Former Rum Jungle Mine Site; Detailed Civil Works Design for Rehabilitation - Design Report

22 June 2016

Northern Territory Government

O'Kane Consultants

Integrated Mine Waste Management and Closure Services
Specialists in Geochemistry and Unsaturated Zone Hydrology

Former Rum Jungle Mine Site; Detailed Civil Works Design for Rehabilitation - Design Report

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Prepared for:

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EXECUTIVE SUMMARY

The former Rum Jungle Mine site (Rum Jungle) is located 105 km south of Darwin in the Northern Territory. The mine was active at various times between 1953 and 1971, with ores mined including uranium, copper, nickel and lead. Substantial environmental effects have developed, both within and downstream of the site, primarily from the long-term generation of acid and metalliferous drainage (AMD).

In 2009 the Commonwealth and Northern Territory Governments entered into a four-year National Partnership Agreement on the management of the former Rum Jungle Mine site (Stage 1). This agreement is accompanied by an Implementation Plan (IP), managed by the Northern Territory Department of Mines and Energy (DME) with technical input from the Rum Jungle Working Group (RJWG).

Following completion of Stage 1, the Commonwealth and Northern Territory governments entered into a new Project Agreement for the Management of the Former Rum Jungle Mine Site (Stage 2).

The DME is responsible for site maintenance, environmental monitoring and investigations to inform the development of the preferred rehabilitation strategy by mid-2016

Rehabilitation Success:

The vision of success is to restore Rum Jungle so that it can be freely accessed by adopting leading practice rehabilitation to reduce the impacts of Acid and Metalliferous Drainage (AMD) on site with authentic consultation. Hence, rehabilitation planning for Rum Jungle has not just focussed on the technical rehabilitation project but has also sought to acknowledge and embrace traditional cultural and environmental knowledge.

As a result, successful rehabilitation must certainly include “typical” AMD rehabilitation “measurable drivers”, such as water quality and flow; however, rehabilitation success at Rum Jungle is also defined by other drivers such as seeing and feeling that balance and harmony for the people has been restored with their land and their environment.

Rehabilitation Objectives:

The detailed design contained herein for Rum Jungle represents the culmination of all tasks in Stages 1 and 2.

The rehabilitation objectives developed during Stage 1 of the project are that the project:

- Is safe for people and wildlife;
- Is chemically, radiologically, and physically stable;
- Has a significantly reduced contaminant load (associated with AMD) beyond the boundaries of the site; and,
- Supports sustainable land uses by traditional Aboriginal owners of the area with few, if any, limitations.

The aforementioned objectives provided the framework and guidance for the detailed civil works design including the environmental outcomes to be achieved. The environmental outcomes are a statement of the acceptable impact on the environment caused by the rehabilitation. In consultation with DME and stakeholders, the Project Team defined key parameters for rehabilitation at Rum Jungle and defined closure performance criteria specific to the achievement of specified environmental outcomes on which this detailed design will be evaluated against once it is constructed.

Summary of Works

The design and programme of civil works has been developed to achieve the rehabilitation outcomes, comprising:

- Upgrade of site access to enable works, which includes the intersection with Litchfield Road, provision of a new access ramp to Main Pit and establishment of site wide light vehicle (LV) and haul roads;
- Commissioning of buildings and services required to undertake the rehabilitation activities;
- Dredging and dewatering of previously disposed tailings from Main Pit;
- Bulk earthworks to relocate AMD generating waste from existing site waste rock dumps (WRDs) to Main Pit, below the water table. Waste rock dumps will be removed below the pre-mine surface level to remove AMD affected soils under the WRDs. A 'mounded' landform will be constructed from clean imported fill over the Main Pit footprint which will form the part of the re-alignment of the East Branch of the Finniss River;
- Bulk earthworks to excavate and dispose various sources of AMD from around site including old tailings, Dysons Pit, the old stockpile areas, copper extraction area, and miscellaneous areas of contamination.
- Bulk earthworks to manage potential AMD generating waste from the Mt Burton and Mt Fitch;
- Bulk earthworks for the construction of a new waste storage facility (WSF) from the excess waste that cannot be accommodated in Main Pit. The WSF is to be located in the north of the site;
- Commissioning of the Finniss River Land Trust (FRLT) borrow area located east of the Rum Jungle site. The borrow area will supply all required clay and growth medium for rehabilitation initiatives;
- Construction of drainage features for construction phase water management, including flood prevention levees and diversion drainage;
- Construction of the final East Branch River geometry, which is intended to emulate surrounding flow regimes and emulate the pre-mine surface water flow as far as practicable, and in accordance with rehabilitation objectives; and
- Decommissioning of unwanted roads and supporting infrastructure.

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1 REPORT ORGANISATION

For convenient reference, this report has been subdivided into the following sections:

- Section 2 – provides context, site history and rehabilitation
- Section 3 – details aspects relating to implementation success
- Section 4 – provides an overview of design elements
- Section 5 -- documents the detailed design approach and technical data informing the design of each domain
- Section 6 – provides detailed design visualisations
- Section 7 – provides materials volumes and movements
- Section 8 – provides the overall rehabilitation schedule
- Section 9 – Provides a discussion of costs

Tables and figures referenced hereinafter are located in the main body of this document.

2 SITE HISTORY AND REHABILITATION

2.1 Site Climate and Setting

The region in which the former Rum Jungle site is situated is characterised by a tropical climate and receives approximately 1500 mm of annual rainfall (BOM, 2012a). More than 90 per cent of the rainfall occurs during a distinct wet season that lasts from November to April. No substantial rainfall occurs from May to October. It is not uncommon to receive rainfall volumes of more than several hundred millimetres a day during monsoons or tropical lows.

Mean monthly maximum temperatures at the Batchelor Airport range from 31.2°C in June to 36.8°C in October, during the period leading up to the wet season.

Rum Jungle is also located in the tropical savannah region of Australia. Tropical savannah climates have monthly mean temperature above 18°C in every month of the year and a pronounced dry season. Tropical savannah is distinguished from the tropical rainforest (monsoonal) climate by the dryness of the driest month.

Vegetation surrounding the site is savannah woodlands, comprising primarily various Eucalypt species, shrubs, and grasses.

2.2 Previous Rehabilitation Activities

In the early 1970s, the significant environmental effects of the mining activities and the resulting pollution of the East Branch of the Finniss River, primarily caused by AMD, were recognised in correspondence between the Australian Atomic Energy Commission and the Northern Territory Administration (National Archives of Australia, 1962/1824). The Commonwealth Government initiated an aesthetic clean-up of the mine site in 1977. The government also formed a Rum Jungle Working Group to develop rehabilitation options for the site. The outcome of this technical assessment and planning effort was a four-year rehabilitation project funded by the Commonwealth Government and undertaken from 1982 to 1986. The total cost was $18.6 million, the major proportion of which was spent treating highly contaminated water in the Main Pit (Allen & Verhoeven 1986). The Final Project Report provided by Allen and Verhoeven (1986) provided a full description of the remediation project, including the rationale for the rehabilitation and the results of preliminary monitoring.

The rehabilitated site was considered to have successfully achieved its set engineering and environmental criteria, based on the results of a 12-year monitoring program undertaken between 1986 and 1998 funded jointly by the Commonwealth and Northern Territory Governments (Pidsley et al., 2002). The rehabilitation of Rum Jungle was recognised as being world-leading practice at the time, especially the installation of a multi-layer cover system. Cover system design and construction technologies were then in their infancy, so the site attracted international attention as one of the first implementations of a cover system for remediation of sulfidic waste rock dumps (DME, 2013).

According to Allen and Verhoeven (1986), the objectives of the Rum Jungle Rehabilitation Project were to:

1. Achieve a major reduction in surface water pollution, aimed at reducing the average quantities of copper by 70 per cent; reduce average quantities of zinc by 70 per cent, and reduce average quantities of manganese by 56 per cent as measured at the confluence of the East Branch and the Finniss River.

2. Reduce pollution levels in the Main and Intermediate pits.

3. Reduce public health hazards, including radiation levels at the site to at least the standards set by the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (Commonwealth of Australia, 1980).

4. Implement aesthetic improvements, including revegetation.

Four primary rehabilitation treatments were undertaken:

1. A three-layer cover system was constructed over the waste rock dumps to reduce infiltration to less than five per cent of annual rainfall. The waste rock dumps were also reshaped and drainage structures installed to mitigate erosion and maintain the integrity of the vegetation cover. A mix of introduced pasture species and legumes were used for rapid revegetation. Grass cover was the specified re-vegetation condition for the waste rock dumps.

2. A water treatment plant was constructed to treat heavily contaminated water from the Main Pit. Water was withdrawn from depth, with lower density treated water returned to the surface of the pit where it formed a layer of clean water overlying the untreated water at depth. Water in the Intermediate pit was treated in-situ with lime to remove heavy metals and neutralise pH. Wet season flows were then re-instated through both pits so that the system would be flushed each wet season. Based on the results from limnological modelling, it was anticipated that this process would slowly cleanse the contaminated water that remained at depth in the pits by a combination of seasonal partial vertical mixing and wet-season flushing of the surface layers. Filter cake from the water treatment process was buried in Borrow Area 5, to the north of the site and capped with a three-layer cover system.

3. Dysons pit was partially backfilled with tailings from the tailings area and Tailings Creek. The surface of the tailings was covered with a coarse geotextile and a nominally one-metre thick rock blanket drainage layer. The drainage layer was overlain with low-grade copper ore, copper launders from the copper extraction pad, and contaminated soils from both sites. A moisture barrier, a moisture retention zone, and an erosion-resistant cover were installed on top and the final surface was revegetated in the same way as the waste rock dumps.

4. After the tailings were removed to Dysons pit, the tailings area footprint was reshaped to control drainage, limed, and covered with a one-layer soil cover system to enable revegetation with introduced pasture species and native trees and shrubs.

A sub-surface drainage system and a four-layer cover system were also installed over the copper extraction pad area to address residual surface and sub-surface contamination. The surface was revegetated in the same way as the waste rock dumps (DME, 2013).

2.3 Lessons learnt from previous rehabilitation

The results from the 1993 to 1998 monitoring period conclude that the rehabilitation objectives, ‘reflected contemporary thinking in mine site rehabilitation and were considered appropriate and practical considering the scope of the problems to be dealt with and the level of resources available’ (Kraatz, 2002). Monitoring identified that all four key objectives were successfully achieved (Kraatz and Applegate, 1992; Kraatz, 1998; Pidsley, 2002). However, this work did not result in a final condition for the site that would meet contemporary water quality standards. In addition, the works were completed without any input from the sites traditional Aboriginal owners.

Richards, Applegate, and Ritchies (1996, as cited in Kraatz, 2004) observed that the treatments were focused on water quality improvements and ‘compromise(s) were made on other lesser objectives in order to prolong the life of pollution control structures’. For example, the rapid establishment of vegetation and prevention of erosion using introduced pastures overrode the original intention to maintain similar vegetation to the surrounding environment (DME 2013).

Apart from significant changes that have occurred in rehabilitation standards and practice over the last thirty years, there is sufficient anecdotal and documentary evidence to suggest that certain factors affected the implementation of the rehabilitation program as it was originally conceived. These factors included budgetary overruns and inconsistent adherence to design criteria, especially in construction and quality control for the covers over the waste rock dumps (for example a 0.2 m clay layer was placed on the Main waste rock dump when the design thickness was 0.5 m). Significant budget overruns in the early stages of the program substantially affected on the remaining budget and the ability to complete the rehabilitation program as it was originally intended (DME, 2013).

Subsequent monitoring has identified ongoing site management issues relating to wildfires, weeds, feral animals, and control of access by the public. These issues largely resulted from an extended interruption to funding after 1998 despite recommendations in the final monitoring report that site maintenance activities should continue in relation to weed and fire management and erosion control (Pidsley, 2002).

Cessation of weed management and invasion by gamba grass (*Andropogon gayanus*), with a subsequent substantial increase in fire risk (and intensity when a fire occurs), resulted in general degradation of vegetation diversity, and subsequent erosion of waste rock covers (DME, 2013).

2.4 Current Rehabilitation Planning

In 2009 the Commonwealth and Northern Territory (NT) government entered into a four-year National Partnership Agreement on the management of the former Rum Jungle Mine site, which is referred to as Stage 1. This agreement was accompanied by an Implementation Plan (IP), managed by DME with technical input from the Rum Jungle Working Group (RJWG).

Stage 1 comprised investigations and development of the site-wide rehabilitation requirements, culminating in the Conceptual Rehabilitation Plan (CRP), completed in May 2013. The plan summarised the current condition of the site, presented case studies of examples of leading practice of rehabilitation worldwide, and identified the preferred rehabilitation strategy.

Following completion of Stage 1, the Commonwealth and NT governments entered into a new Project Agreement for the Management of the Former Rum Jungle Mine Site, referred to as Stage 2, which involved detailed design. In order to progress the preferred rehabilitation strategy from concept to detailed design phase, a series of multi-disciplinary technical investigations including numerical modelling were required (Table 2.1).

Table 2.1: Investigations informing detailed Civil Works

Report/Presentation	Domain	Authors/Working Group
Development of Locally Derived Water Quality Trigger Values	Site-wide and downstream	Hydrobiology
Impact Assessment	Downstream	Hydrobiology
Surface Water Modelling	Site-wide	Water Technology
Flora and Fauna Surveys	Site-wide	Ecological Australia
Revegetation Trial	Borrow Area 5	DME/EcOz
Groundwater and Contaminant Transport Modelling	Site-wide	RGC
Borrow Material Investigation	Site-wide, with a focus on low permeability clay	SLR/OKC/Landloch
Waste Placement Specification and Advective Airflow	WSF	OKC
Waste Placement and Contaminant Loading	WSF	OKC
Waste Relocation and Sequence	WSF	RGC/ Dr Jones Environmental Excellence (DJEE)/OKC
Geotechnical Investigations Constructing Foundations on Dolostone – Literature Review	WSF	OKC
Foundation Investigations Below WSF	WSF	RGC/OKC
Rum Jungle: Bathymetric Survey	Main Pit	Charles Darwin University
Dewatering and Water Treatment	Main Pit	RGC/DJEE
Groundwater Flow into Main Pit During Backfilling	Main Pit	RGC
Hydrogeological Drilling Program	Old Tailings Dam	RGC
Types of Acidity and Closure Risk	All waste rock dumps	DJEE
Waste Rock Geochemistry	All waste rock dumps	DJEE/RGC
Dysons Backfilled Pit Cover System Modelling	Dysons Pit	OKC
Assessment of Contaminated Material	Site-wide	RGC/OKC/DME
Performance Monitoring Requirements and Costing	WRF, backfilled Main Pit and Dysons backfilled Pit	OKC
Completion Criteria	Site-wide	Unger

3 IMPLEMENTATION SUCCESS

3.1 Rehabilitation Vision

The vision of success is to restore Rum Jungle so that it can be freely accessed by adopting leading practice rehabilitation to reduce the impacts of Acid and Metalliferous Drainage (AMD) on site with authentic consultation. Hence, rehabilitation planning for Rum Jungle has not just focussed on the technical rehabilitation project but has also sought to acknowledge and embrace traditional cultural and environmental knowledge.

As a result, successful rehabilitation must certainly include "typical" AMD rehabilitation "measurable drivers", such as water quality and flow; however, rehabilitation success at Rum Jungle is also defined by other drivers such as seeing and feeling that balance and harmony for the people has been restored with their land and their environment.

3.2 Rehabilitation Objectives

Through consultation with stakeholders, rehabilitation objectives for Rum Jungle aim to create a landscape that:

- Is safe for people and wildlife;
- Is chemically, radiologically and physically stable;
- Has a substantially reduced contaminant load (associated with AMD) beyond the boundaries of the site;
- Supports sustainable land uses by traditional Aboriginal owners of the area with few, if any, limitations; and
- Encourages beneficial alternative post-rehabilitation land uses.

To Kungarakan and Warai, rehabilitation of the physical landscape will allow for the identification, protection and preservation of sacred sites of importance and spiritual healing of the country. The following outcomes are required for their vision and for the healing process to be achieved:

1) Active engagement with the Kungarakan and Warai Peoples relating to cultural heritage and environmental matters and the assurance that their cultural and environmental knowledge will be acknowledged as demonstrated by relevant project decisions.
2) Culturally appropriate identification, protection and preservation of Aboriginal cultural heritage.
3) Re-establishment of the original landform as far as is practically and sustainably achievable.
4) Minimising, removing or neutralising pollution sources.
5) Reducing risk of radiological exposure to as low as can be reasonably achieved (ALARA) and ensuring doses are within international standards for radiation protection.
6) Minimising the potential for surface water to become polluted and remediating the effects of polluted groundwater as is practically and sustainably achieved, consistent with the surface water quality objectives.
7) Restoring flora and fauna species endemic to the site and its immediate surrounds.
8) Maximising employment and business opportunities throughout the rehabilitation process.

3.3 Detailed Civil Works Design for Rehabilitation

The details of the preferred rehabilitation strategy are as follows.

- Relocate approximately 2.9 M m^3 of potentially AMD-generating waste from the above grade portion of Dysons backfilled pit, Intermediate Waste Rock Dump and a portion of Main Waste Rock Dump, to Main Pit. This material will be backfilled below the minimum dry season groundwater level in the Main Pit in order to limit further generation and release of AMD. The remaining pit void will be backfilled to the surface with benign material. The remaining waste rock will be consolidated into a new, purpose-built Waste Storage Facility (WSF) specifically designed to limit oxidation of contained waste and AMD.

- Leading practice landform and cover system designs will be developed and implemented for the in-filled pits and the WSF. All covers will be revegetated.

- All residual contaminated soils will also be consolidated to the WSF, including cleaning up of contaminated fluvial areas.

- Re-alignment of a section the East Branch of the Finniss River around the north side of the backfilled Main Pit.

- Intermediate Pit to remain water filled as a “buffer” for water quality and flow management.
- Important cultural aspects of the landscape are understood and taken into account and, wherever possible, protected or reinstated.
- Site infrastructure including access and haul roads will be developed for the construction phase of the project.
- Borrow material will sourced from an area identified as suitable on the Finniss River Land Trust.

3.3.1 Failure Mode and Effects Analysis Workshops

Multiple Failure Modes and Effects Analysis (FMEA) workshops were conducted during Stage 2 in order to identify, quantify, and communicate technical risk for the detailed civil works, and the technical investigations supporting these works. As milestones and new information were developed during Stage 2, failure modes and effects were re-visited and reduction in risk, as well as residual risk and/or more cost effective means to manage the risk were identified and incorporated into the design.

3.4 Rehabilitation Completion Criteria

Completion criteria were developed based on the rehabilitation objectives stated above. These are described in detail in Rum Jungle Mine Site Rehabilitation Project – Stage 2 Detailed Design Completion Criteria & Framework (provided in Appendix A). The completion criteria have been categorised into meeting the needs of the people, the land, and the environment.

- People:
    - Minimal long-term risks to human health and safety;
    - Capacity and knowledge; and
    - Kungarakan and Warai traditional owners are developed and positioned to successfully compete for economic opportunities
- Environment:
    - Improved water quality and aquatic ecosystems;
    - Land no longer generates significant pollution; and
    - Flora and fauna endemic to the site return as terrestrial ecosystems recover.
- Land:
    - Stable landscape;
    - New landforms integrate cultural objectives; and

  - Opportunity for greater access, eventual ownership and ongoing rehabilitation maintenance.

3.5 Design Aspects in Context of Completion Criteria

The detailed civil works design comprises designs for each of the domains within the site. Each of these designs are intimately interconnected, with the design of each domain, and the connectivity, developed such that each of the completion criteria would be met. Table 3.1 presents the completion criteria and the design aspects included in order to achieve each of these criteria.

Table 3.1: Rum Jungle design aspects compared to completion criteria.

Objectives	Completion Criteria	Rum Jungle Design	Criteria Met
Ensure long-term risks to human health and safety are minimised	Radiation: Dose to the public from all sources and all pathways being less than 1 mSv/yr above existing background radiation in adjacent undisturbed areas	Cover system design minimum 2 m thick to meet completion criteria. Cover placed over WSF, Main Pit, Dysons Pit, and all areas where waste removed	✓
Build capacity and position Traditional Owners to participate in the Rum Jungle Rehabilitation project	The Traditional Owners will be able to participate actively and productively during the rehabilitation project – progressively melding western scientific knowledge with cultural knowledge	Construction Schedule (8 years) allows sufficient time to effectively build knowledge allow cultural knowledge to inform the future of the project (including post-rehabilitation management of the site)	✓
Position the Kungarakan and Warai people to successfully complete for economic opportunities as an integral part of the project	Traditional Owners have sufficient capacity and organisational structures in place to successfully tender for tasks as part of the rehabilitation works	Construction Schedule and Workforce Plan developed with a view to facilitating Traditional Owner participation in the project	✓
New landforms constructed during the rehabilitation project will be stable	Waste containment landforms are radiologically, physically and chemically stable	Leading practice design developed to consolidate and management waste currently contained on the site	✓
New landforms will integrate cultural objectives	Re-instate a section of the East Branch of the Finniss River Traditional Owners satisfied with the design	Design has been developed to take into account important cultural aspects of the landscape and, wherever possible, protect or reinstate them	✓
Rehabilitation of the former Rum Jungle site will enhance opportunity for greater access to the site	Site able to be used for cultural and other purposes with limited restriction on land access	Design includes clean-up of contaminated material to meet agreed future land use	✓
Water quality objectives will ensure greater aquatic biodiversity at the mine and downstream	Specific to each zone and measured at the following Gauging stations EB@GS200, EB@GS097, FR@GS204	Design developed to meet water quality targets over the longer term	✓

The land no longer generates significant pollution	Contaminated material is cleaned up to set proposed land use targets Locally derived water quality objectives are met in the longer term	Contaminated materials moved to WSF, over-excavation of materials.	✓
Flora and fauna return as terrestrial ecosystems recover	Increasing biodiversity over time	Design incorporates revegetation with native species Design developed to meet water quality targets over the longer term	✓

4 OVERVIEW OF DESIGN ELEMENTS

The key designs and their components are summarised below:

1) Main Pit
   a. Dewater and maintain dry during the dry season;
   b. Dredge tailings and thicken (tailings placed in WSF);
   c. Place waste (from Intermediate WRD, Main WRD, and Dysons Pit backfill) in Main Pit to RL 58.5 m AHD;
   d. Place clean fill in Main Pit to RL 71 m AHD;
   e. Landform surface designed to drain towards East Branch of the Finniss River (East Branch) and comprise the embankment for the reinstated section of the East Branch channel around the northern side of the Main Pit.
2) WSF
   a. Excavate materials within footprint and construct foundation;
   b. Grade foundation and line with seepage collection system;
   c. Construct starter berm;
   d. Place waste rock and tailings in 2 m lifts with lime incorporated;
   e. Grade final landform to design surface to ensure drainage and landform stability;
   f. Low net percolation cover system placed over landform (rock mulch used on downslope areas for erosion control);
   g. Surface water management system constructed with appropriate hillslopes, channel grades, and lined with specified materials.
3) Dysons Pit Backfill
   a. Remove backfill materials down to original surface elevation on southern sideand place in Main Pit;
   b. Place coarse-textured material to design grade;
   c. Cover system placed over landform to minimise net percolation to low net percolation rate, and eliminate interaction of runoff and seepage with backfill tailings material.
4) Removal of all remaining WRD material including clean-up of footprint areas and place in WSF.
5) Site wide clean-up of contaminated material and place in WSF.
6) Site-wide surface water management design.
7) Revegetation of all rehabilitated areas.

The scope of this project involved completion of the following tasks:

- Design of a New Waste Storage Facility (WSF). This design includes:
    - Design of overall WSF geometry based on selected location and required volume including embankment gradients and curvature to meet specified performance criteria.
    - Design of WSF foundation and seepage collection systems to collect leachate during and post construction for treatment.
    - Construction specifications including lift height, design of starter bunds, and compaction specifications.
    - Design of a cover system to meet the performance criteria of low to very low net percolation rates.
    - Design of a surface water management system to limit erosion to within performance criteria.
    - Design of a performance monitoring system to measure performance against criteria.
- Design of Main Pit as a repository for contaminated waste. This design includes:
    - Prediction of dewatering and settlement.
    - Design of the backfill profile and incorporation of arterial drainage.
- Design of Dysons Pit Backfill to remove shallow contaminated materials to manage net percolation into the remaining in-pit backfill. This design includes:
    - Calculation of excavation volumes.
    - Design of landform and cover system to meet performance criteria of erosion and net percolation.
- Design of rehabilitation for footprints of existing WRDs, copper extraction area and areas where contaminated soils are cleaned-up.
- Design of roads, pads, levees and ancillary earthworks.
- Design of drainage, diversions and impoundments.
- Designs for rehabilitation of satellite operations:
    - Rum Jungle Creek South;

- Mount Burton; and
- Mount Fitch.

5 DETAIL OF DESIGN ELEMENTS

The following section provides the design summary for the civil works; site wide material characterisation is also summarised. For each domain, the specific design objectives, supporting investigations, and relevant design drawings are listed.

5.1 Site Wide Material Characterisation

Extensive material investigation and characterisation were completed across Rum Jungle to quantify and evaluate material types and volumes to support the works. An overview of the investigations are provided.

5.1.1 Site Wide Material Characterisation

Full technical details for site material characterisation can be found in the following reports:

- Physical and Geochemical Characteristics of Waste Materials at the Rum Jungle Mine Site (RGC and DJEE, 2016): Appendix B;
- Environmental Performance Assessment for the Preferred Rehabilitation Strategy for Rum Jungle (183006/7) (RGC, 2016): Appendix B;
- Detailed Civil Works Project for Rehabilitation of the former Rum Jungle Mine: Potential Borrow Material Assessment (OKC, 2016): Appendix B;
- Rum Jungle Rehabilitation – Borrow Pit Identification Geotechnical Field Investigation (SLR, 2015): Appendix B; and
- Rum Jungle Rehabilitation Project Preliminary Assessment: Borrow Pit Area Growth Media Characterisation (Landloch, 2015): Appendix B.

5.1.2 Waste Rock Characterisation

Key findings from investigations showed that about 85% of materials contained in the existing WRDs are considered PAF material. Three categories of PAF waste rock are identified:

- PAF-I waste rock is characterised by the highest sulfide content (and lowest acid-neutralising capacity).
    - PAF-I waste rock will generate the most AMD in the future if it were allowed to oxidise.
    - All PAF-I waste rock is to be re-located to the saturated zone of the Main Pit.
- PAF-II waste rock would generate substantial AMD in the future, but less than PAF-I waste rock.

- 80% of PAF – II material is in the Main WRD and would have to be segregated from NAF waste rock and other PAF waste rock during re-location.

- PAF-III waste rock is the least reactive PAF material.
    - The sulfide content of PAF-III waste rock is comparable to NAF waste rock, but PAF-III waste rock has a lower acid-neutralising capacity (ANC).

Non Acid Forming (NAF) waste rock is defined by an AP/ANC value of two or higher and an existing acidity content of 0.5 kg H_2SO_4/t. The NAF waste rock does not require containment to prevent future oxidation of sulfides. Segregating NAF waste rock from PAF-III waste rock would require an intensive quality control program to be implemented during the process of re-locating waste rock. The distribution of waste types within the current waste rock storage facilities is given in Figure 4.1.

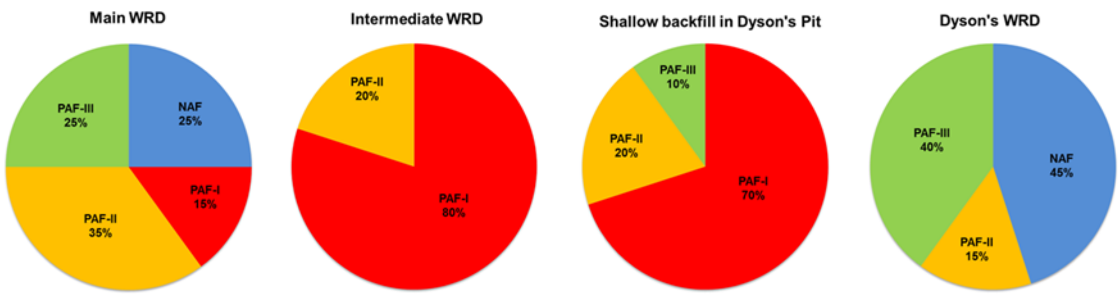

Figure 4.1: PAF and NAF Types in the WRDs and Dysons (backfilled) Pit (RGC & DJEE, 2016).

PAF waste rock that is placed into the Main Pit or the WSF will be amended with neutralant to neutralise existing acidity. The target pH for neutralisation is estimated to be around pH 7 based on the concentrations of soluble metals remaining in solution as a function of pH. Fine grained limestone, commonly referred to as agricultural lime, ($CaCO_3$) is intended to be used to amend waste rock placed in the Main Pit and the WSF. A quality control and quality assurance (QA/QC) program will be implemented during waste rock re-location to ensure that PAF waste rock types are correctly identified and appropriately limed and that NAF waste rock is identified and appropriately segregated and stockpiled.

5.1.3 Contaminated Soils

The location, extent and nature of contaminated soils were determined by soil investigations conducted in 2011 and 2014 (Drawing 871-6-002). These investigations included extensive test pitting and assessment of bore logs which allowed for an estimated of volumes of contaminated soil to be developed. Soil analysis results from these investigations were compared to Health Investigation Level criteria (HIL-C) values for Recreational Areas, as an appropriate value for assessment. Both investigations identified HIL–C exceedances on site. The design has incorporated clean-up and management of contaminated soils to the WSF (Section 5.3).

5.1.4 Borrow Material Investigations

A range of material types will be required for different structural and performance components of the design. The main areas in question requiring material are the WSF, cover systems on Dysons backfilled pit, rehabilitation of footprint areas of current landforms after reclaiming, rehabilitation of contaminated surfaces, final Main Pit landform and for the construction of infrastructure such as roads surfaces and levees.

Borrow material investigations have currently identified 5.3 M m^3 of soil suitable for growth media, backfill applications and low permeability clay layers. The estimate of 5.3 M m^3 was conservatively developed; and additional borrow will likely be available if required. Note that the estimated material volumes allow for a buffer zone around the ephemeral stream and electrical easement. Currently it is estimated that approximately 3.6M m^3 of soil and approximately 1.2M m^3 of low permeability clay is required for the site rehabilitation for a total requirement of 4.8M m^3.

No coarser-textured material was identified in the borrow investigations; see section 5.1.5 for further detail.

Results from the borrow material characterisation program were evaluated for use in low permeability barrier applications (Table 5.1).

Table 5.1: Criteria used to evaluate soil for low permeability barrier

Characterisation Test	Criteria and Comments
Atterberg Limits	• Criteria: PI above 10 and plot above the A-line • Anticipated that approximately 96% of samples meet the criteria based on subset of samples
Activity	• Criteria: activity between 0.5 and 1 • Anticipated that approximately 96% of samples meet the criteria based on subset of samples
% Clay	• Criteria: per cent clay greater than 10 • Approximately 96% of samples meet the criteria
% Fines	• Criteria: per cent fines greater than 30 • Approximately 96% of samples meet the criteria
% Gravel	• Criteria: per cent gravel less than 50 • Approximately 98% of samples meet the criteria
K_{sat}	• Criteria: ≤1 x 10^{-7} cm/s for compacted clay layers • Approximately 50% of samples tested meet criteria, but all samples would meet criteria if Standard Compaction was completed at 2-3% wet of optimum moisture content

Borrow material was also evaluated for suitability as growth media and in backfill applications (Table 5.2). Results of the classification suggest a non-dispersive material that will sustain vegetation. It is anticipated that amelioration of surface layers will be required in some areas by for example; rock armouring.

Table 5.2: Geotechnical and chemical testing to evaluate growth medium material.

Characterisation Test	Criteria and Comments
Texture	• All material sampled is relatively finer textured and suitable for a growth medium material • Limited ability for self-armouring and will require rock mixture on slopes of WSF
Emerson	• Samples were classified as non-dispersive • Suitable for mixing with rock for armouring on slopes of WSF
EC, pH, ESP	• Soil classified as normal with flocculated structure • Surface permeability should evolve to approximately 1 x 10^{-4} cm/s from as-constructed traffic compacted surface, which will attenuate peak runoff, encourage plant growth, and minimise erosion
CEC	• Values are considered relatively low and additional time may be required for vegetation to establish, permeability to increase from as-constructed conditions and soil tilth to develop • Ameliorate with fertiliser in first year to accelerate plant growth and soil tilth
XRF	• No elevated elements of concern to limit plant growth or generate acidity

5.1.5 Rip Rap and Rock Aggregates

Coarser-textured material will be required for rip rap, channel lining, diversions, cover system construction including drainage layers, among other uses.

Coarser-textured material was not specifically targeted in the borrow investigations as geological investigations indicate 276,650 m^3 of coarse material available in the WSF foundations. The coarse material available in the WSF will be reclaimed during preparation of the foundations. Furthermore there is ~20,760 m^3 of cobble & boulder sized aggregate, present as armouring on existing WRDs, and is to be reclaimed and re-used for similar applications.

Aggregate required for sub-base and base course road construction will be imported from a local quarry.

5.2 Backfilled Main Pit (Main Pit)

Main Pit will be backfilled with waste rock from Intermediate WRD, a portion of Main WRD, and backfill materials from Dysons Pit. Specific design objectives for backfilling Main Pit are to:

- Prevent future oxidation of waste materials.
- Limit future generation of AMD.
- Create a stable landform including reinstatement of a section of the East Branch.

5.2.1 Support Investigations for development of the Main Pit backfill design:

Support investigations for the Main Pit design are listed below.

- Main Pit Backfilling Concept Approaches Study (RGC, 2015): Appendix B;

- Groundwater Flow and Transport Model for Current Conditions (RGC, 2016): Appendix B;
- Water Technology Surface Water Modelling (Water Technology, May 2016): Appendix B; and
- Physical and Geochemical Characteristics of Waste Materials at the Rum Jungle Mine Site) (RGC and DJEE, 2016): Appendix B.

5.2.2 Drawings Relevant to Main Pit Design

- 871-6-030: Central Area Rehabilitation Plan
- 871-6-031: Central Area Rehabilitation Sections
- 871-6-032: Central Area Rehabilitation Details

5.2.3 Main Pit Design Summary

The design objectives will be achieved by placing waste material backfill below the groundwater table so as to ensure it is constantly saturated, then a covering with a backfill of benign material to create a raised water shedding landform.

Following dredging of the tailings currently stored at depth in Main Pit, it will be de-water and then backfilled with waste rock sourced from Intermediate WRD, a portion of Main WRD, and backfill materials from Dysons Pit. The waste material will be placed in the Main Pit to a final level of RL 58.5 m AHD (the minimum dry season ground water level) in order to fully submerge contaminated waste and prevent future oxidation of waste materials within the pit. Selected coarse waste rock (from Dysons WRD) will initially be deposited into the pit to provide a solid foundation over any remaining tailings. Overall consolidation of the backfilled pit is expected to be 5% to 10%. An allowance will be made for subsequent consolidation in order to ensure that the landform remains free draining.

A raised landform will be constructed of clean fill over the backfilled pit. The landform of the backfilled pit will be elevated from ground level and shed surface water to the re-aligned East Branch (Drawing 871-6-030). The elevation of the ground over the backfilled pit will limit any potential inundation of flood waters to the area. The northern and eastern sides of the landform provide embankments for the re-instated East Branch.

5.3 New Waste Storage Facility

Design objectives for the new Waste Storage Facility (WSF) are to provide long term isolation and containment for all waste rock material with the exception of those used as backfill for Main Pit. Material to be placed in the WSF includes dewatered tailings from Main Pit, waste rock from Main, Main North and Dysons WRDs, waste rock from Mount Burton, and contaminated soils from the copper extraction area, Old Tailings Dam area, Old Stockpile area, material from the excavated East Branch and from miscellaneous salt-affected soils across site.

Key design objectives for the WSF are to provide a long-term containment of PAF waste through:

- Provision of a stable base to support the new landform to minimise the potential for subsidence;
- Reduction of the volume of net percolation (NP) that will be transmitted through the WSF during and post construction;
- Reduction of the quantity of basal seepage that may report to shallow groundwater during and post construction;
- Reduction of the flux of oxygen through the waste mass in the short and long term, primarily through waste placement techniques (i.e. shallow lifts), and a cover system as a secondary means of managing oxygen;
- Reduction of the potential for AMD to be generated and report as seepage from the WSF in the short- to long-term; and
- Provision of a means to collect and treat seepage from the WSF during construction, immediately post-construction, and into the short- to medium-term steady-state condition.

5.3.1 WSF Support Investigations

Investigations to support WSF design development are listed below.

- Physical and Geochemical Characteristics of Waste Materials at the Rum Jungle Mine Site (RGC and DJEE, 2016): Appendix B;
- Rum Jungle Numerical Modelling for Waste Storage Facility Construction (OKC, 2015a): Appendix B;
- Groundwater Flow and Transport Model for Current Conditions (RGC, 2016): Appendix B;
- Rum Jungle Waste Storage Facility Waste Placement and Load Modelling (OKC, 2015b): Appendix B;
- Rum Jungle Waste Storage Facility Waste Placement and Advective Airflow (OKC, 2015c): Appendix B;
- Rum Jungle new Waste Rock Storage Facility - Slope Stability Analysis (OKC, 2015d): Appendix B;
- New Waste Storage Facility Investigations (RGC, 2015): Appendix B; and
- Rum Jungle New WSF Performance Monitoring (OKC, 2015e): Appendix B.

5.3.2 Drawings Relevant to WSF Design

- Drawing 876-6-010: WSF Layout Plan

- Drawing 871-6-11: WSF Foundation Plan
- Drawing 871-6-12: Foundation Excavation Plan
- Drawing 871-6-13: Foundation Fill Plan
- Drawing 871-6-14: WSF Fill Plan
- Drawing 871-6-15: WSF Sections

5.3.3 WSF Design Summary

The WSF has been designed to provide a long-term containment of PAF waste, contaminated soil and tailings dredged from Main Pit. The design is comprised of the following elements with a summary of each provided in the sections below:

- Overall WSF landform geometry based on selected location and required volume including embankment gradients and curvature.
- Foundation and seepage collection systems to collect leachate during and post construction for treatment.
- Construction specifications including lift height, design of starter bunds, and compaction criteria.
- Cover system to meet net percolation requirements.
- Design of a surface water management system to limit erosion.
- Design of a performance monitoring system to measure performance against criteria.

5.3.4 WSF Landform Design

The WSF landform is a water shedding design with surface water management and slope aspects to minimise erosion. At the same time, infiltration, and subsequent evapotranspiration, are expected to be substantial components of the water balance for the cover system. Landform surface specific design features are described below.

5.3.4.1 WSF Plateau

The plateau of the WSF is to be constructed with a cover system designed to allow infiltration into the growth medium component of the cover system, whilst allowing sufficient hydraulic relief should saturation during intense rainfall periods occur. The surface is designed on a variable gradient of approximately 1-4% towards a wide, shallow central swale, transitioning to a recessed ‘spine drain’ where the gradient steepens and transitions to meet the ground surface on the eastern end of the WSF. The cover system and waste underneath will be shaped to the same profile as the final surface above to retain a consistent cover thickness of 2.5 m over the entire plateau area.

The designed profile comprises a trilinear concave slope that transitions from 1:2.5 to 1:3.5 to 1:5 (Drawing 871-6-010). Continuous concave shaped embankments were specifically designed to maximize stability. Given the combination of gradients and climate, vegetation can be expected to preferentially establish on the lower shallower slopes, which is desired for long term stability.

5.3.4.2 Erosion Protection

The WSF is to be constructed predominantly from PAF waste and as such constitutes a significant contaminant source should excessive or incisive erosion of the embankments occur. Rip rap type scour protection is designed for the spine drain to protect the cover system against erosion from concentrated surface water flow. Rip rap will be sourced from quarried rock from foundation construction.

On the mid and lower embankment slopes, surface materials consist of a mixture of graded material that provides a coarse rocky matrix of minimum 40% of graded 100mm NAF rocky mulch, combined with growth medium a depth of 0.5m. On the upper (1:2.5) slopes, a minimum of 75% of coarse material is designed to enhance geotechnical stability and for erosional stability. The rocky mulch is to be mixed with selected growth medium with high moisture holding capacity to support vegetation growth.

5.3.5 WSF Foundation and Seepage Collection System

Water that percolates through to the base of the WSF is to be collected by a seepage collection system comprising a low permeability barrier layer to drain water to a collection point, constructed in the WSF foundation, (Drawings 871-6-11 and 871-6-12). Seepage will be conveyed to Intermediate Pit via a buried pipe network.

The location selected for the WSF overlies a bedrock geology of Dolostone. Initially, an excavation of variable depth, (Drawing 871-6-012) will be completed across an area broader than the actual footprint of the new landform. The depth of excavation will generate an overall gentle gradient focusing in the southern centre of the footprint. Foundations will be built up over the footprint, allowing for the gradient to be maintained. The excavation allows for:

- Construction of compacted foundations with increased bearing strength and low permeability;
- Quarrying of additional rock and growth medium material for cover system and erosion embankment construction;
- Collection of any seepage; and
- Management of perimeter drainage.

The foundation of the WSF will be constructed from two 0.5 m compacted laterite layers and a low permeability clay layer, to minimise the potential for subsidence, and for the low permeability clay layer to provide an opportunity for the majority of seepage water from the WSF to laterally divert to toe collection systems, and minimise basal seepage. The upper surface of the clay layer, is at a level of approximately equal relief as adjacent natural ground outside the WSF and the surface transitions to the surrounding topography outside the dump toe.

Following emplacement of the foundations the seepage collection system will be installed. This system is designed to utilise the gradient of the foundation to drain any seepage into the seepage collection sump. The sump will be lined to prevent seepage. The sump is to be filled with gradations of filter sand and gravel to prevent clogging. Dual 280 mm diameter HDPE pipes will be installed to convey seepage to the Intermediate Pit.

The primary seepage collection pipe will flow by gravity following natural site grades and discharge into Intermediate Pit (Drawing 871-6-11).

5.3.6 WSF Internal Dump Construction

The construction method is fundamental to the design achieving the performance criteria. The required construction method of the WSF produces the least seepage through the waste material into the seepage collection system. Minimal seepage is achieved by limiting hydraulic conductivity of the waste material contained in the WSF through layering and compaction of sequential lifts. The reduced porosity also reduces airflow in the WSF and increases the time for the material to wet up, and also increases seepage travel times through the WSF. The WSF will be constructed by layering in 2 m lifts.

The design also includes low-permeability ‘starter bunds’ (refer to Drawing 871-6-10). Starter bunds are constructed from finer-textured (clayey) material to limit oxygen and water transport through the embankment cover. Analytical modelling suggests that medium-grained sized waste material may be used as an additional limiting material to oxygen ingress if placed at 60% saturation. The 2 m lift construction option is also preferred because this reduces the starter bund size required in the WSF, and provides an improved overall capacity. Lime will be applied to each lift in a thin layer.

Construction of the landform will be suspended during wet seasons. A 0.3m minimum thickness low permeability cover will be placed on the landform to minimise water and oxygen ingress over the wet season.

5.3.7 WSF Cover System Design

The cover system design is a “barrier layer” type cover system design as the compacted clay layer component of it has a permeability of 1×10^{-7}cm/s. The compacted layer also enhances the moisture store-and-release component of the cover system. The cover system is comprised of 2.0 m non-compacted growth medium overlying 0.5 m compacted clay layer over waste rock. The cover system design uses materials specifically selected for their physical properties, by encouraging revegetation and providing drainage for surface runoff. The cover system configuration is illustrated in Figure 5.1.

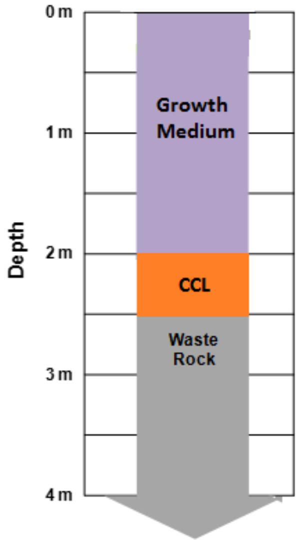

Figure 5.1: Rum Jungle cover system design

5.3.8 WSF Peripheral Water Management

Specific surface water diversion drains have been designed on the periphery of the WSF (Dwg 871-6-010). The purpose of the peripheral drainage channels is to manage incident meteoric water running off the surface of the WSF. The perimeter drains also reduce ingress of surface water into the WSF by removing surface water from the landform.

The perimeter drainage system will consist of a simple v-type channel, with the express purpose of conveying water off the landform. The channels will be constructed as a result of the over-excavation of the WSF foundation. The base of the foundation will consist of either the typical foundation excavation section over rocky areas or over laterite (Dwg. 871-6-012). The foundation will be constructed in such a way that the surface of the WSF landform transitions smoothly into the v-type channel for the perimeter drainage system.

5.3.9 WSF Performance Monitoring

Field performance monitoring systems are required to demonstrate that the facilities are meeting closure objectives and performance criteria. The Rum Jungle Mine Rehabilitation Project – Stage 2 Detailed Design Completion Criteria & Framework (Appendix A) outlines the completion criteria which are required to be met.

Assessment of oxygen and water ingress (during construction and post-construction), and water levels and quality are required to assess performance of the WSF in terms of reducing net percolation and thus, the reduction in the formation and transport of oxidation products from the waste rock into the surface water and groundwater. The designed monitoring system consists of elements to measure surface water balance, net percolation, internal conditions of the waste rock (pore-gas concentrations, temperature and moisture conditions) and groundwater levels and quality (inside and outside the footprint of the facility). Refer to Dwg. Nos. 871-6-080 and 871-6-

082 for locations and Rum Jungle – Field Performance Monitoring System Work Plan in Appendix B for details.

Additional environmental monitoring will be required to illustrate compliance with completion criteria for:

- Radiation
- Water quality
- Vegetation establishment
- Erosion and landform stability
- Channel stability

5.4 Surface Water Management

5.4.1 Surface Water Management Design Supporting Investigations

Support investigations for the mine surface water management design development are listed below.

- Water Technology Surface Water Modelling (Water Technology, May 2016): Appendix B; and
- Groundwater Flow and Transport Model for Current Conditions (RGC, 2016): Appendix B;

5.4.2 Surface Water Management Design Drawings

The surface water management plan is provided in Drawing 871-6-070 and is supplemented by specific area layouts including Drawings 871-6-010, 871-6-015, 871-6-020, 871-06-031, 871-6-070, 871-6-071.

5.4.2.1 Re-alignment of East Branch of the Finniss River

The design objective for the re-alignment of the East Branch of the Finniss River (creek re-alignment) is to re-align the section destroyed by mining to emulate the pre-mining surface water flows more closely. Supporting investigations for the creek re-alignment are listed in Section 5.4.1.

The creek re-alignment will occur over approximately 1230 m predominantly though the existing flow path between Main and Intermediate Pits. The creek re-alignment will be constructed following backfilling of Main Pit, as the backfill forms the eventual inside embankment of the creek re-alignment. The creek re-alignment is designed with a base width of approximately 40 m, and shallow embankment slopes to provide stability for establishment of riparian vegetation. The top width is variable due to changes in local topography and flow conditions considered. Flatter areas of the creek re-alignment, between Main and Intermediate Pits have little topographic relief and provide a floodplain towards the north. In higher flows, surface water spills into the floodplain, as is characteristic of the Finniss River catchment.

The shallow gradients prescribed along the creek re-alignment are very close to those existing pre-mining (generally less than 1%), and create a river geometry that much more closely reflects the natural state than the current through-pit flows. Bed materials are to be of a similar texture to bed materials upstream, combined with scour protection. Stabilisation of the river bed will be of great importance whilst riparian vegetation becomes established.

The existing diversion channel provides additional capacity for moderate to high flow events. The channel, along with flood levees, will be utilised during the construction phase of work to provide flood protection to Main Pit. The diversion channel entrance will be upgraded to provide improved flow hydraulics and specific apportioning of flow between the creek re-alignment and diversion channel under various flow conditions. Design ground levels at the diversion channel and creek re-alignment entrances are specifically designed to direct low flows down the creek re-alignment, whilst alleviating stresses associated with high flows on the creek re-alignment.

Creek re-alignment flows are directed into Intermediate Pit to provide a large clean water body, which will act to dilute contaminated groundwater inflow. Annual surface water flows far exceed groundwater flow, and are expected to provide a sustainable system that improves surface water quality to the receiving environment in accordance with design objectives.

5.4.3 Site Drainage Design

A network of temporary and permanent drainage features, including swales, drains and levees will be required at various stages of works. Surface water diversion drains have been designed in the vicinity of the WSF to manage incident meteoric water on the surface of the WSF, and for local surface water catchments surrounding the facility to reduce ingress of surface water into the WSF (Drawings 871-6-010).

A flood protection levee will be required for Main Pit along the eastern and southern sides during the construction phase, to prevent surface water flows into Main Pit. The levee will be formed-up as part of the road earthworks. The levee will include a low permeability core, which will be sourced from the FRLT borrow area, the levee will be removed/decommissioned at the end of the construction phase of the project.

Other, minor works are required for small bunds and levees, including along the south side of the Intermediate WRD (after it is removed) and north of Intermediate Pit to prevent surface water flow avulsion (refer to Drawing 871-6-070 and 71).

5.5 Waste Rock Dumps

Main, Intermediate, Main North and Dysons WRDs will be re-located to either the WSF or Main Pit.

5.5.1 WRD Supporting Investigations

Support investigations for the WRD design development are listed below.

- Physical and Geochemical Characteristics of Waste Materials at the Rum Jungle Mine Site (RGC and DJEE, 2015): Appendix B;
- Groundwater Flow and Transport Model for Current Conditions (RGC, 2016): Appendix B; and
- Rum Jungle Rehabilitation – Borrow Pit Identification Geotechnical Field Investigation (SLR, 2015): Appendix B.

The investigations supported by high quality LiDAR data for the site provided the footprint of each of the WRDs and volumes of material to be excavated and the locations and volumes of contaminated material to be cleaned-up. Borrow material investigations and cover material assessment investigations identified suitable growth medium materials to be used to fill the excavations and complete the landform covers where required.

5.5.2 WRDs Rehabilitation

All waste rock will be removed and the underlying footprint will be over excavated up to a depth of 2 m to remove contaminated soils. The footprint will then be treated with lime and backfilled with clean fill. The lime will provide pH amelioration of the area and the benign backfill will re-instate natural surface profiles. Rehabilitation of excavated footprints will involve leaving the exposed area open for one full season to allow contaminates to flush before the backfill and lime treatment is applied.

Excavated areas will be graded to a 1V:8H slope angle and will be blended into the surrounding area. Areas will be contoured to drain to the perimeter or to one or more ponding locations. If the area is coincident with ephemeral streams, the streams will be incorporated into the landscape to form low lying wetlands.

Once backfilled, footprint areas will be revegetated by seeding with native species. The material to be used for backfilling will provide suitable physical water holding characteristics to support vegetation.

5.6 Dysons Backfilled Pit

Key objectives for Dysons Pit design are to:

- Remove waste material in the backfilled pit down to the in-situ tailings level; and
- Manage net percolation into the remaining in-pit backfill tailings.

5.6.1 Dysons Backfilled Pit Support Investigations

Support investigations for Dysons Backfilled Pit include:

- Rum Jungle Dysons Pit Backfilled Pit Cover System Modelling (OKC, 2015e): Appendix B

- Groundwater Flow and Transport Model for Current Conditions (RGC, 2016): Appendix B; and
- Physical and Geochemical Characteristics of Waste Materials at the Rum Jungle Mine Site (Report 183006/1) (RGC, 2016): Appendix B.

Results from this investigation indicate that estimated current net percolation to Dysons Backfilled Pit is less than 30% of annual rainfall. Results of the investigation suggest that it is likely that there is an up-gradient source of flow into the 2-D cross-section examined in this analysis. In order to maintain a water table below a cover system, the cover system design aims to reduce net percolation to approximately 10% of annual rainfall. Assuming that up-gradient flow accounts for less than 75% of inflows to the Dysons backfilled system, a cover system that reduces net percolation to 10% should also maintain the water table above the current tailings surface level. However, due to the effect of the up-gradient component of flow through Dysons backfilled pit on the water table not being well understood, an increased factor of safety has been included in the design thickness of drainage layer underlying the cover system.

The design requires Dysons Backfilled Pit be excavated down into the existing rock blanket, with the contaminated material transported to the Main Pit. Surface rip rap will be reclaimed and stockpiled during the excavation for reuse. Excavation of Dysons Backfilled Pit is scheduled to occur within one year negating any requirements for wet season surface runoff management. The reclaimed riprap will be placed back on the embankment face after reshaping is complete. Once the rock blanket layer is complete, a store and release cover system will be constructed over the undisturbed underlying tailings.

Drawings Relevant to Design:

- Drawing 871-6-040: Dysons WRD & Dysons Rehabilitation Plan
- Drawing 871-6-041: Dysons WRD & Dysons Rehabilitation Sections
- Drawing 871-6-042: Dysons WRD & Dysons Rehabilitation Details

5.6.2 Dysons Backfilled Pit Design Summary

5.6.2.1 Dysons Backfilled Pit Cover System

The rehabilitation design for Dysons Backfilled Pit consists of a landform and cover system. The cover system consists of placing a 1 m rock blanket over the existing rock blanket material, on top of which a 0.5 m low permeability clay layer is placed. A minimum, a 2 m coarse backfill layer will be placed over the existing tailings surface before placement of the cover system The rock blanket layer provides a trafficable working platform during cover system construction as well as providing a textural break between the tailings and barrier layer of the cover system, improving cover system performance.

A layer of coarser-textured rock will be placed above the low permeability layer to provide a drainage layer to transport up-gradient flow and net percolation waters through the system without contacting tailings. A 2 m growth medium layer will be placed above the coarse rock layer that will provide water holding capacity to near surface and function to store and release infiltrating water.

5.6.2.2 Dysons Backfilled Pit Landform

A crest bund will be constructed along the southern edge of the Dysons Backfilled Pit plateau to prevent surface water flowing over embankments, and potentially eroding the cover system. Plateau water is shed in a north-westerly direction, towards the pit wall, discharging surface water southward towards the East Branch.

5.6.3 Dysons Backfilled Pit Performance Monitoring

Field performance monitoring systems are required to demonstrate that the reclaimed facilities are meeting closure objectives and performance criteria. The Rum Jungle Mine Rehabilitation Project – Stage 2 Detailed Design Completion Criteria & Framework (Appendix A) outlines the monitoring required to meet the completion criteria.

Assessment of oxygen and water ingress (during construction and post-construction), and water levels and quality are required to assess performance of Dysons Backfilled Pit. The performance will be evaluated in terms of reducing net percolation and the reduction in the formation and transport of oxidation products from the waste rock into the surface water and groundwater. The designed monitoring system consists of elements to measure surface water balance and estimate net percolation through the cover system. Refer to Dwg. No. 871-6-081 for locations and Rum Jungle – Field Performance Monitoring System Work Plan in Appendix B for details.

5.7 Copper Extraction Pad Area

Key objectives for the Copper Extraction Pad Area domain are:

- Remove shallow contaminated materials; and
- Refill void with clean fill materials suitable for re-vegetation.

5.7.1 Copper Extraction Pad Area Support Investigations

Support investigations for the Copper Extraction Pad Area include:

- Detailed Civil Works Project for Rehabilitation of the former Rum Jungle Mine: Potential Borrow Material assessment (OKC, 2016): Appendix B;
- Groundwater Remediation Strategy for the Copper Extraction Pad Area (RGC, 2015): Appendix B;
- Groundwater Flow and Transport Model for Current Conditions (RGC, 2016): Appendix B; and

- Physical and Geochemical Characteristics of Waste Material at Rum Jungle (Report 183006/1) (RGC, 2016): Appendix B.

Drawings Relevant to Design:

- Drawing 871-6-020: Main & Intermediate WRD Rehabilitation Plan
- Drawing 871-6-030: Central Area Rehabilitation Plan
- Drawing 871-6-032: Central Area Rehabilitation Details

5.7.2 Copper Extraction Area Design Summary

5.7.2.1 Copper Extraction Pad Area Landform

The design for the Copper Extraction Pad area is excavation, infilling, and regrading of soils. Excavation of the Copper Extraction Pad Area is scheduled to occur within one year, thus negating any requirements for wet season surface runoff management. Contaminated material excavated will be disposed in the WSF. The landform surface for the Copper Extraction Pad Area will closely resemble what currently exists, as excavations will be back filled to approximately the original survey grade forming slopes of 2 to 3° as required.

5.7.2.2 Copper Extraction Pad Area Cover System

Waste in the copper extraction area will be excavated to a depth 2m below existing ground surface (Dwg. 871-6-032). A simple store and release cover system will be placed within the excavation void, primarily as a growth medium to support vegetation.

As per the landform specification in section 5.7.2.1, the cover system will consist of nominally 2 m of growth medium. The growth medium to be used for in-filling the void will provide suitable water holding characteristics to support vegetation. The growth medium will also have sufficient soil fertility so as to support the prescribed mix of vegetation. The cover system will be seeded following cover placement to minimise the loss of soil through erosion.

5.8 Old Tailings Area and Contaminated Soils

Key objectives for the Tailings Area and Contaminated Soils designs are:

- Remove shallow contaminated materials; and
- Refill voids with clean fill materials suitable for re-vegetation where necessary.

Several sub-domains fall under this generalised design approach which include:

- Old Tailings area;
- Old Stockpile Area;
- Dysons SAS;
- Finniss SAS;

- West SAS;
- Eastern Valley;
- Drill Rig Area; and
- Misc. rocky waste.

5.8.1 Tailings Area and Contaminated Soils Support Investigations

Support investigations for the Tailings Area and Contaminated Soils include:

- Detailed Civil Works Project for Rehabilitation of the former Rum Jungle Mine: Potential Borrow Material assessment (OKC, 2016*)*: Appendix B;
- Groundwater Flow and Transport Model for Current Conditions (RGC, 2016): Appendix B; and
- Physical and Geochemical Characteristics of Waste Material at Rum Jungle (Report 183006/1) (RGC, 2016): Appendix B.

Results from the support investigations provided the extent and approximate volume of contamination to be excavated. Borrow material investigations and cover material assessment investigations identified suitable growth medium materials to be used to fill the excavations and complete the landforms to support vegetation growth.

Drawings Relevant to Design:

- Drawing 871-6-002: Contaminated Material Summary
- Drawing 871-6-020: Main & Intermediate WRD Rehabilitation Plan
- Drawing 871-6-030: Central Area Rehabilitation Plan
- Drawing 871-6-050: Old Tails Dam and Stockpile Rehabilitation Plan

5.8.2 Tailings Area and Contaminated Soils Design Summary

5.8.2.1 Tailings Area and Contaminated Soils Landforms

The material from the Tailings Area and Contaminated Soils Areas require excavation and disposal in the WSF. Approximately 2 m of waste material will be removed. Where necessary, an equal volume of growth medium will then be backfilled to replace what was excavated to the original survey grade.

5.8.2.2 Old Tailings Area and Contaminated Soils Cover Systems

Where necessary, excavations will be backfilled with up to 2 m of growth medium, which will be placed so as to support revegetation. The growth medium selected for backfilling will have the requisite soil physical and chemical properties for supporting vegetation growth.

5.9 Roads

A network of temporary and permanent roads is required to access key areas to conduct the rehabilitation works. The network of roads will include haul roads for heavy vehicles and access roads for light vehicle (LV) traffic.

Access to site will be from Litchfield road; on a sealed road leading over a single lane bridge that will provide all-weather access to the site. A concrete bridge will span the Diversion Channel (~50m). The bridge carriageway will be constructed in accordance with NT Government requirements.

The majority of the site roads will be unsealed. Haul roads are designed to be 42.5 m wide, and LV roads are indicated as 17 m wide. The specified width is inclusive of drainage, shoulders and carriageways. Access to Main Pit will be via a 1:10 access ramp.

A sealed road approximately 12 km long suitable for road trains will be constructed from the Borrow Area on the Finniss River Land Trust to site.

The roads layouts are provided as follows:

- Drawing 871-6-060: Rum Jungle Site Roads Layout Plan
- Drawing 871-6-061: Rum Jungle Site Access Road Alignment
- Drawing 871-6-062: Satellite Operations Access & Haul

5.10 Rehabilitation of Satellite Operations

Works will also be undertaken at three satellite operations. These works are described below with relevant design drawing noted.

Drawings Relevant to Design:

- Drawing 871-6-090: Mt. Fitch Rehabilitation Plan
- Drawing 871-6-091: Mt. Burton Rehabilitation Plan
- Drawing 871-6-092: RJCS Rehabilitation Plan

5.10.1 Mount Burton

Mount Burton is located approximately four kilometres west of Rum Jungle, on the north flank of a low ridge of Acacia Gap quartzites (CRP, 2013). There has been no post-mining remediation of the site. Contaminated material present at the site (waste rock dump) is to be excavated and transported to Rum Jungle for disposal in the WSF (Drawing 871-6-091).

5.10.2 Mount Fitch

Mount Fitch site is approximately 3.5 kilometres northwest of Mount Burton on a low rise east of the Finniss River. The pit itself was allowed to fill with water following completion of activities in 1969.

A small overburden heap is located directly south of the pit and some surface disturbance is evident to the west. Material present at surface will be removed and backfilled into the Mt Fitch Pit (Drawing 871-6-090).

5.10.3 Rum Jungle Creek South

Rum Jungle Creek South is located five kilometres south of Rum Jungle. The site was mined from 1961 to 1963. In 1971, the 66 meter deep pit was allowed to fill with water and became an artificial lake. A 13.2 ha waste rock dump is located on the site, the cover system of which will undergo repairs and maintenance (Drawing 871-6-092).

5.11 Revegetation

A revegetation plan has been developed and a detailed summary of the planned method is presented in report number 871/1-01 (OKC, 2013).

The plan provides details regarding:

- Recommended seed mix including sowing rates;
- Timing of sowing, ground preparation, and fertiliser application rates;
- A timetable for completion and implementation of the revegetation plan;
- A weed management plan;
- A fire management plan to assist with exclusion of fires for a short term (up to 5 years) following revegetation; and
- A rehabilitation monitoring plan to evaluate two key aspects of ecosystem development; vegetation development and ecosystem function.

Site revegetation investigations have been completed including:

- Flora and Fauna Surveys of the Former Rum Jungle Mine Site (Ecologial, 2014): Appendix D; and,
- Weed Eradication and Revegetation Trial – What was done (DME, 2015): Appendix D.

6 DESIGN VISUALISATIONS

Pre-and post-rehabilitation visualisations of the site are presented in Figure 6.1 and Figure 6.2 below. Perspective visualisations are provided overleaf (Figure 6.3 and Figure 6.4). Detailed design drawings are provided as Appendix C.

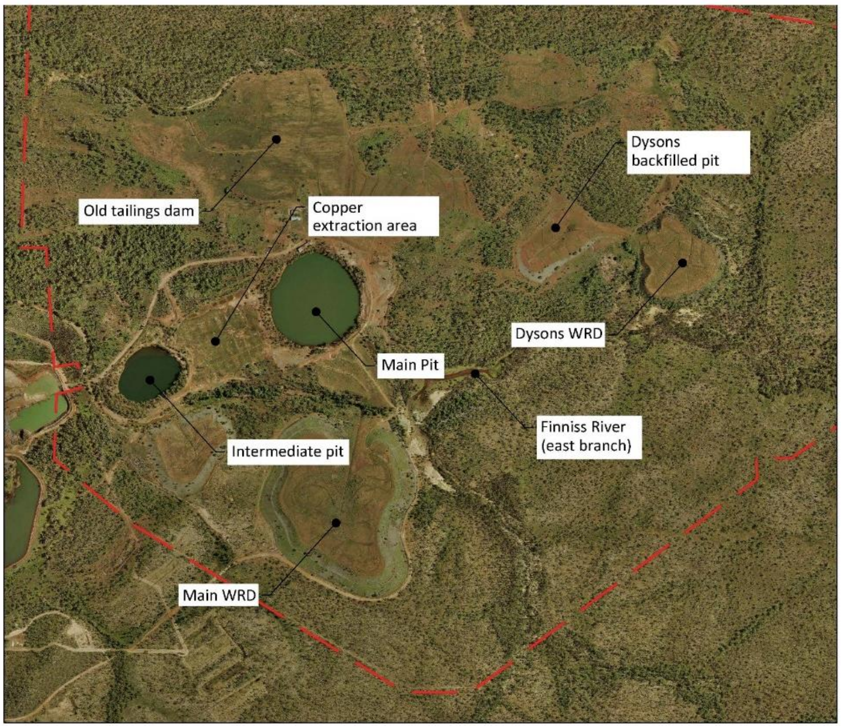

Figure 6.1: Rum Jungle – existing site layout

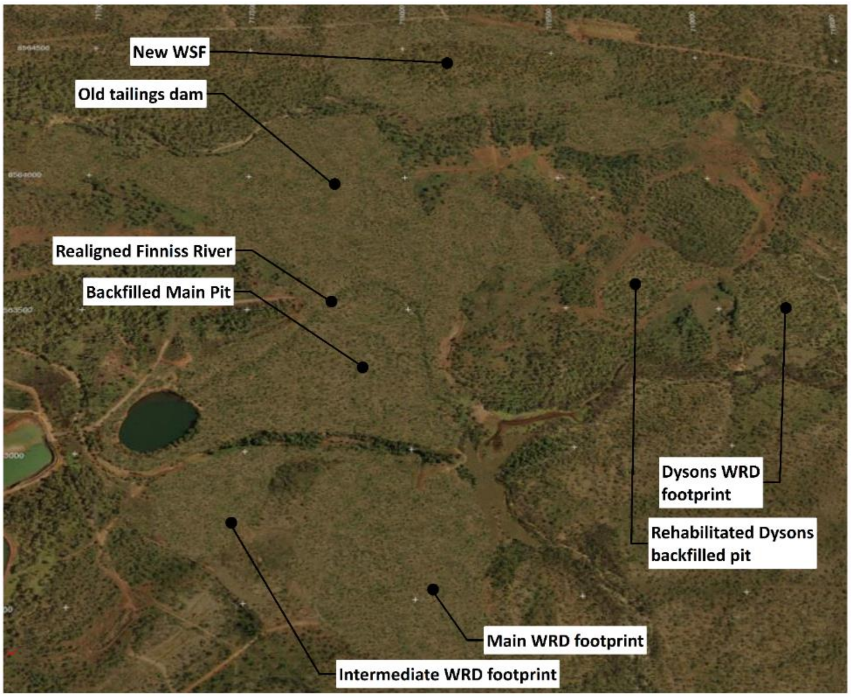

Figure 6.2: Rum Jungle - rehabilitated site visualisation

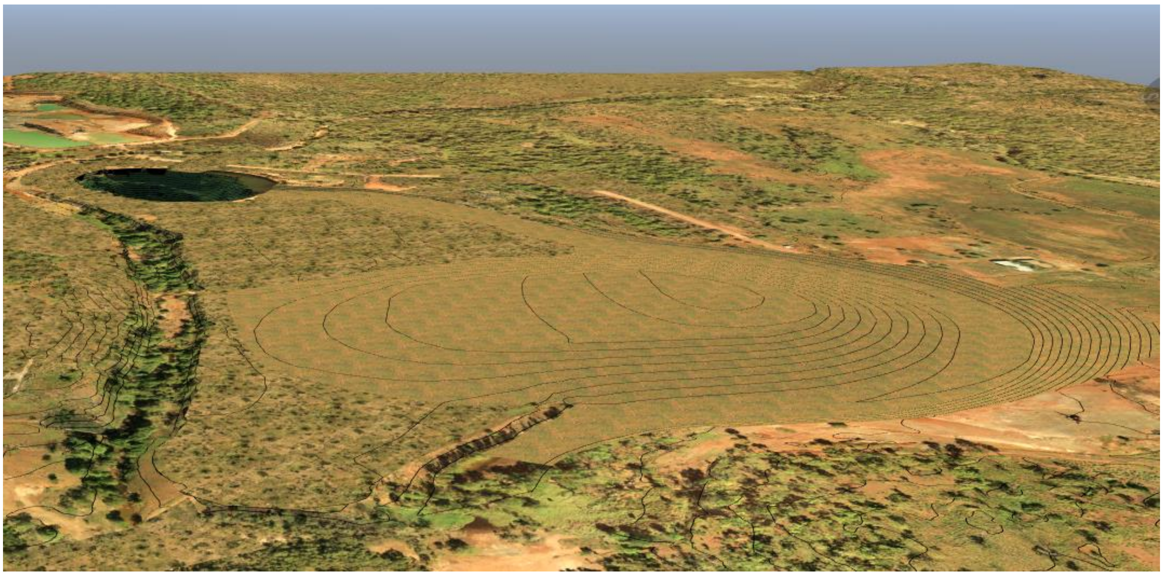

Figure 6.3: Main Pit rehabilitated landform (looking west)

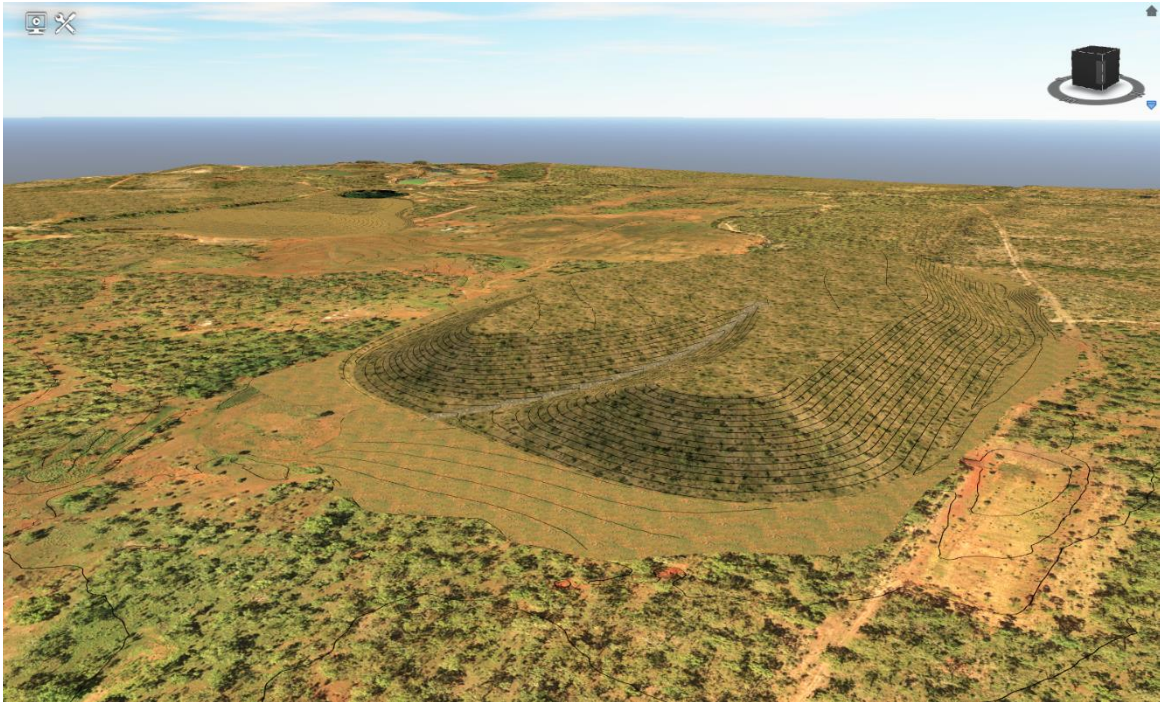

Figure 6.4: WSF landform (looking southwest)

7 MATERIALS MOVEMENTS

7.1 Terrain Design

Engineering designs and supporting calculations have been prepared using detailed digital terrain models (DTMs). Landforms and new surfaces were developed with spatial reference to aerial (LIDAR) survey, using commercial software (Civil 3D). The use of DTMs constitutes industry best-practice as they provide the high accuracy required for large-scale earthworks scheduling, and cost-estimation.

A set of DTMs have been prepared for the entire site and for satellite operations (Mt Burton and Mt Fitch), in both the existing condition and the rehabilitated condition. A separate set of DTMs have also been prepared for the borrow material investigation area and haul roads.

7.2 Site Wide Materials Movement

In order to develop the rehabilitation design, along with earthworks schedules and cost estimates, a detailed materials movement schedule was developed. Volumes to be moved are summarised on Drawing 871-6-002. A variety of material types are required to construct the final detailed design.

Movement of materials on and to site is to occur as four primary activities:

1) Consolidation of wastes to Main Pit as backfill;
2) Consolidation of wastes to WSF;
3) Amendment of lime as a neutralizing agent to PAF materials; and
4) Importation of clean material from the FRLT borrow area.

Main Pit has a total volume of 2.9 M m^3 below RL 58.5 m (following dredging of tailings), and will be filled to 58.5m RL with PAF-I and PAF-2 type material. The primary sources and volumes of waste rock materials destined for backfilling Main Pit are outlined in Table 7.1.

Table 7.1: Total Main Pit Waste Backfill Components.

Source of Waste to Main Pit	Volume (m^3)
Main WRD	1,324,180
Intermediate WRD	781,150
Dysons Pit Backfill	511,500
Dysons WRD (Coarse)	150,000
Lime Addition	29,540
Total to RL 58.5	**2,816,940**

The WSF has been specifically designed to provide a long-term containment of all materials types. Waste allocated to the WSF includes dewatered tailings from Main Pit, waste from Main, Main North and Dysons WRD, waste from Mount Burton, and contaminated soils from the Copper Extraction Area, Old Tailings Dam area, Old Stockpile area, material from the excavated East Branch and from miscellaneous salt-affected soils across site (Table 7.2).

Table 7.2: Total Waste to WSF

Source of Waste to New WSF	Volume (m^3)
Main WRD	2,973,890
Main Pit Ramp	354,200
Main North WRD	151,800
Dysons WRD	1,112,985
Copper Extraction Area	144,000
Old Tailings Area	264,000
Finniss River new excavation	226,600
Pit Levees	144,500
Dried Tailings	574,934
Mt Burton	169,400
Old Stockpile Area	324,000
Drill Rig Site	34,200
Eastern Valley	13,000
Salt affected soils - Dysons	58,500
Salt affected soils - Finniss	65,250
Salt affected soils - West	13,000
Lime addition	15,906
Total	**6,712,165**

Lime addition will also occur as material is placed in the WSF to neutralise stored acidity in the material. A QA/QC program will ensure that waste rock is re-located to the correct location and appropriately amended with lime. PAF material backfilled into the Main Pit will be admixed with lime to address existing acidity. Where PAF waste rock is being relocated, neutralant requirements have been determined by detailed geochemical assessments to be approximately 101,566 tonnes of Ag Lime.

The approach for Main, Intermediate and Dysons WRDs is to re-locate waste rock and contaminated materials to Main Pit and to the WSF. Footprints are to be over-excavated up to a depth of approximately 2 m to remove contaminated underlying soils. The footprints will be later treated with lime and backfilled with clean fill. Clean material volumes required are outlined in Table 7.3.

Table 7.3: Clean Material Input Summary.

Destination for Clean Materials	Volume (m^3)
Backfill to Main Pit	1,,001,000
Backfill to Dysons Backfilled Pit	134,400
Backfill to Main WRD footprint	644,000
Backfill to Dysons WRD footprint	180,000
Backfill to Intermediate WRD footprint	178,000
Backfill to Mt Burton	44,000
Backfill to Copper Extraction Area	288,000
New WSF	
− Temporary covers	279,862
− Starter Bunds	325,976
− Growth medium plateau	332,117
− Cover system liner	83,029
− Growth medium embankment	414,753
− Rip Rap	72,510
− Foundations for WSF	496,000
Construction levees	53,200
Road construction	311,926
Laydown areas	2000
Total	**4,840,773**

The following production rates are assumed for the material movements. These rates are dictated by access to both the excavation and dumping areas, machine types and other construction considerations:

- On-site waste rock to WSF = 10,000 m3/day (dump trucks);
- Tailings to WSF (1:7 to waste rock) = 1,400 m3/day (dump trucks);
- Backfill of Main Pit (below haul road access) = 2,500 m3/day (dump trucks);
- Backfill of Main Pit (above haul road access) = 5,000 m3/day (dump trucks);
- Contaminated soils to WSF = 2,500 m3/day (dump trucks);

- Mt Burton waste rock to WSF = 1,000 m3/day (road trains); and
- Clean fill from borrow pit to either WSF or Main Pit = 2,500 m3/day.

8 SCHEDULE

The rehabilitation program is planned to be implemented over eight years with earthworks only being undertaken during the dry-season. The detailed construction schedule has been outlined by SLR (2015b) and is included in Appendix D.

The following key assumptions are used in the Order of Works and directly affect the timeframe required to complete the works:

- The construction working period occurs in the dry season from 1 May to 30 November each year (214 days).
- The wet season is from 1 December to 30 April (151 days) and the supporting activities occur during this period, they include; environmental monitoring, pit dewatering and water treatment.
- Main Pit will be dewatered to approximately RL 23m AHD for the construction of an access ramp into Main Pit.
- Dredging equipment will be installed and launched from a working platform at the end of the Main Pit ramp.
- Dredging of tailings from Main Pit is to be completed in 2 dry seasons.
- Dewatered filter pressed tailings will be mixed with waste rock, placed and compacted in the new WSF.
- A layer of coarse waste rock is required to be placed on top of residual tailings that remain in Main Pit after dredging is completed. This material will be end tipped from the working platform at first and until an access ramp can be created from the waste.
- Backfilling of PAF material into Main Pit has been prioritised. Material classified as PAF 1 and PAF 2 will be disposed of below the water table in the Main Pit to the greatest extent possible. Only clean fill and growth medium will be placed above the groundwater table in the backfilled pit.
- Construction of the WSF has been based on:
    - excavation of footprint material
    - excavated footprint material will be conditioned then backfilled and compacted to form a stable foundation and seepage collection low permeability layer,
    - paddock dumping (2m lifts),
    - dozing and compaction by trafficking,
    - incorporation of lime and compacted clay layers within the WSF
    - covered by a purpose designed enhanced store and release cover system.
- Rehabilitation of excavated waste rock dump footprints will involve up to a 2.0 m over excavation, lime application, and then fill of the excavation of clean growth medium to re-instate the pre-mine topography.

9 COST

The cost estimate has been developed by a professional cost estimator based on an overall Class-3 budget level of accuracy (+/-15%) (Resource Utilisation Consulting Pty Ltd). Cost estimates have been developed from a combination of first principles, quotations and rates to estimate overall costs and based on detailed calculated quantities for each activity and/or task (Resource Utilisation Consulting, 2016).

9.1 Approach

The approach used to estimate the cost of the civil works plan is summarised as follows:

- Detailed engineering designs were completed for all aspects of the works based on closure criteria, progressive risk and options assessment.
- Supporting investigations were conducted by various consultants and also informed the engineering design. Design parameters were determined and costs estimated from first principles or estimates were sought from reputable suppliers for activities such as dredging and water treatment.
- Detailed DTMs provided by the DME were utilised to prepare three dimensional landforms, rehabilitated surfaces and roads. Accurate quantities of materials, surfaces, haul distances etc. were determined digitally for the design activities and tasks.
- Activity specific unit rates were calculated using detailed plant, labour, materials and fuel cost elements (Resource Utilisation Consulting, 2016).
- A “proprietary database” estimating system was used for overall cost estimation.
- Resources were allocated to distinct activities and the activity cost items were then grouped to determine total cost rates.

More detail is provided in the standalone information, including summaries and extracts from the “proprietary database”, are provided by Resource Utilisation Consulting.

9.2 Key Assumptions

Key assumptions used to complete the cost estimate to Class-3 budget level of accuracy (+/-15%) are:

- Owners costs have been calculated by utilising actual costs currently incurred by DME including; salaries, project managements, royalty payments, and engineering support.
- Contractors Preliminary and General have been established based on similar sized projects.
- Dredging costs were obtained from a dredging contractor and have been based on the Main Pit tailings dredging requirements (to be completed in 2 dry seasons). The cost of pumping dredged tailings and water is included in the dredging cost.

- Tailings thickener and filter costs were obtained from a minerals processing company including pumping rates, slurry density (solids to water ratio) tailings densities (SG) and particle size distributions.
- The WSF will be constructed by paddock dumping (2m lifts), dozing and compaction by trafficking, incorporation of lime and compacted clay layers within the WSF.
- All Growth medium and low permeability clay material required for construction of the works is sourced from the FRLT borrow pit.
- Rock armour will be reclaimed from the existing WRDs and additional rock will be generated from onsite excavations or suitable materials within the footprint of the WSF.
- A single lane, all weather concrete bridge will be constructed over the existing diversion as part of the site access. Pile foundations will be required to depths of 14 m to 27 m on either side of the diversion.
- Typical earthmoving equipment has been utilised for completion of the works. This includes:
  - For smaller works (as required): a CAT D9 dozer, a CAT 988 FEL, a 30t excavator, 40t ADTs, etc.;
  - For moving waste rock: a 190t Excavator, a CAT 992 FEL, two teams of CAT 777 dump trucks, a CAT D9 Dozer, a 16H Grader, a 35 kl water truck, a service truck etc.;
  - For long haul transport (from FRLT to site): a CAT 988 FEL and double or triple road trains; and,
  - For road maintenance and stockpile management: a CAT 14H grader, a D9 dozer, a 30t excavator, compactors, 16 kl water trucks, service trucks etc.
- Revegetation costs have been based on recent revegetation costs at the site, incurred by DME.
- The following production rates were used for the material movements. These rates are dictated by access to both the excavation and dumping areas, machine types and other construction considerations noted above:
  - On-site waste rock to WSF = 10,000 m3/day;
  - Tailings to WSF (1:7 ratio) = 1,400 m3/day;
  - Backfill of Main Pit (below end of ramp) = 2,500 m3/day;
  - Backfill of Main Pit (above end of ramp) = 5,000 m3/day;
  - Contaminated soils to WSF = 2,000 m3/day;
  - Mt Burton waste rock to WSF = 1,500 m3/day; and
  - Borrow material from FRLT borrow pit to either WSF or Main Pit = 2,500 m3/day.

- Rehabilitation of excavated waste rock dump footprints will involve applying lime and then the application of growth medium.
- All facilities will be removed after completion of construction.

9.3 Bill of Quantities and Cost Estimate

The cost estimate is provided separately to this report.

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Appendix A

Completion Criteria

Appendix B

Supporting Investigations

Appendix C

Detailed Design Drawings

Appendix D

Detailed Schedule

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