Designer waste landform modelling and design — Rum Jungle Mine

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Abstract

Rum Jungle is a former uranium mine site near Batchelor in the Northern Territory. Historical mining activities at the site between 1952 and 1971 have led to ongoing and adverse impacts on the surrounding environment. Sulfidic mine waste is prevalent in the Main and Intermediate Waste Rock Dumps (WRDs) and consequently, Acid and Metalliferous Drainage (AMD) is a problem. Even though a technical assessment after rehabilitation determined that the engineering and environmental criteria were met, ongoing impacts have led to contemporary water quality standards not being met in the East Branch of the Finniss River and soils around the site, and led to poor vegetation establishment and coverage.

The Department of Mines and Energy (DME) is directing a collaborative, multi-phased rehabilitation planning process for the site. The Former Rum Jungle Mine Site Conceptual Rehabilitation Plan (CRP) (2013) outlines the objectives, the rehabilitation approach and preferred rehabilitation strategy for the mine site. Objectives for the site are to provide geotechnical and geochemical stability so as to allow for sustainable land uses by traditional Aboriginal owners of the site. To achieve these objectives, it is proposed to relocate all existing above ground WRDs, to either backfill the Main Pit void, or a single, stable and aesthetic waste storage facility (WSF) which will be constructed on site. Development of the strategic approach and detailed design of civil engineering works is currently underway to manage geochemically and radiologically active mine waste prevalent across the site.

O’Kane Consultants Pty. Ltd. (OKC) is preparing rehabilitation designs for the overall site, supported by various (ongoing) technical assessments for the WSF and Main Pit. The detailed numerical modelling includes a material balance assessment, waste placement and oxygen ingress modelling, waste wetting up and drain down modelling, cover system and landform evolution modelling. The control of surface water, seepage, and erosion in the long-term and during construction is central to achieving the rehabilitation objectives. As such, assessment of the proposed WSF geometric design methodology by the practical implementation of landform evolution models, including Water Erosion Prediction Project (WEPP), SIBERIA and CAESAR-Lisflood is being completed. These models are used in conjunction with sophisticated terrain modelling software (Civil 3D) to assess future stability based on surface materials and desired landform geometry. The assessment methodology is based on lab testing and observations of erosion on existing landforms and the validation adds confidence to the assessment. This enables improved aesthetic design for the proposed WSF, an important design objective, and can provide confidence in stability of the landform over long time frames.

The results of the detailed assessments by OKC and other consultants are used to conduct ongoing detailed engineering designs for the overall site including the design of the WSF with appropriate waste placement specification, a natural shape and provide long-term surface stability. This paper discusses the overall approach and integration of the various technical studies and supporting numerical assessments.
1 Introduction

This paper discusses the current site-wide rehabilitation strategy for Rum Jungle (excluding nearby satellite operations). The general approach involves backfilling of the Main Pit with sulfidic waste, and constructing a single purpose-built, consolidated landform from the material that cannot be accommodated in the pit. The proposed new waste storage facility (WSF) is to be designed and constructed using contemporary design principles, and thereby provide a long-term geotechnically and geochemically stable landform.

1.1 Background

Historical mining and mineral processing activities at the site between 1952 and 1971 have led to ongoing and adverse impacts on the surrounding environment. The former Rum Jungle mine site was rehabilitated between 1983 and 1986 consisting of:

- Three WRDs with cover systems — Main, Intermediate and Dysons.
- Two water-filled mine pits — Main and Intermediate.
- One pit backfilled with tailings and overlain with contaminated soil (Dysons).

The site layout is provided as Figure 1. A detailed description of the works and current conditions of the site are provided in The Former Rum Jungle Mine Site Conceptual Rehabilitation Plan (CRP) (DME, 2013). At the time, the rehabilitation was considered successful. However, recent studies show that the deterioration of the works has jeopardised the efficacy.

![Figure 1](image-url)  
Figure 1  Existing site layout of the former Rum Jungle mine site showing three WRDs, two water-filled pits and the backfilled pit (Dysons)
Sulfidic mine waste is prevalent in the site WRDs and given the high seasonal rainfall, acid and metalliferous drainage (AMD) is a problem. Even though a technical assessment after rehabilitation determined that the engineering and environmental criteria were met, deterioration of previous rehabilitation works has occurred, and AMD occurs. The AMD has led to surface water contamination in the East Branch of the Finnis River, with contemporary water quality standard not being met, soils around the site are contaminated in some areas and consequently there is poor vegetation establishment and coverage (DME, 2013).

As part of the current collaborative, multi-phased rehabilitation planning process for the site O’Kane Consultants (OKC) is developing site-wide detailed engineering designs for rehabilitation. Engineering design work is informed by supporting assessments, and numerical models. This includes materials characterisation, volumetric assessments, water balance, soil-plant atmosphere assessment, oxygen-ingress assessment, solute seepage and transport analysis, and erosional stability assessment of the proposed WSF. Groundwater, surface water, ecological assessment and contaminated material identification assessments are being undertaken by other specialist consultants.

This work is currently in progress and this paper aims to present the general approach and the intended use of conceptual models and the detailed numerical assessments to implement site-wide rehabilitation designs.

1.2 Project objectives

The Former Rum Jungle Mine Site CRP (DME, 2013) is being directed by the Northern Territory Department of Mines and Energy (DME) and outlines the objectives for the site, the rehabilitation approach and preferred rehabilitation strategy required. The Conceptual Rehabilitation Plan details the vision of traditional Aboriginal owners for the land and specific objectives are derived from this, including creating a landscape which:

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

2 General approach

The current rehabilitation strategy has been refined from that outlined in the 2013 Conceptual Rehabilitation Plan. The refinement has occurred as a result of a Failure Modes and Effect Analysis (FMEA) risk workshop. The FMEA was undertaken to further refine the conceptual rehabilitation strategy, and provide controls for identified risks.

The proposed rehabilitation strategy involves backfilling of the Main Pit with PAF waste below the dry season minimum groundwater level, constructing a landform above with ‘clean’ fill to accommodate reinstating the East Branch of the Finnis River (East Branch). A WSF is to be constructed from the excess material that cannot be accommodated in the pit. The current vision for the proposed rehabilitated landscape, including rehabilitated landforms, the backfilled Main Pit and re-aligned East Branch is illustrated in Figure 2. The WSF is to be constructed based on a design that limits water and oxygen ingress through surfaces to reduce the potential AMD from the already oxidised PAF waste material.

The WSF is comprised mostly from material from the Main WRD, Dysons WRD and contaminated materials distributed across the site. The footprints of the existing WRDs and old tailings area will be rehabilitated in
a manner that reduces the potential for future impacts and encourages revegetation. Salt-laden river bed materials will be collected and included in the volume of material for disposal in the purpose-built WSF.

2.1 Water management

The rehabilitation strategy involves significant works to re-align the East Branch and thereby emulate the pre-mining surface water flows more closely, and meet the rehabilitation objectives. The planned reinstatement of the East Branch must occur following backfilling of the Main Pit, as the backfilled (clean) overburden forms-up the inside embankment of the East Branch. The re-instated reach of the East Branch occurs for approximately 1230m, predominantly along the existing flowpath between Main and Intermediate Pits. The East Branch is designed with a wide main channel cross section and shallow embankment slopes to provide stability.

An existing diversion channel provides capacity for moderate to high flow events and is to be retained. The channel, along with new proposed flood levees will be utilised during the construction phase of work to provide flood protection for the Main Pit. The diversion channel entrance will be upgraded to provide improved flow hydraulics and specific apportioning of flow between the East Branch and diversion channel under various flow conditions. Design ground levels at the diversion and East Branch entrances are specifically designed to direct low flows to the East Branch, whilst alleviating high velocities and shear stresses associated with high flows on the East Branch embankment.
The proposed WSF and surrounding areas includes surface water drainage that conveys runoff from the WSF, limits erosion of the cover system and connects with site flow paths. The plateau surface has been designed to convey surface water off the proposed WSF via a wide and shallow central swale (Figure 3). The plateau surface is graded to drain towards the central swale at variable gradients up to approximately 5% to limit the potential for ponding, and thereby reduce net percolation (NP) through the cover system. The swale has the capacity to convey at least a 1 in 100 year critical-duration storm event, with freeboard. The selection of 1 in 100 year design storm is based on acceptable risk.

Figure 3 Surface water management on the proposed WSF

Catchment flows and swale hydraulics are assessed using a sitewide hydrological model, based on location-specific intensity, frequency and duration storm characteristics, catchment routing, along with the specific geometry of the drainage.

Surface water perimeter drains are also required around the toe of the proposed WSF to prevent surface runoff from local catchments infiltrating through the embankment of the proposed WSF. These flow paths are also assessed using the site flood model, though is not the subject of this paper. The locations and alignments of permanent features are integrated into the design-landscape using Civil 3D to improve volumetric determinations for waste disposal and ease of modification to the design should changes be required.

Net percolation of water 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 within the WSF foundation. Seepage is conveyed from the WSF by gravity to the Intermediate Pit via a piped network fitted for either passive dilution of seepage in intermediate pit, or installation of an offtake from the pipework if necessary.

2.2 WSF

The WSF is to be designed and constructed to provide long term disposal of excess waste materials. The basis of design is to limit NP as far as practicable, to capture residual seepage and to provide long term stability of the WSF using contemporary landform design principles. OKC investigated the influence alternative construction methods of the WSF may have on oxygen flux, water flux, contaminant production and contaminant release.

The current indicative estimate of the landform size required is 8.3 Mm³, a visualisation of the landform is provided in Figure 4. The WSF location was selected based on a variety of factors considered by multi-
criteria decision making process accounting for aspects such as stakeholder preference, environmental risks and cost. The geometry of the landform was designed based on areal constraints of the selected location and the required capacity of the WSF.

Figure 4  Visualisation of the New WSF

One of the primary strategies to limit the generation of AMD from the WSF is to reduce the NP of surface water through the waste material. This is achieved by providing an enhanced moisture store and release cover system using materials specifically selected for their physical properties, by encouraging revegetation and providing hydraulic relief for surface runoff should saturation of the cover system occur. Poor quality seepage is inevitable and is to be collected by shaping the foundations of the WSF to a low-permeability sump. The collection system comprises dual geosynthetic barrier layers to prevent seepage loss to groundwater. The seepage will be drained from below the WSF via a gravity pipe system that simultaneously allows drainage of leachate, whilst restricting airflow back into the WSF with a downgradient water seal.

Air diffusion into the WSF is limited by layering and compaction of sequential lifts. The increased compaction reduces airflow in the WSF, as well as increasing seepage travel times through the WSF. The design lift-height is 2m, which achieves a superior level of compaction than comparatively higher lifts, derived from increased traffic and overall compaction density.

An enhanced store and release cover system (International Network for Acid Prevention — INAP 2015) is required on the WSF. The cover system is integrated with the internal waste placement specification to reduce NP to be in the very low NP range (O’Kane Consultants, pers. comms., 7 November 2012) and support vegetation establishment. During construction, temporary reduced-permeability covers will be placed prior to the wet season to limit infiltration during the wet. The covers will remain in-situ and form additional low permeability barriers.

A final cover system is required that not only addresses NP and oxygen ingress but also limits erosion on outer embankments. Landform evolution modelling provides strong evidence that concave slopes can reduce erosion of landforms significantly (Hancock et al. 2003). Concave slopes have been selected to limit potential erosion determined and these are to be assessed from flume testing for available borrow materials to used for embankment construction. Armour materials on current outer embankments of the existing WRDs will be reused in combination with other suitable borrow materials to provide suitable
erosion resistance. Figure 5 indicates the conceptual integrated design for the WSF that is being progressed to detailed design.

![Conceptual WSF geometry](image)

**Figure 5  Conceptual WSF geometry**

The cover system design will include monitoring equipment required for validation of the cover system, the specific instrumentation required (sensors and data acquisition systems) and placement guidelines to optimise data output and interpretation of conditions. Internal WSF instrumentation will be included to comprise an integrated overall WSF monitoring system. Erosion and surface water runoff will also be monitored to validate erosion modelling.

### 2.3 Main Pit

The rehabilitation strategy for the Main Pit is for it to be dewatered and backfilled with contaminated waste from Intermediate WRD, Dysons Backfill Pit, Main WRD, the copper extraction area, and from contaminated soils across the site. The pit will be backfilled in distinct layers of coarse waste, well-compacted finer textured and coarse PAF materials, mixed with lime and placed to below the final groundwater level. Clean fill will then be placed above the PAF waste to a sufficient height to allow for settlement whilst maintaining a free draining surface. Unconsolidated tailings at the base of the Main Pit will be dredged out prior to backfilling.

The design of the Main Pit backfill final surface comprises a raised landform to account for settlement over time. The required cover depth over the PAF waste must be sufficiently proud of the reinstated East Branch to compensate for settlement of the backfilled surface. Areas of deeper backfill will be subject to higher settlement rates, this is likely to occur over a decadal time scale, and the final surface design must remain free draining. A visualisation of the Main Pit backfill area (looking west) is provided as Figure 6.
The backfill design also includes monitoring equipment required for validation of the NP, groundwater levels. The specific instrumentation required (sensors and data acquisition systems), the implementation plan and installation costs are to be provided for detailed cost estimates.

2.4 Dysons backfilled pit

The rehabilitation strategy for Dysons backfilled pit is to remove contaminated materials to an existing rock blanket above the infilled tailings. Existing contaminated materials over the rock blanket will be disposed in Main Pit below the water table. A new cover system will be constructed to manage NP into the tailings. A cover system was designed to maintain an appropriate degree of saturation in the deposited tailings over time to simultaneously limit oxidation of the tailings and limit seepage out of the tailings for a range of potential climatic conditions.

A 2 m coarse backfill layer is recommended over the existing tailings surface before placement of the cover system. This provides several benefits in cover system design, including

- providing a potential drainage layer to transport up-gradient flow and net percolation waters through the system without contacting tailings.
- increasing the distance between the tailings surface and the base of a potential cover system which will include a finer-textured barrier layer at the base.
- providing a textural break between the tailings and barrier layer of the cover system improving cover system performance.

The cover system evaluated for Dysons backfilled pit comprises a 0.5 m compacted fine-textured clayey layer and drainage layer underlying a 2 m non-compacted growth medium layer. The growth medium layer provides water storage for vegetation growth and protects the finer-textured layer from the impacts of wetting and drying cycles.

2.5 Existing WRDs, copper extraction area and contaminated soils

Engineering design has to integrate geochemical, geotechnical, cover systems and surface materials, surface water and groundwater assessments. The currently proposed approach for the 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 excavated below ground level to remove contaminated underlying soils and backfilled with clean fill and/or further excavated to provide free draining surfaces. Contaminated material and soils present on site will also be removed and disposed of in the Main Pit or the WSF depending on the level of contamination and space available within the Main Pit. In the intermediate WRD footprint area, residual contaminated groundwater management must be addressed via wet-season water collection within the footprint and dewatering to enable treatment of contaminated water within Intermediate Pit.

Excavation, infilling and regrading of the copper extraction area, along with miscellaneous contaminated soils present on site, are included.

Suitable growth medium will be placed in the areas where required to re-establish vegetation with an established weed management program to restrict the proliferation of invasive species, such as gamba grass, and to return the landscape to a condition in accordance with objectives.

2.6 Roads, pads and ancillary earthworks

A network of temporary and permanent access roads will be required for both the construction and post construction phases of the project. Haul roads for heavy vehicles and access roads for light vehicle traffic will be included. OKC is working with DME to establish preferred routes and potential changes over time based on the current construction schedule.

Ancillary earthworks will be required for development of pads and platforms for key infrastructure. This includes general items such as platforms for buildings, pump pads, tip heads etc. Suitable construction materials will have to be imported to site since on-site materials was depleted during previous rehabilitation projects and original site establishment.

Access is required to facilities such as pits, WSF and borrow areas, and these required alignments will change over successive construction seasons. Suitable fleets, road corridors and spatial requirements for safe and practical operation are being identified as part of the integrated design and scheduling process. Road corridors are to be integrated into the digital terrain model to provide earthworks schedules and cost estimations required for project execution budgeting.

2.7 Drainage, diversions and impoundments

Works relating to drainage, diversions and impoundments are key to the overall success of the rehabilitation design. Surface water must be managed during construction (estimated eight years). Requirements of the surface water management include the ability to divert and drain surface waters, but also to maintain aqueous biological diversity and populations. Subsequent to construction, when new drainage structures have been shown to be sufficiently erosionally stable, surface waters may be re-directed.

During Main Pit backfill construction, surface runoff from the East Branch will be diverted away from Main Pit. Diversion levees are required in conjunction with upgrading the existing Diversion channel to accommodate larger flood events.

The final site-scale water management approach involves major works to re-align the East Branch to emulate the pre-mine hydrology more closely. This involves hydrologic modelling, including upstream Finniss River catchments with particular focus on the Main and Intermediate Pit hydraulic connections and the connecting floodway. Surface runoff will gradually be routed to the new channel alignment whilst maintaining the diversion so as to be able to control flow in the new channel alignment.

2.8 Borrow materials

The overall rehabilitation approach will require large volumes of borrow material for clean infill over Main Pit, for foundations, cover systems and levees. The large volume of cover system material requires detailed characterisation of all potential borrow materials and verification of volumes of suitable borrow materials.
Borrow material investigations are ongoing to investigate sources from on and off site which have the potential to be used for infrastructure, cover systems and general rehabilitation of disturbed areas.

3 Supporting technical assessments

Numerical modelling and targeted assessments are required to inform and support engineering designs. Modelling is a tool to understand key processes and characteristics that influence performance of a particular closure design, and support engineering decisions based on this understanding.

3.1 Overview

The following assessments are currently being undertaken:

- Cover system modelling and assessment(s). Cover systems are required for the proposed WSF and modelling provides an indication of long-term performance. Soil-plant-atmosphere modelling is undertaken to confirm the required cover thickness, materials properties and predicted NP rates. Cover system modelling has to be integrated with oxygen ingress and internal waste placement modelling and design.

- Oxygen ingress. Oxygen ingress into landforms can be limited through waste placement techniques in combination with a cover system appropriate for the climate and with the materials available for cover system construction. Oxygen ingress and NP reduction will be key taking into consideration that most of the waste have already oxidised and will have residual acidity. Special attention is given to outer embankments and the base of the WSF to include features that limit oxygen ingress such as starter bunds and a seepage collections system that limits backflow of air into the WSF. The modelling is used to further inform AMD-generation predictions for the future.

- Assessment of waste volumes. Designs are visualised using 3D design modelling software (Civil 3D) to enable 3D visualisations of the site, interrogate sections of interest through existing WRDs and the WSF and enable the accurate evaluation of earthworks volumes. Construction of 3D digital terrain models using high resolution survey enables the accurate assessment of waste volumes to confirm the size and geometry of the final waste landforms. This is required to estimate load/haul metrics to include for the earthworks schedule and works budgeting.

- Erosion assessment. Erosion of mine waste is an important process to understand because surface instability and the formation of incisive rill and gullies can lead to a landform failing to meet physical stability objectives. The site landforms must be able to provide drainage of surface water without significant erosion to ensure cover systems function as designed and prevent the exposure and transport of reactive waste or AMD products. Designs are to be supported by predictive models. The SIBERIA, CAESAR-Lisflood and Water Erosion Prediction Project (WEPP) models are being used to estimate erosion over design life timeframes and validation of design work using these tools is considered industry best-practice.

3.2 Cover system assessment

Numerical modelling and targeted assessments are required to determine final engineering design specifications for the proposed WSF. An integrated quantitative assessment is ongoing as part of the cover system and landform design. The preferred cover system design for the WSF is 2 m non-compacted growth medium over 0.5 m compacted clay (‘good’ quality barrier), resulting in 5% to 10% NP. 0.15 m of topsoil is to be placed on the surface. This cover system is the preferred alternative based on constructability, cost effectiveness, material availability, and overall performance. The low and very low NP cover systems modelled were saturated during the wet season and are supplemented with a robust, surface water and shallow interflow drainage system is required to manage the surface water runoff in saturated conditions.
Based on an earlier cover system design study, a base case configuration of available materials identified on site was determined for numerical analysis. Soil-plant-atmosphere numerical modelling was completed to evaluate the performance of the cover system design in terms of limiting NP and oxygen ingress to the waste rock. Results of the base case analysis were applied to indicate whether modification of the preferred cover design was necessary to achieve target rates. One-dimensional (1D) numerical simulations were completed to predict the performance of the cover system design using Vadose/W (Krahn 2004), a saturated-unsaturated numerical model that is fully coupled to the atmosphere. The VADOSE/W model uses meteorological inputs such as air temperature, relative humidity, rainfall, and potential evaporation to define the flux to heat and moisture at the soil-atmosphere interface. NP and oxygen ingress was used as the indicator of cover system performance in the modelling program. The probability of the cover systems exceeding given values of NP and oxygen ingress were derived from the results of the 100-year simulations. The probability function allows the inclusion of risk-based analysis into the design of the final closure landform for the Rum Jungle WSF.

Target NP rates required to limit adverse impact to the WSF base liner and ultimately groundwater was verified through numerical analysis. SEEP/W, a two dimensional (2D) finite element model, was used to simulate the saturated and unsaturated movement of water and pore-water pressure distribution within the waste rock. Resulting NP rate below the cover system was applied as a surface flux boundary for steady state simulations. Seepage rate received at the WSF floor, above the base liner, was used as the criterion of performance of the cover system and internal dump structure. This allowed for long-term performance predictions to be assessed (100-years) and thus refinement of the final cover system to be developed for construction of the WSF, in accordance with the preferred rehabilitation strategy.

3.3 Volumetric assessment

In order to develop the design, along with earthworks schedules and cost estimates, a detailed schedule of contaminated earthworks was developed for all waste materials to be removed and relocated. Digital terrain models were developed using 3D design modelling software (Civil 3D) and high resolution survey. The terrain models enable accurate flood modelling and enable the accurate evaluation of earthworks volumes. Further, they allow for 3D visualisations of the site and enable designers to closely interrogate sections of interest. They provide the level of detail required to develop the size and geometry of the final waste landforms and to estimate load/haul metrics to include in the final schedule of quantities. This is of key importance to evaluate how material movements can be optimised, and minimise the significant costs associated with materials movement during construction.

3.5 Landform erosion assessment

Erosion of mine waste is an important process to understand as surface instability and the formation of incisive gullies may lead to the WSF to fail to meet physical and geochemical stability objectives. The WSF is to be constructed predominantly from PAF waste and therefore constitutes a significant potential source of AMD should erosion of the surfaces occur. A reduction of cover system thickness due to erosion reduces the water storage capacity, and if not properly accounted for in the design stage, may result in increased NP, or the development of soil water conditions (i.e. saturation) that do not support the development of a mature vegetation layer. The WSF must simultaneously convey surface water from the plateau, and resist erosion on both the plateau and outer embankments to ensure cover systems function as designed.

The methodology used to assess erosion and to provide recommendations for improvements partially utilises observations from erosion and materials used on the surface of existing site landforms, and utilises commercial computer software designed specifically to assess erosion over long time frames. Various models are used for predictive assessments to provide confidence and as they use different techniques for erosion assessment can be utilised for cross-validation. The models used include the WEPP, SIBERIA and CAESAR-Lisflood models.
3.5.1 **WEPP**

WEPP is a process-based soil erosion prediction model that incorporates the fundamentals of soil hydrologic erosion such as water infiltration, runoff, soil detachment mechanisms, soil water percolation, sediment transport, sediment deposition, evapotranspiration, and plant growth (Flanagan 2013). WEPP was used to develop the general 2D geometry of the embankments and compare erosion along a series of transects of the WSF embankments. Numerous slope configurations were tested and compared to develop a set of profiles that limit overall erosion and erode consistently along the modelled profile length. A 100-year climate sequence was used in WEPP along with material erodibility parameters adopted for the expected cover materials (site material sampling and laboratory testing in 2012/13 provided a good basis for the selection of these parameters). The slope configurations were then combined to form a 3D surface and modelled in SIBERIA to provide a quantitative assessment of erosion.

WEPP was selected for the initial assessment and conceptual embankment design as it allows for the rapid evaluation of different embankments profiles. The profiles adopted for this assessment included various linear and concave slopes constrained by the maximum height of the proposed WSF (approximately 40 m) and known regional flood lines for maximum toe extents. Additionally, the meteorological data used in WEPP allows for the introduction of variability in rainfall and the seasonal nature of the climate. Climatic data used in this assessment was generated for a 100-year time period.

3.5.2 **Landform evolution modelling**

SIBERIA and CAESAR-Lisflood landform evolution models are to be used to assess erosion rates and depths over long time scales. These models are particularly useful in their ability to assess erosion in three dimensions, i.e., they consider erosion as a result of area/runoff accumulation effects and the changes of the catchment morphology. They allow visualisation of the landform at points in time and prediction of erosion form based on selected thresholds for gully initiation and development.

SIBERIA is a model which simulates the geomorphic evolution of landforms over time. The model links widely accepted hydrology and erosion models under the action of runoff and erosion over long-time scales. CAESAR-Lisflood is a landform evolution model and can predict erosion based on specific storm events and sequences, along with the starting landform geometry and the physical properties of surface material. CAESAR-Lisflood is used to evaluate the response to high intensity storm events and add confidence in the designed landform.

The use of SIBERIA and CAESAR-Lisflood is conducted iteratively and on an ad-hoc basis during design to evaluate different landform geometries, as informed by WEPP. Design terrain models are digitally input into the models and their geometry is assessed for stability using a range of input parameters, relating to climate hydrology, specific material properties and erodibility characteristics. Assessment of the WSF geometry is ongoing and results are therefore not presented herein. However, the conceptual geometry of the WSF is anticipated to include a concave outer embankment, in line with contemporary landform design theory.

3.6 **Oxygen ingress assessment**

OKC are investigating the influence alternative construction methods of the WSF may have on oxygen flux, water flux, contaminant production and contaminant release. This assessment aims to evaluate whether oxygen ingress into the WSF can be limited through waste placement techniques and in combination with a cover system appropriate for the climate and with the materials available for cover system construction. Oxygen ingress and net percolation reduction are key taking into consideration that most of the waste has already oxidised and will have residual acidity. This work is dependent on the outcomes of the existing waste material assessment, landform site selection and the borrow assessment.

Gas ingress into waste can occur through diffusive, convective, and advective gas transport. It is hypothesised that convective gas flow is the dominant gas transport mechanism for gas flow in a porous
medium where exothermic reactions are occurring. A key outcome of the assessment is the determination of potential for advective gas flux and thus oxygen ingress and the consequent potential for sulfide oxidation based on placement technique. Various placement scenarios are considered ranging from 2m compacted lifts to 30m high end-tipped lifts.

Paddock dumping of material in 2 m lifts is likely to result in significantly lower gas fluxes that will limit the oxidation of waste. The “in place” volumetric water content, and material texture profile for material placed using this technique has a significant effect on the magnitude of the reduction in oxidation rate that can be achieved.

In addition further scenarios were considered in which toe bunds and/or low permeability compacted surface sealing layers are used to control advective gas flux by placement in each lift as part of construction.

The WSF has a low permeability liner at the base and a seepage collection system. The seepage collection system has the potential to provide a pathway for oxygen ingress due to the coarse nature of the materials used or the layer. A water seal is included to cut off oxygen at this collection layer.

4 Conclusion

This paper provides an overview of the technical approach and supporting studies for detailed engineering designs at Rum Jungle. The design encompasses numerous site area-based domains, including a new WSF, Main Pit, Dysons backfilled pit, existing WRDs and the copper extraction area. It also discusses requirements of supporting infrastructure, including surface water structures and supporting features such as roads, pads and ancillary earthworks.

The rehabilitation strategy involves disposal of contaminated waste in the Main Pit and the construction of a new stable facility to accommodate excess waste material that cannot be disposed in the pit owing to volumetric limitations. The East Branch of the Finniss River will be re-instated through the pit area and other disturbed areas will also be rehabilitated.

Engineering designs and supporting studies aimed at achieving rehabilitation objectives are being conducted by OKC and are presently ongoing. This includes, but is not limited to, a rigorous cover system assessment, site-wide earthworks scheduling, erosional stability assessment and oxygen ingress. Other specialist consultants are conducting additional support studies. The rehabilitation strategy requires significant earthworks and will be conducted over several years in an effort to meet objectives outlined in the Former Rum Jungle Conceptual Rehabilitation Plan (DME, 2013).

References


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