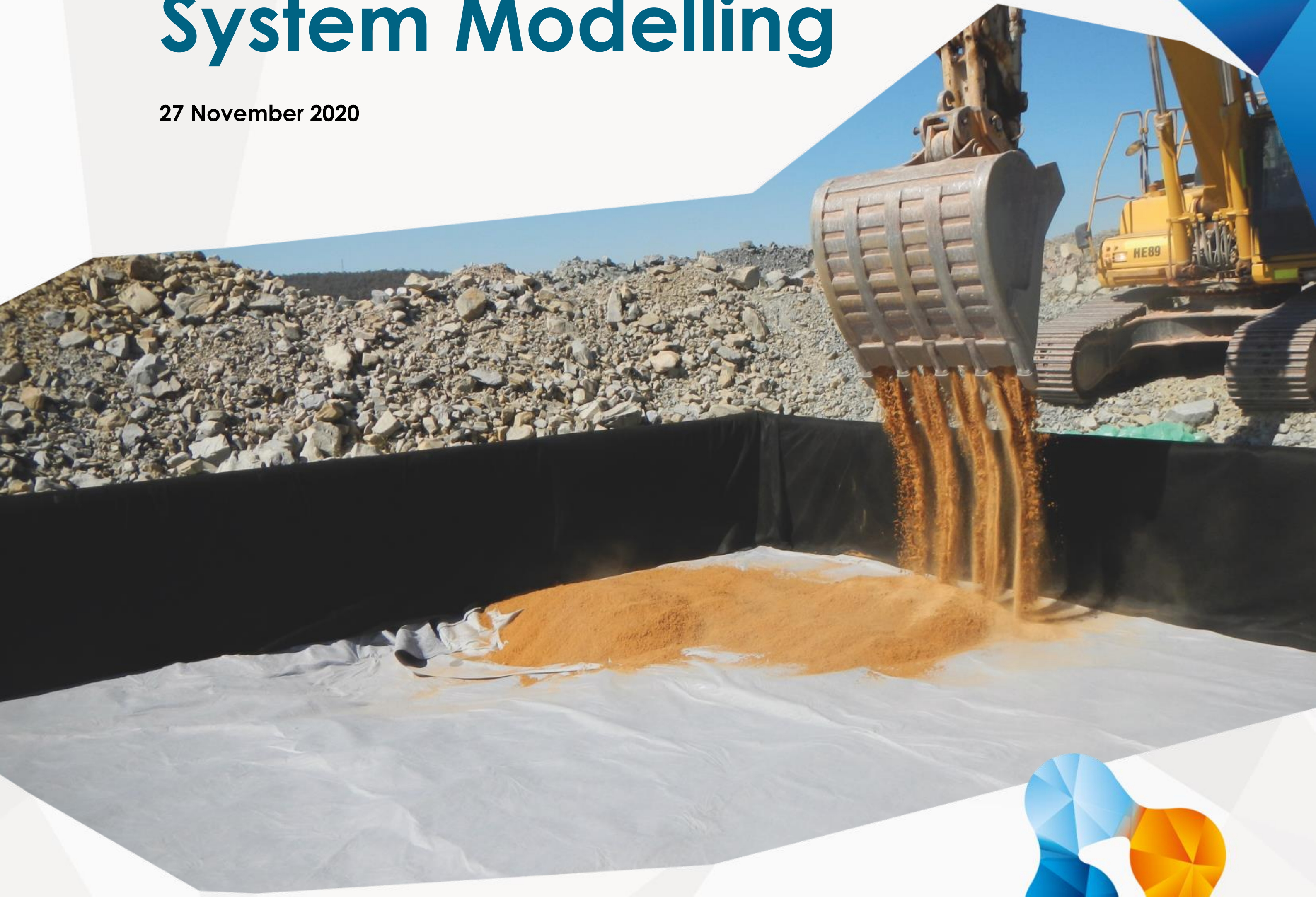
Winu Copper Project - Conceptual Cover System Modelling

27 November 2020



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

Winu Copper Project - Conceptual Cover System Modelling

0662-049-001

November 2020

Prepared for:

RIO TINTO
Level 25, 123 Albert Street, Brisbane, QLD, Australia 4000

Prepared by:

Okane Consultants Pty Ltd

Unit 2, 14 Heussler Terrace
Milton, Brisbane QLD 4064
Australia

Telephone: (07) 3367 8063
Web: www.okc-sk.com

Rev. #	Rev. Date	Author	Reviewer	PM Sign-off
A	16 Oct 2020	Tami Taylor	Robert Shurniak	Becka Barritt
0	22 Oct 2020	Tami Taylor	Robert Shurniak	Becka Barritt
1	08 Nov 2020	Tami Taylor	Robert Shurniak	Becka Barritt
Final	24 Nov 2020	Tami Taylor	Robert Shurniak	Becka Barritt

DISCLAIMER

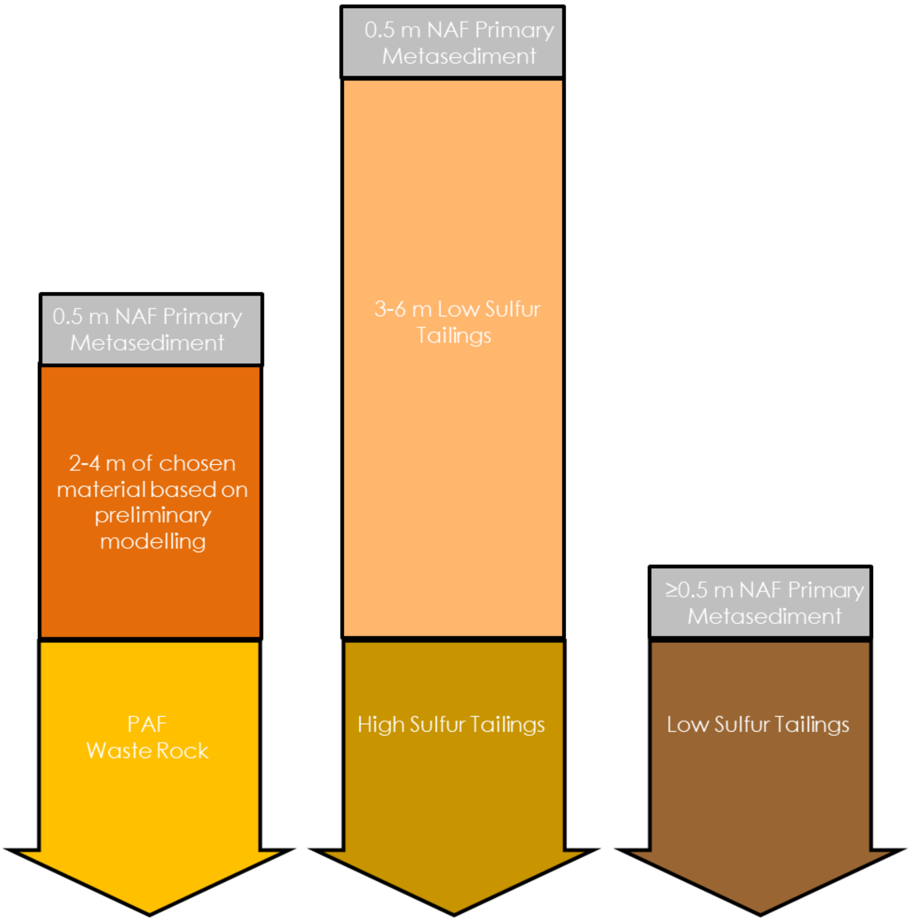
This document has been provided by Okane Consultants Pty Ltd (Okane) subject to the following limitations:

1. This document has been prepared for the client and for the particular purpose outlined in the Okane proposal and no responsibility is accepted for the use of this document, in whole or in part, in any other contexts or for any other purposes.
2. The scope and the period of operation of the Okane services are described in the Okane proposal and are subject to certain restrictions and limitations set out in the Okane proposal.
3. Okane did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referred to in the Okane proposal. If a service is not expressly indicated, the client should not assume it has been provided. If a matter is not addressed, the client should not assume that any determination has been made by Okane in regards to that matter.
4. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation, or information provided by the client or a third party and which have not therefore been taken into account in this document.
5. The passage of time will affect the information and assessment provided in this document. The opinions expressed in this document are based on information that existed at the time of the production of this document.
6. The investigations undertaken and services provided by Okane allowed Okane to form no more than an opinion of the actual conditions of the site at the time the site referred to in the Okane proposal was visited and the proposal developed and those investigations and services cannot be used to assess the effect of any subsequent changes in the conditions at the site, or its surroundings, or any subsequent changes in the relevant laws or regulations.
7. The assessments made in this document are based on the conditions indicated from published sources and the investigation and information provided. No warranty is included, either express or implied that the actual conditions will conform exactly to the assessments contained in this document.
8. Where data supplied by the client or third parties, including previous site investigation data, has been used, it has been assumed that the information is correct. No responsibility is accepted by Okane for the completeness or accuracy of the data supplied by the client or third parties.
9. This document is provided solely for use by the client and must be considered to be confidential information. The client agrees not to use, copy, disclose reproduce or make public this document, its contents, or the Okane proposal without the written consent of Okane.
10. Okane accepts no responsibility whatsoever to any party, other than the client, for the use of this document or the information or assessments contained in this document. Any use which a third party makes of this document or the information or assessments contained therein, or any reliance on or decisions made based on this document or the information or assessments contained therein, is the responsibility of that third party.
11. No section or element of this document may be removed from this document, extracted, reproduced, electronically stored or transmitted in any form without the prior written permission of Okane.

EXECUTIVE SUMMARY

Rio Tinto retained Okane to undertake numerical modelling of conceptual cover system designs for the proposed Greenfield Winu Project (Winu). The conceptual cover system modelling was based upon preliminary material types and projected future climate change conditions. Cover system designs that utilise the store-and-release concept were proposed to be the preferred options for closure of the waste rock dump(WRD) plateau area and tailings storage facilities (TSF) given the climate conditions (low rainfall and high potential evaporation) and available cover system materials.

The conceptual cover system scenarios modelled within this project are provided below.



For the WRD plateau area, it is understood that the primary objective of the conceptual cover system is to limit water ingress to the PAF waste rock. The results of the PAF WRD plateau cover system design modelling indicate that increasing the closure cover system thickness to greater than 2.5 m had little effect on simulated net percolation (NP). All models performed relatively similarly from a NP perspective. This is largely a result of all conceptual design options having the same 0.5 m metasediment erosion protection layer at surface and vegetation inputs with underlying materials that have similar soil texture. For the sand and cemented sandstone store-and-release cover system design options simulated, NP results were categorised as low (1% to 5% of rainfall). Average annual NP was categorised as moderate (5% to 10% of rainfall) for the leached cap cover system design.

For the low sulfur tailings, the primary objective of the closure cover system was to limit NP; therefore, a thin store-and-release cover system was proposed. For the low sulfur tailings, long-term NP is anticipated to be <1% (very low) for a TSF lined with a low permeability geomembrane (representative of 1.5 mm LLDPE liner or equivalent).

The objective of the conceptual cover system for the high sulfur tailings is to maintain a high degree of saturation in the high sulfur tailings. This cover system objective is theoretically achieved by preventing the upward movement of water from the high sulfur tailings by decoupling the saturated high sulfur tailings from the evapotranspiration zone. Hence, the optimal cover system design is thicker than the combined depth of evapotranspiration and capillary rise from the high sulfur tailings. Based on the modelling results, it is anticipated that the proposed high sulfur tailings closure cover system consisting of 3 to 6 m of finer-textured (i.e. higher silt and clay content) low sulfur tailings overlain with 0.5 m metasediment will not maintain a high degree of saturation in the high sulfur tailings. However, a coarser-textured (i.e. higher sand content) low sulphur tailings cover system consisting of a minimum of 4 m of coarser-textured low sulfur tailings (i.e. sand) and 0.5 m of metasediment is anticipated to decouple the saturated tailings from the evapotranspiration zone and maintained a high degree of saturation (<90%) in the high sulfur tailings.

Recommendations for additional design and characterisation studies for closure planning at the Winu site are as follows and are described in more detail in the Recommendations section of this report:

- Material characterisation studies of stockpiled materials during operations including characterisation of water retention and hydraulic characteristics of potential cover system and waste material, and geochemical analysis.

- Complete a vegetation assessment study to characterise native vegetation in the Winu site area which will improve the conceptual model and provide guidance for revegetation planning.

- Integration of closure design options within life of mine (LOM) designs to strategically mine certain lithologies for direct placement at the WRD and thereby promoting progressive closure and limiting closure costs and environmental concerns at the end of the mine life.

- Detailed cover system design assessment should be completed once site-specific materials, climate conditions and vegetation characteristics are further refined and waste storage facilities (WRD and TSFs) designs are optimised and finalised.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Rio Tinto retained Okane to undertake cover system modelling of conceptual cover system designs for the proposed Greenfield Winu Project (Winu). The conceptual cover system modelling was based upon preliminary material types and historical climate / predicted climate change conditions. The main component of Okane's scope of work for the Winu conceptual cover system design project is numerical modelling of proposed cover system configurations for the waste rock dump (WRD) and tailings storage facilities (TSFs).

This technical report summarises the key background data that was provided and assessed for development of model inputs (i.e. material property inputs), conceptual closure cover system designs and the results of the numerical modelling program.

1.1 Project Objectives and Scope

The primary objective of the modelling program was to evaluate the hydraulic performance of conceptual closure cover system designs for the proposed landforms at Winu. Specifically, these comprise the plateau area of the waste rock dump (WRD), high sulfur TSF and low sulfur TSF. The scope of this project involved completion of the following major tasks:

1) Development of material properties for available cover materials based on available field data provided by Rio Tinto;

2) Completion of one-dimensional (1D) soil-plant-atmosphere (SPA) numerical modelling to characterise the unsaturated flow dynamics within the proposed cover system options; and

3) Completion of 1D solute transport numerical modelling to assess the potential for upward movement of salinity in pore water from the low sulfur tailings through the cover system profiles via advective and diffusive transport in response to unsaturated flow dynamics.

1.2 Report Organisation

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

- Section 1 – Provides an introduction to the project and scope.
- Section 2 – Provides pertinent background information and the conceptual model.
- Section 3 – Summarises the modelling program, inputs and results.
- Section 4 – Provides a summary of the project and further recommendations

- Section 5 – Provides reference material quoted throughout this document.

2 BACKGROUND

2.1 Site Background and Closure Objectives

The Winu site is located in the Yeneena Basin of the Paterson Province of Western Australia, approximately 110 km north of the existing Telfer mine and 330 km west of Port Hedland (Figure 2.1). It is understood that the project will target a copper deposit with associated gold mineralisation.

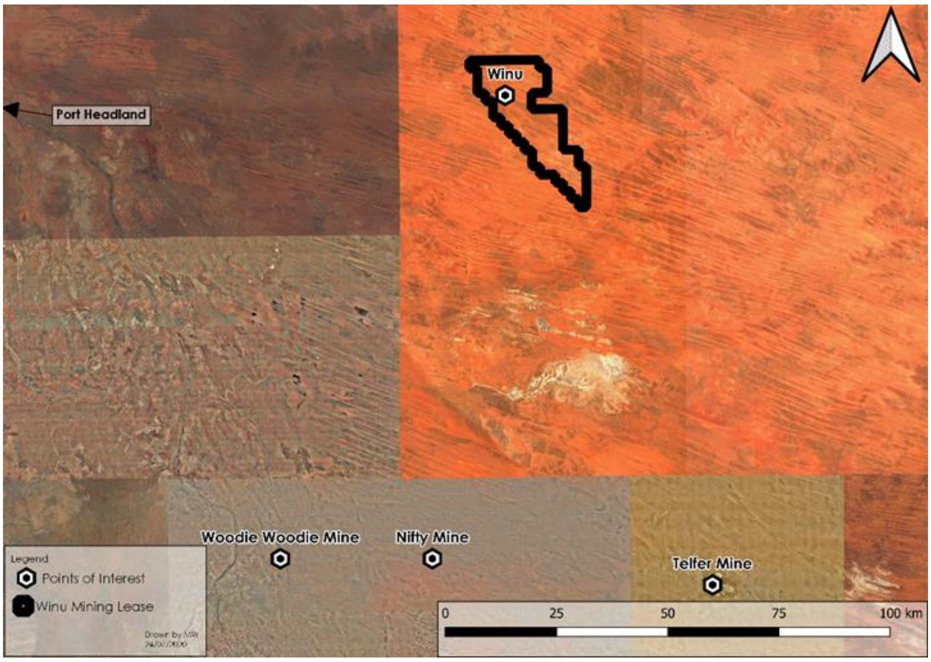


Figure 2.1: Winu Site Location and Mining Lease

Base map adapted from WA Government (2020)

The Winu site is within the Great Sandy Desert and is topographically defined by large sand dunes. Based on the preliminary mine plan, there will be ~ 245 Mt of waste materials produced during mining at Winu which consists mostly of sandy and clayey unmineralised overburden (Rio Tinto, 2020). Based on geochemical characterisation of the waste materials to be mined, the majority of waste materials are anticipated to be benign though some of the waste materials are expected to be potentially acid forming (PAF) materials.

Environmental risks resulting from potential acid and metalliferous drainage (AMD) are proposed to be minimised through:

- Segregation of PAF material primarily found within the mineralised zones (secondary and primary meta-sediment materials) and encapsulation of the PAF material with non-acid forming (NAF) waste materials; and
- Use of closure cover systems on the waste rock dump (WRD) and tailings storage facility (TSF).

Tailings material has been separately characterised into high sulfur flotation tailings from the cleaner flotation circuit and low sulfur tailings from the rougher flotation circuit. Due to the very limited test work completed on tailings to date, it is recommended that a conservative approach is undertaken for tailings management and design. The high sulfur tailings will be managed separately to low sulfur tailings and disposed sub-aqueously (Rio Tinto, 2020a). Maintaining saturation in the high sulfur tailings would reduce the exposure to oxygen during tailings facility development, preventing AMD generation. On closure, it is proposed that a cover system be placed over the high sulfur tailings to maintain a high degree of saturation within the high sulfur tailings.

2.2 Geology

The regional geology is characterised by low-grade metasedimentary rocks with granitoid intrusions. The Winu deposit is a structurally controlled vein-hosted gold and copper deposit, hosted by low-grade metasedimentary rocks (siltstone and sandstones) (Rio Tinto, 2019). Supergene (weathering) alteration has resulted in a leached cap of the metasediments altered to clays, a copper oxide zone, and enrichment of copper mineralisation below the leached cap. The weathering, however, is not uniform and may have localised expressions, for example along a fault plane. Unaltered hypogene primary mineralisation occurs below the enriched supergene.

The Winu deposit is overlain by Permian and Quaternary sedimentary overburden, above an erosional unconformity.

The Winu deposit can be sub-divided into three main zones (Figure 2.2):

1) Oxidised/overburden (upper) zone: comprised of Quaternary sands, Permian sediments (sandstone, mudstone etc), and leached (oxidised) materials (complete leach, Fe leach and Cu oxides). Copper mineralisation has been oxidised;

2) Enriched/secondary sulfide (middle) zone: copper is present as secondary sulfide minerals (enriched); and

3) Hypogene/no enrichment (lower) zone: primary sulfide mineralisation (unweathered).

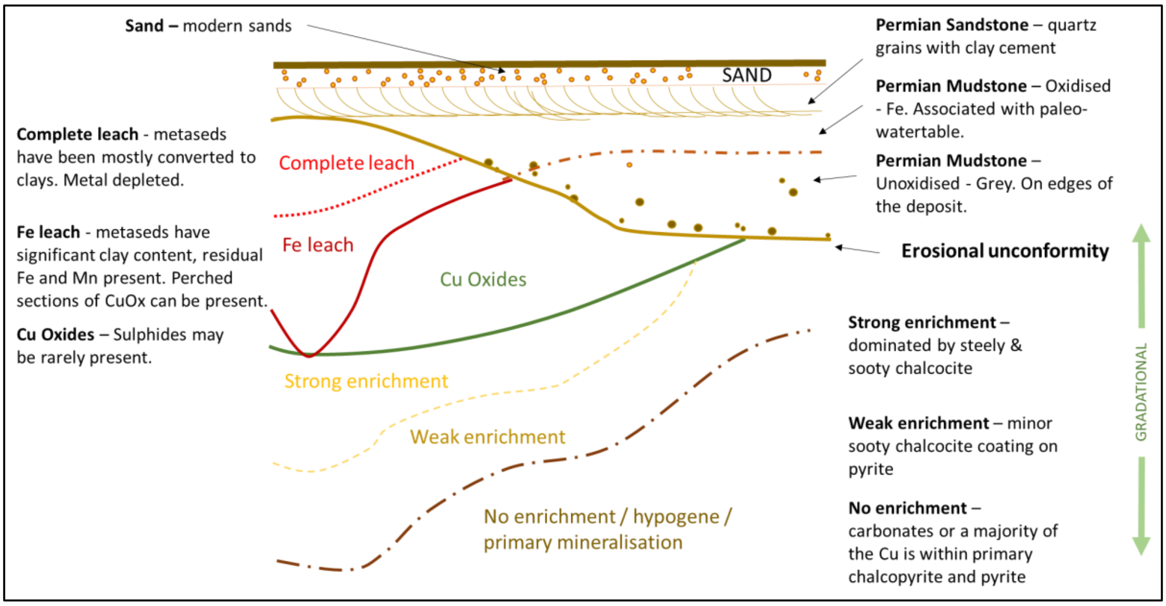


Figure 2.2: Cross Section of the Winu Deposit

Modified from Rio Tinto PowerPoint presentation, Supergene V2.ppt.

2.3 Preliminary Waste Facilities Designs

Rio Tinto provided Okane with preliminary design drawings for the waste storage facilities (Figure 2.3). Based on the preliminary drawings, it is Okane's understanding that the high sulfur tailings (generated from the cleaner processing circuit) will be placed separate from low sulfur tailings (generated from the rougher processing circuit) in two cells lined with a low permeability liner (1.5 mm LLDPE or equivalent). The high sulfur tailings will be stored sub-aqueously during operations, with a cover system proposed at closure to maintain a high degree of saturation in the high sulfur tailings and consequently, minimise oxygen ingress into the high sulfur tailings.

Figure 2.4 illustrates a cross-sectional view of the conceptual WRD design showing potential PAF and NAF waste rock placement strategies. The conceptual WRD landform design incorporates 10 m bench heights with 15% batter face angles and 5 m berm widths to minimise erosion. The maximum WRD height is anticipated to be 80 m (Rio Tinto, 2020a,b). Additional key characteristics to minimise the potential for AMD generation, or implications on the environment, have been considered within the WRD design. These comprise:

- Lining the base of the plateau area of the WRD with a 2 m low permeability layer (mudstone).
- Placing NAF waste only under slopes / embankments.
- Reclaiming the WRD plateau area with a cover system with the primary objective to limit net percolation (conceptual cover system design alternatives to be investigated in this project).

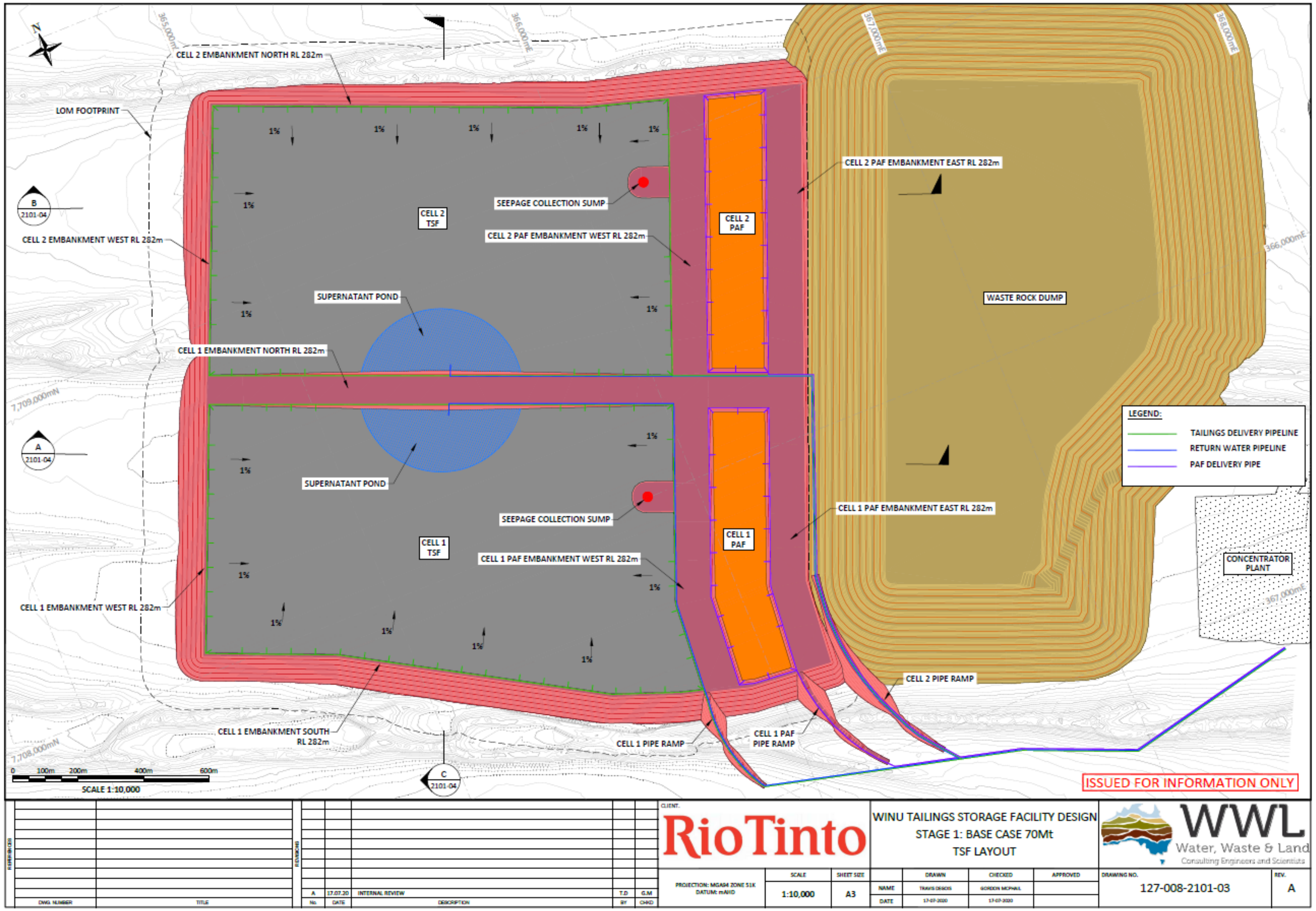


Figure 2.3: Preliminary waste storage facility design for Winu waste rock and tailings. (Rio Tinto 2020, DWG 127-008-2101-03)

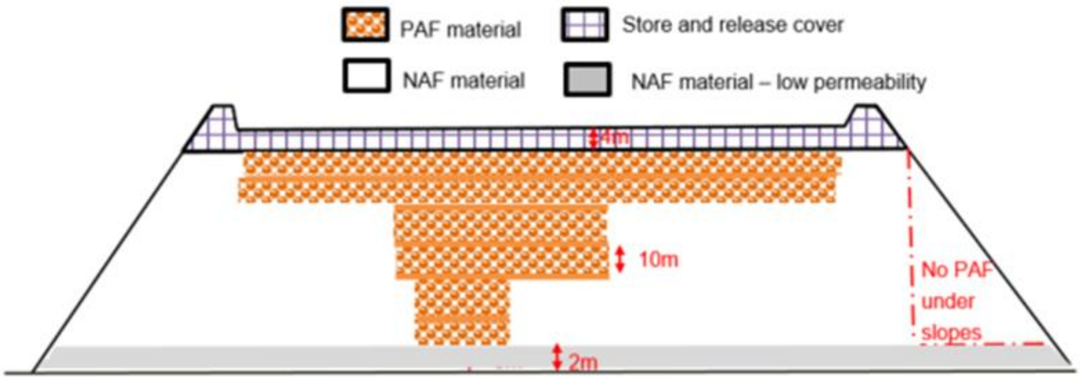


Figure 2.4: Preliminary waste rock dump design

Source: Email from Rio Tinto, August 2020

Based on the preliminary waste storage facilities designs, Okane have considered a range of closure cover system options over three waste materials, namely: low sulfur tailings, high sulfur tailings and PAF waste rock. For modelling, Okane has estimated material property inputs for all three materials based on available data (estimates provided in Section 2.7.3). Proposed cover system options are also described further in Section 2.6.

2.4 Cover System Design Purpose and Performance Classifications

The purpose of a cover system is reclamation of surface mine waste storage facilities to provide a stable, reliable and sustainable engineered interface between the receiving environment and the mine waste. It supports agreed-upon land uses while minimising degradation of the surrounding environment. The cover system design is specific to the design objectives and site-specific conditions such as climate conditions.

Climate is the primary consideration in developing the conceptual model for cover system performance. As illustrated in Figure 2.5, achievable NP rates vary for different climate regimes and within a given climatic regime. The climate at the Winu site is classified by the Köppen-Geiger climate classification as a hot arid desert climate (BWh). For the Winu site (based on the SILO dataset for 1974 to 2020), annual average rainfall is ~400 mm and average annual potential evaporation is ~2,200 mm. Climate conditions for the Winu site region are described in Section 2.7.1 of this report.

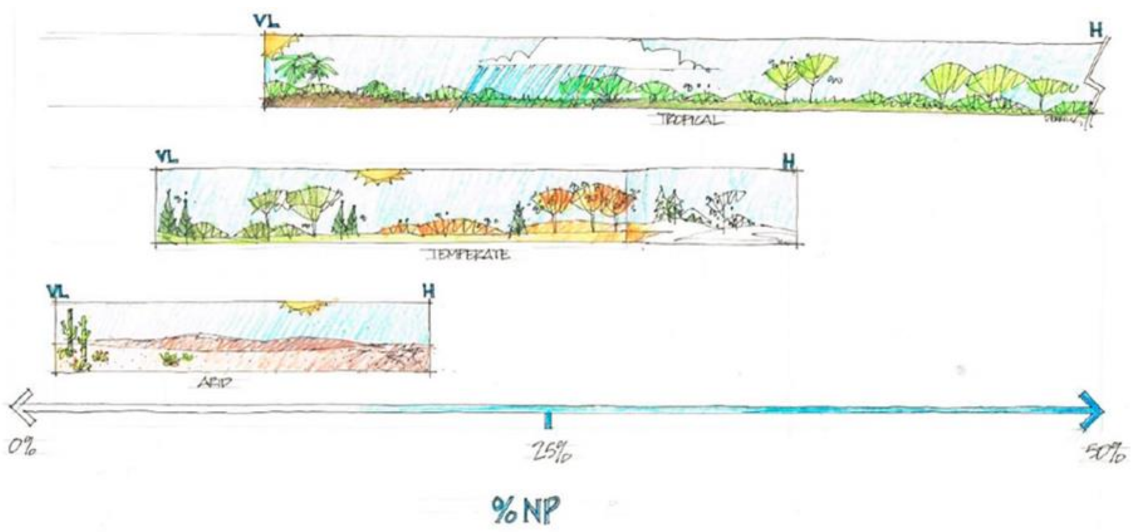


Figure 2.5: Qualitative NP rates for arid, temperate, and tropical regimes.

(INAP, 2017)

Using methods provided in the Global Cover System Design – Technical Guidance Document (INAP, 2017), the cover system performance in terms of NP are presented conceptually.

For the climate conditions experienced at Winu, the INAP NP classifications are as follows:

- Very low: <1% of rainfall;
- Low: between 1% and 5% of rainfall;
- Moderate: between 5% and 10% of rainfall; and
- High: >10% of rainfall.

2.5 Cover System Objectives

For this cover system numerical modelling program, the primary objectives used to assess the conceptual closure cover system designs are stated below for each waste storage facility:

1) WRD Platea Area: limit water ingress (net percolation) to the PAF waste rock.
2) High Sulfur Tailings: maintain a high degree of saturation in the high sulfur tailings and consequently, minimise oxygen ingress into the high sulfur tailings.
3) Low Sulfur Tailings: limit net percolation to the low sulfur tailings/.

2.6 Proposed Conceptual Cover System Designs

For the climate in the Winu region, a cover system that primarily utilises the store-and-release concept is generally recommended to limit net percolation (NP). Store-and-release cover systems reduce NP largely by storing infiltrating water in the rooting zone (near surface) in the cover system to be released through evapotranspiration (evaporation directly from the soil and transpiration from vegetation). Antecedent climate conditions will strongly dictate performance on an annual basis. The cover system design exploits the ability to use available water storage capacity (AWSC) of the soil to store water from large rainfall events and release the water slowly through evapotranspiration multiple times throughout the year. Therefore, if it is not depleted sufficiently in previous years, water will "spill over" to subsequent years negatively affecting performance. The AWSC quantity necessary for the cover system performance will also likely affect vegetation sustainability. For a cover system with less AWSC capacity it requires less time following rainfall events to reach the permanent wilting point and potentially result in untenable conditions for vegetation.

The proposed conceptual cover system options were determined in collaboration with Rio Tinto and are shown in Figure 2.6. The conceptual cover systems proposed for Winu waste facilities utilise the store-and-release concept to limit atmospheric processes (such as water ingress) whilst supporting preferred vegetation communities and limiting surface erosion.

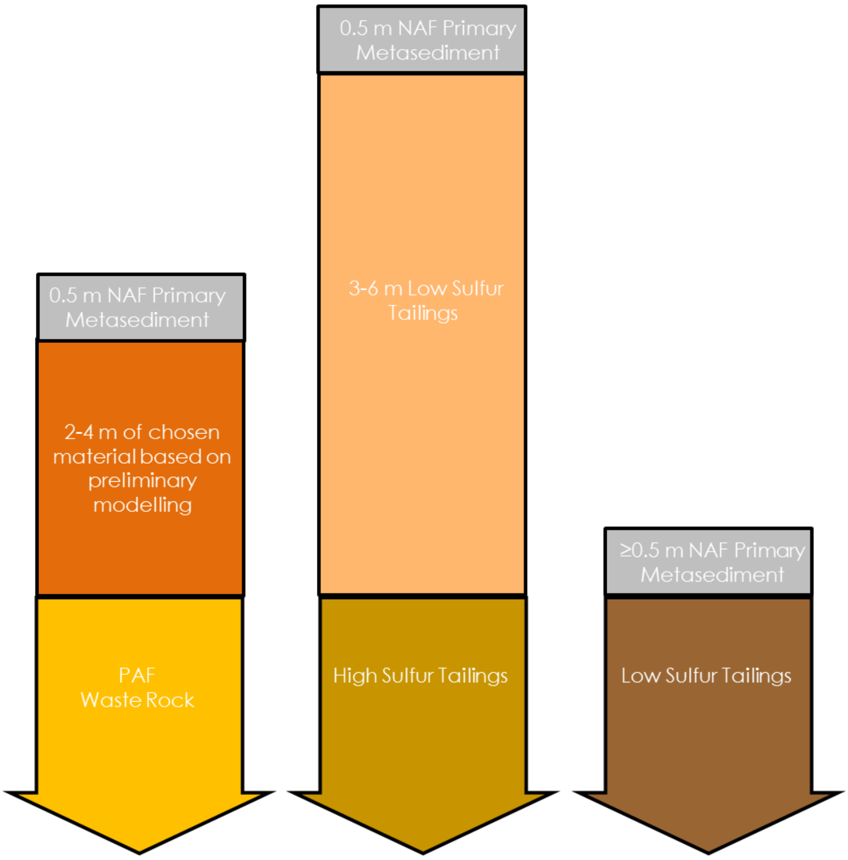


Figure 2.6: Proposed Cover System Options

For the high sulfur tailings, the closure cover system objective is to maintain a high degree of saturation in the high sulfur tailings. This cover system objective is theoretically achieved by preventing the upward movement of water from the high sulfur tailings by decoupling the saturated high sulfur tailings from the evapotranspiration zone. Hence, the optimal cover system design is thicker than the combined depth of evapotranspiration and capillary rise from the high sulfur tailings. Low sulfur tailings are proposed to be used to achieve the majority of the required thickness of the cover system for high sulfur tailings, with some nominal thickness of imported soils for dust control and vegetation.

Key criteria in the design of an effective store-and-release cover system are considerations regarding landform stability (erosion and sediment deposition) and preventing segregation of cover system materials during placement. Store-and-release layers with a coarser- and finer-textured segregation near / at surface can potentially allow for preferential flow deeper into the cover profile during high rainfall which would lead to higher NP rates. To minimise the risk of segregation, it is key to apply appropriate cover materials with appropriate quality assurance and control (QA/QC) measures to ensure homogeneity (no segregation) during placement.

Landform design for erosion and sediment deposition/migration is likely to be important under future climate change scenarios as climate extremes result in potentially higher intensity and higher frequency rainfall events. Establishing and sustaining vegetation is a key driver to the success of reducing erosion, as is the effective design of landforms to minimise erosive potential.

Landloch (2020) completed an erosion potential assessment of the various potential cover system materials. The unmineralised (NAF) primary metasediment without addition of any other material (sand or topsoil) was predicted to be very stable in terms of erosion though placing metasediment at surface without an additive would likely not sustain vegetation. The addition of a soil to the metasediment increased the erosion potential for longer slopes and steeper gradient, though Landloch provided multiple slope configuration that were acceptable in terms of erosion potential. Placing a finer-textured material (i.e. sand) will not be acceptable in terms of erosion potential. Therefore, based on Landloch's assessment and through consultation with Rio Tinto, a minimum 0.5 m thick surface layer representative of NAF primary metasediment with topsoil additive was used in all numerical modelling scenarios assessed.

2.7 Cover System Design Filters/Site Attributes

Proper site characterisation is essential for the design and assessment of suitable cover system designs for WRD and TSFs. For the conceptual cover system designs, the following specific site aspects are summarised as they are key inputs in the design and assessments:

- Climate;
- Hydrogeologic setting;

- Materials; and
- Vegetation.

2.7.1 Climate

According to the Köppen-Geiger climate classification system (Peel *et al*, 2007), the climate of the Winu site is classified as arid, hot desert (BWh). Site specific climate data is not available for the Winu site; therefore, Bureau of Meteorology (BoM) data for the Telfer station (approximately 110 km south of Winu, Station: 013030) and Warrawagine station (approximately 150 km east of Winu, Station 004041) were used to provide an indication of climate in the Winu region. Data at Telfer is available for the period of 1974 to 2020 and for Warrawagine from 1887 to 2020. Based on the BoM data from 1974 to 2020, historical average annual rainfall is 361 mm (BOM, 2020) at Telfer and 404 mm (BOM, 2020) at Warrawagine. For both stations, rainfall is highest in the summer months (January and February) and lowest from August to October.

Okane utilised the gridded data from the SILO tool (Queensland Government, 2020) to obtain predictions of the likely climate conditions at Winu for the available historical period of 1887 to 2020. For the SILO datset, the median rainfall for the period of 1920 to 2018 is 291 mm which matches the SILO climate dataset used in the Hydrological design basis report (Golder, 2020). To check the reliability of the SILO datset, annual rainfall was compared to BoM data for Telfer and Warrawagine for the period of 1974 to 2020 (Figure 2.7). , The Winu SILO annual rainfall data compares well to Telfer and Warrawagine BoM data. For the SILO dataset, average annual rainfall for the 1974 to 2020 period is 399 mm, within the range measured at the Telfer and Warrawagine stations.

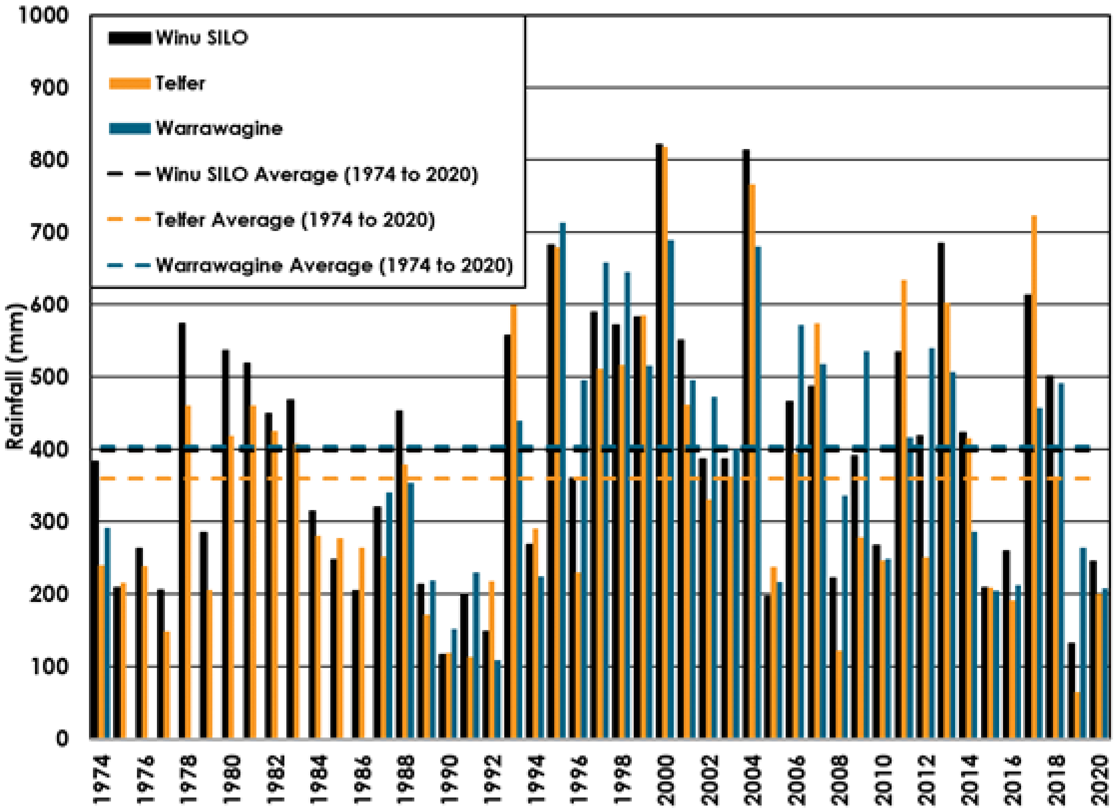


Figure 2.7: Historical rainfall data for SILO dataset, Telfer and Warrawagine

Adapted from (SILO 2020) and (BoM 2020)

Temperature from the SILO database was also compared to the BoM weather station for Telfer. Figure 2.8 shows the range of maximum and minimum temperatures for the SILO database and Telfer station from 1974 to 2020. Both datasets follow similar temperature trends with average maximum temperature of 34°C for both datasets and average minimum temperature of 19°C for the Winu SILO dataset and 20°C for Telfer for the period of 1974 to 2020.

Average annual potential evaporation in the Winu site area is approximately 2,200 mm/yr based on the Silo database from 1974 to 2020.

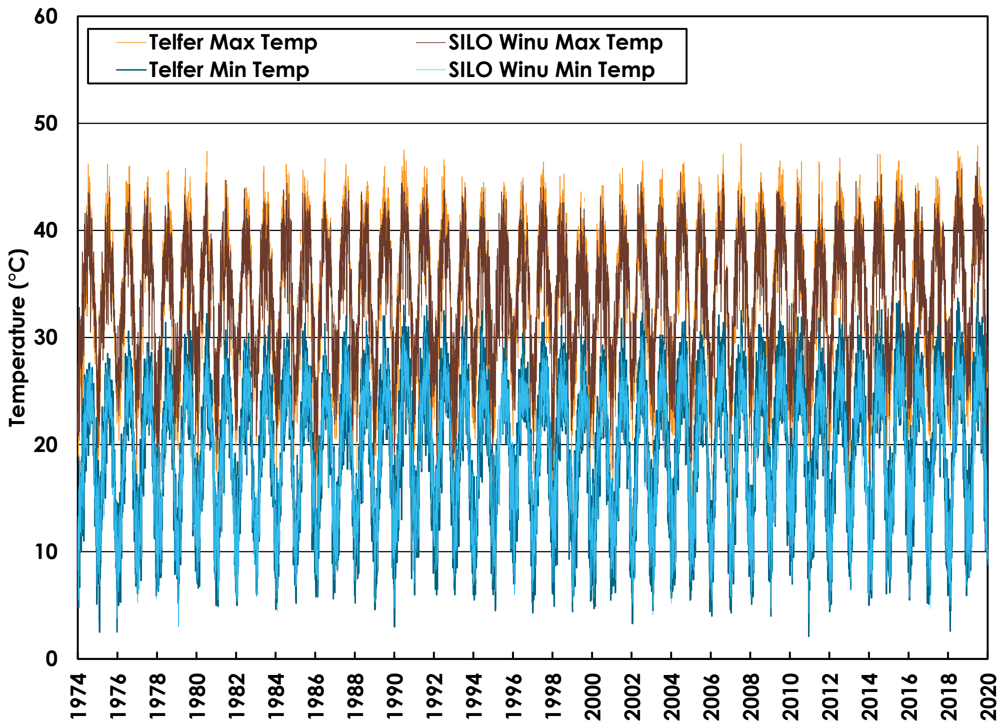


Figure 2.8: Maximum and Minimum temperature ranges for Winu SILO dataset and Telfer BOM station for 1974 to 2020

Adapted from (SILO 2020) and (BOM 2020)

Based on the rainfall and temperature comparisons, Okane used the SILO dataset to represent historical climate conditions at Winu for this project.

2.7.1.1 Future Climate

Climate change is a potential factor influencing performance of cover systems. As part of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5), the IPCC adopted four representative concentration pathways (RCPs); RCP2.6, RCP4.5, RCP6.0 and RCP8.5 which are named after the radiative target forcing level for 2100. Radiative target forcing levels are based on the forcing of greenhouse gases and other agents and are relative to pre-industrial levels.

RCP2.6 represents a very low RCP with a peak of radiative forcing at around 3.1 W/m^2 mid-century, followed by a decline to 2.6 W/m^2 by 2100. To follow this RCP, greenhouse gas emissions would have to be reduced substantially and strict climate policy would need to be undertaken. RCP4.5 represents a medium RCP with stabilisation of radiative forcing before 2100 using technology and climate policy. RCP6.0 represents a medium-high RCP with stabilisation of radiative forcing shortly after 2100 using technology and policy. RCP8.5 represents a high RCP with increasing emissions that do not stabilise until after 2100. This RCP is typically used as a worst-case scenario where no climate policy is undertaken. The RCP8.5 results can be used as an extreme to estimate performance if the change in forcing is lower.

Okane investigated the RCP4.5 and RCP8.5 climate change scenarios for impact on future climate at the site. The percentage change in climate factors from the 1986 to 2005 averages were analysed using the Australian Government and CSIRO Climate futures tool and the ACCESS1.0 climate model (CSIRO, 2020). Climate change comparisons in this document are expressed as the difference between 2020 to 2100 climate data compared to 1986 to 2005 historical averages.

Figure 2.9 shows the likely percentage change in rainfall. Utilising the RCP4.5 scenario, rainfall is predicted to increase by approximately 3%. For the RCP 8.5 scenario, rainfall is predicted to increase initially by approximately 20-25% followed by a decrease in rainfall of up to 20% by 2100. It is currently assumed that the frequency and intensity of storm events will be the primary factors influencing cover system performance under both the RCP 4.5 and RCP 8.5 scenarios.

Temperature is predicted to increase approximately 3°C in summer and 2°C in winter by 2100 under the RCP4.5 scenario. For the RCP 8.5 scenario, temperature is predicted to increase approximately 5°C in both summer and winter by 2100 compared to the 1986 to 2005 period (CSIRO, 2020).

Evapotranspiration is predicted to increase for both the RCP 4.5 and RCP 8.5 scenarios by approximately 7.5% for RCP 4.5 and approximately 12.5% for RCP 8.5 by 2100. Increases in evapotranspiration exceed the predicted increase in rainfall percentage, therefore it is likely that on average cover system NP performance will improve under both RCP 4.5 and RCP 8.5 climate change scenarios, i.e. NP will decrease.

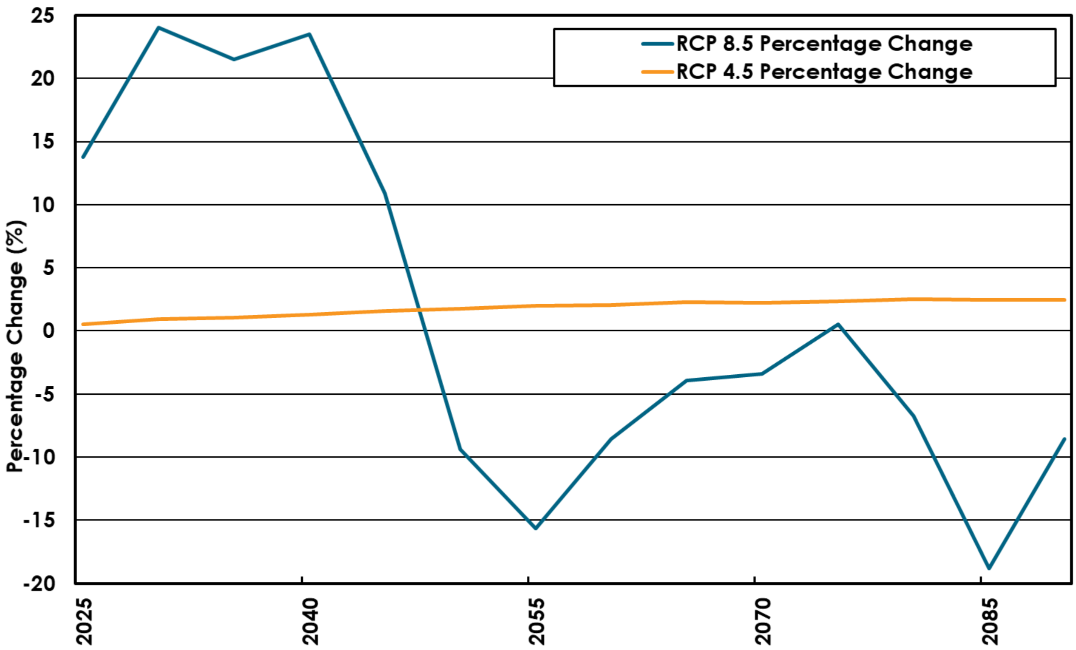


Figure 2.9: Future variation in rainfall applied to 1986-2005 rainfall averages and percentage change in rainfall for RCP4.5 and 8.5 scenarios

Adapted from (Climate Futures 2020)

2.7.1.2 Model Climate Inputs

Okane used the RCP 4.5 and RCP 8.5 future climate scenarios in the modelling program by adjusting the SILO dataset estimate of historical climate data from 1986 to 2005 to be representative of the period 2020 to 2100.

2.7.2 Hydrogeological Setting

The hydrogeological setting includes the boundaries for a given watershed in which the mine waste material is contained. Understanding the larger site context is necessary to assess long-term performance of a waste storage facility. It is understood that the current site groundwater conditions are actively being investigated; however, preliminary results indicate that groundwater levels are approximately 50 m below the existing ground surface and will not intercept the base of the waste facilities (MiningOne, 2019a). The extent of the groundwater catchment in the Winu region is not known, though the groundwater flow direction is believed to be to the north-west (Golder, 2020). It is assumed that during mine operations groundwater flow will primarily be toward the pit (the pit lake will act as a sink). It is therefore likely that initially post closure any basal seepage, reporting from the final landforms will be directed toward the pit.

In the Winu region, topography slopes in a north-westerly direction, with poorly defined divide to the south that separates Winu from the Lake Waukarlycarly catchment (Golder, 2020). There are no major surface water courses in the Winu area and runoff is anticipated to be retained locally (Golder, 2020).

The current TSF design includes lining the base of the overall TSF with a 1.5 mm thick LLDPE liner. The embankments of the high sulfur TSF cells will also be lined to keep the high sulfur tailings saturated during operations and post-closure. For the low sulfur TSF, it is Okane's understanding that basal seepage will be removed via the seepage collection sump during operations (Figure 2.3).

2.7.2.1 Model Inputs

Based on the available hydrological data, a unit hydraulic gradient lower boundary condition will be used in the PAF waste rock models for this project. This boundary condition assumes the water table is far enough below the proposed cover systems as to not influence their performance, and that water flow (once below the depth to be influenced by vegetation and atmospheric forces) will be primarily due to gravity.

For the high sulfur tailings model, the lower boundary condition used in the modelling program represents a low permeability liner (representative of 1.5 mm LLDPE liner or equivalent) at the base of the TSF. The leakage from a geomembrane liner at the base of the TSF is anticipated to be extremely low due to the placement of low permeability tailings directly over the geomembrane. To quantify potential leakage from geomembranes under TSFs, GeoEngineering Centre (Klohn Crippen Berg, 2018) studied the geomembranes under simulated field conditions and found that leakage through holes up to 2 cm in diameter is less than 5 mL/s/km^2 (0.15 mm/yr) (Rowe et al. 2016), which was used as the base case lower boundary condition in the high sulfur tailings models. It should be noted, that the key to maintaining low leakage rates is to minimize damage during construction (including adequate construction quality assurance) and by placing the geomembrane over the proper foundation. A lower boundary condition an order of magnitude above the findings of Rowe et al. (2016) (1.5 mm/yr) was also simulated as a sensitivity.

For the low sulfur tailings simulations, the base case lower boundary condition was the same as the one used for the high sulfur tailings (seepage of 0.152 mm/yr). A sensitivity scenario that assumed that the low sulfur tailings would be free draining (unit gradient lower boundary condition) at closure was also simulated. This sensitivity scenario represents the conditions where the conceptual cover system would report the highest net percolation rates into the low sulfur tailings.

2.7.3 Materials

Site-specific material characterisation and availability are two main elements for cover system design (MEND, 2014). Material selection and strategic placement is a key control on cover system performance and is used to provide a means for such things as vegetation establishment, erosion control, and drainage where required in the cover system design.

Okane was provided a range of geotechnical and geochemical testing results for the PAF waste material, tailings, and potential cover system materials available at site (NAF materials). The main laboratory geotechnical testing data used to characterise site materials comprised: Particle Size Distribution (PSD), Atterberg Limits, Specific Gravity, Triaxial permeability (available for low sulfur tailings only) testing, and log core photos and descriptions (MiningOne, 2019a, MiningOne, 2019b, E Precision Laboratory, 2019, LiquidLabs WA, 2020, and GGC, 2019). Ongoing geochemical characterisation comprises static acid-base accounting (ABA) tests including net acid generation (NAG) and kinetic NAG tests, whole rock digests, mineralogy, static leach tests, and multiple leach extractions on oxidised/overburden materials, as well as oxygen consumption tests and AMIRA kinetic columns for the hypogene and enriched waste materials (Rio Tinto, 2020 c,d,e,f; Graham Campbell and Associates, 2020).

2.7.3.1 Geotechnical Characterisation

Material testing and characterisation work presented in this report was completed on drill core samples, currently the best available source for sampling. It is Okane's understanding that Rio Tinto plans to continue material testing programs to further assess material characteristics and suitability for construction of the TSF and closure cover systems. Particle size distribution testing was completed on most materials found in the drill cores and used to develop material properties for modelling.

A texture triangle (Figure 2.10) was created to characterise the materials based on available PSD data. The sides of the texture triangle are scaled for the percentage of cobble and gravel (>4.75 mm), sand (between 0.075 mm and 4.75 mm), and silt and clay-size particles (<0.075 mm) based on the Unified Soil Classification System.

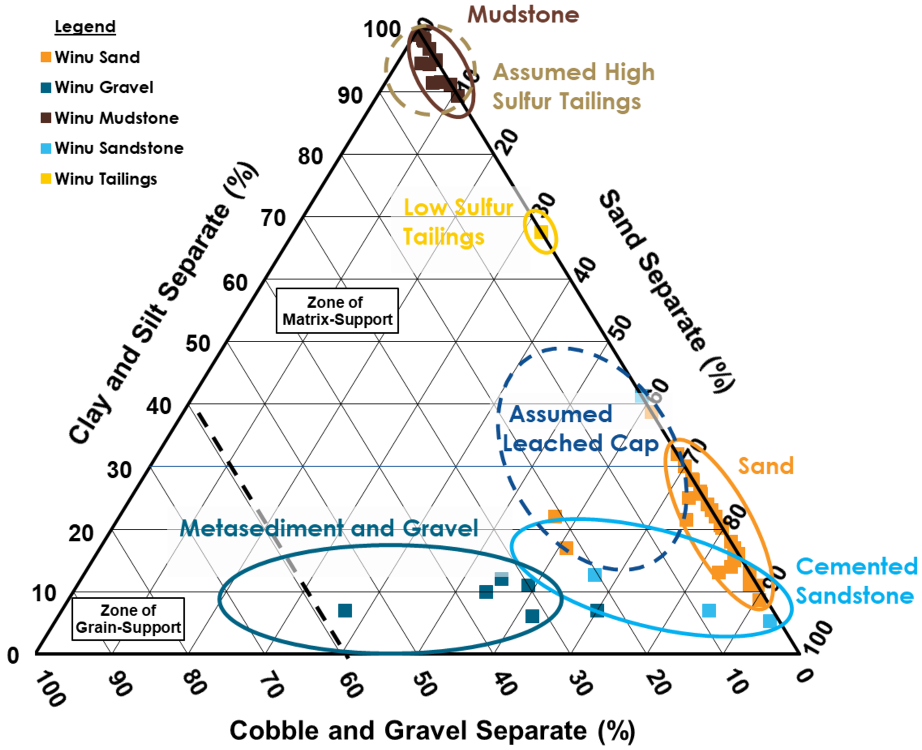


Figure 2.10: Texture triangle of potential cover system and waste materials.

Data Sourced from (E Precision Laboratory 2019/2020), (MiningOne 2019a), (LiquidLabsWA 2020), (GGC 2019)

Based on the available data and PSD data shown in of the texture triangle (Figure 2.10), the anticipated site materials were separated into the following general categories:

- Sand (orange circle): Materials in the sand category consist mainly of Aeolian sands with approximately 10 to 30% clay and silt size and 70 to 90% sand size particles. Atterberg limit results for the sands indicate that the materials are generally non-plastic. The sand material group is anticipated to have low water storage capacity.

- Cemented Sandstone (light blue circle): Cemented Permian sandstone that consists mostly of sand sized particles with up to 30% gravel and cobble sized particles and 5 to 20% clay and silt sized particles.

- Leached Cap (dashed blue circle): this material is classified as loamy sand with variability in terms of fines contents with depth. The upper portion of the leached cap is categorised as fine grained and weak to very weak. Leached cap material at depth has lower fines content and is potentially stronger. Particle size analyses were only measured up to 2 mm therefore the data could not be plotted on Figure 2.10, the leached cap material circle was inferred based on available data. The leached cap category consists of up to 25% gravel and cobble sized particles, 40 to 70% sand and 15 to 50% silt and clay sized particles.

- Mudstone (dark red circle): The PSD results for the mudstone materials indicate that the mudstone is predominantly fine grained with >85% silt and clay size particles. Atterberg limit data for the mudstone material indicate that it generally has high plasticity with a plasticity index range of ~4% to 14% and an average of ~9%. It can be classified as a clayey silt with low to medium plasticity.

- Low Sulfur Tailings (yellow circle): Based on one PSD test, the low sulfur tailings material consists of approximately 30% sand sized and 70% clay and silt sized particles. Clay content was measured to be approximately 6% with a plasticity index of ~8%. Based on two multistage triaxial tests (completed with effective cell pressures of 100 kPa, 200 kPa, 400kPa and 600 kPa and at dry densities of 1.3 t/m^3 and 1.4 t/m^3, respectively) , geometric mean permeability was measured to be approximately $2x10^{-7}$ m/s.

- High Sulfur Tailings (dashed brown circle): The high sulfur tailings consist of the highly pyritic tailings that will be separated from the low sulfur tailings. No PSD data was available for the high sulfur tailings, therefore, physical properties used in modelling are based on the assumed texture showed on Figure 2.10. This material will be finer-textured than the low sulfur tailings and is anticipated to have similar properties to the mudstone material above. This material is expected to have a relatively low hydraulic conductivity, especially once consolidated under the weight of the closure cover system.

- Metasediment and Gravel (teal circle): Figure 2.11 shows representative drill core photos of weathered and fresh metasediment which are classified as medium to extremely strong based on Schmidt hammer values (ISRM 1978). These materials are coarser-textured compared to the available materials. The unmineralised primary metasediment without addition of any other material (sand or topsoil) is predicted to be very stable in terms of erosion though placing metasediment at surface without an additive would likely not sustain vegetation. For modelling, it is assumed that a topsoil would be added to the NAF primary metasediment surface layer for vegetation establishment and sustainability. The addition of a topsoil to the metasediment increases the erosion potential for longer slopes and steeper gradient, though Landloch provided multiple slope configuration that were acceptable in terms of erosion potential (Landloch, 2020). In this report, the surface NAF metasediment layer in all models refers to metasediment with topsoil additive.

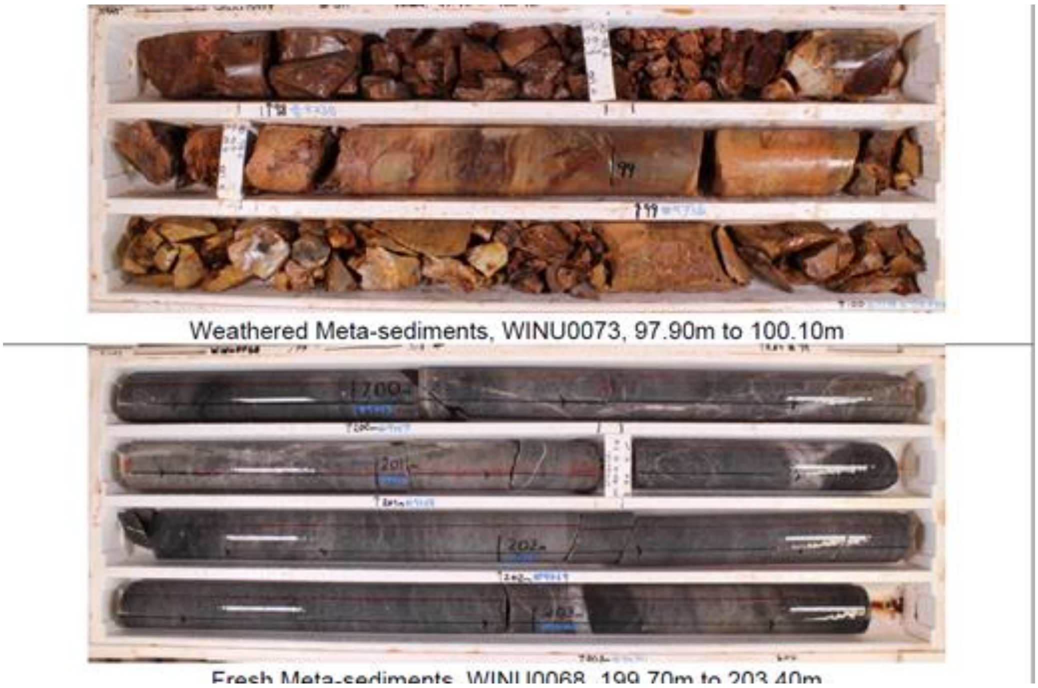


Figure 2.11: Core photo of weathered and fresh metasediments

Source: Mining One Consultants, 2020. Winu Project: Preliminary Open Pit Geotechnical Study for Rio Tinto Exploration

2.7.3.2 Geochemical Characterisation

Waste Material

Ongoing geochemical characterisation has been summarised for the three zones of the Winu deposit (Table 2.1).

- The overburden/oxidised (upper) zone represents the majority of the waste (~80%) and is characterised as NAF, with sulfide-S at or near detection limits of 0.01 wt% S which equates to a maximum potential acidity (MPA) of 0.3 kgH_2SO_4/t.
- The enriched (middle) zone has variable sulfide-S contents and therefore, variable acid generation capacity with average MPA values of 30 kgH_2SO_4/t for the metasandstones and 93 kgH_2SO_4/t, reflective of high sulfide-S contents, for the pre-mineralised mafics. Pyrite is the main sulfide mineral, with minor chalcocite, pyrrhotite associated with mafic units, and chalcopyrite. The majority of samples were classified as PAF. With minor carbonate minerals, limited longer-term acid neutralisation capacity (ANC) may be provided by aluminosilicates minerals.
- The hypogene (lower) zone has both variable MPA and ANC, with resulting variable net potential ratio (NPR) so that samples tested were approximately 42% NAF and 58% PAF or uncertain. Pyrite is the dominant sulfide mineral, with minor chalcopyrite, pyrrhotite and chalcocite. The calcite breccia within the hypogene zone has the highest ANC (dolomite and ankerite minerals) and has the potential

to provide some neutralisation, although volumes of this material are yet unknown. Sulfide breccias and metasandstones were noted to generate acid rapidly and may be an issue if not encapsulated in the short term.

Table 2.1: Geochemical characterisation of Winu Waste Materials

Percentage of Waste	Tonnes	Zones	Characteristics
80%	196 Mt	Oxidised/Overburden (upper zone)	Mostly NAF Low sulfide-S Low MPA - low acid risk No ANC Fluoride mobilisation during leaching (during first flush)
20%	48.6 Mt	Enriched/secondary sulfide (middle zone)	Majority classified as PAF (83%) Sulfide-S up to 5% S High MPA Minimal ANC Secondary Cu sulfide minerals Sulfate, Cd, Co, Cu, Ni, Mn, Zn, Se and fluoride mobilised during leaching
		Hypogene/no enrichment/primary sulfide (lower zone)	Approx. 58% PAF and 42% NAF MPA av. 30 kgH_2SO_4/t Higher ANC av. 25 kgH_2SO_4/t Some ANC (dolomite, ankerite), some siderite (no ANC potential) As, Cd, Co, Cu, Mn, Mo, Ni, Pb, Sb, fluoride mobilised during leaching

Rio Tinto (2020d) Winu Waste Rock Characterisation - Upper (Oxidised and Overburden) Zone. Project Code 15638. Rio Tinto (2020e) Winu Waste Rock Characterisation - Secondary Sulfide (Enriched) Zone. Project Code 15640. Rio Tinto (2020f) Winu Waste Rock Characterisation - Primary Sulfide (Hypogene) Zone. Project Code 5919045639.

Tailings

Material characterisation of the tailings generated from metallurgical test work have been completed on tailings from the low and high sulfur flotation circuit. Processed tailings have been separately characterised by Rio Tinto as follows:

- Low sulfur tails are low sulfur content tailings that are either classified as NAF (net acid production potential (NAPP) < 0 kgH_2SO_4/t, NAG pH > 4.5) or Potentially Acid Forming with a Low Capacity for acid generation (PAF-LC; NAPP > 0 kgH_2SO_4/t; NAG pH <4.5, NAG acidity at pH 4.5 < 5 kgH_2SO_4/t). These are coarse tailings generated from the rougher flotation circuit.

- High sulfur tails are high sulfur content tailings that are classified as PAF with a very high potential for acidity generation (i.e. MPA > 300 kgH_2SO_4/t, or total sulfur > 10%) and negligible ANC. These are fine tailings generated from the cleaner flotation circuit.

Pyrite is the dominant sulfide mineral in the flotation tailings and siderite is the dominant carbonate mineral. The lack of acid neutralisation in the tailings was confirmed by low ANC values < 17 kgH_2SO_4/t (Rio Tinto, 2020o). With regards to metal mobilisation, leach testing indicated that fluoride was elevated in most samples tested. NAG liquor testing for a high sulfur tailings sample with a low NAG pH of 2, had elevated concentrations of a number of metals including As, Cd, Cr, Cu, Co, Fe, Pb, Mn, Mo, Ni, Se, Sb, U.

2.7.3.3 Salinity

For the solute uptake modelling, the pore-water salinity guidelines used by Rio Tinto presented in Table 2.2 were used (Hunt, 1992).

Table 2.2: Soil Salinity Guidelines

Salinity Guideline	EC value (dS/m)
Suitable for a soil growth medium	<0.4
Suitable for some salt tolerant species	0.4 to 1.6
May not be a suitable growth medium	>1.6

Source: Hunt (1992), based on a L:S 5:1 leach

Kinetic tests included short duration standardised AMIRA column tests which were leached every four weeks at approximately L:S 0.7:1 ratios. The lower L:S ratios, compared to soil L:S leach of 5:1 and paste leach of 2:1, and the monthly leaching of the AMIRA columns provide information on the longer term salinity at L:S closer to expected site conditions. As of September 2020, for the primary (lower zone) kinetic columns that have been operating for 20 weeks, no samples have generated saline leachate with all leachate below 1.6 dS/m at leaching rates of L:S 0.7:1 (Rio Tinto, 2020e). For the secondary (middle zone) kinetic columns, some samples are generating salinity with EC exceeding 5 dS/m for one column (Rio Tinto, 2020d). The one tailings leach column operating, with a total S content of 0.35%, had an initial EC of 1.2 dS/m which has declined over the last 22 weeks of operation to 0.65 dS/m.

Deionised leachates at L:S 2:1 ratio on eight low sulfur tailings samplings measured EC that ranged from 0.174 to 0.533 dS/m, with an average of 0.351 dS/m (Rio Tinto, 2020g). None of the low sulfur tailings tested above the 1.6 dS/m guideline value that Rio Tinto uses to guide growth medium suitably (Hunt, 1992). It should be noted that the guidelines stated above (Table 2.2) are conservative as they are based on 1:5 leachate and the EC values measured for low sulfur tailings are for more concentrated 1:2 leachate.

2.7.3.4 Material Availability

The construction of effective cover systems utilising the moisture store-and-release concept is dependent on the availability of appropriate materials. Total material availability defines the range of potential cover system thickness and material layering opportunities. Optimisation of cover system material generation to placement can reduce double handling of materials and reduce the requirement of stockpiling materials for future cover system use.

In terms of waste volumes excluding the mineralised material types, sand accounts for 23%, cemented sandstone 30%, leached cap 27% and mudstone 14% (Graham Campbell and Associates, 2020).

The Comet waste material schedule (Rio Tinto, 2020h) provided by Rio Tinto is summarised in Figure 2.12. Total waste volumes indicate sufficient sand, leached cap and cemented sandstone would be available for the proposed conceptual cover system designs (2 m to 4 m thick cover system). Sand is available until 2029 with mudstone and cemented sandstone available until 2030, and leached cap until 2032 (Figure 2.13). Sand availability is relatively consistent in comparison to the mudstone, cemented sandstone and leached cap that experience sporadic availability during the proposed project life of mine. It is anticipated that a good portion of the sand, cemented sandstone and leached cap materials will be used for TSF embankment construction and mudstone will be used to line the base of the WRD and ore stockpiles. However, it should be noted that mudstone to be used to line the base of the ore stockpile will likely be available for use in reclamation of the WRD and TSF. This is only applicable if the materials are considered suitable from an environmental perspective, for example assuming no PAF leachate has impacted the materials. The primary meta-sediment will be included in the materials investigated as potential cover system materials.

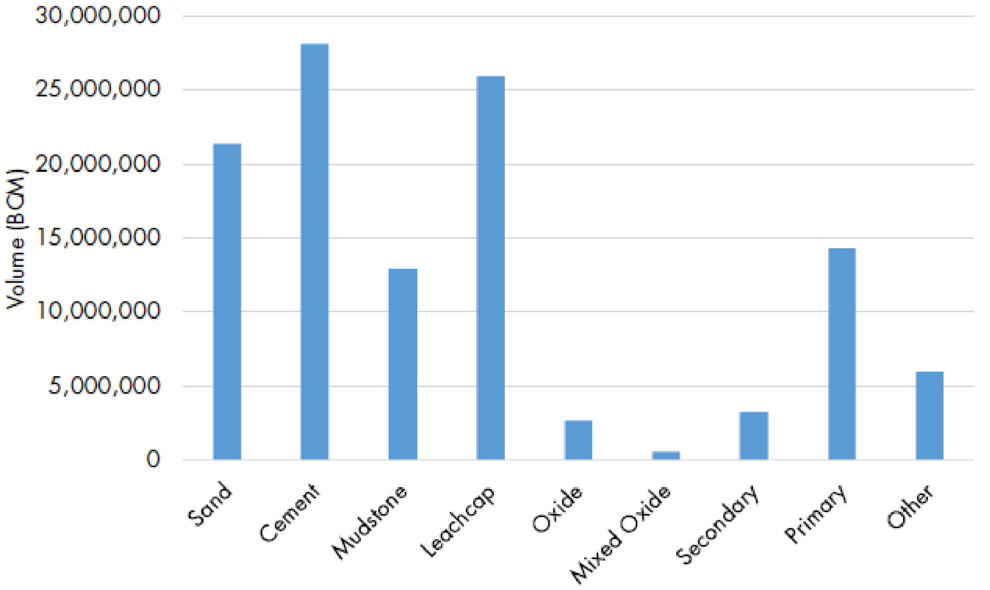


Figure 2.12: Volume of waste material (Figure sourced from Landloch, 2020)

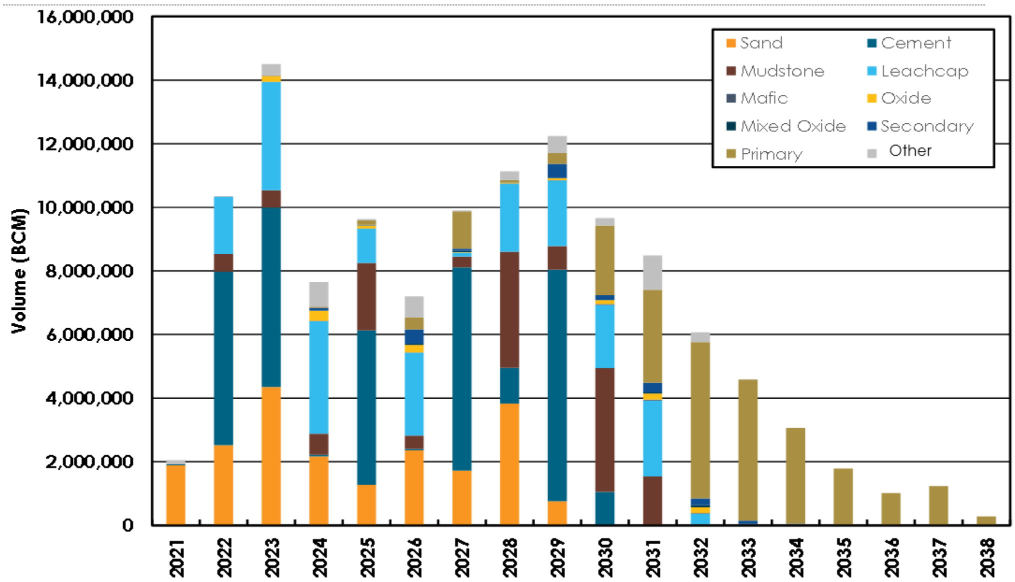


Figure 2.13: Volume of waste material produced by calendar year

Data sourced from Waste material_Comet_Schedule.xslx provided by Rio Tinto 2020h

2.7.3.5 Material Property Model Inputs

Based on the geotechnical testing data available, hydraulic properties have been estimated and are presented in Table 2.3. This includes the range of saturated hydraulic conductivity (k_{sat}), air entry value (AEV) and porosity estimates for each material to be simulated. It should be noted that measured material properties of water retention curves (WRCs) and hydraulic conductivity functions were not available at the time of modelling. Material sampling and testing programs should continue as materials are mined and stockpiled to update material property estimates. Water retention and hydraulic conductivity properties should be included in future material characterisation studies.

WRCs and hydraulic conductivity functions have been estimated from PSDs using the SVSoils software using the methods built-in to the software (such as Fredlund et al. (1997) for WRCs and Kozeny-Carman Equation (Ahuja, 1989) for k_{sat}). These estimated hydraulic properties were then compared to material in the SVSoils database with similar PSDs and measured hydraulic properties. The range of hydraulic properties selected were then fitted with WRCs and k-functions using the van Genuchten (1980) method.

Table 2.3: Summary of Average Material Inputs

Material	Porosity	Air Entry Value (kPa)	n[1]	Residual VWC	k_{sat} (m/s)
Sand	0.3	1	1.2	0	1×10^{-5}
Mudstone	0.4	20	1.2	0	1×10^{-7}
Cemented Sandstone	0.3	5	1.2	0	1×10^{-5}
Leached Cap	0.4	20	1.2	0	1×10^{-5}

Material	Porosity	Air Entry Value (kPa)	n[1]	Residual VWC	k_{sat} (m/s)
Metasediment and Gravel	0.3	10	1.5	0	1×10^{-5}
Low Sulfur Tailings	0.45	10	1.2	0	1×10^{-6}
High Sulfur Tailings	0.4	20	1.2	0	1×10^{-7}

[1.] van Genuchten (1980) parameters.

Salinity from the low sulfur tailings was simulated with a constant source concentration boundary condition applied to the cover system / tailings interface. A constant value of 0.351 dS/m was assigned as the constant concentration boundary condition based on available $EC_{1:2}$ leachate data (Section 2.7.3.3). The modelling does not include depletion of soluble mineral phases and does not account for precipitation of secondary mineral phases, therefore, the modelling is conservative in terms of salinity results.

No salinity data was available for the metasediment material when this modelling program was initiated. For modelling, it was assumed that only non-saline metasediment materials would be used in the closure cover systems.

For solute transport modelling for the low sulfur cover system, the relationships between diffusion coefficients and water content were estimated for the metasediment and low sulfur tailings materials using the functions defined by Olesen *et al*. (1996). The Olesen model is based on using material texture to derive a nonlinear coefficient. Textures for the materials were based on available PSD data. The free-water diffusion coefficient for ammonium (NH_4) (1.2×10^{-5} cm^2/s) (Krom and Berner, 1980) was used to develop the diffusion coefficient curves input to the solute transport model. The diffusion coefficient for NH_4 was used for the salt uptake modelling to represent a high estimate of diffusive mass transport from the tailings material. NH_4 has a relatively low molecular weight and, consequently, a relatively high diffusion coefficient.

2.7.4 Vegetation

Information on density, root depth and size of natural vegetation at the site has not been supplied to Okane at this stage. The Winu site is located in Western Australia where the biome is classified as deserts and dry shrublands. For the purposes of modelling input it was assumed that the vegetation will consist of primarily sparse bushes and grasses with established root depth per the Jackson *et al* (1996) method of estimating root mass distribution and depth. This distribution indicates that the majority (72%) of roots will be shallower than 0.5 m, 90% shallower than 0.9 m, and 100% shallower than 3 m.

In the modelling program a plant water limiting function was used to determine the percentage decrease in the plant's ability to draw water as the negative pore-water pressure increases in unsaturated ground. A generally accepted plant water limiting function was used for this project; the plant reaches a wilting point at a pore-water pressure of -10 kPa and is completely unable to draw water if the pressure reaches -1,500 kPa.

3 MODELLING PROGRAM

3.1 Description of Modelling Processes

Okane completed the modelling exercise using the following process for the PAF waste rock and high sulfur tailings scenarios:

- One-dimensional (1D) soil-plant-atmosphere (SPA) models were completed using the VADOSE Bundle of the GeoStudio software (2021). The models were completed using the SILO climate dataset from 1974 to 2020 for the following cover system options:
  - Comparison #1 - 0.5 m NAF metasediment, 4 m leached cap cover system on PAF metasediment with vegetation established;
  - Comparison #2 - 0.5 m NAF metasediment, 4 m cemented sandstone cover system on PAF metasediment with vegetation established;
  - Comparison #3 - 0.5 m NAF metasediment, 4 m sand cover system on PAF metasediment with vegetation established; and
  - Comparison #4 - 0.5 m NAF metasediment, 6 m low sulfur tailings cover system on high sulfur tailings with vegetation established.
- The results of the 1D GeoStudio models listed above were used to:
  - Ensure the model inputs and results are reasonable; and
  - Provide results to calibrate and validate the Okane's GoldSim SPA model.

Okane's proprietary Goldsim SPA model was used to model a range of cover system thicknesses over the projected RCP 4.5 and RCP 8.5 climate scenarios from 2020 to 2100. The GoldSim SPA model is a finite difference model programmed in the Goldsim (2019) software. The model accounts for water movement within the material profile via Darcy's Law, actual transpiration using a similar method to VADOSE/W (GEO-SLOPE, 2012 – a precursor to the current SPA model in the GeoStudio software), and the empirical relationship between actual evaporation and potential evaporation developed by Wilson et al. (1997). The model requires initial calibration with a proven SPA model software (GeoStudio for this project) to ensure it is correctly simulating the system; however, once calibrated it has the advantages that it can complete simulations more quickly, and (by using GoldSim's Monte Carlo formulation) inputs such as hydraulic properties can be allowed to vary so that their influence on model performance can be more accurately evaluated. Hence, the GoldSim SPA model can evaluate a range of cover system design thickness to determine what thickness would be most effective from a net percolation and overall water balance perspective. The optimised design is then confirmed with the more rigorous GeoStudio model.

The Geostudio software VADOSE Bundle and CTRAN program were used to assess a 0.5 m to 4 m thick NAF metasediment cover system for the low sulfur tailings. The VADOSE bundle was used to simulate the cover system water balance and to assess cover system performance in terms of net percolation, while CTRAN was used in unison to complete solute uptake modelling to assess the potential for salt uptake to the rooting zone of the cover system.

It should be noted that the erodibility of the cover system materials was not considered in this modelling program.

A description of the GoldSim SPA model validation and modelling results follows.

3.2 Validation of Okane GoldSim SPA models

Model inputs (material properties, vegetation and historical climate) summarised in Section 2.7 were used in the Geostudio SPA and Okane GoldSim SPA models to ensure they could produce similar water balance estimates; which was achieved (Figure 3.1 shows a comparison of the volume of water in the model domain for the SPA models). Table 3.1 provides a comparison of the water balance parameters for the Geostudio and GoldSim SPA model comparisons listed in Section 3.1. The results of the 1D models provided validation that the GoldSim SPA model can be used to develop the surface water balances.

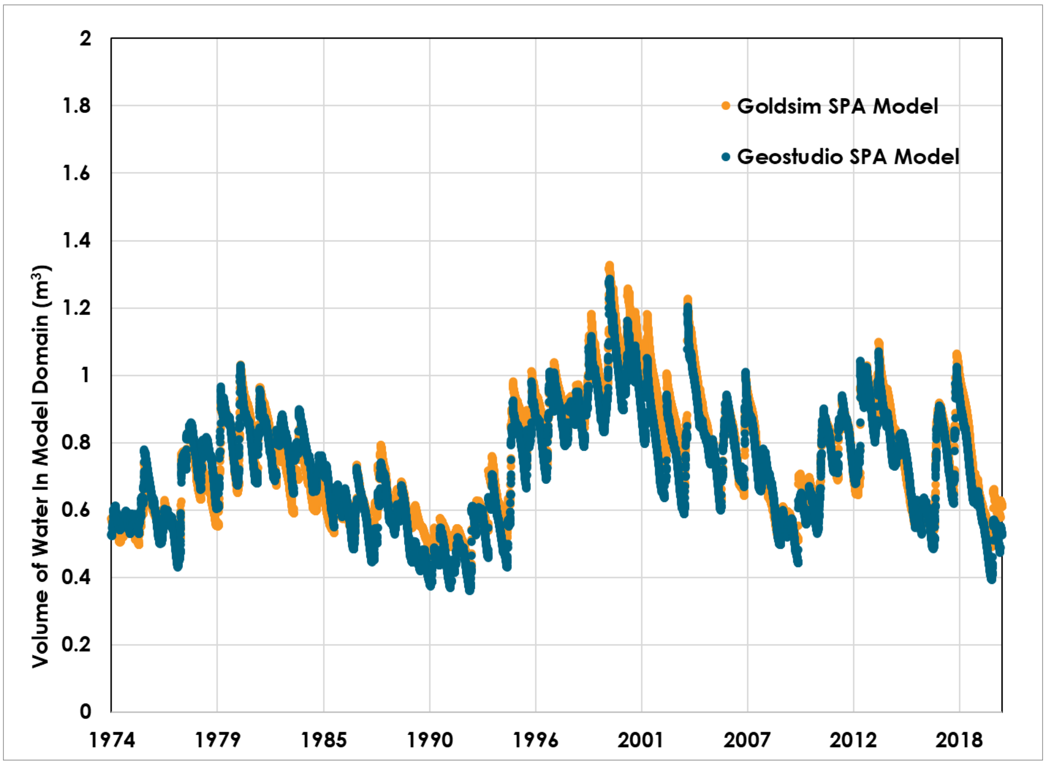


Figure 3.1: Comparison of estimated volume of water in model domain with time in the GeoStudio and GoldSim models for the scenario assuming 0.5 m NAF metasediment, 4 m leached cap cover system on PAF waste rock with vegetation established.

Table 3.1: Comparison of Average Annual Water Balance Parameters

Scenario	Precipitation (mm/yr)	Geostudio Actual Evapotranspiration (% PPT)	Geostudio Net Percolation (% PPT)	Goldsim Actual Evapotranspiration (% PPT)	Goldsim Net Percolation (% PPT)
Comparison #1	401	92%	8%	92%	8%
Comparison #2	401	93%	7%	93%	7%
Comparison #3	401	93%	7%	93%	7%
Comparison #4	401	>99%	<1%	>99%	<1%

3.3 PAF WRD Cover System Assessment

For the WRD Plateau area, it is understood that the proposed cover system is intended to limit water ingress whilst supporting preferred vegetation communities. 1D GoldSim simulations of the conceptual cover system design options proposed for the PAF WRD plateau area were completed to estimate performance with regards to net percolation. Simulations were run for two future climate scenarios (RCP 4.5 and RCP 8.5) from 1 July 2020 to 30 June 2100 (80 years). The initial water content conditions used in the models represented dry materials. The initial volumetric water content for the PAF metasediment was <0.05 and the initial volumetric water content was approximately 0.05 for all cover materials simulated.

A summary of simulated water balance results for the proposed cover system options described further in Section 2.6 are provided in Table 3.2.

Table 3.2: Summary of simulated average annual water balance parameters for proposed cover system options for the PAF WRSF plateau area (2020 to 2100).

Future Climate Scenario	Cover System Option[1]	Precipitation (mm/yr)	Runoff (% PPT)	Actual Evapotranspiration (% PPT)	Net Percolation (% PPT)
Leached Cap Cover System Option					
RCP4.5	0.5 MS / 2m LC	426	0%	94%	6%
	0.5 MS / 3m LC	426	0%	94%	6%
	0.5 MS / 4m LC	426	0%	94%	6%
RCP 8.5	0.5 MS / 2m LC	416	0%	94%	6%
	0.5 MS / 3m LC	416	0%	94%	6%
	0.5 MS / 4m LC	416	0%	94%	6%
Cement Cover System Option					
RCP4.5	0.5 MS / 2m C	426	0%	96%	4%
	0.5 MS / 3m C	426	0%	96%	4%

Future Climate Scenario	Cover System Option[1]	Precipitation (mm/yr)	Runoff (% PPT)	Actual Evapotranspiration (% PPT)	Net Percolation (% PPT)
	0.5 MS / 4m C	426	0%	96%	4%
RCP 8.5	0.5 MS / 2m C	416	0%	96%	4%
	0.5 MS / 3m C	416	0%	96%	4%
	0.5 MS / 4m C	416	0%	96%	4%
Sand Cover System Option					
RCP4.5	0.5 MS / 2m S	426	0%	96%	4%
	0.5 MS / 3m S	426	0%	96%	4%
	0.5 MS / 4m S	426	0%	97%	3%
RCP 8.5	0.5 MS / 2m S	416	0%	96%	4%
	0.5 MS / 3m S	416	0%	96%	4%
	0.5 MS / 4m S	416	0%	96%	4%

[1] MS – Metasediment, LC – Leached cap, C – Cement, S - Sand

For the store-and-release cover system options simulated, NP is controlled mainly by the near surface materials and root mass functions, which are identical for all simulations. All models performed relatively similarly from a NP perspective as all the design options simulated have the same 0.5 m metasediment layer at surface with underlying materials that are only slightly different texturally. Though, the leached cap cover system scenarios are anticipated to have the highest average annual NP (6% of PPT) that is classified as moderate (5% to 10% of rainfall) based on the INAP classifications provided in Section 2.4. For the sand and cement store-and-release cover system design options simulated, NP results were categorised as low (1% to 5% of rainfall) on average.

The results indicate that increasing cover system thickness greater than 2.5 m had little effect on simulated NP, which is due to the active zone of evapotranspiration being in the upper 2 to 3 m.

3.4 Low Sulfur Tailings Cover System Assessment

1D Geostudio VADOSE and CTRAN modelling was completed to simulate performance of the conceptual closure cover system design for the low sulfur tailings. The conceptual closure cover system for the low sulfur tailings consists of a minimum 0.5 m layer of metasediment. For modelling, the cover system objective was to reduce net percolation to the low sulfur tailings. Simulations were run for two future climate scenarios (RCP 4.5 and RCP 8.5) from 1 July, 2020 to 30 June, 2100 (80 years) to assess the performance of a range of cover system thicknesses in regard to net percolation. The initial volumetric water content conditions used in the modelling was 0.2 for the low sulfur tailings and 0.05 for the metasediment. It was assumed that the low sulfur tailings would be partially drained to allow access to construction equipment to place the relatively thin cover system. Though, it is anticipated that the finger-drains will not be maintained post-closure therefore the lower boundary condition used in the modelling represents a lined TSF (described in Section 2.7.2.1).

Table 3.3 provides a summary of simulated water balance results for the proposed cover systems. Long-term NP is <1% for all cover system thickness as NP is primarily controlled by the lower boundary condition (very low leakage rate). Average annual NP results were categorised as very low (< 1% of rainfall). The evapotranspiration active zone reached an approximate depth of 3 m. Therefore, it should be noted that some water that infiltrates past the base of the cover system into the near surface low sulfur tailings may exfiltrate though evapotranspiration.

Table 3.3: Summary of simulated average annual water balance parameters for the proposed cover system for the low sulfur tailings (2020 to 2100).

Future Climate Scenario	Cover System Option[1]	Rainfall (mm/y)	Runoff (% PPT)	Actual Evapotranspiration (% PPT)	Net Percolation (% PPT)
RCP4.5	0.5m MS	426	0%	>99%	<1%
	1m MS	426	0%	>99%	<1%
	2m MS	426	0%	>99%	<1%
RCP 8.5	0.5m MS	416	0%	>99%	<1%
	1m MS	416	0%	>99%	<1%
	2m MS	416	0%	>99%	<1%

[1] MS – Metasediment

3.4.1 Lower Boundary Sensitivity Analyses

A sensitivity analyses was completed on the lower boundary condition used in the model. Simulations were completed with a unit gradient lower boundary condition to represent a free-draining TSF at closure. These conditions represent the upper bound of NP expectation though do not represent the current TSF design (TSF lined a 1.5 mm LLDPE liner or equivalent). Table 3.4 provides a summary of simulated water balance results for the various cover system thicknesses with a unit gradient lower boundary condition. All models performed relatively similarly from a NP perspective as the surface layer of all the design options consist of the same material (NAF metasediment). Average annual NP results were categorised as moderate (< 10% of rainfall).

A minimum 1 m cover system thickness performed slightly better in terms of NP compared to the 0.5 m thick cover system with more available water storage capacity (AWSC) for larger rainfall events. For cover system scenarios thicker than 1 m, little benefit is seen in terms of decreasing net percolation. Though, a thicker cover system will have less potential for salt uptake into the rooting zone of the cover system if highly saline tailings are placed near surface. Though, salinity testing completed to date on the low sulfur tailings have measured low salinity.

Table 3.4: Summary of simulated average annual water balance parameters for the sensitivity simulations (2020 to 2100).

Future Climate Scenario	Cover System Option[1]	Rainfall (mm/y)	Runoff (% PPT)	Actual Evapotranspiration (% PPT)	Net Percolation (% PPT)
RCP4.5	0.5m MS	426	0%	91%	9%
	1m MS	426	0%	93%	7%
	2m MS	426	0%	93%	7%
	3m MS	426	0%	93%	7%
	4m MS	426	0%	93%	7%
RCP 8.5	0.5m MS	416	0%	93%	7%
	1m MS	416	0%	93%	7%
	2m MS	416	0%	93%	7%
	3m MS	416	0%	93%	7%
	4m MS	416	0%	94%	6%

[1] MS – Metasediment

3.4.2 Salt Uptake Assessment

Although the annual average NP predicted for all cover system alternatives shows a long-term average downward flow of percolated water (flushing of salts), dry years or dry periods throughout a year have the potential for salt uptake. In addition to the potential for salt uptake on a year to year basis due to different annual climatic cycles, salt uptake will also result due to seasonal, and even daily, changes in climate conditions within any particular year.

The primary objective of the solute transport analysis was to assess whether transport of salinity from the low sulfur tailings into the overlying cover system material may become sufficiently high that vegetation sustainability would be adversely affected. Largely, high salinity could have adverse effects on plant growth.

The transport mechanisms that were examined for the solute uptake assessment were diffusion and advection. Salinity from the low sulfur tailings was simulated with a constant source concentration boundary condition applied to the cover system / tailings interface. A constant value of 0.351 dS/m was assigned as the constant concentration boundary condition based on available $EC_{1:2}$ leachate testing data summarised in Section 2.7.3.3. The relative concentration throughout the profile into the cover system was simulated from 2020 to 2100 for the RCP 4.5 and RCP 8.5 climate scenarios. Salinity was applied as a conservative solute in the simulations; depletion over time and the effects of secondary mineral precipitation were not accounted for in the modelling. Therefore, the salinity results provided are likely higher than anticipated in the field.

Simulated EC values within the cover system were then used for interpretation of salinity based on the pore-water salinity guidelines used by Rio Tinto presented in Table 3.3 (Hunt, N. A. (1992)).

Table 3.5: Salinity Guidelines

Salinity Guideline	EC value (dS/m)
Suitable for a soil growth medium	<0.4
Suitable for some salt tolerant species	0.4 to 1.6
May not be a suitable growth medium	>1.6

Source: Hunt, N. A. (1992), based on a L:S 5:1 leach.

When soil salinity ($EC_{1:5}$) is below 0.4 dS/m vegetation appears to unaffected by salinity in soils. As salinity increases to 0.4 to 1.6 dS/m salt tolerant species (grasses and shrubs) are likely to become the prominent plant species. When soil salinity becomes unsuitable for most plant species, bare saline areas may develop, and only highly salt tolerant species typically survive.

Simulated daily EC are shown in Figure 3.2 and average simulated EC values are provided in Table 3.6. Simulated EC values for all cover system thickness are classified as being suitable growth mediums for most vegetation species (<1.6 dS/m). Figure 3.2 shows a significant decrease in maximum simulated EC reached at a depth of 0.5 m from surface when the cover system is increased from 0.5 m to 1 m thick.

A decreasing trend is seen in simulated average EC as the cover system thickness is increased though the most significant decrease is seen when the cover system thickness is increase from 0.5 m to 1 m. The 0.5 m thick metasediment cover system option was classified as a suitable growth medium (<0.4 dS/m) based on average EC values and the guidelines in Table 3.5. Though, simulated salinity does exceed 0.4 dS/m seasonally, which could adversely affect some plant species. Again, it should be noted that conservative guidelines are used for soil salinity classifications in the analysis as the guidelines are developed for 1:5 leachate and the EC source term used in the modelling program is based on 1:2 leachate testing data.

Table 3.6: Summary of 1D salt uptake modelling results (2020 to 2100).

Future Climate Scenario	Cover System Option[1]	Avg. EC at 0.5m Depth (dS/m)	Salinity Classification based on Average EC
RCP4.5	0.5m MS	0.3	Suitable growth medium
	1m MS	0.2	Suitable growth medium
	2m MS	0.2	Suitable growth medium
RCP 8.5	0.5m MS	0.2	Suitable growth medium

Future Climate Scenario	Cover System Option[1]	Avg. EC at 0.5m Depth (dS/m)	Salinity Classification based on Average EC
	1m MS	0.2	Suitable growth medium
	2m MS	0.1	Suitable growth medium

[1] MS – Metasediment

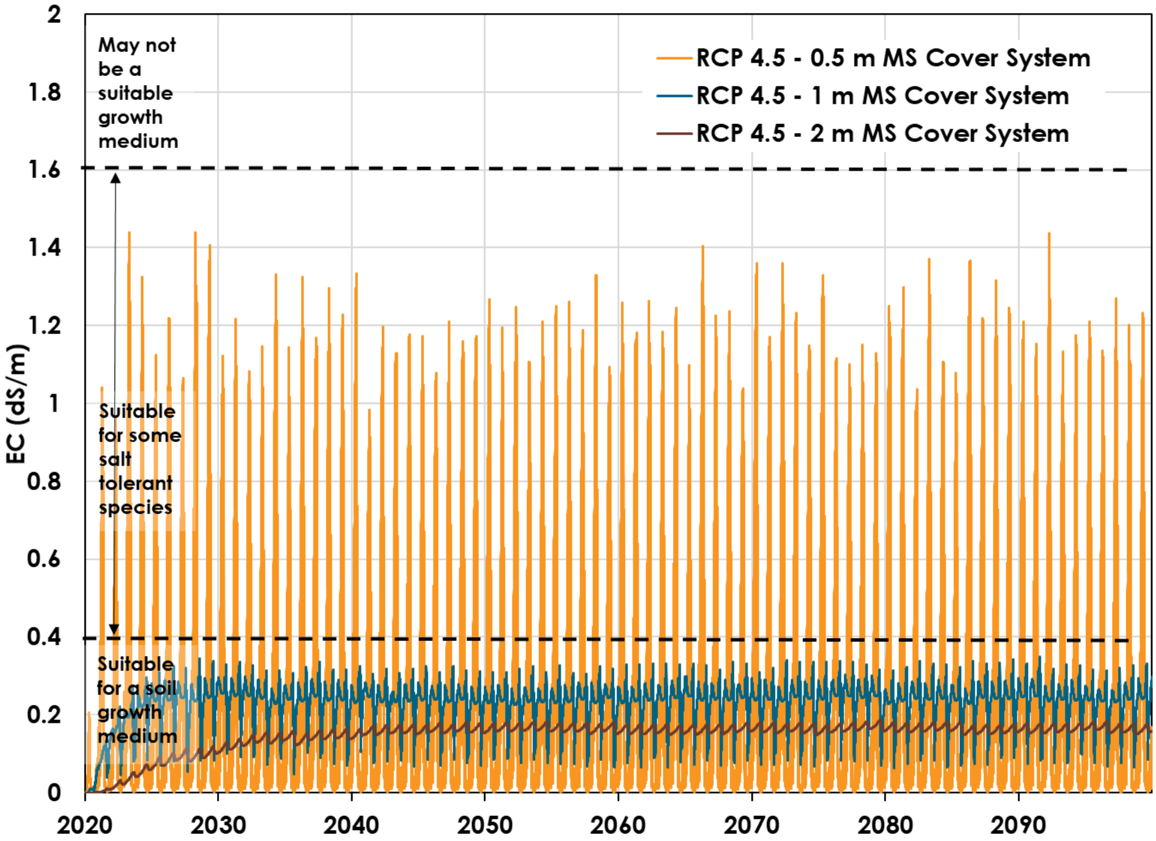


Figure 3.2: Simulated EC for 0.5m, 1m and 2m thick metasediment cover system options for the RCP 4.5 climate scenario.

3.5 High Sulfur Tailings Cover System Assessment

The objective of the proposed cover system design for the high sulfur tailings is to maintain a high degree of saturation within the tailings materials. This would limit oxygen ingress to the high sulfur tailings and prevent AMD generation. Diffusion is anticipated to be the primary mechanism for oxygen transport through a cover system to the high sulfur tailings. Oxygen diffusion can be restricted by creating and sustaining tension-saturated conditions in a layer within a cover system or by maintaining high degree of saturation in the PAF material.

A "tension-saturated" cover system containing a layer that maintains a degree of saturation equal to or greater than 85% is required to efficiently limit oxygen ingress (McMullen *et al* 1997, Bussière and Aubertin 1999, MEND 2004). Though, arid climates, such as the climate conditions at Winu, typically do not possess enough excess water to sustain high degree of saturation annually in a cover system (INAP, 2017); however, the objectives of the conceptual closure cover system design is to maintain high degree of saturation in the underlying high sulfur tailings. This cover system objective is theoretically achieved by preventing the upward movement of water from the high sulfur tailings by decoupling the saturated HS tailings from the evapotranspiration zone. Hence, the optimal cover system design is thicker than the combined depth of evapotranspiration and capillary rise from the high sulfur tailings. Low sulfur tailings were initially proposed to be used to achieve the majority of the required thickness of the cover system for high sulfur tailings, with some nominal thickness of imported soils for dust control and vegetation. Due to the high silt content of the low sulfur tailings (described in Section 2.7.3.1), it is anticipated that the low sulfur tailings will have a significant capillary rise which would decrease the degree of saturation within the high sulfur tailings. Therefore, simulations were completed assuming a coarser-textured low sulfur tailings, which behaved more like the "Sand" material defined in Section 2.7.3.

1D SPA modelling of the conceptual cover system design proposed for the high sulfur tailings was completed to estimate performance with regards to degree of saturation within the high sulfur tailings. Simulations were run for two future climate scenarios (RCP 4.5 and RCP 8.5) from 1 July 2020 to 30 June 2100 (80 years). Cover System thicknesses of 3 m to 6 m and two cover system materials (low sulfur tailings and coarser-textured low sulfur tailings) were assessed. The initial volumetric water content conditions were 0.4 (100% saturated) for the high sulfur tailings, 0.2 for the low sulfur tailings, and 0.13 for the sand.

Figure 3.3 shows degree of saturation over the simulation period (2020 to 2100) for a range of cover system thicknesses for the low sulfur tailings and 4 m sand cover system options for the RCP 4.5 climate scenario. For the proposed closure cover system consisting mostly of low sulfur tailings, the modelling results indicate that the degree of saturation within the high sulfur tailings will drop below 85%. Increasing the cover system thickness from 3.5 m to 6.5 m had little effect on simulated degree of saturation within the high sulfur tailings. Based on the PSD data provided (described in Section 2.7.3.1), the low sulfur tailings consist of 70% silt and clay content. Materials that consist mostly of silt and clay will have a thicker capillary rise zone above a saturated material compared to a sand with larger pore space. Hence, simulations were completed assuming a coarser-textured low sulfur tailings.

The results show that the simulated degree of saturation in the high sulfur tailings with a coarser-textured (i.e. sand) low sulfur tailings cover system is anticipated to maintain a high degree of saturation in the high sulfur tailings. Degree of saturation in the upper 10 m of high sulfur tailings remained above 90% and is starting to reach steady-state conditions by 2100.

Based on the simulation results, the optimal cover system is the 4.5 m coarser-texture (i.e. sand) low sulfur tailings cover system alternative consisting of 4 m sand (coarser-textured low sulfur tailings) and 0.5 m metasediment. With a 4.5 m coarser-textured low sulfur tialings cover system, the saturated high sulfur tailings are decoupled from the evapotranspiration zone.

It should be noted that at the time of this modelling, there was only one PSD available for the low sulfur tailings. As more data becomes available, the material property estimates should be refined, and the conceptual model updated. The inputs used in the modelling for the coarser-textured low sulfur tailings (i.e. sand) material represents a material that consists of 70 to 90% sand sized particles and 10 to 30% clay and silt sized particles.

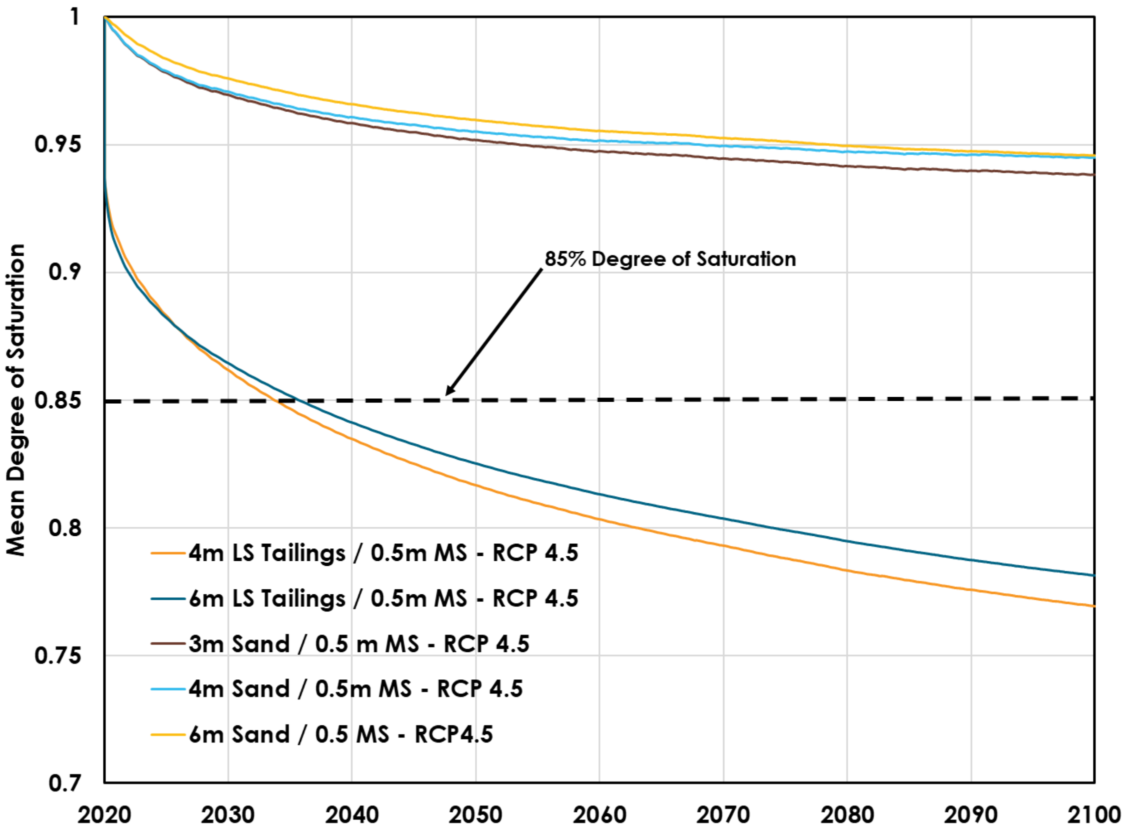


Figure 3.3: Average simulated degree of saturation in the upper 10m of high sulfur tailings for the RCP 4.5 climate dataset.

3.5.1 Lower Boundary Sensitivity Analyses

For the base case high sulfur tailings simulations, the lower boundary condition used represents a low permeability liner (representative of 1.5 mm LLDPE liner or equivalent) at the base of the TSF. The leakage from a geomembrane liner at the base of the TSF is anticipated to be extremely low if constructed properly due to the placement of low permeability tailings directly over the geomembrane, therefore, a leakage rate of 0.15 mm/yr was used based on studies completed by GeoEngineering Centre (Rowe et al. 2016).

As a sensitivity analyses, a lower boundary condition an order of magnitude above the findings of Rowe et al. (2016) (1.5 mm/yr) was also simulated, as well as a no flow lower boundary condition. The simulated average degree of saturation in the upper 10 m of the high sulfur tailings are shown in Figure 3.4.

As the base case leakage rate was already extremely low, a no flow boundary condition had little effect on degree of saturation in the high sulfur tailings. A slight decrease in degree of saturation is seen when the lower boundary condition is increased by an order of magnitude, though the long-term degree of saturation at 2100 is still >90%.

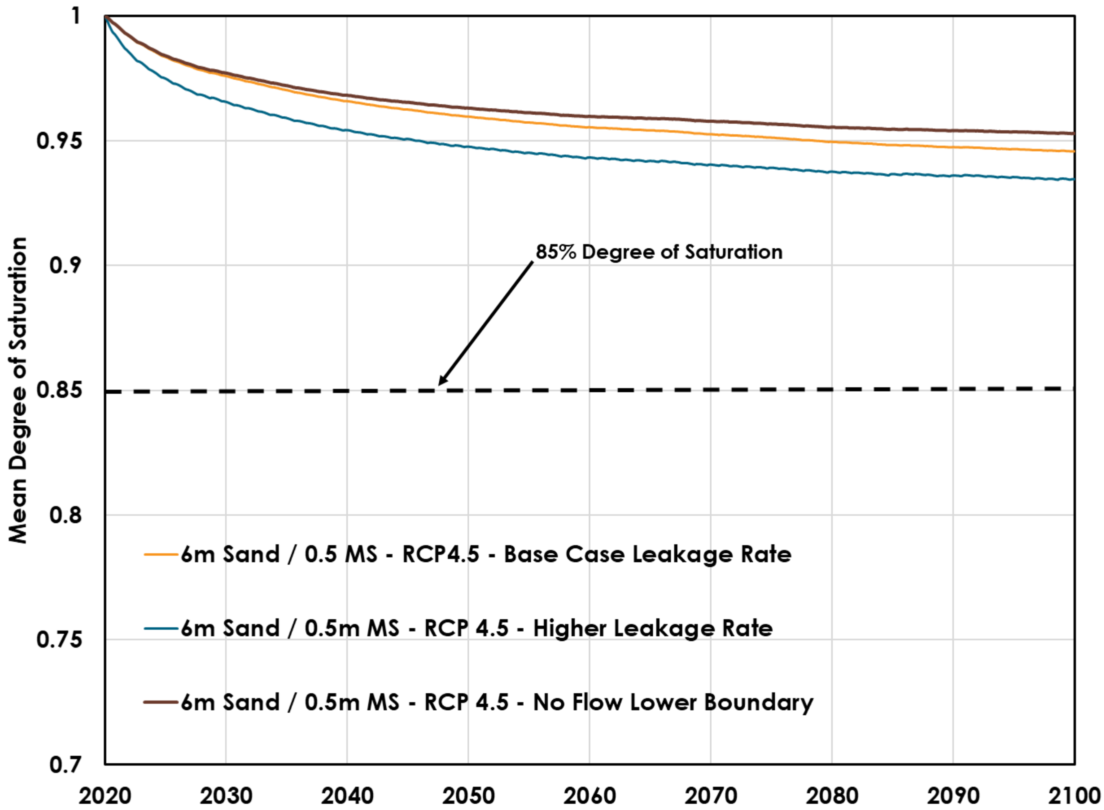


Figure 3.4: Average simulated degree of saturation in the upper 10m of high sulfur tailings for a range of lower boundary conditions.

4 SUMMARY AND RECOMMENDATIONS

The key advantage to the numerical modelling approach summarised herein is the ability to enhance judgment, rather than to lend absolute results. Hence, instead of focusing on the absolute results predicted, it is recommended that the modelling results be viewed as a tool to understand key processes and characteristics that will influence performance of the potential cover system designs, and develop engineering decisions based on this understanding.

Rio Tinto can use the results of this modelling program in collaboration with findings from other site programs (i.e. Landloch's Erosion study) to inform on decisions for management of AMD for the proposed WRD and TSFs at the Winu site through strategic, and optimised, cover system and landform design / construction.

The results of the PAF WRD plateau cover system design modelling indicate that increasing cover system thickness greater than 2.5 m had little effect on simulated NP. For the store-and-release cover system options, NP is controlled mainly by the near surface materials. All models performed relatively similarly from a NP perspective. This is largely a result of all conceptual design options having the same 0.5 m metasediment layer at surface and vegetation inputs with underlying materials that are only slightly different texturally. For the sand and cement store-and-release cover system design options simulated, NP results were categorised as low (1% to 5% of rainfall) and average annual NP was categorised as moderate (5% to 10% of rainfall) for the leached cap cover system design.

For the low sulfur tailings, long-term NP is anticipated to be <1% (very low) for a TSF lined with a low permeability geomembrane (representative of 1.5 mm LLDPE liner or equivalent). Salt uptake modelling results indicated that a minimum 1 m NAF metasediment cover system is expected to be a suitable growth medium. The 0.5 m thick metasediment cover system option was classified as a suitable growth medium growth medium suitable (<0.4 dS/m) based on average EC values, though simulated EC exceeds 0.4 dS/m seasonally, which could adversely affect some plant species.

The modelling results indicate that a 4 m coarser-texture low sulfur tailings (i.e. sand) / 0.5 m metasediment cover system for the high sulfur tailings maintains a high degree of saturation within the high sulfur tailings and is anticipated to decouple the saturated tailings from the evapotranspiration zone.

Preliminary conceptual cover system design models were developed from the available background information and assessed to identify key processes and mechanisms and their controls that are expected to influence cover system performance. The conceptual cover system design modelling results presented in this report can become internal and external stakeholder communication tools that are used to facilitate discussion across technical disciplines, to identify and highlight risks, and explore potential solutions. The process of completing the conceptual cover system design assessment also allows for initial identification and articulation of data gaps. Recommendations for future design and characterisation programs for closure planning at the Winu site are provided below.

4.1 Construction Considerations

The short Life-of-Mine (LOM) at Winu presents challenges with respect to developing effective closure solutions for the reactive PAF waste and high-sulfur tailings. Cover systems serve a variety of purposes, generally providing a protective zone between underlying waste material and atmospheric influences. The design of a cover system is guided by the closure objectives of the facility; for example, limiting net percolation into the waste material, or limiting upward migration of contaminants through capillary rise. In Okane's experience regardless of the design objectives for a cover system, to ensure ongoing structural integrity of a cover system, a consolidated, stable working platform is necessary.

Okane understands the high and low sulfur tailings will be segregated in two cells lined with a low permeability liner. A major constraint in constructing a cover system over this material is the short LOM which will inhibit complete consolidation and dewatering of the tailings material prior to construction commencement. High moisture content and partial consolidation may lead to differential settlement of a final cover system and/or formation of erosional features (such as cracking) which collectively may lead to failure of the cover system to achieve design objectives. Okane understands the properties of the tailings material at placement will be unsuitable to support construction of a straightforward cover system due largely to the unconsolidated nature and high moisture content of the tailings. Consequently, the tailings material will fail to provide a trafficable surface for machinery during construction.

4.1.1 Requirements

Okane have previously led closure studies pertaining to closure of waste facilities at sites across Australia, North America, and northern Europe. Most recently, Okane evaluated a series of closure options for waste facilities at a mine site in South Australia which shares similarities with the closure of the facility at Winu. In line with requirements specified by the governing regulatory body, closure of this facility, which comprises a pond filled with hydrophilic and highly metalliferous, acidic slurry must meet a series of closure objectives to ensure the facility remains safe and stable into the future. Several of the investigated closure options, which are summarised in Section 4.1.2, could be implemented at Winu.

To meet operational safety requirements, as well as ensuring structural integrity of the proposed cover system, the final cover system design may incorporate additional features to expedite the expulsion of water from the underlying tailings and increase its overall solids content, minimise exposure of the tailings, as well as creating a trafficable surface for construction personnel and machinery during construction.

4.1.2 Options Review

This section provides a high-level review of construction options, based on Okane's experience at similar mine sites with similar facilities. Each option describes a series of strengths and weaknesses; however, these are intended to serve as a guide only, and further investigation would be required to develop and refine a solution suitable to the conditions at Winu.

4.1.2.1 Installation of Dewatering tubes

Dewatering tubes, alternatively known as GeoTubes, provide a mechanism to expediate the dewatering of material with a high moisture content. This technology is well developed and has been routinely implemented by mine sites and other industry. Material is pumped into the GeoTubes which is then left to dewater under its own weight. This methodology allows for much more rapid dewatering than would otherwise by achieved by *in situ* tailings deposition; however, additional logistical constraints relating to haulage of the slurry and subsequent dewatered tailings may extend the closure schedule and increase closure costs. Furthermore, a large surface area would be required for construction of a dewatering pad, which may be restrictive depending on available land at Winu. Once the tailings material had been sufficiently dewatered and placed over the PAF waste, the final tailings surface would be trafficable, and a regular cover system could be constructed.

4.1.2.2 Installation of Geosynthetics

Geosynthetics are routinely used across a variety of industries, manufactured using a variety of materials to meet design requirements. Commonly used products include, but are not limited to, bituminous geomembranes (BHM), high density polyethylene (HDPE), and polyethylene terephthalate (PET). Geosynthetics are often included as a layer within a soil/rock cover system to increase bearing capacity as well as lowering permeability of the cover system. A major consideration of using geosynthetics is their cost, which is significant relative to many other closure options. The large initial capital expense of sourcing geosynthetics may be offset in a reduced construction period.

4.1.2.3 Optimisation of Construction Methodology

Optimised construction methodologies such as 'Buttress and Advance' may prove beneficial at Winu, allowing cover system material to be placed from machinery positioned at the perimeter and negating the requirement from machinery to track across the saturated tailings surface. This methodology improves operational safety considerations as well as negating the requirement for additional cover system material. The main weakness associated with this methodology relates to the slow construction period which may extend the closure schedule. Long reach machinery may also be required to place material from working platforms at the perimeter.

Another construction methodology involves division of the larger waste facility into a series smaller cells to reduce surface area, provide additional anchor points for the cover system, and/or increase bearing capacity of the underlying tailings and waste rock. This methodology may be implemented exclusively for a soil/rock cover system; however, may also incorporate geosynthetics and/or other materials which may prove more effective if installed over smaller surface area. Further investigation would be required to determine an optimal surface area for each cell, as well as the width required for each cell wall to accommodate construction machinery. Whilst this methodology would likely expedite the construction schedule, it may substantially increase construction costs associated with the greater material volumes and may be constrained by material availability.

4.1.2.4 Chemical Treatment

Chemical reagents are routinely used to strengthen saturated materials across a range of industries. Such technology generally requires a research component, with testing of the material required to allow a chemically compatible binding agent to be developed. With design objectives in mind, a binding agent may be developed to increase bearing capacity of the tailings to a degree such that regular mine machinery can safety track across the surface to construct the cover system, and the potential for differential settlement will reduce. Chemical treatment of mine waste has been successfully used in Oil Sands sites in northern Canada, and Okane have investigated using a variety of products for the closure of an evaporation pond in southern Australia.

4.1.2.5 Mixing Tailings and Waste Rock

Okane has assisted a mine site in western Canada to develop closure solutions for saturated tailings, whereby saturated tailings are mixed with waste rock to increase strength to meet design specifications. Okane are currently conducting field trials at the site to investigate mixing various ratios of dry to saturated tailings with waste rock; a technique which could be adopted by Winu should the tailings properties be suitable. Recommendations

4.1.3 Materials Characterisation

Material testing and characterisation work presented in this report was completed on drill core samples, currently the best available source for sampling. Rio Tinto is currently undertaking additional testing on materials to further assess material characteristics and suitability for construction of the TSF. Material sampling and testing programs should continue as materials are mined and stockpiled to update material property estimates, material availability and the conceptual cover system design model. Water retention and hydraulic conductivity properties should be included in future material characterisation studies. Defining hydraulic properties and geotechnical properties of stockpiled materials during operations will serve as crucial input for the detailed design of the closure cover systems and improve confidence in the performance expectations.

4.1.4 Vegetation Assessment

A vegetation assessment of native vegetation in the Winu area will improve inputs in future cover system assessment work. Assessing existing natural sites allows representation of the establishment that is likely to occur on the closure cover systems to be defined; thus, providing the opportunity to quantify the interactions between near surface material characteristics and plant root depth / distributions, and its impact on cover system performance. Vegetation species identified and information collected would also be utilised in developing a revegetation plan for Winu site reclamation.

4.1.5 Integrated Mine Planning

Given Okane's expertise in the area of mine waste management, communicating risk to stakeholders through a framework of risk identification, and management of those risks to progress a project (Okane's "Roadmap to Closure") we feel that there could be an opportunity for Okane to provide value to the Rio Tinto Winu project development. Specifically ensuring that mine waste risks are fully understood so that unrecognised and unfunded liabilities are avoided. We would welcome the opportunity to review Winu's closure plans to see if there are opportunities where Okane can add value by optimising the management of waste rock, and development of tailings storage facilities.

Okane are versed at coupling both mine planning and closure considerations within an active mine site. This process allows a site to actively utilise closure requirements through their life of mine (LOM), benefiting the operation with reduced closure costs and potential environmental concerns. At Winu there may be opportunities to refine the existing LOM to ensure that sufficient suitable cover system materials are available throughout the mine life, thereby reducing double handling of materials, or utilising cover materials elsewhere if the ability to stockpile overburden prior to usage is not an option.

4.1.6 WRD Design

Internal waste dump processes will have a large influence on the water quality exiting the facilities. In arid climates, it is possible that some waste dumps will never fully wet up and contribute acidity to the bottoms of the facility. From a solute transport perspective, only a portion of the storage facility in semi-arid and arid climates may be transmitting load for the majority of the time, generally the side slopes or flanks of the facility.

The way a WRD is designed and constructed is important in term of the amount of acidity produces by the PAF waste. For example, you can place identical PAF material into two different landforms: the first is a conventional end tipped WRD that does nothing to limit the oxygen ingress and subsequently the oxidation of pyrite. Meteoric water is allowed to freely infiltrate, and with it, flush the resulting oxidation products. This "PAF" waste material therefore has a high associated risk due to its generation of acidity. Conversely, if that same "PAF" waste material was constructed in a WRD with smaller lifts to limit the development of coarse rubble zones, or employed fines layers which act to control the ingress of oxygen and hence subsequent oxidation, there would not be the same resulting acidity produced as the first example. Therefore, although the material was identical in its PAF classification, the physical setting in which the material is placed is of more importance on its risk factor.

The use of 1D models prevents several important phenomena from being accurately modelled, such as lateral hydrology and advective gas transport. These processes are important in the WRD design as the use of various construction techniques will increase the physical complexity of the WRD. 2D Geostudio modelling of gas transport and O_2 consumption would provide the opportunity to compare various WRD construction techniques in terms of limiting oxygen ingress to PAF waste rock encapsulated internally in the WRD.

4.1.7 Detailed Closure Cover System Design

Once site-specific materials, climate conditions and vegetation characteristics are further refined and waste storage facilities (WRD and TSFs) designs are optimised and finalised, detailed closure cover system design assessments should be completed.

5 REFERENCES

Ahuja, 1989. Evaluation of Spatial Distribution of Hydraulic Conductivity Using Effective Porosity. Soil Science Journal. Vol 148, pp. 404-411.

Australian Government Bureau of Meteorology, BOM. (2020). Climate Data Online, http://www.bom.gov.au/climate/data/, Accessed 21/7/2020

Bussière, B. and Aubertin, M. 1999. Clean tailings as cover material for preventing acid mine drainage: an *in situ* experiment. In Proceedings of Sudbury '99, Mining and the Environment II, Sudbury, Ontario, September 12-15, 1999, pp. 19-28.

CSIRO. (2020). Climate Change in Australia – Projections for Australia's NRM Regions, https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/data-download/, Accessed on 21/7/2020

E Precision Laboratory. (2019). Test Report, Rio Tinto Exploration, Winu 2019 Testing

Fredlund, M.D., Wilson, G.W., and Frendlund, D.G., 1997. Prediction of the Soil-Water Characteristic Curve from the Grain-Size Distribution Curve. Proceedings of the Third Syposium on Unsaturated Soils, Rio de Janeiro, Brazil. April 20-22, pp. 13-23.

GGC (2019) Factual and Interpretive Report Geotechnical Studies Supporting Preliminary Study and Infrastructure Planning, Winu Project, Pilbara, Western Australia

Geoslope. (2021). https://www.geoslope.com/

Golder. (2020). Winu Water Studies, Conceptual Hydrogeology. Submitted to Ricardo Quevedo in June. Golder report ref. 20136763-009-R-RevA

Goldsim (2020). https://www.goldsim.com/

Government of Western Australia. (2020). WA Locate Public Imagery, https://services.slip.wa.gov.au/public/rest/services/SLIP_Public_Services/Locate/MapServer, Accessed on 21/7/2020

Graeme Campbell & Associates Pty Ltd. (2020). Winu Project: determination of oxygen-consumption rates (OCRs) and carbon dioxide release rates for mine-waste, ore and tailings-solids samples.

Hunt NA. 1992. *Farm monitoring handbook.* Perth: University of Western Australia.

International Network for Acid Prevention (INAP). (2017). Global Cover System Design – Technical Guidance Document. September.

Jackson et al. (1996). A global analysis of root distributions for terrestrial biomes, Oecologia (1996) 108: 389-411

Klohn Crippen Berger. (2018) *Research Update on Geomembranes at Tailings Storage Facilities*. Collected November 24, 2020. https://www.klohn.com/blog/kcblog-research-update-geomembranes-tailings-storage-facilities/

Landloch. (2020). Rehabilitated Waste Landforms at The Winu Project: Strategic Guidance, Rio Tinto Copper and Diamonds, Project No. 2443.20, June

LiquidLabsWA. (2020). Soil Classification Test Reports, May 2020

McMullen, J, Firlotte, R., Knapp, R, and Aubertin, M. 1997. Les Terrains Aurifères property site closure and rehabilitation – conceptual to construction. In, Proceedings of the 29th Annual Meeting of the Canadian Mineral Processors, Ottawa, Ont., 274-292.

MEND. (2004). Design, Construction and Performance Monitoring of Cover Systems for Waste Rock and Tailings. July

MiningOne. (2019a). Winu Project, Preliminary Geotechnical Study Waste Rock Dumps & Stockpiles for Rio Tinto Exploration, Job No.5268_G, Report No.P1468v1

MiningOne. (2019b). Winu Project, Preliminary Geotechnical Study Waste Rock Dumps & Stockpiles, Rio Tinto Exploration, Job No.5268_G, Report No.P1469v1

Morin KA, Hutt NM. 2001. Environmental geochemistry of minesite drainage: practical theory and case studies. Digital Edition.

Peel, M., Finlayson, B.L., and McMahon, T.A. (2007). Updated world map of the Köppen-Geiger climate classification. Hydrology and earth system sciences discussions, 4(2), 439-473.

Queensland Government. (2020)., SILO – Australian Climate Data from 1889 to Yesterday, https://www.longpaddock.qld.gov.au/silo/point-data/#responseTab1, accessed on 21/7/2020

Rio Tinto. (2019). Chapter 11. Mineral Waste Management, Winu Preliminary Study.

Rio Tinto. (2020). Mineral Waste Management RevB Document

Rio Tinto. (2020a). 9 Mine Planning RevD, Winu Preliminary Study, March

Rio Tinto. (2020b). 11 Mineral Waste Management RevB, Winu Preliminary Study, October

Rio Tinto. (2020c). Winu Waste Rock Characterisation - Upper (Oxidised and Overburden) Zone. Project Code 15638.

Rio Tinto. (2020d). Winu Waste Rock Characterisation - Secondary Sulfide (Enriched) Zone. Project Code 15640, Version 4.

Rio Tinto. (2020e). Winu Waste Rock Characterisation - Primary Sulfide (Hypogene) Zone. Project Code 5919045639, Version 3.

Rio Tinto. (2020f). WINU_DATABASE_ColumnLeach spreadsheet provided by Rio Tinto.

Rio Tinto. (2020g). Winu Tailings - geochemical characterisation interim results. Memorandum from Mike Hutton-Ashkenny, Bundoora Technical Development centre. Dated 5 October 2020.

Rio Tinto. (2020h). Waste material. Comet_Schedule provided by Rio Tinto 2020.

Rio Tinto. (2020i). Memorandum Re: Winu tailings: guidance on management of potentially acid forming material. Written by Ros Green Dated 6 March 2020.

Rowe, R.K., P. Joshi, R.W.I. Brachman and H. McLeod. 2016. "Leakage through Holes in Geomembranes below Saturated Tailings." Journal of Geotechnical and Geoenvironmental Engineering. 143(2), DOI: 10.1061/(ASCE)GT.1943-5606.0001606.

Wilson, G.W., Fredlund, D.G., and Barbour, S.L., 1997. The effect of soil suction on evaporative fluxes from soil surfaces. Canadian Geotechnical Journal, Vol. 34, pp. 145-155.

Van Genuchten, M. Th. (1980). A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils, Soil Science Society of America Journal 44(5), September

For further information contact:

Becka Barritt
Oceania Regional Project Lead - Operations Manager Oceania
rbarritt@okc-sk.com

Okane Consultants Pty Ltd

Unit 2, 14 Heussler Terrace
Milton, Brisbane QLD 4064
Australia

Telephone: (07) 3367 8063
Facsimile: (07) 3367 8052
Web: www.okc-sk.com