9 Closure implementation

Issued Date: October 2022

Revision #: 1.22.0

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

GLOSSARY

The following key terms are used in this section of the Ranger Mine Closure Plan

Key term	Definition
Bulk material movement	Abbreviated to BMM, he movement of stockpiled waste rock for the purposes of backfill and the construction of the final landform
Capping	Initial and secondary. The placement of waste rock above the tailings in Pit 3. Capping layers provide drainage and act to dissipate the bearing pressure of construction equipment.
Closure domain	Areas with similar features, decommissioning and/or rehabilitation requirements for closure.
Conceptual Reference Ecosystem	Abbreviated to CRE, a conceptual model of a natural reference ecosystem adjusted to accommodate changed or predicted environmental conditions, synthesised from numerous natural reference sites and modified based on evidence from research, trials, experience, benchmarking, and historical and predictive records
Digital Elevation Model	Digital representation of the land topography
Georgetown Billabong	Abbreviated to GB. The statutory surface water monitoring point for Georgetown Billabong, which is located downstream of Corridor Creek and the Corridor Creek wetland filter.
Land Application Area(s)	Abbreviated to LAA. An area on the RPA used as an evapotranspiration disposal method polished and unpolished pond water from the constructed wetlands filters and, more recently, permeates from the water treatment plants. However, irrigation of unpolished pond water ceased at the end of 2009. The concept of land application is to retain metals and radionuclides in the near-surface soil profile.
Maximum Operating Level	Maximum height permitted for process water in the RWD and Pit 3. Maximum operating level also applies to the maximum deposited height of tailings in Pit 3.
Pit 1	The mined out pit of the Ranger #1 orebody, which is used as a tailings repository. Mining in Pit 1 commenced in May 1980 and was completed in December 1994, after recovering 19.78 million tonnes of ore at an average grade of 0.321%.
Pit 3	The mined out pit of the Ranger #3 orebody, which is currently being backfilled with tailings. Open cut mining in Pit 3 commenced in July 1997 and ceased in November 2012.
Processing	Processing is the mining term to describe all phases of the ore treatment from milling through to the final product packaging of uranium oxide.
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.
Ranger Water Dam	Abbreviated to RWD. Surface dam used to hold tailings and process water at Ranger. Commonly referred to as "tailings storage facility" or "RWD" in other ERA material. The Ranger Water Dam was one of three tailings storage facilities at Ranger, the others being Pit 1 and Pit 3.

Key term	Definition
Reference level	Abbreviated to RL. Denotes a specific elevation relative to mean sea level and is regularly used to identify the height or depth of plan or mine infrastructure – e.g. the height of the Ranger Water Dam, depth of Pit 3.
Retention Pond	Abbreviated to RP. A large constructed storage facility that collects runoff and stores pond water for treatment (RP2 & RP6) or release water post-treatment (RP1).
Revegetation domains	Areas of disturbance, to be revegetated, differentiated on their likely physical and chemical constraints that will influence both the initial establishment and the long-term growth, development and functioning of revegetated plant communities.
Subaerial tailings deposition	Deposition of tailings in air, e.g. from spigots or pipes above the surface of the water
Subaqueous tailings deposition	Deposition of tailings below the surface of the water
Tailings Dam / Tailings Storage Facility (TSF)	The Ranger Water Dam (RWD)
Expressed Pond Water	Process water squeezed from reducing pore spaces during the consolidation of tailings formerly known as the Pit Tailings Flux (PTF)
Underfill	Initial fill of waste rock placed in the base of Pit 3.
U3O8	The most stable form of uranium oxide and the form most commonly found in nature. Uranium oxide concentrate is sometimes loosely referred to as yellowcake. It is khaki in colour and is usually represented by the empirical formula U3O8. Uranium is normally sold in this form.
Vadose zone	Abbreviated to VZ. The portion of the sub-surface that lies between ground surface and the water table or saturated zone.
Waste rock	Abbreviated to WR. The mineral waste produced in the mine but is stockpiled due to its low grade i.e. material which does not enter the processing plant. For example, 1s waste rock is typically material that has a grade of less than 0.02% U3O8; 2s waste rock (or low-grade ore) is typically material that has between 0.02% and 0.12% U3O8.
Wetland filter	A man-made system that is purpose built to emulate the ecosystem services provided by natural wetlands as a low cost, efficient means to polish/remediate/clean-up effluent.
Wicks / Prefabricated Vertical Drains	Abbreviated to PVD. Drains inserted vertically into unconsolidated tailings material in Pit 1 and 3. The drains consist of plastic strips wrapped in geofabric with extruded channels that allow water to drain upwards from the tailings as it consolidates

ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used in this section of the Ranger Mine Closure Plan.

Abbreviation/ Acronym	Description
1s rock	Waste rock material that typically has a grade of less than 0.02% U_3O_8
2s rock	Waste rock (or low grade ore) material that typically has between 0.02% and 0.12% U_3O_8
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALARA	As Low As Reasonably Achievable
BC	Brine Concentrator
BMM	Bulk Material Movement
BPT	Best Practicable Technology
C&M	Care and Maintenance
CCD	Counter Current Decantation
COPC	Constituents of Potential Concern
CRE	Conceptual Reference Ecosystem
CRF	Cemented Rock Fill
CSIRO	Commonwealth Scientific, Industrial Research Organisation
DEM	Digital Elevation Model
DISR	Commonwealth Department of Industry, Science and Resources (formally DIIS)
DITT	Department of Infrastructure, Tourism and Trade
DPIR	Now DITT formerly the Northern Territory Department of Primary Industry and Resources
ER(s)	Environmental Requirements
ERA	Energy Resources of Australia Ltd
ERISS	Environmental Research Institute of the Supervising Scientist
FLF	Final Landform
GAC	Gundjeihmi Aboriginal Corporation
GCMBL	Georgetown Creek median bund leveline
GPS	Global Positioning System
H2	Second Half
HDPE	High Density Polyethylene
HDS	High Density Sludge
LAA	Land Application Area(s)
MCP	Mine Closure Plan

Abbreviation/ Acronym	Description
MOL	Maximum Operating Level
mRL	Metres Reference Level
MTC	Minesite Technical Committee
NLC	Northern Land Council
NP	National Park
PAW	Plant Available Water
PMP	Probable Maximum Precipitation
PSD	Particle Size Distribution
PTF	Expressed process water formerly termed Pit Tailings Flux (PTF)
PVD	Prefabricated Vertical Drains (wicks)
Q1	Quarter 1, as in first quarter of the calendar year. Also Q2, Q3 & Q4
R3D	Ranger 3 Deeps
RL	Reference Level
RMV	Ranger Mine Village
ROM	Run-of-mine
RP1	Retention Pond 1 – also denotes other retention ponds used on site – e.g. RP2, RP3, RP6
RPA	Ranger Project Area
RWD	Ranger Water Dam formerly the Tailings Storage Facility or Tailings Dam
SSB	Supervising Scientist Branch; formally the Supervising Scientist Division
SX	Solvent Extraction
TDS	Total Dissolved Solids
TLF	Trial Landform
TSF	The Ranger Water Dam (RWD) formerly known as the Tailings Storage Facility or Tailings Dam
WTP	Water Treatment Plant

9 CLOSURE IMPLEMENTATION

9.1 Introduction

This chapter provides:

- a description of the closure work program for each closure domain; and
- a description of the closure activities that are required across multiple closure domains.

Within the description of closure works for each domain, the status of completion for each closure activity is provided. This chapter details the ‘what’, ‘where’ and ‘when’ of closure activities at the Ranger Mine. Studies used to inform the closure strategy for a domain are the ‘why’ and have been previously described in *Section 5 KKN Supporting Studies*.

9.2 Closure domains

Closure domains for the Ranger Mine are areas with similar closure features, decommissioning and/or rehabilitation requirements (DMIRS, 2020). The location and spatial extent of each closure domain is shown in Figure 9-1. Table 9-1 identifies the area of disturbance that has occurred within each domain, whilst

Table 9-2 identifies the area that has been progressively rehabilitated.

For each domain, discussion is included about the tasks that have already been completed, those currently underway, those planned, and relevant contingency plans. Closure activities that apply across more than a single domain, such as revegetation, or activities that do not fit into a specific domain, such as the treatment of the process water inventory, are discussed in Section 9.3.

Table 9-1: Land disturbance by domains

Domain No.	Domain Description	Disturbance (ha)	
1	Pit 1	41.40	41.40
2	Pit 3	107.12	107.12
3	Ranger Water Dam (formerly the Tailings Storage Facility)	185.18	185.18
4	Land Application Areas		
4A	Corridor Creek LAA	13.50	
4B	Magela LAA	45.56	
4C	Djalkmarra LAA	12.50	
4D	Djalkmarra LAA ext.	5.80	
4E	Retention Pond 1 LAA	36.0	
4F	Retention Pond 1 LAA ext.	0.9	
4G	Jabiru East Land Application Area	43.0	158.00

Domain No.	Domain Description	Disturbance (ha)	
5	Processing plant, administration buildings and Water Treatment Plant	39.86	39.86
6	Stockpiles	268.65	268.65
7	Water Management Areas		
7A	Retention Pond 1	53.89	
7B	Retention Pond 2 & 3	21.80	
7C	Retention Pond 6	12.85	
7D	Retention Pond 1 wetland filter	11.43	
7E	Corridor Creek wetland filter	9.48	
7F	Georgetown Creek Mine Bore	13.84	
7G	Sleepy Cod Dam	2.33	125.61
8	Linear Infrastructure (tracks, service corridors)	40.79	40.79
9	Miscellaneous		
9A	Gagudju Yard	1.80	
9B	Ranger Mine Village (temp)	3.04	
9C	Nursery/Coreyard	4.05	
9D	Levee	2.82	
9Ei	Borrow Pits	2.32	
9Eii	Borrow Pits	16.40	
9Fi	Landfill Sites	3.62	
9Fii	Landfill Sites	6.79	
9G	R3 Deep Decline	2.63	
9H	Magazine	0.95	
9I	Trial Landform	10.60	55.02
10 A & B	Airport & ERISS	44.08	44.08
11	Residual RPA	0	0
Total			1062.53

Table 9-2: Area of progressive revegetation at RPA

Site	Area
Trial landform	6.38
Borrow pit	1.39
RPI Site 3	0.12
Closed track at RMV	0.31

Site	Area
RMV revegetation track	3.34
RMV (Ranger Mine Village)	1.40
Drill pad east of Djalkmarra 1	0.13
Drill pad east of Djalkmarra 2	0.22
Drill pad east of Djalkmarra 3	0.19
Magela B drill pad 1	0.06
Magela B drill pad 2	0.04
Drill pad	0.16
Stage 13.1	4.00
Pit 1	40.00
Total	*57.74 ha*

C:\Users\jrivera\UMWELT (AUSTRALIA) PTY. LTD\22545 - 03 S&V\F_MCP_2022\22545 MCP2022.aprx

Figure 9-1: Ranger Mine closure domains

9.2.1 Pit 1

Figure 9-2: Pit 1 (June 2021)

9.2.1.1 Completed rehabilitation

Upon the completion of mining in December 1994, ERA commenced activities for the closure and rehabilitation of Pit 1 (Figure 9-2). A summary of the activities that have taken place from 1995 to present is provided in Table 9-3.

Table 9-3 Completed Pit 1 rehabilitation

Year	Closure activity
1995-96:	Preparation of the pit to receive tailings included the construction of an underdrain in the base of the pit of approximately 10,000 m2 in area, and construction of a horizontal rock-filled adit from the base of the pit to intercept a vertical dewatering bore. Tailings deposition into the pit began in August 1996.
2005	Installation of a seepage limiting barrier in the south-eastern part of the pit occurred to seal permeable wall zones and ensure the effective containment of process water.
2006	Grouting and ongoing monitoring of the seepage limiting barrier.
2008	Tailings deposition in Pit 1 ceased in Quarter 4. The void volume of Pit 1 is 24.0 Mm3. The volume of unconsolidated tailings in Pit 1 was approximately 18.9 Mm3 and the average level of the tailings was less than +12 mRL, in accordance with the interim approval to store tailings in Pit 1 (Marshall, 2014).
2012	The installation of 7,554 prefabricated vertical drains (PVDs) occurred to assist with dewatering the pit prior of capping and rehabilitation. The wicks were installed within the top 40 m of the tailings mass. The purpose of the wicks was to dewater the upper level of the tailings and promote tailings consolidation, thus establishing a stable surface upon which to commence backfill activities.
2013-14	Installation of a geotextile layer occurred across the exposed tailings surface area and, subsequently, a 2.5 m thick rock initial capping was placed across 97% of the pit. The rock placement was designed to activate the vertical wick drains and promote porewater expression. A laterite layer was placed over the northern half the pit to form the pond water interception layer, to prevent rainwater adding to the process water inventory.

Year	Closure activity
	Prior to the placement of the initial capping layer in the fourth quarter of 2013 and in 2014, 28 settling monitoring plates were installed across the pit to enable regular verification and updating of the consolidation model.
2015	A geotextile layer was installed across the remaining exposed tailings surface (3% of total surface).
2016	In January, the remaining 2.5 m thick rock initial capping[1] and laterite layers were placed so the entire pit surface was covered. Two decant towers were installed to remove the expressed process water from the pit. A subsequent decant well was installed in 2017. Bulk backfill of Pit 1 commenced in May following regulatory approval of the final average tailings level of +7 mRL.
2018	Bulk backfill was halted in July, pending regulatory approval for final backfilling works.
2019	In May the final backfill commenced following regulatory approval of the final landform design.
2020	The final backfill and landform contouring was completed in August, with scarification of the final landform occurring in November. Works on the Interim Water Management System (IWMS) are completed prior to the commencement of the wet season.
2021/22	Initial planting on the final landform (Figure 9-3)

Key elements of Pit 1 closure were (these are further described in the sections that follow):

- construction of an underdrain across the floor of the pit, connected to a vertical dewatering bore via a horizontal rock filled adit;
- deposition of unconsolidated mill and RWD tailings in the base of the pit;
- installation of vertical wick drains to assist with dewatering;
- installation of an initial capping layer of geotextile and waste rock;
- ongoing removal of pit tailings flux during tailings consolidation to reduce the risk of contaminants entering groundwater or surface waters and potentially impacting the RPA or offsite aquatic ecosystems;
- placement of Grade 2 (2s) waste rock material below the water table to reduce the risk of contaminants impacting RPA or offsite aquatic ecosystems, and below a layer of Grade 1 (1s) material to ensure any gamma radiation from the 2s material is sufficiently attenuated;
- construction of a surface layer of non-mineralised 1s material, with consideration given to the physical characteristics and thickness of the material required to support a self-sustaining native ecosystem similar to target reference ecosystems;

[1] Note: “Initial capping layer” and the term “Preload” has been interchangeably been used in numerous studies for Pit 1

- construction of drainage channels to manage erosion of the surface layer and reduce the risk of mobilised sediments or other contaminants impacting RPA or offsite aquatic ecosystems;
- revegetation to initiate the establishment of a self-sustaining ecosystem; and
- monitoring and research to continue to improve on the trials and modelling already completed. This will further reduce the risks associated with aspects of the Pit 1 closure and inform the closure planning for the rest of the final landform.

Tailings preparatory works

It was recognised that the shape of Pit 1 would result in rapid filling of the lower benches, with little opportunity for beaching and air drying of the tailings during deposition. The intent of the pre-deposition works was to maximise the rate of consolidation of the tailings by providing a hydraulic gradient towards the base of the deposited tailings (Knight Piesold, 1997).

Preparatory works consisted of an underdrain, constructed from the base of the pit to around -142 mRL and approximately 10,000 m^2 in area. A horizontal rock filled adit, was also installed, from the base of the pit to intercept a vertical de-watering bore. Process water from the rock filled adit, was pumped to the Ranger Water Dam to maintain a zero head at the level of the underdrain (Coghill *et al*., 2003).

Tailings deposition

ERA commenced the deposition of tailings within the mined-out Pit 1 in August 1996. Between 1996 and December 2008, ERA deposited approximately 18.9 Mm3 (25.6 Mt) of tailings into the pit (ATC, 2012, CSIRO, 2014). Concurrent with tailings deposition, Pit 1 was also used to store process water.

The original tailings application specified a maximum tailings level of 0 mRL (ERA, 1995). This allowed for approximately 15.2 Mm^3 of unconsolidated tailings to be deposited into the pit (Kenny, 2003). To maximise the volume of tailings able to be stored in Pit 1, ERA constructed a seepage-limiting barrier in the southeast section of the pit. The barrier sealed permeable sections of the pit wall and formed part of ERAs successful application to increase the tailings deposition level to an interim +12 mRL, in 2005 (ERA, 2005).

The deposited tailings undergo a geotechnical process called consolidation. Consolidation causes the volume of the tailings to decrease as the mass compresses, due to self-weight and the application of capping and backfilling loads (Fitton, 2020). Consolidation in Pit 1 is measured using 28 settlement monitoring plates, installed as part of the initial capping works.

Consolidation of tailings, in Pit 1, has proceeded in accordance with modelled outcomes in ATC (2012) and Fitton (2015a) (Fitton, 2021). Based on the predicted ultimate settlement of 4.52 m the degree of consolidation at the time of the last survey is approximately 98 to 99% (Fitton, 2021).

Wicking

Prefabricated vertical drains or wicks were installed over the period May to September 2012 (ATC, 2012). A total of 7,554 wicks, covering an area of approximately 18.4 ha, to depths between 18 m and 34 m, were installed on the tailings surface in Pit 1 (Figure 9-3, ATC, 2012; ERA, 2013a). The purpose of the wicks was to facilitate consolidation of the upper 40 m of tailings in order to release water and densify the tailings (ERA, 2013b).

Figure 9-3: A view of some of the 7,554 vertical wick drains installed in Pit 1 in 2012

Geotextile placement and initial capping

Following the installation of wick drains and the draining of water from the surface of Pit 1, a geotextile layer was placed across the exposed tailings surface area. An initial waste rock cover, called a pre-load at the time, accompanied this and was designed to activate the vertical wick drains and promote porewater expression. Initial capping works were carried out during the last quarters of 2013, 2014 and 2015.

Backfill

Following the construction of the initial capping layer, ERA commenced works to complete the remainder of the backfill and construction of the final landform in Pit 1. The two types of waste rock used in rehabilitation are termed 1s and 2s (Table 9-4). Waste characterisation is further discussed later in this chapter. Placement of bulk backfill into Pit 1 by Ranger's mining production fleet commenced in 2017 and was completed in 2020. The backfill progressed in two distinct phases (ERA 2019a):

- Placement of mineralised (low 2s) and un-mineralised (1s) rock fill up to the '2's Cap' between April 2017 and November 2018; and
- Placement of un-mineralised (1s) material as the surface layer, up to the Final Landform (FLF) level.

Table 9-4: Type of waste rock used in rehabilitation

Type	Term	Uranium oxide grade (U3O8) %wt
Non-mineralised waste rock	1s (Grade 1)	Less than 0.02
Mineralised waste rock	2s (Grade 2)	0.02 – 0.05

The design for the backfill of Pit 1 prioritised maximising the volume of mineralised (low 2's) material placed in the pit (Fitton, 2018a). Therefore the key to the backfill design of Pit 1 was to place fill to an elevation so that, after the potential settlement due to tailings consolidation, the 2s material is below the height of 20 mRL with minimal need for modification of the surface levels.

The bulk backfill design also aimed to minimise the potential disturbance to the decant towers, settlement plate upstands and future drainage patterns. ERA placed the 2s waste rock in seven stages using three metre paddock-dumped layers. This dumping method allowed for the raising of the settlement standpipes and decant wells, and therefore more accurate monitoring of fill depths (Fitton, 2015b) (*Section 5 KKN Supporting Studies*).

The final level of 2s waste rock was completed in 2018. Surveys demonstrated that the level of 2s is below the 20 mRL, achieving the desired design parameters (Fitton, 2018b). The conservatism built into the design allows for additional tailings settlement induced by the weight of the final waste rock cover.

Following placement of the 2's, construction began on the surface layer in 2019. The surface layer was not constructed in thin lifts, like the underlying 2's layer, but two lifts, called the FL-2.5 m layer and final landform layer. The backfilling and contouring of the surface layer was completed in August 2020.

9.2.1.2 Current rehabilitation

Tailings consolidation and removal of pit tailings flux

Water from various sources contributes to the water balance of Pit 1 (Figure 9-4). Rainfall is collected both on the immediate surface of Pit 1, and indirectly via overland flow from nearby catchments that report to the pit. The bottom of the pit is filled with tailings that are nearly fully consolidated. The pore spaces between the tailings solids contain process water and, as the tailings have consolidated, that process water has been squeezed up as a consolidation flux (pit tailings flux). Above the tailings are several layers of waste rock backfill. Most layers of the waste rock backfill are porous and, as such, can accumulate water from the various sources. Groundwater from surrounding rock formations may enter this waste rock backfill.

Decant wells have been installed and extend from the surface of the waste rock backfill down to near the top of tailings. The towers consist of stacked concrete rings, with the bottom ring slotted to allow water to enter the decant.

As the tailings in Pit 1 approaches the completion of consolidation, the flow rate of expressed process water has declined to low levels. The decant towers have been retained as a contingency for managing any future tailings consolidation flux and mitigating seepage from the waste rock cap to the surrounding perimeter drain. The towers are currently operated on an 'as required' basis.

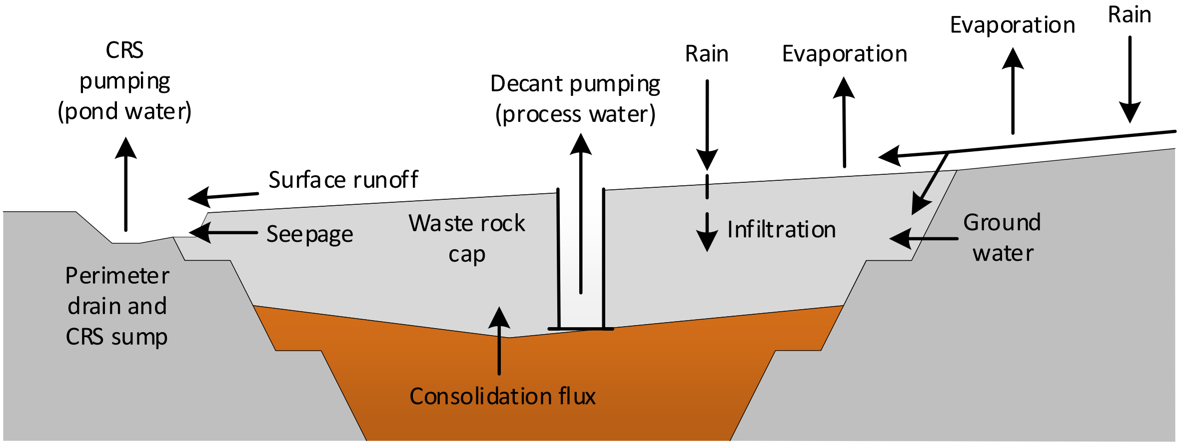


Figure 9-4: Pit 1 water balance schematic

Landform

In preparation for revegetation and further trials (Chapter 9.1.1.1), the surface of Pit 1 was lightly scarified in Q3 2020. This measure was implemented to reduce sediment movement and erosion during the 2020/2021 wet season (Figure 9-5).

Figure 9-5 Scarification as seen on 28 Oct 2020 (top), 6 Jan 2021 (middle), 17 Feb 2021 (bottom)

Pit 1 was walked and visually inspected for parameters such as accessibility and traversability by the representatives of the traditional owners (or themselves) once the surface preparation was completed. No additional surface preparation is currently planned to be applied to Pit 1.

To ensure that the final surface topography for the Landscape Evolution Model (LEM) was built to the design requirements, a high-resolution DEM of Pit 1 will be produced annually and provided to stakeholders. An annual topographic survey across the pit is also planned, as is a year-on-year DEM change detection to inform changes in surface topography.

Drone photography (high-resolution orthomosaic) was undertaken on a monthly basis to monitor the micro-erosion features on the Pit 1 surface. Comparison was made between drone captures, to enable a visual assessment of sediment movement across the Pit 1 landform and mapping of sediment transport zones. Identification of erosion from the aerial comparison will be complemented by field observations on a weekly basis throughout the wet season. The monthly stitched-orthomosaic proved to be a helpful monitoring tool to identify the leading indicators for landscape changes, which will inform the preparation works for next year's wet season (Figure 9-6).

Interim water management works were completed in 2020, and further upgraded in 2021, to mitigate the water and sediment risk from Pit 1. These included:

- The installation and improvement of a water collecting drain around the edge of Pit 1 to capture rainfall runoff (Figure 9-7). Hydraulics of the channel had been modified in 2021 by reinforcing the check dams near the inlet channel.
- The extension of the previous sump (CRS) to a sufficient capacity to collect this rainfall runoff.
- The installation and further capacity upgrade of the pumping and piping infrastructure (Figure 9-8).

These interim water management structures will remain in place until the final landform construction commences in the neighbouring Corridor Creek catchment, at which time the final erosion and sediment control features will be installed. The ongoing management, maintenance and monitoring of the interim water management structures will be described in the latest version of the Ranger Water Management Plan.

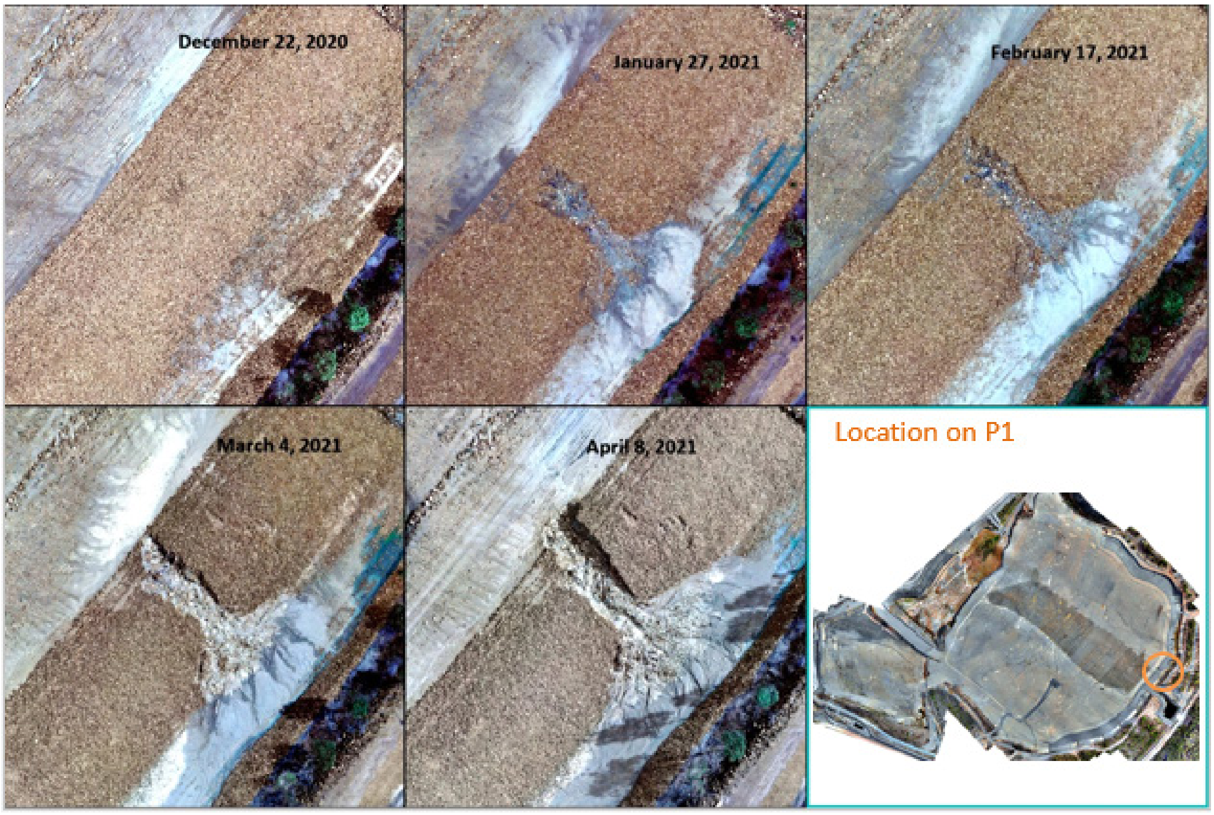


Figure 9-6 Time sequence of one channel forming on Pit 1. (2rog, 2021)

Figure 9-7: View of the perimeter drain along the southeast edge of Pit 1 (January 2021)

Figure 9-8 Completed CRS upgrade works with pumping infrastructure installed (January 2021)

Monitoring and maintenance activities

Pit 1 will be available two years before other sections of the FLF and, as such, it provides an opportunity to develop, and fine tune ERA's ecosystem re-establishment approach. The *Pit 1 Ecosystem Re-establishment Plan: Trials and monitoring program* developed the monitoring and research aspects that were key to to align with the *Pit 1 Progressive Rehabilitation Framework* and inform ongoing progressive rehabilitation across the Ranger Site (ERA, 2021c).

ERA intends for the monitoring proposed within the plan to be holistic as well as adaptive. Monitoring outcomes may change once more data is collected and the success of a method, including the suitability, is understood (ERA, 2021c). New monitoring techniques may also become available, and inform objectives. Key aspects described in the plan cover:

- Landform,
- Water,
- Ecosystem, and
- Radiation themes

Further details of the planned monitoring and maintenance aspects can be found in Section 10 *Monitoring and Maintenance,* and the *Pit 1 Ecosystem Re-establishment Plan: Trials and monitoring program* (ERA, 2021c)

Irrigation

A central pivot tower has been installed to operate as the main irrigation system for the whole Pit 1 area. A solid-state sprinkler system was temporarily used to irrigate revegetated areas from March – July until the pivot system was operating. The pivot was operational by the end of July, and was installed using a 310 m, 30 ha Upton Australian-made corrosion resistant system (ERA, 2021c). The location of the central pivot tower, including the wheel tracks, is shown in Figure 9-9.

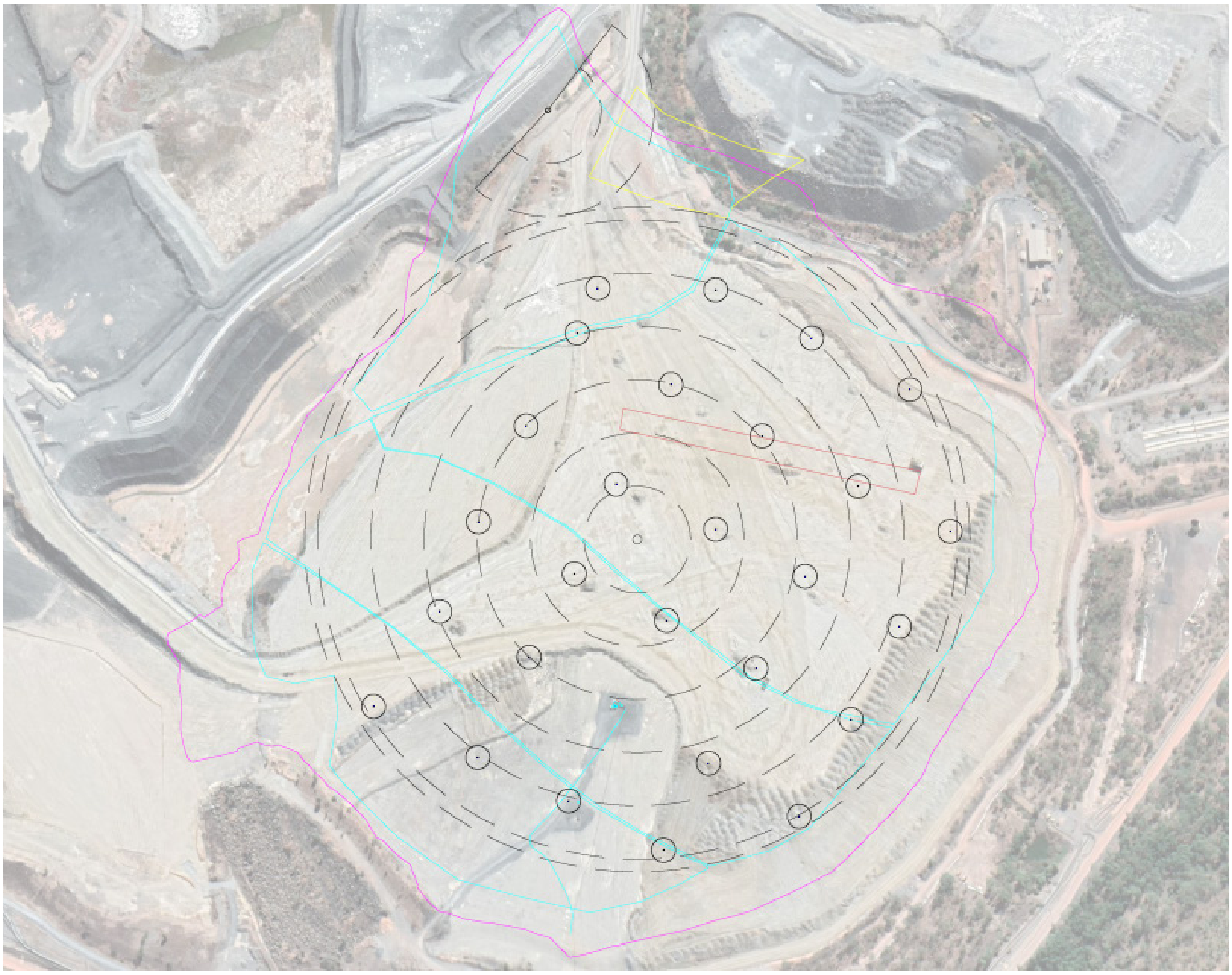


Figure 9-9 Location of the central pivot tower, including the wheel tracks. Total area of the pivot circle is approximately 29 hectares (ERA, 2021c)

Revegetation

Thirty-six hectares of revegetation was completed on Pit 1 over a ten month period in 2021 - 2022, including research trials and progressive revegetation (Table 9-5, Figure 9-10 & ERA, 2021c). Further details on the trial objective, methodology and preliminary results are discussed in *Section 5*, KKN ESR3. Further information on species planting lists, including conceptual reference ecosystem (CRE) work is discussed in *Section 5,* KKN ESR1.

Table 9-5 Summary of revegetation trials (ERA, 2021c)

	Research			**Progressive Revegetation**	
Timeline	March 2021 - April 2021	July 2021	October 2021	May -June 2021	November/ December 2021 and January 2022
Area (ha)	6.6	3.9	3.9	2.9	18.8
Vegetation	Trial species			CREv2 2020 version	CRE 2021 version

Irrigation	Solid state sprinklers until August	Pivot system	Solid state sprinklers until August	Pivot system

Figure 9-10 Pit 1 Revegetation Areas

Habitat creation

The revegetated final landform in its early years will have very little habitat areas and as such is unlikely to see the early return of fauna. To assist with the re-creation of the ecosystem, ERA has been working with traditional owners as part of the cultural reconnection committee (refer *Section 8*

Post Closure Land Use), to use rocks to create habitat areas (Brady *et al.,* 2021). These areas also provide the dual purpose of creating features on a relatively flat landform.

The rock habitat features have been placed on pre-determined lines that will link the surrounding ecosystem to the final landform (Figure 9-11). This will encourage the return of fauna from the surrounding areas.

The habitat features have been designed by local Bininj man, Peter Christophersen, who has decades of experience with mine rehabilitation. Peter has identified natural landscape features in the form of rocky outcrops that occur throughout Kakadu and in the area around the Ranger Project Area (Brady *et al.,* 2021). Several rocky habitat features were placed on Pit 1 during 2021 (Figure 9-12). The cultural reconnection committee is now being engaged to determine the selection of plant species for these rocky outcrops based on traditional ecological knowledge. The committee have begun discussing links between desired flora and fauna and their connection to each other and to places, people, story and cultural practice. Planting is expected to occur during 2022.

Figure 9-11 Preliminary plan for location of rocky outcrop habitat features on the final landform

Figure 9-12 Rocky outcrop habitat feature on installed on Pit 1

9.2.1.3 Planned rehabilitation

The only remaining rehabilitation in pit 1 is the removal of the interim water management drain and ponds, decant wells and infrastructure and revegetation of these disturbed areas.

9.2.1.4 Contingency planning

There is an ongoing monitoring program (*Section 10 Closure monitoring and maintenance*) that will consider the consolidation, erosion rates and revegetation success. Remedial action will be determined and implemented, where required, with appropriate consultation with the Minesite Technical Committee (MTC) stakeholders. This may include, for example, additional waste rock brought on to Pit 1 to remediate areas of excessive erosion.

9.2.2 Pit 3

Figure 9-13 Pit 3

9.2.2.1 Completed rehabilitation

Open-cut mining in Pit 3 commenced in July 1997 ending in November 2012, resulting in a base (floor) elevation of -265 mRL. The Pit 3 activity timeline is summarised in Table 9-6.

Table 9-6: Completed Pit 3 rehabilitation

Year	Works
1995	ERA submitted application to the MTC to mine Ranger Pit #3 orebody
1996	Approval received to mine the Ranger Pit #3 orebody
1997	Mining commences
2006	ERA submitted and application to deposit tailings to an average interim fill level of approximately -20 mRL which included preparatory works to construct a waste underfill and drainage bed
2007	Approval is received for the 2006 Application. ERA applied to extend the proposed pit outline “Shell 50” delaying tailings deposition until 2020.
2008	Approval received to commence additional mining works. Extension works commenced mining an additional 54.5 Mt of material containing 7,400 t of U3O8 of high-grade ore.
2012	Cessation of mining resulting in 94 million tonnes (Mt) of product to an elevation of -265 mRL in the east of the pit (INTERA 2014) altering the final tailings level to approximately -27 mRL, lower than previously identified.
2012 – 2014	Completion of the underfill, underdrain and dewatering systems. Waste stockpiles from the Ranger 3 Deeps exploratory decline are disposed of into Pit 3 (ERA, 2017a). Total material movement of 31.7 Mt into Pit 3 to an approximate elevation of -100m AHD (ERA, 2015).

Year	Works
2015	Five brine injection bores, piping and infrastructure are constructed within the underfill zone in Pit 3. Commencement of tailings deposition from mill processing. Predicted average consolidated tailings level is -30.2 mRL.
2016	Commencement of Brine injection. Commencement of tailings transfer from RWD into Pit 3.
2018	Commencement of alternating the discharge of dredged tailings from multiple discharge points on the Southern wall. Preparation for subaqueous dredged tailings deposition trial commences. Diffuser discharging dredged tailings from the RWD into Pit 3 trial commences.
2019	Installation and commissioning of second dredge. Final maximum level altered to -15 mRL at end of deposition. Subaqueous discharge of dredged tailings and subaerial discharge of mill tailings continues. Installation of multiple spigots along the eastern wall for mill tailings discharge (Figure 9-15).
2020	Final maximum tailings level altered to -10 mRL across the pit at end of deposition
2021	Cessation of mill operations and wind down of mill tailing deposition to Pit 3 on January 8 Cessation of dredging and bulk transfer of tailings from the tailings storage facility to Pit 3 on February 15 Successful wicking trials undertaken Construction of tailings dumping point on wall Approval to transfer remnant tailings from RWD to Pit 3 Remnant tailings transfer begins via truck and dozer Completion of remnant tailings transfer in December.
2022	CPT Campaign Rapid water drawdown to wicking level of RL -14.1 Reconstruction of Western Ramp Construction of Western Ramp Crane Pad & working platform for wicking Transfer and mobilization of workboats (Mudskipper & Ginga) into Pit 3 Reconstruction of Southern Ramp Construction of laydown areas for wicking (Stage 9 & Pit 3 South Laydown) Construction of dedicated access and egress to Pit 3 Western Ramp Installation of wash bays at controlled/supervised intersection points Installation of 2x time lapse cameras

Underfill and brine injection

Prior to tailings being deposited into the mined-out Pit 3, preparatory works were completed to enable the pit to receive tailings and brine, the conceptual design provided in Figure 9-14. The construction of the waste rock underfill and overlying underdrain raised the floor of the mined-out Pit 3 from -265 mRL to -100 mRL providing a broad, level surface area for tailings deposition. The construction of the underfill facilitated a low rate of tailings rise as well as optimising tailings consolidation rates. Early and rapid consolidation will support a stable waste rock capping design, improving the success of revegetation and rehabilitation programs.

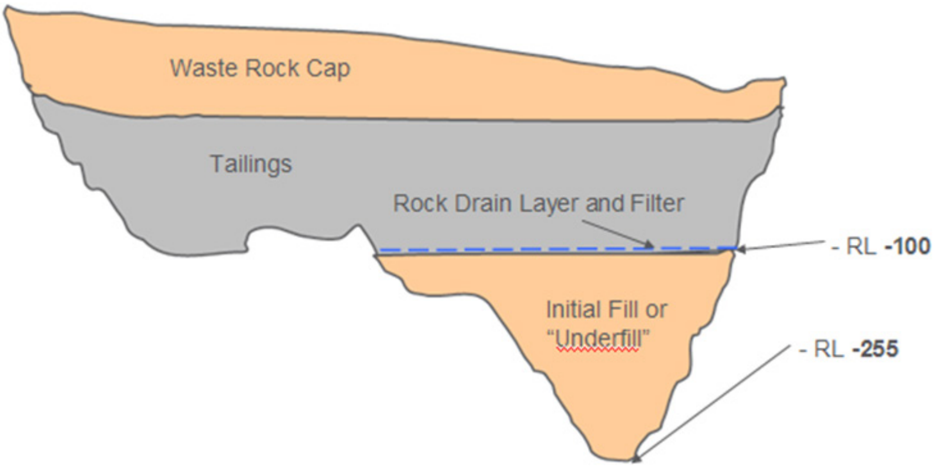
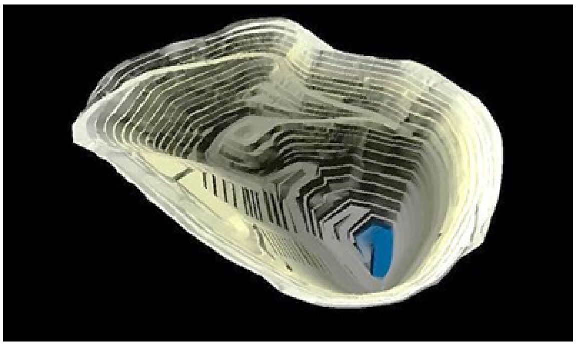
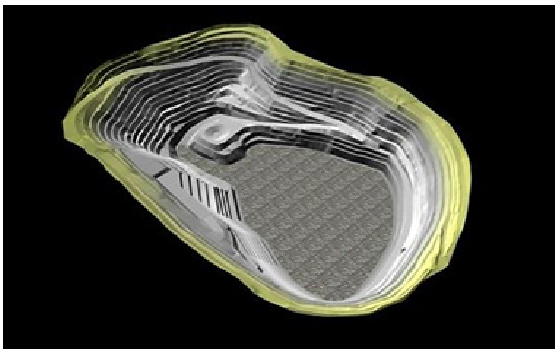


Figure 9-14: Pit 3 backfill conceptual design

The underfill material was sourced from low grade (2s) stockpiles. Deposition was in a fan pattern radiating outwards from a fixed point to maximise material segregation. This method ensured the larger size material filled the bottom of the pit, with fines content increasing as the underfill approached its maximum elevation (Figure 9-15 and Figure 9-16).



Empty pit shell: December 2012



Pit base at end of underfill construction

Figure 9-15: Pit 3 before and after underfill construction

Figure 9-16 Pit 3 underfill during construction in 2014

The porous underfill is the final repository for the concentrated brine waste stream produced by the Brine Concentrator (MacKenzie 2018). Process water treatment by the Brine Concentrator is described further in Chapter 9.4.3.

The current water model forecasts approximately 1.8 GL of brine will be generated prior to final site closure. Available void volume, assuming a waste rock specific gravity of 2.65 and gravimetric moisture content of 2%, is 2.48 GL (Coghill 2016) determined from test work on the waste rock and final survey volumes. Overlaying the underfill is an engineered underdrain to remove process water expressed from the overlying tailings as they consolidate, and water displaced upwards from within the underfill from the brine injection process (Figure 9-17). The underdrain consists of a nominal 2 m thick waste rock drainage layer constructed at the interface of the underfill and tailings surface, graded slightly to the west to direct water towards an engineered sump located at a low point along the south-west wall of the pit.

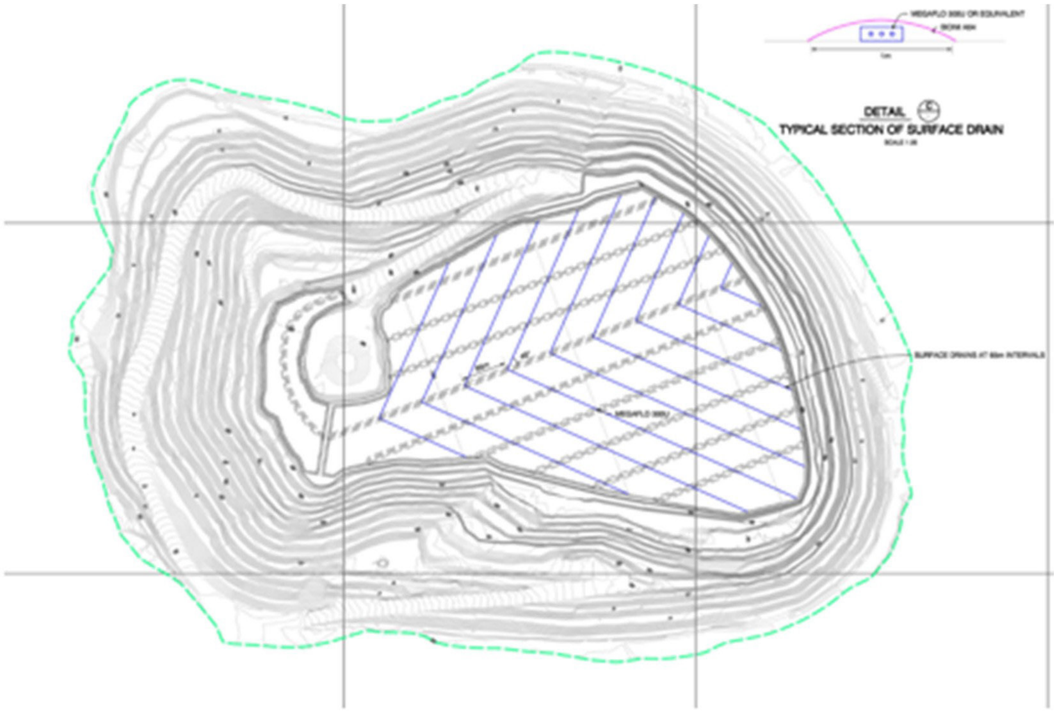


Figure 9-17 Pit 3 underdrain schematics

Collected water flows from the sump through a lateral borehole into a vertical borehole termed the Underdrain Bore. A pumping system consisting of a submersible pump and associated power and piping infrastructure transfers the collected water to the process water inventory via Process Water Return Tanks located on the southern margin of Pit 3. The flow and electrical conductivity of water collected by the Underdrain Bore is monitored.

The principal pathway for process water treatment over the closure period is through the Brine Concentrator, which generates a concentrated brine waste product requiring permanent disposal. Following construction of the underfill and underdrain in Pit 3, five brine injection bores were installed into the underfill, each with a dedicated pipeline connecting back to a valved manifold located on the western ramp of Pit 3.

A brine cooling and pumping system installed at the Brine Concentrator cools the otherwise hot brine to temperatures compatible with the feed pipelines, delivering the brine to the manifold. The hot concentrated brine uses indirect heat exchangers with process water as the cooling medium, which is then pumped to a storage (surge) tank. The brine is drawn from the surge tank and pumped to the brine injection system (Figure 9-18).

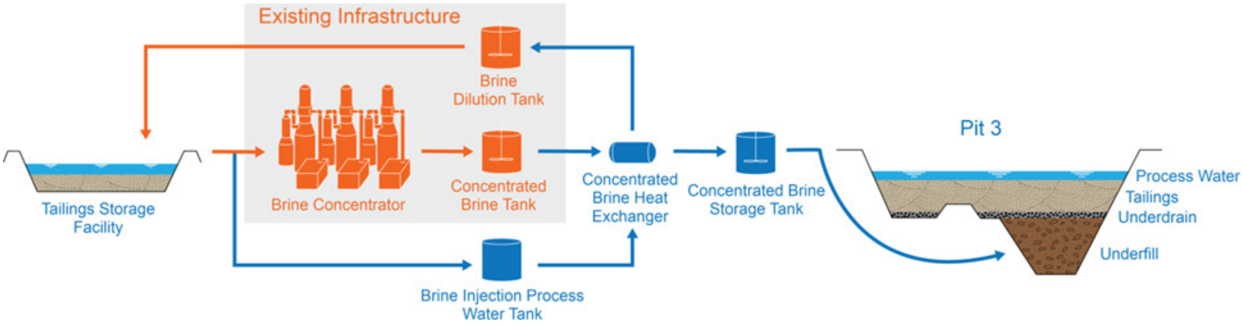


Figure 9-18: Flow Diagram of Brine Injection

Inherent scaling issues associated with concentrated brine requires all lines and equipment within the brine injection area to be regularly flushed with process water. In addition to this, a 'pigging' system removes any residual scale.

When the brine injection system is inoperable, Brine Concentrator brines are recirculated to the process water inventory causing the process water salt content to increase. The Brine Concentrator is specifically designed to treat high salt content water. At a total dissolved solids concentration over 120 g/L, however, the distillate production capacity is impacted. ERA regularly monitors the total dissolved solids concentration in process water and forecasts future concentrations through its operational water balance modelling software (refer *Section 2 Project Overview*).

Operational issues has required brines to be temporarily diverted back to the process water inventory. Remediation work completed in the second half of 2020 enabled Brine Injection to be resumed as the Brine Concentrator operations permitted in 2021. All of five original injection bores are now considered to have irrevocably failed, the in-pit components of that system decommissioned. Replacement bores are being installed described further in Chapter 9.2.2.3.

Tailings deposition

Tailings deposition into Pit 3 as defined by Environmental Regulation 11.2 requires all tailings are placed in the mined out pits. A schematic cross-section of Pit 3 prior to tailings deposition is presented in Figure 9-19.

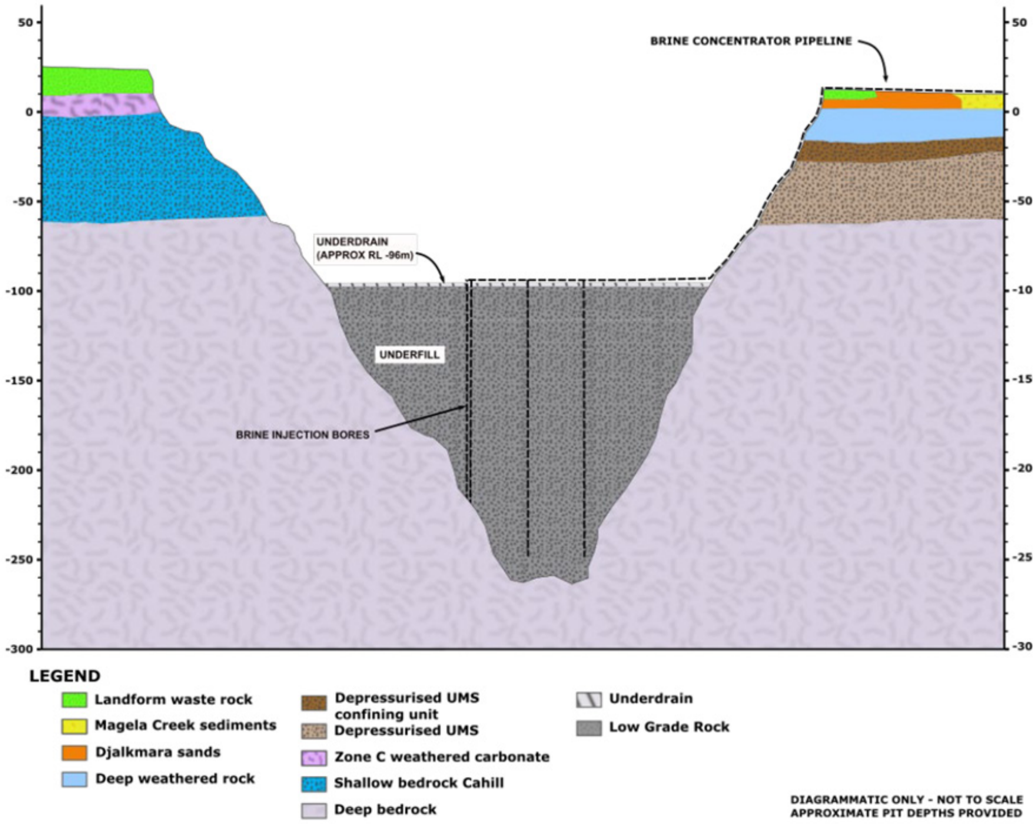


Figure 9-19 Schematic cross-section of Pit 3 before tailings deposition commenced

Tailings deposition into Pit 3 occurred by direct deposition of processing plant (mill) tailings commenced in 2015 and practically ceased on 8 January 2021, with the cessation of mill operations. Mill tailings were pumped as a neutralised slurry of approximately 50% solids by weight directly into Pit 3 via an overland high-density polyethylene (HDPE) pipeline.

Tailings were additionally transferred from the Ranger Water Dam (RWD) into Pit 3 via dredging operations from early 2016, with practical completion on 15 February 2021. Initial transfer was via a single diesel-powered cutter suction dredge. In 2019, a second dredge was installed and commissioned increasing dredging capacity. Dredged tailings transfer was via HDPE pipelines, the dredged slurry varied between 18 and 28% by weight solids, dependant on the type of tailings solid material (i.e. fine or coarse) and the dredge cutting head sweeping from side to side.

Both mill and dredged tailings slurry were originally deposited into Pit 3 subaerially via a number of spigots on the pit crest forming a sloping beach across the pit floor shown in Figure 9-20 and Figure 9-21. Coarse and fine tailings segregation was observed, the coarse tailings forming an elevated beach in the eastern end of the pit with the finer tailings migrating towards the western end and settling below the water surface.

Figure 9-20 Southeast wall of Pit 3 - subaerial discharge point for mill tailings (November 2019)

Figure 9-21: Pit 3 showing the original location of mill and dredge tailings deposition points

This segregation was a result of concentration of low discharge solids combined with fluctuating process water volumes, a consequence of dredging operations, creating a differential in tailings elevation from east to west of approximately 10 m, demonstrated in the surface contours from surface surveys conducted in April 2019 shown in Figure 9-22.

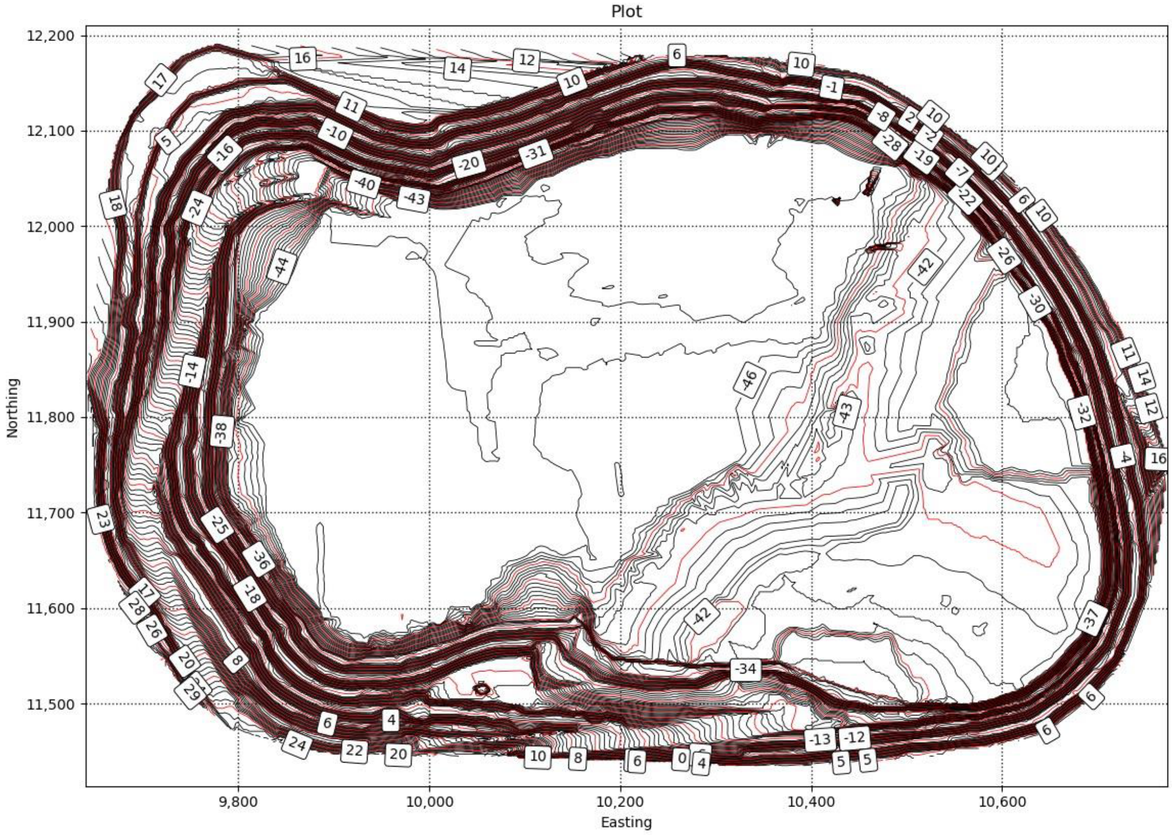


Figure 9-22: Tailings surface in April 2019 (Source: Fitton, 2019)

The segregation and subsequent differential in tailings elevation indicated the approved maximum tailings elevation of -20 mRL may be exceeded. Initial investigations how to attenuate the levels commenced in 2017, followed by studies into subaqueous deposition of dredged tailings in 2018. Subaqueous tailings deposition would potentially mitigate the risk of segregated coarse tailings exceeding -20 mRL. The identified benefits of subaqueous deposition in a fluctuating water level situation included:

- elimination of a coarse tailings beach deposited higher in the pit;
- elimination of a steep uneven tailings surface; and
- promotion of the homogenous deposition of tailings by systematically moving the deposition point.

On 15 and 16 January 2018, ERA hosted a stakeholder workshop discussing Pit 3 tailings deposition. Stakeholders agreed that subaqueous tailings deposition would be unlikely to increase the risk of long-term environmental impact to ground and surface water from solute egress. Subsequent approval to deposit tailings sub-aqueously was provided pending the completion of tailings characterisation studies (*Section 5 KKN Supporting Studies*, Chapter 5.4.1), groundwater modelling (*Section 5 KKN Supporting Studies*, Chapter 5.4.3), a subaqueous deposition trial and formal application to change the tailings deposition method. The studies validated that changing the tailings deposition method and consequent maximum tailings level would not result in any long-term environmental impacts to the surrounding Kakadu NP at the end of deposition nor have any material impacts on the Pit 3 closure schedule.

The tailings consolidation model was updated to provide understanding of the impact of tailings segregation and proposed subaqueous deposition of dredged tailings from a moving discharge pipe at the western end of the pit, estimating tailings surface during deposition and post deposition phases. Comparison between 2019 and 2018 results concluded the model accurately predicted distribution of the coarser/finer tailings split up to the commencement of the subaqueous deposition trial providing confidence in future consolidation modelling.

The subaqueous discharge trial of dredged tailings commenced in December 2018, concluding in March 2019, followed by an MTC application to modify deposition of dredged tailings from tailings beach (subaerial deposition) to inundation and deposition into water (subaqueous deposition). The application also requested a final average tailings level of -15 mRL (ERA, 2019b). Approval was received in August 2019 to increase maximum tailings level to -15 mRL, but this approval was specific to the fixed mill deposition spigots only. In August 2020 the level was increased to -10mRL across the pit based on low risk to the offsite environment during deposition provided process water levels in Pit 3 remained below 3.5 mRL.

The dredge tailings deposition system was modified (Figure 9-23) enabling the subaqueous deposition of dredged tailings (Figure 9-24), retaining existing subaerial discharge points for maintenance, pontoon movement operations and monthly bathymetric surveys.

Figure 9-23: Subaerial deposition of mill tailings from multiple spigot points

Figure 9-24: Subaqueous deposition of dredge tailings via floating pipelines and diffusers

Key elements for subaqueous deposition were:

- pumping of tailings by separate HDPE pipelines sized to match dredge flow;
- floating sections of pipeline enabling discharge over the entire pit area;
- each pipeline fitted with a novel diffuser to lower slurry velocity at the discharge point to reduce tailings segregation (Figure 9-25);
- diffusers supported by a single pontoon; and
- diffusers followed a deposition plan (Figure 9-28) and were moved using diesel-powered winches promoting even deposition across the pit.

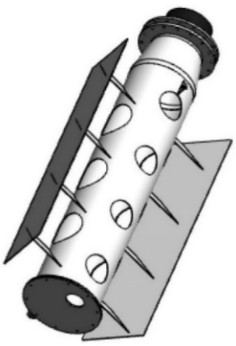


Figure 9-25: Novel subaqueous diffuser design

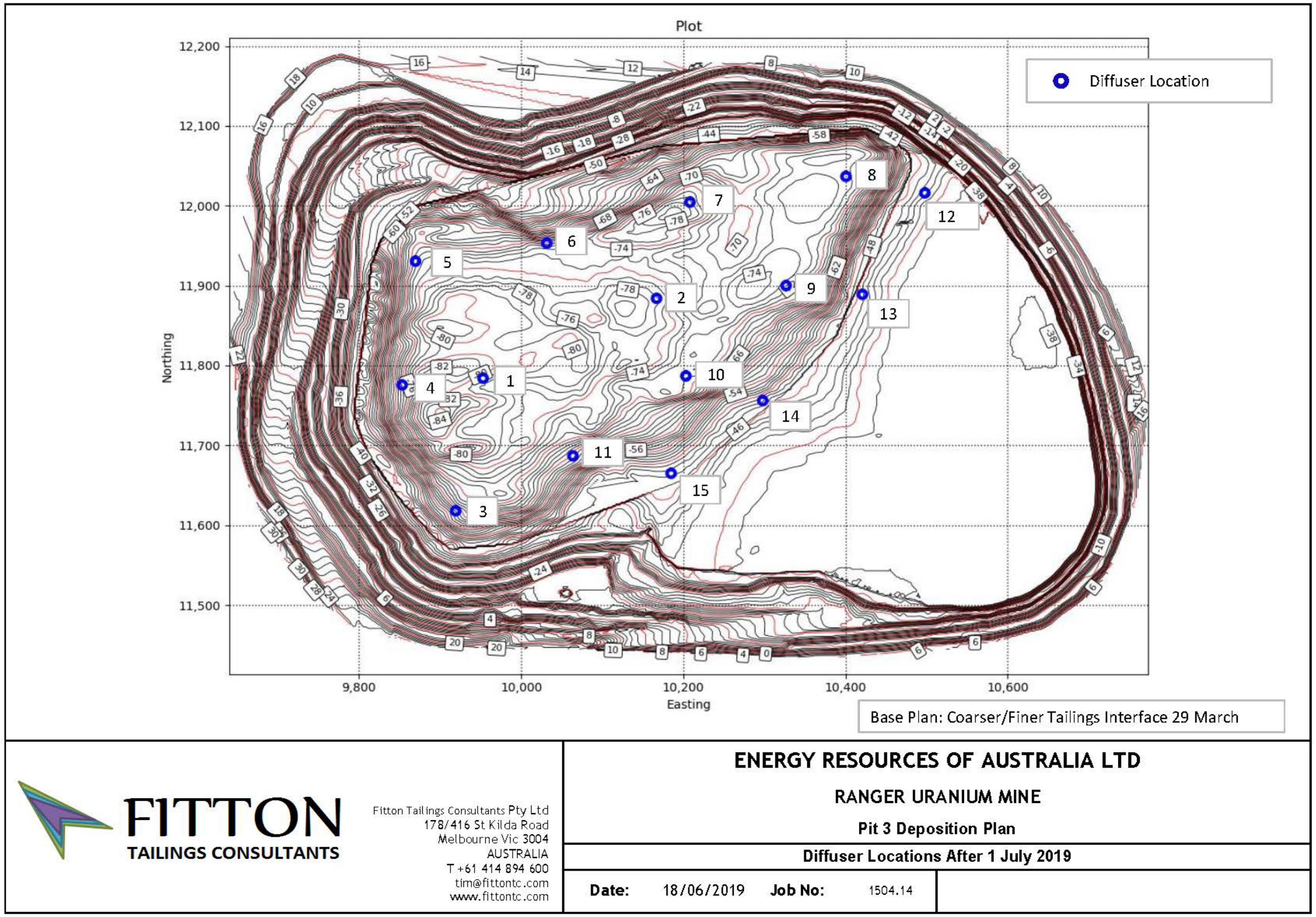


Figure 9-26: Pit 3 dredge tailings deposition plan

Remnant Tailings Transfer from Ranger Water Dam to Pit 3

Dredging of tailings from the RWD left a considerable volume of residual tailings. Regulatory approval was received to leave the RWD subfloor *in situ* in August 2020 enabling commencement of the RWD deconstruction planning and consideration of future remediation options (ERA, 2020d).

Following the cessation of dredging, a BPT assessment identified Option 3, pre-cap truck as the most appropriate approach to transfer remnant tailings material from the RWD to Pit 3 with a notification submitted to the MTC (ERA, 2021d).

Wall and floor cleaning activities are described in more detail in the *Tailings Storage Facility - Plan for Removal of Remnant Tailings* (ERA, 2021c).

Tailings material, from the floor, walls and borrow pits were dozed into stacks to dewater and dry loaded onto trucks for transfer to Pit 3 via the northeast ramp (Figure 9-27 and Figure 9-28).

Figure 9-27 Transfer of tailings works from the Ranger Water Dam to Pit 3 2021

Figure 9-28 Ranger Water Dam floor

Trucks approached the tip head, transferring tailings material onto an area next to the pit crest (Figure 9-29 and Figure 9-30).

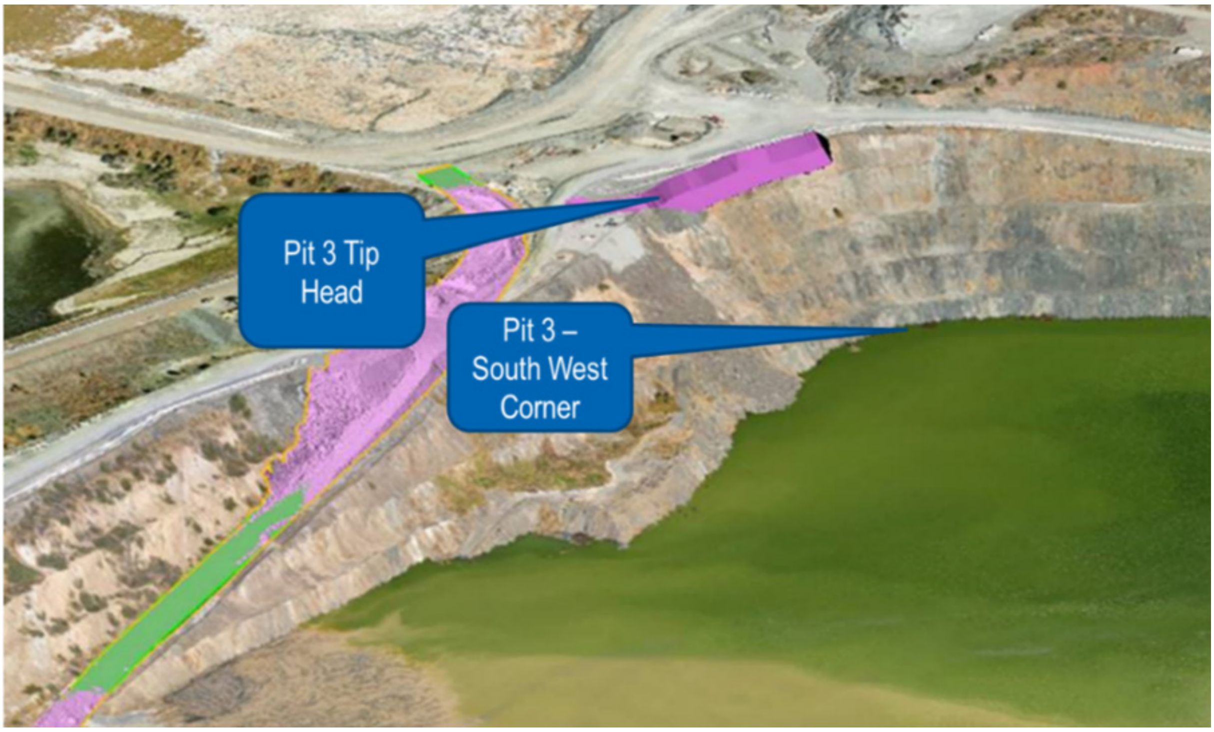


Figure 9-29 View of the Pit 3 wall for proposed tip head (south west view)

Figure 9-30 Construction of Pit 3 tip head

An excavator or dozer pushed tailings material down the pit wall (Figure 9-31). A water cannon aimed to clean material off the benches or push tailings material down the pit wall as it became hung up, resulting in some tailings remaining on the deposition point.

Figure 9-31 Transfer of tailings down tip head in Pit 3

Truck transfer commenced in July 2021 completed in December 2021 as summarised in Table 9-7. An estimated 1.77M m^3 of tailings material was transferred from the RWD to Pit 3 over the underdrain layer (ERA, 2021d), the estimate based on mill feed and lime consumption records, RWD to Pit 1 dredge tailings volume estimates, RWD to Pit 3 truck monitoring records, end of RWD dredging bathymetric surveys and cleaning floor surveys.

Table 9-7 Pit 3 tailings quantities

Description	Dry solids mass (Mt)
Tailings transferred from the RWD by dredge	24.2
Tailings deposited directly from the mill	15.4
Tailings transferred from the RWD by truck	2.0
RWD floor and wall material	0.5
TOTAL	42.2

A bathymetric survey of Pit 3 on 10 March 2022 shown in Figure 9-32 confirmed the total volume of deposited material above the underfill layer as 32.1M m^3.

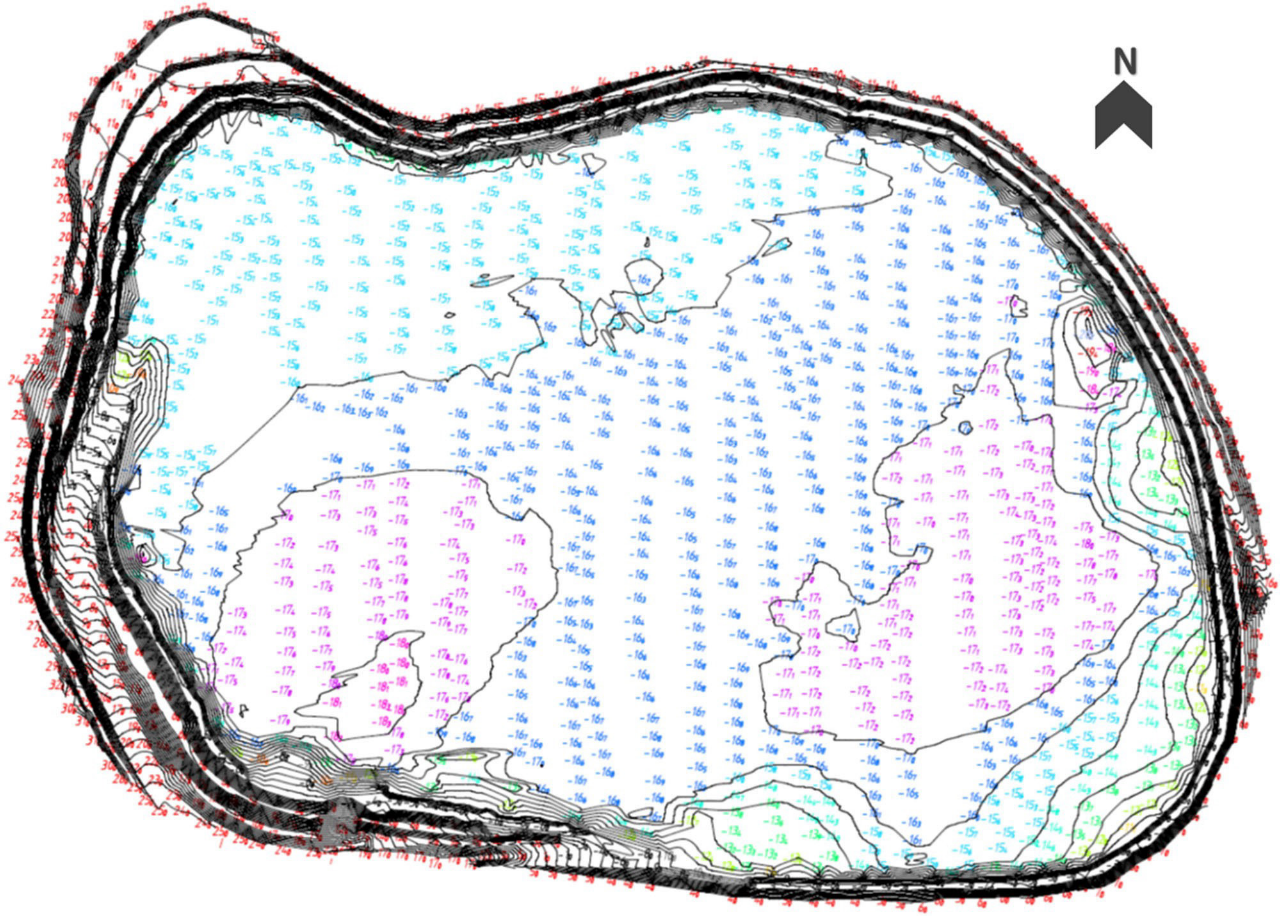


Figure 9-32 Pit 3 bathymetric survey, 10 March 2022

9.2.2.2 Current rehabilitation

The Pit 3 capping, waste disposal and bulk backfill closure activities are described in a standalone application for approval from both the MTC and Ministers detailing the closure of Pit 3 components and associated supporting studies. The final 6 m of the landform will be considered in a separate ‘Final Landform’ application.

To inform the Pit 3 capping design, geotechnical investigations determined the strength of the tailings and assessed the geotechnical risk of construction prior to commencement of capping activity. Investigations from September to November 2020 included cone penetration tests with pore pressure measurement, vane shear tests, recovery of tailings samples and laboratory testing. Tailings strength will inform the selection of geosynthetic material to ensure adequate bearing capacity and the size and weight of the construction equipment to be utilised in the secondary capping layer and bulk fill activities. The thickness of each capping layer is consequently influenced by equipment size.

9.2.2.3 Planned rehabilitation

A series of activities to facilitate tailings consolidation and waste rock backfill of Pit 3 have commenced. It is noted the standalone Pit 3 capping, backfill and waste disposal application has been lodged and is not yet approved, where the following summarised activities may change based on future discussions with stakeholders.

Brine injection

The bores of the original brine injection system are considered to have completely failed. ERA is in the process of installing three replacement injection bores. The concept design for well locations and piping layout is shown in Figure 9-33. Replacement bores will be directionally drilled from outside the perimeter of Pit 3, down towards the underfill shown in Figure 9-34. The system design includes:

- Tie in of the delivery pipework into the Brine Concentrator at the same location as the existing injection wells – downstream of the brine cooling heat exchangers;
- The ability to ‘pig’ and flush the delivery piping system, to remove accumulated scale and settled solids;
- Containment bunds and shields around the well heads, pipe-in-pipe protection of connecting pipelines, and leak detection systems to protect against egress of brine or flushing water to the environment around the Pit 3 rim; and
- Features to accommodate expected changes in Pit 3 and surrounding landforms, with progression of capping, backfill and revegetation, such as return pipework to enable delivery of flushing water back to the process water inventory that does not rely on an open pit void.

Unlike the existing system, where the well heads are buried under a substantial thickness of tailings, the surface accessible well heads allow for remedial works, such as re-drilling or descaling, on the injection wells proper. The design enables a choice of well casing material and use of a portable positive displacement pump that permits brine or process water injection into the Pit 3 underfill under pressure, reducing the impact of scaling on well lifetime. Installation of the new wells commenced in August 2022.

Figure 9-33 : Concept design for additional injection wells

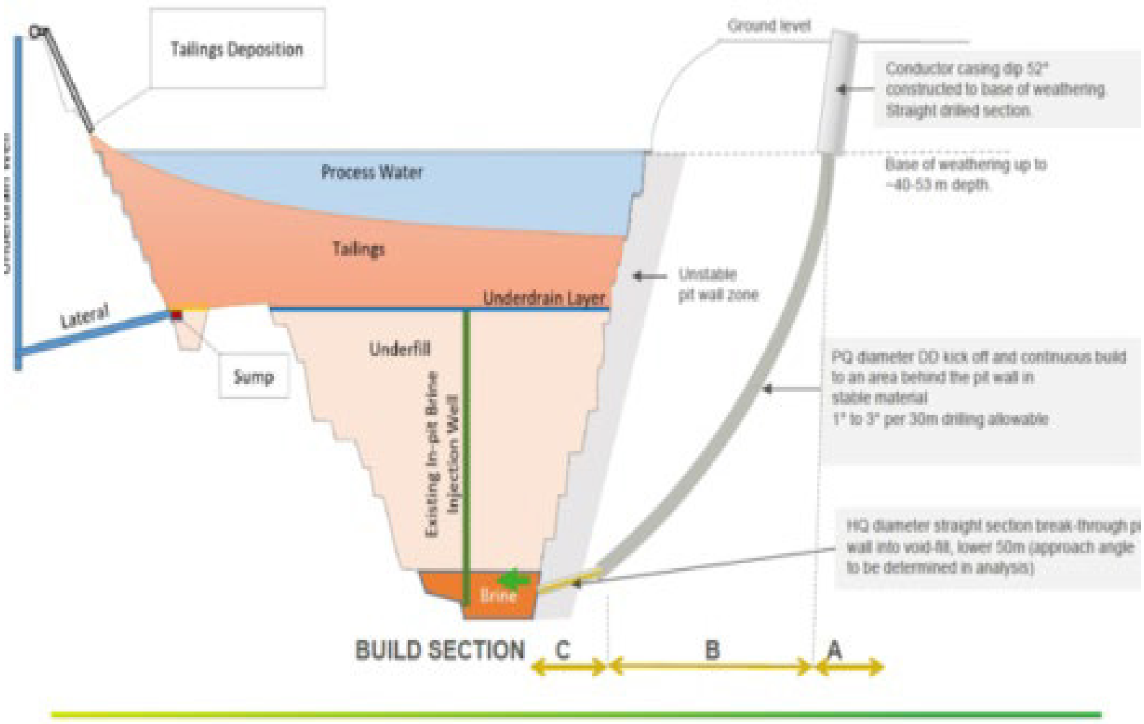


Figure 9-34: Concept section for additional injection wells

Wick drains

Wick drains or prefabricated vertical drains (PVD), increase the rate of tailings consolidation, reducing the time for the closure final landform to reach its final profile. Wick drains were successfully installed to consolidate tailings deposited in Pit 1 (Chapter 9.3.1.1). Faster consolidation increases both the rate of tailings strength with time and rate of removal of consolidation flux (water trapped within the tailings) as process water.

The wicks are a polypropylene drainage core wrapped in a geotextile filter with extruding channels to promote vertical drainage; the filter prevents soil particles from clogging the drain. Wicks significantly shorten the tailings drainage path length, increasing the removal rate of trapped liquid, dissipating pore pressure build-up and reducing the risk of sudden failure during the capping and bulk fill activities. Wicks installation will aid dissipation of pore water pressure in the upper tailings profile to a depth that the wicks can reasonably be deployed. Wicks are of greatest benefit where the fine tailings are deepest, the relative rate of rise of the tailings is greatest and the degree of consolidation at the end of deposition is least (highest excess pore pressures).

Tailings strength is improved through consolidation, the rate influenced by flow path length of the water expressed both vertically upwards and downwards. Wicks decrease this flow path improving the shear strength of the tailings, fundamental to progressing capping works by enabling safe access for heavy equipment. Installation of wicks in soft tailings will:

- Achieve dissipation of pore pressure increasing undrained shear strength to facilitate capping;

- Achieve early expression of pore water for decant and treatment (minimising remnant consolidation volume); and
- Be an ongoing mechanism for acceleration of pore pressure dissipation during capping works.

Wicking trials between March and April 2021 informed installation methodology, anchor system, resistance to deformation and position stability of the wicking plan. The wicking trial layout is presented in Figure 9-35 with an example anchor provided in Figure 9-38.

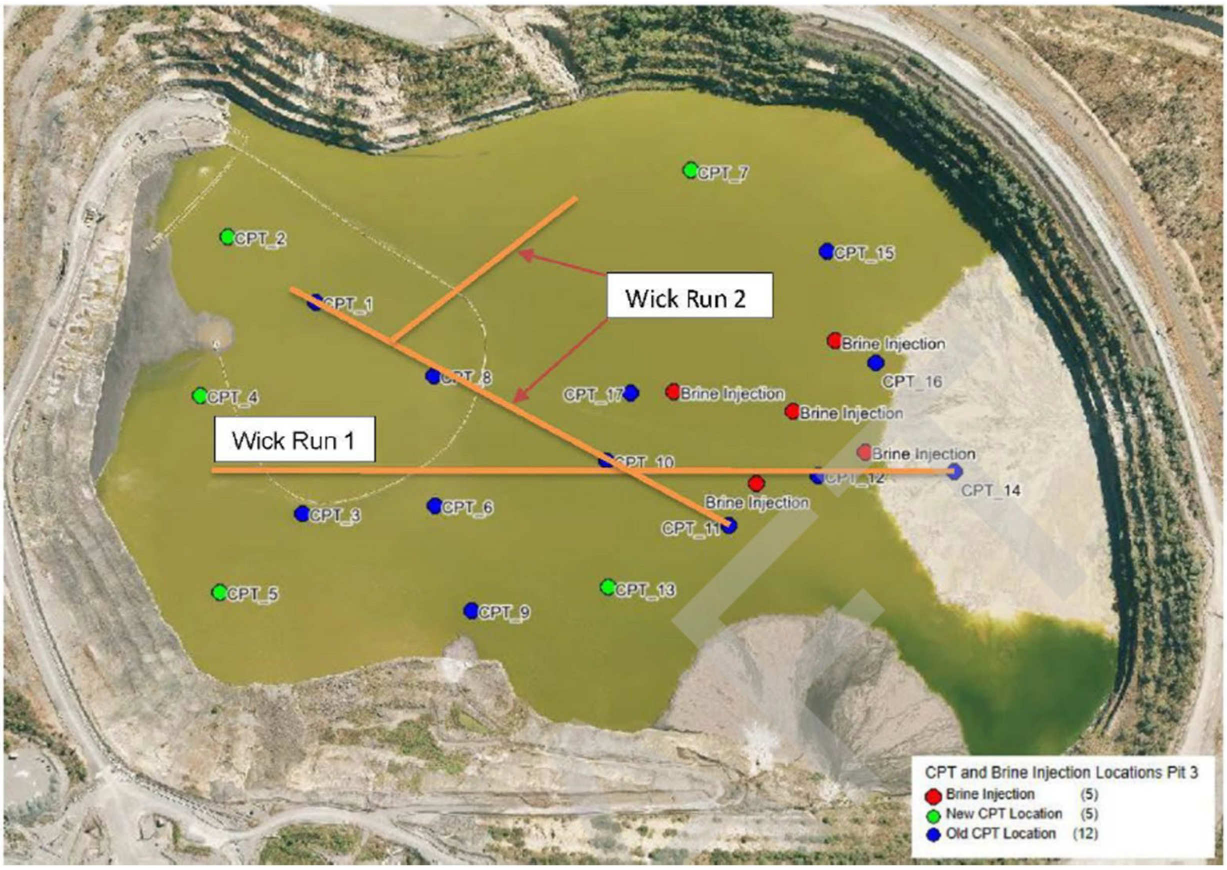


Figure 9-35 Wicking Trial Layout

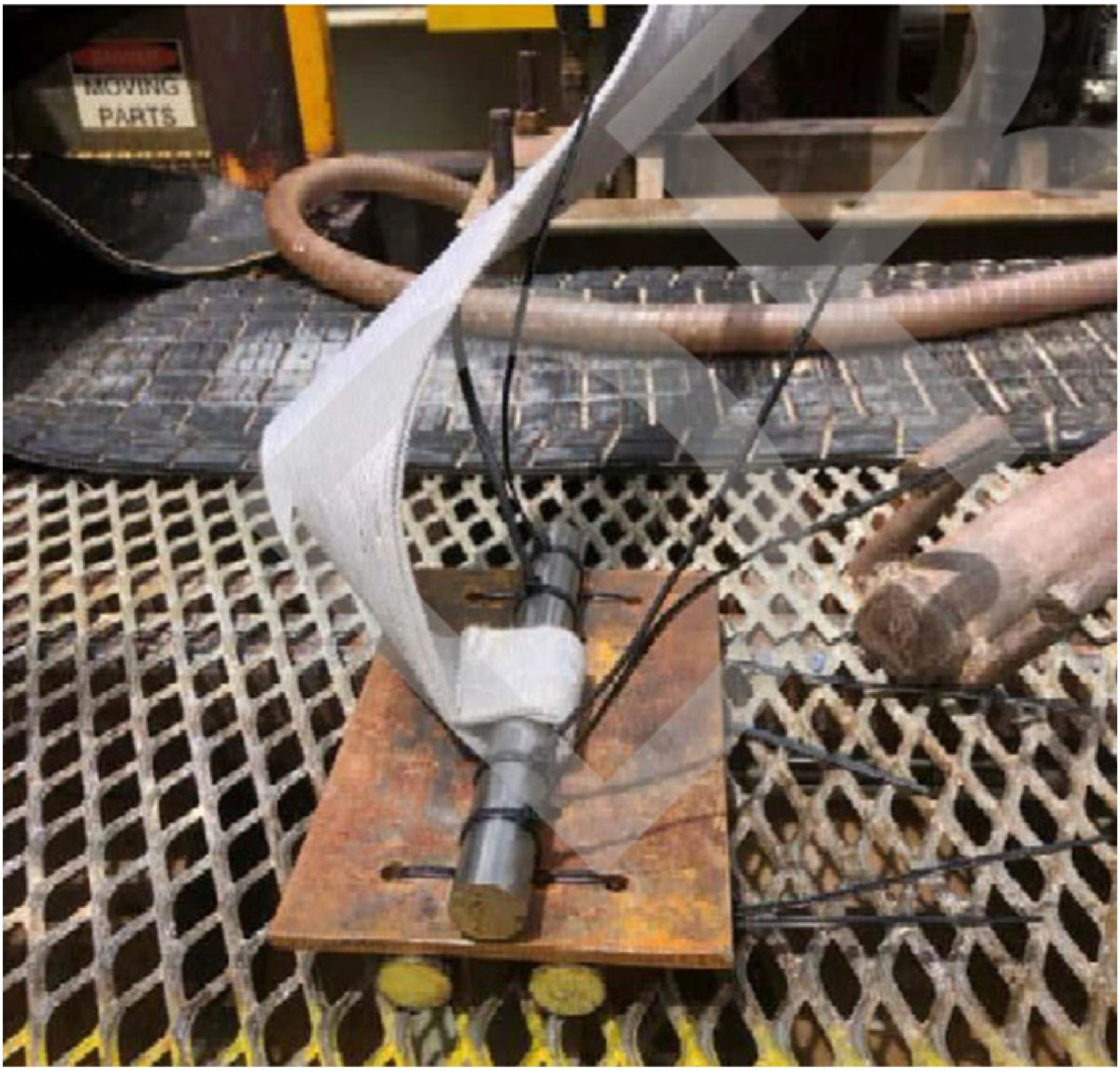


Figure 9-36 Typical anchor as used in the trial

The final wicking plan shown in Figure 9-37 was developed from the most recent tailings properties data, consolidation model and wicking trial outcomes. Wicking zones will focus on the finer tailings in the west of Pit 3 that contains the most under-consolidated tailings and highest excess pore pressures. Wick quantities are described in Table 9-8.

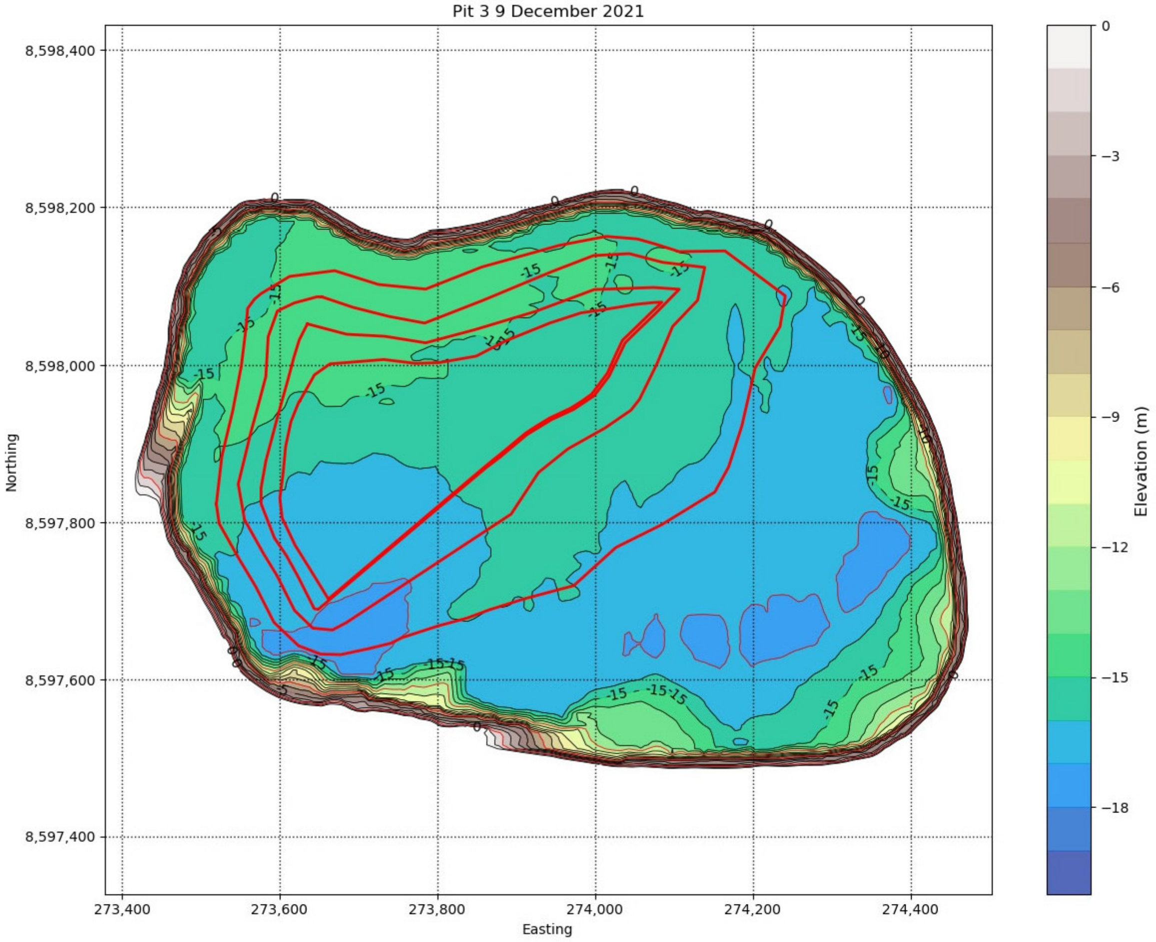


Figure 9-37 Pit 3 tailings bathymetry (horizon) as at 9 Dec 2021 with North up the page. The red lines show the wicking zones, Zone 1 the inner most to Zone 4 the outer most area.

Table 9-8 Current wicking plan per zone

Zone	Depth (m)	Spacing (m)	Area (m^2)	Wick quantity (count)	Linear metres of wick / zone
1	40	2.5 x 2.5	76,861	12,298	491,910
2	40	2.5 x 2.5	22,238	3,558	142,323
3	40	2.5 x 2.5	59,151	9,464	378,566
4	20	2.5 x 2.5	113,696	18,191	363,827
Total				43,511	1,376,627

To access to the low strength tailings, wicks will be installed from a floating barge, a preliminary design shown in Figure 9-38. The wicking barge and rigs will require management of water levels in Pit 3. Wick spacing will dissipate surface pore pressure, accelerate consolidation and increase surface strength of the tailings. Following wicking activity, limited activities will be undertaken in this zone to ensure interference with wick tails is minimal.

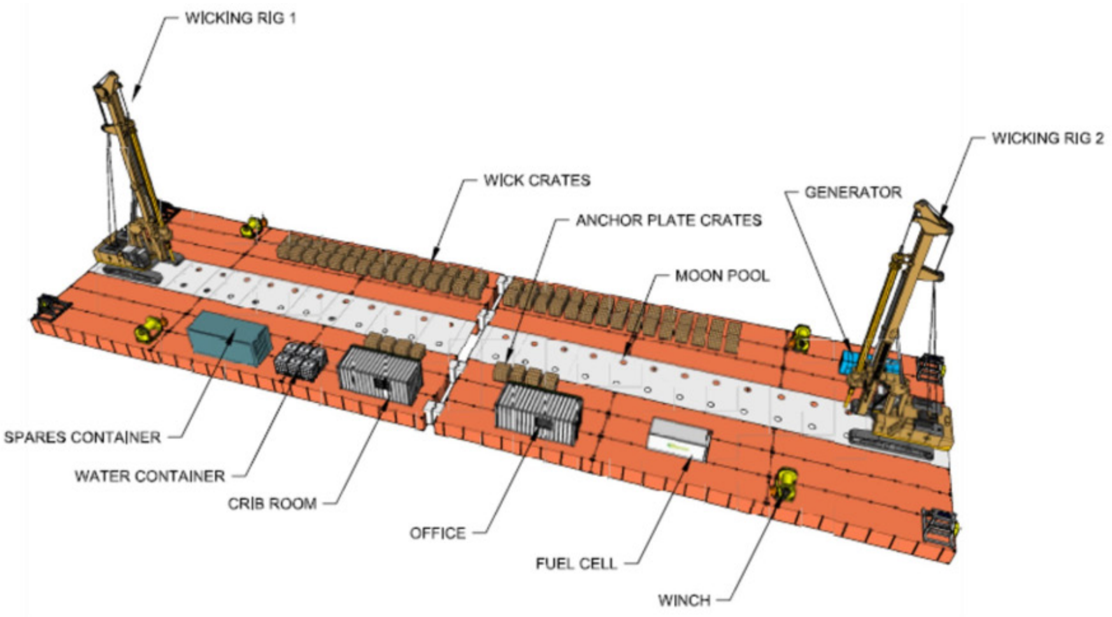


Figure 9-38 Diagram of wicking barge

The completion of tailings transfer from the former Tailings Storage Facility to Pit 3 the Tailings Storage Facility was re-commissioned to a Ranger Water Dam. Most of the process water from Pit 3 was transferred into the RWD water storage facility, with the remaining water levels held at approximately -14 mRL during construction of the wicking barge and the installation of the wicks.

Pit 3 dewatering and drainage

Following completion of wicking, Pit 3 will be dewatered to facilitate desiccation of the tailings surface and facilitate capping works. Suitable pumping infrastructure similar to Figure 9-39 will be installed to keep the pit tailings surface as dry as possible as well as manage expected and usual flows.

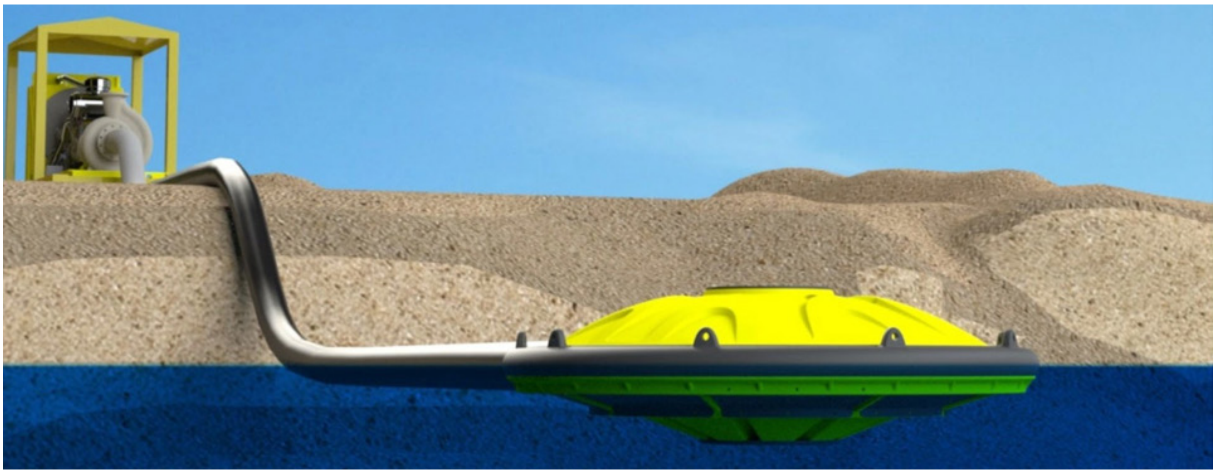


Figure 9-39 Shallow water turret suction intake

Amphibious or barge mounted equipment may be utilised to construct drainage channels or alter the tailings profile to promote surface drainage in the non-wicked zone. The water management plan is summarised in Table 9-10.

Table 9-9 Pit 3 Water management during capping works

Stage	Mechanism to get water to storage or treatment infrastructure
Wicking	Water level managed by pumping system
Tailings	Amphibious equipment for maintenance of drainage paths
Post initial capping	Transition from pumping system to decant wells during initial capping activity.
Secondary capping Bulk backfill	Decant wells Capping works profile and pit water storage to manage surface inflow and groundwater Water pumped out of pit as required

Accelerating tailings desiccation

The Pit 3 capping schedule is less than for Pit 1. Accelerating the desiccation of tailings in un-wicked areas of Pit 3 by mechanical means will create a higher strength in the tailings surface crust to facilitate overlaying of geotextile and capping material on a stronger base.

Mechanisms to accelerate tailings desiccation include:

- drainage channels and surface drainage creating water flow away from the tailings;
- machine weight to aid in expression of tailings water; and
- disturbance of crust layer and tailings shown in Figure 9-42 to promote solar drying.

Figure 9-40 Mud Master at Yarwun Alumina Refinery Red Mud Dam

Where a crust cannot be constructed and low surface strength is observed, low strength capping techniques may be utilised. Alternatively, activities may be excluded if tailings conditions are better than predicted.

Tailings strength surveys, tests and investigations

Surveys and tests will be undertaken throughout capping operations.

Terrestrial, aerial and bathymetric surveys of tailings surface and sub-surface horizons at the end of tailings deposition, prior to installation of wick drains and ongoing as required to monitor tailings behaviour and consolidation.

Wall surveys will be conducted to monitor pit slope stability through automated stations and pit mounted prisms. Barge, equipment, or hand shear vane tests will determine tailings surface strengths confirming tailings condition limits to support safe capping works.

Tailings strength gain will be identified from vibrating wire piezometers within the tailings to measure pore pressure dissipation during placement of initial capping.

Monthly bathymetric data from sonar (echo sounder) will be used to survey the upper surface layers of the tailings body informing consolidation rates and levels across the pit. The data will provide trends in consolidation and tailings behaviour.

Prior to wick installation, cone penetration testing (CPTu) investigations will be undertaken to:

- provide an understanding of the strength gain in the upper portion of the tailings;
- provide progress of excess pore pressure dissipation at depth from consolidation under tailings self-weight;
- inform construction of the eastern platform, perimeter access road and similar works;
- predict and validate behaviour of the tailings, and inform consolidation model updates; and
- to monitor progress of excess pore pressure dissipation at depth and strength gain in tailings following installation of wick drains.

Figure 9-41 presents the CPTu locations and tests to monitor the behaviour of tailings over time. CPTu tests will be undertaken from a barge shown in Figure 9-42.

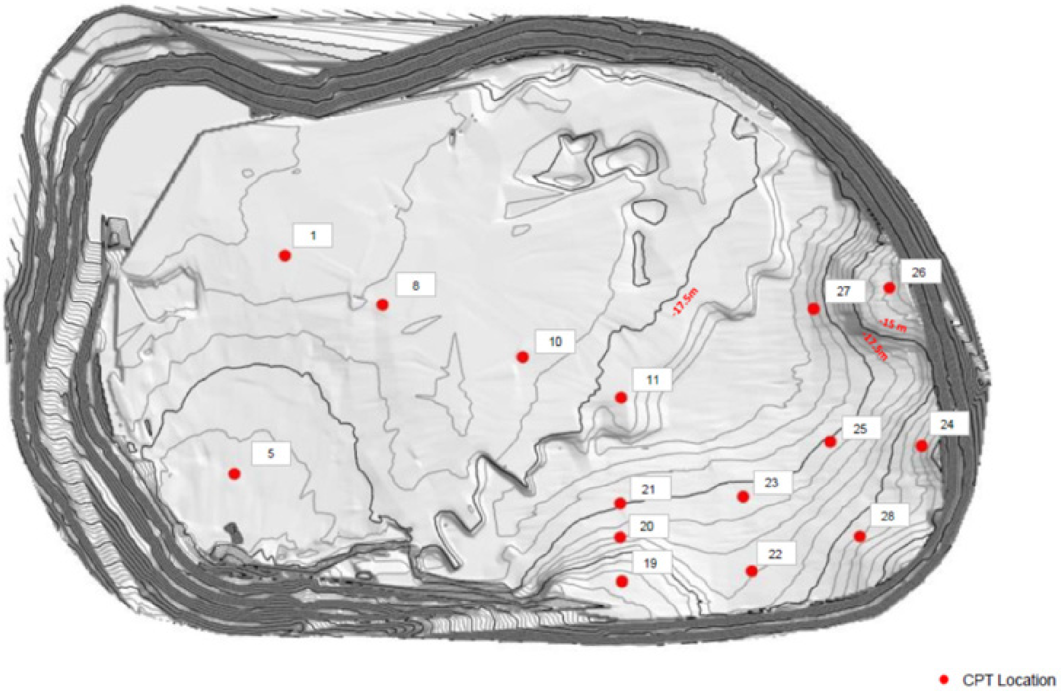


Figure 9-41 CPTu locations within Pit 3

Figure 9-42 Placing CPTu barge in Pit 3 with CPTu rig mounted

Construction of staging and wharf facilities

Material and equipment laydown areas may be constructed at the bottom of the western and eastern ramps, improving access for surveys and test, wicking, personnel and barge activity. A crane pad may also be constructed.

Initial Capping Works

The initial capping design consists of a layer of geotextile and one or more metres of select waste rock to provide a working platform for subsequent capping and backfill layers. Surveys prior to execution works will determine tailings properties and inform capping design and geotextile requirements.

Geotextile

A geotextile layer between the capping layers and the tailings will:

- improve the bearing capacity, stability and constructability of the capping layer on very soft tailings;
- provide tensile strength to the underside of the capping layer;
- reduce capping layer thicknesses; and
- support bulk backfill with heavy mine fleet activity.

Geotextile placement will be developed by the contractor in consultation with ERA. If required, larger geotextile blankets will be constructed and pulled across and capping material.

Trial platform

Trial platform construction on the coarse tailings will optimise capping methods, enable study of tailings consolidation behaviour and verify tailings segregation assumptions through assessment of tailings segregation at various locations. Bearing capacity and CPTu tests of the platform over time will provide understanding of tailings strength.

Capping methodology

A dry capping methodology similar to Pit 1 shown in Figure 9-43 was identified as the current best practicable technology, with planned reviews and updates as new data becomes available. The capping execution plan for Pit 3 will be sequentially constructed, each area employing specific capping techniques. Each area for Pit 3 capping works are delineated in Figure 9-44.

Aspects of capping works quality and control include:

- regular surveys of tailings at the work front;
- review by qualified engineer to inform capping design;
- construction of the cap with onsite geotechnical and earthwork expertise;
- inspection and quality systems; and
- final inspection and signoff by design engineer (Rio Tinto D5 standard).

Figure 9-43 Pit 1 Capping construction method showing material 'fingers' pushed across the geotextile.

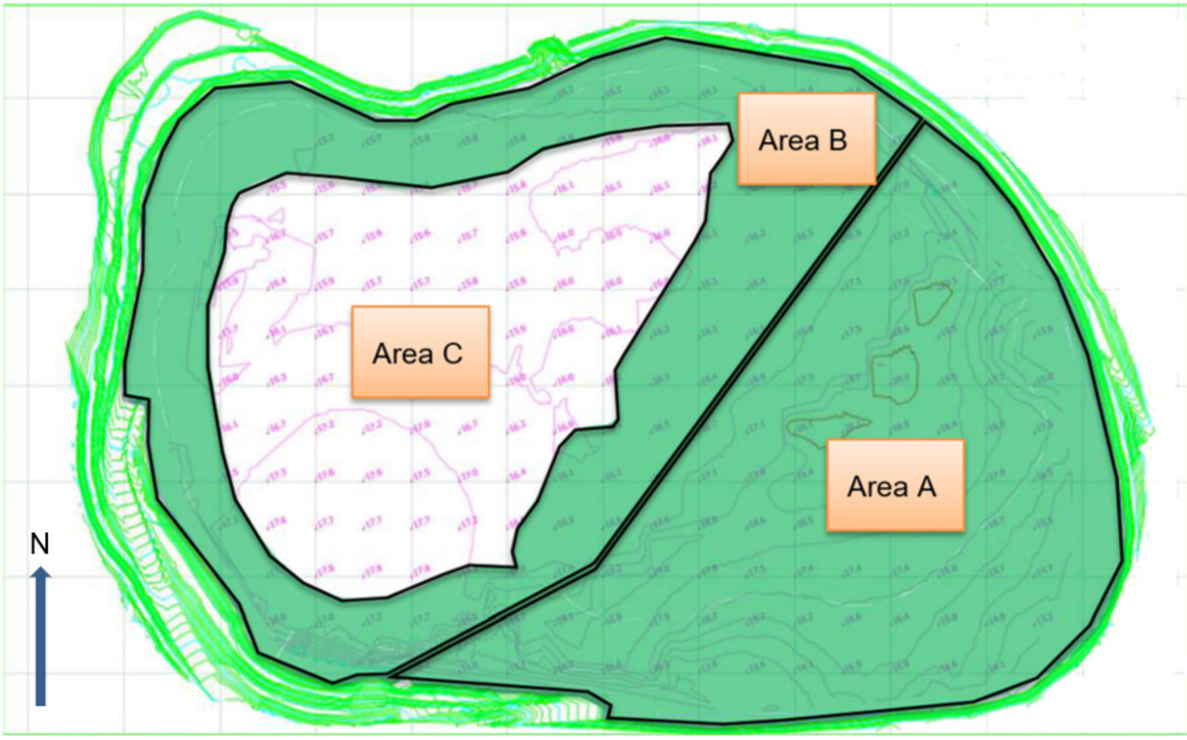


Figure 9-44 Pit 3 capping locations delineating based on expected tailings surface conditions

Contours are tailings surface.
Lime green identifies pit walls and features.
Dark green defines non-wick areas.
White area identifies the proposed wicked zone

Water draw-down and dewatering of Pit 3 will initiate solar desiccation. Progressive construction of an access road from the southern access ramp will extend to the most northerly tailings deposition point to facilitate capping works. The access road can be strengthened by initial capping material and geogrid spreading the load, minimising liquefaction and equipment movement impact.

Area A - eastern platform - Capping works in Area A will be constructed over a coarse tailings beach with underlying fine tailings similar to the northern section of Pit 1. Construction of the capping layer will be via material pushing and 'finger' or groyne infill techniques as shown in Figure 9-45 to Figure 9-48.

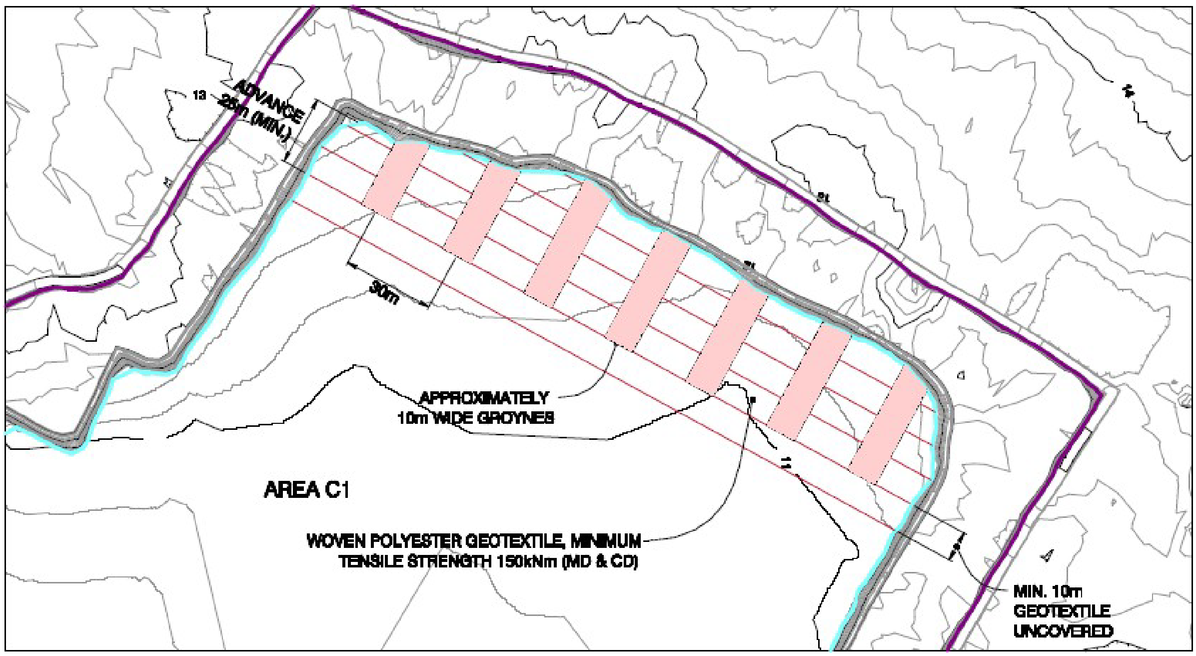


Figure 9-45 Typical geotextile placement (plan view)

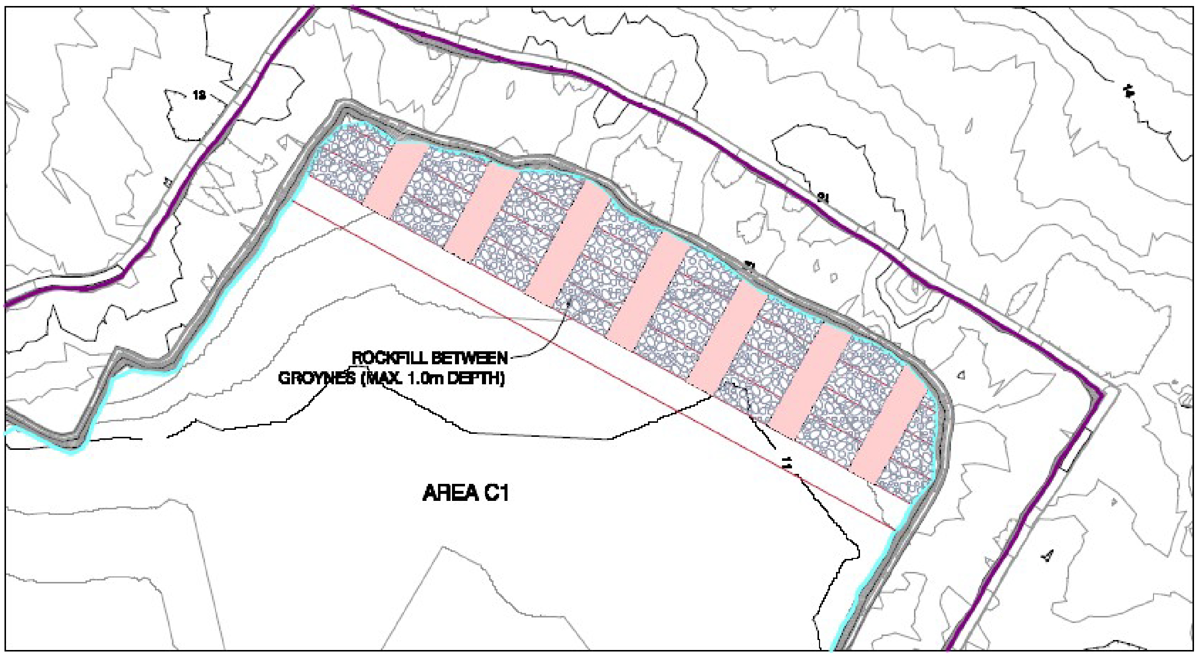


Figure 9-46 Typical initial capping layer placement, post geotextile, finger or groyne method, infill (plan view)

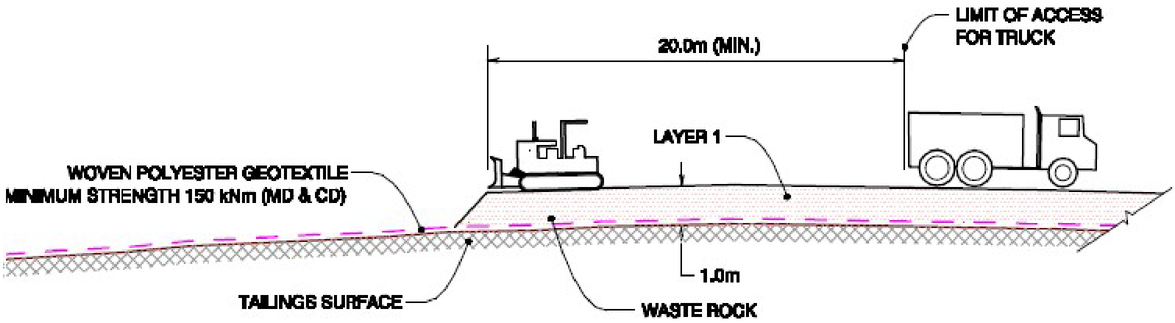


Figure 9-47 Initial capping placement typical detail – section view

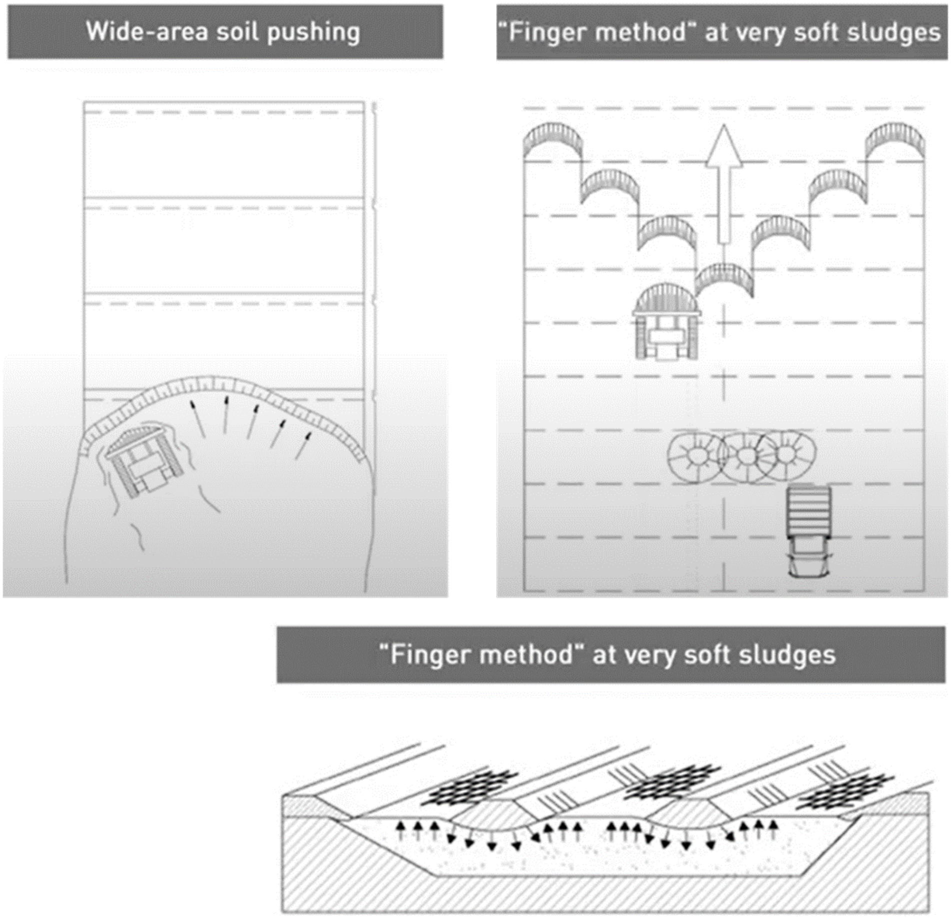


Figure 9-48 Options for initial capping progression

Area B - perimeter access- Area B will have less tailings strength than Area A. Capping works will progress around the perimeter using the underlying pit wall berms and benches creating a perimeter access 30 to 50m wide to progress capping work fronts and facilitate construction of a solid anchor point for the geotextile (Figure 9-49). Capping construction will be similar to Area A.

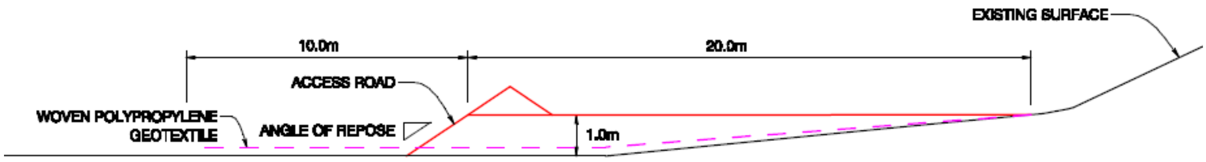


Figure 9-49 Typical perimeter access road – section view

Area C - wicked area capping- Wicking works will improve the low tailings strength of Area C. The fine tailings are predicted to slowly form a crust to installation of the geotextile and initial capping layer. Construction of the geotextile anchor berm will commence near the perimeter access to enable anchoring of the geotextile towards the lowest point shown in Figure 9-50. The geotextile will be securely anchored along its length during capping activity.

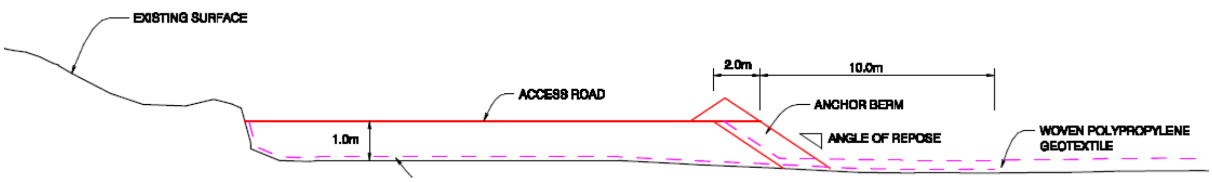


Figure 9-50 Typical geotextile anchor berm detail – section view

Following completion of initial works, the edge of the capping layer can be stabilised to support further capping works. Low strength tailings capping techniques may be employed where rock material is placed with low ground pressure equipment and long reach excavators. If the tailings strength is observed to be sufficient, capping works may be undertaken similar to those in Areas A and B.

Decant Towers and Settlement Monitoring Towers

Expressed tailings pore water due to tailings consolidation will be collected by Decant Towers and supporting infrastructure, the primary risk control for solutes transported from the tailings pore water into the environment. Three decant towers will be constructed at low points around Pit 3 on top of the consolidating tailings surface following initial capping works. Pore water expressed from the tailings, mixed with groundwater and infiltrating rainwater, will migrate through the lower waste rock capping layer and collected in the decant towers and transferred to the process water inventory by submersible pump.

The stacked tower sections will be supported by a concrete slab located as close as practical to the top of tailings surface. The bottom sections will be perforated to enable water migration into the tower. Additional rings and supporting backfill will be progressively constructed in stages. Each tower will remain for the entire duration of the capping and backfill activity.

The nominal location for the three towers was developed through tailings consolidation modelling shown in Figure 9-51. Decant Tower location will be reviewed based on tailings surface surveys prior to installation and consolidation model updates. Two submersible diesel-powered pumps will transfer process water to the return tanks by overland pipe. These pumps can be relocated between towers dependant on capping and bulk backfill activity requirements. Water removed by the decant towers will be measured by flowmeter.

At least 20 Tailings Settlement Towers will be installed across the pit shown in Figure 9-51 to monitor tailings settlement. The towers will be constructed as close as practical to the top of tailings surface shown in Figure 9-52 with some towers used to monitor water quality, level and Electrical Conductivity (EC). Remaining towers will be configured for water extraction with their lower segments perforated to enable migration of water into the tower. Pumps can be fitted to aid water extraction which will prevent concurrent use for water quality profiling. When not being actively pumped, decant towers and tailings settlement towers will measure the standing level of water in the capping layer across Pit 3 on a monthly basis.

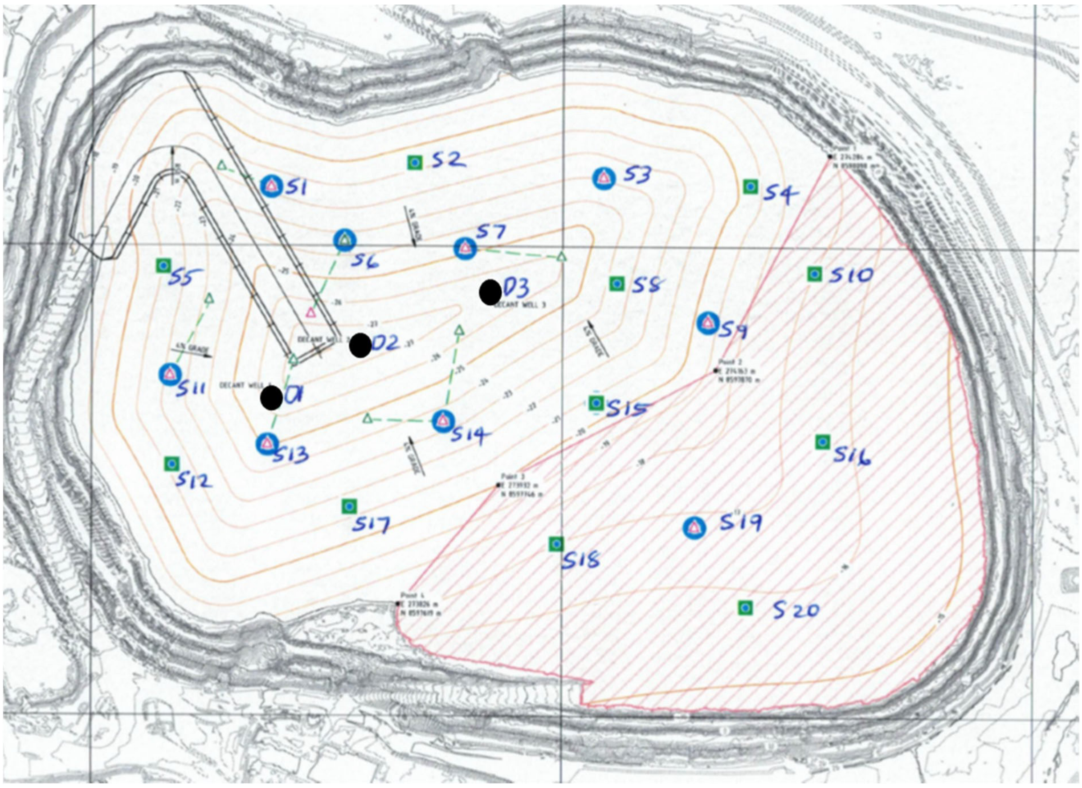


Figure 9-51 Locations of Decant and Settlement towers

+Green squares represent towers to monitor water quality. Blue circles indicate towers for water extraction. Black circles represent the decant towers.

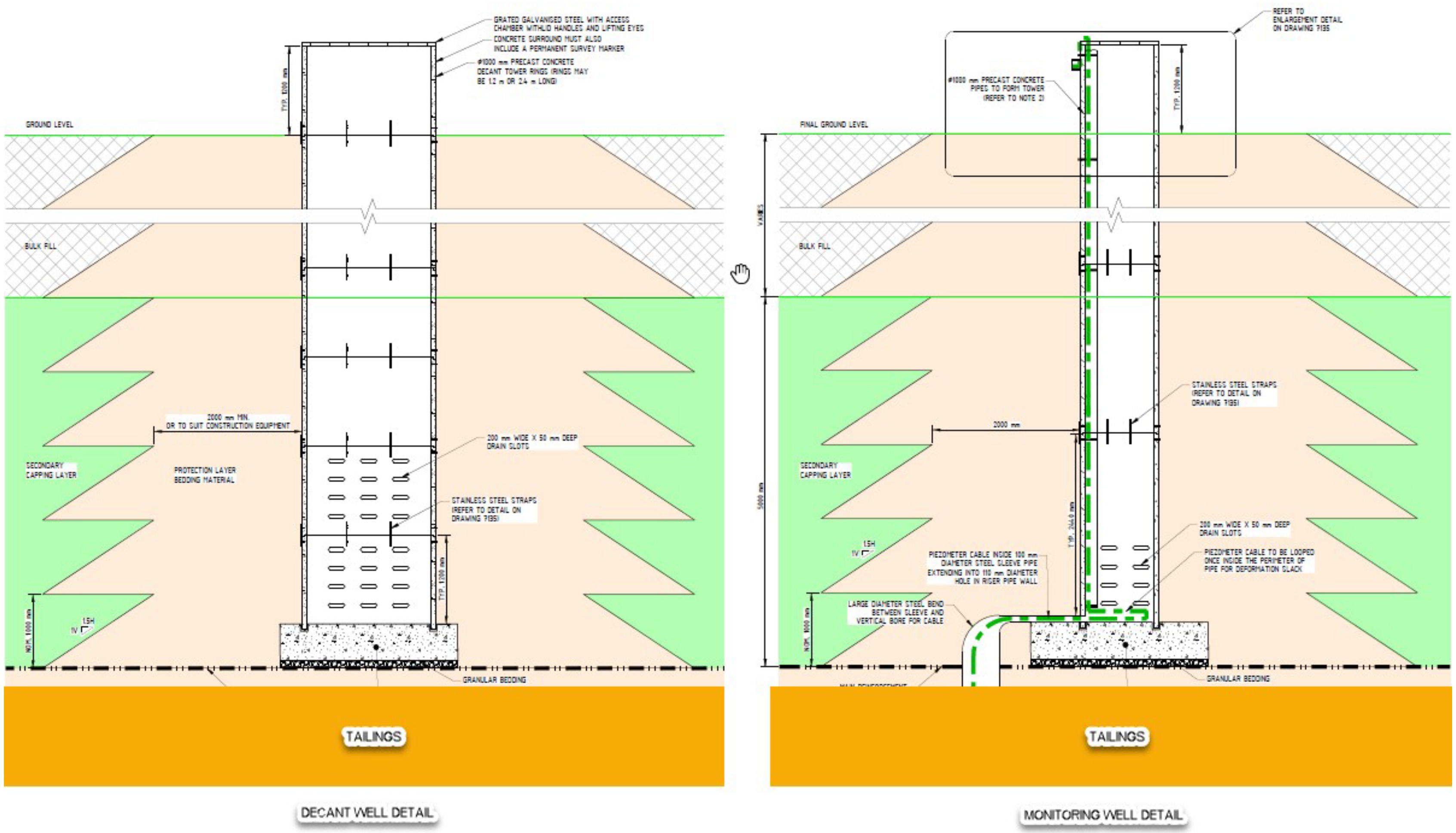


Figure 9-52 Decant well (left) and monitoring well (right)

Secondary capping works

Following the assessment of the initial capping layer and tailings strength, secondary capping layer works can commence. The carefully controlled works will place approximately five to ten metres of waste rock material on top of the initial capping layer via dozers and dump trucks shown in Figure 9-53, creating a working surface to enable larger mining fleet equipment for bulk backfill activity.

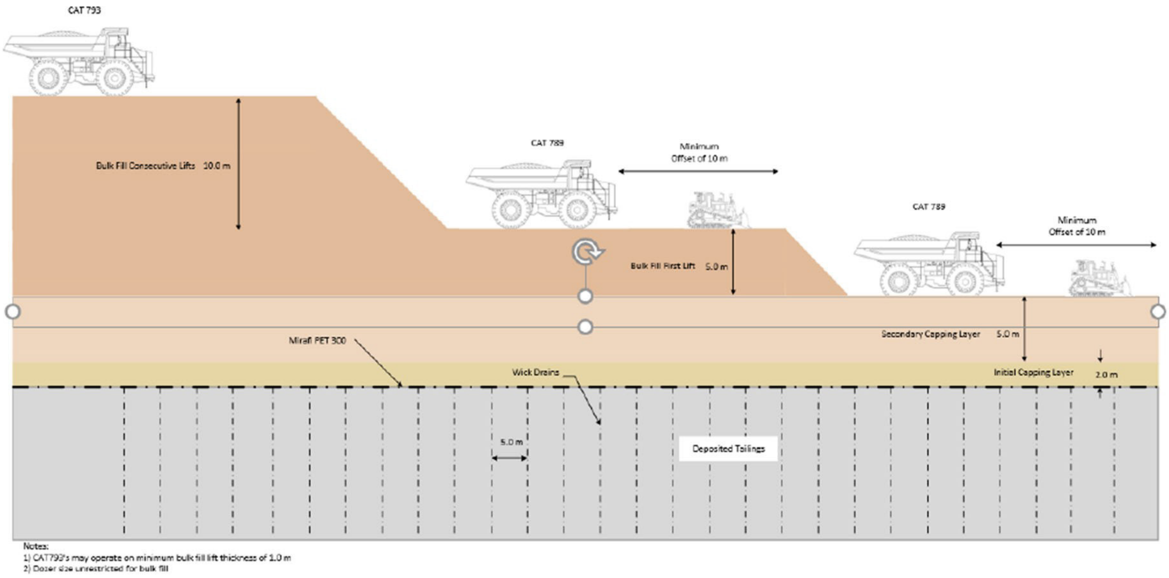


Figure 9-53 Backfill layer construction method. Note thickness, offset and machines are typical and subject to final tailings testing and capping designs

Bulk backfill

The estimated waste rock to be placed into the Pit 3 void is approximately 60 Mt. Bulk material movement to backfill Pit 3 will be dependent on tailings strength and associated geotechnical constraints.

Bulk backfill works can sequentially commence in parallel with the capping activities as shown in Figure 9-53 with the first 5 m lift layer tipped directly on top of the secondary capping layer, followed by successive layers tipped with progressively less constraints. Some geotechnical constraints to capping and bulk fill are summarised in Table 9-10.

Table 9-10 Pit 3 Backfill Geotechnical Design Criteria

Backfill Layer	Layer Thickness (m)	Lift Height (m)	Maximum Grade (%)	Minimum Bench Offset (m)
Initial Capping	2	2	-	10
Secondary Capping	5	1 - 5	10	10
Bulk Fill – 1st Layer	5	5	-	-
Bulk Fill – Successive Layers	Variable	Variable	-	-

Pit access is via two ramps on the western and southern side the locations shown in Figure 9-54. Vehicle movement and traffic control will form a critical part of the works.

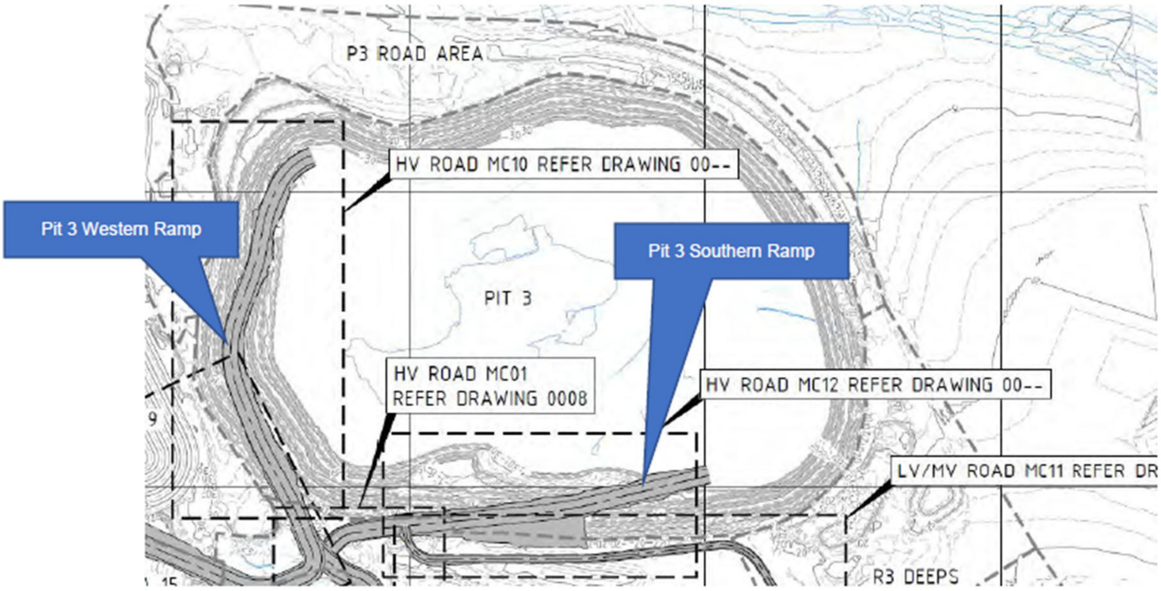


Figure 9-54 Pit 3 access ramps

The bulk backfill requirements for Pit 3 are included in Table 9-11.

Table 9-11 Bulk Material Movement to Pit 3

Stage	Material movement (m^3)	Haul distance (m)
Stage 9	3,188,633	1,000
ROM/crusher stockpile	996,641	2,000
Stage 6	3,015,822	2,100
Stage 8	3,162,177	2,050
Stage 10	37,932	1,800
Stage 11	6,254,874	2,100
Stage 14	2,909,829	1,500
Stage 15	4,242,621	1,500
Stage 12	913,582	2,700
Stage 16	44,481	1,500
Stage 16 (non-mineralised)	7,082,833	1,500
TOTAL	***31,849,425***	

Solute transport source term modelling identified a better environmental outcome if all mineralised material is placed below the 2s cap called the vadose zone located between 8 to 14 mRL across the Pit 3 surface. Approximately 50 M tonnes of material must be placed below the surface of the 2s cap in Pit 3. A void may remain open for late placement of demolition and/or contaminated material, subject to the completion of the detailed demolition execution plan and schedule.

Disposal of Demolition waste into Pit 3

The process plant, administrative offices, workshops and warehouses, mobile operational equipment and other waste materials will be decommissioned, demolished and transferred by truck to Pit 3 for disposal. Multiple demolition phases may occur, the final demolition plan will be included in future Mine Closure Plans. Demolition phases will be timed to fit in with Pit 3 backfill activities. Demolished material for disposal will be held either near it's point of origin or on an interim pad prior to Pit 3 availability.

Key assumptions for disposal of demolition waste includes:

- most demolition material will be disposed of in Pit 3;
- hazardous materials (except bulk contaminated hydrocarbons and returnable items) will be disposed of in Pit 3;
- disposal activities in Pit 3 will be concurrent with bulk backfill activities;
- disposed items in Pit 3 will be buried 6 m below final landform; and
- demolition materials will be prepared, placed and backfilled to minimise voidage and settlement issues.

An environmental assessment in 2018 determined the minimum depth for burial of non-mineral waste beneath the final waste rock landform is 6 m based on:

- plant (vegetation) available water and vegetation requirements;
- Northern Territory asbestos disposal requirements;
- predicted denudation over 10,000 years;
- diffusion length for 222Radon;
- Northern Territory general landfill requirements; and
- The Ranger Conceptual Model.

The outcome of the assessment determined revegetation is the most restrictive aspect for minimum depth of waste rock, associated with plant available water and rooting depth in waste rock. An estimate of the current waste material that requires disposal in Pit 3 (or RP2) is summarised in Table 9-12.

Table 9-12 Waste materials for management and/or disposal at closure

Waste Material	Amount
Demolished material	
Demolished structural & non-structural steel, concrete, asphalt, piping	130,000 m^3 (235 kt)
Listed wastes	
Asbestos	400 t
Rubber and other hazardous wastes	8,000 t
General waste	
General rubbish	17,000 t
Heavy Mining Equipment	21,000 m^3
Special Items	
Calciner to Pit 3	1 unit
Geological ore samples (mixed uranium content) to Pit 3	1,400 t
Rags and Pads 77 x 44Gal drums (hydrocarbon/uranium)	100 t

Asbestos

Asbestos is a 'listed waste' under the Northern Territory Waste Management and Pollution Control Act (*WMPC Act*). The *WMPC Act* does not apply to mining; therefore no approval under this act is required. However, ERA is committed to achieving the best environmental outcome for Ranger rehabilitation and will ensure that all disposal of asbestos in Pit 3 is in accordance with the *WMPC Act* guideline *Asbestos disposal in the Northern Territory*.

9.2.2.4 Contingency planning

Brine injection

The deviated drilling of wells to facilitate brine injection into the underfill is currently underway. Included in the well design is the ability to access the well head, enabling clean-out of redrilling of the well, casing material selection and well head infrastructure design to permit injection of brine or flushing fluids into the well under significant pressure. Either of these design features may enable otherwise blocked wells to be recovered. If these remedial activities fail, then additional injection wells can be constructed.

Should injecting brine into the Pit 3 underfill cease to be a viable option and/or the allowed void space is insufficient for the brine volume, additional contingency options will be required. Currently ERA is developing contingency options for two scenarios:

- the brine injection system fails to operate early in the closure project; and
- the brine injection system fails and/or void spaces are exhausted late in the closure project.

During 2021, ERA engaged consultants to assess a range of potential disposal locations and methods against those two scenarios, and develop a short list for more detailed evaluation, including best practical technology assessment. The preferred options selected for the two scenarios will be included in future updates of the MCP.

Tailings consolidation

The volume and rate of water expressed during consolidation of tailings is dependent upon the properties of the tailings and the mass of rock placed as part of the overall capping works. Both of these are well understood by ERA, refer to *Section 5 KKN Supporting Studies*, Chapter 5.4.2 for the tailings properties data. The consolidation model will inform the safe design of the capping layer and provide an estimate of the timing for expressed water. ERA has a number of contingency options should either the consolidation target be shown, through solute transport modelling, to be insufficient to protect the environment, or the consolidation model update determines that the consolidation will take longer. These options relate to the timing of achievement of the closure project and will not impact on the environmental outcome.

For the case where no design options remain to increase the speed of consolidation or where it is identified during execution that consolidation is taking longer than expected, the contingency would be to operate the decant structures and treat the expressed water until the consolidation target was achieved.

Learnings from Pit 1 wet season indicate that large rainfall events that flood the tailings, will not impact tailings settlement or damage completed capping works because water can be pumped out and works resumed following appropriate safety inspections.

The 20 tailings settlement towers are a contingency for expressed pore water extraction in the event that the lowest point of the consolidated tailings surface is not located in the vicinity of the 3 decant towers.

Geotextile

Varying tailings conditions may exhibit liquefaction resulting in capping ‘boil’ failures. Geogrid in high traffic areas will aim to spread load. Any repairs required will be by careful placement of material or covered by extra geotextile and re-capped. The weight of the initial capping layer expresses pore water from the tailings facilitating consolidation and increasing strength. The capping layer will be surveyed to confirm strength and enable access for the bulk backfill fleet (larger HME) for construction of the secondary capping layers.

9.2.3 Ranger Water Dam

Figure 9-55: Ranger Water Dam (September 2021)

The Ranger Water Dam (RWD) is the former Tailings Dam or Tailings Storage Facility (TSF). Bulk dredging and transfer of tailings from the RWD to Pit 3 was completed in February 2021. Transfer of remnant tailings from the RWD floor and walls to Pit 3 was completed in December 2021. Process water is currently stored in the RWD. Deconstruction of the RWD will commence once it is no longer required to store water.

9.2.3.1 Completed rehabilitation

Mill tailings deposition into the RWD ceased in 2016, following the conversion of Pit 3 into a tailings storage facility. Progressive rehabilitation of the RWD commenced with dredging and transfer of tailings to Pit 3. A summary of completed rehabilitation works in the RWD is provided in Table 9-13.

Table 9-13: Completed RWD rehabilitation

Year	RWD closure activity
1996	Tailings deposition from the RWD into Pit 1 commenced in August
2015	The tailings dredge 'Jabiru' was launched and commissioned in the RWD
2016	In January, commencement of transfer of approximately 27 Mt of dredged tailings from the RWD to Pit 3
2019	Remnant tailings cleaning from the walls of the RWD commenced
2019	A second tailings dredge 'Brolga I' was fully commissioned
2019	Tailings transfer upgraded to new flow rates to meet the requirements of the two dredges
2020	ERA received MTC approval to leave the RWD subfloor material in-situ
2021	Completion of bulk dredging 15 February 2021 Initiation of floor and wall cleaning activities (Figure 9-57) Transfer of remnant tailings from the RWD to Pit 3 via heavy vehicle commenced in June and was completed in December
2022	Water transferred from the RWD to Pit 3 to complete floor and wall cleaning Transfer of process water from Pit 3 to RWD to commence wicking in Pit 3

Tailings transfer

The bulk tailings reclamation system recovered tailings material from the RWD by means of two dredges, the 'Jabiru' and the 'Brolga I' and their supporting maintenance crafts 'Mudskipper' and 'Ginga' respectively. The Jabiru shown in Figure 9-56 a stainless steel dredge, weighing approximately 170 t used a five-wire, three-anchor, system to manoeuvre whilst dredging.

Figure 9-56: The Jabiru dredge

The Brolga I (Figure 9-57) was a Damen CSD500S cutter suction dredge, using two spuds and two side wire anchors.

Figure 9-57: The Brolga 1 dredge

Maintenance craft (or workboats) set the anchors and assisted the dredge moves under tow, mobilised crew and equipment and supported the servicing of the vessels. The Mudskipper

(Figure 9-58) is a 13 m maintenance craft that serviced the Jabiru. The Ginga serviced the Brolga I.

Figure 9-58: The Mudskipper

A dredge plan was developed by ERA based on HYPACK DredgePack dredging software to control dredging practices, with accurate positioning and monitoring of progress. Run lines allowed for a 40 m swing cut for the Jabiru and 50 m wide run lines for the Brolga I.

Each dredge operated in its own working area so as not to impede each other's operation. The south side was dredged by the Jabiru and the remainder dredged by the Brolga I. The result was a 60 /40 volume split between the Brolga I and Jabiru. The north side of the RWD was allocated to the Brolga I due to the deeper floor providing for more consistency in the water level over the course of the project. The maximum dredging depths for the Jabiru and Brolga were 10 m and 14 m, respectively.

The upstream clay core of the RWD embankment was protected from contact with the dredge cutter head by the inclusion of a 0.5 m standoff zone programmed into the dredge computer.

The dredged tailings were transferred to Pit 3 via a dedicated single overland pipeline for each dredge until the completion of bulk dredging on 15 February 2021. The pipelines connect directly to the discharge of the floating pipeline from the dredge on the eastern notch. Tailings were discharged into Pit 3 via subaqueous and subaerial deposition.

Process water return Pit 3 to RWD

The process water stored within the tailings in Pit 3 is continuously expressed as sedimentation/consolidation occurs. The water that flowed upwards (decant), while the dredges were operational, was pumped back to RWD to keep up with the dredge operation, the process shown in the block diagram in Figure 9-59.

RWD wall notches

The progressive reduction in water level associated with the dredging operations necessitated the creation of notches within the RWD walls to facilitate safe access to floating infrastructure and improve return water pumping efficiency. Figure 9-60 shows the location of RWD wall notches. The East wall notch was installed to improve the pump efficiency for process water and tailings pipelines. Stages one and two of the North wall notch, were built to allow safe access to floating infrastructure in the RWD as the tailings was progressively removed. Finally, two shallow notches, in the western wall and south-western corner, were constructed to allow access into the RWD for wall and floor cleaning activities in 2020.

Prior to the construction of each notch engineering designs and stability assessments were completed. The design and assessment were reviewed by an independent specialist to meet the requirements of the Rio Tinto Group Standard D5 – Management of tailings and water storage. Regulatory approvals were also obtained prior to the execution of notch works where the notches result in a change to the certified clay core crest height and associated decrease to the maximum operating level (MOL) of the RWD.

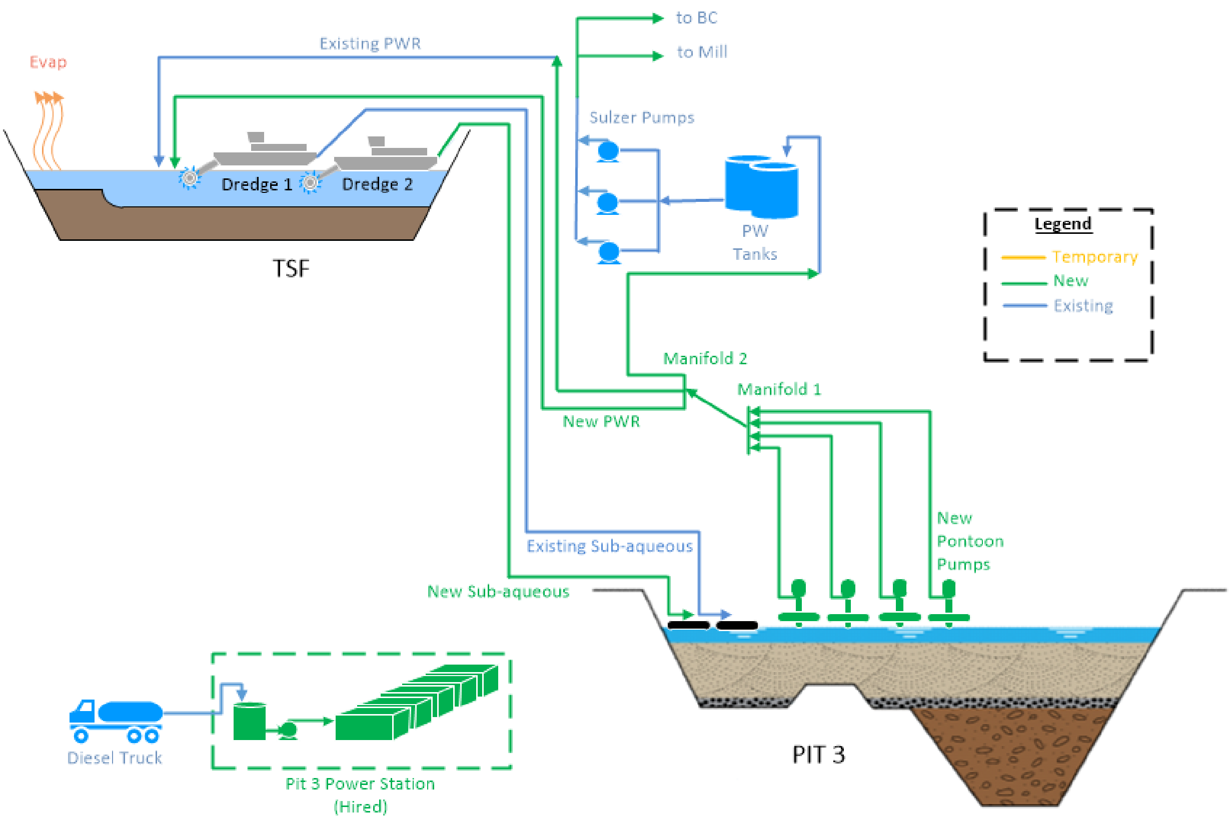


Figure 9-59: Process water return from Pit 3 to the RWD

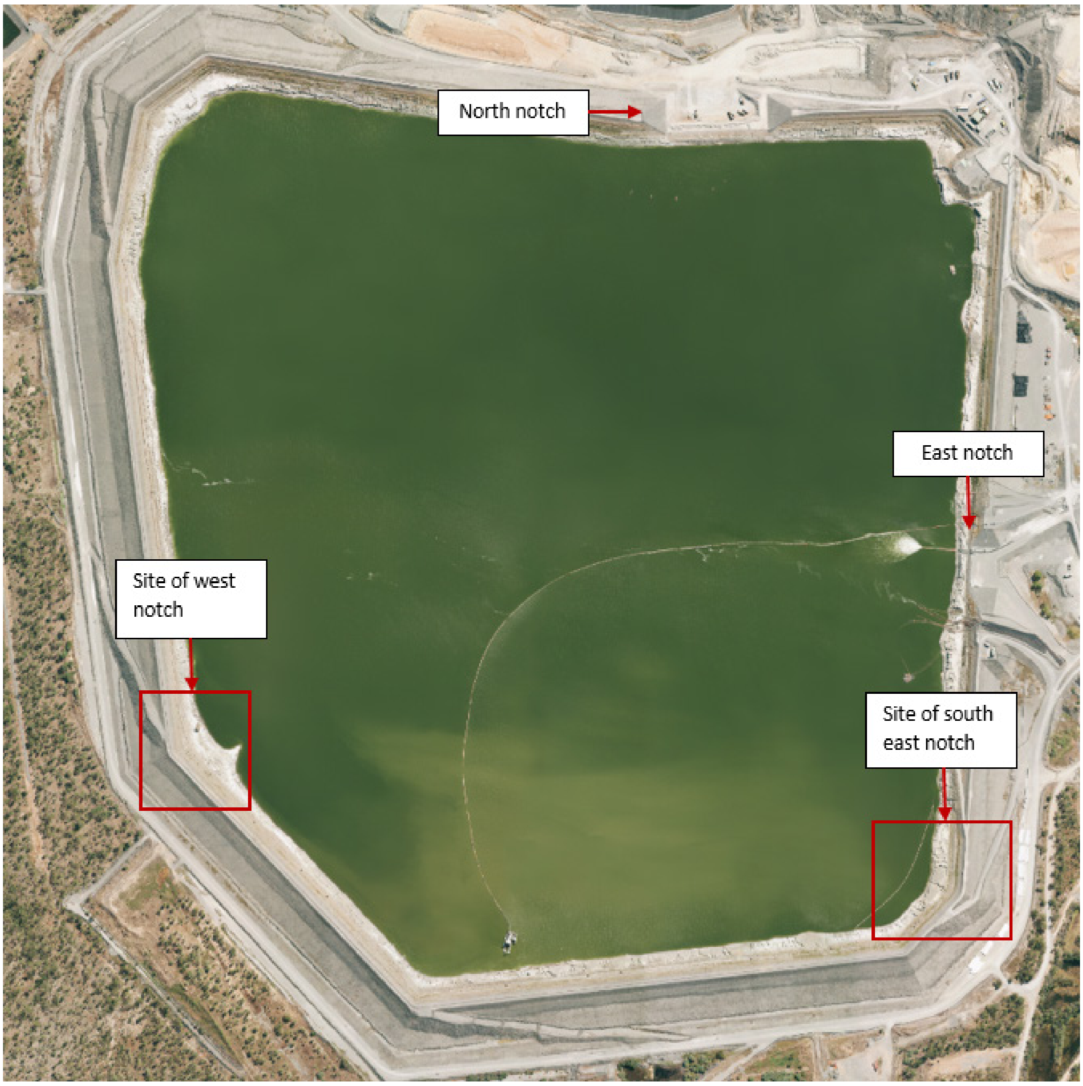


Figure 9-60: Location of notches within the RWD walls

RWD wall cleaning

Condition 11.2 of the Environmental Requirements of the Commonwealth of Australia for the Operation of Ranger Uranium Mine (the ERs), requires that all tailings must be placed in the mined out pits. In order to comply with this condition ERA completed a wall and floor cleaning program to remove the remnant tailings within the facility. ERA continues to collaborate with stakeholders to determine the final criteria to confirm compliance with condition 11.2.

The upstream clay core of the RWD embankment was protected from contact with the dredge cutter head by the inclusion of a 0.5 m standoff zone resulting in tailings 'hang-up' on the RWD walls (Figure 9-61). ERA used excavators to scrape remnant tailings from the internal RWD walls, progressively transferring the tailings down the walls onto the RWD floor. The excavators manually sorted larger rocks or rubbish material within the tailings. An amphibious excavator was used to access to wet areas not accessible by conventional excavators. The cleaning methodology steps were:

Step 1: Bulk Tailings Removal

An excavator removed hung up tailings material down the wall, stacking the tailings on the RWD floor while maintaining the wall integrity.

Step 2: Scrape

With a flat bladed bucket, excavators scraped tailings from the wall surface, able to occur concurrently with Step 1, removing all visible tailings from the wall surface shown in Figure 9-62.

Figure 9-61 Typical wall cleaning operation above 45 mRL

Figure 9-62 –RWD wall post step 1 & 2, with tailings patches indicated (dark grey/khaki colour)

Step 3: Inspect and Correct

The work crew undertaking the wall cleaning inspected the work and took corrective action if required. This is recorded in an Inspection and Test Plan (or verification plan) and included further, targeted removal of tailings material with an excavator where required. It is noted that rainfall also assisted in wall cleaning by washing tailings down the slope.

Current visual inspections show that one wet season has cleaned a significant amount of fine tailings from the walls. This is apparent in the before and after pictures taken of one section of wall shown in Figure 9-63 and Figure 9-64.

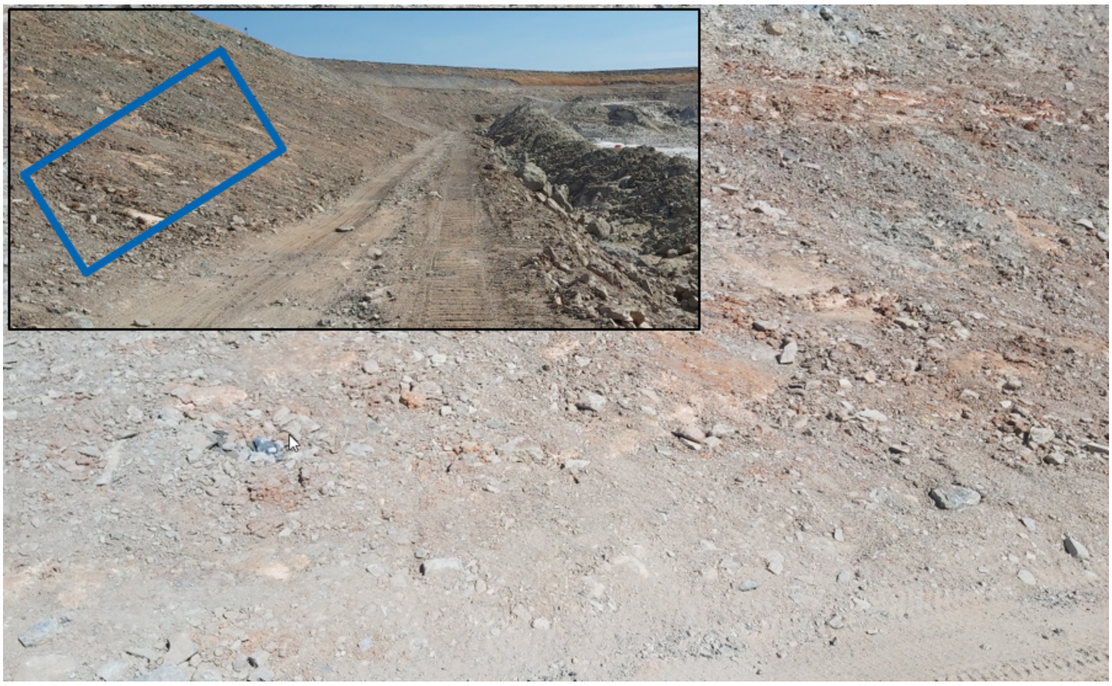


Figure 9-63 Section of the West wall showing a scraped clean wall section prior to wet season 2020/21. Some fine tailings may potentially sit in between wall armouring

Figure 9-64 Same section of the West wall of Figure 9-63 showing cleaned surface following rain

RWD floor cleaning

The dredges removed most of the tailings material from the RWD. However, due to the presence of buried waste material, large displaced rock armour and 'spill' from the dredges, some remnant tailings remained on the RWD floor following the completion of the dredging program.

Cleaning of the RWD floor commenced early 2021. Low Ground Pressure (LGP) 'swamp' dozers and all terrain excavators (ALTEX) created initial drainage paths, allowing the RWD floor to gradually drain, creating a more trafficable surface. Excavators and LGP 'swamp' dozers then pushed tailings into stacks and rows, further dewatering the tailings.

ERA undertook a BPT assessment on 24 February 2021 to determine the most appropriate approach for the disposal of the remnant tailings within the RWD. Trucking the tailings to a tip head in Pit 3 had the best performing approach with the highest, or equal highest, ranking for every criterion.

In June 2021, ERA commenced the remnant tailings transfer from the RWD to Pit 3, utilising trucks, which access and depart the RWD floor via the northeast ramp. The most stable and competent tailings were moved first, in small volumes, to verify contamination and material management controls.

The remnant tailings transfer followed a designated haul route, through the mine area, between the RWD and Pit 3 with restricted access classified as a controlled area.

Foreign material removal

Magnetometer surveys of the RWD completed in 2012 and 2019 located potential buried iron objects (Fugro 2012 & Surrich Hydrographics, 2019). The 2012 survey reported 'a very strong anomaly on the south-eastern side of the RWD, believed to be the sunken remains of the old survey barge / pontoon'. Data acquired through the 2019 magnetometer surveys (Surrich Hydrographics, 2019) with a towed magnetometer compared to the 2012 is shown in Figure 9-65.

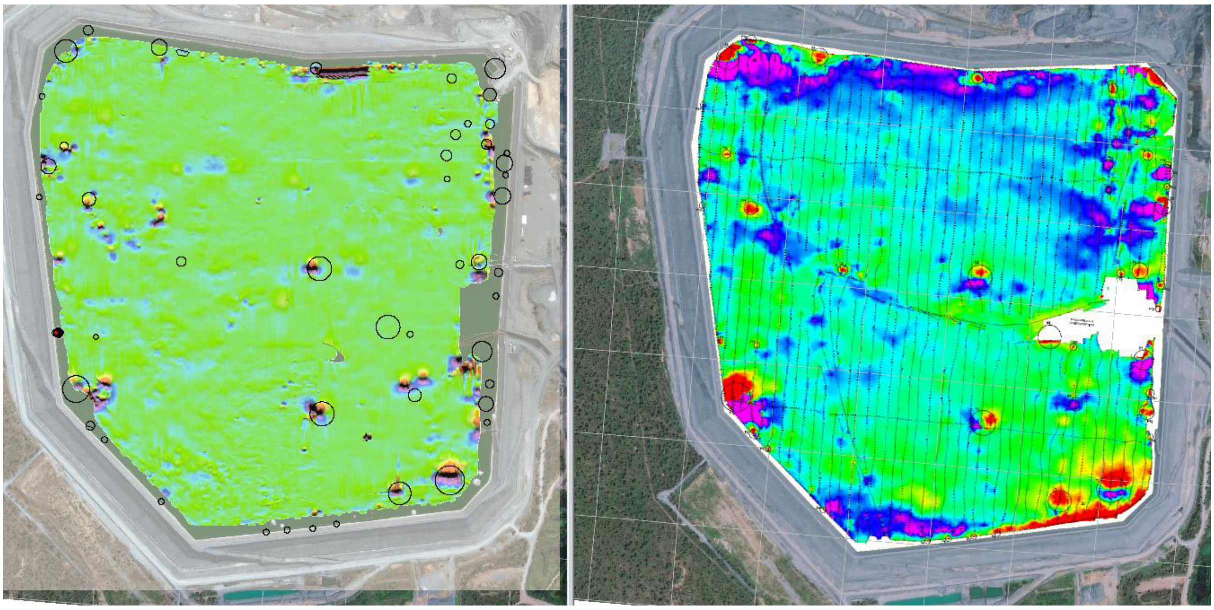


Figure 9-65: April 2019 Magnetic Anomaly Map (left frame) comparison with the 2012 Magnetic Anomaly Map (right frame)

Objects were identified close to the RWD embankment, whilst the central area was relatively free of anomalies. The magnetometer detected a very strong anomaly on the south-eastern side of the RWD, again, believed to be the sunken remains of the old survey barge/pontoon. No other features of similar magnitude were found. Many anomalies, either localised or diffuse, were likely caused by magnetic material in the tailings, accentuated by variations in the water depth that changes the range between source and detector. Small, localised anomalies, particularly around the RWD perimeter, probably represent iron debris.

Throughout the dredging operations, foreign materials were encountered and they were either removed from the RWD, cleaned and stored, or placed temporarily on the walls as they were encountered. All waste materials found in the RWD will either be buried in-situ, transferred to Pit 3 or transferred to RP2 for final burial.

9.2.3.2 Current rehabilitation

The RWD is currently storing process water returned from Pit 3. No current rehabilitation activities are occurring.

9.2.3.3 Planned rehabilitation

RWD subfloor material management

The management of contaminated sites is a critical step for rehabilitating Ranger mine and meeting closure criteria. The RWD subfloor was identified as an area requiring further investigation to assess the levels of contamination and solute egress risk based on a final disposal location. In June 2020, ERA submitted an application to the MTC to remove the option of transferring RWD subfloor material to Pit 3 as part of the closure strategy. An assessment was undertaken to identify a management option that would achieve the best environmental outcome in terms of minimising contaminant loading to the environment. The supporting studies (including solute egress modelling discussed below) and a BPT assessment indicated that the most viable management option involved leaving the subfloor material *in situ*. This decision was important for informing the list of source terms for the closure of Pit 3, and to allow commencement of RWD decommissioning planning with consideration of future remediation options.

The solute egress modelling undertaken by INTERA indicated that all options involving the transfer the RWD subfloor material to Pit 3 would increase the direct Magnesium (Mg) peak loadings to Magela Creek by a significant margin in contrast to leaving the material *in situ*. In addition, the physical removal of the RWD subfloor, and backfilling with waste rock, would further alter the hydraulic characteristics within the RWD footprint, causing changes to the surrounding drainage dynamics and increasing the peak Mg loading to drainage areas within the Ranger Project Area (RPA). It was also found that Mg loadings to the Coonjimba catchment (the nearest sensitive receptor to the RWD) will not differ significantly if the RWD subfloor material remains *in situ* or is removed, when considering the contribution from the broader RWD groundwater plume. The modelling work is discussed detail with *Section 5 KKN Supporting Studies*, Chapter 5.5.2.

The RWD subfloor risk assessment concluded that the risks associated with leaving the RWD subfloor material *in situ* can be adequately managed. Any potential consequences resulting from this management option are likely to be confined to RWD footprint and surrounding drainage areas and represent consequences that are as low as reasonably achievable (ALARA) within the boundary of the RPA. In implementing this management option, ERA recognised the opportunity to undertake *in situ* remediation to further minimise levels of contamination. This will be investigated through further assessment.

Regulatory approval to leave the RWD subfloor *in situ* was received in August 2020. The RWD deconstruction application will include a BPT assessment of potential remediation options and an updated risk assessment to demonstrate how risk ratings can be improved.

Dredge disposal

One of the two RWD dredges (the Brolga 1), has been removed from the RWD, cleaned, decontaminated, radiation cleared and sold. Ideally, this same process would occur for the second dredge (the Jabiru) and the two supporting vessels (the Mudskipper and the Ginga, which are currently being used in Pit 3 to support wicking activities). If this does not happen, this equipment will be made safe and disposed on-site. Options for disposal are:

- burial in the RWD;
- burial in Pit 3 (or RP2).

An environmental assessment, completed in 2018, determined the depth for burial of non-mineral waste as 6 m below final landform. ERA has identified a suitable location in the south-east corner of the RWD; where the surface area and cover depths in relation to the final landform and minimum burial requirements allow for burial without the need for further excavation. This option allows for the burial of the dredging equipment and any other miscellaneous waste material remaining in the RWD at the time of deconstruction.

Removal of HV power supply and telemetry

As activities at the RWD are reducing, so too is the power demand. High Voltage (HV) power distribution lines (mostly aerial but some buried) will start to be decommissioned and removed. This will occur progressively, with HV power in the area of the processing plant being retained for some time for the BC, Brine Squeezer and water treatment plants. The removal of the HV line to the RWD including the HV spur line to the Brockman Bore will also necessitate the conversion of the Brockman borefield power supply to a diesel-powered generator or similar.

Process water storage

At the commencement of Pit 3 capping activities, water in Pit 3 will be pumped back to the RWD for storage pending treatment. Once the process water volume in the RWD falls below 1 GL, the process water will be transferred out of the RWD into RP6. This allows the deconstruction of the RWD to occur before the completion of process water treatment.

Once the RWD is empty of process water, decommissioning, including any contaminated material management activities, will commence. During the deconstruction work, the RWD will be converted to a pond water catchment. Any water captured in the RWD area after this time will be collected and transferred to Retention Pond 2 (RP2). Upon completion of the final landform in this area, the RWD catchment will be converted to a release water catchment.

RWD decommissioning

The decommissioning of the RWD involves both the management of the contaminated material remaining in the RWD sub-floor and the deconstruction of the facility. The options for management of contaminated material remain under assessment and will be provided in future updates to this MCP and a standalone approval application.

RWD deconstruction will involve reducing the walls to final landform level. Wall material will be used to fill in the RWD. The majority of the material used in the construction of the RWD walls will fit into the RWD to achieve the final landform. A small volume of the wall material may need to be transported to a nearby stockpile area. The material in the wall will be mined using standard material movement practices with dozers, trucks and excavators. The RWD deconstruction material quantities are shown in Table 9-14 with sequencing shown in Figure 9-66.

Table 9-14: RWD deconstruction material quantities

RWD Segment	Material Movement	Brief Description
RWD EAST	Excavation and distribution to final landform levels: 835,121 m^3 Final landform surface area: 24.99 ha	Deconstruction of the eastern RWD walls. Utilise material to shape final landform surface in the eastern area.

RWD Segment	Material Movement	Brief Description
		Excess material taken to other site fill areas.
RWD WEST	Excavation and distribution to final landform levels: 2,440,743 m^3 Final landform surface area: 43.07 ha	Deconstruction of the western RWD walls. Utilise material to shape final landform surface in the western area. Excess material taken to other site fill areas.
RWD SOUTH	Excavation and distribution to final landform levels: 2,881,980 m^3 Final landform surface area: 98.15 ha	Deconstruction of the southern RWD walls. Utilise material to shape final landform surface in the southern area. Excess material taken to other site fill areas.
RWD NORTH	Excavation and distribution to final landform levels: 1,463,850 m^3 Excavation and distribution to Pit 3: 1,086,537 m^3 Final landform surface area: 31.19 ha	Deconstruction of the northern RWD walls. Utilise material to shape final landform surface in the northern area. Excess material taken to site fill areas.

RWD plume

Gradual seepage from the RWD, since the time of its construction, has resulted in the formation of a groundwater contamination plume. The extent and behaviours of the plume have been investigated over time (Weaver, 2010). Test work and studies were completed during 2020 to further define the plume and model the groundwater transport (*Section 5 KKN supporting studies*, Chapter 5.5.2.5). A BPT assessment of potential remediation options for this plume is planned to be completed in conjunction with the other RWD contaminated material, as discussed above. These assessments and any remediation plans required will be included in the RWD deconstruction application and subsequent updates of this MCP.

Landform and erosion control

The final surface of the RWD will be shaped to form the final landform. The RWD topography forms a drainage flow path running south to north along the historic Coonjimba Creek. Landform and erosion controls for the RWD will be included in the RWD deconstruction application and subsequent updates of this MCP.

Revegetation

ERA is currently assessing the potential impacts on vegetation from any contaminated materials buried under the final landform. The outcomes of this work and any risk mitigation measures required will be included in the RWD deconstruction application and included in the relevant update of the MCP.

9.2.3.4 Contingency planning

RWD deconstruction methods are currently being finalised by ERA in preparation for the RWD deconstruction application. This involves a best practical technology assessment of the options. The options not selected for progression, that have not been show stopped for environmental or cultural reasons, will then form the basis of ERA's contingency planning.

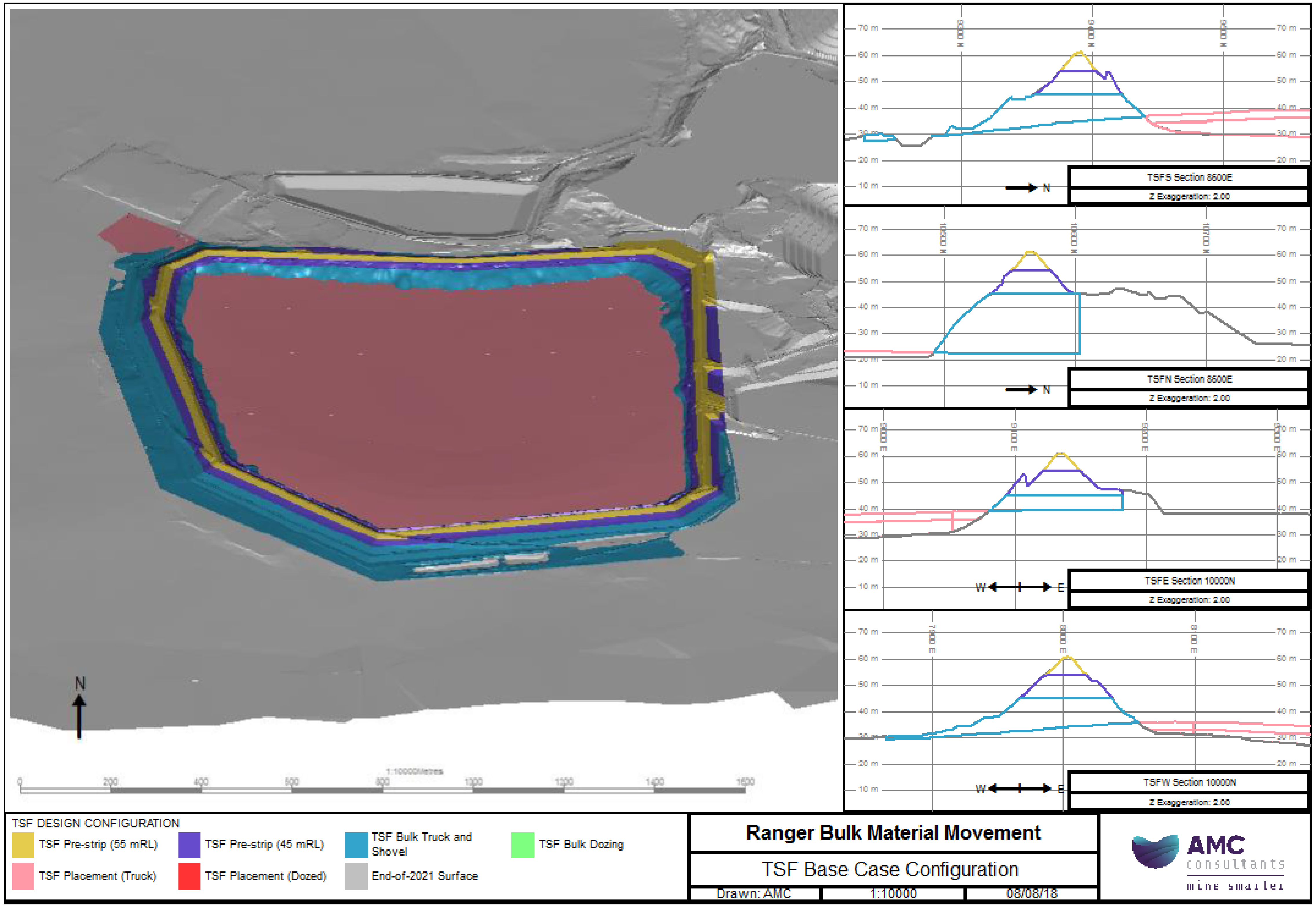


Figure 9-66 RWD wall deconstruction sequence

9.2.4 Land Application Areas

Figure 9-67 Djalkmarra and Djalkmarra Extension Land Application Areas (May 2019)

Land application areas (LAAs) allow for the disposal of water through spray or flood irrigation (Figure 9-69). The quality of water disposed on the LAAs has varied over time, however LAAs are now used purely for the disposal of release quality water, Water Treatment Plant permeate and Brine Concentration distillate water. The LAAs are designed to retain uranium in near-surface soils. Ranger mine has eight LAAs in total, with a combined size of 328 hectares.

LAAs will be required throughout closure to allow for the ongoing disposal of release water, generated through rainfall runoff and water treatment. As catchment areas transition to direct release and water treatment requirements reduce, these areas will gradually become available for decommissioning. Decommissioning of these areas will involve:

- removal of any infrastructure (i.e. pipes, irrigation spray heads). Figure 9-68 and Figure 9-69 provide examples of infrastructure at each LAA;
- completion of any remediation works, as determined from contaminated sites and best practical technology assessments;
- scarifying of tracks, as required; and
- completion of any infill revegetation, as required.

Figure 9-68: Infrastructure for removal at Corridor Creek LAA

A preliminary assessment of the total percentage of each LAA requiring revegetation has been made (Addison, 2011). The size of these areas is dependent on the quantity and quality of the native vegetation and the density of weeds, present after years of irrigation.

Table 9-15: Area of the LAAs

#	LAA		AREA (ha)
A	Corridor Creek LAA	Total area:	131
		Planned revegetation (10%):	13.1
B	Magela A LAA	Total area:	33
		Planned revegetation (100%):	33
B	Magela B LAA	Total area:	20
		Planned revegetation (70%):	14
C, D	Djalkmarra East (DLAA) & Djalkmarra West (DLAA ext) LAA	Total area:	38
		Planned revegetation (50%):	19
E	Retention Pond 1 LAA	Total area:	46
		Planned revegetation (80%):	36.8
F	Retention Pond 1 LAA ext.	Total area:	8

#	LAA		AREA (ha)
		Planned revegetation (10%):	0.8
G	Jabiru East LAA	Total area:	52
		Planned revegetation (80%):	41.6
LAA – TOTAL HA			328
TO BE REHABILITATED – TOTAL HA			158

Figure 9-69: Infrastructure for removal at Corridor Creek LAA

9.2.4.1 Completed rehabilitation

There has been no progressive rehabilitation undertaken of the LAA sites to date as these areas remain in use.

9.2.4.2 Current rehabilitation

Assessments to characterise the LAA substrates have been completed. ERA will be deriving site specific Environmental Investigation Levels (EIL) for Uranium in order to assess the required rehabilitation. All LAA rehabilitation assessments will be informed by a BPT assessment and an ALARA assessment.

Previous assessment of the Land Application Areas (LAAs) was conducted in 2009 by Jane Addison Consulting, and more recently in October 2021 by the Supervising Scientist Branch (SSB). EcOz Consultants were engaged to provide an update of the current condition of the

LAAs, with the collected information used to inform future rehabilitation and management objectives and strategies (EcOz, 2022). The objective of the study was to provide an up-to-date, detailed assessment of each LAA, with a focus on vegetation composition and structure, weeds and disturbance, and fire history (EcOz, 2022). The surveys undertaken follow the methods described in Addison (2011) with the study following a similar structure to enable data comparisons where possible (EcOz, 2022).

A total of 34 sites were assessed across the seven LAAs shown in Figure 9-70 and described in Table 9-16. Sites were selected from Addison (2011) and resampled to update the dataset as well as for comparison to previous data and existing reference sites (EcOz, 2022). Sites were initially selected by overlaying a grid containing 150 m^2 cells within the LAAs and placing one 20 x 20 m quadrat in the centre of 34 chosen cells (Addison 2011). Each site was assessed for vegetation composition and cover, presence of weeds, fire history, and disturbance. The methods mostly replicated those described in Addison (2011), with some minor changes. Data were obtained from within each 20 x 20 m quadrat. A single photograph was taken facing due south from the centre of each quadrat with a team member holding a measuring tape to 2 m height for reference, standing approximately 5 m away from the camera.

A comprehensive report on the 2022 ground surveys was drafted in September 2022 (EcOz, 2022), and key findings will be used to develop individual rehabilitation strategies for the different areas. The LAA rehabilitation strategies will also consider the findings from the Dendra aerial monitoring trial (Section 10.6) and the contaminated site surveys. More details will be provided in the 2023 MCP. Several changes were observed in the LAAs compared to their last survey in 2009, including an increase of weeds and a marked decreased in fire activity.

Table 9-16 Land application areas surveyed within the Ranger Project Area

LAA	Approximate Area (ha)	Number of sites surveyed	Sites within LAA
Jabiru East	5305	5	S01 – S05
RP1	45.1	3	S11 – S12
RP1 Extension	8.6	2	RP1 a, b, c
Djalkmarra	23.5	4	S06 – S09
Djalkmarra Extension	11.0	1	S10
Magela (incl. Extension)	48.7	5	S13 – S17
Corridor Creek	146.1	14	S18 – S31

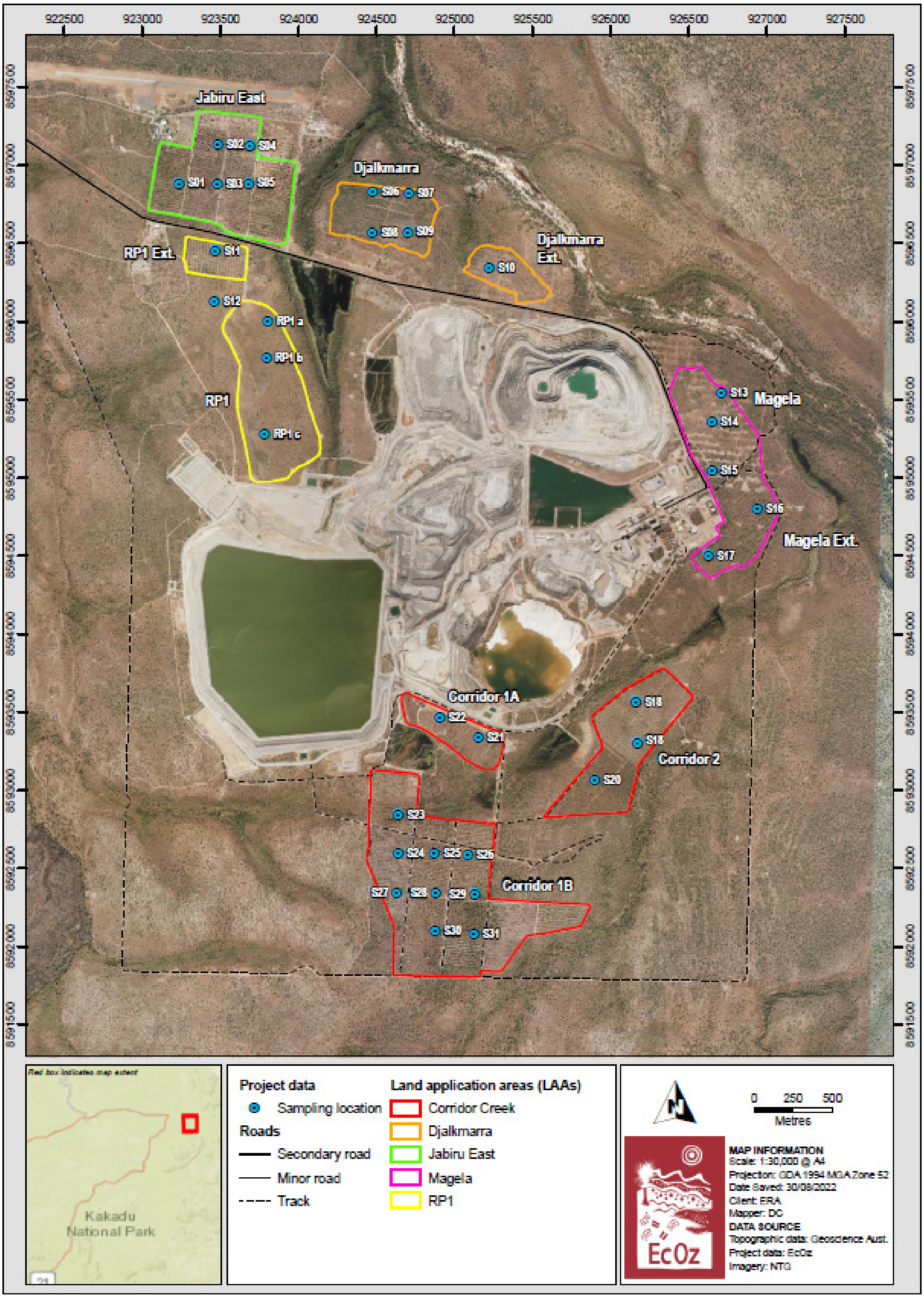


Figure 9-70 Map of Land Application Areas and survey locations within the Ranger Project Area

9.2.4.3 Planned rehabilitation

As described above and shown in , it has been determined that only 158 ha within the total area of LAAs will require active revegetation (i.e. planting in addition to self-regeneration). It is noted that the basis of this work was completed in 2011 and will be updated with the new information from the 2022 survey described above This will be included in future updates of the MCP.

9.2.4.4 Contingency planning

No contingency planning is required for the LAAs:

- Land application areas will not be rehabilitated until the areas are no longer required for water disposal.
- Historical soil sampling has been undertaken across all the LAAs. The analysis of these soil assessments will be used to undertake a BPT assessment to determine, if required, the best strategy for remediation of the LAAs.
- Monitoring will determine whether the selected revegetation strategy has been successful and if any further additional works are required.

9.2.5 Process plant, water treatment plants and other infrastructure

Figure 9-71 Process plant, mill and water treatment plants (May 2019)

This domain, as shown in Figure 9-71, includes all infrastructure from the processing plant, administration block, heavy vehicle area, power station, gatehouse and water treatment plants.

A discussion on the activity of water treatment is provided in Chapter 9.3.3, whilst this Chapter describes the removal of the water treatment infrastructure.

External services (Telstra) has been excluded from the Ranger Mine closure demolition scope as discussions are currently underway on the transfer of the facilities to the Northern Territory or Commonwealth government.

9.2.5.1 Completed rehabilitation

Prior to commencement of the decommissioning and demolition of the Ranger processing plant, ERA obtained a ‘Permit to Decommission Facility’ from the Australian Safeguards and Non-Proliferation Office (ASNO). The application for a permit outlined timeframes and estimated start and completion dates for the decommissioning of infrastructure associated with the leaching and solvent extraction circuits and areas of calcination, drying and product packing. This permit was received on 8 January 2021 at the completion of milling activities and allowed decommissioning works to proceed.

Decommissioning

Work on decommissioning and decontamination of all infrastructure within the processing plant has now been completed. The main goals of the decommissioning and decontamination implementation strategy are:

- controlled shutdown of all assets within a demolition area;
- decontamination of all infrastructure to the extent required to ensure safe and efficient demolition and disposal;
- de-energisation and isolation of each demolition area, scheduled in conjunction with the continuity of services works;
- interim management of the demolition area until handover to the demolition contractor; and
- walk-down, punch-listing (checklist) and handover to the demolition contractor once contract has been awarded.

The main stages of the decommissioning works are represented in Figure 9-72.

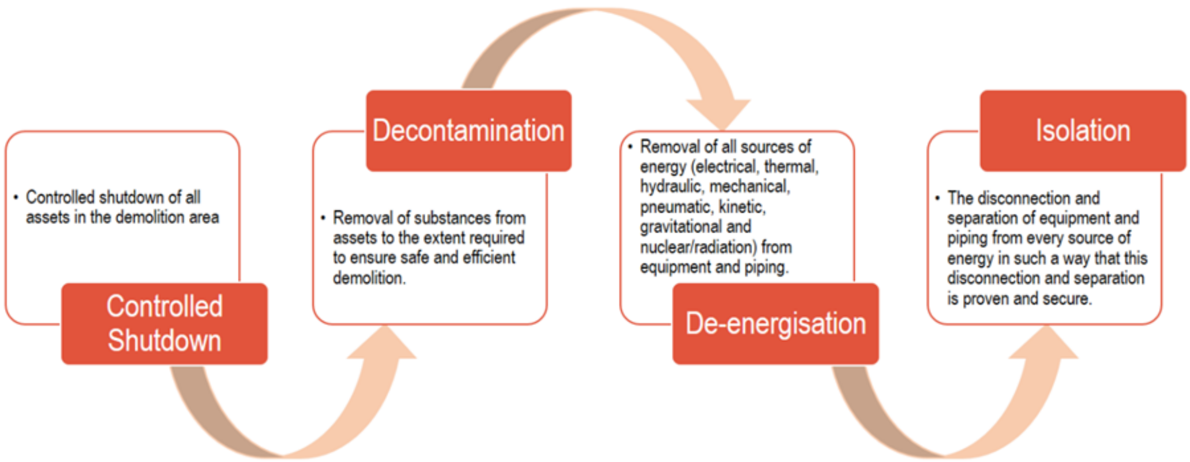


Figure 9-72 Decommissioning stages

All de-energisation and isolation activities of the demolition area were divided into electrical and control, piping, structural and miscellaneous and all activities completed according to ERA standards.

Works to ensure the continuity of services have also commenced. This involves moving service corridors, such as power and water lines, outside of the future zone of demolition. This process is required to be completed before the commencement of phase 1 demolition.

9.2.5.2 Current rehabilitation

With the completion of decommissioning of the processing plant, current rehabilitation involves only care and maintenance work to ensure the area remains safe prior to completion of demolition work. This, and the management of the demolition area (prior to handover to the demolition contractor), will involve the following activities:

- management of rainwater in the process area bunds via existing sump pumps while power remains live in decommissioned area;
- once the existing system of sump pumps are shutdown the following installation will be reviewed:
    - sampling and testing of rainwater in 'decontaminated' sumps to confirm that it is still sufficiently contaminated that it cannot be released
    - installation of a system of portable diesel pumps and lay flat hosing to pump contaminated rainwater to the retention ponds
    - documentation of the system to enable handover of management to the demolition contractor.
- demarcation of the demolition area boundary with tape, spray paint or similar;
- where required, installation of a temporary generator to connect to the light and power board to provide power for lighting in de-energised buildings during inspection activities. This generator is to be removed after inspection activities are completed;
- completion of the decommissioning work pack and handover check sheet (by the responsible party as the work is completed), including:
    - initialled and dated sign-off of all work by the responsible party
    - identification of any residual hazards on registers and drawings
    - results of radiation survey, and underground services surveys appended to the work pack (gas clearance surveys will be completed by demolition contractor prior to demolition activities commencing)
- walk-down of the demolition area to confirm completion of all activities in the decommissioning work pack and punch-listing (checklist) of incomplete items for handover to Continuity of Services team. Sign-off of the completion of activities is to be performed by the following accountable parties:

  - Area Superintendent – to confirm that all shutdown and decontamination work is complete
  - Radiation Safety Officer – to confirm all radiation surveys have been completed correctly and radiation levels are acceptable
  - Safety Officer – to confirm that all gas clearances have been completed correctly and explosion risks have been removed
  - Closure Project Engineering – to confirm that all continuity of services and de-energisation and isolation work is complete
- gas clearance and radiation surveys will be re-performed immediately prior to handover to demolition, to confirm areas are still safe after any extended period between decommissioning and demolition;
- second walk-down and punch-listing (check list) will be undertaken with the demolition contractor (to be conducted with demolition contractor prior to mobilisation of demolition equipment and crew to site and with sufficient schedule float for rectification works).

9.2.5.3 Planned rehabilitation

Continuity of services

Some services are required to be kept online or re-routed to allow continued operation of some aspects of the mine beyond cessation of milling operations.

Key aspects of the continuity of services plan are:

- essential services are assumed to remain operational, as per the current operating system, until commencement of Phase 1 demolition (Table 9-18);
- services within the Phase 1 demolition zone which are required after Phase 1 demolition are subject to continuity of services;
- equipment will be reused where possible;
- purchase of new equipment will be minimised; and
- Pipe and cable routes will avoid the Phase 1 demolition zone, where possible.

Continuity of services requires multiple piping tie-ins for various services. These services are split into the following:

- acids and reagents;
- potable water;
- plant air;
- diesel;
- fire water;
- pond water;

- instrument air;
- process water; and
- sewage.

Demolition and disposal

A demolition sequence has been determined for the areas of the plant based on the interaction of the plant with other activities in the overall closure project. Each plant area is colour coded according to the phases of demolition and are shown in Figure 9-73 and described in Table 9-17.

Demolition is defined as the tearing down of buildings and other structures (including the underground infrastructure) within the boundaries of the RPA. It includes:

- fixed or demountable process plant, buildings, mechanical or electrical infrastructure;
- tanks, both above and below ground;
- all pavements (bitumen and/or concrete) and associated infrastructure such as kerbs, gutters and gully pits;
- concrete slab and foundations to a depth of 1.5 m below existing ground level;
- all piping to a depth of 1.5 m below existing ground level;
- all cabling to a depth of 1.5 m below existing ground level;
- bitumen surfaces from roads;
- asbestos;
- loose solid materials across the sites;
- processing of demolished materials to approximately 1.5 m x 1.5 m lengths to ensure maximum density can be achieved at the disposal location; and
- removal and final disposal of the materials and hazardous waste.

Demolished items must be buried on site at 6 m level deep below final landform in Pit 3, RP2 or other purpose excavated locations on site (Figure 9-74).

There is one deep underground structure where some equipment will be left *in-situ*. Using the same burial depth of 6 m applied to other demolition material, anything at or below that depth within the Primary Crusher area shall be left *in-situ*. Fill material will be added in and around the equipment within the Primary Crusher shaft up to final landform.

The environmental impact from burial in these locations has been assessed as part of ERA solute transport model. Some hazardous wastes will be returned to suppliers following strict removal guidelines and requirements.

Demolition of infrastructure within a certain area is deemed to be complete when the area is available for rehabilitation activities (bulk material movement and final landform works) and, subsequently, revegetation activities.

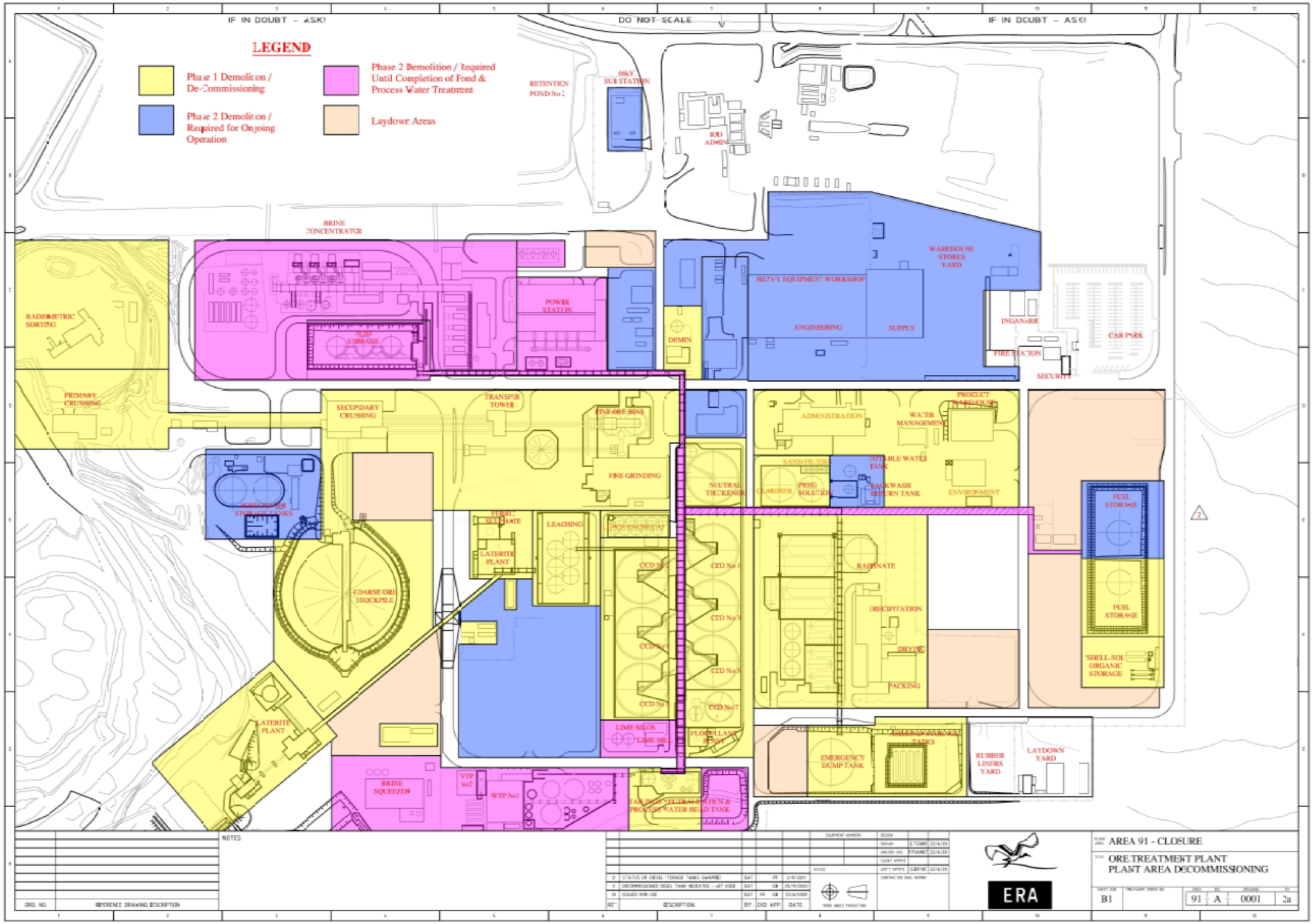


Figure 9-73 Plant demolition sequence

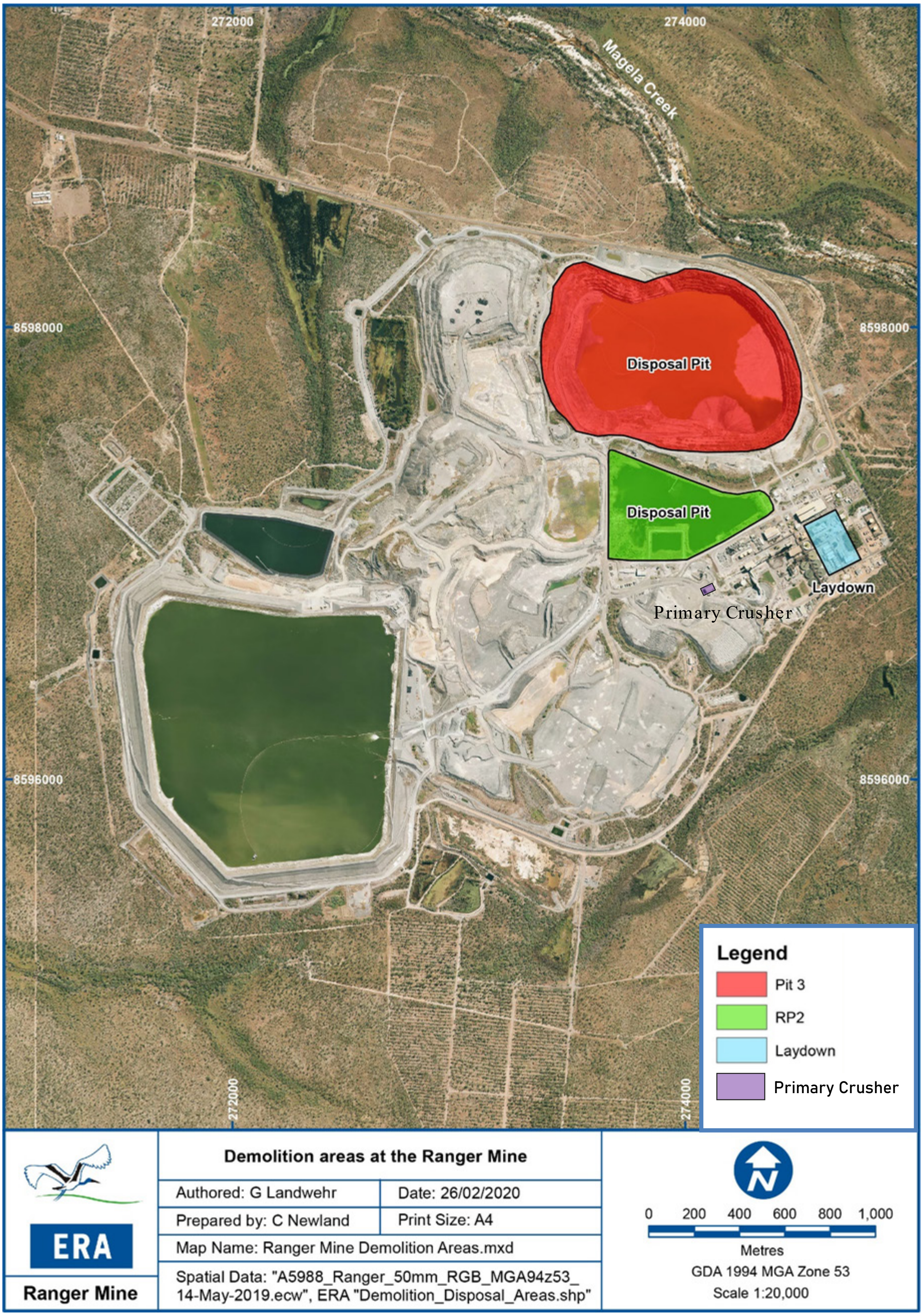


Figure 9-74 Areas for disposal of demolition material

Table 9-17: Demolition phases

Phase	Associated infrastructure
1	Mill, processing plant and tailings transfer infrastructure
2	Process water treatment / transfer, mine and closure activities infrastructure
3	Post-closure management infrastructure

The following demolition methods may be used to demolish the facilities on the RPA:

- manual demolition;
- mechanical demolition;
- cut and pull;
- induced collapse; and
- explosive demolition.

Wherever possible, large-scale demolition activities will be performed using machinery as it is the quickest, safest and cheapest method. Where explosive demolition is required, the demolition contractor will provide a detailed explosives Work Method Statement prior to mobilisation.

The key infrastructure and services for Phase 1 works, including demolition and transportation of the waste (including hazardous materials) to Pit 3, are listed in Table 9-18. The key infrastructure and services for Phase 2 works are listed in Table 9-19.

Asbestos was identified in the processing plant, power station and associated administration buildings through an initial audit of the Ranger Mine by Environmental Health Services in February 2003, and a subsequent audit by SLR Consulting in 2016. The quantities of asbestos across the site are relatively small and are located in clearly defined areas. Asbestos shall be removed by an appropriately qualified contractor and buried in Pit 3.

Detailed material take-offs (a list of materials with quantities and types) have been completed to provide a more accurate estimate for major process buildings. These include the fine crushing building, grinding building, solvent extraction plant, Calciner and product packing, engineering supply workshop and power station. Quantities were approximated based on similar metrics for remaining areas.

Phase 1 demolished materials will be disposed of in Pit 3, whilst it is open and accessible, concurrently with bulk material movement works. Demolished items will be processed at the designated laydown area and transferred to Pit 3.

The following items have been identified as materials that should not be processed but placed in Pit 3 whole due to the expected level of contamination post decommissioning:

- Calciner;
- sand filter in SX building; and
- asbestos drums.

The key assumptions for Phase 1 are:

- all Phase 1 demolition material to be disposed of in Pit 3, with the exception of equipment left in Primary Crusher shaft;
- all Phase 1 demolition hazardous materials (except for contaminated hydrocarbons and items returnable to vendor, such as density gauges, acid and ammonia) to be disposed of in Pit 3;
- disposal activities in Pit 3 will be concurrent with bulk backfill activities; and
- disposed items in Pit 3 to be buried at least 6 m below final landform.

Table 9-18: Phase 1 demolition areas

Area	Infrastructure/service demolished
Radiometric sorting	All infrastructure and services
Primary crushing	All infrastructure and services
Fine crushing	All infrastructure and services
Demin plant	All infrastructure and services
Grinding	All infrastructure and services
Leaching, counter-current decantation (CCD) and clarification	All infrastructure and services
Neutralisation	All infrastructure and services
Solvent extraction	All infrastructure and services
Laterite treatment plant	All infrastructure and services
Product warehouse	All infrastructure and services
Precipitation, drying and packing	All infrastructure and services
Ammonia handling	All infrastructure and services
Pond water	Pond water tanks demolished, pond and fire water system and pumps relocated to R3D
Acid storage	Acid storage tanks A and B, and distribution pumps
Bulk fuel storage	Bulk fuel storage tank B and shellsol tanks
Administration	All

Phase 2 demolished materials will be disposed of in RP2 concurrently with rehabilitation works. Key assumptions for the Phase 2 demolition are:

- Phase 2 materials can be disposed of in RP2 if pond water storage requirements permit;
- ERA mobile fleet, consisting of 18 heavy vehicles (21,000 m^3), and light vehicles will be disposed of in RP2. Forklifts and service trucks will be taken offsite; and
- Items disposed in RP2 are to be buried 6m below final landform.

Table 9-19: Phase 2 demolition areas

Area	Infrastructure/service demolished
Sewage treatment	All infrastructure and services
Bulk fuel storage	All remaining infrastructure and services
R3D	All infrastructure and services
Brine Concentrator	All infrastructure and services
Mine centre	All infrastructure and services
Water treatment plant 3 (WTP3)	All infrastructure and services
Power station	All infrastructure and services
Security, gatehouse and emergency services	All infrastructure and services
Acid storage	All infrastructure and services
Orica yard	All infrastructure and services
Tailings Storage Facility (RWD)	All infrastructure and services
Retention ponds	All infrastructure and services
WTP1 and WTP2	All infrastructure and services
Brockman bore field	Remain post-closure for potable water supply
Plant services	All infrastructure and services
Engineering and supply	All infrastructure and services

Relocation of gatehouse and office spaces

To maximise Phase 1 demolition efficiency, the following is planned:

- the gatehouse and security check-point will be relocated to near the Gagudju yard area on the main Access Road; and
- some of, or all of, the site offices, facilities, amenities and carpark may be relocated or replaced at the previous Ranger Mine Village footprint (adjacent to the Gagudju yard).

Power stations

The mine site has two main power stations:

- Ranger Power Station (RPS), with five 5.1 MW diesel alternators (shared with BCPS); and
- Brine Concentrator Power Station (BCPS), with four 2.1 MW diesel alternators.

As various parts of the mine progress through decommissioning, demolition and closure, the demand for power reduces. With this reduced demand comes an opportunity to reduce the current generation capacity on-site and progressively decommission/demolish the RPS. Planning for this reduction in generation capacity is occurring and several options are being investigated, including the installation of a temporary modular or containerised diesel power generator/s. At some point ERA will decommission the RPS and move to temporary Independent Power Plant (IPP).

9.2.5.4 Contingency planning

If the demolition of specific infrastructure planned to be deposited into Pit 3 is delayed, then RP2 has the capacity to take extra material than currently planned.

9.2.6 Stockpiles

Figure 9-75: Stockpile area (May 2019)

Bulk material movement from the stockpiles (Figure 9-75) is covered in the activities Chapter 9.3.4.

9.2.6.1 Completed rehabilitation

Stage 13.1 (Areas A-C) is a 4 ha section of final landform that became available for revegetation at the beginning of 2020 (Figure 9-76, Figure 9-77). A waste rock stockpile was cut down to the designed final landform surface level and used to backfill Pit 1, leaving an average 3.1 m thickness of waste rock overlying natural ground.

In February 2020 the entire surface of Stage 13.1 was ripped at 3 m intervals to a depth of 50 cm to provide surface roughness and alleviate any compaction. A relatively saturated substrate and an abundance of large rocks brought to the surface resulted in a generally undesirable planting surface with significant bogginess in some places. The ripping outcome was different to the Trial Landform (TLF), likely due to a higher portion of fine material in the waste rock substrate (assessed visually). The majority of the surface was re-graded to flat in November 2020, however a small area (approximately 0.75 ha) was considered suitable for planting, and was used for Area A and some of Area B trials.

Area A (0.6 ha) was planted out in April 2020 with 1,207 tubestock of 22 species and Area B (1 ha) was planted out in October 2020 with 1,012 tubestock of 50 species. Both areas are part of opportunistic, small-scale pilot trials that have informed large-scale Pit 1 activities. These trials are further discussed in *Section 5 KKN Supporting Studies*, KKN ESR3.

Area C (2.4 ha) was planted out in August 2021 with 2,370 stems of 50 different species. This area is progressive revegetation consisting of species typical of a *Eucalyptus tetrodonta / miniata* savanna woodland ecosystem, with a slight increase in the density of contingency species that are well suited to finer substrate and potentially water logging conditions.

Figure 9-76: Monitoring of native seedlings planted on Stage 13

Figure 9-77: Planting areas A, B and C of Stage 13.1

9.2.6.2 Current rehabilitation

Refer to bulk material movement Chapter 9.3.4.

9.2.6.3 Planned rehabilitation

Central services corridor

A services corridor, which accommodates several waste streams pipelines and an access road, is currently located in the stockpile domain to the north of Pit 1. The pipelines supply feed process water to the Brine Concentrator and allow movement of water between Pit 3 and the Ranger Water Dam. The corridor is located primarily on non-mineralized material (termed 1s), but some mineralized material (termed 2s) may be encountered in the stockpiles north of Pit 1 (red shaded zone in Figure 9-78). The mineralized material is to be excavated and placed into Pit 3, requiring a relocation of the services corridor.

Figure 9-78: Existing pipeline corridors (blue lines) and proposed central services corridor (green line)

Another existing pipeline corridor, allowing transfer of process water between the various water treatment plants and the Ranger Water Dam, runs along Corridor Creek Road. Both pipeline corridors are proposed to be replaced by a single central service corridor, to be constructed across surfaces that are already predominantly at final landform level to the west and north west of Pit 1.

New-build parts of the corridor will be designed to provide secondary containment for the process water lines planned to run in the corridor, in a similar manner to the current Corridor Creek pipeline corridor. The surface of the corridor will be compacted to reduce infiltration, and the corridor will be isolated from the surrounding landform by windrows. Sumps at low points along the corridor will direct collected water to the pond water inventory. Water collected in these sumps will be monitored for electrical conductivity to detect process water leaks.

Some bulk earthworks will be required to get the corridor to be as close as final landform as possible. For any surface run segments in the vicinity of the run-of-mine stockpiles, these bulk earthworks will include over-digging and backfill with waste to remove mineralized material from the surface of the corridor. The connection between the central services corridor and Pit 3 will run as per the current Ranger Water Dam to Pit 3 corridor. Existing pipe-in-pipe pipework in this section will continue to be used, rather than constructing a new corridor. The corridor is expected to be available for services in the first half of 2023. Relocation of services to the corridor will be staged to maximise re-use of existing pipework on site. While the intent is to minimise the need for further pipeline relocations, future minor modifications to the pipeline corridor route, particularly through the run-of-mine area, may be required as bulk material movement activities progress.

The corridor will be decommissioned in its entirety once process water storage in the Ranger Water Dam or RP6 is no longer required. Pipeline materials removed from the corridor will be disposed of with the demolition materials arising from removal of the process water treatment plants. Contaminated surface material within the corridor will be scraped and disposed of in RP2.

Landform and erosion controls

Earthworks for final landform construction, including erosion control structures, will be implemented after the bulk material movement from the stockpiles is complete (Chapter 9.3.5).

Revegetation

Revegetation of stockpile areas will be undertaken following standard methods that are outlined in Chapter 9.3.6.

9.2.6.4 Contingency planning

There are no contingencies specific to the stockpile domain as:

- all mineralised material will be moved to Pit 3 through bulk material movement scheduling; and
- contingencies for unsuccessful revegetation or erosion control are covered later in this Chapter.

9.2.7 Water management areas

Figure 9-79: Retention Pond 1 (RP1) and RP1 Wetland Filter (May 2019)

The effective management of water at the Ranger Mine is critical for successful closure implementation and to ensure the surrounding Kakadu NP remains protected. There is an ongoing need to actively manage water throughout the closure phase. At the completion of rehabilitation works, all water management areas will have been rehabilitated. These water management areas include:

- pond water storages (RP2 and RP6);
- release water storages (RP1 (Figure 9-80), GCMBL and Sleepy Cod);
- wetland filters (Corridor Creek wetland filter and RP1 wetland filter);
- various water management sumps; and
- onsite billabongs that have received release discharge water.

Further details of each water management area, the different classes of water at Ranger Mine, and their use during operations is provided in Chapter 9.3.3.

9.2.7.1 Completed rehabilitation

No progressive rehabilitation has been possible to date as all water management areas are in use.

9.2.7.2 Current rehabilitation

There is no current rehabilitation underway as no water management areas are available.

9.2.7.3 Planned rehabilitation

The exact timing and methods for the rehabilitation of the various water management areas depend upon a number of factors, primarily rainfall and the requirements of other closure activities. Currently, within the closure schedule, each water management area is assumed to undergo rehabilitation as late as possible.

Catchment management

As described in detail in the Ranger Water Management plan, surface runoff and seepage from disturbed areas of the site is typically collected and diverted to pond water storages, while runoff from undisturbed areas may be collected and diverted to release storages. To complete closure, ultimately all catchments across the site will need to be able to passively shed water into the surrounding environment, without any collection and diversion infrastructure. The process the enables the decommissioning the collection and diversion infrastructure for a catchment is known as catchment conversion.

The water management infrastructure for the current collection and diversion of surface water from site catchments has developed over time to suit the operational configuration of the site. As closure activities, such as capping of Pit 3 and the construction of the final landform progress, this infrastructure will need to be modified and augmented to suit the changing nature of the site.

The principles that will inform the design of this modified infrastructure include:

- Runoff from active mining areas, for example where stockpiles are being removed, landform is being built up or the haul road network, will be collected and potentially managed for sediment and solute quality.
- Surface water from active mining areas will be collected and directed using infrastructure such as channels, drains, levees, collection sumps, and pumping and piping systems.
- Water collected from freshly completed landform will also be monitored for sediment and solute quality.
- Collected water that is of a quality that can be released off site without further treatment will be directed to releases storages. Water with unacceptable sediment or solute loads will be directed to infrastructure such as active sedimentation basins (where solids settling characteristics enhanced by the use of coagulants and flocculants), passive sedimentation basins, wetland filters or the existing pond water storages.
- Collection infrastructure around a catchment will be removed once active mining is no longer occurring in an area, and runoff is consistently of release quality. Local infrastructure, such as collection sumps and sediment basins, will be recontoured to match the final landform design, and revegetated.

To reduce sediments loads from freshly constructed landform, temporary surface treatments such as scarification, spray polymers, erosion socks, sediment fences and grassing may be applied. These will complement more permanent features, such as rock mulch, leaky weirs, and sporadic rip lines.

The conceptual design of the surface water management infrastructure, the details of the temporary and permanent erosion management treatments and features, and the criteria for runoff to be directed to release will be discussed in the Final Landform Application, and reflected in future updates to the Ranger Water Management Plan.

Pond water storages

Pond water collected on the RPA is transferred to RP2 (the main pond water storage) or RP6. The inventory within the pond water storages is maintained to a minimum level to ensure the supply of pond water for dust control and other onsite service requirements. The total inventory of pond water is balanced between RP2 and RP6 to reduce the likelihood of overflow of RP2 into Pit 3.

Retention Pond 6

To allow earlier deconstruction of the RWD, as the process water inventory nears exhaustion the process water in the RWD may be transferred out of the RWD into RP6. This transfer can be initiated once:

- catchment conversion activities have progressed to the extent that RP6 is no longer required for pond water storage,
- the process water volume in the RWD falls approaches the design storage capacity of RP6 for process water (approximately 800 ML), and
- any existing pond water in RP6 has been transferred to RP2.

When water transfer starts, all infrastructure associated with process water must be relocated from the RWD to RP6. This includes infrastructure associated with:

- WTP brine discharge;
- Brine Squeezer brine discharge;
- Brine Squeezer process water feed;
- BC diluted brine discharge; and
- BC process water feed.

Whilst RP6 is currently a pond water storage, it was originally designed with the ability to store process water, being fitted with two layers of plastic liner and a liner leak detection/recovery system. Ahead of the use of RP6 as a process water storage, the integrity of the liners and associated leak detection/recovery system will be assessed and remediated if required.

If RP6 is used as a process water storage, then it will remain a process water store and catchment until process water treatment exhausts the free process water inventory, and then be decommissioned and demolished.

If RP6 is not used as a process water storage, then it will be decommissioned and demolished once it is no longer required to augment RP2 for pond water storage.

Decommissioning and demolition of RP6 will involve the removal of the liners and their burial in RP2, followed by the re-contouring of the site to form the final landform. Retention Pond 2

Retention Pond 2

RP2 is the hub of the pond water collection and distribution system on site and is expected to be required for pond water storage until late in the closure sequence. It is also an identified site for the disposal of waste generated during phase 2 demolition. Consequently, RP2 is expected to be one of the last areas on site to be decommissioned and rehabilitated.

An environmental assessment, completed in 2018, determined the minimum depth for burial of non-mineral waste beneath the final waste rock landform as 6 m. Following the completion of any waste disposal, the pond will be backfilled to final landform with waste rock.

Release water storages

Release waters are stored within RP1 and GCMBL. As detailed in the land application areas Chapter 9.2.4, these ponds will be required until almost to the end of closure. Once no longer required, these areas will have any infrastructure removed, be re-contoured and revegetated. Refer to Chapter 9.3.1 for details of further assessments to determine if any additional remediation works are required.

Wetland filters

ERA has installed wetland filters at Ranger Mine to passively treat water prior to release. Historically, raw pond water was sent to these wetland filters. More recently, however, the filters provide final polishing of water of better quality.

Wetland filters will be required throughout the majority of closure for ongoing water management. Once no longer required, the areas will be rehabilitated by the removal of any infrastructure, and by re-contouring and revegetation. The use of these areas for passive water treatment over the years may have resulted in some level of contamination. These areas will be assessed to determine the extent of any contamination and if any additional remediation work is required.

Onsite billabongs

There are two billabongs on site that have received release quality water throughout operations. These billabongs, Georgetown and Coonjimba, will continue to receive release water from the final landform during and after closure.

Studies are currently underway to assess the rehabilitation strategy for these billabongs (Appendix 5.4). This information will be provided in future versions of the MCP.

Revegetation

Revegetation will be undertaken in accordance with the Ranger Mine revegetation strategy (Appendix 5.4). A detailed revegetation plan for the water management areas will be provided in future updates of the MCP.

9.2.7.4 Contingency planning

As the final rehabilitation plan for many water management areas is not complete, contingency plans have not yet been developed. If RP2 is later determined to be unsuitable as a waste disposal site, an alternative landfill will be constructed on site following an appropriate approvals process.

Studies assessing the current level of contamination of various water management areas are currently underway and have been detailed in *Section 5 KKN Supporting studies*, Chapter 5.5.2. Once complete, these studies will be used to determine if remediation of any area is required and inform the final closure strategy for each. This closure strategy will be provided in future updates of the MCP.

9.2.8 Linear infrastructure

Linear infrastructure around the site includes the various road, tracks, fences and other minor miscellaneous infrastructure and/or corridors that have been installed during operations. These areas are outside of the final landform footprint. Rehabilitation will include removal of infrastructure and scarifying the natural soil, as required. This has been a successful rehabilitation protocol for areas disturbed during exploration on the RPA and requires neither direct seeding nor planting to achieve acceptable outcomes.

The planned rehabilitation of the ERA groundwater bore network is divided into three stages. Stage 1 was completed in late 2020 and involved the collation of all the information on the ERA groundwater monitoring network into AcQuire, a geoscientific data management software package. This will be used to track the progressive rehabilitation of groundwater bores located across the RPA. Stage 2 will involve the ground-truthing of sites recorded in AcQuire. Stage 3 involves the active decommissioning of redundant infrastructure.

The timing for the rehabilitation of linear infrastructure will be based on the utilisation requirements for closure implementation work. Some linear infrastructure, for example the boundary fence and various access roads, may be required following the completion of rehabilitation work, as part of the ongoing monitoring, maintenance and security of the site. Discussions with Traditional Owners are underway to determine preferred pathways for cultural use in the future.

9.2.8.1 Completed rehabilitation

There has been minimal opportunity for progressive rehabilitation of the linear infrastructure. Two redundant tracks have been rehabilitated, totally an area of 3.65ha.

There have also been six drill pads rehabilitated, representing 0.8ha of previous disturbance.

9.2.8.2 Current rehabilitation

No current rehabilitation underway.

9.2.8.3 Planned rehabilitation

Planned works will be completed once the infrastructure is no longer required.

9.2.8.4 Contingency planning

There are no contingencies required for this domain.

9.2.9 Ranger 3 Deeps exploration decline

Figure 9-80: R3 Deeps portal and offices

The Ranger 3 Deeps (R3D) exploration decline (the decline) is a 2,710 m long exploration decline, constructed between May 2012 and October 2014. The decline allowed for exploration and delineation of the Deeps resource associated with the proposed R3D underground mine, east of Pit 3 (Figure 9-81, Figure 9-82, Figure 9-83).

The proposed R3D underground mine project was not progressed and the decline was placed in care and maintenance in June 2015. Closure planning has considered the major R3D infrastructure including the:

- decline (which is 5.5 m wide by 6.0 m high, and descends at a gradient of 1 in 6 to approximately -430 mRL);
- ventilation shaft (approximately 3 m wide, extending to 280 m below the ground);

- portal (a steel lined tunnel that extends 185 m from the ground surface, through the weathered rock zone to approximately -8 mRL); and
- major infrastructure including pumps, fans, compressors, generators and refuge chambers.

ERA submitted an application to commence rehabilitation and closure of R3D in September 2018 and received approval from both the Commonwealth and Northern Territory Ministers in April 2019. An update to the plan was submitted to stakeholders in January 2021, incorporating changes to water level management and outlining the decommissioning progress that was completed by that time.

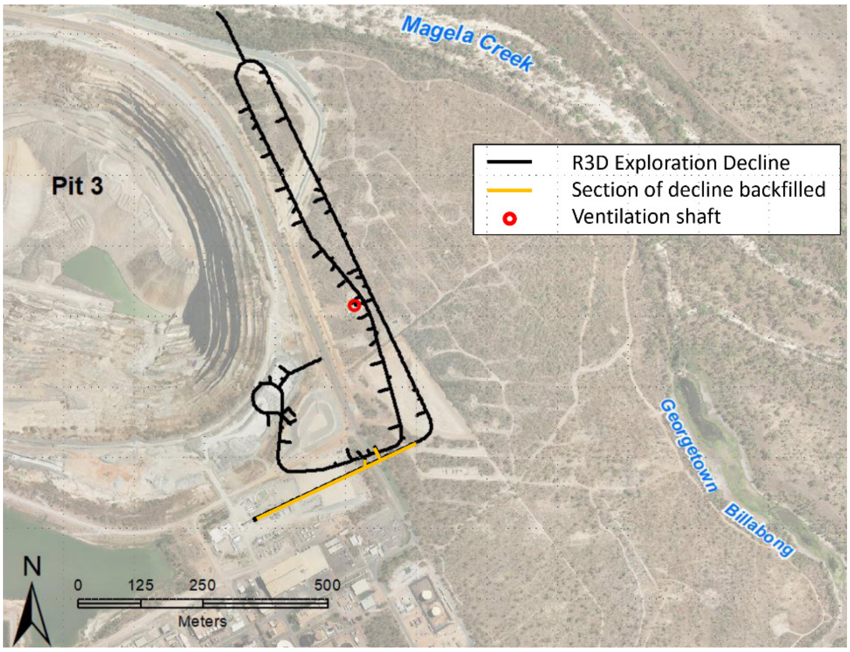


Figure 9-81: Plan view of the decline

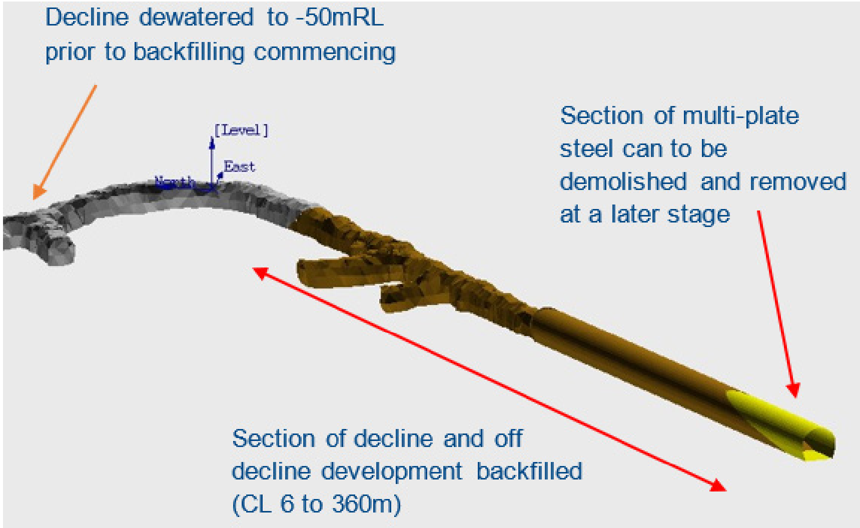


Figure 9-82: Oblique view of R3D decline and main closure elements

Geotechnical considerations

The geological conditions (strength and weathering of schist) varied along the depth of the portal and decline. Considerations for closure of the decline and portal relating to these conditions are described in Table 9-20.

Table 9-20: Geological conditions, decline reinforcement methodology

Depth (m)	Substrate	Methodology
0 - 185	Low strength, weathered schist	Cut and cover tunnel (see below).
185 - 213	Low strength, highly weathered to moderately weathered schist	Category 5 support and consisted of lattice girders, spiling bars and 290 mm thick fibrecrete.
213 - 290	Low, then medium strength; moderately weathered to fresh	Category 3 support. This support comprises 2.4 m galvanised fully encapsulated chemset bolts and 100 mm thick fibrecrete.
290 - 675	Medium strength fresh schist	Category 2 support. This support comprises 2.4 m galvanised fully encapsulated chemset bolts and 50 mm thick fibrecrete.

Due to the poor ground conditions in the vicinity of the portal, the first 185 m of the decline down to a depth of 35 m was developed as a cut and cover tunnel. A 35 m deep box-cut was excavated; then a steel arched tunnel was constructed from the bottom of the box-cut back to ground level (Figure 9-83). The box-cut was progressively backfilled with sized waste rock and box-cut material. When the box-cut was excavated groundwater was intersected 6 m below surface at 17 mRL.

Figure 9-83: Boxcut and portal, completed in December 2012

The schist is foliated and jointed, giving rise to a blocky structure. These blocks were supported by the ground support that was installed at the time of development (pattern bolted with 2.4 m long, galvanised rock bolts at 1.5 m centres, plus 50 mm thickness of plastic fibre reinforced, pneumatically sprayed concrete). The ventilation shaft was developed in low strength to medium strength hanging wall schist. On completion, the shaft walls were sprayed with a layer of shotcrete. The top 21 m has a steel liner.

Hydrological conditions

INTERA conducted an assessment of the expected hydrological conditions at the decline once dewatering pumps are turned off, and the decline and ventilation shaft flooded. INTERA also assessed the requirements for grouting of the four standpipe holes and construction of bulkheads (INTERA 2018).

9.2.9.1 Completed rehabilitation

Works commenced immediately after approval of the closure plan in April 2019. During early 2019, many of the demountable accommodation units at Ranger 3 Deeps were sold and transported off site.

2019 works program

The 2019 works program incorporated the removal of infrastructure, including pumping and electrical equipment, within the vicinity of the base of the ventilation shaft and subsequent backfilling of the vent shaft access. These works were completed between mid-April 2019 and end of June 2019 and included:

- installation of water level monitoring equipment in the vicinity of the base of ventilation shaft and monitor water level;
- removal of existing pumps to allow the decline to flood;
- backfilling of the -263 mRL ventilation shaft access with 700 m^3 of fresh rock;
- removal of refuge chambers;
- removal of the underground 11kVA substation;
- removal and demobilisation of the two twin 90 kW fans;
- installation of a 25 kW submersible pump in the ventilation shaft to maintain the water level below -20 mRL;
- cleaning and radiation clearance of the removed infrastructure;
- blocking of access to the decline through the portal; and
- demobilisation.

The ventilation shaft access at -263 mRL was backfilled with waste rock to form a plug to mitigate the possibility of the backfill material flowing out into the decline. The decline was then allowed to naturally flood to -20 mRL.

Care and maintenance program

Following the 2019 works program the decline was put into reduced care and maintenance until the remainder of the rehabilitation works could be completed. These activities include:

- keeping the decline dewatered to -20 mRL via the submersible pump in the ventilation shaft;
- monitoring the submersible pump on a weekly basis;
- prevention of access to the decline unless under special permit; and
- monitoring of the water level rise in decline by the decline monitor installed near the base of the shaft at -263 mRL and from existing surface monitoring bores.

2021 works program

In May 2021 ERA notified stakeholders of their intent to commence the final closure and backfill component of the R3D exploration decline decommissioning plan. The key components of the program were the closure of the ventilation shaft, and the waste rock backfill of the decline. The Ranger 3 Deeps Radiation Management Plan was revised and updated. This update incorporates information relating to the closure and backfill program, including radiation controls for backfilling works (ERA 2021d).

Sufficient waste rock was moved to the decline stockpile pad, 200 m north of the decline portal, and the decline dewatered to -50 mRL in preparation for the commencement of closure works (ERA 2022). Prior to re-entry the decline was inspected and a ventilation system was installed (Figure 9-84).

Figure 9-84 Photo taken on 3 June, during decline inspection, from the end of the steel multiplate tunnel (ERA 2022)

Backfilling of the decline commenced on 22 June 2021 and was completed on 7 August 2021 (ERA 2022). The original 300 m backfill commitment in the R3D closure plan, was extended to a minimum 350 m backfill, following consultation with stakeholders, as a mitigation against the risk of a decline collapse propagating through the weathered zone to the surface.

Backfilling commenced at a centreline (CL) distance from the portal of 361 m and finished at CL 6 m, completing a 355 m backfill (Figure 9-85). All the backfilling was done with CAT 740 ejector trucks with a total volume 14,525 m3 to be filled (ERA 2022). Backfilling in the decline was completed as tight as practicable. 13,970 m3 of waste rock was placed with a bulk density of 2.077 m3/t (Figure 9-86, Figure 9-87 & ERA 2022).

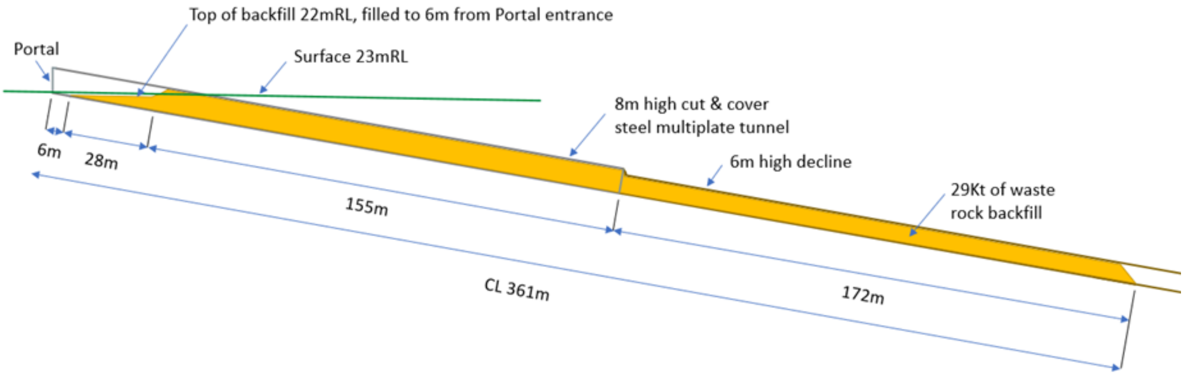


Figure 9-85: Decline long section looking North. Backfilling commenced at a CL distance from the portal of 361 m and finished at CL 6 m (ERA 2022)

Figure 9-86: Picture taken 24 June after approx. 2,600 t of backfill has been placed in the decline (ERA 2022)

Figure 9-87: Picture taken after completion of backfilling to 22 mRL, (CL 06 m) with a total of 29,015 t waste rock placed (ERA 2022)

Closure of the vent shaft included backfilling the 2,065 m^3 void and installing a cement-rockfill (CRF) plug to prevent settlement in the shaft expressing as surface subsidence. The backfilling of the shaft commenced on 2 August 2021 and was completed on 9 August 2021 (ERA 2022). An 11 m length CRF plug was installed in the ventilation shaft from 15 m through to 4 m below the surface. Crushed rock was then placed above the CRF plug to surface.

The R3D closure plan stipulated that the CRF plug would be placed from 10 to 20 m below surface. This was modified, for operational reasons, to 5 to 15 m below surface in the scope of work that was appended to the 2021 notification (ERA 2022). It was moved closer to surface to be out of the ground water and enable observations on mix progress. The as-built location of the plug achieves a satisfactory tie-in to the corrugated steel liner and is considered fit-for-purpose (ERA 2022).

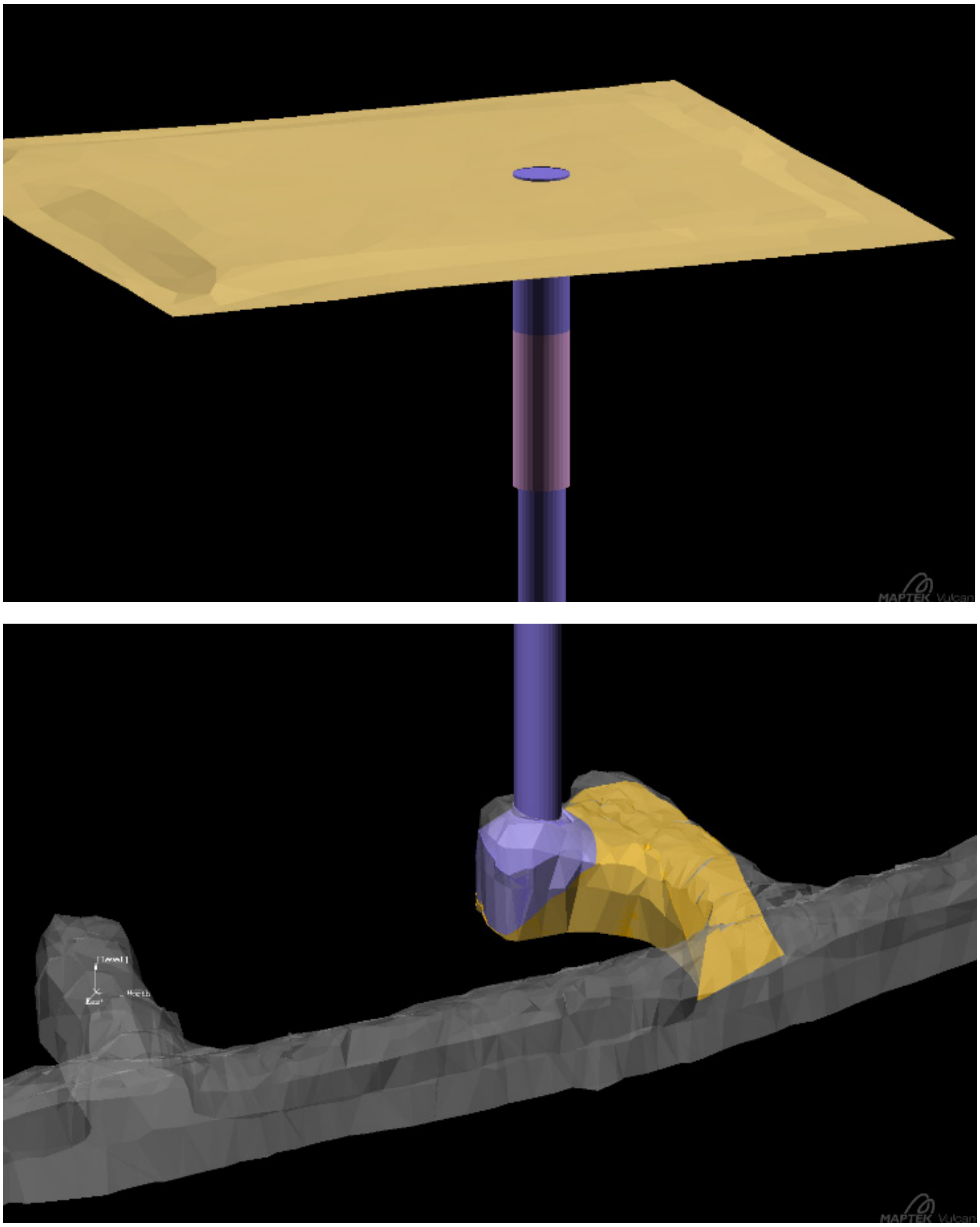


Figure 9-88: Oblique view of shaft and decline (grey), showing previously backfilled vent access in tan; rock backfilled shaft in purple and CRF plug in maroon.

Figure 9-89: Cement slurry being added to the rockfill at ventilation shaft to create the CRF plug (ERA 2022)

Figure 9-90: Top of CRF plug in the vent shaft to 4 m below surface (ERA 2022)

9.2.9.2 Current rehabilitation

There are currently no rehabilitation works occurring at Ranger 3 Deeps.

9.2.9.3 Planned rehabilitation

Remaining portal and ventilation shaft closure activities

The steel multi-plate tunnel will be dismantled/cut down to final ground level. The portal closure works will form part of the broader demolition works as described in Chapter 9.2.5. If this situation changes, a separate demolition plan and risk assessment will be completed prior to commencement.

Signage, fencing and other minor installations associated within controlling access to the vent shaft and portal area will also be removed.

Final landform and revegetation

Contouring to final landform and revegetation of the R3D area will form part of the broader final landform and revegetation schedule. This includes the portal area and the removal of the very course rock at the top of the ventilation shaft.

9.2.9.4 Contingency planning

The closure of the Ranger 3 Deeps decline is well advanced and so no contingency plans are required.

9.2.10 Miscellaneous

9.2.10.1 Gagudju Yard

Figure 9-91: Gagudju Yard

Completed rehabilitation

There has been no rehabilitation of this site Figure 9-91).

Current rehabilitation

There is no current rehabilitation activity at the site.

Planned rehabilitation

As mentioned in Section 9.2.5.3, it is planned that the gatehouse and security checkpoint will be relocated to near the Gagudju yard to maximise the efficiency of the Phase 1 demolition.

Progressively, as infrastructure is no longer required, it will be demolished and placed into Pit 3. Site works and revegetation will be completed as soon as practicable after the infrastructure is removed.

Contingency planning

No contingency planning is required for the rehabilitation of Gagudju Yard, other than remedial revegetation works if required.

9.2.10.2 Ranger Mine Village

Completed rehabilitation

The contactor camp, and nearby old workshop area, had all infrastructure and concrete removed (Figure 9-92). The accommodation and other demountable units were sold, where possible.

Figure 9-92: Ranger Mine Village

A 1.4 ha site was revegetated in February 2020 (Figure 9-93 and Figure 9-94). The natural soil surface was prepared with 20 cm deep rip lines at 1 m spacing using a grader. Approximately 2,000 stems of 44 species were planted, with a combination of overstorey, midstorey and understorey species. Several kilograms of additional understorey seed from 10 species was also sown in between tubestock. The revegetation occurred during a rainy period and no irrigation has been used in the area.

Figure 9-93: Ranger Mine Village area prior to planting (January 2020)

Figure 9-94: Rehabilitation site at Ranger Mine Village (June 2020)

Current rehabilitation

There are no current ongoing rehabilitation activities at the site.

Planned rehabilitation

As mentioned in Chapter 9.2.5.3, it is planned that site offices, facilities, amenities and carpark may be relocated to the site of the previous Ranger Mine Village to maximise the efficiency of the Phase 1 demolition.

Progressively, as infrastructure is no longer required, the remaining infrastructure disturbance at the site will be rehabilitated in a similar manner as described above and when services are disconnected.

Contingency planning

No contingency planning is required for this area. The workshop area may have some minor contaminated soils from old oil spills or similar. If this material is encountered during closure it will be removed and stored for eventual burial in Pit 3.

9.2.10.3 Nursery / core yard

During 2018 and early 2019, ERA converted the old exploration area in Jabiru East into a nursery to support closure operations (Figure 9-95). This work included the removal of exploration infrastructure and general clean-up of the area. In addition, benches to facilitate the propagation of seedlings have been installed along with associated irrigation system and security.

Figure 9-95: Nursery and old core yard at Jabiru East (May 2019)

The nursery will be required to support the revegetation through the Ranger Mine rehabilitation works and, subject to confirmation of continuing access to the RPA by ERA, could also be used into the monitoring and maintenance phase.

Completed rehabilitation

Fencing and security has been installed at the site which would facilitate utilisation following closure.

Current rehabilitation

No rehabilitation is currently underway as the site is actively functioning as a nursery and seed store.

Planned rehabilitation

In addition to the nursery, core is currently stored from the exploration of the Ranger 3 Deeps deposit, MLN1 and other exploration around the RPA. This diamond drill core is an important asset as it constitutes the fundamental data underpinning resource modelling of ERA uranium deposits on the RPA. Options for storing certain core, including transport to Darwin or another secure storage facility are being investigated. Core material that is not stored for future reference will be disposed to Pit 3 or RP2 during the backfill operations.

Progressively, areas of the core yard will be converted into additional nursery space to increase the capacity of the plant nursery.

Contingency planning

Appropriate approvals will be required prior to closer to enable the nursery asset to remain on the RPA. No further contingency planning is required.

9.2.11 Magela Levee

Figure 9-96: Magela levee (May 2019)

Completed rehabilitation

No rehabilitation has been completed as the levee is still utilised for water diversion (Figure 9-96).

Current rehabilitation

No rehabilitation is underway as the levee is still utilised for water diversion.

Planned rehabilitation

The levee will be able to be removed and rehabilitated as part of the Pit 3 final landform earthworks and revegetation. Levee material will be returned to the original borrow pit with any excess material either placed in Pit 3 or used for any site works requiring lateritic material.

Contingency planning

No contingency planning is required for the levee as it will not be removed until it is no longer required.

9.2.11.1 Borrow pits

Completed rehabilitation

No borrow pits have been rehabilitated.

Current rehabilitation

There is no current rehabilitation underway.

Planned rehabilitation

There are currently two borrow pits located on the RPA:

- borrow pit for the construction of a RWD lift located at the proposed site for Retention Pond 5 that was not constructed (Figure 9-97); and
- borrow pit for the construction of the Magela Creek levee (Figure 9-98).

Figure 9-97: Borrow pit for RWD lift

Figure 9-98: Borrow pit for Magela Creek Levee

The site of the old RP5 will be re-contoured as part of the final landform for the corridor creek catchment.

The levee borrow pit will have levee material returned, re-contoured to the natural contours and revegetated.

Contingency planning

If these borrow pits are required over the closure period, rehabilitation will be delayed until no longer required.

9.2.11.2 Landfill sites and bioremediation pad

All wastes generated at Ranger are managed on site. This has been primarily through the use of landfills or disposal in mined-out pits. In addition, ERA have managed any hydrocarbon contaminated soils though the use of bioremediation pads, located to the north west of Pit 1.

The following landfill sites are located at Ranger:

- historic industrial waste landfills to the south of the RWD;
- domestic waste landfills to the north of Pit 1; and
- temporary industrial waste landfill to the west of Pit 3 (Figure 9-99).

Figure 9-99: Temporary waste storage facility on the western edge of Pit 3 (May 2019)

Completed rehabilitation

Contaminated sites sampling of the historic landfills and the bioremediation pads were completed during 2019. Details of this are provided in *Section 5 KKN supporting studies*, Chapter 5.5.2.5. This information has been used to define a source term for inclusion into the whole of site groundwater solute transport model *Section 5 KKN supporting studies*. The results of this model will be used to assess remediation options via a best practical technology assessment. Several of the old domestic landfills to the north of Pit 1 were covered with waste rock during 2020 as part of the final backfill of the pit.

Current rehabilitation

There is currently no rehabilitation of landfills underway.

Planned rehabilitation

The temporary landfill to the west of Pit 3 will have the waste removed and for placement in Pit 3 with the other demolition waste.

Domestic landfills, once they are no longer required, will be covered by the final landform waste rock material.

The plan for rehabilitation of the historic industrial landforms to the south of the RWD, and the bioremediation pads will be finalised once the best technology assessments are completed and detailed included in updates to this MCP.

Contingency planning

No contingency planning is required for this site.

9.2.11.3 Explosives magazine area

Completed rehabilitation

All explosives have been removed from the magazine and it has been de-registered (Figure 9-100).

Figure 9-100: Old magazine site (May 2019)

Current rehabilitation

No current rehabilitation underway.

Planned rehabilitation

Demolition requirements at the old explosives magazine involve the removal of the magazine, concrete slab and associated footings. The surrounding fence will also be removed. The area will then be contoured and revegetated.

Contingency planning

No contingency plan is required for this site.

9.2.11.4 Trial landform

Completed rehabilitation

An 8 ha Trial Landform (TLF) constructed in 2008/2009 located near the north-western corner of the RWD is shown in Figure 9-101.

Figure 9-101: Trial landform (March 2022)

The TLF has allowed testing of landform design and ecosystem establishment strategy, including different types of surface substrates, different depths of mixed materials over the waste rock only layer, different planting methods and different irrigation regimes (Figure 9-102; adapted from Pugh et al 2008).

Three materials were used to construct the TLF; primary and weathered waste rock, and laterite material. Primary material (1P) consists of unweathered host rock, which primarily consists of altered quartz-feldspar schists and to a lesser extent cherts and carbonaceous materials. Weathered material consists of friable rock (usually quartz-feldspar schist) with altered mineral assemblages, but is generally still low in clay content (Figure 9-103). Laterite is a near surface, highly weathered and sometimes reconsolidated material that is generally high in iron and aluminium clays.

The surface substrates investigated on the TLF were: waste rock only; and waste rock blended with 30 percent volume/volume of laterite material (Figure 9-102). To facilitate treatments, the trial landform was divided into several areas. Areas 1A and 1B of the TLF were constructed with waste rock only substrate. Areas 2A and 3A were constructed as a five-metre thick layer of laterite/waste rock mix over a 1P rock base 0 to 2 metres thick. Areas 2B and 3B were constructed as a two-metre thick layer of laterite /waste rock mix over a base of 1P rock 3 to 5 metres thick.

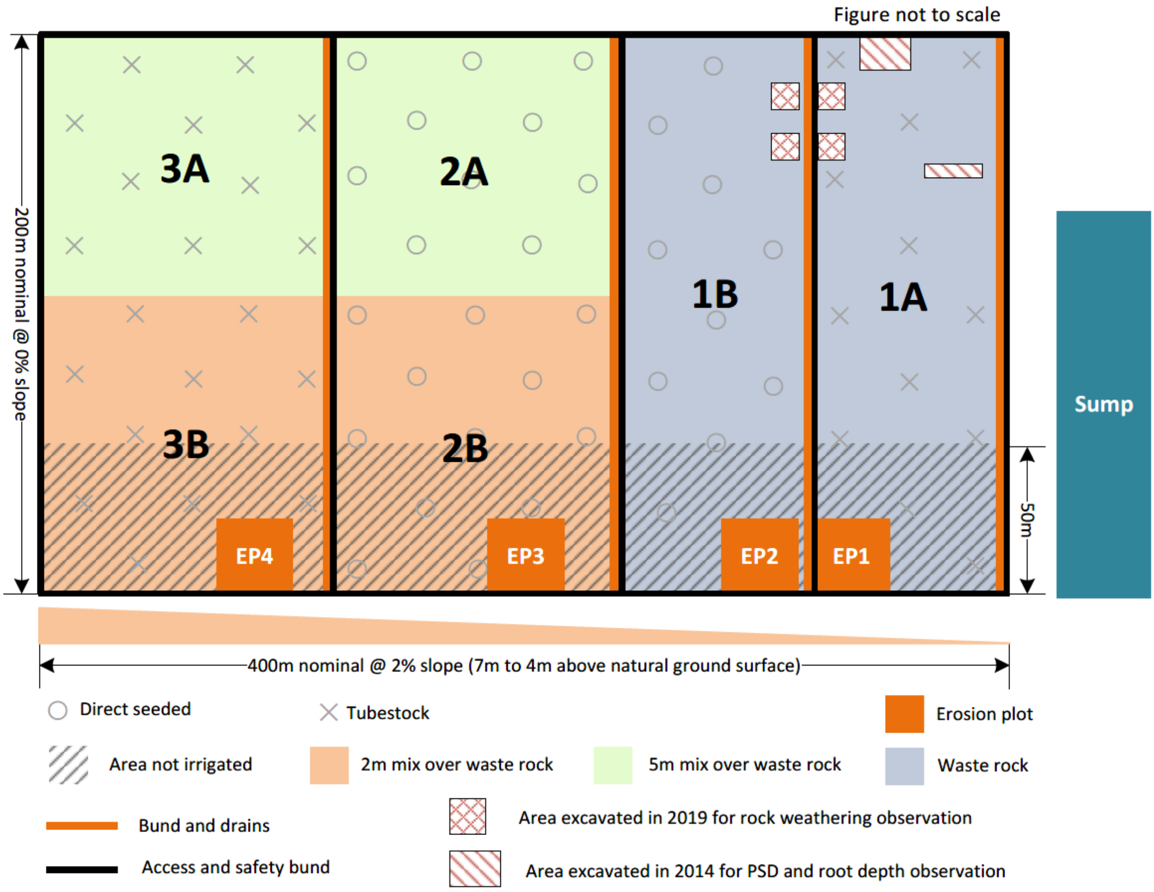


Figure 9-102: Trial landform – treatment design and associated infrastructure

Figure 9-103: Rock types used to construct the trial landform

The Ranger Final Landform (FLF) surface layer will be similar to the waste-rock only section of the TLF (Area 1), in that it will primarily be constructed with 1P and weathered waste rock without purposely mixing in laterite. Area 1 of the TLF was built by first constructing a base layer approximately 2 m thick, by tip-head dumping, and then placing another layer 2 m thick over it, by paddock dumping. As a result of this construction method, a sub-surface consolidated horizon was created by the activity of the dozers and dump trucks on the surface of the TLF base layer, underneath the final paddock dumped layer (Figure 9-104). Construction records show that the surface of the base layer of the TLF (prior to the commencement of paddock dumping) had a high proportion of visible fines compared to underlying material.

Bulk density of the substrate layer of the TLF is estimated at about 2.0 t/m3, with a specific gravity of solids of 2.65 t/m3 (Stephen Pevely, Senior Resource Geologist, ERA, pers. comm. Oct 2017). This equates to a void space of about 25% (void volume/ total volume). In its natural state this void space will be filled partially by air and water.

An extensive monitoring system was installed during the TLF construction to assess the soil water holding capacity, runoff and infiltration of the landform (Shao 2015). Instrumentation installed included 66 soil moisture probes, a weather station, and four erosion plots.

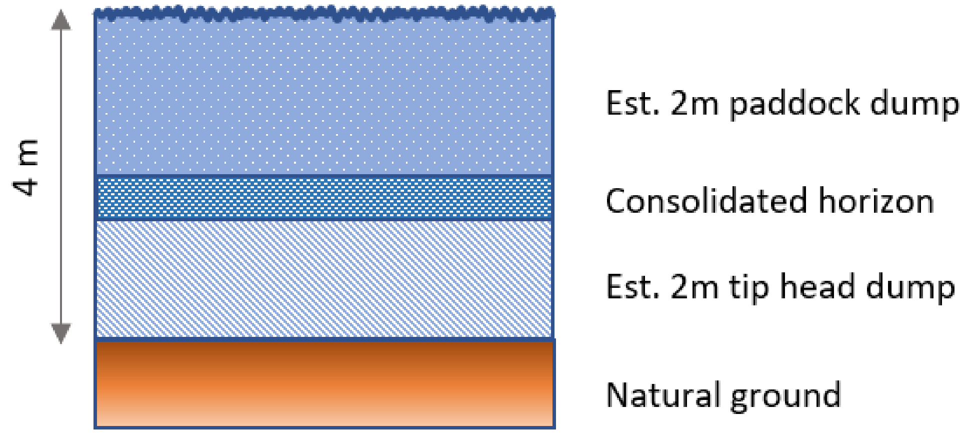


Figure 9-104 Profile of the waste rock only section Area 1 of the TLF

The completed TLF stands four to seven metres above the original natural ground surface, has a 2% slope and was constructed using 800,000 tonnes of waste rock and laterite material. The surface was ripped at 2 metre intervals down to approximately 0.5 m deep. Vegetation establishment commenced in March 2009 with tubestock planting in Areas 1A and 3; direct seeding was performed in Areas 1B and 2 in July and December 2009, and infill planting was performed in January 2010 and 2011. An area 50-metres wide on the front, north-eastern side of the TLF was left unirrigated. The revegetation trial results are discussed in *Section 5 KKN supporting studies*, KKN ESR3.

Current rehabilitation

Ongoing trials are underway on the TLF to further establish understorey and improve the overall biodiversity and weed management.

Planned rehabilitation

The TLF will be integrated into the final landform, requiring the removal of infrastructure and reshaping of edges.

This integration is somewhat unique across the final landform, as the combination of the desire to avoid vegetation disturbance on the TLF proper, the height of the TLF surface, the proximity of the TLF to the perimeter of the disturbed area and typical criteria for final landform slopes, requires the removal of a reasonably significant area of mostly undisturbed vegetation (Figure 9-105). This disturbance of additional vegetation was not viewed favourably by traditional owners, and alternative landform designs are currently being assessed.

The area of backfill required to blend the rectangular shape of the TLF into the natural topography was proposed to be one of the areas for catchment management trials. The use of this area for catchment management trial work may be revisited once questions around final landform shape in the area have been resolved.

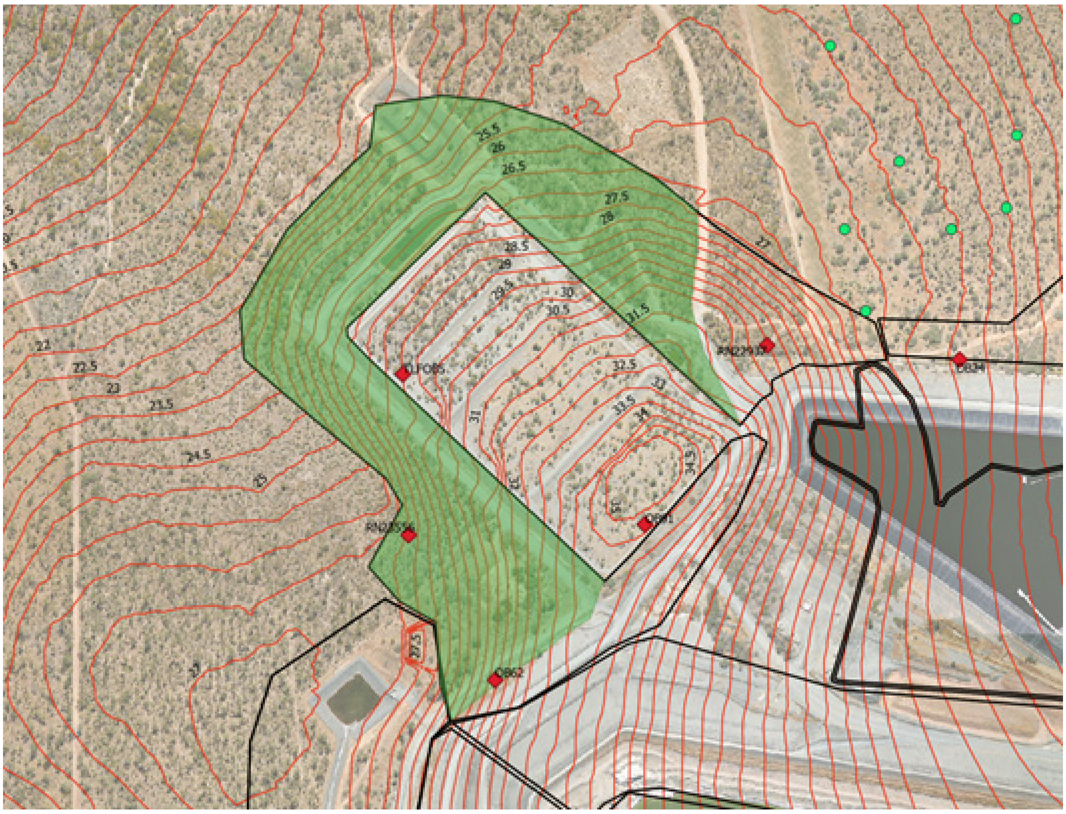


Figure 9-105: Final landform footprint around the TLF Green shading shows the area proposed to be backfilled as part of the catchment management trial.

Contingency planning

Appropriate weed and fire management will be implemented as necessary.

9.2.12 Airport

The airport at Jabiru East and other infrastructure, such as the Environmental Institute for the Supervising Scientist (ERISS) (Figure 9-106) and the Telstra building, are considered to be of high value to the community and, as such, are currently assumed to remain following closure of the Ranger Mine. Under the current arrangements, the Commonwealth is required to rehabilitate and restore the area occupied by ERISS before vacating, including the removal of the buildings.

Figure 9-106: Jabiru airport (May 2019)

Under the current legislative framework, ERA is obliged to rehabilitate the airport precinct. ERA is currently operating the airport largely for the benefit of third parties, including the Commonwealth and NT Governments. ERA is working with the Department of Industry, Science, Energy and Resources (DISER), the Northern Land Council (NLC) and the Gundjeihmi Aboriginal Corporation (GAC) to develop a plan that allows for the airport facility and associated infrastructure to continue to be in operation throughout the rehabilitation period.

Completed rehabilitation

No rehabilitation has been completed to date.

Opportunistic sampling and analysis of soils for metals, hydrocarbons and radionuclides was conducted in August 2020 and November 2021 to understand if contamination exists at Jabiru Airport. Sampling was undertaken using a source-pathway-receptor approach, using the locations of historical and current infrastructure such as storage tanks and wash down bays to better understand and delineate the potential contaminated sites at the airport and nursery areas. Results from the opportunistic investigations will be used to inform whether future works are required.

Current rehabilitation

No rehabilitation is currently occurring on the site as it is still operating as an active airport.

Planned rehabilitation

Planning for removal of the airport, should it be required, is in the initial stages. The access road to the airport will remain to allow access to the ERISS and Telstra buildings. The airport tourist centre contains asbestos. Demolition will include provision for the removal of this asbestos for burial in Pit 3.

Following the completion of the contaminated sites sampling described above, results will be reviewed to determine if any remediation is required.

Contingency planning

Any agreed plan for the continued operation of the airport by an operator other than ERA will include provisions confirming responsibility for the rehabilitation of the airport facility and associated infrastructure, including contaminated site management and remediation.

9.3 Closure activities

Closure activities are those that occur across multiple domains and, although referred to within domains, are discussed in this section.

9.3.1 Contaminated sites

This section provides details of contaminated sites that are not presented within a specific domain. *Section 5 KKN Supporting Studies*, Chapter 5.5.2.5 presents details regarding contaminated sites studies. The following chapter relates to closure activities required as a result of those studies.

The *Contaminated Site Land Register* (current version was last updated in 2021) has been developed and is maintained at the Ranger Mine, in accordance with the operational *Hazardous material and contamination control plan* (Appendix 9.2). The *Contaminated Site Land Register* identifies all sites where activities have occurred that have the potential to contaminate land.

A significant number of targeted contaminated land assessments have been undertaken previously on the RPA at known contaminated sites between 2006 and 2016. Whilst the focus of previous assessments was predominantly identifying groundwater contamination, soil and sediment profiles have also been assessed at known contaminated sites to define the lateral extent of contamination in the soils and sediments at the RPA.

As part of the feasibility study undertaken in 2018, a review of the *Contaminated Site Land Register* was undertaken to provide a register (at that point in time) suitable for closure planning purposes. The review involved ensuring all areas of potential contamination were captured as well as aligning historical investigations undertaken to date, thereby developing a current site contamination knowledge base. Sites were also classified according to risk (costs of remediation).

Following this review, a *Plume and contaminated site management plan* was developed during the feasibility study. The plan describes future work (site assessments and BPT assessments), post remediation validation assessments and post-closure monitoring. This plan was further reviewed for appropriateness in April 2019 to confirm whether broad remediation statements made during the feasibility study were supported by outcomes of previous studies and outcomes of the feasibility study. A gap analysis was also completed. Areas identified during the gap analysis as having insufficient data to adequately determine a remediation treatment option were identified for further investigation including depth and COPC data.

A Contaminated Sites investigation was completed to address these gaps between December 2019 and January 2020. This involved a targeted soil bore drilling campaign and installation of groundwater wells to facilitate future closure monitoring.

Soil sampling included a selection of analytes including hydrocarbons, metals and nutrients in line with the requirements detailed in the National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended 2013) (ASC NEPM, 2013). The data (ERA, 2021a) has been used to inform the whole-of-site contaminant transport modelling and will inform the future rehabilitation and risk management of the site.

Additional opportunistic field sampling has been undertaken throughout 2021 and early 2022 where questions have arisen or gaps identified. Such areas have included the Jabiru Airport, Nursery (previously the exploration yard), Gatehouse, Heavy Vehicle Workshop, and the area around the Pond Water Tank.

Results from the historical work summarised above as well as any recent investigations will be used to inform BPT assessments to determine future actions if required. The outcomes of these assessments and details of any remediation plans will be included in future updates of the MCP.

9.3.1.1 Per- and Poly-fluoroalkyl Substances (PFAS)

As part of environmental investigations carried out in 2019 and 2020, Per- and Poly-fluoroalkyl Substances (PFAS) were found in several areas including the emergency dump tank area, Coonjimba Billabong (CB), pond water streams and most of the groundwater monitoring bores that were sampled. The majority of soil samples possessed low concentrations of PFAS, however concentrations in the majority of water samples exceeded relevant drinking water criteria. Concentrations in the vicinity of the emergency dump tank area presented the highest concentrations by an order of magnitude in comparison with groundwater results from other areas.

The understanding of the magnitude and extent of PFAS in soils, surface water and groundwater has further been assessed to a level where a robust and scientifically defensible risk-based assessment can be completed. A Sampling Analysis and Quality Plan (SAQP) was developed to outline a framework to assess the extents of PFAS impacts and their potential risks to downstream environments and receptors. As well as data collation and desktop review, field investigations were undertaken in accordance with the SAQP including:

- soil investigation and installation of additional groundwater monitoring bores (November 2021);
- concrete pad characterisation samples (April 2022);
- sediment and surface water investigation (February 2021, December 2021 and April 2022); and
- groundwater monitoring (December 2021 and May 2022).

A Detailed Site Investigation (DSI) Report is currently in preparation summarising the contamination magnitude and extent across the RPA. The DSI will also identify potential contamination sources, pathways and receptors (a Conceptual Site Model) with a view to identify potential and significant pollution linkages and related risks to human health and the environment. The Conceptual Site Model will assist in the assessment of risk, and where required, provide rational for the design of remedial solutions for areas of contamination. The Conceptual Site Model is a working hypothesis for the understanding of site contamination and is updated as new information is obtained.

9.3.1.2 Sediment investigation program

A sediment investigation program was conducted between November 2020 and February 2021. The objectives for this monitoring program were to characterise the acid sulfate soils (ASS) contamination potential and fill knowledge gaps in the inventory of sediment metal and radionuclide contamination on the RPA. Sampling was conducted at nine surface water bodies located on and surrounding the Ranger Project Area, these included:

- Mudginberri Billabong (ASS, Metals and Radionuclides);
- Gulungul Billabong (ASS , Metals and Radionuclides);
- RP1 (ASS, Metals and Radionuclides);
- GCT2 (ASS only);
- Georgetown Billabong (ASS, Metals and Radionuclides);
- GCMBL (ASS, Metals and Radionuclides);
- Sleepy Cod (ASS, Metals and Radionuclides);
- Indium (ASS only); and
- DJKRP (ASS only).

Results from this investigation have been used to inform the broader aquatic source-pathway-receptor model and risk assessment approach (Iles and Rissik, 2021). Future work will switch to ongoing monitoring by ERA of sediment contamination to inform and refine future aquatic pathway risk assessments and vulnerability assessments (where applicable), and will be included in the MCP as appropriate.

Additionally, ERA is undertaking supplementary studies to inform the TSF (Ranger Water Dam) deconstruction (which includes the Coonjimba catchment drainage line) and Final Landform applications, and any new data will be assessed using the risk assessment tool (Iles and Rissik, 2021) and updated accordingly in the MCP.

A summary of the complete aquatic sediments and the ASS assessment is provided in *Section 5 KKN Supporting studies*, Chapter 5.5.2.2 and Chapter 5.5.2.5.

9.3.2 Waste and hazardous material management

This section contains the management of waste and hazardous material that is applicable across numerous domains. Further details are provided within the Hazardous Material and Contamination Control Plan (Appendix 9.2).

ERA has identified that the following waste and hazardous material has remained onsite after cessation of ore processing activities up until time of writing:

- tailings;
- BC brine and sludge from the HDS plant;
- mineralised waste rock (2s rock or higher);
- non-mineralised waste rock (1s rock);
- materials to be demolished (steel, concrete, asphalt);
- listed wastes - non-radiation contaminated hydrocarbon, asbestos, rubber, tyres and other hazardous wastes;
- general waste (non-hazardous2) – domestic, HDPE pipe, concrete, fencing;
- heavy mining equipment and other vehicles;
- special items:
- radiation contaminated hydrocarbons
- calciner
- geological core samples.

The total volumes of each waste have been provided in Table 9-21.

Table 9-21: Waste materials for management and/or disposal at closure

Waste Material	Amount
Tailings	
Pit 1 tailings	25.2 Mt
Pit 3 tailings (June 2019)	36.7 Mt
RWD tailings (June 2019)	4.9 Mt
Estimated tailings produced in mill Jun 19 – Dec 20	1.27 Mt
Mineralised waste rock (2s and above)	
Pit 3 underfill (mixed rock of various grades)	32.5 Mt
Pit 3 forecast backfill	28.1 Mt
Pit 1 mineralised waste rock (below water table)	3.8 Mt
Pit 3 mineralised waste rock	6.9 Mt
Beneath RP6	0.7 Mt
1s waste rock	

[2] Current testing of samples indicates no significant radiation or contamination

Waste Material	Amount
Pit 1 (below water table)	1.7 Mt
Pit 1 (above water table)	7.1 Mt
Pit 3 (below water table/above tails)	20.3 Mt
Pit 3 (above water table)	12.6 Mt
Stockpile areas	14.1 Mt
Ranger Water Dam (RWD) (backfill from walls)	13.0 Mt
Site area fills to final landform	9.6 Mt
Brine	
BC Brine to Pit 3 underfill total	1.8 GL
Demolished material	
Demolished structural steel, concrete, asphalt	60,000 m^3 (150 kt)
Non-structural steel	11,000 t
Concrete up to 1.5m below ground	115,000 t
Asphalt	16,000 t (84,000 m^2)
Phase 1 demolition to Pit 3	40 – 50,000 m^3
Phase 2 demolition to RP2	10 – 20,000 m^3
Phase 3 demolition off site following closure	<1,000 m^3
Listed wastes	
Non-radiation contaminated hydrocarbons to offsite disposal	1,500 t
Asbestos to Pit 3	35 t
Rubber and other hazardous wastes	8,000 t
General waste	
General (non-hazardous) wastes	
General rubbish	3,500 t
HDPE	170 t
Fencing	75 t
Heavy Mining Equipment (18 heavy vehicles to RP2)	21,000 m^3
Special Items	
Radiation density gauges to be disposed in suitable location off site	20 – 30 units
Calciner to Pit 3	1 unit
Geological ore samples (mixed uranium content) to Pit 3	1,400 t
Radiation contaminated hydrocarbons to offsite disposal (blackjack, grease and oily rags)	120 t

9.3.3 Water treatment

This section describes the reduction of the water inventory, and separation of pond and process water. The closure of the physical areas, such as RP2 or the water treatment plants, are described previously under each specific domain. The overall management of water on site is detailed within the Ranger Water Management Plan.

The main water inventories relevant to closure are those associated with pond water and process water. Pond water is derived from rainfall that falls on the active mine site catchments and results in runoff that is of a quality that requires active management. Process water is the most impacted water class on site and is derived predominantly from water that has passed through or encountered the uranium extraction circuit, and from rainfall onto designated process water catchments.

To enable the successful closure of the Ranger Mine, both the pond and process water inventory on site must reduce to a zero balance. ERA uses a water balance model to forecast the pond and process water inventories until closure of the RPA. Details of the latest water model are provided in *Section 2 Project overview*, Chapter 2.2.9.9.

Pond water treatment will continue with the existing water treatment plants discharging permeate to available wetland filters and LAAs. The ultimate reject from pond water treatment, after further treatment using the Brine Squeezer, is discharged to the process water inventory.

The flow diagram provided in Figure 9-107 shows the flows on site relevant to process water treatment. Process water treatment for the current model is undertaken through a number of operational processes and infrastructure; namely, the BC, High Density Sludge Plant (HDS) and the Brine Squeezer, details of each treatment method are provided in the subsequent sections. The most recent water model, completed in July 2021, assumes the following for future active process water treatment:

- The BC continues to be the principal route for process water treatment. Distillate production capacity following the completion of the fan upgrade in early 2021 is 2.41 GL/a. BC treatment concludes once all process water sources have ceased. As described in Chapter 9.2.2, the concentrated brine produced by the BC is permanently disposed of by injection into the Pit 3 underfill, although there may be periods where the brine is recycled to the bulk process inventory.
- The HDS plant operates with a feed capacity of 2 ML/d, generating product water of a quality suitable for final treatment by the existing pond water treatment plants.
- When not treating pond water brine, the Brine Squeezer treats process water to produce 1.9 ML/d of release water. This reverse osmosis-based treatment commenced in July 2022.

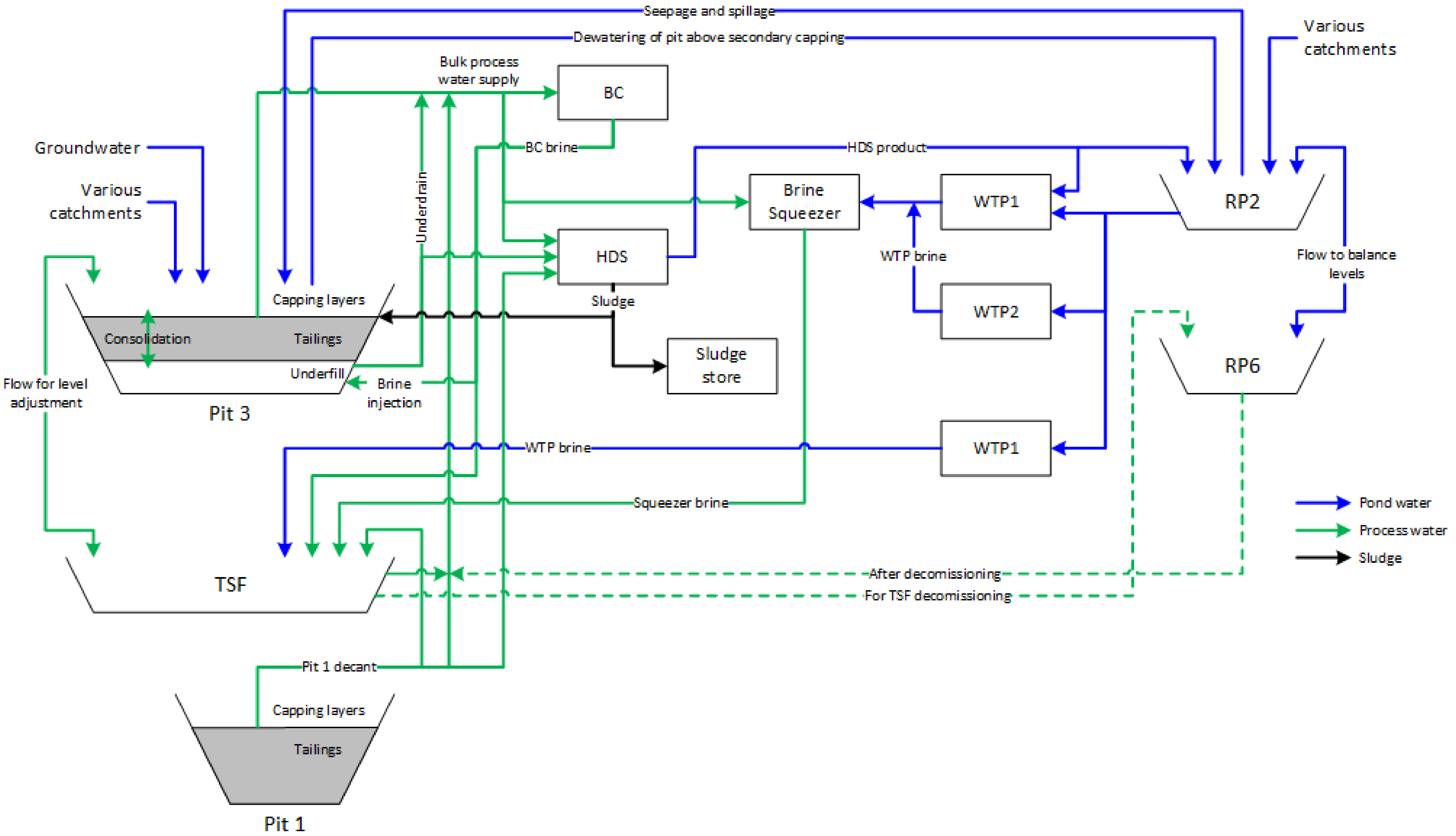


Figure 9-107: Process water flow diagram for the current water model

9.3.3.1 Brine Concentrator

The Brine Concentrator (BC) is a process water treatment plant, constructed in 2012 and commissioned in 2013. The BC consists of three trains: BC1, BC2 and BC3. Each train comprises of a falling film evaporator and a vapour recompression fan. The three trains are arranged so that BC1 and BC2 are fed in parallel, with their combined concentrate, along with additional process water, fed to BC3 (Figure 9-108).

Process water is delivered via overland pipeline to the BC. The plant produces a clean distillate product that is discharged to available release storages, and a concentrated brine, which is either injected into an underfill layer of waste rock deep inside Pit 3 or diluted with process water and returned to the process water inventory. Injection of concentrated brine into the Pit 3 underfill is the primary method to dispose of salt from the process water inventory.

BC capacity is specified via the flow of product distillate. The assumed BC capacity of 7 ML per operating day is based on observed distillate production rates following the completion of a fan upgrade in early 2021. An allowance of twenty days of downtime for planned and unplanned maintenance then gives an annualised rate of distillate production of 2.41 GL/a.

Once the free process water inventory has been drawn down to zero, the supply of process water to the BC is expected to be less than the treatment capacity of the BC.

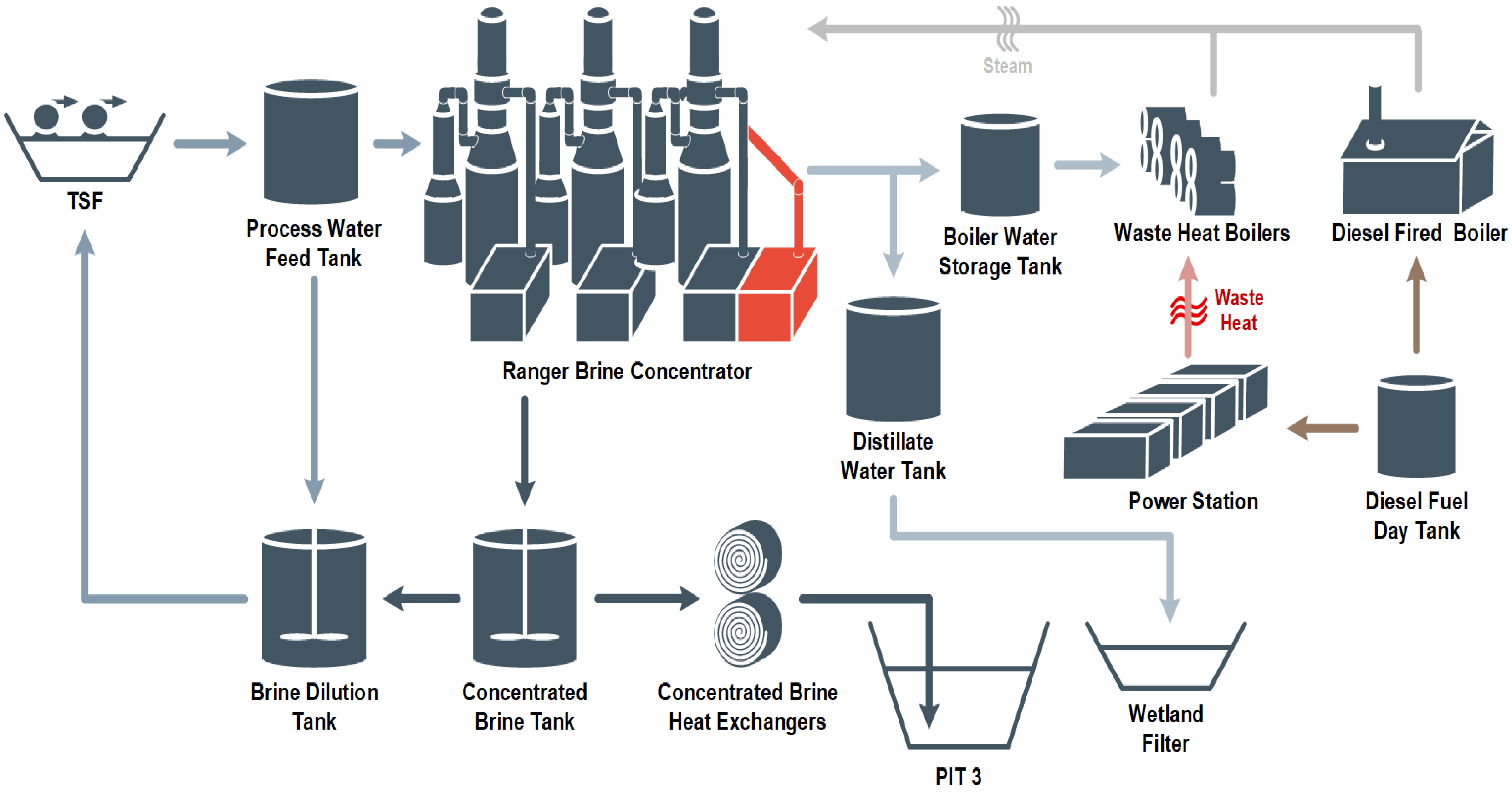


Figure 9-108: Block flow diagram for the Brine Concentrator following BC3 fan upgrade

9.3.3.2 HDS Plant

The HDS plant treats process water, through to a water quality similar to pond water, through two processing stages (Figure 9-109). In the first stage (primary softening), acidic process water is mixed with alkaline milk of lime, resulting in the precipitation of gypsum and the precipitation of most of the metals originally in the process water as metal hydroxides. The precipitates are separated from the solution in a thickener as a sludge, some proportion of which is recycled to act as a seed for precipitate growth, the remainder is sent for disposal. The separated solution, known as primary softened water, is saturated in calcium from the milk of lime and is sent onward for secondary softening.

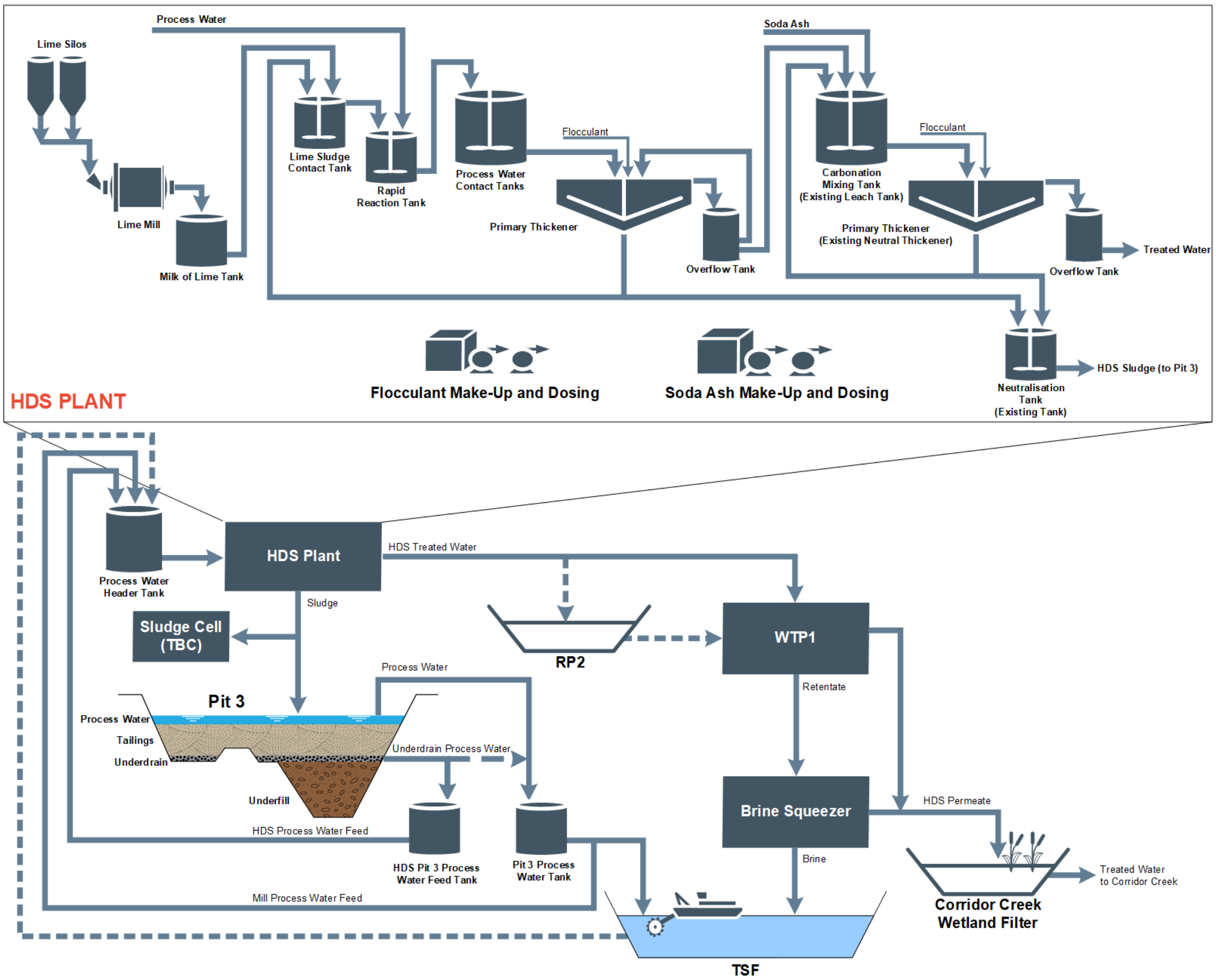


Figure 9-109: HDS Plant Block Flow Diagram

In the second stage (secondary softening), a solution of soda ash (Na_2CO_3) is dosed into the primary softened water, precipitating most of the contained calcium as calcium carbonate ($CaCO_3$). Again, the precipitate is separated from the solution as a sludge, some proportion is recycled as a seed for precipitate growth and the remainder is sent for disposal. The alkalinity of the separated secondary softened water is neutralised by addition of a small quantity of sulfuric acid solution and discharged from the plant to either the pond water inventory (via RP2) or directly to water treatment plant (WTP) 1 depending on water treatment plant requirements and the condition of the pond water inventory. HDS product discharged to the pond water inventory may be then treated by any of the pond water treatment plants.

HDS product water contains ammonium that is originally present in the feed process water to the plant – this ammonium is not removed by the primary and secondary softening stages of HDS treatment. HDS product also contains some sodium that arises from the soda ash dosing in secondary softening. Treatment of HDS product water through the pond water treatment plants removes the vast majority of the ammonium and sodium present in the HDS product. If further ammonia removal is required, options are available such as passage through wetland filters, additional holding time in RP2, or partial recycling through additional polishing stages within the pond water treatment plants.

The HDS plant was built in 2005 and overhauled in 2009. Operations ceased due to operability issues with the HDS plant and the impending installation of the BC. Subsequently, parts from the plant were re-purposed elsewhere on site.

In 2019, the plant was restored to its 2009 condition. ERA subsequently obtained approvals to operate the recommissioned plant with discharge of the product water to the pond water inventory or directly into the feed for pond water treatment plant 1 (WTP1). In recent years the plant has been preferentially treating water from low salt sources such as the Pit 1 decant, with the sludge from the plant being directed through the Pit 3 sub-aqueous tailings disposal infrastructure where it combines with the Pit 3 tailings mass.

It is expected that the ability to dispose of the sludge with Pit 3 tailings will cease shortly after Pit 3 wicking activities commence in the second half of 2022. Continued operation of the plant beyond this time requires an alternative sludge disposal location.

In 2020 an order of magnitude study was conducted into a range of future sludge disposal locations and methods. A preferred option - pumping of sludge to a dedicated disposal repository to the west of RP2 – was selected after a BPT assessment and progressed through further engineering studies, but the option was subsequently set aside due to cost and conflict with other closure activities.

Consequently, HDS operations are expected to cease in late 2022. The plant will be retained in a mothballed state as a contingency against changes in the site process water treatment context. The plant will ultimately be demolished either in conjunction with the Brine Concentrator or WTP1.

9.3.3.3 Brine Squeezer

The Brine Squeezer is a water treatment plant that further extracts clean water from the reject of pond water treatment. The plant consists of two stages of reverse osmosis treatment in series; the permeate from the first stage of high salt tolerance membranes is subsequently passed to a second, polishing stage of reverse osmosis treatment that yields a high quality permeate suitable for direct release. Prior to the installation of the Brine Squeezer, a significant proportion of the reject from pond water treatment was directed to the process water circuit.

The implementation of the Brine Squeezer effectively intercepts and minimises the volume of this process water source.

An application to discharge permeate from the Brine Squeezer was approved by the MTC in the first half of 2019. Permeate from the Brine Squeezer is discharged through the existing pond water treatment permeate system and is subject to the same release conditions and controls. Reject from the Brine Squeezer is sent to the process water circuit.

The process water treatment strategy requires use of the Brine Squeezer to also generate permeate for release from process water. Pilot scale testing of process water treatment by the membranes used in the first stage of the Brine Squeezer was conducted in the second half of 2020. This pilot was successful in the generation of suitable quality first stage permeate under practical membrane maintenance conditions when treating process water drawn from the bulk inventory and water that had been subjected to some degree of pre-treatment by the HDS plant. Contrary to expectations, the squeezer membranes were unable to practically generate permeate when treating lower salt sources such as Pit 1 decant, due to oxidation of iron and manganese species in the water resulting in precipitation of solids and fouling of the reverse osmosis membranes

Informed by the results of the pilot testing, detailed engineering has commenced to allow modifications to the Brine Squeezer for its use in process water treatment. These modifications include the installation of pre-filtration units ahead of the Brine Squeezer proper (these pre-filtration units are similar to those at the front end of the pond water treatment plants), upgrades to the membrane feed pumps, installation of additional membrane cleaning infrastructure and process water feed and reject delivery systems.

The process water treatment strategy assumes that the Brine Squeezer will continue to treat pond water brine, typically during the wet season, in priority to process water treatment. Upgrades to enable process water treatment enable the plant to generate 2 ML/d of process water permeate.

9.3.3.4 Pond water treatment

The three water treatment plants are the primary method of managing pond water on the RPA. Each is a micro-filtration reverse osmosis plant. The water treatment plants treat pond water from RP2 and RP6, and produce a clean water stream (permeate) and a reject stream (pond water treatment brine). Permeate from the pond water treatment plants is directed to the release water catchments of either Corridor Creek or RP1. Currently, reject is typically discharged to the process water inventory, though it may be recycled back into the pond water inventory if pond water quality permits. With the availability of the Brine Squeezer, reject from WTP1 and WTP2 may be diverted to the Brine Squeezer, whilst reject from WTP3 will continue to be handled as before.

The water treatment plants are operated on an as-required basis to manage the accumulation of pond water from rainfall in the wet season, and a relatively small quantity of HDS product. Based on a median rainfall scenario, the total pond water treatment capacity delivers 1,400 kL/a of permeate to release. Treatment capacity across the three plants is approximately

14,100 kL/d, allowing for the discharge of most permeate to Magela Creek during the wet season with the remainder disposed of by irrigation to land during the dry season.

Operation of the pond water treatment plants is triggered based on total pond water inventory. Trigger volumes will be set consistent with the water management plan and water treatment strategy. The pond water treatment plants will continue to treat water until the entirety of the

9.3.3.5 Contingency plans

The final volume of process water that will require treatment prior to the end of process water treatment is directly dependent upon rainfall. The current closure strategy is based on a median forecast (or a 50th percentile – i.e. P50 case) of outcomes given historical variation in rainfall.

In the case where current process water treatment rates are not achieved, or higher than average rainfall is experienced earlier in closure, then the contingency plans for water treatment, in turn, are potentially to:

- purchase a second Brine Squeezer;
- construct and operate additional evaporative plant; and/or
- further extend the duration of process water treatment.

There is potential for rainfall scenarios to exceed the practical amount by which water treatment capacity can be expanded, particularly if a significant rainfall occurring late in the closure phase. Should this occur, extension in duration of process water treatment is the only practical contingency.

It is noted that whilst the cumulative volume of water to be treated will depend on many factors, predominantly rainfall, the inventory of contained salt is much less variable and thus there is a high degree of confidence in the capacity of the Pit 3 underfill void space for brine disposal.

Additional evaporator

The additional evaporator is a small scale standalone evaporative plant. The plant will operate similarly to the existing BC, with a distillate production of 1.8 ML/d. The plant can be located so as to not interfere with other decommissioning and closure activities.

This contingency strategy is not constrained by the closure demolition schedule, can be implemented at any time and can operate as long as necessary. This option will require engineering development, an implementation plan and approval. The plan must include the trigger for proceeding so as to optimise evaporator impact on process water treatment in the closure phase.

9.3.4 Bulk material movement

The bulk material movement (BMM) plan was updated during 2020 and is under regular review. It includes the movement of all waste rock to final destination and the construction of the final landform.

The bulk of the BMM activities will be executed after tailings has been transferred from the RWD to Pit 3 and after Pit 3 is prepared for capping activities. The BMM mining equipment is not able to start backfilling Pit 3 until a geotechnically stable capping layer is installed. The BMM interfaces with the tailings capping methodology described in Chapter 0.

The BMM works cover the specific disturbed footprint area of 795 ha. A dynamic mine model, including haulage simulations, has been created to assist in producing the closure strategy. This model determined a complex sequence of material movements to ensure all mineralised material ended up in Pit 3 below the vadose zone. Using predominantly excavators and trucks, a total of approximately 96 Mt of material will be moved.

Mining of stockpiles and final landform creation has already commenced with the backfilling of Pit 1 and stockpiling of material for crushing and screening for Pit 3. The final landform construction will be an ongoing process to enable areas to be released progressively for revegetation.

The BMM plan excavates areas above the final landform (stockpiles and RWD). However, mineralised material will be mined below the final landform in many of the stockpiles to be placed into Pit 3. A minor amount of mineralised material in the RP6 area will be excavated very late in the closure project and will be buried in the low part of RP2 because Pit 3 backfilling will have reached the point where no more mineralised material can be placed into Pit 3. The plan for excavation and placement areas are shown in Figure 9-110 and Figure 9-111 respectively.

Manual and dynamic mine modelling was performed as an iterative process where output was reviewed, and assumptions and constraints modified as required. Material was only scheduled to be mined, where necessary, as a proportion of material in stockpiles remains in place due to not having mineralised material and being already below final landforms level. The location and alignment of haul roads was optimised and determined by the dynamic mine model.

The feasibility study investigated individual stockpiles, the material make-up (presence of 2s and high 1s material) and the volumes within each mining excavation area for each of the material groups. The ability to bury mineralised material in Pit 3 below the 2s material cap (defined by forecasted permanent water table) generally requires material in the southern stockpiles to be prioritised for initial bulk movements. The non-mineralised material in the central and northern stockpiles, will be moved later to form final landforms.

Stockpiles have variable content of uranium oxide (U_30_8) present. Grade class 1s material is categorised as non-mineralised rock, whereas grade class 2 materials are categorised as mineralised material.

In 2008 an extensive drilling program was conducted to allow a stockpile block model to be developed, and tonnages and grades to be further evaluated. This block model has been maintained via GPS locations of sources and destinations of materials since that time. The block model was used as the base information for the closure mine plan. The material grades distribution across the main stockpile areas are shown in Figure 9-112. The majority of mineralised material is in the southern stockpile areas. The majority of non-mineralised material is in the central and northern stockpiles as well as within the RWD walls. Non-mineralised material is present in the southern stockpiles as well, as confirmed in the block model.

All mineralised material will be placed in Pit 3 as described above and non mineralised rock is scheduled to be used for the final landform. Due to overall cut and fill being balanced, mining of 2s material is prioritised so that it can be placed below this non mineralised rock.

During active mining operations, extracted material was transported by truck to pass beneath a radiometric discriminator, which uses scintillometer heads to measure the gamma particle emissions of each load and categorise the material. Material was allocated to tipping locations based on grade classification. A discrimination plan has been developed for stockpiles to ensure the correct final emplacement of material. More discrimination is planned on the southern stockpiles than the northern stockpiles, due to more mineralised material being present. The discrimination plan has a reduced level of discrimination compared to that which occurs for milling, as it is unnecessary to determine whether material should be milled or re-stockpiled.

All the material used in the construction of the RWD walls was confirmed as un-mineralised during construction; therefore, can be used for final landform shaping and does not require to be buried in RP2 or below the Pit 3 2s material cap.

Details of the material movements plan by mining source and placement location are shown in Figure 9-110 to Figure 9-111. Details of the tonnes are provided in Table 9-22.

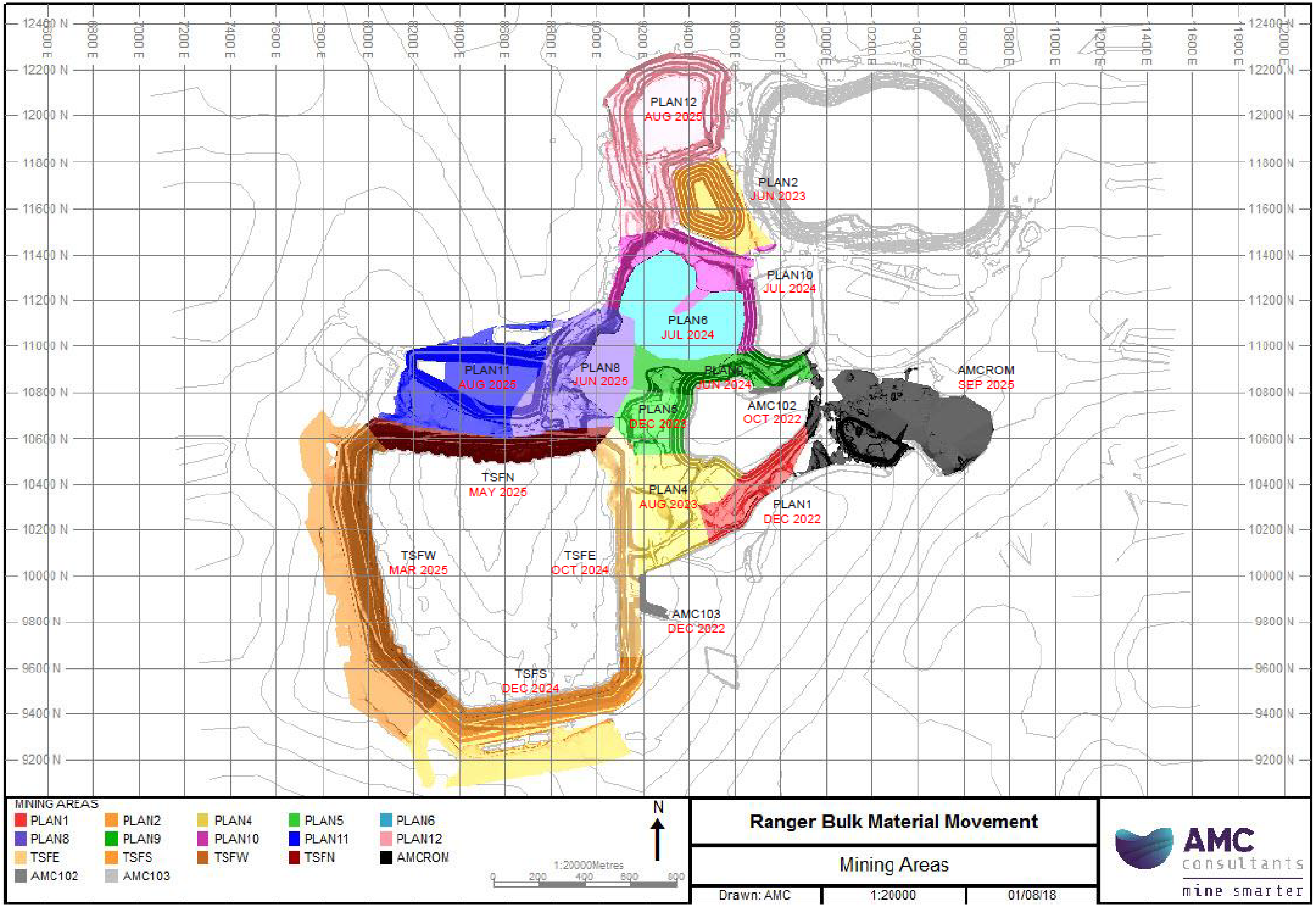


Figure 9-110: Material movement excavation areas

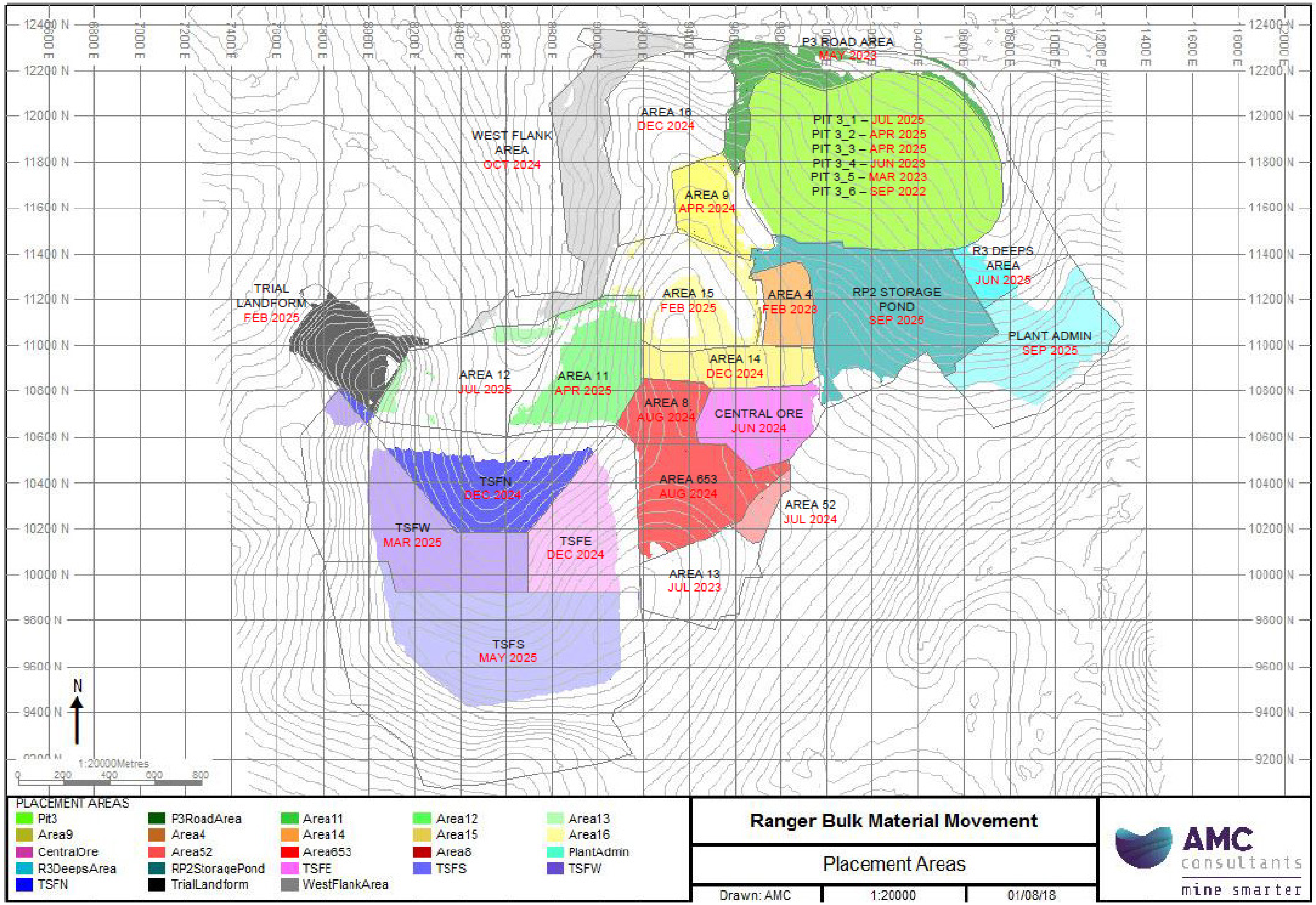


Figure 9-111: Material movement placement areas

Table 9-22: Bulk material movements

Excavation Area	Material movement quantity (t)	Pit 3	Other / Final Landform	TSF	RP2
Plan 1	1,368,486	1,210,465	158,022	0	0
Plan 2	6,305,221	4,676,466	1,628,755	0	0
Plan 4	7,905,547	5,867,893	2,037,653	0	0
Plan 5	7,172,219	6,378,274	793,945	0	0
Plan 6	12,683,261	12,036,622	646,639	0	0
Plan 8	8,617,015	7,556,059	1,060,956	0	0
Plan 9	6,296,065	4,196,980	2,099,085	0	0
Plan 10	2,591,330	2,280,646	310,684	0	0
Plan 11	3,295,667	0	81,040	0	3,214,627
Plan 12	15,525,962	13,443,634	1,130,661	0	951,667
TSFE	2,429,966	0	954,429	1,475,537	0
TSFS	3,484,063	0	1,175,859	2,308,203	0
TSFW	4,958,672	0	244,688	4,713,984	0
TSFN	5,488,161	0	1,230,670	4,257,491	0
AMCROM	2,344,560	0	533,461	0	1,811,099
AMC102	0	0	0	0	0
AMC103	339,715	43,147	296,568	0	0
TOTAL	**90,805,909**	**57,690,186**	**14,383,114**	**12,755,215**	**5,977,394**

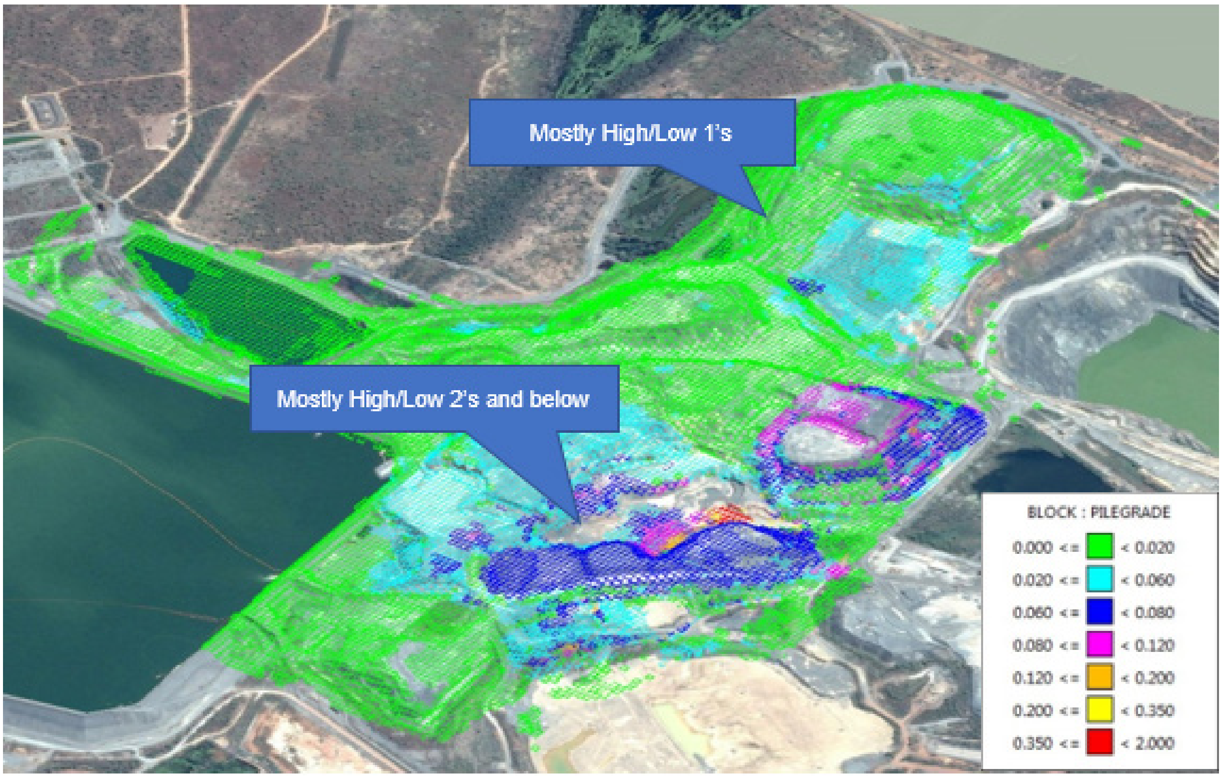


Figure 9-112: Stockpile material grades variance

9.3.5 Final landform / surface preparation

The Final Landform total area will be 795 ha, with the boundary shown in Figure 9-113.

During the closure feasibility study, the final landform topography was updated to create Digital Elevation Model (DEM) Version FLV6.2 which included progression of the following aspects:

- material balance for closure works defining the total material available;
- flood modelling for erosion;
- location of drain flow paths to prevent channels forming over pits;
- overall landform slope gradient to minimise sediment transport;
- slope contour ripping to minimise sediment transportation and improve water ingress;
- in-stream environmental rock bars to slow sediment transportation;
- in-stream sediment control structures to prevent as far as practical the loss of sediment from the disturbed area; and
- learnings from land evolution modelling conducted by the SSB.

The final landform design continues to mirror the original topography as much as possible. The proposed Final Landform topography (FLv 6.2) is shown in Figure 9-114 and Figure 9-115. In February 2022, the landform design optimisation was progressed to incorporate stakeholder comments and lessons learnt from Pit 1 final landform construction, as well as progressive erosion and sediment control management. The landform evolution model, CAESAR-Lisflood, was used to evaluate the effectiveness of each iterative new element introduced to the landform design version (*Section 5, KKN Supporting Studies*, Chapter 5.1.1.1). Final Landform Version 7 (FLv 7) will additionally incorporate into the design landform constructability, short-term and long-term sediment and erosion control if practical.

Figure 9-113: Final landform boundary

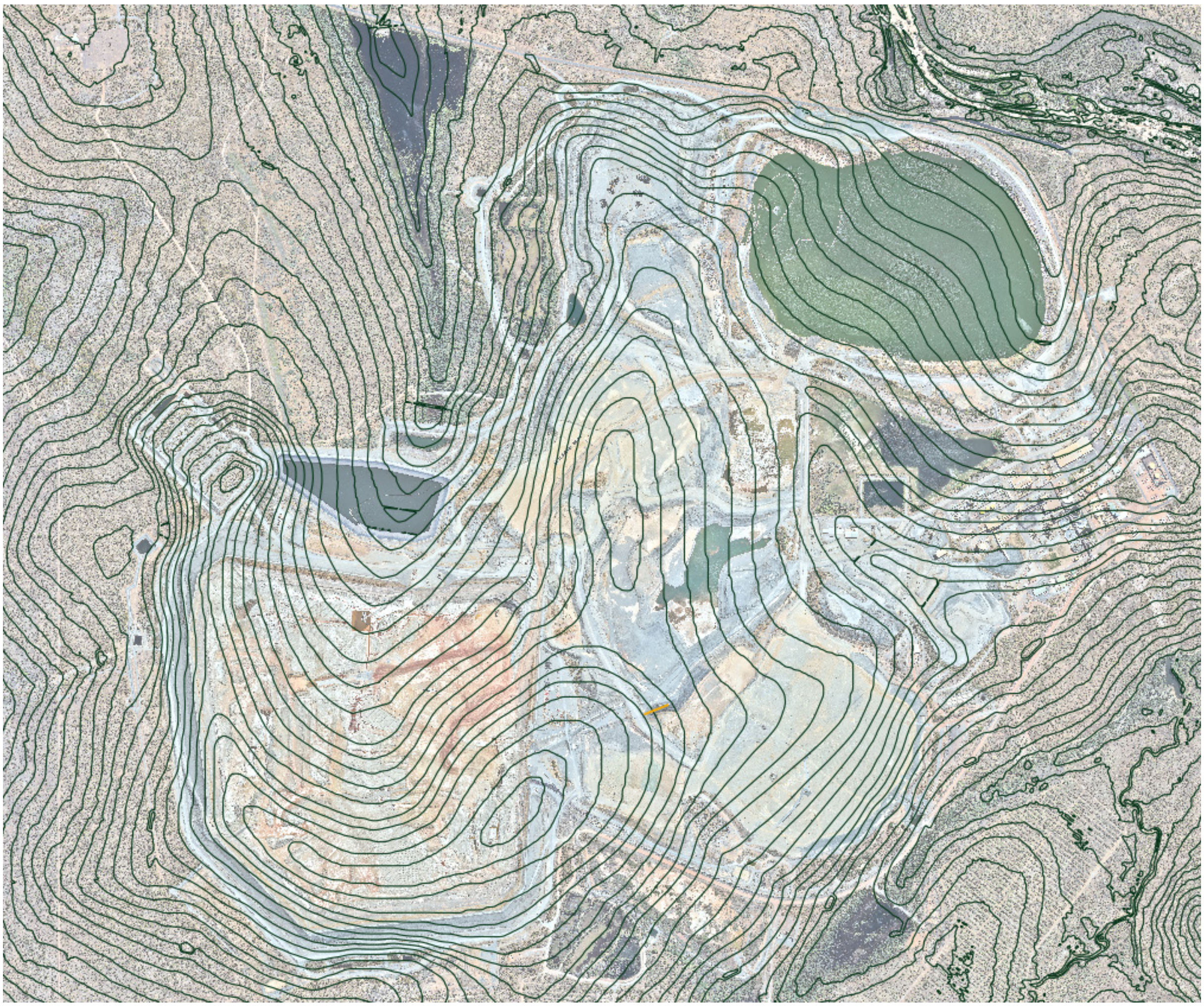


Figure 9-114: Final landform topography contours (FLv 6.2) overlain on the most recent aerial photo

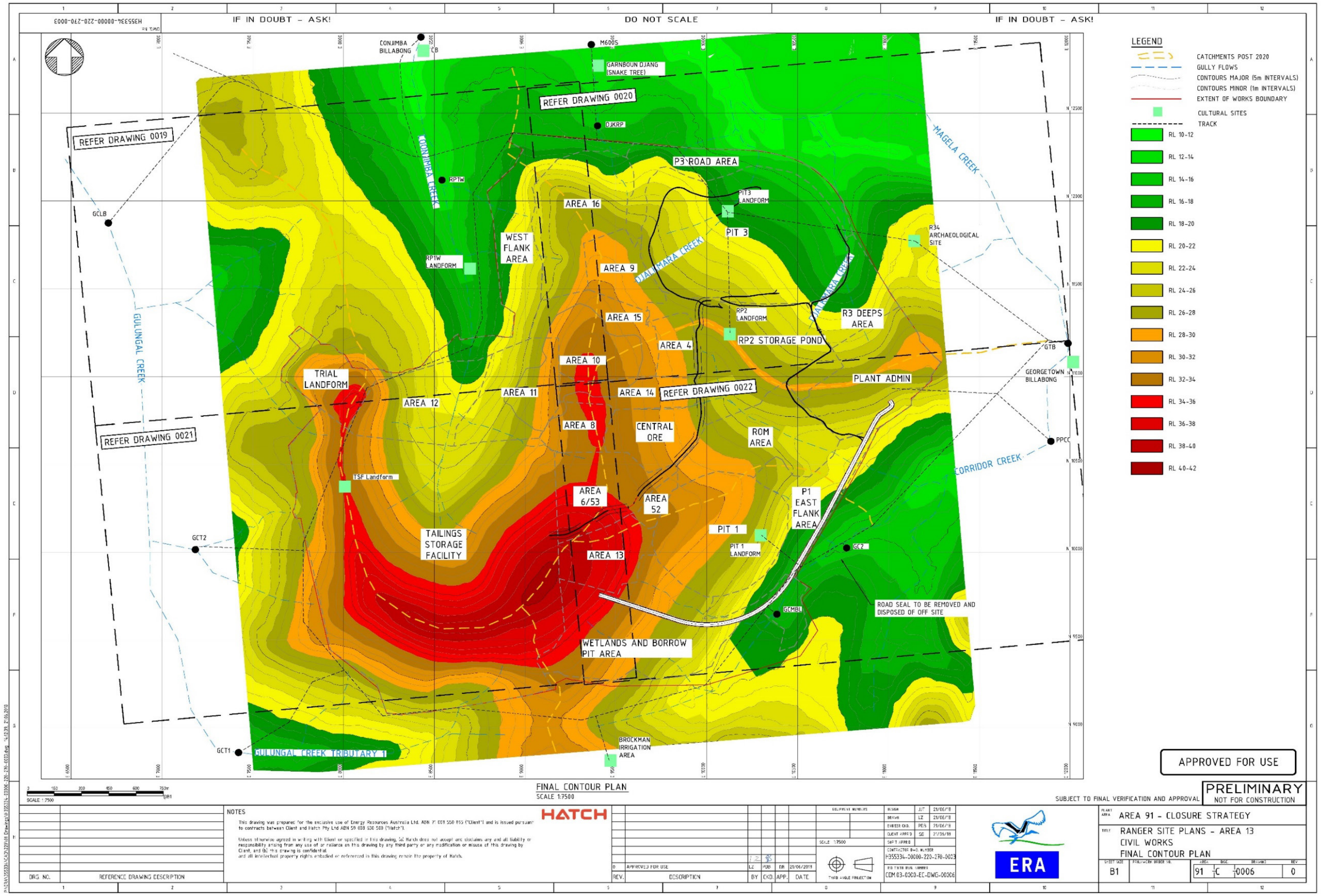


Figure 9-115 Final landform contours

9.3.5.1 Source of waste rock for surface layer

The surface layer of the final landform will be constructed from non-mineralised 1s waste rock to ensure that radiation doses are as low as reasonably achievable (ALARA). The results of an extensive drilling program in 2008 resulted in the development of a block model of the stockpiles and identified non-mineralised 1s material in several stockpile locations (Chapter 9.3.4). The block model has been used to identify potential sources of 1s waste rock for construction of the final landform. Commonly used mine planning systems inform the schedule of the material required for construction of the surface layer. The source and destination of waste rock material for final landform construction will be driven by waste rock type and timing of landform construction.

ERA will include in its routine operational records information on the general source and destination locations of surface layer material. Other activities during construction of the final landform will include surveying and mapping of the excavation and fill surfaces as part of mine rehabilitation. Checks of the Tritronics database and reconciliation against the predicted model grades will be completed as landform construction progresses. Any major portions of above grade fill materials detected will be excavated and redirected to the correct location.

9.3.5.2 Surface layer construction

To achieve the revegetation objectives, design and construction of the surface layer requires consideration of plant available water, depth and heterogeneity of the waste rock surface layer, material chemical characteristics, and surface treatments to optimise nutrient cycling.

There is a range of vegetation community types in areas outside the mine footprint that represent the spectrum of environments likely to be found across the rehabilitated Ranger Mine final landform and RPA. By understanding the environmental features that are associated with the normal range of native vegetation community types, the conditions required to support these communities and/or the community types that best suit particular environmental conditions of the Ranger Mine final landform can be identified (Humphrey *et al*. 2009). This information informs the final landform design and construction techniques, including the maximisation of the potential plant available water (PAW) stored in the final landform cover (*Section 5 KKN Supporting Studies*, KKN ESR7).

The design and construction methodology for the final landform has been based on the studies outlined in *Section 5 KKN Supporting Studies*. The methodology is based on outcomes of additional WAVES modelling and sensitivity analysis on PSD (particle size distribution) and surface layer thickness, as well as review of literature on the effects of dumping and construction methods on particle size distribution, consolidation of placed materials, and macropores and preferential flow.

The final landform surface layer over mined out pits is planned to be between 4 m and 6 m thick (depending on location) in order to provide sufficient PAW to sustain vegetation. As a conservative approach, a layer of at least 6 m will be provided wherever possible. The surface layer will be constructed in at least two lifts, similar to the TLF. Constructing the layer in two lifts will result in a consolidated layer between lifts, as observed in the TLF, which will be beneficial in cutting off preferential flow paths, thus improving steady water percolation and improving water-holding capacity.

The first layer will be constructed using end-tipping methods. This method results in heavy equipment traffic over the layer and the development of a consolidated layer. The second (and final) layer will be constructed using paddock dumping methods and dozed using GPS-guided dozers to create the final landform.

The final landform will be constructed to achieve the approved final landform model. The current Digital Elevation Model (DEM) is Version FLV6.2. ERA is currently undertaking landform evolution modelling to enable the final landform DEM to be optimised and achieve the closure criteria (refer *Section 5 KKN Supporting Studies*). Once completed the updated model will be provided to MTC stakeholders for review and approval.

Frequent surveying and GPS guidance will enable the approved design landform topography to be followed with a high degree of accuracy. Non-compliances will be discovered by survey during backfilling and can be rectified as operations continue or if any consolidation or compaction requires in-filling after construction. Tolerances on the final construction compared to design are driven by the size of equipment and rock material being handled, these are likely to be in the order of +/- 0.5 m at drainage boundaries and +/- 1 m elsewhere.

9.3.5.3 Erosion and sediment controls

In 2017 Water Solutions Pty Ltd undertook the *ERA Ranger Mine Final Landform Preliminary Flood Modelling and Hydraulic Design* associated with flooding, sediment and erosion control for the proposed Ranger Mine final landform profile. This was further developed as part of the Ranger Closure Feasibility study with drainage channel and sediment basin designs and locations finalised (Figure 9-122). The key changes to the final landform design (FLv 6.2) surface are:

- diversion of flow paths further from the Pit 1 region a previously raised concern;
- modelling which included sediment control structures demonstrated a reduction in velocities upstream; and
- comparison between ten per cent and one per cent annual exceedance probability (AEP) events to the (probable maximum precipitation) PMP highlight the low velocities expected through the main channels. Stream velocity rarely exceeds the recommended limit of 1.5 m/s for events up to the one per cent AEP event. Velocities would only approach the 2 m/s to 2.5 m/s in the unlikely event PMP occurs.

The changes to the final landform design surface were incorporated into the DEM Version FLv6.2. The changes included the diversion of all major drainages away from the pits and areas identified in the modelling predictions on the landform version FLV5_02 (Supervising Scientist, 2016).

Management of water and sediment are key issues during the construction phase of the final landform. ERA plans to construct temporary drainage structures and sumps with appropriate pumping infrastructure. These will be installed as required with details provided in the Ranger

Water Management Plan. Temporary structures will remain in place until the installation of the permanent erosion control measures.

Surface treatment

A variety of surface treatments have been identified by ERA to limit erosion and sediment discharge on the general surface of the landform. If erosion can be limited, then the amount of sediment that travels downstream can be reduced significantly. The treatments applied to the various areas of the final landform will depend upon various factors, including slope and location.

The two main surface treatments are revegetation and ripping/scarification. Revegetation is critical to reducing erosion from the site as plant roots bind the soil together, the canopy intercepts direct rainfall on the soil surface, and the leaf matter and woody debris falling from vegetation will, in the longer term, help to protect the surface.

The current areas of the final landform identified as requiring ripping or scarification are shown in Figure 9-116. These were the locations of higher flow identified in flood modelling undertaken during the Ranger Closure Feasibility Study. In addition to erosion controls, some shallow ripping and/or scarification of the landform surface is required to allow water to infiltrate and capture other resources locally for plants use and soil development, such as fine sediments, seeds, litter/organic matter and nutrients. However, advice received through stakeholder consultation with the Northern Land Council (NLC) and the Gundjeihmi Aboriginal Corporation (GAC) have indicated that ripping of the landform may impact traversability, and should be minimised wherever possible. To address these stakeholder concerns ERA conducted a small ripping trial on the Pit 1 landform (Figure 9-117). This, in conjunction with previous ripping and scarification completed at Ranger (Figure 9-118 and Figure 9-119) will be used to inform the final ripping and/or scarification plan included in the final landform application and future MCP updates.

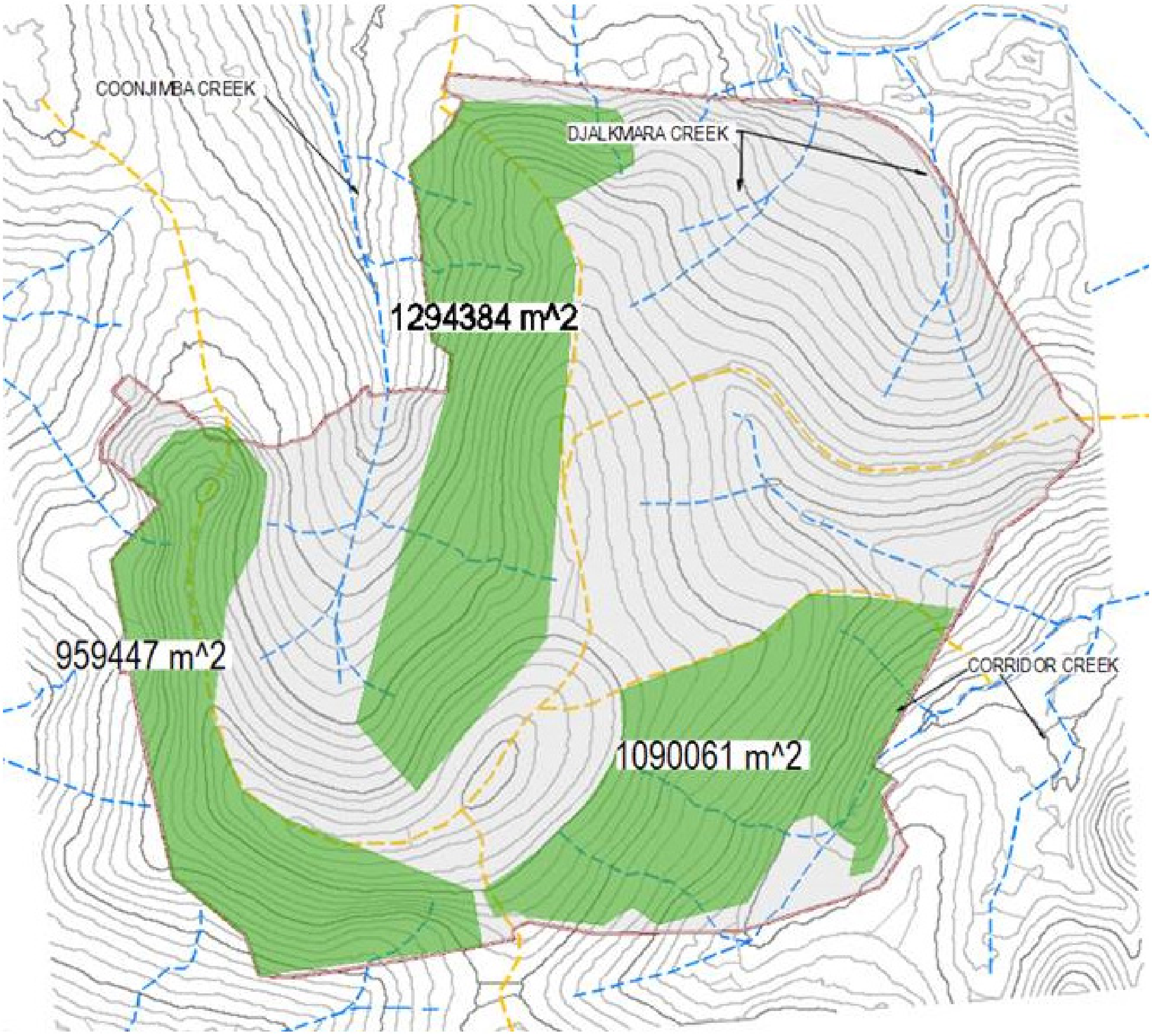


Figure 9-116: Footprint of final landform requiring contour ripping

7 tyne grader scarification

2 tyne grader scarification

Modified grader scarification blade

Figure 9-117 Small scarification trial on Pit 1 (2020)

Figure 9-118: Contour ripping on trial landform trial of 2m interval (2010)

Figure 9-119: Contour ripping on Stage 13, with 3 m intervals (March 2020)

Environmental rock bars

Where the streambeds exceed the maximum desired slope of two per cent or flood modelling has indicated that stream velocity exceeds 1.5 m/s, environmental rock bars will be installed to mitigate streambed erosion. The alignment of environmental rock bars ensures both edges are tied into the crest height level for proper functionality.

The following catchments will have environmental rock bars:

- Coonjimba Creek (CJ) (four rock bars);
- Djalkmarra Creek (DJ) (three rock bars); and
- Corridor Creek (CR) (two rock bars).

Additionally, environmental rock bars will be placed upstream as one of the main sediment control structures in the major flow paths near key areas such as Pit 1, Pit 3 and the RWD. Figure 9-122 shows the location of erosion control structures along with the storage data based on FLV 6.2. Figure 9-120 shows the typical section for the environmental rock bars. Table 9-23 provides design details for typical rock bars.

Table 9-23: Environmental rock bar design features

Environmental rock bar design features	
Height at centre	0.8 m
Crest width	0.8 m
Rip rap sizing	d_{50}=400 mm
Downstream slope	1V :4H
Upstream slope	1V :2H
Key trench depth	300 mm
Geotextile	A44 BIDIM or equivalent

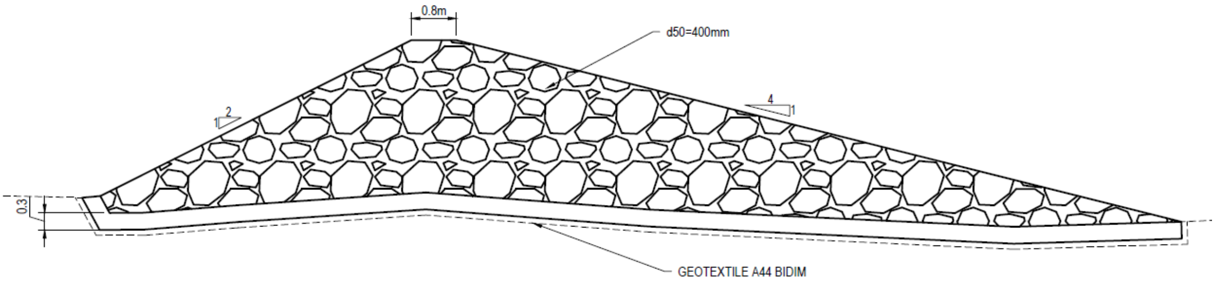


Figure 9-120: Environmental rock bars – section view

The general drawings of the environmental rock bars planned for installation on the final landform are provided in Appendix 9.1.

Sediment control structures

There are 18 boundary sediment control structures to be installed in streambeds to prevent sediment from leaving the current disturbed areas. Figure 9-122 shows the location of each along with the sizing and storage volume. The control structure consists of a leaky wall with a fine filter on the upstream side of the embankment. The structures are similar but larger than the environmental rock bars and include additional features. The design features and positioning of the structures are summarised in Table 9-24 shown in Figure 9-121. The designs in these figures are typical for these structures.

Table 9-24: Sediment control structure design features

Sediment Control Structure Design Features	
Height at centre	1.2 m
Crest width	1.2 m
Rip Rap sizing	d_{50}=400 mm
Downstream slope	1V :4H
Upstream slope	1V :2H
Key trench depth	300 mm
Upstream rock pad	Length=5 m, d_{50}=200 mm, thickness=400 mm
Downstream rock pad	Length=2.4 m, d_{50}=200 mm, thickness=400 mm
Filter layer	300 mm thick, 15-25 mm aggregate
Geotextile	A44 BIDIM or equivalent

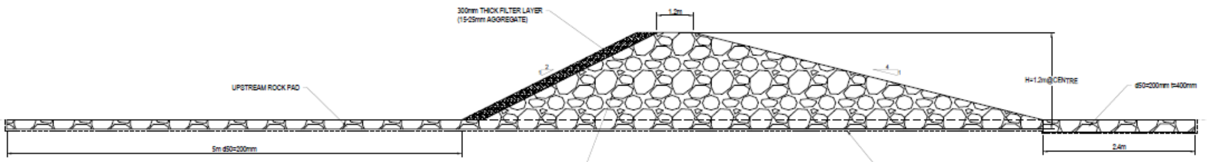


Figure 9-121: Boundary sediment control structure – section view

The height of the structures will vary based on the width / depth of drain. The locations and design of erosion and sediment control features on the final landform are provided in Appendix 9.1. The short-term sediment and erosion sediment control infrastructure have been identified as a requirement for interim landform shape as the landform progressively constructed to achieve Final Landform. Catchment Conversion Trial project design in Stage 52 was being finalised at the time of writing of the 2022 MCP. A series of infrastructure designs, once constructed, will be located to enable collection of water and sediment monitoring data. This will in turn inform the future sediment and erosion plan as part of the mine area rehabilitation and progressive construction of the Final Landform.

IF IN DOUBT – ASK! DO NOT SCALE IF IN DOUBT – ASK!

DWG. No. H355334-00000-220-290-0048

TABLE 1 – SEDIMENT BASINS					
ID	DESCRIPTION	STORAGE AREA* (m^2)	STORAGE VOLUME* (m^3)	(W) WEIR SPILLWAY WIDTH (m)	(C) CREST LENGTH (m)
1	SB01	21189	15557	20	174
2	SB02	28203	16921	20	131
3	SB03	2707	1561	20	155
4	SB04	2637	1347	15	136
5	SB05	3601	1974	20	149
6	SB06	1358	657	11	96
7	SB07	845	408	10	78
8	SB08	20055	8230	30	169
9	SB09	15360	8024	60	250
10	SB10	2190	1114	15	123
11	SB11	3714	2097	20	168
12	SB12	3553	2167	25	154
13	SB13	4577	2476	35	177
14	SB14	8250	4182	35	204
15	SB15	3481	1798	15	148
16	SB16	3778	2120	35	165
17	SB17	4026	2205	15	149
18	SB18	1596	845	15	102

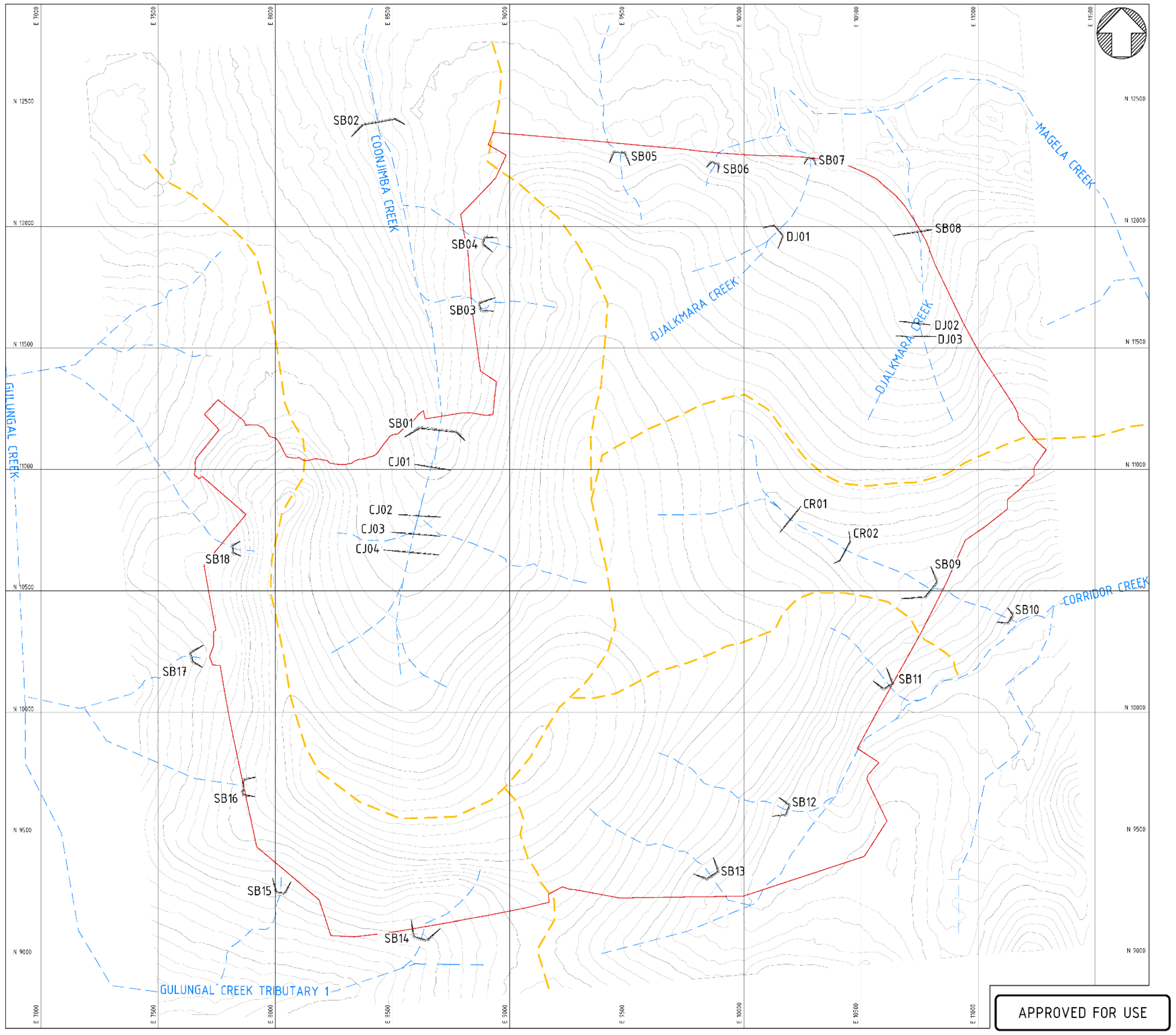
*ALL BOUNDARY SEDIMENT BASINS ARE 1.2M HIGH AT CENTRE. BASIN AREA AND STORAGE VALUES ARE THEORETICAL AS STRUCTURES DESIGNED AS LEAKY ROCK WALL (PERMEABLE).

TABLE 2 – ENVIRONMENTAL ROCK BARS					
ID	DESCRIPTION	STORAGE AREA* (m^2)	STORAGE VOLUME* (m^3)	(W) WEIR SPILLWAY WIDTH (m)	(C) CREST LENGTH (m)
1	CR01	5292	2381	4075	143
2	CR02	25742	10157	20	163
3	CJ01	5128	1511	20	158
4	CJ02	9042	2810	20	183
5	CJ03	10479	3324	20	215
6	CJ04	12294	3811	20	237
7	DJ01	4083	1452	40	160
8	DJ02	4862	1399	20	136
9	DJ03	5698	1583	50	173

*ALL ENVIRONMENTAL BARS ARE 0.8M HIGH AT CENTRE. BASIN AREA AND STORAGE VALUES ARE THEORETICAL AS STRUCTURES DESIGNED AS LEAKY ROCK WALL (PERMEABLE).

LEGEND

- CATCHMENTS POST 2020
- GULLY FLOWS
- CONTOURS MAJOR (5m INTERVALS)
- CONTOURS MINOR (1m INTERVALS)
- EXTENT OF WORKS BOUNDARY
- SEDIMENT BASINS (SB)
- ENVIRONMENTAL ROCK BARS



APPROVED FOR USE

CATCHMENT PLAN – FINAL LANDFORM

SCALE 1:7500

SUBJECT TO FINAL VERIFICATION AND APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

HATCH

AREA 91 – CLOSURE STRATEGY

GENERAL – AREA 00
CATCHMENT PLAN
FINAL LANDFORM

B1 | 91 | C | 0067 | 2

Figure 9-122: Catchment plan for final landform with sediment basins and environmental rock bars

9.3.5.4 Surface rock structures

Excess large rocks on the landform surface may pose increased safety risks for revegetation execution activities (personnel and equipment) and later access by Traditional Owners traversing the land. However, these rocks may be in high demand for construction of water management features and provide an opportunity to improve early revegetation ecological variability and habitat quality through increased surface heterogeneity.

Many large rocks (e.g. between approximately 500-1,500 mm diameter) exposed on the landform surface following construction shall be relocated for use in constructing water management features, such as rock lined drains or sediment traps.

There should be few rocks larger than this, but in areas where very large rocks occur, there is an opportunity to pile them together to form structures that will provide important habitat refugia to encourage early colonisation by fauna and specialist plant species. For example, some reptiles have been found to more-rapidly recolonise degraded landscapes where rock pile habitat is provided (e.g. Croak *et al.* 2013; Goldingay and Newell 2017; McDougall *et al.* 2016).

These structures have been installed on Pit 1 in consultation with the traditional owners (refer Chapter 9.3.1.3).

9.3.5.5 Access track installation

Revegetation Execution tracks

Revegetation execution tracks provide access for equipment and teams undertaking:

- irrigation installation and removal;
- tubestock planting; and
- irrigation operations and maintenance.

These tracks will be located across the area requiring revegetation to provide access to the trucks, excavator and vehicles required for revegetation execution activities. As revegetation execution concludes, some of these tracks can be removed (e.g. prepared and revegetated in the following wet season) to reduce the remaining track network to those required for ongoing monitoring and maintenance.

Monitoring and Maintenance tracks

Monitoring and maintenance tracks provide access for teams undertaking:

- water, vegetation and weed monitoring;
- weed control activities;
- minor revegetation maintenance works (e.g. infill planting, secondary introductions); and
- site perimeter access for fire and weed control.

These tracks need to be suitable for 4WD access and at a general frequency of at least every 100-200 m (loose grid formation) across the landform (this is based on the reach of a hose from a standard slip-on herbicide spray unit). The tracks will be required to remain for at least 2 years following planting, and can be removed (rehabilitated / revegetated) as the vegetation develops and weed risks reduce (e.g. across a 5-10 year period).

Long-term access tracks

Long term access tracks provide access for:

- long term monitoring and maintenance of the developing, rehabilitated site (water, vegetation, weeds);
- stakeholders to inspect the landform, undertake cultural criteria assessments; and
- Traditional Owners to access the area.

9.3.5.6 Schedule of progressive tasks

The final landform construction of Pit 1 commenced in Q2 2020 and was completed in September 2020. The remainder of the final landform construction will be ongoing to enable areas to be released progressively for revegetation.

9.3.5.7 Contingency planning

Following construction of the final landform the post closure monitoring and maintenance phase will commence. Adaptive management processes will be used to manage erosion and ensure long term revegetation success.

9.3.6 Revegetation implementation

Revegetation planning and implementation will be guided by the ERA Ecosystem Establishment Strategy that has been developed based on the learnings from over 30 years of revegetation trials and research and an understanding of the natural surrounding ecosystems.

Initial revegetation activities commence after site preparation is complete for an entire revegetation area. However, revegetation planning and preparation begins several years earlier; for example, with seed collection. The initial revegetation process broadly includes:

- planting design (planting density and distribution according to domain);
- seed collection and plant production;
- revegetation activities such as:
- site preparation (irrigation installation, herbicide application, , planting site cultivation), and
- tubestock planting (hole digging, fertiliser application, planting, watering in and/or irrigation).

Post-planting monitoring and maintenance activities including vegetation monitoring, infill planting and secondary species establishment, weed, fire and feral animal management are covered in *Section10 Closure Monitoring and Maintenance*.

Site revegetation plans will be prepared for each area to be revegetated. These plans will detail all revegetation activities, how these activities will be implemented and the schedule of implementation. Included will also be maps, field layout plans, monitoring and reporting requirements for each area. The plans will also include any on-ground activities required with respect to the identification of planting boundaries, planting configuration and location of species, monitoring plots and service tracks. This approach will ensure that lessons learnt from previous revegetation trials are incorporated in the future revegetation activities.

There is approximately 1,062 ha of land to rehabilitate for the successful closure of the Ranger Mine, including 795 ha of waste rock covered area. Unless specified in the respective domain descriptions in Chapter 9.2 previously, all areas shall receive the following standard revegetation implementation.

9.3.6.1 Reference ecosystem and species selection

As described in detail in *Section 5 KKN Supporting Studies*, KKN ESR1, natural community variability and potential constraints that may impact the type of ecosystem that is able to be re-established have been considered when developing a conceptual reference ecosystem (CRE) for Ranger (Table 9-25). Agreed CRE(s) will form the basis of the species list and target densities for revegetation planning and implementation. Whilst the CRE(s) are yet to be finalised, the intention is to revegetate the majority of the post-mining landform as *Eucalyptus tetrodonta / miniata* savanna woodland, which is one of the ecosystems in the surrounding areas near Ranger.

ERA have developed a Species Establishment Research Program (SERP) database of 165 flora species (mostly terrestrial), including 21 overstorey tree species, 74 midstorey tree and shrub species, and 70 understorey species (or genus). The selection of these species is based on previous stakeholder-agreed lists, historic and recent reference site surveys, and consultation with CDU researchers, Bininj ecology experts, and Traditional Owners. The species included in the database will continue to be refined as outcomes from ongoing CRE work, revegetation trials, risk assessments and further stakeholder consultations are completed. Currently, approximately 110 of the SERP species have been identified for initial revegetation.

The majority of stems (approximately 70%) used for revegetating the Eucalyptus savanna woodland domain on the FLF will consist of a handful of species, including dominate Eucalyptus and Corymbia trees, Acacias, and common fruiting shrubs. The remaining stems will be a range of tree, shrub and groundcover plants that, although in smaller densities, contribute significantly to the ecosystem's species richness, provide food and shelter for fauna, and/or are important species for Traditional Owners.

For further details on the research behind species selection and the ecosystem establishment strategy, see *Section 5 KKN Supporting Studies* in KKN ESR1 and ESR3.

Table 9-25: Information available for the major physical and/or chemical substrate constraints for ecosystem establishment.

Potential Constraint	Planning Information Source
Material type and relationships to plant water availability, rooting depth and so on	• The final landform design indicates where waste rock will generally be located and the depth of waste rock over natural soils. • Stockpile inspections, observations during construction and upon final handover inspection shall identify localised areas of particularly low or high fines. • LAAs and other areas of disturbance have been mapped as separate closure domains
Surface hydrology and subsurface hydrogeology, including seasonal variations.	• The post closure Ranger groundwater modelling (INTERA 2019) will indicate locations where groundwater exfiltration is likely to occur identifying where increased seasonal water logging may be expected
Substrate chemical status, including nutrients and contaminants of potential concern.	• Contaminated land assessments • Groundwater quality monitoring and modelling

9.3.6.2 Seed collection and tubestock propagation

ERA has been working extensively with Kakadu Native Plants Pty Ltd (KNPS), a locally owned and run indigenous supplier, to collect seed and provide seedlings for progressive revegetation that has occurred both at Ranger Mine and Jabiluka over the past 17 years. This supplier has extensive expertise in local plants including seed biology, propagation, revegetation and weed and fire management.

Seed Collection

ERA and KNPS have developed a collaborative process of planning and implementing the seed collection program that is visually presented in the flowchart provided as Figure 9-123.

Area-specific revegetation plans based on the rehabilitation schedule and the most current CRE(s), including required species stems per hectare, determine the tubestock and seed plan. The seed collection plan is underpinned by a wealth of knowledge, research and data, including a comprehensive understanding of native species phenology, seed processing and storage requirements, seed viability and germination testing, and previous nursery experience. These aspects of the SERP are discussed in more detail in *Section 5 KKN Supporting Studies* in KKN ESR3.

With consideration of the rehabilitation schedule and the storage specifics of the different species, ERA issues a monthly ‘order’ to KNPS to proceed with seed collection. This monthly frequency enables routine update and review of the status of the stock on hand against plan, modification of the collection plan to respond to any low collections, and to take advantage of any opportunities (such as a group of plants flowering / seeding earlier than usual due to localised seasonal variations).

KNPS undertake ongoing field reconnaissance (including during other 'on country' activities such as weed and fire management) to continuously build on their knowledge of what looks likely to flower and fruit and when. Following collection, KNPS air-dry and process the seed based on a species-specific approach to optimise viability and longevity (when stored). ERA is accountable for final storage of the delivered seed and maintains the seed management database with all relevant information for each seed lot.

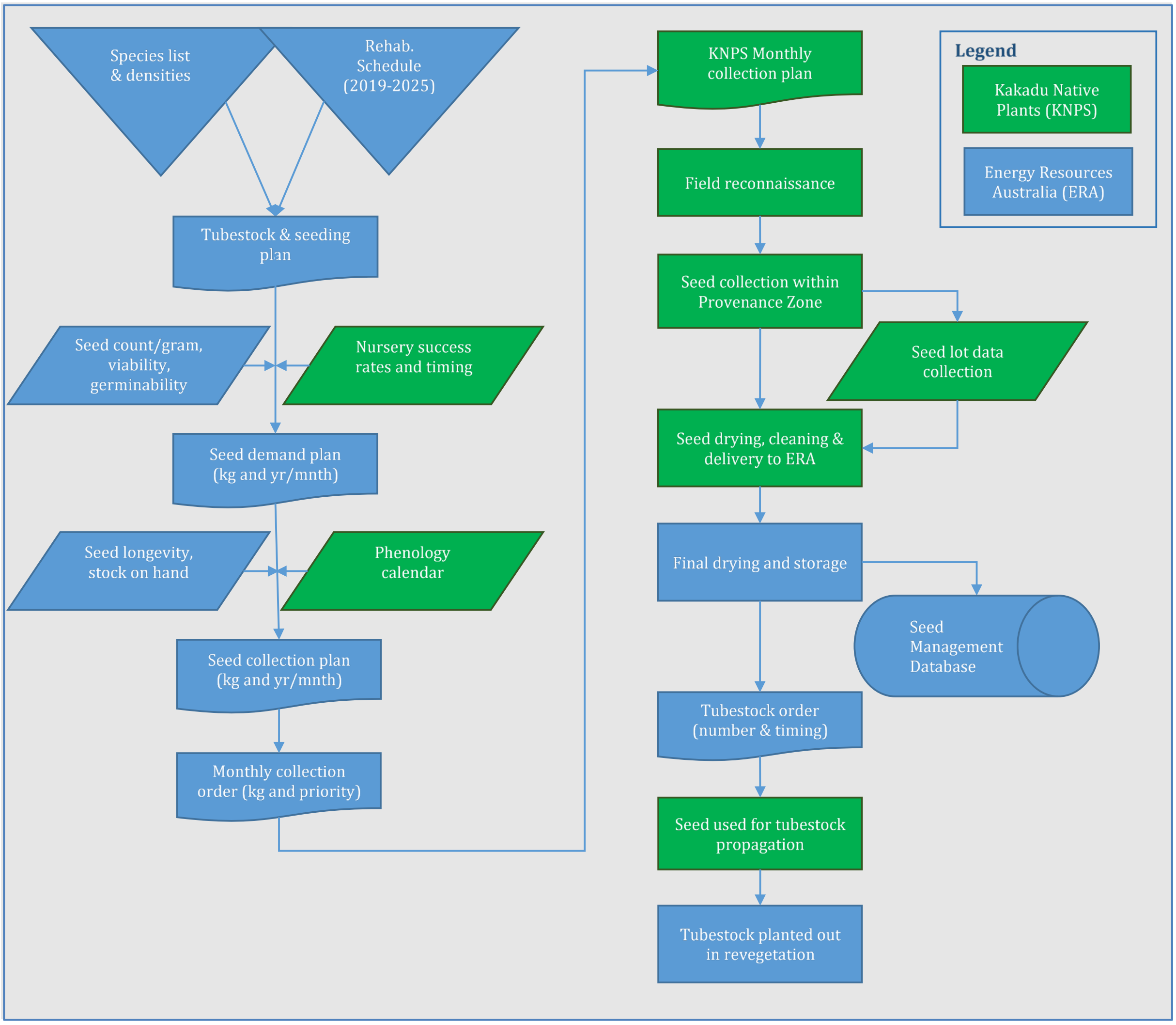


Figure 9-123: Flow chart of seed collection program

The closure revegetation program is highly influenced by the timing of the rehabilitation schedule, especially the bulk material movement and final landform handover process. Whilst some tubestock (and therefore seed) is required for research trials and small progressive revegetation areas, the majority of planting will occur late in the rehabilitation schedule. Fortunately, the majority of species seed needed for revegetation have sufficient longevity to be collected early and stored until required. Collection of these species has already commenced and is progressing well to be fully stocked before the peak tubestock propagation and planting period commences. A small portion of the species have seed with limited storage life, which either require propagating immediately after collection (termed 'perishable') or within one year of collection (termed 'fresh'). For these species, collections must be timed to optimise seed availability and time from planting.

Regardless of carefully thought-out seed collection plans, there remains a risk that seed availability is impacted by uncontrollable factors such as repeated 'failed' wet seasons, high levels of herbivorous predation (e.g. cockatoos), or high fire frequencies or intensities within the provenance collection zone, all of which can reduce the seed of many species. For these species, ongoing reconnaissance will ensure that collection tactics are primed for the instance when they are available and required, to make sure that targets can be achieved, and quality is maintained. ERA also take a conservative, proactive approach when collecting seed of important, dominant species required for revegetation. For example, if a species is known to have highly variable seed production or is sensitive to fire, herbivory etc. and the seed has a long storage life, that species may be 'over collected' when good quality and quantities of seed are available to minimise risk from poor collection years.

Tubestock propagation

Tubestock is propagated in the recently commissioned ERA Nursery, refer Chapter 9.2.10.3. Current annual capacity is 250,000 seedlings which is more than sufficient for the majority of revegetation requirements. For any peak demand it may be necessary to temporarily expand the facility and/or engage additional, approved suppliers; options for this are being explored (Chapter 9.3.6.7).

Tubestock is propagated to meet an agreed specification to ensure that seedlings have the best chance of survival after planting out. The ERA tubestock specification is based on best practice (NGIA 2018; Standards Australia 2018), field trials, observations and local knowledge and includes criteria relating to plant form, health, size, and rooting characteristics (Table **9-26**).

Propagation of tubestock for any given area of revegetation commences approximately 2-6 months before the target planting out date, depending on the expected growth rate of the species and the growing season (e.g. some species germinate and grow slower in the cooler dry season months). If any particular species does not have seed available exactly on time for propagation (e.g. species with perishable seed or due to seasonal impacts to seed collection), they can always be introduced later on during the infill planting program or through alternative methods (Chapter 9.4.6.8). It is highly unlikely that these will ever be the dominant Eucalyptus, Corymbia or Acacia species as these generally have long seed storage times and collection can start early and cover a number of years.

Table 9-26 Seeding specifications for nursery tubestock

Title	Specification for Ranger Mine Revegetation
Pot condition	Seedling supplied in specified pot, without significant damage, holding shape when handled and with appropriate growing media within 5 mm of pot lip.
Size and Age	Seedling is appropriate size and age as verified by reference material and/or ERA supervisor, i.e. with multiple sets of leaves and without major signs of root bounding.

Title	Specification for Ranger Mine Revegetation
General Health	Leaf colour and size is true to species form, without signs of active pests, disease, dieback or injury.
Seedling structure	Seedlings should be growing in accordance with natural habit (i.e. free standing where applicable without staking or tip pruning).
Stem position	The seedling stem base should be at least 10 mm from the edge of the pot.
Arrange ment	Prior to planting, seedlings must be arranged into planting trays of up to 18 pots as specified by the area-specific planting plan.

9.3.6.3 Irrigation installation and operation

On the waste rock final landform, newly planted seedlings will be irrigated to ensure good plant survival rates across all species during the dry season, and during wet seasons which can have erratic rainfall. Irrigation infrastructure will be installed after final land forming is complete and prior to pre-emergent herbicide application and tubestock planting. Irrigation will generally be applied for a maximum of six months, depending on the season of planting and prevailing weather conditions.

Tubestock will be irrigated frequently throughout planting and during the days immediately following planting to maintain moisture levels in the upper substrate profile and minimise transplant shock. After this initial period, irrigation will gradually be reduced to nightly soaks over the course of a few weeks and less frequent, heavier soaks over several months. This is important for root development, encouraging resilience during a typical dry season and for withstanding strong winds. Seedling condition will be monitored as irrigation is adjusted to ensure the hardening off is not too sudden or extreme. In the last few months of irrigation once seedlings have properly settled (e.g. Post-planting mortality rate has stabilised, plants are showing signs of growth etc.), the irrigation will be significantly reduced so that the soil profile is saturated but allowed to dry before further irrigation. Specific irrigation amounts applied to each area will depend on the season of planting, substrate type, temperatures, wind, evaporation, infiltration and rainfall.

The current proposed irrigation design will utilise a combination of rotational solid-state sprinklers and travelling large-scale pivot systems, connected by polypipe networks to generator-powered pumps at the two water sources (RP1 and GCMBL). If required, additional bore field water sources can also be utilised. Wherever possible, irrigation equipment will be relocated and reused following each six month irrigation period.

Monitoring and maintenance of the irrigation system during operation is critical. Issues that have arisen previously, or may arise in the future, include animal interference and/or mechanical damage to piping, sediment clogging up filters and smaller-aperture fittings, pump failures, inadequate water being delivered to plants and more. Any damage or malfunctioning of the irrigation equipment must be recognised within 48 hours of occurring to minimise impact upon vegetation. The use of pressure-based alarms and a log recording the operation of each panel will ensure that any incidents are recognised and rectified. A stock of critical spares will be maintained so that most maintenance activities can be undertaken without delay.

9.3.6.4 Preventative weed control

Substrates used to create the final landform shall be carefully managed during construction to prevent site contamination with weeds or their seeds. Furthermore, a weed control buffer zone (approximately 200 m wide) around the revegetation sites will be established to assist in preventing weed incursion into revegetation areas.

The revegetation areas will receive a blanket spray of Cavalier 500 (1.9 L/ha) and Sulfomac 750 (300g/ha) herbicide four weeks prior to planting to ensure no weeds are present that may threaten young establishing seedlings.

9.3.6.5 Mechanical planting site cultivation

Initial planting of tubestock will be at a density of between 800-1,200 stems per hectare (averaging approximately 1,000 st/ha) which requires spacing of between 2.5 - 3.5 metres. To achieve a ‘natural’ planting effect planting sites shall be positioned non-uniformly across the prepared surface. Planting sites shall be cultivated by an excavator auger attachment (Figure 9-124) or similar mechanical device. This will ensure there are no large rocks directly in the planting location and loosen the substrate in preparation for manual planting that follows soon after hole digging (Figure 9-125).

Figure 9-124: Example of a specially modified auger cultivator attached to a small excavator, here seen being trialled in waste rock on the Trial Landform in March 2020.

Figure 9-125: A mechanically cultivated planting site.

9.3.6.6 Tubestock planting

Once the preceding steps are completed, the required tubestock in the nursery shall be prepared for planting out. Tubestock of the different species shall be arranged into each tray to reflect the planned species distribution in the field and any plants targeted for ongoing monitoring will be tagged. The revegetation area will be irrigated prior to planting to moisten the substrate and reduce plant stress. The key steps of the planting procedure are:

- Planting locations should already be in place, being the mechanically cultivated site holes.
- Where sites have not been cultivated (or the cultivated hole has collapsed), check the revegetation plan for location and use a forestry shovel (or similar) to prepare a planting hole approximately 400 mm deep and 150 mm wide (Figure 9-126, Step 1).
- Add one slow release fertiliser tablet (e.g. Agriform® or Typhoon®) and, if planting without irrigation (e.g. at the LAAs), a small handful of pre-soaked Earthcare® or Aquasorb 3005 KL® water crystals to the base of each planting hole. Cover the tablet with a small amount of soil to avoid root burn (Figure 9-126, Step 2).
- Place tubestock into the planting hole. Plants in biodegradable pots can be placed directly into the hole, with the biopot lightly crushed immediately before being placed to increase rate of pot material breakdown. Plants in plastic pots shall be removed from the pot and carefully placed into the hole to minimise loss of any loose potting mix that is not held together by the plant roots. The holes will then be backfilled with the surrounding loosened substrate, focusing on fines and removing large rocks. The surface of the potting mix should be just below the final surface leaving a very slight depression which will assist with collecting water for the plant. The rims of biodegradable pots should be buried below the surface to improve thermal insulation of the root ball and prevent moisture wicking. Taking care not to damage the root system, the soil should be pressed firmly into place to ensure there are no air pockets (Figure 9-126, Step 3).
- Newly planted tubestock shall be watered in, either by the irrigation system or low pressure hoses.
- For individual plants requiring monitoring, a stake or tag shall be placed into the ground at least 10 cm from the base.

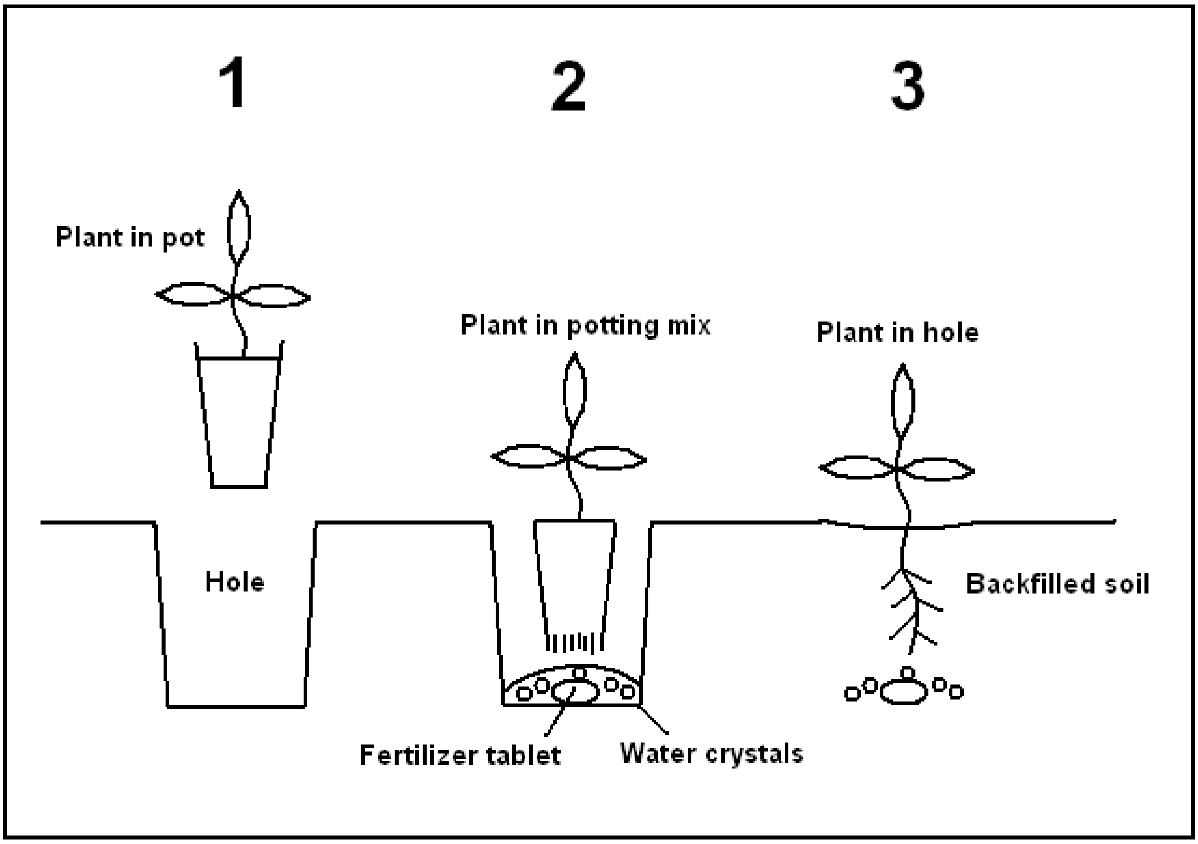


Figure 9-126: Tubestock planting out steps

9.3.6.7 Contingency plans

Tubestock production

The Ranger Mine nursery has been commissioned with a current annual capacity of 250,000 plants. ERA has begun planning for an expansion of the nursery facility to boost annual capacity to approximately 400,000 plants.

A contingency option to mitigate potential issues associated with tubestock production, should the need arise, is to establish an additional arrangement with a suitably qualified service provider to grow tubestock from seeds provided by ERA. Under this option, the provider would be required to supply tubestock in accordance with the intended nursery and seedling specifications (e.g. soilless substrate, seedling quality etc.). ‘Offsite’ nursery trials are currently underway to investigate this potential contingency option.

Seed collection and propagation

More than 150kg of clean seed and 50,000 fresh fruit of the target species is required to raise the 760,000 plus seedlings for the initial planting of the Ranger final landform. A permit to collect seed within Kakadu NP has been obtained for more than 500 kg of seed and 60,000 fresh fruit to allow for variable seed quality and also any final adjustments of the target species lists and/or densities.

It is highly unlikely that the required quantities of seed could be obtained for all species in any one collection campaign due to a number of factors, including:

- seasonal variation in seed set and availability due to environmental conditions such as rainfall, predation and/or bushfires;
- logistical constraints associated with finding sufficient plants within the approved collection area with mature fruits/seeds before seeds are naturally dispersed; and
- timing requirements for matching tubestock propagation and planting with rehabilitation earthworks schedule.

Thus, the seed collection program is a multi-year exercise with many ‘moving parts’ that requires a structured yet agile management approach. Despite the proactive collection strategies ERA implements, some species may not have adequate seed available exactly when needed, particularly perishable seeded species during year-round propagation. These species (especially those of particular cultural importance) are candidates for alternative propagation or revegetation introduction strategies, such as:

- careful use of limited seed to establish ‘source’ populations in the revegetation to provide for ongoing self-colonisation of the ecosystem as it develops;
- use of older, larger plants that were propagated when seed was fresh and have been stored in the nursery for longer than usual periods (transferred into larger pots when necessary to maintain optimal seedling health) until required for planting;
- propagation of tubestock from vegetative material (rather than seeds); and
- introductions as part of the secondary introduction program, whenever seed becomes available, and/or conditions are more favourable such that plants from any seed obtained will be more likely to survive and establish.

These, and other methods, are being investigated by ERA and KNPS as part of the continued refinement of the revegetation program, and are discussed further in *Section 5 KKN Supporting Studies.*

REFERENCES

2rog. 2021. Pit 1 and Stage 13 UAV Monitoring Trial - End of 20/21 Wet Season Report. Presentation to ERA Ranger Closure Consultative Forum May 2021.

Addison, J, 2011, *Vegetation Assessment and Closure Requirements of Ranger's Land Application Areas*, Energy Resources of Australia. RH118.

Australian Tailings Consultants. 2012. *ERA Ranger Integrated Water, Tailings and Closure Prefeasibility Study. Draft Report - Pit #1 Updated Consolidation Analysis*. Report to ERA (107025R16Rev.A). December 2012.

Brady, B, and Brown, E, 2014. *Rock Mechanics for underground mining*, third edition, pp 484-497.

Brady, C, Christophersen, P & O'Brien, J 2021. Incorporating Indigenous Knowledge in Mine Closure: Ranger Uranium Mine. *The Royal Society of Victoria*, 133, pp. 18–22.

Coffey 2015, *Stage VIII / RL60.5m Dredging Stability Assessment, Ranger Mine Tailings Dam*. Report prepared for Energy Resources of Australia. September.

Coghill, M, Jewell, R, Ring, B & Boger, D. 2003. *ERA Ranger Pit #1 Tailings Deposition.* Report prepared for Energy Resources of Australia Ltd. 31 January 2003.

Coghill 2016 Ranger Pit 3 void volume estimation, RioTinto.

Croak B. M., Pike D. A., Webb J. K. and Shine, R. (2010) Using artificial rocks to restore non-renewable shelter sites in human-degraded systems: colonization by fauna. *Restoration Ecology* 18, 428-438.

CSIRO. 2014. *Final Report on Ranger Minesite Pit#1 Closure Strategies*. CSIRO June 2014, p 561.

Daws, M & Poole, P. 2010. *Construction, revegetation and instrumentation of the Ranger uranium mine trial landform: Initial outcomes*. Report by Energy Resources of Australia Ltd, Darwin NT. February 2010, p 25

Department of Mines, Industry Regulation and Safety, 2020, *Statutory Guidelines for Mine Closure Plans.* Government of Western Australia. March 2020.

DPIR 2020, *Re: Tailings Height for Pit 3 exceeds -20 mRL,* Letter of Approval, Department of Primary Industries and Resources, August 2020

EcOz, 2022. Land Application Area Survey; Ranger Uranium Mine, Energy Resources Australia. EcOz Environmental Consultants, Darwin.

Energy Resources of Australia Ltd. 2005. *Interim Deposition of Tailings to RL+12 in Ranger #1 Pit*. Application by ERA to the MTC. 11 May 2005.

Energy Resources of Australia Ltd. 2013a. *Pit 1 Preload Programme: Pit 1 Wicks and tailings characterizations.* Powerpoint presentation to the MTC Pit 1 Initial Backfill Workshop. 2 May 2013.

Energy Resources of Australia Ltd. 2013b. *Pit 1 Closure - Stage 2 (Preload Placement).* Notification by Energy Resources of Australia Ltd to the MTC. 24 June 2013.

Energy Resources of Australia Ltd. 2014 *Assessment of Potential Environmental Impacts from an 'Interim' Final Tailings Level of RL-20m in Pit 3* 29 August 2014, p 92.

Energy Resources of Australia Ltd 2018*, Contaminated Land Risk Register*

Energy Resources of Australia Ltd. 2019a. *Application to Progress Pit 1 Final Landform*. Application by ERA to the MTC. March 2019.

Energy Resources of Australia Ltd. 2019b. *Solute and volume balances around Pit 1.* Memorandum prepared by by Ian Harvey (ERA). 11 April 2019.

Energy Resources of Australia Ltd (ERA) 2020a. *Ranger Mine Closure Plan*, issued October 2020, Energy Resources of Australia Ltd. Available from: http://www.energyres.com.au/sustainability/closureplan/

Energy Resources of Australia Ltd. (ERA). (2020b). *2019/2020 Contaminated Sites Drilling Interpretive Report.* Energy Resources of Australia (ERA).

Energy Resources of Australia Ltd. 2021c. *Pit 1 Ecosystem Re-establishment Plan: Trials and monitoring program*. Energy Resources of Australia Ltd. Rev 2. 30 June 2021.

Energy Resources of Australia Ltd. 2021d. *Radiation Protection Program: Radiation Management Plan – Ranger 3 Deeps*. Report produced by Energy Resources of Australia Ltd. 8 March 2021.

Energy Resources of Australia Ltd (ERA) & Eco Logical Australia (ELA) 2018. *Ranger Mine Closure Plan*, issued May 2018, Revision number 0.18.0, Energy Resources of Australia Ltd. Available from: http://www.energyres.com.au/sustainability/closureplan/

Energy Resources Australia (ERA) (2021a). *Weed control management plan 2021-2022.* Energy Resources of Australia Ltd, Darwin.

Energy Resources Australia (ERA) (2021b). *Fire management plan 2022*. Energy Resources of Australia Ltd, Darwin.

Fitton Tailings Consultants Pty Ltd. 2015a. *Pit 1, Consolidation Review.* Report to Energy Resources of Australia Ltd. Ref 1504.02R02. 28 October 2015.

Fitton Tailings Consultants Pty Ltd. 2015b. *Pit 1, Final Preload Works, Design Report* Ref 1504.02R01 Rev 0. Victoria. 7 September 2015.

Fitton Tailings Consultants Pty Ltd. 2018a. *Pit 1 Backfill Design Report*. Report to Energy Resources of Australia Ltd. Ref 1504.07R01 Rev 1. 24 July 2018, p 61.

Fitton Tailings Consultants 2018b. Pit 3, Revised Consolidation Analysis. Report to Energy Resources of Australia Ltd. Document 1504.06R03, 24 September 2018

Fitton 2019, Ranger Uranium Mine Northern Territory - Pit 3 Interim Tailings Deposition Plan. Prepared for Energy Resources of Australia Ltd. 19 June 2019.

Fitton Tailings Consultants Pty Ltd. 2020. *Pit 1 Status, June 2020.* Report to Energy Resources of Australia Ltd. Ref 1504.09R02 Rev 1. 11 August 2020.

Fitton Tailings Consultants Pty Ltd. 2021. *Consolidation Settlement Monitoring.* Memorandum from Steven Murphy to Energy Resources of Australia Ltd. Ref 1504.09 Mem 006. 27 April 2021.

Fugro Survey Pty Ltd. 2012. *Report on the geophysical survey tailings storage facility Ranger mine, Northern Territory. Geophysical results, operations and drawings*. Report to Energy Resources of Australia Ltd. 8 June 2012, p 161

Goldingay R. L. and Newell D. A. 2017. Small-scale field experiments provide important insights to restore the rock habitat of Australia's most endangered snake. *Restoration Ecology* 25, 243-252.

Humphrey, C., Fox, G., and Lu, P. 2009. *Use of vegetation analogues to guide planning for rehabilitation of the Ranger minesite*. In ERISS research summary 2007–2008. eds Jones DR & Webb A, Supervising Scientist Report 200, Supervising Scientist, Darwin NT, 136-146.

IAEA. 2019. *Guidelines on soil and vegetation sampling for radiological monitoring.* International Atomic Energy Agency. Vienna : International Atomic Energy Agency, 2019. Series: Technical reports series (International Atomic Energy Agency), ISSN 0074–1914 ; no. 486.

Iles, M. and Rissik, D. (2021) *Ranger closure aquatic pathway receptors risk assessment. Project 1221-09 Water Pathway Risk Assessments (Release pathways from onsite contaminants).* Energy Resources of Australia Ltd and BMT. August 2021, rev.0.

INTERA. 2018. *Evaluation of hydrological conditions after halt of pumping in the Ranger 3 Deeps decline*. Confidential technical memorandum prepared for Energy Resources Australia.

INTERA 2019, *Final Report: Sitewide Conceptual Model Update and Calibrated/Post-Closure Groundwater Flow Models for Ranger Mine*, Prepared for ERA, 14 March 2019

Kenny, D. 2003. *Ranger #1 pit tailings placement.* Position Paper for Energy Resources of Australia Ltd. August 2003.

Knight-Piesold. 1997. *In-Pit Tailings Disposal Construction Report.* Report to Energy Resources of Australia Ltd. Ref 518/8. May 1997.

Lowry, J, Coulthard, T & Hancock, G 2013. *Assessing the long-term geomorphic stability of a rehabilitated landform using the CAESAR-Lisflood landscape evolution model*. In: Tibbett, M, Fourie, A & Digby, C, eds. Proceedings of the 8th International Conference on Mine Closure, 18–20 September 2013 2013 Perth. Australian Centre for Geomechanics

MacKenzie, B. (2018). ERA Closure Water and Tailings Project - Pit 3 Deposition Option Analysis. HATCH.

McDougall A., Milner R. N., Driscoll D. A. and Smith A. L. (2016) Restoration rocks: integrating abiotic and biotic habitat restoration to conserve threatened species and reduce fire fuel load. *Biodiversity and Conservation* 25, 1529-1542.

Murphy, J, 2018. *Ranger 3 Deeps exploration decline decommissioning plan*. Energy Resources of Australia Limited, Darwin, NT

NGIA (Nursery and Garden Industry Australia), 2018. *Nursery Industry Accreditation Scheme, Australia – Best Management Practice Guidelines* 7th Edition.

Parry, ML. 2018. *Treatments to improve native understorey establishment in mine waste rock in northern Australia*. Honours thesis, Charles Darwin University, Darwin.

Pugh, L, Iles, M & McLellan, A. 2016. *Pit 1 Notification: Final in-pit tailings level (DRAFT)*. Report by Energy Resources of Australia Ltd, Commercial-in-confidence. 16 March 2016, p 287.

Saragih, EW. 2017. Vegetation development in gold mine rehabilitation in relation to cattle grazing in the Northern Territory, Australia. PhD thesis, Charles Darwin University, Darwin.

Shao, Q. 2015. Surface hydrological modelling for rehabilitated landforms. PhD Thesis, Sustainable Minerals Institute, The University of Queensland. doi:10.14264/uql.2015.394

Spain, AV., Reddell, P. 1995. Ecosystem establishment on the southern waste rock dump at Ranger No 1 uranium mine. Report for Energy Resources of Australia Limited, CSIRO Minesite Rehabilitation Research Program.

Standards Australia 2018. Tree Stock for Landscape Use, AS2303: 2018, Standards Australia, NSW.

Supervising Scientist (2016) Interim_ERA_FLV5_02 assessment, Letter report to ERA, dated 29 January 2016, Department of the Environment, p 18.

Surrich Hydrographics. 2019. Magnetic Survey Report, Ranger Uranium Mine, May 2019. Report to Energy Resources of Australia Ltd. 31 May 2019.

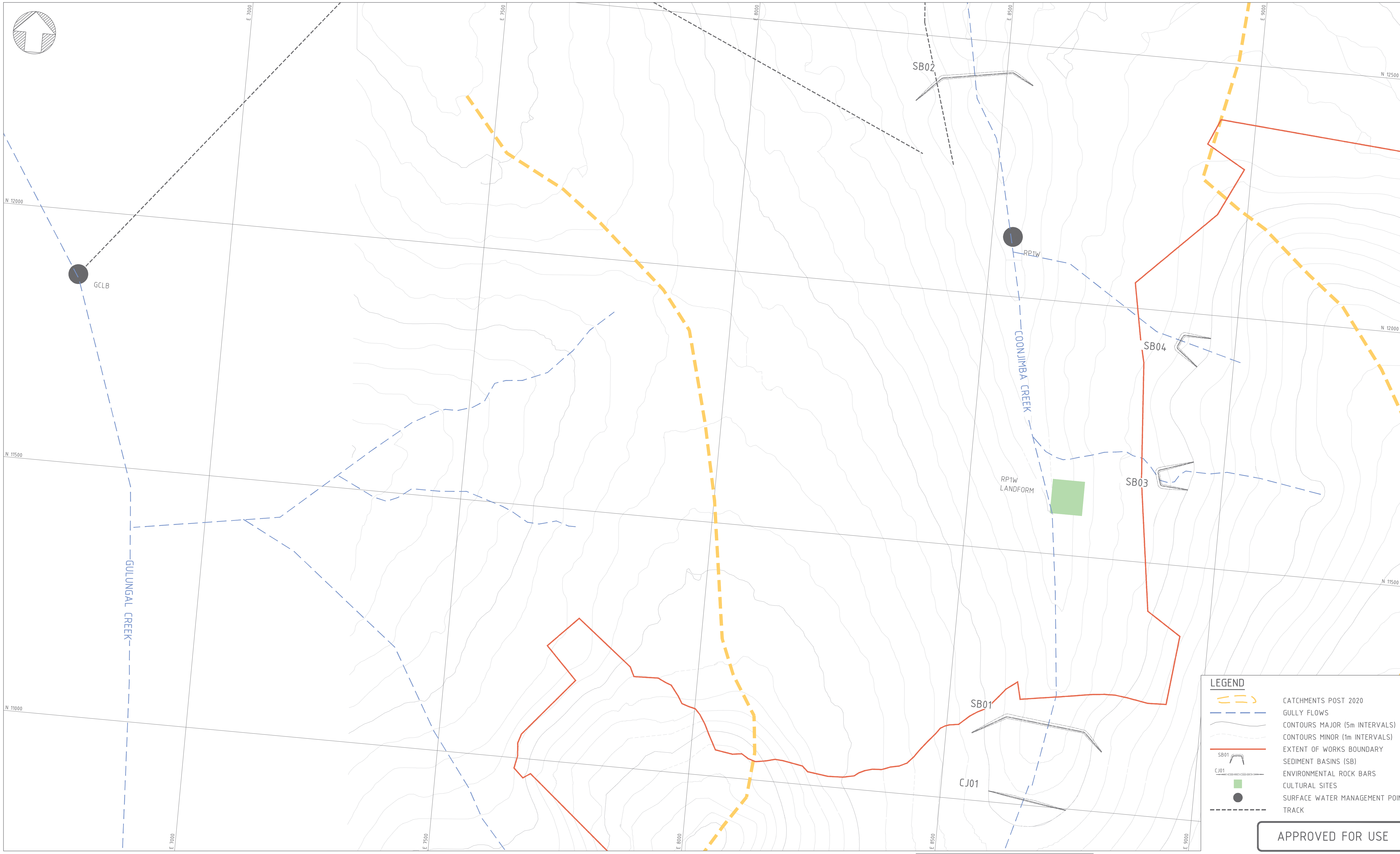
Water Solutions. 2017. ERA Ranger Mine Final Landform Preliminary Flood Modelling and Hydraulic Design. Water Solutions, Kenmore, Queensland Commercial-in-Confidence. 22 May 2017

Weaver, T, Makin, S, O'Neill, A, Murfitt, T, Berryman, S & McGowan, P. 2010. Independent Hydrogeological Review: Tailings Storage Facility. Ranger Mine (Final Report). URS. 15 October 2010, pp. 143, plus appendices, illustrations, maps & CD.

APPENDIX 9.1: FINAL LANDFORM DRAWINGS

IF IN DOUBT – ASK! DO NOT SCALE IF IN DOUBT – ASK!

DWG No. H355334-00000-220-272-0001



0 75 150 225 300m
SCALE: 1:3000 @B1

FINAL CONTOUR PLAN 1
SCALE 1:3000

JOINS DRAWING 0021

APPROVED FOR USE

SUBJECT TO FINAL VERIFICATION AND APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

DRG. NO.	REFERENCE DRAWING DESCRIPTION

NOTES

This drawing was prepared for the exclusive use of Energy Resources Australia Ltd. ABN 71 008 550 865 ("Client") and is issued pursuant to contracts between Client and Hatch Pty Ltd ABN 59 008 630 500 ("Hatch").

Unless otherwise agreed in writing with Client or specified in this drawing, (a) Hatch does not accept and disclaims any and all liability or responsibility arising from any use of or reliance on this drawing by any third party or any modification or misuse of this drawing by Client, and (b) this drawing is confidential and all intellectual property rights embodied or referenced in this drawing remain the property of Hatch.

HATCH

REV.	DESCRIPTION	BY	CKD.	APP.	DATE
2	APPROVED FOR USE	PK	PDB	DB	06/02/19
1	APPROVED FOR USE	PK	PDB	DB	17/12/18
0	APPROVED FOR USE	LZ	PDB	DB	21/06/18

EQUIPMENT NUMBERS

SCALE 1:3000

THIRD ANGLE PROJECTION

DESIGN	JJT	21/06/18
DRAWN	LZ	21/06/18
ENG'EER CKD.	PDB	06/02/19
CLIENT APPR'D	SG	06/02/19
SUP'T APPR'D		

CONTRACTOR DWG. NUMBER H355334-00000-220-272-0001

RIO TINTO DWG. NUMBER CDM.03-0000-EC-DWG-00019

ERA

PLANT AREA: AREA 91 – CLOSURE STRATEGY

TITLE: RANGER SITE PLANS – AREA 13
CIVIL WORKS
FINAL CONTOUR PLAN 1

SHEET SIZE	PROJ/WORK ORDER NO.	AREA	DISC.	DRAWING	REV
B1		91	C	0019	2

P:\ERA\355334\CAD\220\01 Drawings\H355334-00000-220-272-0001.dwg 14:51:18, 06.02.2019

IF IN DOUBT – ASK!   DO NOT SCALE   IF IN DOUBT – ASK!

APPROVED FOR USE

0 75 150 225 300m
SCALE: 1:3000 @B1

JOINS DRAWING 0022

FINAL CONTOUR PLAN 2

SCALE 1:3000

SUBJECT TO FINAL VERIFICATION AND APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

DRG. NO.	REFERENCE DRAWING DESCRIPTION

NOTES

This drawing was prepared for the exclusive use of Energy Resources Australia Ltd. ABN 71 008 550 865 ("Client") and is issued pursuant to contracts between Client and Hatch Pty Ltd ABN 59 008 630 500 ("Hatch").

Unless otherwise agreed in writing with Client or specified in this drawing, (a) Hatch does not accept and disclaims any and all liability or responsibility arising from any use of or reliance on this drawing by any third party or any modification or misuse of this drawing by Client, and (b) this drawing is confidential
and all intellectual property rights embodied or referenced in this drawing remain the property of Hatch.

HATCH

REV.	DESCRIPTION	BY	CKD.	APP.	DATE
2	APPROVED FOR USE	PK	PDB	DB	06/02/19
1	APPROVED FOR USE	PK	PDB	DB	17/12/18
0	APPROVED FOR USE	LZ	PDB	DB	21/06/18

EQUIPMENT NUMBERS

SCALE 1:3000

THIRD ANGLE PROJECTION

DESIGN	JJT	21/06/18
DRAWN	LZ	21/06/18
ENG'EER CKD.	PDB	06/02/19
CLIENT APPR'D	SG	06/02/19
SUP'T APPR'D		

CONTRACTOR DWG. NUMBER
H355334-00000-220-272-0002

RIO TINTO DWG. NUMBER
CDM.03-0000-EC-DWG-00020

ERA

PLANT AREA: AREA 91 – CLOSURE STRATEGY

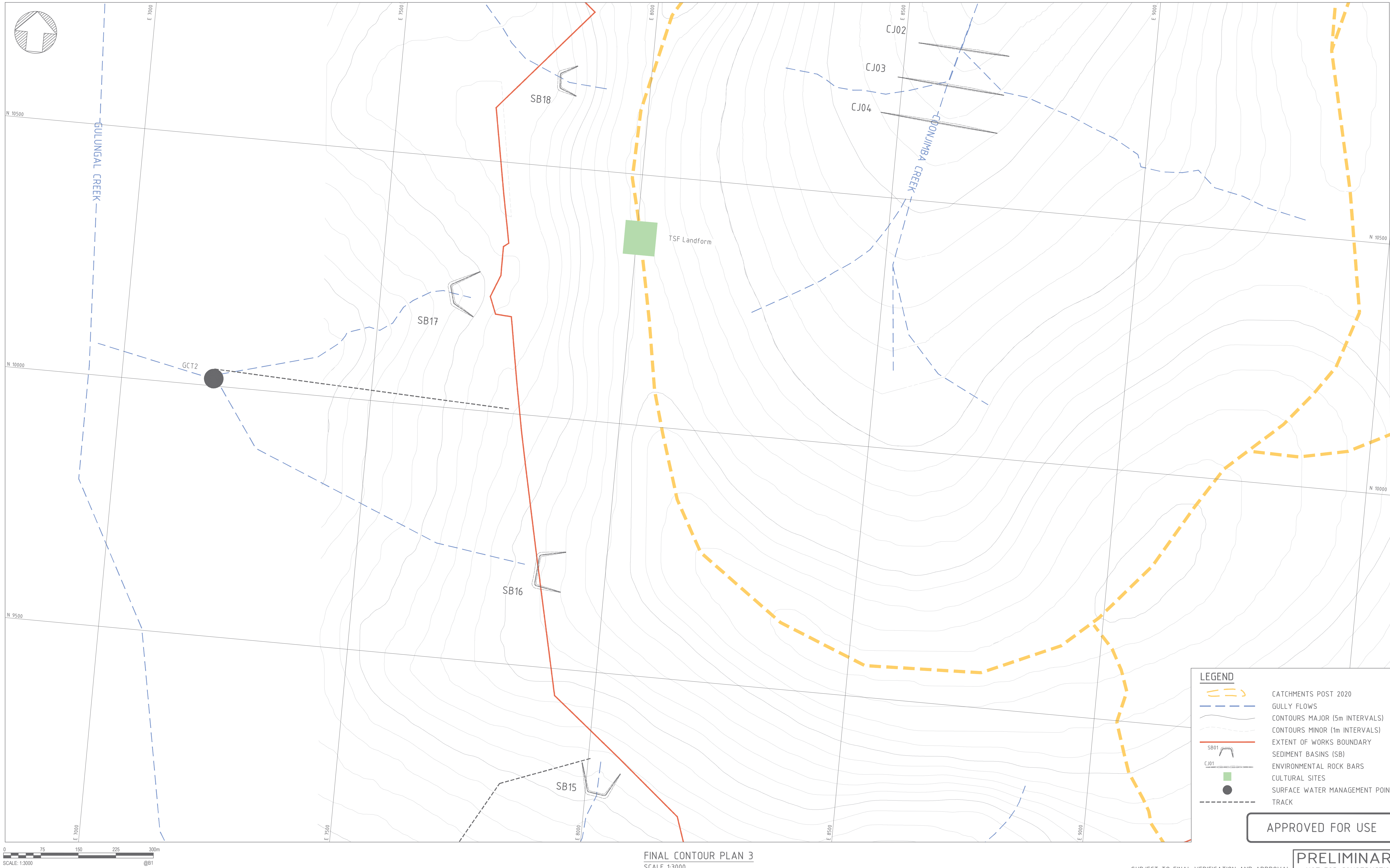
TITLE: RANGER SITE PLANS – AREA 13
CIVIL WORKS
FINAL CONTOUR PLAN 2

SHEET SIZE	PROJ/WORK ORDER NO.	AREA	DISC.	DRAWING	REV
B1		91	C	0020	2

IF IN DOUBT – ASK!   DO NOT SCALE   IF IN DOUBT – ASK!

JOINS DRAWING 0019

DWG No. H355334-00000-220-272-0003



APPROVED FOR USE

FINAL CONTOUR PLAN 3

SCALE 1:3000

SUBJECT TO FINAL VERIFICATION AND APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

NOTES

This drawing was prepared for the exclusive use of Energy Resources Australia Ltd. ABN 71 008 550 865 ("Client") and is issued pursuant to contracts between Client and Hatch Pty Ltd ABN 59 008 630 500 ("Hatch").

Unless otherwise agreed in writing with Client or specified in this drawing, (a) Hatch does not accept and disclaims any and all liability or responsibility arising from any use of or reliance on this drawing by any third party or any modification or misuse of this drawing by Client, and (b) this drawing is confidential and all intellectual property rights embodied or referenced in this drawing remain the property of Hatch.

HATCH

DRG. NO.	REFERENCE DRAWING DESCRIPTION

REV.	DESCRIPTION	BY	CKD.	APP.	DATE
2	APPROVED FOR USE	PK	PDB	DB	06/02/19
1	APPROVED FOR USE	PK	PDB	DB	17/12/18
0	APPROVED FOR USE	LZ	PDB	DB	21/06/18

EQUIPMENT NUMBERS

SCALE 1:3000

THIRD ANGLE PROJECTION

DESIGN	JJT	21/06/18
DRAWN	LZ	21/06/18
ENG'EER CKD.	PDB	06/02/19
CLIENT APPR'D	SG	06/02/19
SUP'T APPR'D		

CONTRACTOR DWG. NUMBER H355334-00000-220-272-0003

RIO TINTO DWG. NUMBER CDM.03-0000-EC-DWG-00021

ERA

PLANT AREA: AREA 91 – CLOSURE STRATEGY

TITLE: RANGER SITE PLANS – AREA 13
CIVIL WORKS
FINAL CONTOUR PLAN 3

SHEET SIZE	PROJ/WORK ORDER NO.	AREA	DISC	DRAWING	REV
B1		91	C	0021	2

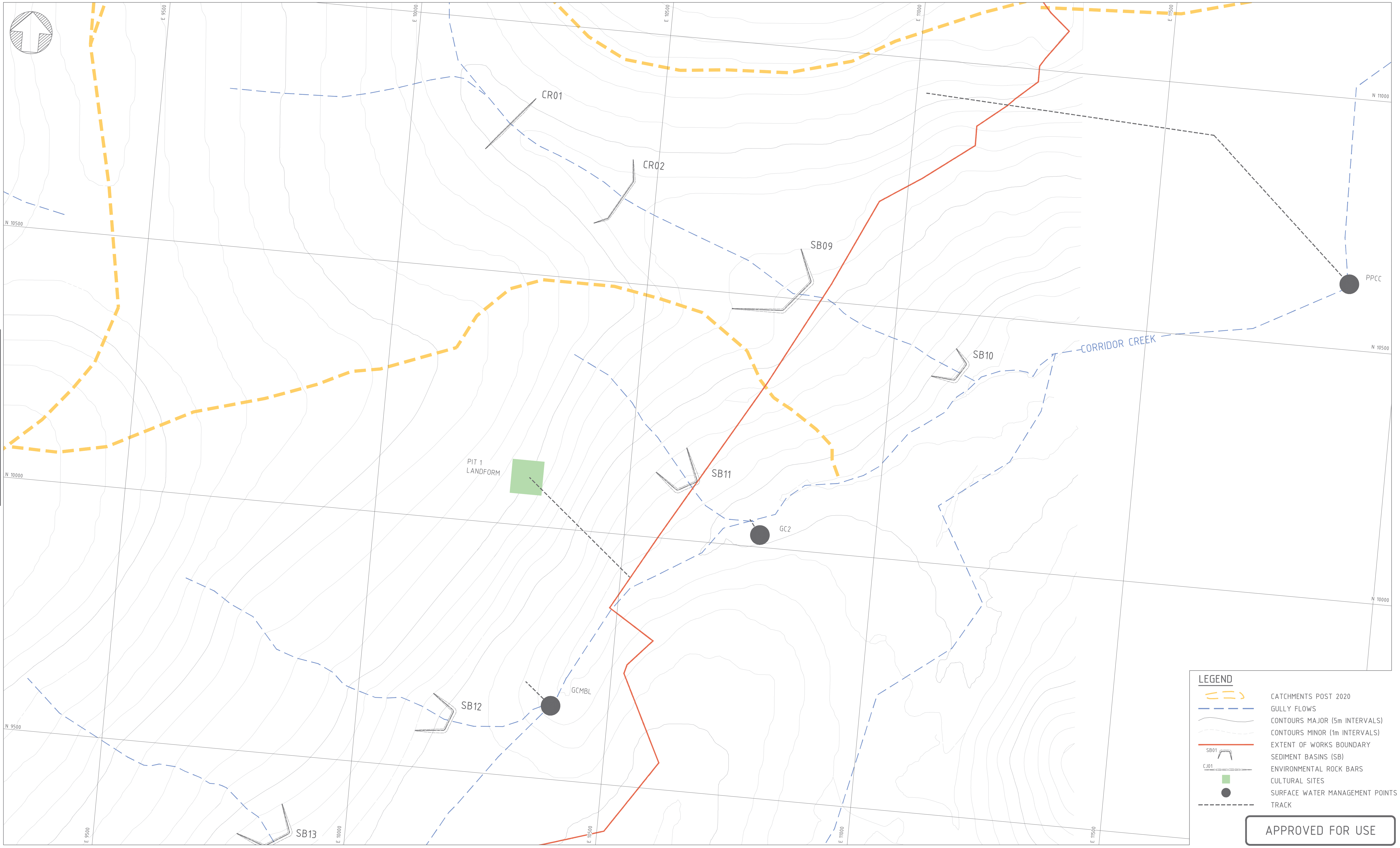
P:\ERA\355334\CAD\220\01 Drawings\H355334-00000-220-272-0003.dwg 14:51:37 06.02.2019

IF IN DOUBT – ASK!

DO NOT SCALE

JOINS DRAWING 0020

IF IN DOUBT – ASK!



APPROVED FOR USE

SCALE 1:3000

FINAL CONTOUR PLAN 4

SCALE 1:3000

SUBJECT TO FINAL VERIFICATION AND APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

DRG. NO.	REFERENCE DRAWING DESCRIPTION

NOTES

This drawing was prepared for the exclusive use of Energy Resources Australia Ltd. ABN 71 008 550 865 ("Client") and is issued pursuant to contracts between Client and Hatch Pty Ltd ABN 59 008 630 500 ("Hatch").

Unless otherwise agreed in writing with Client or specified in this drawing, (a) Hatch does not accept and disclaims any and all liability or responsibility arising from any use of or reliance on this drawing by any third party or any modification or misuse of this drawing by Client, and (b) this drawing is confidential and all intellectual property rights embodied or referenced in this drawing remain the property of Hatch.

REV.	DESCRIPTION	BY	CKD.	APP.	DATE
2	APPROVED FOR USE	PK	PDB	DB	06/02/19
1	APPROVED FOR USE	PK	PDB	DB	17/12/18
0	APPROVED FOR USE	LZ	PDB	DB	21/06/18

EQUIPMENT NUMBERS

SCALE 1:3000

THIRD ANGLE PROJECTION

DESIGN	JJT	21/06/18
DRAWN	LZ	21/06/18
ENG'EER CKD.	PDB	06/02/19
CLIENT APPR'D	SG	06/02/19
SUP'T APPR'D		

CONTRACTOR DWG. NUMBER
H355334-00000-220-272-0004

RIO TINTO DWG. NUMBER
CDM.03-0000-EC-DWG-00022

ERA

PLANT AREA: AREA 91 – CLOSURE STRATEGY

TITLE: RANGER SITE PLANS – AREA 13
CIVIL WORKS
FINAL CONTOUR PLAN 4

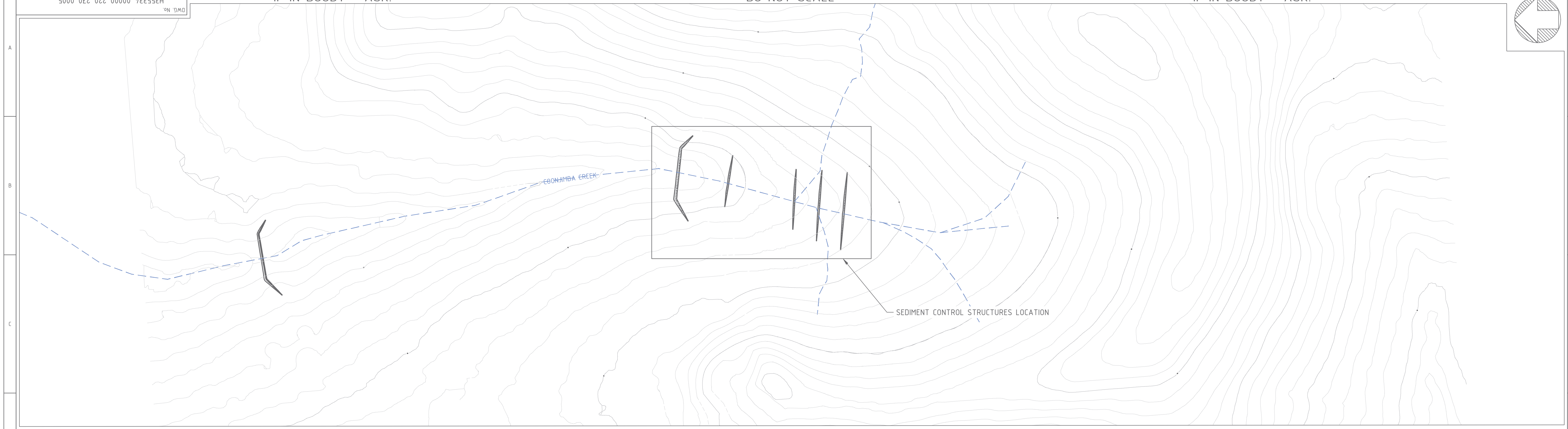
SHEET SIZE	PROJ/WORK ORDER NO.	AREA	DISC.	DRAWING	REV
B1		91	C	0022	2

DWG No. H355334-00000-220-272-0004

P:\ERA\355334\CAD\220\01 Drawings\H355334-00000-220-272-0004.dwg 14:51:47, 06.02.2019

IF IN DOUBT - ASK!   DO NOT SCALE   IF IN DOUBT - ASK!

DWG No. H355334-00000-220-270-0005

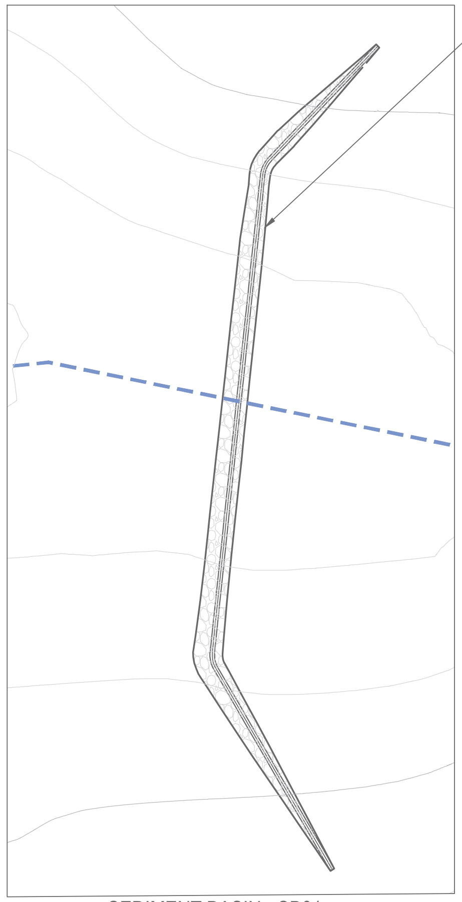


KEY PLAN - SEDIMENT CONTROL STRUCTURES
SCALE 1:5000

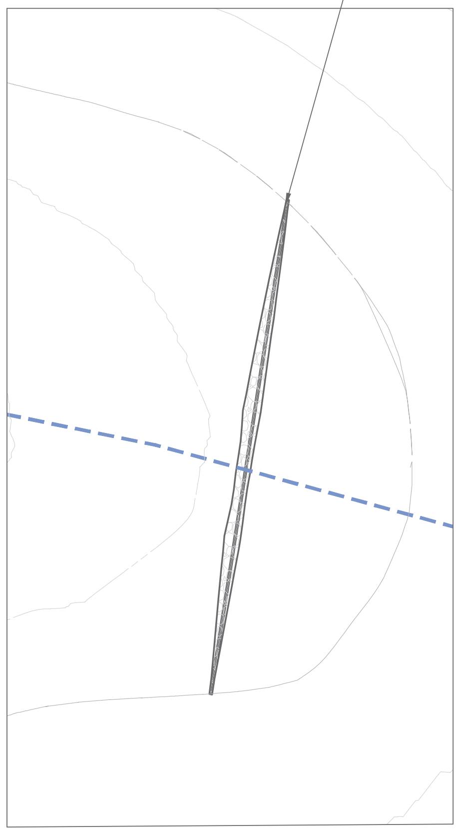
NOTES:

1. ALL WORKS REQUIRE 300mm STRIPPING AND FOUNDATION PREPARATION.
2. DESIGN SURFACES BASED ON PROVIDED SURVEY. LEVELS SHOULD BE CONFIRMED ON SITE.

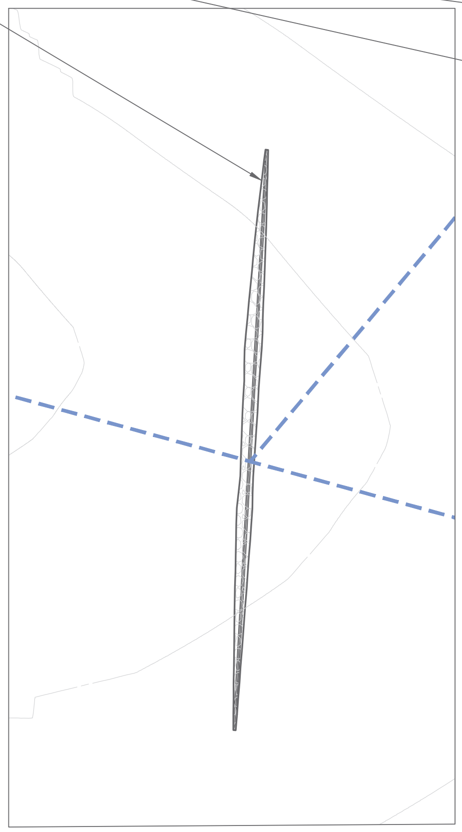
FOR TYPICAL SECTIONS FOR SEDIMENT BASIN AND ENVIRONMENTAL ROCK BARS REFER DRAWING 91-C-0071.



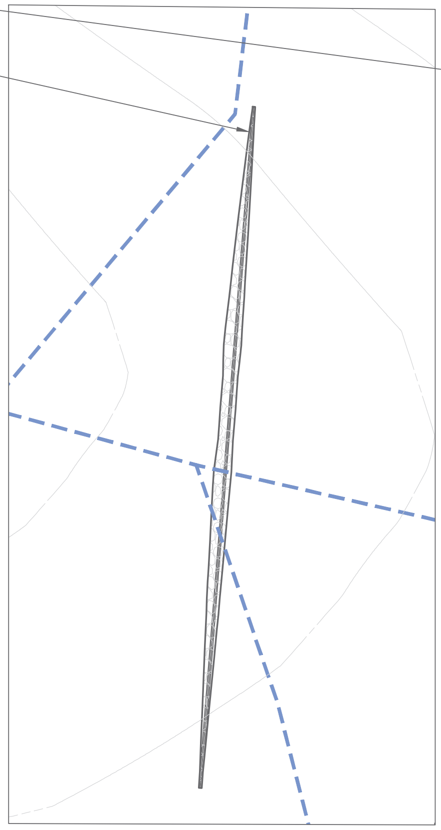
SEDIMENT BASIN - SB01
SCALE 1:1000



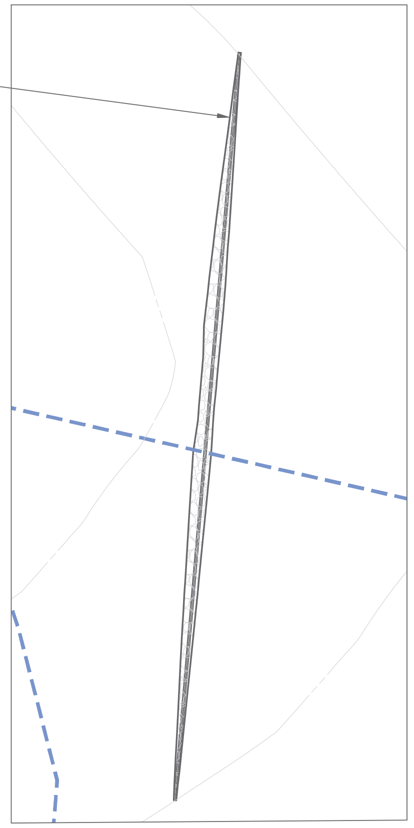
ENVIROMENTAL ROCK BAR CJ01
SCALE 1:1000



ENVIROMENTAL ROCK BAR CJ02
SCALE 1:1000



ENVIROMENTAL ROCK BAR CJ03
SCALE 1:1000



ENVIROMENTAL ROCK BAR CJ04
SCALE 1:1000

0 0.5 1.0 1.5 2.0m
SCALE: 1:20 @B1

APPROVED FOR USE

PRELIMINARY
NOT FOR CONSTRUCTION
SUBJECT TO FINAL VERIFICATION AND APPROVAL

DRG. NO.	REFERENCE DRAWING DESCRIPTION

NOTES

This drawing was prepared for the exclusive use of Energy Resources Australia Ltd. ABN 71 008 550 865 ("Client") and is issued pursuant to contracts between Client and Hatch Pty Ltd ABN 59 008 630 500 ("Hatch").

Unless otherwise agreed in writing with Client or specified in this drawing, (a) Hatch does not accept and disclaims any and all liability or responsibility arising from any use of or reliance on this drawing by any third party or any modification or misuse of this drawing by Client, and (b) this drawing is confidential
and all intellectual property rights embodied or referenced in this drawing remain the property of Hatch.

HATCH

REV.	DESCRIPTION	BY	CKD.	APP.	DATE
1	APPROVED FOR USE	PK	PDB	DB	06/02/19
0	APPROVED FOR USE	LZ	PDB	DB	21/06/18

EQUIPMENT NUMBERS

SCALE AS NOTED

THIRD ANGLE PROJECTION

DESIGN	JJT	21/06/18
DRAWN	LZ	21/06/18
ENG'EER CKD.	PDB	06/02/19
CLIENT APPR'D		
SUP'T APPR'D		

CONTRACTOR DWG. NUMBER H355334-00000-220-270-0005

RIO TINTO DWG. NUMBER CDM.03-0000-EC-DWG-00053

ERA

PLANT AREA: AREA 91 - CLOSURE STRATEGY

TITLE: GENERAL ARRAGEMENT
CIVIL WORK
ENVIRONMENTAL ROCK BARS

SHEET SIZE	PROJ/WORK ORDER NO.	AREA	DISC.	DRAWING	REV
B1		91	C	0053	1

P:\ERA\355334\CAD\220\01 Drawings\H355334-00000-220-270-0005.dwg 15:02:57, 06.02.2019

IF IN DOUBT – ASK!　DO NOT SCALE　IF IN DOUBT – ASK!

DWG No. H355334-00000-220-290-0048

TABLE 1 – SEDIMENT BASINS

ID	DESCRIPTION	STORAGE AREA* (m^2)	STORAGE VOLUME* (m^3)	(W) WEIR SPILLWAY WIDTH (m)	(C) CREST LENGTH (m)
1	SB01	21189	15557	20	174
2	SB02	28203	16921	20	131
3	SB03	2707	1561	20	155
4	SB04	2637	1347	15	136
5	SB05	3601	1974	20	149
6	SB06	1358	657	11	96
7	SB07	845	408	10	78
8	SB08	20055	8230	30	169
9	SB09	15360	8024	60	250
10	SB10	2190	1114	15	123
11	SB11	3714	2097	20	168
12	SB12	3553	2167	25	154
13	SB13	4577	2476	35	177
14	SB14	8250	4182	35	204
15	SB15	3481	1798	15	148
16	SB16	3778	2120	35	165
17	SB17	4026	2205	15	149
18	SB18	1596	845	15	102

*ALL BOUNDARY SEDIMENT BASINS ARE 1.2M HIGH AT CENTRE. BASIN AREA AND STORAGE VALUES ARE THEORETICAL AS STRUCTURES DESIGNED AS LEAKY ROCK WALL (PERMEABLE).

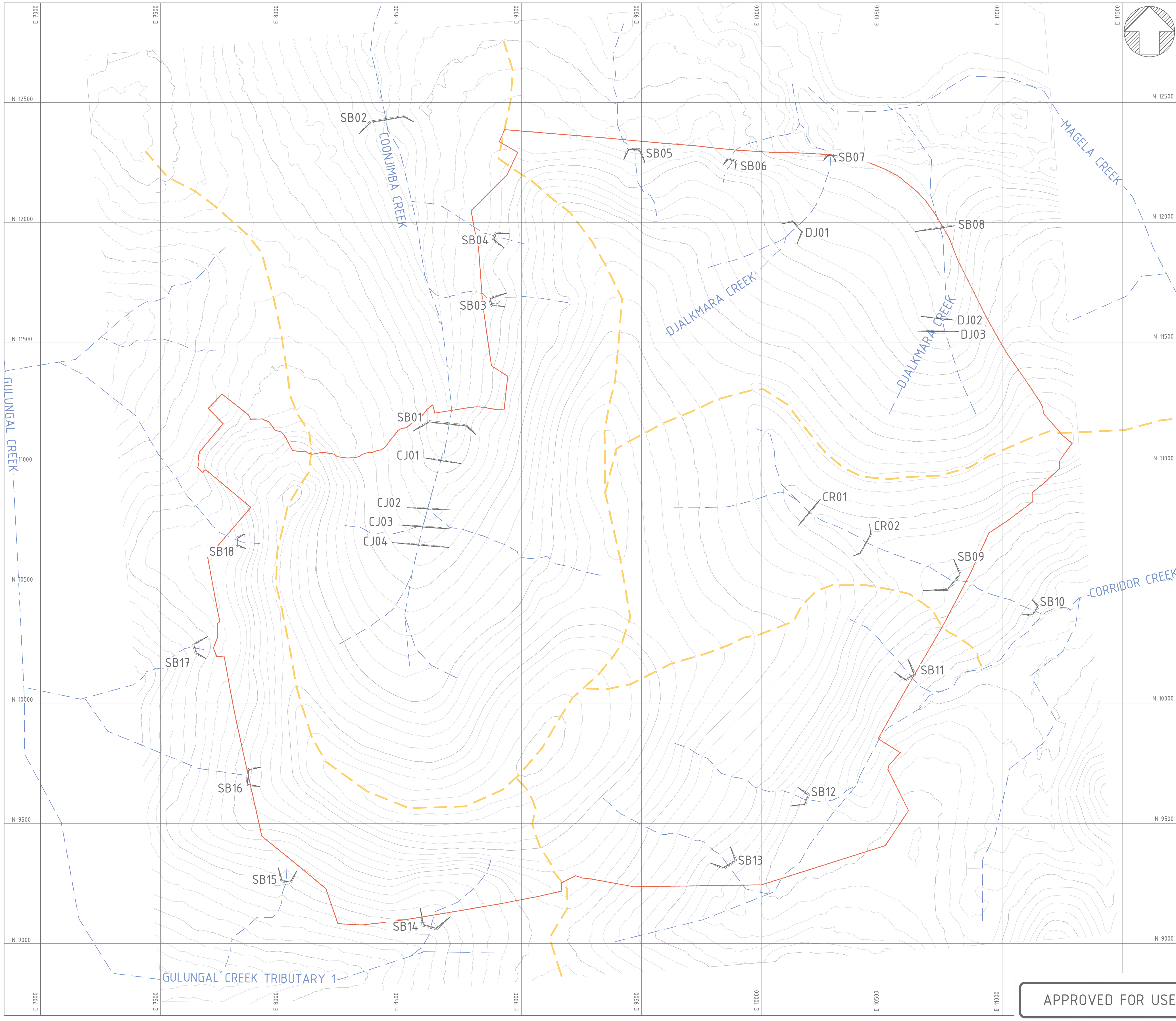
TABLE 2 – ENVIRONMENTAL ROCK BARS

ID	DESCRIPTION	STORAGE AREA* (m^2)	STORAGE VOLUME* (m^3)	(W) WEIR SPILLWAY WIDTH (m)	(C) CREST LENGTH (m)
1	CR01	5292	2381	4075	143
2	CR02	25742	10157	20	163
3	CJ01	5128	1511	20	158
4	CJ02	9042	2810	20	183
5	CJ03	10479	3324	20	215
6	CJ04	12294	3811	20	237
7	DJ01	4083	1452	40	160
8	DJ02	4862	1399	20	136
9	DJ03	5698	1583	50	173

*ALL ENVIRONMENTAL BARS ARE 0.8M HIGH AT CENTRE. BASIN AREA AND STORAGE VALUES ARE THEORETICAL AS STRUCTURES DESIGNED AS LEAKY ROCK WALL (PERMEABLE).

LEGEND

- CATCHMENTS POST 2020
- GULLY FLOWS
- CONTOURS MAJOR (5m INTERVALS)
- CONTOURS MINOR (1m INTERVALS)
- EXTENT OF WORKS BOUNDARY
- SB01 SEDIMENT BASINS (SB)
- CJ01 ENVIRONMENTAL ROCK BARS



0 150 300 450 600 750m
SCALE: 1:7500 @B1

APPROVED FOR USE

CATCHMENT PLAN – FINAL LANDFORM

SCALE 1:7500

SUBJECT TO FINAL VERIFICATION AND APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

DRG. NO.	REFERENCE DRAWING DESCRIPTION

NOTES

This drawing was prepared for the exclusive use of Energy Resources Australia Ltd. ABN 71 008 550 865 ("Client") and is issued pursuant to contracts between Client and Hatch Pty Ltd ABN 59 008 630 500 ("Hatch").

Unless otherwise agreed in writing with Client or specified in this drawing, (a) Hatch does not accept and disclaims any and all liability or responsibility arising from any use of or reliance on this drawing by any third party or any modification or misuse of this drawing by Client, and (b) this drawing is confidential and all intellectual property rights embodied or referenced in this drawing remain the property of Hatch.

HATCH

REV.	DESCRIPTION	BY	CKD.	APP.	DATE
2	APPROVED FOR USE	PK	PDB	DB	06/02/19
1	APPROVED FOR USE	PK	PDB	DB	17/12/18
0	APPROVED FOR USE	LZ	PDB	DB	21/06/18

EQUIPMENT NUMBERS

SCALE 1:7500

THIRD ANGLE PROJECTION

DESIGN	JJT	21/06/18
DRAWN	LZ	21/06/18
ENG'EER CKD.	PDB	06/02/19
CLIENT APPR'D	SG	06/02/19
SUP'T APPR'D		

CONTRACTOR DWG. NUMBER H355334-00000-220-290-0048

RIO TINTO DWG. NUMBER CDM.03-0000-EC-DWG-00067

ERA

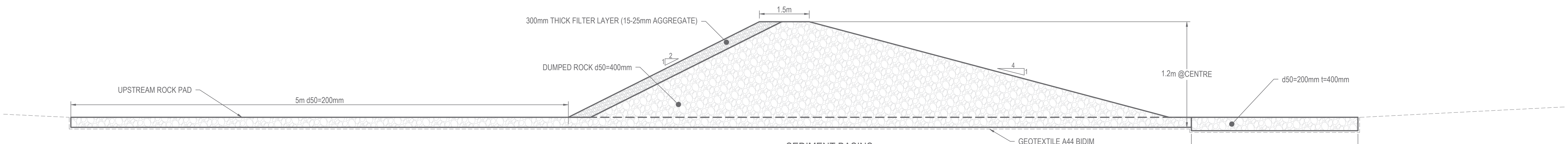
PLANT AREA: AREA 91 – CLOSURE STRATEGY

TITLE: GENERAL – AREA 00
CATCHMENT PLAN
FINAL LANDFORM

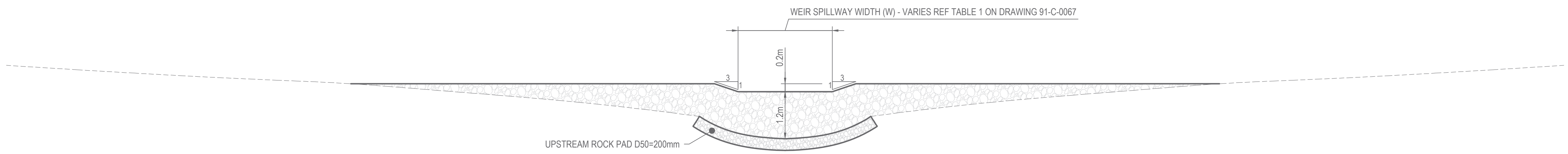
SHEET SIZE	PROJ/WORK ORDER NO.	AREA	DISC.	DRAWING	REV
B1		91	C	0067	2

IF IN DOUBT – ASK!　　DO NOT SCALE　　IF IN DOUBT – ASK!

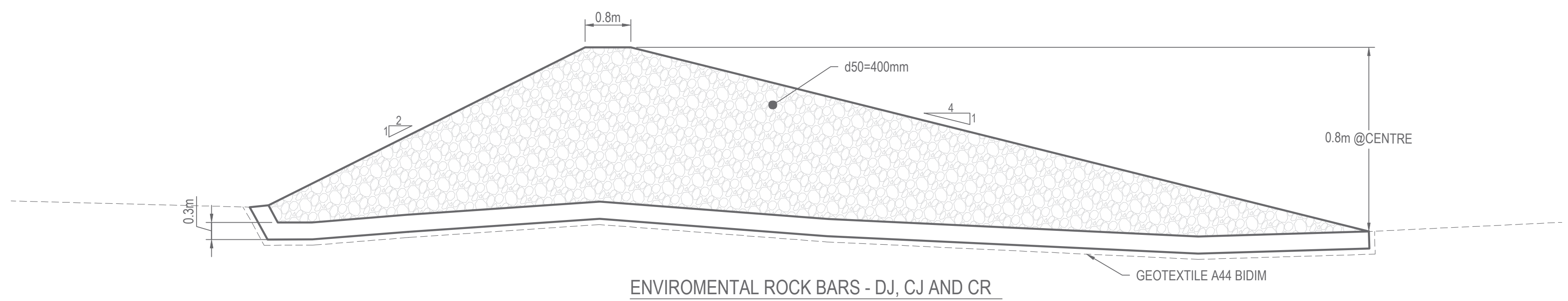
DWG No. H355334-00000-220-273-0034



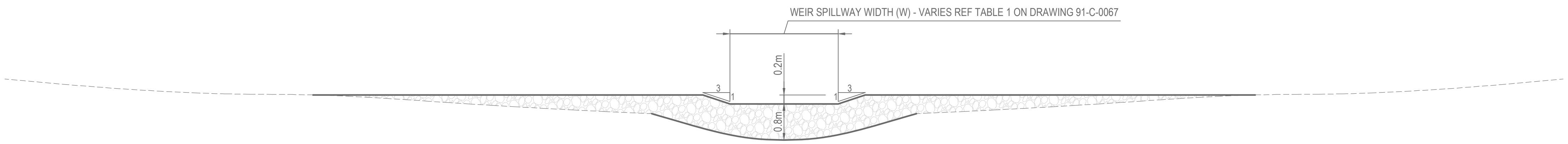
SEDIMENT BASINS
N.T.S



LONG SECTION - SEDIMENT BASINS
N.T.S



ENVIROMENTAL ROCK BARS - DJ, CJ AND CR
N.T.S



LONG SECTION - ENVIROMENTAL ROCK BARS
N.T.S

NOTES:
1. ALL WORKS REQUIRE 300mm STRIPPING AND FOUNDATION PREPARATION.
2. DESIGN SURFACES BASED ON PROVIDED SURVEY. LEVELS SHOULD BE CONFIRMED ON SITE.

APPROVED FOR USE

SUBJECT TO FINAL VERIFICATION AND APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

DRG. NO.	REFERENCE DRAWING DESCRIPTION

NOTES

HATCH

REV.	DESCRIPTION	BY	CKD.	APP.	DATE
1	APPROVED FOR USE	PK	PDB	DB	06/02/19
0	APPROVED FOR USE	LZ	PDB	DB	21/06/18

EQUIPMENT NUMBERS

SCALE AS NOTED

THIRD ANGLE PROJECTION

DESIGN	JJT	21/06/18
DRAWN	LZ	21/06/18
ENG'EER CKD.	PDB	06/02/19
CLIENT APPR'D	SG	06/02/19
SUP'T APPR'D		

CONTRACTOR DWG. NUMBER: H355334-00000-220-273-0034

RIO TINTO DWG. NUMBER: CDM.03-0000-EC-DWG-00071

ERA

PLANT AREA: AREA 91 – CLOSURE STRATEGY

TITLE: ENVIROMENTAL ROCK BARS & INTREAM CHECK DAMS SECTION DETAILS

SHEET SIZE	PROJ/WORK ORDER NO.	AREA	DISC.	DRAWING	REV
B1	.	91	C	0071	1

P:\ERA\355334\CAD\220\01 Drawings\H355334-00000-220-273-0034.dwg 14:52:04, 06.02.2019

APPENDIX 9.2 HAZARDOUS MATERIAL AND CONTAMINATION CONTROL PLAN

Hazardous Material and Contamination Control Plan HMP001

Approvals

	Name	Position	Signed	Date
Originator	Anthony Cullen	Advisor Environment	A.Cullen	04/04/2019
Checked	Peter Lander	Environment Superintendent	P.Lander	04/04/2019
Approved	Julie Crawford	Manager HSEC	J.Crawford	04/04/2019

Revisions

	Date	Description	By	Check	Approved
0.14.0	28/05/14	Internal Distribution	M Bush	P Lander	T Simms
1.16.0	22/06/16	Major review – incorporate revised RT Environment and Health Standards	A Lonergan/A Reid	P Lander	S Miller
0.19.1	05/02/19	Minor review	A Cullen	P Lander	J Crawford

Contents

Figures

1. Purpose

The purpose of this plan is to ensure the safe and responsible use, storage, transport, disposal and control of all hazardous materials handled by Energy Resources of Australia Ltd (ERA).

The purpose of this is also to ensure that contaminated sites are appropriately characterized and managed in accordance with the Rio Tinto Environmental Standards. A range of standard operating procedures have been developed that relate to specific aspects of hazardous materials and contamination management. This plan provides the overarching strategy for hazardous materials and contamination management on ERA managed lands.

2. Scope

This plan applies to all ERA managed lands including but not limited to Ranger Uranium Mine (Ranger). It covers the management of hazardous materials through mine life from exploration, construction and operation to closure. This document also includes the evaluation and approval through storage, transport and disposal of hazardous materials as well as prevention and remediation of contamination. Asbestos is addressed separately in ERW103 Asbestos and Non-Asbestos Fibrous Silicates Management Work Instruction and radiation hazards are addressed in RAP001 Radiation Management Plan.

3. Planning

3.1 Objectives and Targets

The objective of hazardous material and contamination control at Ranger is to eliminate, as far as practicable, high risk chemicals and hazardous substances used at ERA.

To support achievement of this objective, ERA will target reviews (e.g. periodic audits) of stockholdings and storage of high risk chemicals and hazardous substances with a view to eliminating and/or reducing high risk chemicals and hazardous substances where practicable.

3.2 Legal and Other Requirements

ERA has a COR001 Compliance Obligations Register in order to identify and record all compliance, conformance and other legal obligations imposed by environment, safety and health legislation applicable to ERA's operations. The ERS002 Compliance Standard together with ERW002 Compliance Work Instruction provide details in relation to the identification of legal requirements, the maintenance of legal information and also the means by which employees seek legal information.

Management of hazardous materials and contamination on ERA managed lands must be in compliance with the requirements of Schedule 6 Other Services, Operations and Requirements of the most up-to-date version of Ranger Authorisation 0108. Corporate legal and regulatory requirements for hazardous materials and contamination management exist in the following documents:

Rio Tinto - The Way We Work

Rio Tinto HSE Performance Standards - Environment

Rio Tinto HSE Performance Standards - Health

Rio Tinto Closure Standard

ERA Environment Policy

3.2.1 Auditing

The Hazardous Materials and Contamination Control Plan and its implementation are subject to periodic audits via Rio Tinto Business Conformance Audit and other audit internal and external processes.

In accordance with the Rio Tinto Health Performance Standard H1 – 'Chemicals and hazardous substances exposure control', written procedures for the use, storage and disposal of hazardous substances with a health, safety or environment risk classification of critical must exist and must be internally audited at least annually. Also, through the Departmental HSE representatives and the relevant RT Health Standard Team, ERA also undertakes periodic inspections of hazardous substances storage areas throughout the year. The purpose of these audits and inspections is to reconcile stock holdings and storage locations and to monitor for conformance to the Standard.

4. Hazardous Material Management

The overarching document relating to risk management at ERA is ERS003 Hazard Identification and Risk Management. ERS057 ERA Standard Hazardous Substances outlines the process for purchasing, handling, storage, use and disposal of chemical substances and other hazardous substances, and the roles and responsibilities relevant to this. The HSEQ Risk Register includes several risks relating to hazardous materials.

4.1 Approval for New Hazardous Materials

Introduction of a new hazardous substance to ERA is controlled by standard operating procedure ERW022 Introduction of a New Chemical to ERA. This procedure ensures the Safety Data Sheet (SDS) is obtained and the hazardous substance is assessed and relevant controls applied prior to introduction to a work area. Such controls may include, subject to risk, hazardous substances and/or spill response training, for example.

ERA's chemical management system ChemAlert is used to register and record details of new hazardous substances once approved for use in a work area. If ChemAlert rates a substance as amber or red, a risk assessment must be completed using the Risk Assessment module on ChemAlert. A new chemical request form (F0096) must be completed for the introduction of a new hazardous substance to a work area. The form must be accompanied by the current SDS for the product and a completed risk assessment (where applicable) for review by the Hazardous Substances Coordinator.

4.2 Hazardous Materials Inventory

ERA maintains the Hazardous Substances Register within ChemAlert. SDS's for each product stored and used on site can be sourced through ChemAlert. All employees and contractors (through ERA work supervisors) can access ChemAlert via ERAs intranet. Hardcopies of SDS's are available at point of use at Ranger and Energy House Darwin.

4.3 Handling, Storage and Transport of Hazardous Materials

Employee exposure to hazardous substances and their associated potential impacts to the environment should be eliminated or minimised through the appropriate application of the hierarchy of controls. Risks and control measures associated with the use of hazardous materials have been identified and documented in ERAs Risk Register in accordance with ERS003 HSEQ Hazard Identification and Risk Management.

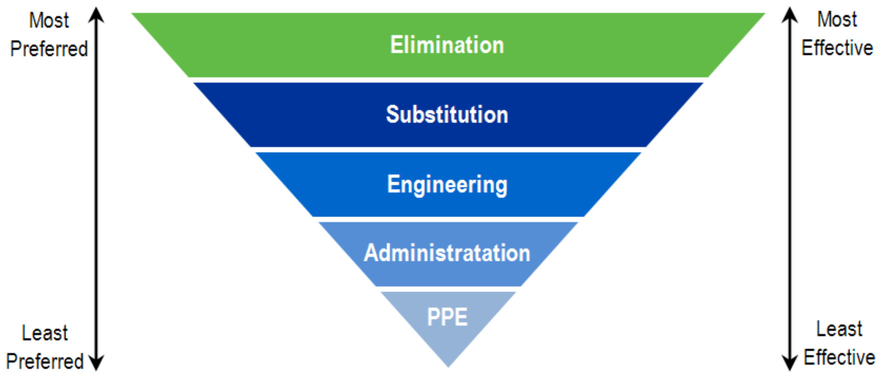


Figure 1: Hierarchy of Controls

It is the responsibility of the department and work area handling and storing a hazardous material to ensure all materials are managed and stored in accordance with the SDS for that material. The labelling, storage and segregation of hazardous materials shall be in full compliance with all relevant legislative requirements and codes of practice.

The ChemAlert system identifies where each material is stored and ERS057 Appendix A Segregation of Dangerous Goods details segregation requirements for dangerous goods. Hazardous materials shall be stored in bunded areas with secondary containment mechanisms, and bunding shall comply with the relevant Australian and Rio Tinto Standards.

4.4 Disposal of Hazardous Materials

Each department is responsible for disposing of chemicals produced by normal process activities and those which may arise from accidental leaks or spillage in their work area. ERP028 Off-Site Hazardous Substance Disposal Procedure outlines the process for disposing of a chemical substance at ERA. Most hazardous substances are disposed of off-site via a Licensed Waste Handler (i.e. a business licensed under the Waste Management and Pollution Control Act).

Hazardous substances which have been stored, used or generated in a controlled area or which fail a radiation clearance must be stored or disposed of on-site. All hazardous materials to be removed from site shall be dispatched through the warehouse. The warehouse dispatch process ensures relevant ERA and legal requirements are complied with. A Waste Transport Certificate must be completed for any transport of hazardous waste off-site. Environment Department approval is required for on-site disposal of hazardous substances (via EVF045).

4.5 Emergency Response Measures

In the event of a spill or incident involving a hazardous material, ERA standard operating procedure SFP030 Responding to Emergencies shall be followed. The procedure provides specific guidance for incidents with a serious threat to people, the environment or property. Emergency drills for HAZMAT incidents are carried out by the Emergency Response Team (ERT).

In the event of a spill or other incident requiring Emergency Response, the incident reporter must contact Emergency Services by dialling 222 from a Cisco phone. The Business Resilience and Response Plan (BRRP) has been established to coordinate the sites' response to emergency situations.

The Emergency Response Plan (Ranger) describes the tasks for specific roles in the event of a HAZMAT incident both on and offsite. Annual BRRP exercises are conducted to ensure that the BRRP continues to meet the sites' business requirements and legal obligations. After the occurrence of an emergency incident where the BRRP has been invoked, ERA debriefs the involved teams and action is taken to improve the efficiency and appropriateness of the BRRP.

4.6 Training

An overview of hazardous substance management at ERA is provided as part of the general induction (online, occupational health and environment inductions) that is required for all employees and contractors to complete. Training on managing hazardous substances at ERA is available as a web-based course for employees and contractors. ERA training co-ordinators can advise on role specific training in chemical and hazardous material management.

5. Contamination Control Management

5.1 Contaminated Site Assessment

Site investigations have been undertaken to assess soil and groundwater contamination in the Ranger processing plant area. The findings of these investigations have been used to develop a risk assessment of relevant sites following AS/NZS4360 Risk Management and National Environmental Protection Council (NEPC) guidelines. These investigations and risk assessments contribute to development of remediation strategies for closure.

The Closure Criteria Working Group (CCWG) has been established as a working group of the Ranger Mine site Technical Committee (MTC). Progress towards establishing closure criteria for Ranger mine is tracked through discussion and negotiations with stakeholders and is supported by ongoing research from both ERA and the Environmental Research Institute of the Supervising Scientist (ERISS). Research and monitoring related to the key knowledge needs associated with closure planning is reviewed by the Alligator Rivers Region Technical Committee (ARRTC). Final landforms are required to be constructed such that wastes will be securely contained to provide long-term protection of human health and the environment, as per the Ranger Authorisation.

ERA currently conditionally adopts criteria presented in the National Environmental Protection Measure (NEPM) Assessment of Site Contamination for the purpose of providing guidance on contaminated site investigation matters on a day to day basis only. The conditions on which the adopted NEPM Assessment of Site Contamination criteria is subject to include:

- The adopted criteria is interim only, secondary to and will be replaced by the Ranger mine closure criteria once approved by the MTC;
- The purpose of the adopted NEPM Assessment of Site Contamination criteria is to provide day to day guidance on matters relating to the assessment of site contamination only (for example, assessment and verification of the suitability of bio-remediated hydrocarbon impacted soil) in the absence of and until Ranger mine closure criteria are established and approved;
- The adopted NEPM Assessment of Site Contamination criteria will not be used for ERA Ranger mine site closure, closure planning, treatment and or remediation of potential or actual site contamination;
- Closure criteria approved by the MTC will be those applied to assess the adequacy of site closure, contribute to closure planning and for treatment and or remediation of potential or actual site contamination.

5.2 Contaminated Sites Register

The Contaminated Sites Register identifies all sites (including Jabiluka and Djarr Djarr) that have supported land use activity having the potential to contaminate land. The Contaminated Site Register is warehoused in GIS format and includes, but is not limited to, information on the location, land use activity, potential contaminants and risk. The register is maintained by the Environment Team.

Allowance has been made in the Ranger Mine Closure Plan for the investigation and remediation of sites identified as having potential or actual contamination. Notwithstanding this, in the event actual contamination is identified that is assessed as posing potential to harm the surrounding environment or human health, ERA shall consider containment, mitigation and/or remedial measures to manage the risk.

5.3 Remediation of Contaminated Sites

Remediation of contaminated sites may occur as progressive rehabilitation throughout the remaining life of operations at Ranger, or be addressed through the closure process. The CCWG has agreed that closure criteria will be developed under six themes:

- Landform
- Radiation
- Water and sediment
- Flora and fauna
- Soils
- Cultural

Where appropriate, closure criteria from each theme will be applied to remediation of contaminated sites as per the contaminated sites register as well as to guide closure across Ranger.

5.4 Prevention

Prevention of contamination on site is managed through (but not limited to):

- Assessment of alternative substances through the chemical approval process;
- Bunding of relevant materials to relevant standards;
- Integrity inspections for relevant under and above ground tanks and pipelines;
- Condition monitoring and housekeeping inspections to detect leaks / cracks;
- Preventative maintenance on equipment;
- Groundwater monitoring;
- Incident / spill response and clean up;
- Stock reconciliation;
- Standard operating procedures for hazardous substances and associated tasks;
- Informing all workers at ERA of their requirements with respect to managing hazardous substances, reporting spills and incident response / clean up.

5.5 Containment Systems

ERA has a suite of standard operating procedures relating to the management of hazardous substances. Hazardous material containment is addressed (but not limited to) the following documents:

- AS1940 Storage and handling of flammable and combustible liquids
- ERP003 Waste Hydrocarbon Disposal Procedure
- ERS057 ERA Standard Hazardous Substances

Secondary containment systems are also in place at locations where there is a higher risk of hydrocarbon / process spills or leaks. These locations include but are not limited to the bulk diesel tanks, sulphuric acid tanks, powerstation diesel day tanks, warehouse product and waste oil tanks, acid leach tanks, CCD's, tailings pump station, tailings and brine pipelines and the sand filters.

Containment valves must be locked in the closed position except under supervision when opened to release clean storm water. It is noted that any storm water that has accumulated in a controlled area is managed as pond or process water as appropriate.

Relevant work area owners are responsible for routine and non-routine inspections and maintenance of containment systems (including bunds) to ensure:

- Containment systems are free from product spillage;
- Storm water is identified and removed to ensure adequate containment capacity is maintained; and
- Containment systems are competent and fit for intended purpose.

5.6 Monitoring

Groundwater monitoring is conducted on site through targeted routine bore monitoring programs. As additional bores are installed on site they are incorporated into the programs. Groundwater monitoring is undertaken by the Water Management team, who are also custodians of the data obtained from the monitoring program.

5.7 Third Party Transport and Disposal

The third party transport of hazardous substances is managed through a services contract which allows ERA to competently apply controls to manage the associated risks. Transport providers and any waste receivers and/or disposers shall be appropriately licensed to transport and receive such waste.

It is noted that the interstate movement of hazardous wastes may trigger the need for additional State & Federal government approvals including but not limited to the National Environmental Protection (Movement of Controlled Waste between States and Territories) Measure.

Uranium oxide produced at Ranger is transported from site by road. The requirements for transport and incident response in the event of a spill are addressed in the UTP001 ERA UOC Transport Plan. Compliance with the requirements of the aforementioned document exceeds current statutory requirements.

6. Spill Response and Incident Reporting

6.1 Spill Response

ERA procedure MTP007 Hydrocarbon Spill Clean-Up details the guidelines and procedures for spills of different materials. Spill response kits (yellow bins labelled 'spill kit') containing the appropriate spill response equipment are available for requisition through Stores. Spill kits shall be readily available at those locations where spills have a likelihood to occur, such as at fuel bowsers, workshops and transfer points. Each work area is responsible for ensuring that their spill kit is maintained and re-stocked.

Contaminated spill kit materials shall be recovered and disposed of as per ERP003 Waste Hydrocarbon Disposal procedure.

The Ranger Environment induction outlines the requirements for every worker for spill response and clean up.

6.2 Incident Reporting

Environmental incidents are reported to regulatory authorities in accordance with Section 29 of the Mining Management Act and via the monthly Environmental Incident Report.

Health, Safety and Environment incidents are managed through the Rio Tinto Business Solution in accordance with ERS014 Non-Conformance Incident and Action Management Standard. Reporting an incident via this system requires information about spilled volume, response action and recovered volume where practicable.

Complaints are considered an incident and must be reported as above. In the event of an incident or complaint, an investigation is conducted to determine the root causes and to determine if additional controls are required.

7. Hazard Reduction

ERA shall pursue the reduction of hazardous substance use in the workplace and endeavour to substitute less hazardous substances where practicable. ERA regularly reviews the hazardous substances inventory and practical application purposes to identify redundant chemicals along with recommendations to seek alternate non-hazardous substances or less hazardous substances where practicable. Form F0096 New Chemical Request, along with work instruction ERW022, assesses the environmental risk of hazardous substances and details controls required to reduce hazards during the use, storage and transportation of the hazardous materials.

8. Accountabilities

Role / Title	Responsibility
General Managers	• Ensure adequate resources are allocated to departments to facilitate compliance with the Hazardous Materials and Contamination Control Plan (the Plan).
Department Managers	• Maintain the requirements of the Plan and all associated procedures. • Ensure employees and contractors are appropriately trained in the correct methods for handling and storage of hazardous materials. • Ensure that onsite storage facilities are inspected and maintained and inventories are kept up to date.
Manager HSE & Communities	• Ensure that ERA implements and maintains the requirements of the Plan and all associated procedures. • Ensure the Plan is regularly audited and reviewed according to Rio Tinto Standard E15.
H&S Advisor	• Maintain the HSEMS risk register, including items related to hazardous materials
Environment Team	• Provision of environmental advice relating to new hazardous substances, spills and clean up • Periodically review and maintain the Contaminated Sites Register • Assessment of requests to dispose of chemicals off site
Environment Superintendent	• Ensure the Plan and associated procedures are reviewed and maintained at periodic intervals. • Periodically review hazardous waste transporters and receivers.
Hazardous Substances Coordinator	• Ensure the Hazardous Substances Register is maintained and SDS' are available for all substances on ChemAlert. • Assessment of requests for new chemicals and hazardous substances.
ERA Company Rep	• Ensure contractors comply with the Hazardous Materials and Contamination Control Plan and all associated standard operating procedures and other associated documents.
Document Controller	• Maintain authorised system procedures, department procedures and other related documentation on the ERA drive • Ensure that the most recent issues of the documentation are available.

Role / Title	Responsibility
All ERA Employees and Contractors	• Adhere to the requirements of the Plan and all associated procedures. Specifically: ○ Follow approvals process for bringing new hazardous substances to site, or to a new work area ○ Refer to and understand Safety Data Sheets (SDS') when handling hazardous materials ○ Participate in induction and training programs ○ Wear personal protective equipment (PPE) provided, as specified ○ Assist in audits as required ○ Comply with the guidelines set out in this plan ○ Comply with ERA and regulatory requirements for spill response, clean up and reporting.

9. Review

The Hazardous Materials and Contamination Control Plan will be reviewed and updated no later than every three years from the date of last review. A review may occur sooner consequent to a material change in risk, legal requirements or an incident relevant to hazardous materials management.