Chapter 13
Rehabilitation and closure

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13 REHABILITATION AND CLOSURE

13.1 INTRODUCTION

This chapter assesses the risks presented by the Project with respect to rehabilitation and closure. The Project rehabilitation strategy is described along with existing controls and additional treatments that ERA will implement as part of closure planning and decommission works. The closure of Ranger mine is currently being discussed separately with the government and other stakeholders. This chapter discusses the potential rehabilitation and closure implications of the Project, providing only an overview of current closure planning for context.

This chapter is based on the findings of the solute egress modelling for closure undertaken by INTERA Incorporated (INTERA) (**Appendix 9**). The potential impact of the Project on the life of mine closure for the existing Ranger mine is also discussed. Assessment of potential impacts resulting from the Project was undertaken using the risk assessment approach described in **Chapter 5**. Specifically, this chapter discusses:

- current operations closure planning (Section 13.2);
- the Ranger 3 Deeps (the Project) rehabilitation strategy (Section 13.3); and
- assessment of risks from rehabilitation and closure (Section 13.4).

13.2 CURRENT OPERATIONS CLOSURE

Environmental protection at Ranger mine is subject to strict controls for a number of reasons, these include the world heritage values of the area and the occupancy and use by Aboriginal people of the area (including for sourcing traditional bush foods). During operations and rehabilitation, Energy Resources of Australia Ltd (ERA) must not adversely impact on the world heritage values or the Ramsar listed wetland, or adversely affect human health, biodiversity or ecological processes. Following rehabilitation, the disturbed areas are to be of a standard such that they can be incorporated into Kakadu National Park. More specifically, the Ranger Authorisation[1] to operate sets out the overall rehabilitation goal requiring ERA to:

> *Rehabilitate the Ranger [P]roject [A]rea to establish an environment similar to the adjacent areas of Kakadu National Park such that, in the opinion of the Commonwealth Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into Kakadu National Park.*

ERA, in consultation with key stakeholders, has developed specific closure objectives and is in the process of determining the final closure criteria for the Ranger operations. Part of this process is determining specific details of the post closure land use through consultation with the Traditional Owners.

Rehabilitation and closure of the Ranger mine will occur in four distinct phases:

- progressive rehabilitation during the operational phase of the mine

[1] The same rehabilitation requirements are contained with the Ranger Environmental Requirements contained in the section 41 Authority under the Atomic Energy Act. Throughout this document any reference to the Ranger Authorisation should be taken as also a reference to the Environmental Requirements.

- decommissioning;
- stabilisation and monitoring; and
- post closure.

13.2.1 Progressive Rehabilitation and Decommissioning

ERA has developed an "integrated tailings water and closure strategy" to ensure decommissioning and eventual closure of the Ranger Project Area (RPA) is achieved with due consideration of Traditional Owner, stakeholder and community expectations. This strategy has been developed through the application of best practicable technology within a risk based framework and is the foundation for closure design and planning at Ranger mine.

Progressive rehabilitation has been ongoing for a number of years with unused tracks being revegetated, exploration areas progressively rehabilitated and trial rehabilitation of the land application areas.[2] More recently this has involved the initial backfilling of the Pit 1 tailings management facility and the engineering and construction of key infrastructure associated with the scheduled transfer of tailings into Pit 3 for final disposal.[3] Engineering and construction will continue to progress according to the closure schedule in time for the commencement of formal decommissioning in January 2021 and to ensure that all decommission works are completed by January 2026.[4] The current schedule, showing each of the key activities to be completed, has been provided in **Figure 13-1**.

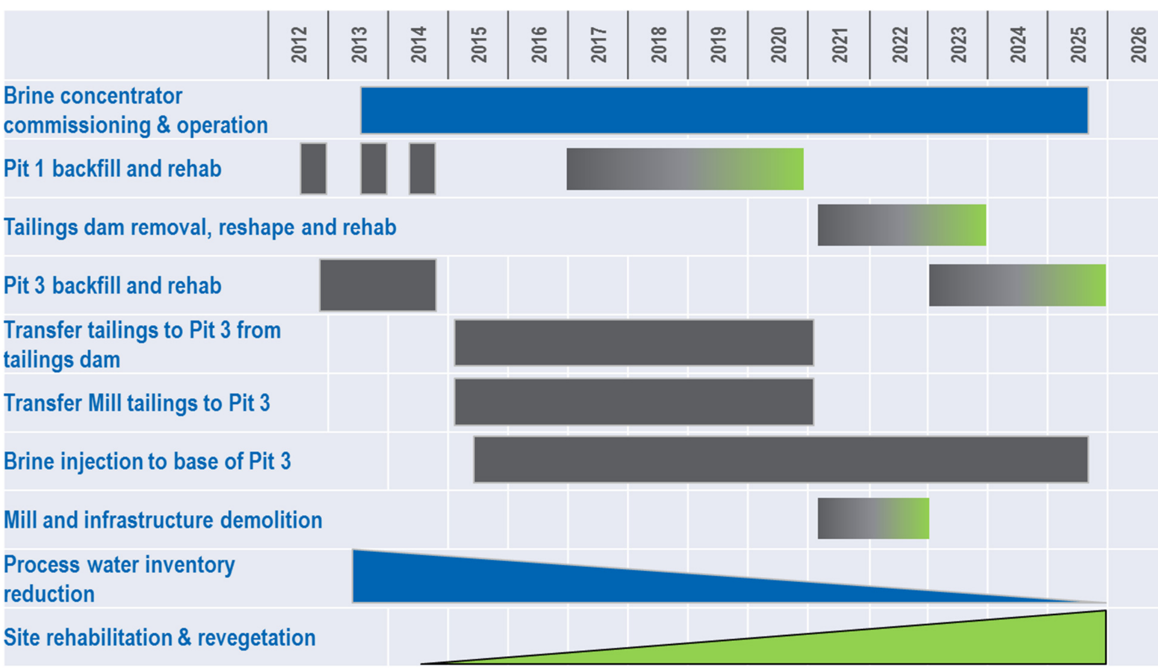

Figure 13-1: Current Ranger mine closure schedule

2 Land application areas have had water irrigated on them as part of the Ranger mine water management system.

3 Pit 1 has been backfilled with tailings and the rehabilitation process commenced with the placement of the first layer of capping. At the expected commencement date for the Project, Pit 3 is scheduled to have the waste rock under fill in place and be operating as a tailings storage facility (subject to final regulatory approval via the MTC approval process).

4 The current section 41 Authority only permits ERA to explore, mine and process uranium ore at the Ranger mine until January 2021 with an allowance of an additional 5 years to complete decommissioning works.

Each of the key closure activities are planned and engineered with the support of detailed environmental studies to ensure that the surrounding environment of Kakadu National Park is not detrimentally impacted as a result of the mine closure. In particular the Ranger Authorisation requires ERA to demonstrate, through appropriate modelling, that any contaminants arising from the tailings will not result in any detrimental environmental impacts for at least 10,000 years.

Prior to the commencement of each of these closure activities, approval will be obtained from the regulatory authorities through the Ranger Mine Site Technical Committee (MTC).[5] Applications for these approvals are supported by environmental studies to demonstrate that the engineering is to the required standard of environmental protection.

In addition to the approvals process, each environmental study is reviewed by the Alligator Rivers Region Technical Committee (ARRTC), which includes a panel of independent scientific experts appointed by the Commonwealth Minister for the Environment. This independent review provides additional confidence that the engineering associated with closure will be of an appropriate standard.

13.2.2 Stabilisation and Monitoring

The stabilisation and monitoring phase is the period post decommissioning when the site has commenced the progression or trajectory towards developing a long-term viable ecosystem in accordance with the agreed closure criteria.

Some initial management may be required through the stabilisation period as the landform settles, subsidence and minor erosion occurs, and vegetation starts to propagate. A number of sumps will be installed to trap silt and contaminants as a passive water management mechanism. These will be removed once they are no longer required.

Other management practices in this phase may include:

- minor earth works to repair erosion;
- infill planting of vegetation;
- active weed and fire management; and
- active feral animal control.

The closure monitoring program will commence in this phase with the objective of:

- identifying if there is a requirement to undertake mitigation works; and
- demonstrating that the site is trending towards the final closure criteria.

Closure criteria are the performance benchmarks against which the long-term success and sustainability of rehabilitation will be measured. They represent targets that are measurable and quantifiable and will be used as the basis for demonstrating that ERA has met the closure objectives and its rehabilitation responsibilities. The scientific basis for these criteria is reviewed by ARRTC.

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5 The Ranger Minesite Technical Committee (MTC) is the body set up to provide advice on the regulation of Ranger mine to the NT Minister for Mines and Energy. This committee comprises representatives of the Northern Territory Department of Mines and Energy (Chair), Supervising Scientist Division (SSD), ERA, Gundjeihmi Aboriginal Corporation (GAC) and the Northern Land Council (NLC).

The final closure criteria for the Ranger mine are currently being prepared in consultation with Traditional Owners, Department of Mines and Energy, Supervising Scientist Division, Department of Industry, the Northern Land Council, Parks Australia and ARRTC. This process is occurring through the closure criteria working group established under the MTC.

The closure criteria are being developed under six themes:

- landform;
- radiation;
- water and sediment;
- flora and fauna;
- soils; and
- cultural.

Separate closure objectives have been developed for each theme. These incorporate both the rehabilitation requirements from the Ranger Authorisation and the assessment endpoints identified in the Ranger mine rehabilitation and closure ecological risk assessment conceptual models (Bartolo, *et al.* 2013). Specific and measureable endpoints are currently being developed for each of these objectives. Once completed these endpoints will have parameter values allocated and following approval by the MTC will form the Ranger closure criteria.

An essential step in developing closure criteria is the design of a monitoring program. This program is currently being created as part of the work undertaken by the closure criteria working group and is focussed on:

- measuring the success of rehabilitation against each of the criteria; and
- timely identification of potential issues with rehabilitation such that appropriate mitigation measures can be implemented.

Results of the rehabilitation monitoring program for each closure criteria will be reported regularly to the MTC. The frequency and format of this reporting will be determined as part of the closure criteria development.

It is expected that the stabilisation and monitoring phase will be ongoing until monitoring demonstrates that the site has achieved the closure criteria.

13.2.3 Post Closure

The post closure phase is the period where monitoring has demonstrated that the closure criteria have been achieved and ERA has been released from responsibility for the site.

This period of the post closure phase is indefinite from this point.

13.3 RANGER 3 DEEPS PROJECT CLOSURE STRATEGY

A closure strategy for the Project, that aligns with closure planning for the current Ranger mine operations detailed in **Section 13.2**, has been developed. Following approval of the Project, this strategy will be integrated into the overall Ranger mine operations closure planning. This section details the Project's rehabilitation strategy.

The key tasks associated with closure of the Project are:

- backfill of underground mined voids;
- backfill of decline and ventilation shafts and grouting of underground drill holes;
- tailings and waste rock management;
- infrastructure removal and grouting of surface holes;
- revegetation of disturbed areas;
- management of fire and weeds; and
- rehabilitation monitoring.

13.3.1 Backfill of Underground Mined Voids

Mined out stopes will be progressively backfilled as part of the mining process to:

- provide ground support to continue mining;
- allow tailings placement at depth, thereby minimising the potential for solute transport to the environment; and
- allow progressive rehabilitation of mining areas.

Backfill material will be a mixture of tailings, cement and aggregate (crushed waste rock) made into a paste. This material is called cemented tailings paste aggregate fill. A description of the backfill plant and backfill methods has been provided in **Section 3.5.1** and **Section 3.3.3.3**, respectively.

The paste backfill material has been designed to minimise the potential for leaching of contaminants of potential concern into local groundwater. The material will be subjected to a dewatering pre-treatment and washing (refer **Section 3.5.1**), resulting in a very low volume of process water remaining in the material that is available to leach or seep. The addition of cement to the paste will both provide strength for ground support and help to further minimise seepage of contaminants out of the tailings and thus minimise groundwater contamination.

In the hydrogeological modelling (refer **Section 13.4.1.1**), cemented tailings paste aggregate fill has been conservatively estimated to leach in a manner that will be similar to leaching of tailings scheduled to be placed into Pit 3 (i.e. no cement).

13.3.2 Decline and Ventilation Shaft Backfill

The decline and ventilation shafts will be backfilled at the completion of mining. The backfill method will focus on mitigating the risk of solute transport through the weathered zone to Magela Creek or cross contamination of aquifers.

Either paste fill or cemented aggregate (waste rock) fill will be used to backfill from just below the weathered zone through to the surface in the decline and the ventilation raises. This will:

- remove these voids as a preferential flow path for the movement of solutes from the underground tailings sources to Magela Creek; and
- make the location safe by removing surface voids.

The paste fill will consist of waste rock that has been crushed and ground, which is then mixed with binder (e.g. cement) and water in the backfill plant. For the decline, a barricade will be placed just below the weathered zone. Paste fill will then be pumped or gravity fed to fill the void between the barricade and the surface. For the ventilation raises, the bottom of the raises will be filled with waste rock to a level below the weathered zone. The paste fill will then be pumped or gravity fed to fill the void between the top of the waste rock and just below the surface.

The cemented aggregate fill will consist of crushed and screened waste rock combined with cement slurry and used to fill the same voids (as per the paste fill scenario) between the weathered zone and surface. This material will be placed using a loader.

There will be sufficient waste and low grade rock remaining at the completion of operations to backfill all voids, refer **Table 13-1**.

In the hydrogeological modelling (refer **Section 13.4.1.1**), the backfill materials have been conservatively estimated to behave geochemically similarly low grade rock placed within the saturated zone.

Underground diamond drill holes used for resource definition have also been identified as a potential pathway for solute transport. Each hole will be progressively grouted by filling with cement following the completion of activities associated with the hole.

Depressurisation holes installed in the walls of Pit 3 have been identified as a potential pathway for contaminant transport if they are intersected by a ventilation shaft. The locations of these holes are well known and ventilation shafts will be located to avoid intersection.

13.3.3 Tailings Management

The Ranger mine processing plant has a fixed maximum throughput which exceeds the ore production rate of the Project. Therefore, Project ore will be blended, or otherwise processed with existing lower grade stockpiled ore that was originally obtained from the open pit. The tailings generated during the life of the Project will thus not be discretely of the Project origin. In addition, Project ore has very similar mineralogy to that previously generated from the open pit (refer **Section 3.4.1**). Therefore, tailings generated during the life of the Project are expected to have similar chemical and radiological properties to that of current operations.

Once the Project commences, tailings material generated from the processing plant will be managed in two ways:

- A portion of the tailings will be placed underground in the backfill material, refer **Section 13.3.1**.
- The remaining tailings material will be directed to the current operations tailings storage facility (scheduled to be Pit 3).

The Ranger mine water and tailings management design for the decommissioning stage, with the Project integrated, is shown diagrammatically in **Figure 13-2**.

The management of tailings focusses on minimising the potential for solute transport into Magela Creek. The placement of the tailings in the mined out underground voids at a depth of over 300 m from the surface in very low permeability host rock inherently minimises the potential for any solutes generated from the tailings to leach into Magela Creek. This has been demonstrated for a 10,000 year timeframe through hydrogeological modelling (refer **Section 13.4.1)**.

The current Ranger mine closure planning assumes that tailings produced in the processing plant will be placed in Pit 3 until January 2021. Specifically, the current operations closure design for Pit 3 includes a bottom layer of low-grade rock (under fill) up to approximate elevation -100 mRL, followed by a layer of tailings up to approximate elevation -20 mRL, and an upper layer of waste rock (**Figure 13-3**). For the Project closure strategy there will be a slightly lesser volume of tailings material directed to Pit 3 and a slight increase in waste/low grade rock. More details of the tailings and waste rock material balance at closure is discussed in **Section 13.3.4**.

The final design of the Pit 3 tailings and waste rock disposal has been based on hydrogeological modelling, refer **Section 13.4.1**.

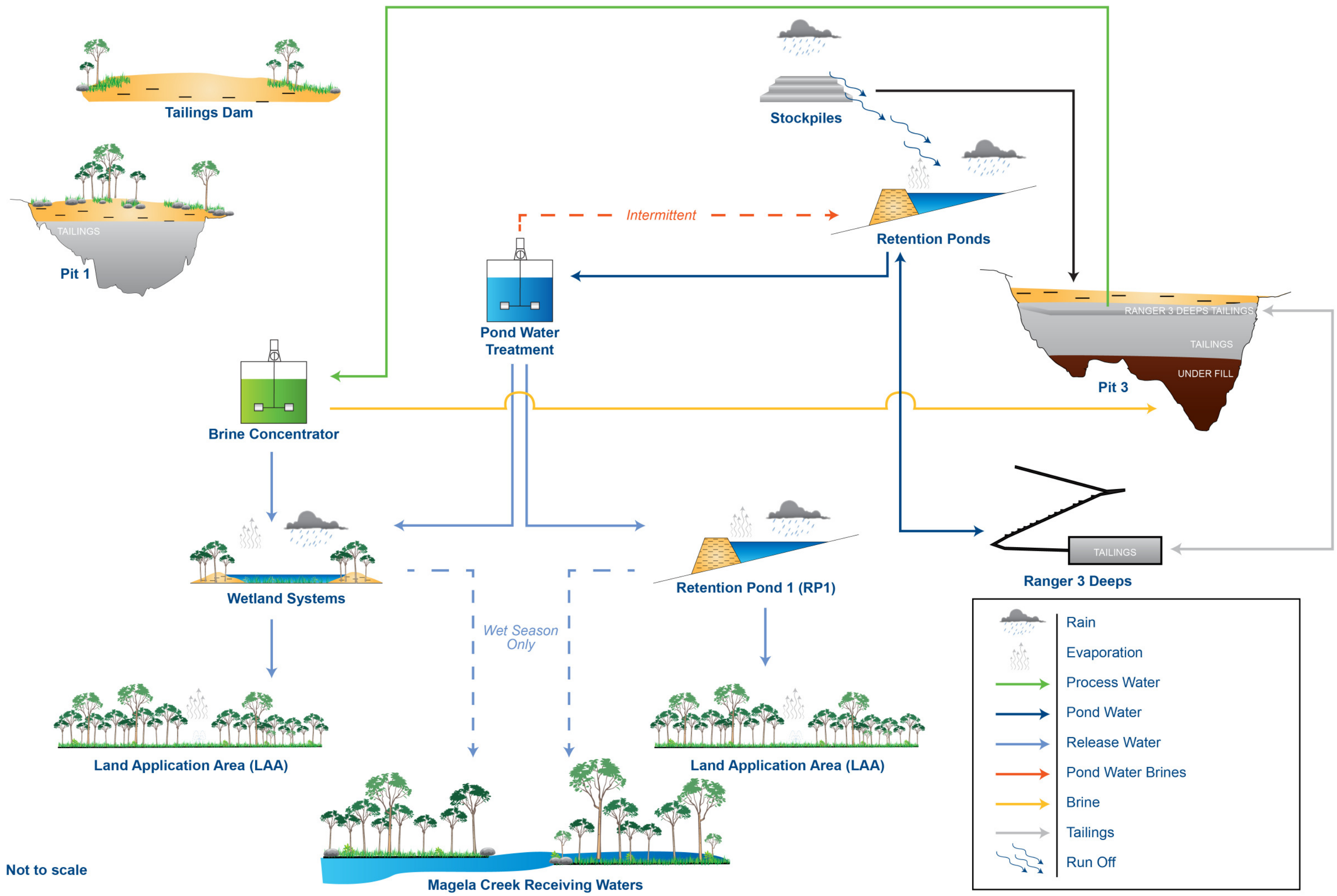

Figure 13-2: Ranger mine water and tailings management in decommissioning phase with the Project

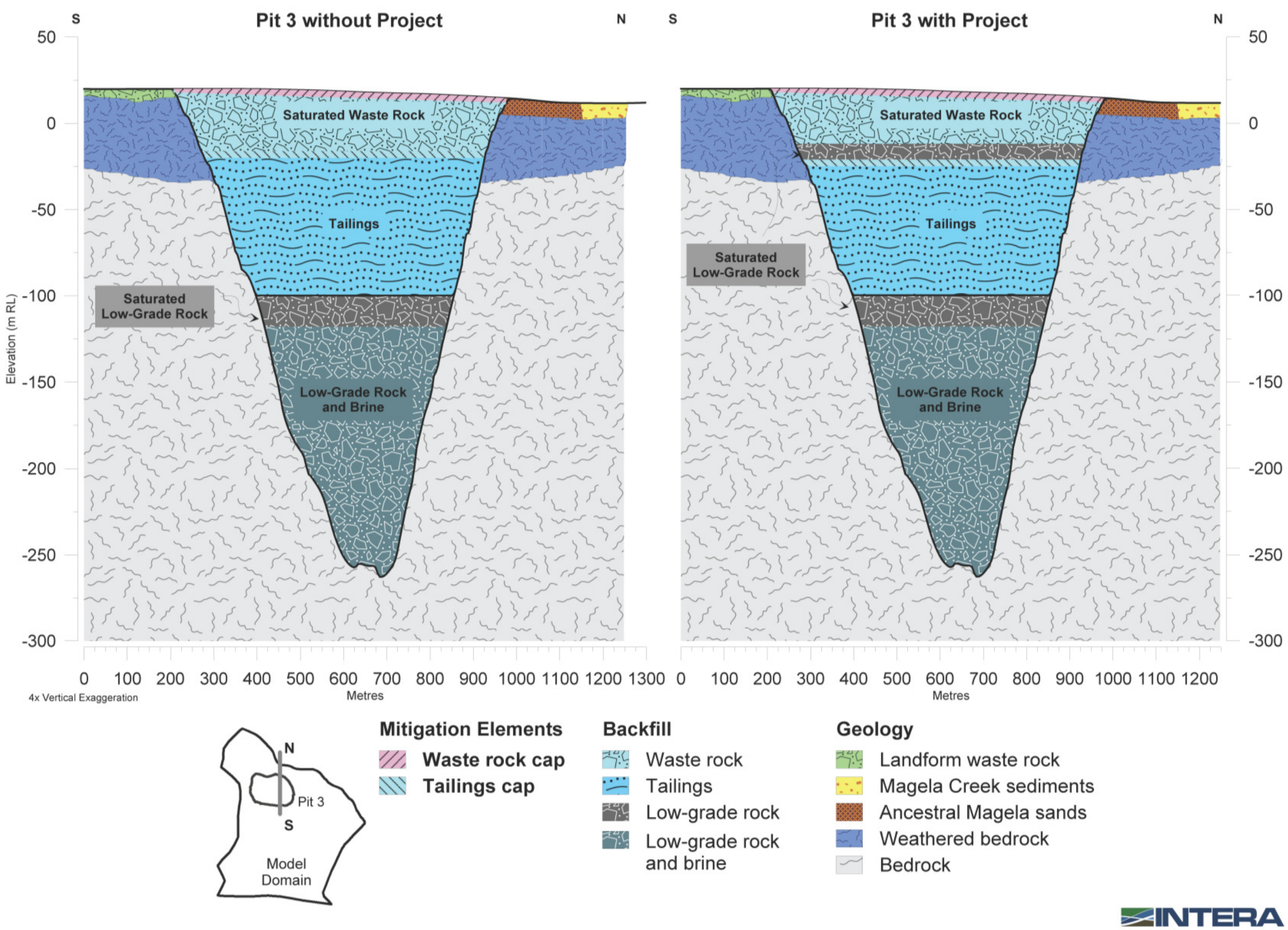

Figure 13-3: Planned tailings and waste rock placement in Pit 3 – comparison between current closure and the Project integrated case

13.3.4 Waste Rock Management

Mine rock at Ranger mine is categorised as 1s, 2s, 3s, and so on up to 7s, each of which is discriminated on the basis of its uranium oxide (U_3O_8) content. The U_3O_8 content of 1s waste rock is less than 0.02 wt%, for 2s rock (low-grade) is 0.02 – 0.05 wt%, and for 3s rock (low-grade) is 0.05 – 0.1 wt%. All other classes of rock, 4 through 7, are not considered waste, refer **Chapter 2, Section 2.6.2.**

Waste and low grade rock generated by the Project will be of similar mineralogy and behave geochemically similar to that previously generated from the open pit (refer **Section 3.4.1** and **Section 3.8.1**); therefore, management of this material at closure will be the same as for current operations closure. Management will be based on the potential for acid generation and contaminant mobilisation. Characterisation of waste rock at Ranger mine is based on the uranium grade. While uranium grade cannot typically be used to determine if waste rock will be geochemically adverse (i.e. have high sulfur content), ERA has undertaken studies that indicate a relationship of increasing sulfur content with uranium grade for category 1s through 3s rock. This work demonstrated that category 1s waste rock has a very low sulfur content of <0.03% and is thus classified as a very low acid rock drainage risk with 2s and 3s having slightly higher risk.[6] Based on this classification system, only 1s waste rock will be used to create the waste rock cap in Pit 3 and the final landform surface so as to minimise the potential for acid generation and contaminant mobilisation.

The estimated waste rock and tailings material balance for final closure with and without the Project is provided in **Table 13-1.** Quantities of waste generated by the Project are detailed in **Section 3.8.1**. The currently estimated volumes are 0.5 Mt of non-mineralised 1s waste rock and 0.4 Mt of low grade 2s rock, this is very small compared to the 90 Mt of waste rock remaining from open pit operations.

Table 13-1: Closure waste material balance

Waste material	**Current operations without Project (Mt)**	**Current operations with Project (Mt)**
1s waste rock	90	90.5
2s low grade rock (Project generated)	Nil	0.4
Unprocessed existing low grade rock	Nil	4.5
Total for waste rock	***90***	***95.4***
Tailings generated from stockpiles (2016-2020)	12	6
Tailings generated from Project (2016-2020)	0	6
Total final tailings scheduled for deposit in Pit 3	41	39
Total tailings underground	Nil	2
Total for tailings	***41***	***41***

6 It should be noted that over the 30 years of operations at Ranger, waste rock runoff shows a circumneutral pH as any potentially acid forming sulfide minerals are neutralised by an abundance of chlorite and carbonate minerals.

The current closure planning will use the 90 Mt of waste rock to complete the final backfill and capping of Pit 3 (62 Mt), capping of Pit 1 (23 Mt) and construction a final landform that blends in with the surrounding environment (5 Mt). The additional small volume of waste rock generated by the Project can easily be accommodated into this existing closure planning. In the unlikely event that waste rock volumes generated by underground mining are underestimated by a factor of 10, there will still be no material impact on the final closure volumes for Pit 3 or the final landform surface. The Project will not use the existing stockpiled 1s waste rock; therefore, will not impact on the ability to complete the backfill of Pits and construction of the final landform.

In addition to the small volume of underground mine waste and low grade rock, there will be an additional small volume of 1s waste rock produced as part of the operation of the ore sorter (refer **Section 3.4.1** and **Section 3.8.1**). This material is expected to be higher in carbonate and of very low uranium content so will be preferentially used as good quality road base material for underground operations with no material expected to remain at closure. The exact volume of this material cannot be known, as it will depend upon both the amount of carbonate in the ore and the need for ore sorter operations. Based on current knowledge of the Project ore body it is estimated that there will be approximately 0.5 Mt of this material produced.

Should the Project proceed, there will be approximately 4.5 Mt[7] of existing stockpiled low grade rock (2s and 3s) that will not be processed and require management at closure. The Project closure strategy plans to use a small volume of this rock to backfill to the remaining underground voids (vent raises and decline, refer **Section 13.3.2**) with the remainder being placed in Pit 3. Since this rock has a slightly higher acid generation potential it will be placed above the tailings but in the saturated zone to minimise the potential for solute mobilisation. **Figure 13-3** shows the proposed layout of waste for the final rehabilitation of Pit 3. The material balance, based on the scenario discussed, demonstrates that Pit 3 has sufficient room to accommodate this additional waste material.

13.3.5 Infrastructure and Surface Holes

All surface infrastructure installed as part of the Project will be removed at the completion of operations and where possible decontaminated then cleared for off site release and sale. Where this is not possible infrastructure will be placed in either Pit 3 or the underground voids prior to final backfill. This includes the paste backfill plant, ventilation fans, pumps, pipelines, settling ponds and the electrical reticulation system. Ventilation infrastructure underground will be retrieved as backfilling advances.

At the completion of operations, or progressively if appropriate, all surface exploration and paste delivery holes installed for the Project will be grouted by filling with cement and/or capped to make the area safe to walk across for the public and prevent fauna falling down the voids.

[7] Equivalent to the total volume of ore produced by the Project (6.5 Mt) minus the volume to be used in backfill material underground (2 Mt) (refer Section 3.3.5 and Section 3.8.1).

13.3.6 Revegetation Strategy

There is approximately 950 ha of land to rehabilitate and revegetate for the successful closure of Ranger mine. Approximately 340 ha is part of the water management areas, including wetland filters and land application areas which are currently vegetated so may not require the same level of revegetation. The final 530 ha will be re-contoured waste rock forming the final landform for Ranger mine and 80 ha will be the re-contoured disturbed area for the processing plant, other infrastructure and roads. The Project is wholly contained within this existing rehabilitation and revegetation 950 ha and therefore will form part of the existing Ranger closure rehabilitated surface. The location of the project places it underneath the proposed waste rock re-contoured landform, with the exception of some ventilation shafts which will be rehabilitated and revegetated as part of the Magela Land Application Areas. No change to the final landform contouring will be required as a result of the Project.

The final landform has been designed to recreate, as far as practicable, a landscape with features similar to those of the surrounding area. The landform will comprise in situ, reshaped waste rock, which will eventually weather to create proto-soils[8], but initially may pose challenges for vegetation growth. The waste rock will be run of mine rock that is contoured to appropriately manage erosion. Surface roughness and ‘patchiness’ will be maximised during site preparation and undulating contours will be created across the landform. The aim is to create a heterogeneous land surface that has localised run-on/runoff zones for control and capture of sediment, water and nutrients, and micro sites for seedling establishment and litter accumulation. No surface smoothing and/or compaction of surfaces will be undertaken. The most recent version of the landform is currently being reviewed by stakeholders to confirm that it meets the closure objectives, an extract of the topography and drainage morphology in the location of the project has been provided for information. It should be noted that this design is subject to change depending upon the outcomes of the current consultations. **Figure 13-4** shows this most recent landform topography contours and drainage morphology with the location of proposed Project infrastructure overlaid.

A trial landform project is currently underway at Ranger to determine the best methods for revegetation of this waste rock material.

Early revegetation trials at Ranger demonstrated that the use of top soil results in a lack of framework species, where the future developmental pathways are unstable and unlikely to result in eucalypt-dominated woodlands. These areas are a major source of weeds and are very vulnerable to fire. These results and the general lack of available top soils in the area have guided the choice for a waste rock surface.

The area of disturbance from the Project is very small in comparison to the current Ranger operations. The majority of Project surface disturbance will occur in areas that are currently disturbed and form part of the current operations closure. The area of vegetation clearance for the Project is expected to be less than 1 ha or 0.1% of the total rehabilitation area for Ranger mine, (refer **Section 3.2**). There will be sufficient key material available as part of the larger Ranger closure revegetation strategy to complete revegetation of this small area.

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[8] The very first stage of soil development.

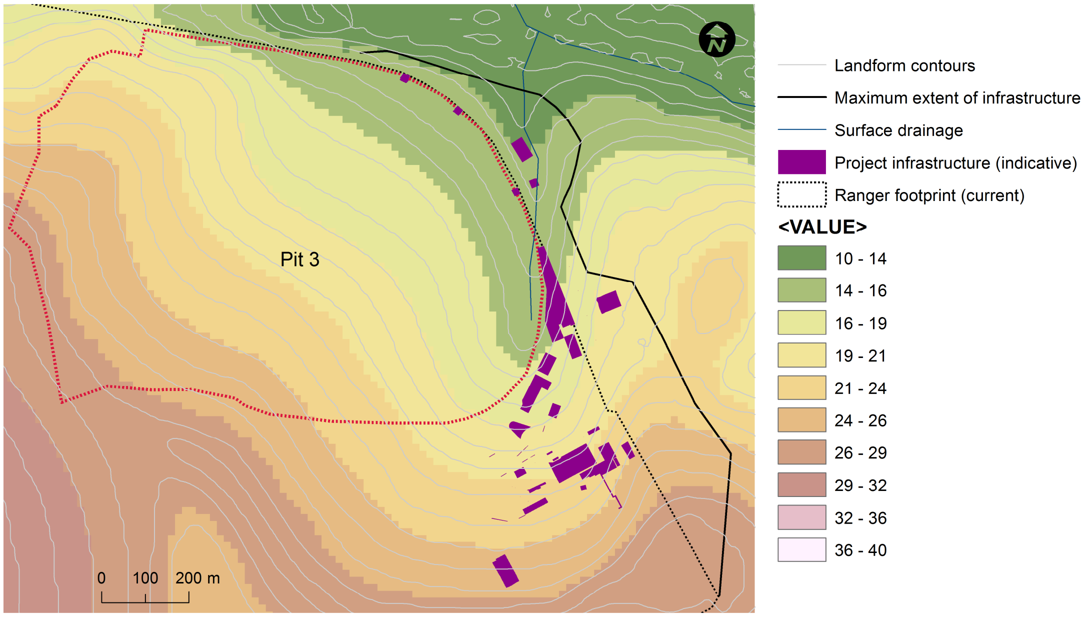


Figure 13-4: Draft final landform topography and drainage morphology in the location of Project infrastructure

The Ranger mine revegetation strategy has been developed from the overall objective for revegetation of the current operations outlined in the Ranger Authorisation:

> *Revegetate 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.*

Implicit in this objective is the need to:

- use locally-sourced native plant species;
- establish vegetation that can exhibit sustained growth and development on predictable trajectories towards desired endpoints, which include being:
  - resilient to the fire management regime used in the Kakadu National Park;
  - tolerant of extreme climatic events, such as cyclones or drought; and,
  - competitive enough to resist invasion by environmental weeds.
  - restore functional ecosystems with characteristics of sustainability, resistance and resilience to disturbance, and habitat values that are consistent with, and can be integrated into, the surrounding landscape.

ERA's revegetation strategy is underpinned by an understanding of both general ecological principles and ecosystem dynamics in northern Australia, and also based on the knowledge gained through 30 years of revegetation trials and research.

The general aim of revegetation is to first establish the framework species. These are long lived native trees and shrubs which in a natural ecosystem control much of a site's nutrient and water resources, dominate the canopy, provide habitat for other flora and fauna species, and have a high contribution to ecosystem functioning and stability. Once framework species are established, other species will colonise the site, provided it is within reasonable proximity to other vegetation. Introduction of an understorey is delayed to allow framework species to establish without competition and to decrease the risk of fire.

A current species list, for both framework and understory species, has been developed based on characterisation work conducted in collaboration with the Environmental Research Institute of the Supervising Scientist (ERISS) at a number of analogue sites in the regions, including the Georgetown analogue site, located to the south east of current operations. This species list is provided in **Table 13-2** and is subject to ongoing review and refinement.

Revegetation will occur as a mixture of both tube-stock and direct seeding, depending upon the species and site conditions. Short term irrigation may be required to assist with initial tube stock establishment and survival and will depend on the time of year that revegetation is occurring and the meteorological conditions at the time.

Seed required for revegetation will be collected from the within the Ranger mine provenance zone. ERA is conducting ongoing seed collection, propagation and general revegetation studies to develop methods that will enable the generation of sufficient tube stock and direct seed material to complete its revegetation strategy.

Table 13-2: Current species list for the revegetation of Ranger mine

Genus and species	Density in mixed Eucalyptus woodland community (stems per ha)	Number of tube-stock per ha[1]
Over and mid-storey species		
Acacia dimidiata	<1	15
Acacia hemignosta	0	15
A. latescens[2]		
Acacia mimula	260	200
Asteromyrtus symphyocarpa	0	15
Brachychiton diversifolius subsp. *diversifolius*	0	15
Brachychiton megaphyllus	4	15
Buchanania obovata	7	20
Cochlospermum fraseri subsp. indeterminate	9	20
Corymbia bleeseri	28	40
Corymbia disjuncta	20	40
Corymbia foelscheana	0	15
Corymbia latifolia	6	15
Corymbia polysciada	0	15
Corymbia porrecta	77	140
Corymbia setosa subsp. Indeterminate	12	20
Erythrophleum chlorostachys	25	40
Eucalyptus miniata	48	80

Genus and species	Density in mixed Eucalyptus woodland community (stems per ha)	Number of tube-stock per ha[1]
Eucalyptus phoenicea	9	20
Eucalyptus tectifica	<1	15
Eucalyptus tetrodonta	120	200
Eucalyptus tintinnans	1	15
Gardenia megasperma	6	20
Grevillea decurrens	18	40
Grevillea pteridifolia	0	15
Hakea arborescens	0	15
Jacksonia dilatata	2	Seed
Livistona humilis	12	Seed
Livistona inermis	41	Seed
Meleleuca viridiflora	<1	15
Owenia vernicosa	2.5	seed
Pandanus spiralis	<1	15
Petalostigma pubescens	<1	seed
Petalostigma quadriloculare	0	seed
Planchonia careya	11	20
Stenocarpus acacioides	1	15
Syzygium eucalyptoides subsp. *Bleeseri*	<1	15
Syzygium suborbiculare	0	15
Terminalia carpentariae	<1	15
Terminalia ferdinandiana	35	60
Wrightia saligna	4	15
Xanthostemon paradoxus	107	180
Understorey species		
Aristida hygrometrica	-	Seed
Aristida holathera	-	Seed
Eragrostis sp.	-	Seed
Eriachne shultziana	-	Seed
Psuedopogonantherum irritans	-	Seed
Schizachyrium fragile	-	Seed
Spermacoce sp.	-	Seed

1 – Note target density of approximately 1400 stems per ha

2 – Due to limited seed availability of *A. mimula*, *A. latescens* may be partially substituted

At the completion of operations, areas disturbed by the Project will be re-contoured along with existing site disturbed areas to form the final contoured landform. Revegetation of these areas will be in accordance with this overall Ranger operations revegetation strategy.

13.3.7 Management of Fire and Weeds

Successful rehabilitation requires the protection of revegetation from fire and the management of species with a high fuel load, which includes both native and weedy grasses. Fire within the first 1 – 2 growing seasons can lead to a large proportion of the plants being killed. Fire within subsequent seasons will also increase mortality, especially when the fire is a hot late dry season fire.

The risk of fire will depend on the surrounding land use. If the revegetation site is surrounded by vegetation with high fuel loads then allowance for the creation of firebreaks by burning or clearing of adjacent grassy vegetation areas in a controlled manner is needed. These firebreaks will involve creating a buffer rather than burning extensive areas. Delaying the establishment of an understorey and control of weeds and native annual grass will also minimise risk from fire.

By excluding fire, the plants will be provided with a window of opportunity for growth. However as the ultimate goal for revegetation is that the area can be integrated into the management of surrounding Kakadu National Park, this implies that ultimately the revegetation will need to be resilient to the fire management regime used in Kakadu National Park.

Fire will be excluded from all revegetation for at least the first 3 – 5 years after planting. After this time controlled cool burns can be introduced to reduce fuel loads. All fire management will be carried out in accordance with existing operational procedures.

Weeds may compete with and smother plants, or may increase the risk of fire, and thus increase mortality. They may also become a source of weeds to the surrounding landscape.

Prior to planting, the site and its immediate surrounds will be inspected for the presence of weeds, and where found these will be sprayed with herbicide. All weed management and control will be carried out according to existing operational procedures.

13.3.8 Rehabilitation Monitoring

A key component of rehabilitation and closure planning for Ranger operations is the development of closure criteria to measure site rehabilitation success and the associated rehabilitation monitoring and reporting program, refer **Section 13.2.2**. As previously described these closure criteria, the associated monitoring program and any mitigation or contingency measures required should the site rehabilitation deviate from predicted trajectories, are currently being developed in collaboration with key stakeholders, after which they will be approved by the Ranger MTC. The Project will not require specific closure criteria parameters, contingency measures or a separate monitoring program.

The rehabilitation monitoring and reporting program for cumulative closure will be conducted as part of the stabilisation and monitoring phase (refer **Section 13.2.2**) of rehabilitation and will continue until such time as it demonstrates that the site has achieved the closure criteria.

13.4 ASSESSMENT OF RISKS

The environmental risk assessment identified a total of 80 risks. The initial identification of risks was aided by applying a 'prompt list' derived from the major identified risks in the EIS guidelines and augmented by previous and current operational risk registers. Potential impacts to sensitive receptors (e.g., world heritage values of Kakadu National Park, Mount Brockman) were considered when evaluating and rating each risk scenario. Where multiple potential impacts are associated with a risk scenario, the impact with the highest risk rating defines the risk management class. Risk ratings reflect the implementation of appropriate mitigation measures (existing controls and new treatments).

Of the 80 risks referred to above, 15 are associated with rehabilitation and closure activities. Of these, three risks were identified as having a current (inherent) high (Class III) risk rating and one had a critical (Class IV) current risk rating (**Table 13-3**). A comparison of the current and residual risk profile shows that these risks have been reduced to one moderate (Class II) risk and three low (Class I) risks. No residual high and critical risks are associated with rehabilitation and closure.

The level of certainty associated with the overall risk ranking, based on the quality of data and information available, and the effectiveness of the treatments in mitigating the risk has also been included in **Table 13-3**.

This chapter will discuss the four risks mentioned above. All remaining risks had either an inherent or residual Class I or Class II risk rating. These will be discussed where they are of particular interest to stakeholders and/or additional treatments were identified.

A description of the risk assessment method is provided in **Chapter 5**. Additional discussion of the risks associated with the Project is provided in **Appendix 5**.

Table 13-3: Class III and Class IV rehabilitation and closure risks

Risk identification and title	Possible causes	Potential impacts	Risk ranking [1]		Certainty level [2]
			Current	Residual	
TB5-01: Solutes from tailings paste backfill may transport through host rock and affect groundwater quality and Magela Creek.	Paste contains tailings and Category 2 waste that may leach solutes (including radionuclides) in the long term. Permeability characteristics of host rock may influence transport.	Solute delivered to surface water systems in unacceptable concentrations. Groundwater in the weathered zone becomes contaminated.	III	I	C3
TE3-01: Vent shafts may provide pathway for solute transport to Magela Creek post closure.	Intersecting Pit 3 depressurisation holes provides a pathway for Pit 3 tailings solutes to Magela Creek. Higher permeability pathways for solutes to Magela Creek from underground mine tailings storage areas.	Additional solute loading to Magela Creek (over 10,000 years).	IV	I	C3
TE3-02: Decline may provide a conduit for solute transport from Pit 3 sources to Magela Creek.	Open void spaces underground. High permeable material used to backfill decline.	Reputational compliance. Solute egress to Magela Creek.	III	I	C3

Risk identification and title	Possible causes	Potential impacts	Risk ranking [1]		Certainty level [2]
			Current	Residual	
TE7-01: There may be an inability to meet the closure schedule due to restrictions imposed by the active underground operations.	The overlap of underground mining with closure activities. Closure of the Project may damage existing revegetation works. The Project changes materials balance at closure.	There may be delay to establishment of the final landform impacting on closure schedule.	III	II	C3

1 – Risk ranking: Class IV – Critical; Class III – High; Class II – Moderate; Class I – Low.

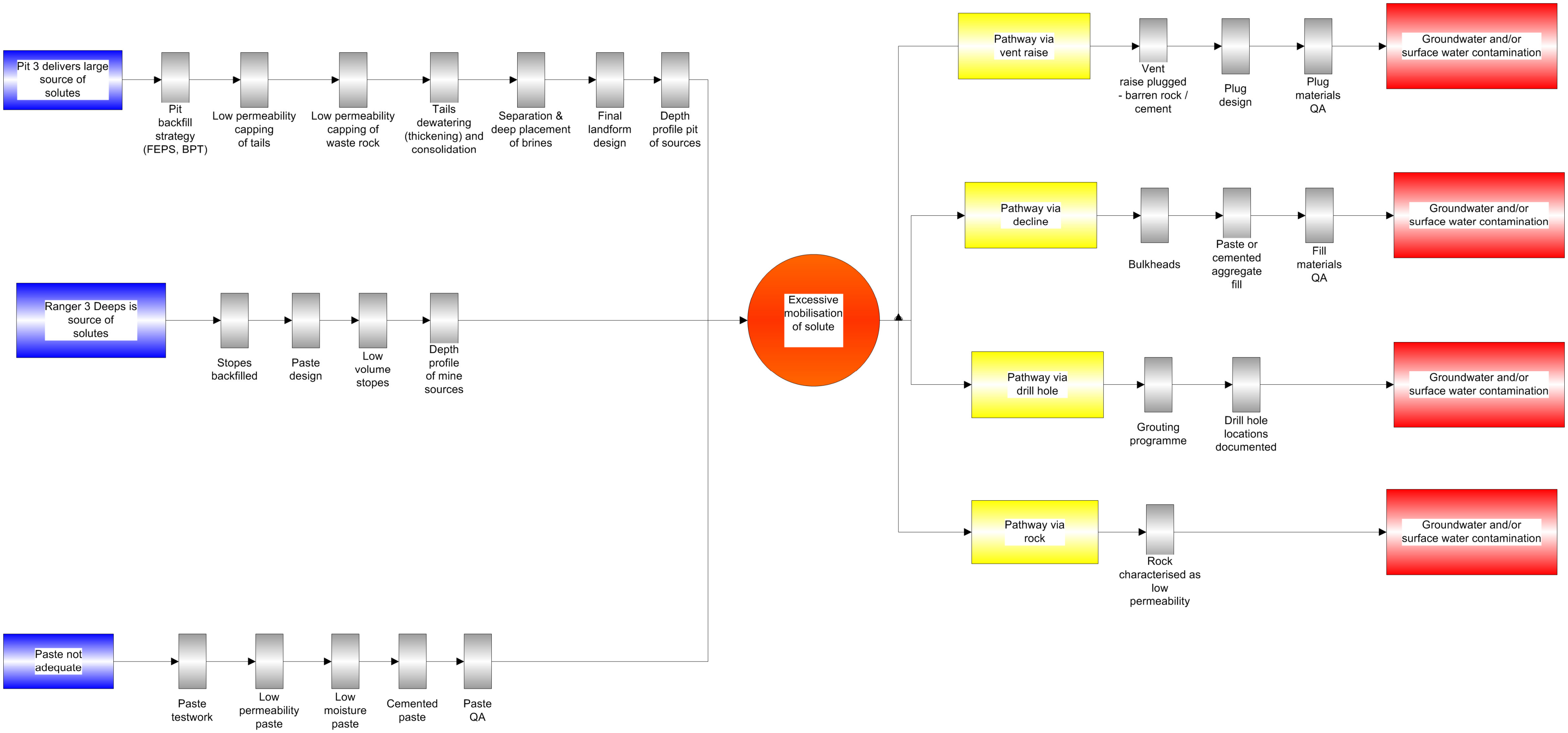
2 – Certainty level: C1 – Low; C2 – Moderate; C3 – High. (refer Chapter 5)

13.4.1 Solute Transport from Tailings and Waste Rock

The one rehabilitation and closure risk identified as having an unacceptable current risk (Class IV) ranking was TE3-01: Vent shafts may provide pathway for solute transport to Magela Creek post closure. This risk and the other identified risks (TB5-01, TE3-02 and three lower ranked risks) related to the transport of solutes to Magela Creek from tailings or waste rock, contained within either the underground void backfill material or Pit 3 were subjected to a Bow Tie analysis to gain a better understanding of the extent, quality and effectiveness of mitigation measures being proposed. Details of the Bow Tie analysis are provided in **Appendix 5**, with the overview shown in **Figure 13-5**.

The preventative and mitigation controls identified in this Bow Tie analysis may be deemed critical risk controls, i.e. they are controls associated with the most significant risks. As such these controls will be embedded in ERA management systems to ensure ongoing application. The design controls have been incorporated into the Project rehabilitation strategy, detailed in **Section 13.3**, with management controls being incorporated into the Project environmental management plan provided in **Chapter 15**.

Taking into account these controls for the management of solutes from tailings and waste rock for the Project, the final risk profile is low. Details of modelling that was undertaken to better understand the potential for solute transport are provided in this section.



Abbreviations:

BPT: Best Practicable Technology
FEPS: Features, Events and Processes analysis
PP: Backfill plant
QA: Quality assurance

Figure 13-5: Bow Tie analysis of excessive mobilisation of solutes

13.4.1.1 Hydrogeological Modelling

ERA engaged the services of INTERA to develop a hydrogeological model and conduct solute transport modelling to better understand and quantify the long-term risks associated with the placement of tailings and waste rock (as either cemented tailings paste aggregate fill or cemented rock fill) into the mined out voids of the underground mine and the change to the tailings and waste rock materials balance in Pit 3. INTERA, based in Austin Texas, has experience in the development of hydrogeological models and performance assessment analyses needed to demonstrate the long-term safety of radioactive waste repositories. INTERA's report on the solute transport modelling is provided in **Appendix 9**.

INTERA expanded the set of previously developed conceptual and numerical modelling tools designed to evaluate the closure of Pit 3 to include the Project. This included the hydraulic and transport properties of host rock and the leaching behaviour for the backfill material. The hydraulic properties of the host rock and other hydrolithologic units that formed part of the hydrogeological modelling have been derived from a number of sources. These include previously published information and recent testing, both in the laboratory and the field. Porosity measurements were conducted on core samples from the different sequences of the host rock and estimates of hydraulic conductivity were obtained from straddle-packer hydraulic testing performed on 16 intervals within 2 bores accessing Project rock from the surface. Details of the host rock permeability and how it has been used within the hydrogeological model are provided in **Appendix 9.**

The overall objective of the INTERA work was to develop modelling tools that quantify the potential impacts to Magela Creek for 10,000 years post closure. Potential impacts were defined as the mass loading to the creek over time for contaminants of potential concern[9] that leach into groundwater from the waste rock and tailings used for underground mine backfill or placed into Pit 3. In order to conduct the assessment over a 10,000 year time frame a Features, Events and Processes analysis was conducted with key stakeholders to assess the potential impact of a number of scenarios and natural events; including earthquake, cyclone, fire and flood, that could occur during the model time frame. This technique is commonly used by the International Atomic Energy Agency for safety assessments for these long time periods.

For the initial modelling magnesium (Mg) was chosen as the contaminant of concern because of both its potential toxicity to the Magela Creek biota and because its transport through the host rock to Magela Creek is unlikely to be significantly attenuated by geochemical reactions. Magnesium loads from the backfill materials to Magela Creek were quantified by modifying and applying a three dimensional numerical model of groundwater flow and transport that had previously been used to evaluate impacts from Pit 3 closure in the absence of the Project.

The remaining contaminants of potential concern are reactive and will therefore have some attenuation during transport through the host rock. Loads from these reactive contaminants were estimated by scaling Mg loads using ratios of long-term source concentrations.

Modelling was conducted for a period of 10,000 years in order to demonstrate that contaminants from tailings will not result in any detrimental environmental impacts for this

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[9] Contaminants of potential concern included magnesium (Mg), uranium (U), manganese (Mn), radium (^{226}Ra), total ammonia as nitrogen (TAN), nitrate as nitrogen (NO_3-N), total phosphate (total-P), and polonium (^{210}Po).

period, as required by the Ranger Authorisation. More details of the modelling approach are provided in **Appendix 9**.

Throughout the modelling a conservative[10] approach was taken for the various input parameters to assess potential impacts from the Project. One example was the estimation of the contaminant concentrations in both waste rock and tailings; these were estimated using the 87.4th percentile[11] of the available empirical data set. This conservatism will allow for any potential changes to the geochemical nature of the Project's waste rock and tailings. Other areas in which the model is conservative is that it eliminates trapping of solutes by groundwater ponding and evapoconcentration, it assumes solute sources will leach uniformly for 10,000 years and all solute loads report to Magela Creek (as a model boundary condition).

The model was also tested to determine the sensitivity of predictions to changes in assumptions for various input parameters. The sensitivity analyses demonstrated that the Mg loads from Project backfill materials remained negligible for a tenfold increase in backfill hydraulic conductivity, a tenfold increase in hydraulic conductivity for the underground mine water-producing zone, and for changes in recharge on the waste rock landform. This gives added confidence in the modelled predictions of no detrimental impact and supports the rating of C3 – high confidence in **Table 13-3**.

Backfilling of the Project stopes with cemented tailings paste aggregate fill, and of the vents and decline with cemented waste rock fill, were found to have a negligible impact on Mg loads to Magela Creek. The total Mg load from all Project backfill is predicted to be up to 3 kg per year, with the total loads from the reactive solutes proportionately lower. These are provided in **Table 13-4** and compared to both the limits in the current Ranger Authorisation and that currently being released from Ranger mine operations, with no observable detrimental impact.

Table 13-4: Predicted long-term annual additional loads to Magela Creek

Contaminant	Unit	The Project loads	Current limit (authorised annual additional loads)	Average current operations loads
Uranium (238 + 234)	GBq/y	0.00001	88	0.55
Radium 226	GBq/y	0.000004	13	0.14
Polonium 210	GBq/y	1.7×10^{-10}	7	0.05
Manganese	t/y	0.000002	6	0.02
Phosphate	t/y	0.000003	2.8	0.01
Nitrate	t/y	0.000007	4.4	0.13
Magnesium	t/y	0.003	n/a	-

10 In the context of environmental modelling, a conservative approach is one that intentionally increases the likelihood that impacts will occur when selecting from ranges of uncertain model inputs. That is, given a range of values for a model input, under a conservative modelling approach, the input value will be selected from the part of the range that is more likely to result in impacts being predicted than if other values were selected.

11 This value represents a number that is higher than the average but not the maximum observed, making it conservative but not worst case. In this case only 12.6% of the results are higher, or 87.4% are equal or lower.

Given these very low additional loads, corresponding changes to concentrations in Magela Creek are also expected to be negligible. The predicted concentrations in the creek and an assessment of the potential impact from these concentrations has been provided in **Appendix 11** with a summary provided in **Section 8.5.2.2** and **Table 8-6**. These show the very small loads would be fully diluted in the flowing creek system during the wet season and result in very low concentrations above background in Magela Creek. It can therefore be concluded that the egress of constituents of potential concern from the Project post-closure will not have any environmental impact in the aquatic environment and furthermore will not compromise the ecological and/or cultural values of Magela Creek and associated wetlands.

13.4.2 Impact on Existing Operations Closure

The other high rehabilitation and closure risk (TE7-01) related to the potential for the Project to impact on the existing operations closure and progressive rehabilitation schedule. Details of each potential impact area and its potential to affect the closure methods, the closure schedule, or the likelihood of achieving closure objectives has been provided in **Table 13-5**. This table demonstrates that the Project will not impact on the closure of Ranger mine in any substantive manner.

Table 13-5: Potential for the Project to impact on existing closure

Potential impact area	**Potential to impact on**		
	Closure methods	**Closure schedule**	**Closure objective**
Ore derived from the Project will generate tailings a portion of which will be placed underground. The remaining tailings being deposited in the current operations tailings storage facility (scheduled to be Pit 3).	As ore is blended with existing stockpiled ore, tailings originating from the Project will be combined and indistinguishable from existing tailings. Tailings will be deposited the same as for current closure with the same moisture content and density. Tailings are geochemically the same as for current operations, refer **Section 3.4.1**. The methods for closure will therefore be the same.	The current Ranger mine closure planning assumes that the processing plant will continue operating at maximum capacity though to January 2021, generating tailings at the same rate as would occur with the Project. There will be no change to the consolidation rate of tailings and the subsequent backfilling and closure of Pit 3.	Modelling has shown there is no impact to Magela Creek due to solute mobilisation from the placement of tailings underground.
With the fixed capacity of the Ranger operations processing plant, lower grade stockpiled ore that would otherwise have been processed will remain un-processed at the completion of operations and require disposal.	The lower grade rock will be placed in Pit 3 above the tailings. The small reduction in tailings volume will partially compensate for the volume requirement of the overall increment of un-processed low grade rock.	The amount of waste rock to be moved as part of final closure is not significantly changed; representing <5% of material to be placed (refer **Section 13.3.4** and **Table 13-1**).	This low grade material will be placed in the saturated zone, thus minimising its potential for solute mobilisation (refer **Section 13.3.4** and **Figure 3-3**). Modelling has shown there is no change to the solute mobilisation from Pit 3.

Potential impact area	Potential to impact on		
	Closure methods	**Closure schedule**	**Closure objective**
The Project will generate additional waste rock that requires disposal	The Project waste rock is geochemically similar to the current waste rock so the methods of final disposal will be the same as for current operations	The underground mine will generate a very small amount of waste rock, moving this material will not change the closure schedule (refer **Section 13.3.4** and **Table 13-1**).	The very small incremental waste rock (<1% of current operations) can easily be incorporated into the existing Pit 3 backfill and final landform (refer **Section 13.3.4** and **Table 13-1**).
Operation of the underground mine and processing of Project ore may impact on closure activities.	Closure methods will not change with the operation of the Project.	Inclusion of the Project into the Ranger operations schedule shows that mining and processing will be completed in January 2021 (refer **Section 3.9.1**).	Closure objectives will not change with the operation of the Project.
Rehabilitation of the underground voids will increase the time required for closure.	Closure of the underground voids will be independent of other closure activities. Methods for closure form part of mine operations.	Rehabilitation of mined out voids will be progressive, resulting in minimal post mining additional rehabilitation works.	Closure objectives will not change with the operation of the Project.
Closure of the Project may impact on existing revegetation works or progressive revegetation	Current operations rehabilitation would likely include removal of any contaminated soils in the land application (water irrigation) areas. Any additional localised contamination around ventilation stacks will be removed as part of this work. No additional remediation works will be required.	There is very minimal infrastructure for the Project and this is well away from existing revegetation works. Progressive rehabilitation of the majority of the Magela land application area can progress in parallel with the Project with a small section remaining to be completed with other rehabilitation works.	Closure objectives will not change with the operation of the Project.
The Project will increase the amount of pond and process water requiring treatment and disposal at closure.	Pond water volumes will increase with the Project, but remain within the capacity of existing water management systems. No significant change will occur to process water inventory.	Modelling has shown that all water can be treated without materially altering the inventory trajectory to closure (refer **Section 8.5.2.3**).	Closure objectives will not change with the operation of the Project.
New infrastructure will require removal at closure.	At closure the current operations infrastructure will be placed in either Pit 3 or the Ranger 3 Deeps exploration decline. The additional Project infrastructure will be decommissioned using the same methods and disposal sites as for current operations.	There is only a small amount of additional infrastructure for the project (refer **Section 3.5**). Removal can occur within the same decommissioning time through deployment of marginally increased resources.	Each year, ERA includes all newly installed infrastructure in its annual plan of rehabilitation (see **Section 13.3.7**). All new infrastructure installed for the Project will be included in this plan, thereby mitigating the risk of not removing items during the decommissioning phase.

13.4.3 Disturbance during Infrastructure Removal

A risk identified for the decommissioning phase was the potential for disturbance or damage to heritage areas or the unexpected removal of habitat. In order to mitigate this risk, ERA will conduct all decommissioning works according to current operational standards:

- *Interim Cultural Heritage Protocol*, which considers the decommissioning area;
- cultural heritage management system;
- site management plans;
- physical barriers and signage, including fencing of the cultural heritage site R34;
- land disturbance permit system (including cultural controls);
- cultural heritage management system training; and
- on site cultural inductions for Project employees and contractors.

13.4.4 Contingencies for Unexpected Closure

Each year, ERA is required to submit an annual plan of rehabilitation to the supervising authorities[12]. This plan details the works that need to be undertaken if unexpected (or short notice) closure were to occur and included details of how to make the landforms secure and non-polluting. This plan provides a cost for completing these activities, effective from 31 March in a given year. This annually calculated amount must be provided as a bond to the Australian Government to be held in trust.

The current plan has incorporated the Ranger 3 Deeps exploration decline. Following approval of the Project and commencement of operations, subsequent annual plans of rehabilitation will incorporate the cost for rehabilitating any mined out areas or infrastructure installed as part of the Project.

Should unexpected closure occur at any time through the Project life, the Australian Government will hold sufficient funds in trust from ERA to rehabilitate the Project according to this plan.

[12] The includes; the MTC, Commonwealth and Northern Territory ministers.

13.5 SUMMARY

A rehabilitation and closure strategy for the Project has been developed that fully aligns with closure planning for the current Ranger mine operations and will be integrated into the overall Ranger closure planning upon commencement of construction and mining. The main elements of this closure strategy include:

- placement of tailings in mined out voids as a cemented paste aggregate fill, designed to minimise solute transport to Magela Creek;
- backfilling ventilation shafts and the decline to minimise solute transport to Magela Creek;
- grouting, by filling with cement, or covering all surface drill and paste backfill holes to prevent injuries to the public and fauna falling down the holes post closure; and
- using the current operational management system to minimise the potential for disturbance or damage to cultural heritage areas or the unexpected removal of habitat during decommissioning works.

The key rehabilitation and closure risks posed by the Project related to the potential for solute transport into Magela Creek for at least 10,000 years post closure and for the Project to interfere with the ability to complete closure of the current operations.

Hydrogeological modelling conducted for tailings and waste rock disposal according to the closure strategy has demonstrated that the Project will have no detrimental impact on the ecological and/or cultural values of Magela Creek and associated wetlands over a 10,000 year period.

It has been demonstrated that the Project will not have a significant impact on waste materials balance, the amount or type of infrastructure requiring decommissioning, water management requirements, revegetation works or the operations schedule to complete processing by January 2021. Based on this it can be concluded that the Project will not materially alter the closure method, schedule, or the likelihood of achieving current closure objectives and can be successfully integrated into existing Ranger mine closure.

13.6 REFERENCES

Bartolo, RE, Paulka, S M, van Dam, RA, Iles, M & Harford, A (2013) *Rehabilitation and closure ecological risk assessment for Ranger Uranium Mine: Documentation of initial problem formulation activities. Internal Report 624*, Supervising Scientist, Darwin, October 2013.