategy is based on BPT and ALARA. ERA proposes that the analyte concentration associated with the option that is considered BPT-ALARA will be the water quality that is adopted as W/SQO for on the RPA. This aligns with the ALARA approach for radiation protection described by Oudiz *et al*. (1986), shown in Figure 8-6. Refer to Appendix 6.2 for further details.

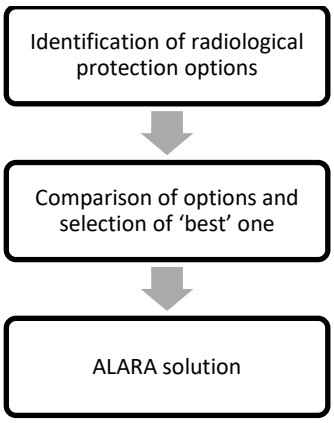

Figure 8-6: The main features of the ALARA procedure (Oudiz *et al*. 1986)

Step 9. Assess whether water/sediment quality objectives are achievable

Use information gained from Steps 6 to 8 to assess whether the water/sediment quality objectives are achievable.

As discussed at step 6 predicted water quality post-closure will be compared with the agreed objectives for ecosystem protection onsite and offsite.

Step 10. Implement agreed management strategies

Document and implement agreed management strategies, including, in some cases, a suitable and agreed adaptive management framework.

Management strategies will be documented in applications to stakeholders and regulators for approval for key activities. Applications will include the results of BPT assessments and the descriptions of mitigations and management actions.

Stakeholder feedback will occur again at this stage. Future Ranger Mine Closure Plans will be updated with a record of progress.

8.3.3 Radiation

There are two objectives derived from the ERs relating to the radiation theme (Table 8-3).

Radiation objective 1:

The first objective comes from ER 2.2 (b) and 11.3 (iii):

> *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*

Radiation objective 2:

The second objective comes from ER 1.2 (d and e):

In particular, the company must ensure that operations at Ranger Project Area do not result in:

> *(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.*

Two outcomes have been derived from these objectives (Table 8-7), one related to the terrestrial environment and one for the aquatic. This division is based on the guidance for assessment provided within the ICRP document. Both outcomes are based on the potential risk to the environment (plants and animals) from above background radiation exposures sourced from the mine. The outcomes have been derived from the guidance provided by the ICRP in its publication 124 *Protection of the Environment under Different Exposure Situations* (ICRP, 2014). This document describes the framework for protection of the environment and how it should be applied within the ICRP system of protection.

The ICRP states that the aims in terms of environmental protection are to prevent or reduce the frequency of deleterious radiation effects on biota to a level where they would have a negligible impact on the maintenance of biological diversity; the conservation of species; or the health and status of natural habitats, communities and ecosystems. The biological endpoints of most relevance are therefore those that could lead to changes in population size or structure.

Table 8-7 provides a summary of the closure objectives, the outcomes derived from these objectives, parameters used to measure the outcomes and the proposed closure criteria. In some cases, corrective action is also provided in the event that the expected outcome is not accomplished. Some criteria also have linkages to cultural criteria. Where this occurs, reference has been made to the cultural criteria section for more details. These criteria are all consistent with the SSB Rehabilitation Standards on radiation (SSB 2018c, SSB 2018d)

Reflecting the guidance of the International Atomic Energy Agency (IAEA) (2006) and the ICRP (2014), radiation closure criteria are provided as radiation dose rates. To confirm that the radiation closure criteria proposed in Table 8-7 will be met in the post-closure phase, ERA commissioned a radiological impact assessment be undertaken, which commenced in the third quarter of 2017. The radiological impact assessment considers potential radiation exposure to members of the public, as well as terrestrial and aquatic biota. A summary of the radiological impact assessment is provided in Section 7.9.1.

Section 8.3.3.1 provides justification for the outcomes, parameters and closure criteria for each of the key elements of the radiation theme: radiation doses to members of the public and radiation doses to terrestrial and aquatic biota.

Table 8-8: Closure criteria – radiation

ER	Objective	Outcome	Parameter	Summary of criteria for Minister Approval[11]	ID	Cultural link
2.2 (b) and 11.3 (iii)	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.	Radiation doses to members of the public are ALARA	Using the agreed restrictions on land use the total above-baseline radiation dose from pathways: External gamma Inhalation of Radon decay products (RDP) Inhalation of dust Ingestion of bush food (including water)	0.3 mSv per year	R1	-
		Radiation doses to members of the public are below limits	Should land use restrictions fail, the total above-baseline radiation dose from pathways: External gamma Inhalation of RDP Inhalation of dust Ingestion of bush food (including water)	1 mSv per year	R2	--
1.2 (d,e)	In particular, the company must ensure that operations at the Ranger do not result in: (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.	Minimise the deleterious radiation effects on terrestrial biota to a level where they would have a negligible impact on the maintenance of biological diversity; the conservation of species; or the health and status of natural habitats, communities, and ecosystems.	Total above-baseline absorbed dose rates to the most highly exposed terrestrial plants and animals	100 µGy/h to the most highly exposed terrestrial species	R3	--
		Minimise the deleterious radiation effects on aquatic biota to a level where they would have a negligible impact on the maintenance of biological diversity; the conservation of species; or the health and status of natural habitats, communities, and ecosystems.	Total above-baseline absorbed dose rates to the most highly exposed aquatic plants and animals	400 µGy/h to the most highly exposed aquatic species	R4	--

[11] Criteria to be read in conjunction with the closure criteria details provided in Mine Closure Plan Section 8.3.3.

8.3.3.1 Justification for outcome, parameter and criteria

Radiation doses to members of the public

Two outcomes have been derived from this objective, the first relates to the requirement to have radiation doses to members of the public remain below limits and the second to also keep these doses as low as reasonably achievable.

The premier international body for radiation protection is the ICRP. The limits for exposure to radiation and recommendations of the ICRP have been generally adopted worldwide.

The primary aim of the ICRP is to contribute to an appropriate level of protection for people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure.

The ICRP has recommended a three-tier approach to radiation protection, called *the Fundamental Principles of Radiation Protection*:

> **The principle of justification:** Any decision that alters the radiation exposure situation should do more good than harm.
>
> **The principle of optimisation of protection:** The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors (the ALARA principle).
>
> **The principle of application of dose limits:** The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission.

The recommendations of the ICRP are taken by the IAEA to develop radiation safety standards and guidelines that are then used internationally to protect human health and the environment.

The recommendations of the ICRP have no regulatory power in Australia; but are adopted in a joint Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and National Occupational Health and Safety Commission (NOHSC) document. Likewise, the various standards and guidelines published by the IAEA are adopted in Australia through various codes of practice and safety guides published by ARPANSA. The recommendations are also applied to the mining industry through the Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing. This Code is applied to the Ranger Mine operation by several pieces of Commonwealth and Northern Territory Legislation and implemented at site through the Ranger Authorisation.

In the international standards, human activities that add radiation exposure to that which people normally incur due to background radiation, or that increases the likelihood of their incurring exposure, are termed ‘practices'. For uranium mining and processing the various stages of the practice are: design; construction; operation; decommissioning; and release of regulatory control.

The radiation protection principles of justification, dose limitation and optimisation apply to all these stages of the practice.

ERA has adopted a radiation protection policy and developed a Radiation Management System, based on the justification, optimisation and limitation principles established by the ICRP. The policy and system will be applied to the decommissioning phase through the Radiation Management Plan. During the post-closure phase, the principles will be applied through the development and demonstration of compliance with closure criteria. The closure criteria presented in Table 8-7 have been set so that radiation exposures to the public, and risk to the environment, post-closure are ALARA.

The IAEA guidance document *Release of Sites from Regulatory Control on Termination of Practices* (IAEA 2006) sets an upper level structure for the development of radiation closure criteria. The release of sites from regulatory control is the final stage in the decommission process and is also the final stage of the practice; therefore, the radiation protection principles of justification, dose limitation and optimisation apply.

The principle of justification is applied at the adoption of the practice of uranium mining as a whole, which includes construction, operation, decommissioning and final close-out of the project. Therefore, it can be assumed that the decommissioning and closure phases of the practice are justified.

The normal dose limitation for the uranium mining practice will apply, which is set out in the ARPANSA National Directory for Radiation Protection (ARPANSA 2017) For members of the public this will be one milli-Sievert in a year, determined from the sum of effective doses from all possible combinations of exposures.

The optimisation process for decommissioning and release from regulatory control starts with the setting of a dose constraint. The IAEA recommend that the dose constraint should take into account multiple pathways of exposure and should not exceed 300 micro-Sieverts in a year above background; however, each dose constraint should be site specific. When setting a public dose constraint, consideration must be given to the potential for other exposure pathways in the region. Given the Koongarra lease has been relinquished, the only remaining uranium mining lease in close proximity is Jabiluka. Based on the limited exposure pathways in the region, a dose constraint of 0.5 milli-Sieverts (500 micro-Sieverts) would be in keeping with the principles for setting dose constraints; however, ERA has elected to keep the recommended 300 micro-Sieverts per year default from the IAEA.

The IAEA system recommends that the final dose to members of the public is to be optimised below the dose constraint. If this is not achievable without any restrictions on the use of the land, then these may be applied with the additional requirement that the dose to members of the public should not exceed the dose limit of one milli-Sievert per year in case the restrictions fail. This process is illustrated in Figure 8-8 and forms the basis for setting of the radiation criteria for protection of human health outlined previously in Table 8-7.

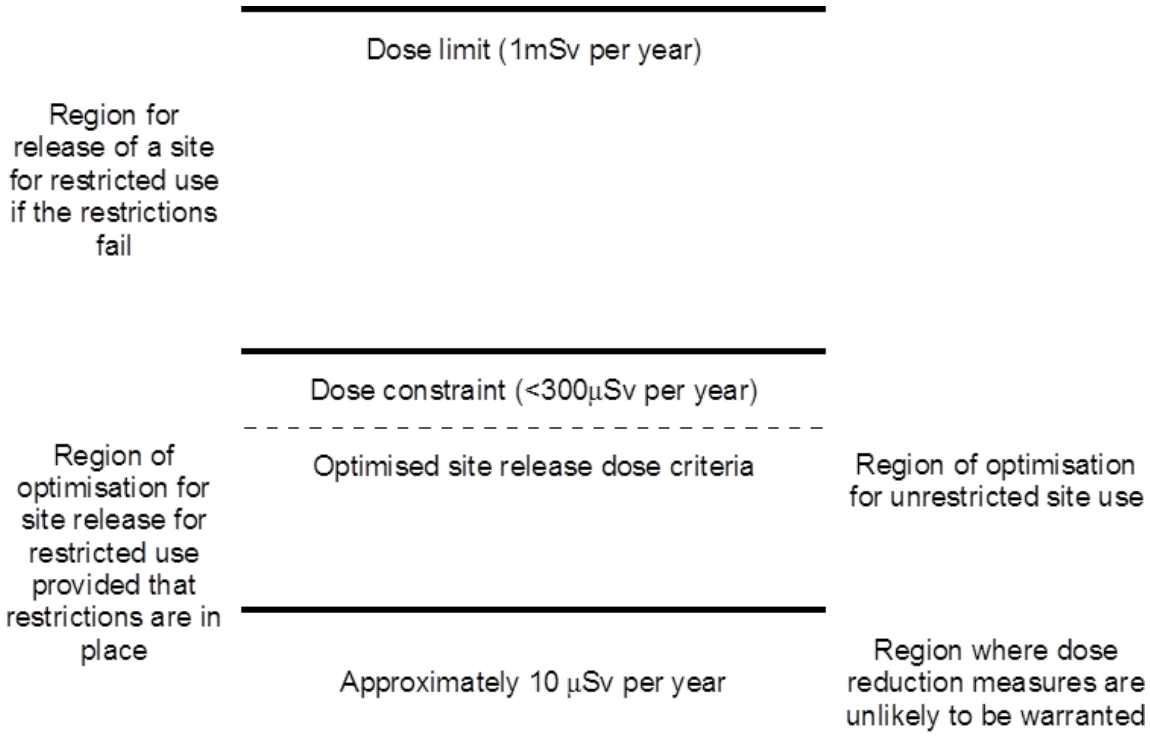

Figure 8-7: Constrained optimisation and regions of effective dose for members of the critical group in the release of sites (IAEA 2006)

To assess if the radiation criteria for human health have been achieved, the following process will be undertaken:

- documentation of baseline radiological conditions for the site
- identification of the representative person
- definition of the probable habitation scenarios and identification of the exposure pathways
- compilation of data for these scenarios and pathways, including definition of all sources, and
- development of radiation dose model for rehabilitated site.

The four main exposure pathways for human exposure to radiation will be direct external radiation, inhalation of dusts, inhalation of radon and its decay products and ingestion of food stuffs (including ancillary ingestion of soil and drinking of water). Member of the public dose assessment will therefore consider the following exposure pathways:

- inhalation of long-lived alpha activity (e.g. radioactive dust)
- inhalation of radon decay products
- ingestion of radioactive material in (or with) food or water
- external irradiation from gamma radiation.

Given the possible post-closure use of the landform, the representative person will be an Aboriginal person using the site for traditional activities including transient camping and the gathering of traditional bush foods for consumption. Details of the land use, occupancy and diet has been discussed in Section 8.1.

To assist with estimating the dose and subtraction of natural background, several radiological studies have been undertaken on the RPA, these include:

- pre-mining, area-wide radiological conditions, as a first step to assessing post-mining changes and the success of rehabilitation from a radiological perspective (e.g. Bollhöfer *et al.* 2014, Bollhöfer *et al.* 2011, Esparon *et al.* 2009)
- above background radiation doses through different pathways, to the public that may access the RPA post-closure (e.g. Akber & Lu 2012, Akber *et al.* 2011a, b, c, Akber & Marten 1991, Lu *et al.* 2009). These studies have primarily focused on potential post-closure occupation in the LAAs on the RPA.

A summary of the pre-mining background levels is provided in Section 5.

Radiation effects on biota

Two outcomes have been derived from the objectives in relation to radiation effects on biota (Table 8-7), with both based on the potential risk to the environment (plants and animals) from above background radiation exposures sourced from the mine. The outcomes have been derived from the guidance provided by the ICRP in its publication 124: *Protection of the Environment under Different Exposure Situations* (ICRP 2014). This document describes the framework for protection of the environment and how it should be applied within the ICRP system of protection.

The ICRP states that the aims in terms of environmental protection are to prevent or reduce the frequency of deleterious radiation effects on biota to a level where they would have a negligible impact on the maintenance of biological diversity; the conservation of species; or the health and status of natural habitats, communities and ecosystems. The biological endpoints of most relevance are therefore those that could lead to changes in population size or structure.

This has been the basis for selection of the outcomes, one related to the terrestrial biota and one for aquatic biota. This division is based on the guidance for assessment provided within the ICRP document (ICRP 2014).

The risk assessment and management of radionuclides entering or present in the environment has historically been based on human health considerations alone. This approach has been underpinned by the ICRP (1991) recommendations that state: *"… if man is protected then it can be assumed that the environment is protected."*

More recently there has been increasing awareness of the potential vulnerability of the environment and of the need to be able to demonstrate that it is protected against the effects of industrial pollutants, including radionuclides. The ICRP, in its recent publications (ICRP 2007, 2008, 2014), has addressed this by recommending that assessments be undertaken of the risk from radiation to animals and plants.

Recommendations for assessment of radiation risk to the environment have been published by multiple international organisations, including the ICRP, IAEA and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). These detail frameworks for assessment of risk through the comparison to a benchmark dose rate value that is considered to provide an acceptable level of protection to the environment (i.e. prevention of deleterious impacts to wildlife populations and ecosystem biodiversity). Recent studies conducted by ERISS have reviewed the international literature relating to benchmark dose rates and determined that the values published by UNSCEAR were considered to be the most appropriate to apply to the Ranger closure criteria (Doering & Bollhöfer 2016).

In order to assess if the radiation criteria for radiation effects on biota have been achieved, the framework documented in ICRP (2014) or similar international guidance will be used to:

- determine the radiation dose rate to a reference set of both terrestrial and aquatic biota
- compare this to the benchmarks documented as the closure criteria

The benchmark dose rates documented as closure criteria are based on the recommendations of UNSCEAR (2008) and recommended for use under the SSB rehabilitation standard for the Ranger uranium mine - Environmental Radiation (Supervising Scientist, 2018c). If the dose rates are below the benchmark dose rate, it can be concluded that there is an acceptable level of protection to the environment (i.e. that deleterious impacts to wildlife populations and ecosystem biodiversity will be prevented).

If dose rates are above the benchmark dose rate, a more detailed review of the doses to that organism will be undertaken along with a review of the actual radiation effects for that organism. An assessment will be made to determine if actual effects will occur and therefore if mitigations are required.

8.3.4 Soils

There is one objective derived from the ERs relating to the soils theme (Table 8-3), which is one of the primary environmental protection objectives, ER 1.2 (e)

> *1.2 In particular, the company must ensure that operations at Ranger do not result in:*
>
> *(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.*

The outcome derived from this objective is that impacted soils are remediated to as low as reasonably achievable to protect the environment.

Table 8-8 provides a summary of the closure objectives, the outcome, parameters used to measure the outcome and a summary of the proposed closure criteria for minister approval. For the case of soils, no link to cultural criteria has been identified. Section 8.3.4.1 provides justification of the outcomes, parameters and closure criteria that were derived.

8.3.4.1 Justification for outcome, parameter and criteria

An objective for closure is that, where needed, soils will be remediated to a level where their environmental impact is as low as reasonably achievable. The preferred option identified during the best practicable technology assessment will be progressed whilst the other options then form the contingency plan, prioritised by rank. Outcomes of contaminated sites assessments will be included in future versions of the MCP.

Achievement of these criterion will either be through demonstration that contamination levels are currently or remediated to be low enough that no action is required or through development of a site management plan based on ALARA (refer Section 6.3 and Appendix 6.2).

Table 8-9: Closure criteria – soils

ER	Objective	Outcome	Parameter	**Summary of criteria for Minister Approval**[12]	ID	Cultural link
1.2 (e)	The company must ensure that operations at Ranger do not result in: (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.	Impacted soils are remediated to as low as reasonably achievable to protect the environment.	Contaminated soil assessment for uranium and manganese in LAA	Demonstrate risk is ALARA	S1	-
			Contaminated assessment of identified COPCs for other soils identified as not being part of the larger decommissioning works	Demonstrate risk is ALARA	S2	-

[12] Criteria to be read in conjunction with the closure criteria details provided in Mine Closure Plan Section 8.3.4.

8.3.5 Ecosystem

There is one objective derived from the ERs relating to the ecosystem theme (previously termed flora and fauna) This is one of the primary rehabilitation objectives, ER 2.2 (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.*

Three outcomes have been derived from this objective:

First outcome - relates to the use of local native plant species

Second outcome - relates to the flora and fauna species composition and community structure being similar to Kakadu NP

Third outcome - relates to the long-term viability of the ecosystem and the associated maintenance regime

Closure criteria have been developed for both revegetation and fauna recolonisation. Table 8-9 and Table 8-10 provide a summary of the closure objectives, the outcomes derived from these objectives and parameters used to measure the outcome with the former providing a summary of the proposed Revegetation closure criteria for minister approval and the latter proposed fauna recolonization criteria that remain in draft for further review. Some criteria also have linkages to cultural criteria. Where this occurs, reference has been made to the cultural criteria section for more details.

Section 8.3.5.1 provides justification for the outcomes, parameters and closure criteria for each of the key elements of flora and fauna.

Table 8-10: Closure criteria – Ecosystem (Revegetation)

ER	Objective	Outcome	Parameter	Summary of criteria for Minister Approval[13]	ID	Cultural link
2.2 (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	Revegetate the disturbed sites of the RPA using local native plant species	Provenance	Revegetation has used (100%) local native species from Kakadu NP.	E1	C10
		Species composition and community structure is similar to adjacent areas of Kakadu NP	Species composition and relative abundance	Species composition for all overstorey and midstorey species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E2	C10 C12
				Species composition for all understorey species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E3	
				Stems per hectare of overstorey and midstorey framework species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E4	
				Total species richness of framework species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E5	
				Total species richness of all overstorey and midstorey similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E6	
				Total species richness of understorey species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E7	
			Community structure	Vegetation structure similar to, or on a trajectory towards that of the agreed reference ecosystem(s).	E8	C9, C10
				% Cover of overstorey and midstorey is similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E9	C9
				% Cover of understorey vegetation is similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E10	
				Overstorey and midstorey species distribution ('naturalness') is similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E11	-
		Long term, viable ecosystem which would not require a maintenance regime significantly different from that appropriate to adjacent areas of Kakadu NP.	Reproduction (flowering and seeding)	Flowering and fruiting of framework species (based on species present), similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E12	C10
			Recruitment / regeneration	Recruitment and regeneration of framework species (based on species present), similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E13	C9 C11
			Nutrient cycling	Chemical and biological indicators provide evidence that nutrient cycling will sustain ecological processes, similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).	E14	-
			Resilience	Following implementation of an appropriate fire regime, all other closure criteria must be shown to have been met, demonstrating recovery.	E15	-
				In the event of natural disturbances (e.g. wind, drought, or disease), all other closure criteria must be shown to have been met, demonstrating recovery.	E16	C8
			Weed composition and abundance	No Class A weeds or Weeds of National Significance (WoNS).	E17	C11
				Abundance of Class B weeds no greater than agreed reference ecosystem(s).	E18	
				Abundance of other introduced flora species would not require a maintenance regime significantly different from that appropriate to adjacent areas of Kakadu NP.	E19	
			Exotic fauna	Density of buffalo, horses and pigs on the RPA no greater than adjacent areas of Kakadu NP.	E20	C12

[13] Criteria to be read in conjunction with the closure criteria details provided in Mine Closure Plan Section 8.3.5.

Table 8-11: Draft Closure criteria – Ecosystem (Fauna recolonisation)

ER	Objective	Outcome	Parameter	Draft criteria for review	ID	Cultural link
2.2 (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	Long term, viable ecosystem requiring maintenance similar to adjacent areas of Kakadu NP	Habitat connectivity	Lack of physical barriers (e.g. fences) provides the potential for external exchanges similar to, or on a secure trajectory towards, that of the agreed reference ecosystem(s).	E21	
			Native fauna species richness and diversity	Number of vertebrate species is on a trajectory towards that of agreed reference sites.	E23	
				Evenness of birds species across sites (Pielou's evenness) is on a trajectory towards that of agreed reference sites.	E24	
			Functional diversity of native fauna	Species richness for each of four Key Functional Groups of ants is on a trajectory towards that of agreed reference sites.	E25	
				Species richness of nectivorous and frugivorous species is on a trajectory towards that of agreed reference sites.	E26	
			Target native fauna species	Appropriate criteria for culturally significant fauna when identified.	E28	
				Activity, diversity, and functional diversity of subterranean active termites is on a trajectory towards that of agreed reference sites.	E29	
				Number of threatened species are on trajectory towards that which occurs in the agreed reference sites.	E30	

8.3.5.1 Justification for outcome, parameter and criteria

Derivation of the ecosystem (flora and fauna) criteria is underpinned by an understanding of both general ecological restoration principles (SRG 2017), ecosystem dynamics in northern Australia, and the knowledge gained through 30 years of flora and fauna studies, revegetation trials and research on RPA and surrounding areas. Background information on the various aspects of appropriate reference site selection and the research underpinning the trial landform; plant available water; flora and fauna baseline monitoring; landform design, performance and properties; and, ecosystem establishment is provided in Section 5.3.3 and Appendix 5.1.

Revegetation

The closure criteria for revegetation (Table 8-9) were developed through a process of stakeholder consultation, benchmarking against relevant contemporary practices at other operations and within other jurisdictions, as well as consideration of information from appropriate reference sites and rehabilitation trials. Due to the permanent and irreversible changes to the site, particularly in terms of topography, hydrology and substrate of the final landform, ecological conditions will be different to the pre-mining environment and no real analogue exists in the natural surroundings, which means that one (or more) local indigenous ecosystem/s more ecologically appropriate to the changed conditions may be suited as a guide for revegetation of the site (SRG 2017). Therefore, the target revegetated ecosystem/s in the case of Ranger Mine will be a conceptual ecological model synthesised from numerous appropriate reference sites, revegetation trials, cultural values and historical and predictive records (e.g. modifications for predicted climate change or substrate limitations, Prober *et al.* 2015).

Whilst work is ongoing to obtain and consider additional information from reference sites, development of the Ranger Mine conceptual ecological model for the revegetation objective continues. This model is key to defining the target ecosystem/s and will determine the quantitative, semi-quantitative and/or qualitative closure criteria for assessment of success. It is generally understood that the ecological attributes and parameters proposed for the assessment by ERA are sound, however the criteria may be further revised once the conceptual model is further developed and/or finalised.

Further information on the justification for each component of the ecosystem theme is provided in below including: locally native species; species composition and community structure; and long-term viability of the ecosystem.

The ERA revegetation strategy is based on harnessing and manipulating natural ecological processes such as reproductive phenology and the structural and functional importance of framework species. A key principle is to actively facilitate establishment of framework overstorey species along with a subset of important and predictable midstorey and understorey species (Appendix 5.1). Once these species have established, they will control much of a site's nutrient and water resources, confer resilience to weeds and other threats, and will provide many of the core habitat values for other plants and animals to colonise.

Despite the functional importance of framework species for the long-term sustainability and stability of the plant communities, they are not necessarily the major components of species diversity in the Eucalypt-dominated open woodlands typical of the region. Annual and perennial grasses and forbs in the ground layer often dominate total plant species diversity (measured as species richness, density, cover etc). However, these components can be very ephemeral in their nature, resulting in considerable year-to-year variation in both species diversity and composition, even at a single natural woodland site (eg Fenshaw 1990, Williams *et al* 2003). In particular, the frequency, timing and intensity of fire can cause large changes in the composition of the ground stratum in these woodlands within a single year. As a result, measures of total species diversity and composition can be quite dynamic and variable in a manner that is largely unrelated to the overall functional performance of the plant community (which is controlled by the framework species). This has implications for revegetation in that standard measures of diversity which focus on total species numbers are not necessarily an appropriate indicator of the functional performance, sustainability or habitat values of the plant community at a site.

Reflecting this situation, some closure criteria have been specified for overstorey and midstorey framework species, such as species composition, density, species richness, and reproductive or recruitment measures. This approach ensures that framework species are given the appropriate priority in any assessment. In most cases, the combined vegetation community (all overstorey, midstorey and understorey species) are also considered for the same parameters, although with a degree of similarity reflective of the variability and dynamism of the holistic ecosystem.

Local native plant species

The first outcome for flora and fauna is that the disturbed site must be revegetated using local native plant species. In order to determine what would be considered as "local" a number of provenance studies have been conducted and consultations have occurred with GAC and many national and local experts (Section 5.3.3 and Appendix 5.1).

The resultant criterion is that: "*Revegetation has used (100%) local native species from Kakadu NP*".

In order to achieve this, any plants introduced to the rehabilitation landform as part of the revegetation implementation program will be identified from an agreed revegetation species list which shall only include appropriate species found within the Kakadu NP, as derived from:

- Surveys of suitable reference sites from the RPA and adjacent areas selected to account for the changed conditions of the rehabilitated landform. For example earlier studies jointly by ERA and the SSB, the ERA long-term monitoring program and more recent studies by the SSB (Appendix 5.1);
- A list of culturally important plant species, identified by the Mirarr Traditional Owners in Garde (2015).

The species list is included in the revegetation implementation plan (Section 9.4.6.1) and shall undergo further refinement considering outcomes from ongoing reference site survey and

analysis, revegetation trials, risk assessments, expert advice (including CDU researchers and local native seed experts from Kakadu Native Plants Pty Ltd) and further stakeholder consultation (including appropriate formal review by stakeholders).

Seed collection and revegetation establishment records will be maintained as evidence that the agreed species list was used and this criterion achieved.

Species composition and community structure

The second outcome is that species composition and community structure is similar to adjacent areas of Kakadu NP. Ten parameters are being proposed to measure the achievement of this outcome, which are described in the following sections.

Species composition and relative abundance

Plant species composition and relative abundance in the RPA and surrounding landscape have been studied extensively and have been summarised in Appendix 5.1. An assessment of species composition and relative abundance will ensure that the range of species present and their densities in the revegetation are similar to the agreed conceptual reference ecosystem/s.

Species composition is the array and relative proportion of organisms, in this case vascular plants, within an ecosystem (SRG 2017). This measure is important to understand how an ecosystem works, and how important different species are to an environment. In mature, successful revegetation, these criteria should indicate that a good diversity of characteristic species (based on the agreed conceptual reference ecosystem) have been established and/or that there is improved potential for colonisation of more species over time (SRG 2017). Species composition is generally expressed as a per cent (so that all species components add up to 100%) and can be considered on either an individual species basis, or by species groups depending on the objectives of the revegetation or monitoring program (e.g. Eucalyptus spp., perennial grasses, etc.). The degree of compositional similarity between two ecosystems (e.g. a reference ecosystem and a revegetated ecosystem) can be assessed using a range of indices, for example the Bray-Curtis similarity (or dissimilarity) index (Bray and Curtis 1957).

The relevant criteria are:

- Species composition for all overstorey and midstorey species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).
- Species composition for all understorey species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

Density

“Density” in plant ecology is defined as the number of individuals of a group (e.g. species, genera, or overstorey / dominant trees and shrubs) that occur within a given area, for example stems per hectare. Density of overstorey and midstorey framework species (as a group) is a basic metric used to ensure that sufficient representatives of that important cohort are present

to confer the requisite ecological functions (site capture / dominance; long-term resilience to disturbance; amelioration of lcoalised environmental conditions).

The relevant criterion is:

- Stems per hectare of overstorey and midstorey framework species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

Species Richness

Species richness is simply a count of the number of different species represented in an ecological community, landscape or region. It does not take into account the abundances of the species or their relative abundance distributions.

As described above in the discussion on local species, the target diversity and abundance of species for Ranger revegetation is derived from suitable reference ecosystems, culturally important species and outcomes of revegetation trials. The current revegetation R&D list includes 119 species, dominated by overstorey and midstorey framework species but including other trees, shrubs, palms, lianes and understorey species (Appendix 5.1). This is comparable to the total number of species (127) detected in earlier surveys of Eucalypt-dominated savannah woodlands in the Georgetown reference area (Hollingsworth & Meek 2003).

As discussed in the introduction above, closure criteria for the species richness of the different cohorts (framework, overstorey and midstorey, and understorey) are considered separately to enable differentiation of their relative importance to the revegetated ecosystem at Ranger Mine.

The relevant criteria are:

- Total species richness of framework species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).
- Total species richness of all overstorey and midstorey similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).
- Total species richness of understorey species similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

Community Structure

The forests and woodlands of the Kakadu NP are multi-strata systems, typically with distinct canopy, midstorey and ground layer (Russell-Smith 1995b) (Appendix 5.1). At a given site, the structural characteristics of the vegetation are determined primarily by the availability of water and, to a lesser extent, nutrients within that part of the regolith accessible to plant roots. As a consequence, the accessible depth and hydrological storage characteristics of the regolith under the final landform will be important controls on the potential for structural development in the revegetation.

Structural characteristics may be assessed as vegetation height, the depth and total leaf area of each stratum, and/or the density, diameter and size class distribution of stems.

The relevant criteria are:

- Vegetation structure similar to, or on a trajectory towards that of the agreed reference ecosystem(s).
- Percentage cover of overstorey and midstorey similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).
- Percentage cover of understorey vegetation similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

Tree distribution or 'naturalness'

The composition and distribution of vegetation across the revegetated landscape may be impacted by physical and chemical constraints, which is why it is important that these measures are considered within the different domains, and based on comparison with suitable, agreed conceptual reference ecosystems.

Following early revegetation activities, the revegetated ecosystem/s will develop and mature with time and appropriate management, with increasing diversity and structural complexity, internal recruitment as well as external colonisation of new species and/or additional plants into new locations on the landform. In the long term (and following some generational turnover of framework overstorey species), the initial planting layout is likely to be barely discernible and the natural occurrence of vegetation community preferences and therefore distribution is more likely to be a result of localised site conditions, fire regimes, and proximity to different recruitment sources. By 25 years, the mature, overstorey and midstorey trees and long-lived shrubs may still largely reflect the initial planting layout (although cohorts of recruits will likely be present), and so a closure criterion relating to the distribution of these is reasonable.

The relevant criterion is:

- Overstorey and midstorey species distribution ('naturalness') similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

A suitable assessment approach will ensure that other criteria (such as composition, density, structural stratification and cover) combine to ensure that a reasonably 'natural' distribution of the important overstorey and midstorey species within the different revegetated domains is achieved. Assessment of achievement of these criteria will be based on surveys conducted according to the Northern Territory vegetation survey guidelines (Brocklehurst *et al.* 2007).

Long-term viability of the ecosystem

The third outcome is to achieve a long-term, viable ecosystem 'which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park'. There are eight parameters proposed to measure the achievement of this outcome, which are described in the following sections.

Reproduction (flowering and fruiting)

Under normal conditions reproductive (sexual) propagation is the key to the survival of the vegetation population. Flowering and fruiting (or seeding) also provides other vital ecological functions such as pollen, nectar and seeds for various insects, birds and other animals, and cultural function such as bush foods and traditional produce (such as bush soaps).

The relevant criterion is:

- Flowering and fruiting of framework species (based on species present) similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

Recruitment and regeneration

Under current land management practices in the Kakadu NP area, particularly fire management regimes, the majority of the successful natural regeneration of terrestrial plants is via vegetative propagation (e.g. root suckers). Therefore, recruitment and regeneration of vegetation will include regeneration from both seedlings and root suckering.

The relevant criterion is:

- Recruitment and regeneration of framework species (based on species present), similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

Nutrient cycling

The process of nutrient cycling will be important for the ongoing sustainability of revegetation, and can be assessed through a range of biological attributes including litter cover, depth and and degree of decomposition (Ludwig *et al.* 2003), the presence of soil organisms including soil fauna and saprophytic fungi (including wood decomposers for woody stems and logs), and plant health. Direct chemical analysis of the nutritional status of soils (and plants) may also prove useful to assessing this parameter.

The relevant criterion is:

- Chemical and biological indicators provide evidence that nutrient cycling will sustain ecological processes, similar to, or on a trajectory towards, that of the agreed reference ecosystem(s).

Resilience

The current landscapes found across Australia's tropical savannah are largely a product of the various fire regimes and climatic dynamics in these regions i.e. distinct wet and dry seasons.

Local native woodland species in the surrounding Kakadu NP are mostly fire resilient. The fire resilience of these plants is by inherent characteristics, although the development stages will also influence resilience. ERA revegetation will use only locally native species in similar proportions to surrounding communities, and therefore it is considered that the fire resilience should be similar. Based on the ERA trial landform studies (Wright 2019) and studies on the RPA (e.g. Gardener *et al.* 2007), it is expected that the majority of the framework tree and

shrub species planted as tubestock would achieve resilience to fire within five to seven years. The proposed revegetation strategy therefore requires fire exclusion of the revegetation area for five to seven years.

Following this initial exclusion timeframe, fire will be introduced in a controlled manner prior to allowing uncontrolled fire entry. Following introduction of a fire regime typical for that of Kakadu NP, the mature revegetation will demonstrate resilience through key composition and density metrics being sustained following fire. Assessment of achievement will be through a post-fire vegetation survey of an area determined in consultation with the Supervising Authority.

The relevant criterion is:

- Following implementation of an appropriate fire regime, all other closure criteria must be shown to have been met, demonstrating recovery.

A resilient ecosystem can be simply thought of as one which can experience the range of reasonably anticipated, 'natural' disturbance events and maintain (or return to) its pre-disturbance condition (given natural degrees of inherent variation).

Resilience of the revegetated Ranger ecosystem to wind and drought will be largely dependent upon appropriate species composition and, particularly for overstorey and midstorey trees and shrubs, the development of a good root system. Early watering of the revegetation post planting can decrease the risk of mortality. However, long-term watering can lead to shallow root development and decrease resilience to wind and drought. The current revegetation strategy involves initial watering (3-6 months), then reliance on only wet season rainfall to ensure appropriate root development.

The relevant criterion is:

- In the event of natural disturbances (e.g. wind, drought, or disease), all other closure criteria must be shown to have been met, demonstrating recovery.

Weed composition and abundance

In order to have a maintenance regime that is not significantly different from that of the surrounding Kakadu NP, weed populations will need to be comparable. The closure criteria are based on the applicable national and Northern Territory legislation. In addition to the prescribed weeds, there are also some introduced species that have the potential to increase the maintenance programs above that of the surrounding Kakadu NP, for example Annual *Pennisetum*. Any weed that is assessed as presenting this risk will be monitored and demonstrated to not require a maintenance regime significantly different from that appropriate to adjacent areas of Kakadu NP.

Demonstration of achievement will be through weed survey conducted according to the Northern Territory Weed Management Branch Guidelines (2015a, b).

The relevant criteria are:

- No Class A weeds or Weeds of National Significance (WoNS).

- Abundance of Class B weeds no greater than agreed reference ecosystem(s).
- Abundance of other introduced flora species would not require a maintenance regime significantly different from that appropriate to adjacent areas of Kakadu NP.

Exotic fauna

In accordance with the ERs, feral animal numbers on the RPA (specifically buffalo, horses and pigs) may be at similar densities to those in adjacent areas of Kakadu NP. The ERA revegetation and post-closure land management program will continue to actively control feral animals whilst revegetation establishes and develops to a mature, resilient ecosystem. Thereafter, the revegetated ecosystem should have the same degree of resilience to these pressures as the *adjacent areas* of Kakadu NP.

The relevant criterion is:

- Density of buffalo, horses and pigs on the RPA no greater than adjacent areas of Kakadu NP.

Fauna recolonisation

Historically, mine closure globally and in Australia and has focused on the restoration of vegetation communities, while fauna communities have been assumed to passively recolonise restored vegetation (e.g., Palmer *et al.* 1997, Cristescu *et al.* 2012, Cristescu *et al.* 2013, Cross *et al.* 2019a, Cross *et al.* 2019b). This approach is reflected in previously proposed draft closure criteria for Ranger, including the ERs which do not specifically address fauna. The closure criteria for native fauna identified in the 2018 Ranger MCP (Energy Resources of Australia Ltd and Eco Logical Australia 2018) included 'presence of major functional groups (vertebrate and invertebrate)' and 'feral animals … are similar in density on the RPA compared to the adjacent areas of KNP'. In the same MCP, 17 criteria for vegetation were presented. Fauna recolonisation closure criteria were expanded in the 2019 MCP (Energy Resources of Australia Ltd and Eco Logical Australia 2019) to include:

- 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.
- Local native mammals, birds, reptiles and invertebrates using the site (or likely to). 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.
- Feral animals (specifically buffalo, horses and pigs) are similar in density on the RPA compared to the adjacent areas of Kakadu NP.

The feral animals criteria has now been finalised for minister approval, see exotic fauna section above. The remainder of the fauna recolonisation criteria are in draft and require further studies and stakeholder consultation. Table 8-10 presents the current draft criteria, these will be reviewed with stakeholders and updated ready for minister approval in the 2021 MCP. Details of each of the draft criteria are provided in the following sections.

Fauna habitat

Tree hollows provide important habitat for amphibian, bird, mammal and reptile species, including many species which are hollow-dependent (Taylor *et al.* 2003, Goldingay 2009, Goldingay 2011, Lindenmayer *et al.* 2014). Individuals of hollow-using and dependent species generally use multiple hollows selected on a number of characteristics, which potentially include tree size, height of hollow, entrance size, hollow form and position, hollow aspect and/or hollow depth (Goldingay 2009, 2011). Hollows (particularly uncommon large hollows) occur most frequently in large, old trees and Goldingay (2011) estimated that most trees used as mammals dens (including those in the NT) were >100 years of age. The development of a self-sustaining array of tree hollows (where recruitment of new hollows balances attrititon of exisiting hollows) suitable to support hollow-using or dependant fauna is therefore predicted to occur far beyond the 25 year timeframe for achievement of closure criteria. The development of tree hollows will be assessed based on the density of potentially hollow bearing tree species.

Fauna habitat including the provision of hollow bearing tree species and edible fruit species, is addressed in the flora closure criteria.

Habitat connectivity

Habit connectivity criteria for physical barriers have been included and is based on the SSB standards with minor word changes. Criteria for pollinators and frugivores is discussed under functional diversity of native fauna.

Native fauna species richness and diversity

The similarity of fauna richness and diversity with pre-mining or reference ecosystems is the most frequently studied indicator of fauna responses to mine rehabilitation globally (see reviews by Cristescu *et al.* 2012, Cross *et al.* 2019b). Empirical evidence demonstrates that fauna richness and diversity can be expected to increase over time, and that values approach (or in some cases exceed) values in reference ecosystems for a range of fauna groups (e.g., Nichols and Grant 2007, Brady and Noske 2010, Gould 2011, Frick *et al.* 2014, Triska *et al.* 2016, Houston *et al.* 2018).

Criteria are being proposed for both vertebrate species overall and for birds (for which a sufficient number of species for assessment of evenness are likely to be detected (Anderson 2019) including:

- Number of vertebrate species is on a trajectory towards that of agreed reference sites.

- Evenness of birds species across sites (Pielou's evenness) is on a trajectory towards that of agreed reference sites.

Functional diversity of native fauna

Ants have been widely used as ecological indicators of habitat disturbance in the Australian tropics (King *et al.* 1998, Andersen *et al.* 2002, Hoffmann and Andersen 2003, Lawes *et al.* 2017), and were the dominant ground-active invertebrates on the Ranger Trial Landform and reference sites surrounding the mine surveyed by Andersen and Oberprieler (2019).

A widely used classification of ants into nine functional groups, based on their responses to stress and disturbance, is provided by Andersen (1995). This list was refined based on the outcomes of surveys at the Ranger Trial Landform and reference sites, and four functional groups are were identified as the Key Functional Groups for the site (Andersen and Oberprieler 2019):

- dominant Dolichoderinae
- hot-climate specialists
- specialist predators
- subordinate Camponotini

The draft criteria for functional diversity of ants is:

- Species richness for each of four Key Functional Groups of ants is on a trajectory towards that of agreed reference sites.

The SSB Rehabilitation Standards include reference to vertebrate pollinators/frugivores, but does not give further details; this has been further refined. In contrast to invertebrates, there is no widely accepted classification of Australian vertebrates to functional groups. Within the Alligator Rivers Region a number of studies have inconsistently classified the same species as belonging to different functional groups (including inconsistent classifications by the same authors). We thus recommend a simplified approach to vertebrate functional groups, whereby species that use specific resources, which are among the later to develop in the rehabilitated landscape, and species that perform key ecological functions are targeted. These species include nectivorous and frugivorous bird species (which both indicate that suitable habitat resources are available, and facilitate dispersal and pollination of plant species), and species that use hollows[14] (assessment of frugivorous and hollow using species is also supported by Andersen 2019 and Einoder *et al.* 2019).

[14] Acknowledging that until the rehabilitation has developed self-sustaining array of tree hollows, it is likely to comprise only part of the home range of any hollow using fauna

Frugivorous and nectivorous vertebrate species that will potentially occur within the rehabilitated Ranger mine site identified by John Woinarski are listed in Table 8-11.

Table 8-12: Frugivorous and nectivorous bird species that may occur within the rehabilitated Ranger Mine site

Common Name	Scientific name	Importance of fruit*	Importance of nectar*
Australasian Figbird	*Sphecotheres vieilloti*	1	
Banded Honeyeater	*Cissomela pectoralis*		1
Bar-Shouldered Dove	*Geopelia humeralis*	2	
Blue-Faced Honeyeater	*Entomyzon cyanotis*	2	1
Brown Honeyeater	*Lichmera indistincta*		1
Channel-Billed Cuckoo	*Scythrops novaehollandiae*	1	
Dusky Honey-Eater	*Myzomela obscura*		1
Eastern Koel	*Eudynamys orientalis*	1	
Great Bowerbird	*Phalacrocorax carbo*	2	
Helmeted Friarbird	*Philemon buceroides*	2	1
Little Friarbird	*Philemon citreogularis*	2	1
Little Shrike-Thrush	*Colluricincla megarhyncha*	2	
Mistletoebird	*Dicaeum hirundinaceum*	1	
Northern Rosella	*Platycercus venustus*	2	
Olive-Backed Oriole	*Oriolus sagittatus*	2	
Red-Collared Lorikeet	*Trichoglossus haematodus*	2	1
Red-Winged Parrot	*Aprosmictus erythropterus*	2	2
Rose-Crowned Fruit-Dove	*Ptilinopus regina*	1	
Rufous-Banded Honeyeater	*Conopophila albogularis*		1
Rufous-Throated Honeyeater	*Conopophila rufogularis*		1
Silver-Crowned Friarbird	*Philemon argenticeps*	2	1
Spangled Drongo	*Dicrurus bracteatus*	2	
Torresian Imperial Pigeon	*Ducula bicolor*	1	
Varied Lorikeet	*Psitteuteles versicolor*		1
White-Bellied Cuckoo-Shrike	*Coracina papuensis*	2	
White-Gaped Honeyeater	*Lichenostomus unicolor*	2	1
White-Throated Honeyeater	*Melithreptus albogularis*		1
Yellow Oriole	*Oriolus flavocinctus*	1	
Yellow-Throated Miner	*Manorina flavigula*		2

The proposed vertebrate functional diversity closure criteria is:

- Species richness of nectivorous and frugivorous species is on a trajectory towards that of agreed reference sites.

Target native fauna species

Culturally significant species - ERA is conducting ongoing regular stakeholder consultation with the Gundjeihmi Aboriginal Corporation (GAC) and the Northern Land Council (NLC). However, fauna of importance within woodland ecosystems have not been addressed to date. This criteria is yet to be developed.

Environmentally significant species - The key fauna groups of environmental significance include groups that indicate key ecosystem functions are occurring (i.e. decomposer fauna) and groups whose recolonisation is considered relatively challenging and dependent on the provision of specific resources. Species dependant on fruit and/or nectar and hollows, which could also be considered environmental key target species, are addressed as key functional fauna groups.

The SSB Rehabilitation Standards refer to the abundance and diversity of key invertebrate species (including ants and termites) in their consideration of nutrient cycling (Supervising Scientist Branch 2018). Ant abundance and diversity is addressed in other criteria.

Using 'termite activity' as an indicator can be problematic, as 'termites' as a whole are diverse and difficult to systematically survey. An alternative approach that provides a measurable outcome of termite activity is the method for sampling subterranean termite species diversity and activity in tropical savannas described by Dawes-Gromadzki (2003). This approach uses multiple bait types (including paper rolls, cardboard, and wooden stakes) from which the activity and diversity of subterranean termites can be assessed. The assessment of subterranean termite fauna will be to compare to their activity in reference sites.

- Activity, diversity, and functional diversity of subterranean active termites is on a trajectory towards that of agreed reference sites.

The Black-footed Tree-rat, Fawn Antechinus and Partridge Pigeon, which are listed as threatened under the TPWC Act or the EPBC Act, have been identified in the assessment of vertebrate species in the Ranger Mine site surrounds. The Black-footed Tree-rat and Partridge Pigeon are considered 'detectable' (Einoder *et al.* 2019). The presence/absence of these species will be assessed.

- Number of threatened species are on trajectory towards that which occurs in the agreed reference sites.

8.3.6 Cultural

There is one objective for closure under the cultural closure criteria theme, which is the combination of two ERs: ER 1.1 (a); and ER 2.1:

> *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:*
>
> *(a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list;*
>
> *2.1 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.*

ER 1.1 (a) requires that ERA maintains the attributes for which Kakadu NP was inscribed on the world heritage list. These world heritage values have multiple criteria that are based on the cultural values in the park. ER 2.1 is the overall objective for closure of Ranger Mine, stating that it must be rehabilitated to a standard that could be incorporated into Kakadu NP, linking rehabilitation to the requirement that there is no impact on the World Heritage Values of Kakadu NP.

Several outcomes have been extracted from these objectives. These outcomes were all based on consultation work completed by Murray Garde in 2014 (Garde 2015). This work built upon a large body of previous consultation work and studies into cultural closure criteria completed by ERA, NLC and GAC. There is regular and ongoing stakeholder consultation with the GAC and NLC to finalise the cultural criteria that will be provided in the 2021 MCP.

The cultural closure criteria are closely linked to other criteria, with the linkages shown in each of the criteria tables.

A summary of the closure objectives, the outcomes derived from the objectives, parameters used to measure the outcome and the proposed closure criteria as at 2020 is provided in Table 8-12. Each cultural criterion has been numbered to show links to the various other closure criteria listed in the previous sections. Section 8.3.6.1 provides justification for the outcomes, parameters and closure criteria for each of the key elements of the cultural theme.

Table 8-13: Closure criteria – cultural

ER	Objective	Outcome	Parameter	Summary of criteria for Minister Approval[15]	ID #	Other criteria link
1.1 (a) 2.1	The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives: (a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list; 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.	Landform design supports cultural land use: An-berrk, savannah woodland An-bouk, riparian margins An-gabo, water courses An-labbarl, billabongs Traditional Owners satisfied with the landform.	Size of rocks	≥7 Surface rock suitability verified by Bininj monitoring - confirm mostly correctly sized	C1	
			Presence / absence of erosion	≥7 Erosion verified by Bininj monitoring – limited to very minor concerns and only small areas	C2	L3, L4
			Accessibility, traversability[16]	≥7 Traversibility verified by Bininj monitoring – limited to minor difficulties only and few in number	C3	L4
			General aesthetics (does it look 'natural')	≥7 Natural aesthetic verified by Bininj monitoring – confirm most areas look natural, limit of a few not satisfactory	C4	-
		Traditional Owners are observing improvement in the progression of revegetation on the landform	Vegetation growth rate	≥7 Growth rate verified by Bininj monitoring – relative to the number of seasons, the growth of plants across all areas is satisfactory and is improving	C8	E16
			Vegetation diversity	≥7 Diversity verified by Bininj – all of the expected species are present in a natural combination in nearly all of the area	C9	E8, E13, F7
			Correct species for ecological zone	≥7 Species verified by Bininj – all of the species are correct for nearly all ecological zones	C10	E1, E2, E3, E4, E5, E6, E7, E8, E12,
			Presence of weeds	≥7 Weeds verified by Bininj – weeds are present in only a minor portion of the area, low level of concern	C11	E13, E17
		Traditional Owners are satisfied that there are not additional water bodies present	Presence or absence of artificial water bodies	Absence of water bodies verified by Bininj monitoring – no artificial water bodies present	C5	L1
		Traditional Owners satisfied with the water quality and that no silting or sedimentation is occurring	Visual impressions of water quality (colour, flow, expected clarity, visible contaminants), silting, sedimentation	≥7 Water quality verified by Bininj monitoring – water appears to be of high quality in most areas, only very minor water quality concerns	C7	L6, W2, W3, W6,
		Traditional Owners satisfied that the riparian zones are in good condition	Condition of water course margins, creek banks	≥7 Watercourse margins and creek banks verified by Bininj monitoring – appear to be in a natural condition in most of the area, only minor concerns	C6	L5
		Traditional Owners are observing improvement in biodiversity on the landform	Natural species numbers and diversity appropriate for stage of rehabilitation	≥ Species numbers and diversity verified by Bininj monitoring – natural species occurring according to expectations for natural rate relative to the number of seasons and is improving	C12	E20
		Traditional Owners are satisfied with the final landform and state of key landmarks	Line of sight assessment prior to finalising landform design	Visual connection with key cultural sites verified by Bininj monitoring – sites visible from the same areas and to the same extent as prior to disturbance	C14	-

[15] Criteria to be read in conjunction with the closure criteria details provided in Mine Closure Plan Section 8.3.6.

[16] Bininj may agree that ripping of landform will lead to a better revegetation outcome, therefore there will be a need to consider and consult on 'pathways' through the landscape.

8.3.6.1 Justification for outcome, parameter and criteria

In determining the success of the rehabilitation over time, significant emphasis will be placed on ensuring that culturally important flora and fauna are present on the final landform. Garde (2015) speaks to the importance of social organisation, moieties, and conceptions of landscapes, all of which, if not satisfactorily addressed, will ultimately influence the assessment by Mirarr of the rehabilitation.

Garde (2015) also describes a process by which to monitor the success of rehabilitation using a set of cultural health indices. The following discussion is provided as an example only and should not be considered the final agreed mechanism for cultural criteria monitoring.

The cultural health indices described in Garde (2015) have been taken as the parameters for cultural closure criteria with proposed final endpoints presented in Table 8-13. Garde (2015) states that there are very few established models or methodologies to inform such a program. One notable example comes from New Zealand: *Cultural Health Index for Streams and Waterways: Indicators for Recognising and Expressing Maori Values* (Tipa & Teirney, 2003, 2006). The index attempts to apply indicators that Maori land owners use to assess the health of waterways.

The proposed indicators that could be used to reflect the attitudes of Traditional Owners towards the progress of rehabilitation are largely based on visual and aesthetic factors proposed in Garde (2015), provided in Table 8-13.

In addition to the cultural health indices, one additional criterion has been included into the table being that traditional burning practices have resumed, which was included at the request of GAC.

Table 8-14: Suggested indicators of cultural health of rehabilitated site (Garde 2015)

Landscape surface	**Vegetation**	**Riparian zone**	**Biodiversity**
Size of rocks	growth rate	presence or absence of artificial water bodies	natural species numbers and diversity
Presence/absence of erosion	botanical diversity	visual impressions of water quality, sedimentation, silting of rehabilitated water courses	impressions of hunting potential
Accessibility	correct species for ecological zone	condition of water course margins, creek banks	impressions of vegetable food availability
General aesthetic (does it look ‘natural’)	presence/absence of weeds		

The design of the program will involve long-term periodic assessment of attitudes and opinions of Traditional Owners and their kin in relation to the dynamics of rehabilitation over time. These assessments will be undertaken annually and will determine whether or not the Traditional Owners feel that rehabilitation in the RPA is progressing towards a desirable trajectory.

Measurements of impressionistic responses are scalar and individual indices are averaged out to provide a score. Scalar numeric assessment will also be accompanied by discursive data that provides a rationale for the score given. There is provision to provide other comments; these are hoped to provide an indication of areas that require management. Scores are to be calculated annually and then compared to determine whether perceptions of rehabilitation are moving in a trajectory that demonstrates achievement of cultural objectives as determined by Traditional Owners and their relevant kin.

There are several options for determining final scores. The first option is for sites to be individually assessed by a number of Indigenous stakeholders (barriredweleng 'Traditional Owners' and djunggai 'mother's country managers') and their scores collated and averaged. The second option is for the assessment to be done as a group activity where consensus on a score is established by the group at each site during visitation. This will be determined closer to the completion of decommissioning in consultation with GAC.

The assessment scale will be in a bilingual format that includes information in both Gundjeihmi and English. Each site will not necessarily be assessed for all indicators as some may not be relevant. For example, an indicator such as size of rocks will only be relevant at those sites where high levels of disturbance has required reconstruction of the landform with waste rock. Riparian sites will be assessed for relevant indicators which will not apply to other areas e.g. condition of water course margins will obviously not apply to assessment of areas away from water courses. An example of what the scalar measurement tool has been provided in Table 8-14.

Table 8-15: Example of scalar measurement tool for cultural criteria monitoring

ga-djalbolkwarre yerre	**ga-bolkwarre yiga ga-bolkmakmen gun-yahwurd**	**kareh ga-bolkmakmen gare lark**	**ga-bolkmakmen wurd**	**bon, ba-bolkmakminj wanjh**
no improvement yet noticed	some minor improvements	some areas improved, some areas not	noticeable return to healthy state in most areas	satisfactory return to natural state
1 | 2	3 | 4	5 | 6	7 | 8	9 | 10

Work is continuing to ensure the final landform delivers the appropriate cultural outcome, and ensure the right species are planted in the right places. This includes overlaying the final landform design with the Gundjeihmi system of ecological zones (an-gabo, an-labbarl etc.), and then within each of these zones prescribe the layout/placement of various flora species. The GAC has proposed a series of workshops and meetings with Mirarr participation to progress this work.

Cultural criteria for closure monitoring will be conducted at a number of sites that collectively provide a cross section of the range of site types where rehabilitation has been undertaken. An assessment of cultural criteria will need to be completed at each of the selected sites on an annual basis. The approach to monitoring of cultural criteria is described in Section 10.8.

8.4 Status of closure criteria

The closure criteria presented in this MCP include both those proposed for ministerial approval and draft for further review. The following sections describe the status of criteria for each theme. The draft closure criteria will continue to undergo review and refinement, based on studies and consultation with MTC members with a plan to finalise all criteria for the 2021 MCP.

8.4.1 Landform

Five of the seven landform criteria have now been finalised and are proposed for ministerial approval. The remaining two criteria will be finalised for minister approval in the 2021 MCP.

8.4.2 Water and sediment

Agreement with stakeholders has been achieved for 50% of the draft water and sediment quality objectives. These include drinking water, recreational use and ecosystem protection off the RPA for all parameters except copper and zinc in water and uranium in sediment.

Further studies and/or stakeholder consultation require to finalise the remaining draft criteria includes:

- SSB water quality standard for copper
- SSB water quality standard for zinc
- Determination of the diet parameters to be included in the diet model and assessment
- SSB standard for uranium in sediment
- Stakeholder agreement of processes for assessment of water quality as ALARA

8.4.3 Radiation

All radiation criteria have now been finalised and are proposed for ministerial approval.

8.4.4 Soils

All soil criteria have now been finalised and are proposed for ministerial approval.

8.4.5 Ecosystem

Ecosystem criteria have been developed for both revegetation and fauna. All criteria for revegetation and that of exotic fauna are being proposed for ministerial approval.

There are a number of studies currently underway to inform the development of fauna recolonisation criteria. The current status of draft fauna recolonisation criteria is presented for review. These will be finalised and proposed to the minister for approval in the 2021 MCP

8.4.6 Cultural

The cultural criteria presented in this MCP have been developed in consultation with the GAC and NLC. Ministerial approval is not being sought for cultural criteria.

Figure 8-8: Georgetown Creek

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