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RIO TINTO

Winu Mine Pit Lake Environmental Risk Assessment (ERA) – 2024 Update

Submitted to:

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EXECUTIVE SUMMARY

Rio Tinto Winu Pty Limited's (RTW) proposed Winu Project Area ("the Project") is located in the Northern Pilbara, east of Port Hedland in Western Australia. The Project encompasses mineralised copper deposit and the surrounding survey area and will feature a single non-backfilled pit on completion. Water balance modelling indicates this void will fill with groundwater to form a terminal evaporative-sink pit lake.

Mine Lakes Consulting (MLC) undertook a preliminary ecological risk assessment (ERA) for project approvals in 2021 (2015-02-R-Rev0). However, risk assessment are dynamic closure planning tools and should be updated as the mine closure knowledgebase grows during closure planning. Following revisions to the mining plan, further ecological survey, and updated water balance and tailings storage facility and waste dump seepage modelling, Rio Tinto required update of this preliminary ERA.

Following national and international guidance for pit lake closure planning and mine closure risk assessment, a source-pathway-receptor conceptual modelling approach was undertaken specific to this particular mine pit lake characteristics and geographic location. environmental risk sources, pathways and receptors were determined in a source-pathway-receptor (SPR) model. All three components were required for a hazard to be a risk. A conceptual model (CM) was also developed to demonstrate how risks might present to wildlife.

A significant amount of Potentially Acid Forming (PAF) material will be intersected throughout the course of operations with all but 19% PAF wall exposures covered with water at closure. The pit lake may contain elevated concentrations of contaminants of potential concern (COPC) that might present an ecological risk to local and regional wildlife.

The SPR model demonstrated the only valid pathways were from the contaminant source as pit lake water, through direct contact, drinking and biomagnification of pit lake aquatic organisms to birds and terrestrial wildlife. Potential receptors of conservation value potentially interacting with the pit lake or pit lake biota included the Gull-billed Tern (*Gelochelidon nilotica*), Fork-tailed Swift (*Apus pacificus*) and Oriental Plover (*Charadrius veredus*). The only likely terrestrial mammal of conservation-significance to potentially interact with the pit lake was Brush-tailed mulgara (*Dasycercus blythi*).

Risk magnitude was then ascribed from an assessment of the consequence and likelihood of occurrence in line with Australasian/international standards for risk management. Risk magnitude was further refined from spatio and temporal distribution of the consequence occurring as per Commonwealth guidance.

The risk assessment showed that birds, and specifically waterfowl, were the key wildlife at risk of the pit lake (Table 1).

Table 1. Summary of key potential Winu pit lake receptors, pathway and residual risk rating.

Receptor	Pathway	Risk ranking
Birds	Direct contact with lake water over long periods of time.	Very low
Birds	Direct consumption of a high total proportion of water from the lake.	Very low

In conclusion, this preliminary risk assessment shows that the proposed Winu pit lake is likely to present a very low risk to key environmental receptors of birdlife. However, this risk assessment should be validated by further studies; especially mine water and lake hydrochemistry, and lake sediment geochemistry and hydrology. Furthermore, this preliminary ERA should be updated as more data becomes available, during operations but particularly during closure as the pit lake fills, and as knowledge gaps of pit lake water quality are addressed.

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GLOSSARY OF TERMS AND ACRONYMS

ABA: Acid-base accounting.

AHD: Australian height datum.

AMD: Acidic and metalliferous drainage.

BGL: Below ground level.

COPC: Contaminants of potential concern.

CM: Conceptual model.

DEMIRS: Department of Energy, Mines, Industry Regulation and Safety.

DWER: Department of Water and Environmental Regulation.

ERA: Environmental Risk Assessment.

GDE: Groundwater dependent ecosystem.

LLDPE. Linear low-density polyethylene.

LOD: Limit of detection.

MIA: Mine Infrastructure Area.

PAF: Potentially acid forming.

PMLU: Post mining land use.

PMP: Probable Maximum Precipitation.

RL: Relative level.

SPR: Source-pathway-receptor model.

TSF: Tailings storage facility.

PEC: priority ecological communities.

RTW: Rio Tinto Winu Pty Limited.

TEC: Threatened ecological community.

WRL: Waste rock landform.

1 BACKGROUND

Rio Tinto Winu Pty Limited (RTW) is evaluating the potential development of mineralised deposits for a copper resource within the Winu Project Area (the "Project"). The Project is a copper-gold-silver deposit located within the Paterson Province, on the western margin of the Great Sandy Desert in a remote section of the Northern Pilbara, in Western Australia. The Project is located approximately ~125 NNW of Telfer and 330 km ESE of Port Hedland (-20° 43' 26"S, 121° 44' 28"E) (Dalstra *et al.*, 2023) (Figure 1). The section of the development envelope that contains the pit and mining activities is called the Mine Infrastructure Area (MIA) and is 13,274 ha in size.

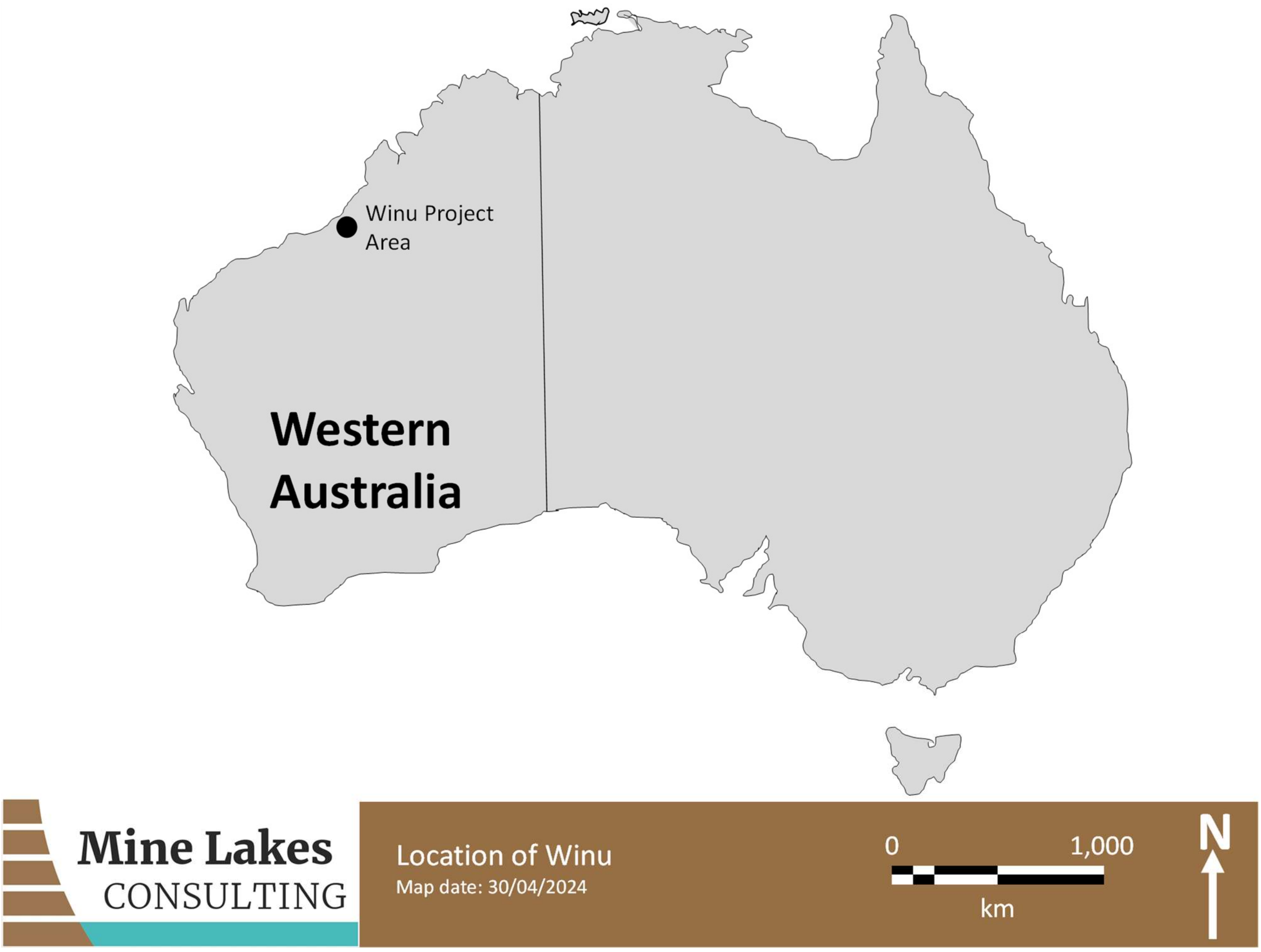

Figure 1. Regional location of Winu.

Conventional open pit mining methods (cut, drill and blast, load, and haul) will be implemented at Winu. Mining will be conducted above and below the water table over a 35-year mine life. A combined waste rock landform (WRL) and tailings storage facility (TSF) with multiple cells (including a high-sulfur tailings cell) will be constructed adjacent to the open pit (Figure 2). Any potential seepage from these facilities will report to the pit dewatering system during operations and to the pit lake post mine completion.

At closure, pit dewatering will cease, the TSF and top of the WRL will be capped and remaining mine facilities will be decommissioned. Winu will consist of a single pit that is not planned for backfill and the open pit will be 485 m deep with around 170 ha of disturbance.

Figure 2. Conceptual mine layout (Rio Tinto, 2024a).

1.1 Environmental Context

The Pilbara region is arid hot desert with very hot summers (up to 50°C) last from October to April and mild to cool winters (near zero degrees) occur from May to September (Figure 3). Summer rainfall occurs from either tropical cyclones or thunderstorms, while winter rainfall is typically from low pressure trough systems. Average annual rainfall in this highly active mining region is low while evaporation can be very high and exceeds rainfall throughout the year. Sporadic and intense thunderstorms are typical for the region from January to March, and an annual average of two tropical cyclones make landfall. Flooding is enhanced when multiple tropical lows occur within a few weeks of each other.

The broader Pilbara region has long been regarded as one of Australia's centres of biological diversity, endemism and refugia and the region is an area of exceptionally high biotic diversity and endemism and harbours taxa genetically distinct from neighbouring regions, despite close geographical proximity of populations. Although no mammal species are endemic to the Pilbara bioregion, it is also home to some of Australia's most charismatic vertebrate species, including northern quoll, mulgara and greater bilby, and also includes some endangered bat species.

325 bird species are known to occur in the Pilbara, with a variety of seabirds, migratory wading birds and Asian vagrants, although the overall harshness of the environment means that few species are resident. The region provides important refugia for a variety of Australian species and includes a range of endemic subspecies and colour morphs. Following cyclonic rains, Mandora Marsh and Fortescue Marsh are of continental importance for waterbirds.

The Project is located in the aptly named Great Sandy Desert (GSD) bioregion (Thackway & Cresswell, 1995) near the coast of north-west Western Australia where red sand dunes and rocky gibber plains dominated by hummock grasses of *Triodia* "spinifex" and sparse, white-barked eucalypts and acacia shrubs (van Etten, 2020). Flora recorded from the region generally comprises drought-tolerant plant taxa with no reliance on groundwater for survival.

The GSD is characterized by low rainfall, high evaporation rates and generally sandy soils, and therefore there are very few permanent surface-water features (the main exception being a small number of surface water seeps and springs). The topography at the site is characterized by extensive west northwest trending sand dunes with poorly defined surface water drainage routes. Internal drainage systems between dunes are common and form soakaways across the region leading to the development of ephemeral, perched water tables. These ephemeral streams and wetlands exist throughout the GSD, these holding surface water following large deluges, which occur every 5–10 years, with major floods occurring once every 20 years on average (Halse *et al.*, 2005).

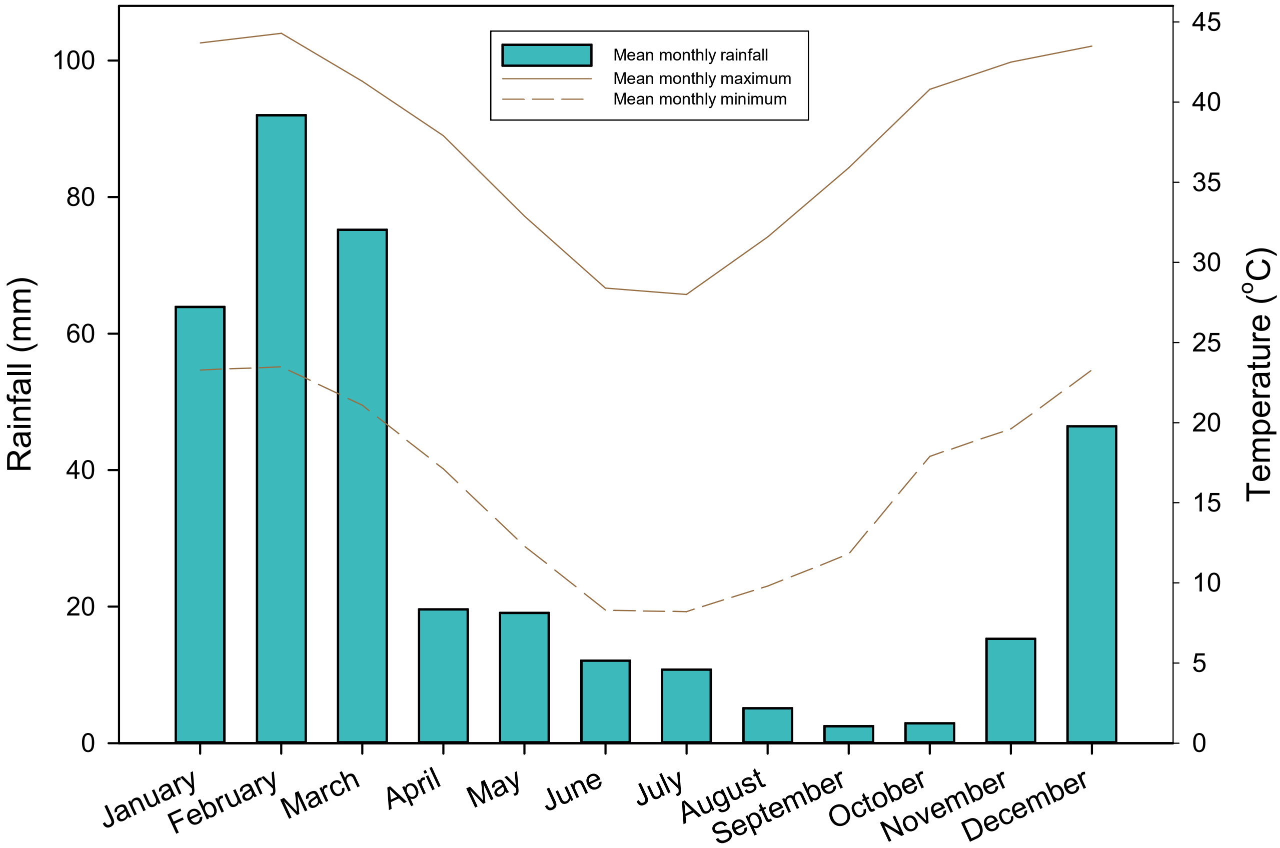

Figure 3. Mean monthly climate for nearby Telfer Aerodrome (BOM, 2024).

1.2 Introduction

A Request for Quote was sent from Ros Green of Rio Tinto (Rio) to Dr Cherie McCullough of Mine Lakes Consulting (MLC) on 6 December 2023 to provide professional advice services for pit lake risk assessment for the proposed Winu open cut mine. This proposal was accepted as purchase order 3105993787 and project managed by Chris Eason.

Contaminants of Potential Concern (COPC) may be elevated in mine waters and may present risk to the environment. The greatest environmental risk of COPCs is typically from AMD (DMP & EPA, 2015; DFAT, 2016a, b, c, e; ICMM, 2019b). The high speed and long distances of water transport mean that the risk of these COPC often presents primarily in receiving waters. The risk of the proposed Winu pit lake potentially contaminated lake water to environmental receptors was identified by Rio as a knowledge gap that required addressing as part of applying for mining project approvals under the Mining Act 1979 (WA) (DMIRS, 2020).

Mine Lakes Consulting (MLC) undertook a preliminary ecological risk assessment (ERA) for project approvals in 2021 (2015-02-R-Rev0). Risk assessment are dynamic closure planning tools and should be updated as knowledgebase grows during closure planning (DFAT, 2016d; McCullough & Sturgess, 2020). Following revisions to the mining plan, further ecological survey, and updated water balance and tailings storage facility and waste dump seepage modelling, Rio Tinto required update of this preliminary ERA.

2 SCOPE OF WORK

Rio engaged MLC to complete a knowledge synthesis and conservative Environmental Risk Assessment (ERA) for water quality environmental risk including potential sources, pathways and receptors for Winu pit lake.

The following studies were undertaken to evaluate risk from the proposed Winu pit lake to wildlife values. This approach was first based upon understanding the environmental values of wildlife that might use the pit lake. The risk of the pit lake water quality was then understood as a potential hazard through SPR modelling, then the risk was assessed, based upon both likelihood and consequence, and also upon receiving environmental spatial and temporal magnitudes.

Focussing on environmental risks, the following Scope of Work (SOW) was undertaken, as below.

1. Review new background documents–Update ERA report to reflect expected project changes i.e., expansion details. Update Introduction and approach to match changes in industry leading practice and scientific literature since last study. Update conclusions to discuss potential limitations regarding end use and risk.
2. Conceptual Model (CM)–Summary of expected lake physico-environmental conditions. Graphical with accompanying narrative. In particular, the expanded pit shell and new pit shell geochemical exposures, TSF and WRD seepage modelling was incorporated into the model.
3. Source-Pathway Receptor (SPR) modelling–Potential COPC pathways to receptors were graphically and narratively defined. The likelihood of contaminant pathways considered and key pathways for risk assessment were also identified. The receptor component of SPR was reassessed in light of recent terrestrial ecological surveys.
4. Environmental Risk Assessment (ERA)–The environmental risk of elevated hazard presented by the lake accounted for in a formal risk assessment process. Risk assessment accounting included the use of management of inherent risks to mitigate unacceptable risks, followed by reassessment of residual risks.

These four study components were organised together to provide advice on pit lake risk as follows (Figure 4).

Figure 4. Staged pit lake risk assessment framework.

Conceptual modelling was congruent with DMIRS (2020); DFAT (2016c, 2016d) guidelines for CPOC risk from mining. Further guidance for pit lake closure risk assessment and mitigation advice for:

- general risk assessment principles and methodology from (AS/NZS ISO, 2018);
- identification of key issues and data requirements in mine closure planning related to pit lakes from McCullough (2011); Vandenberg and McCullough (2017) and Vandenberg *et al.* (2022);
- pit lake geochemical and biotic processes from Doupé and Lymbery (2005); McCullough and Lund (2006); McCullough (2016); McCullough *et al.* (2018); DMIRS (2020) (the 2006 paper is cited by DMIRS 2020), and;
- pit lake approaches to ecological risk assessment from Sampson (1996); Hakonson *et al.* (2009); Nicholson *et al.* (2013); McCullough and Sturgess (2020).

3 APPROACH

3.1 Legislative requirements

Legislative requirements provided guidance as to species of significance to be considered in this assessment. The conservation and management of terrestrial vertebrate fauna in Western Australia is primarily dealt with by the Wildlife Conservation Act (1950). Federally, species or habitats of national importance are covered by the Environment Protection and Biodiversity Conservation Act 1999 (EPBC). There are also several international agreements that are relevant to the conservation and management of terrestrial vertebrate fauna. The species listed under these agreements are primarily waders (shorebirds) or waterbirds that might encounter the Winu pit lake. International Agreements include migratory bird agreements with other countries relevant to species. Species were defined as migratory if they were listed in an international agreement approved by the Commonwealth Environment Minister, including the:

- Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals) for which Australia is a range state;
- agreement between the Government of Australia and the Government of the Peoples Republic of China for the Protection of Migratory Birds and their Environment (CAMBA); or
- agreement between the Government of Japan and the Government of Australia for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA).

The *Contaminated Sites Act 2003* WA (CS Act) also creates an obligation to report known or suspected contaminated sites to the Department of Water and Environmental Regulation (DWER) for classification and potential remediation of some contaminated sites.

Risk management of potentially contaminated mine water is specified in mining environmental management guidance for the Asia-Pacific (APEC, 2018) region, the Commonwealth (DFAT, 2016c) and specifically also in Western Australia (DMIRS, 2020). A risk assessment process is recommended by Department of Energy, Mines, Industry Regulation and Safety (DEMIRS) for this purpose (DFAT, 2016d).

3.2 Relevant water quality guidance

The pit lake end use is for water management of the broader site as a terminal sink of all mining-influenced surface and groundwaters (sensu McCullough & Sturgess, 2020). Not atypical of pit lakes in remote arid regions (McCullough & Lund, 2006; McCullough *et al.*, 2020), the constructed pit lake is expected to have no particular wildlife values, either stated or implied. The proposed pit lake will therefore not be a natural aquatic ecosystem with associated aquatic ecosystem values.

However, there is still expected to be some wildlife use of the lake, with potential for the lake to function as an "attractive nuisance" c.f., Parshley and MacCallum (2016) if the lake attracts wildlife. There is a risk that wildlife attracted to the pit lake could face poor health outcomes if water quality was poor. Default guideline values (DGVs) provide a generic starting point for assessing water quality risk to wildlife (ANZG, 2018). However, regional aquatic ecosystems are defined by regionally and site-specific climate, geochemistry and ecology which can differ significantly between geographic locations and following different land uses (Wetzel, 2001). In particular, mining regions often contain enriched catchment geochemistries with resultant surface and groundwater hydro-chemistries of elevated COPC concentrations (McCullough & Pearce, 2014). Local species assemblages can also become adapted to local chemical conditions through evolutionary adaptation (McCullough *et al.*, 2008a).

As a result of these ecological considerations, ecosystem risk assessment is recommended to be undertaken through a weight-of-evidence process (Burton *et al.*, 2002). The ANZG (2018) guidelines emphasise:

- site-specificity (e.g., catchment geology, regional climate and local ecology);
- being risk-based; and,
- following a multiple lines-of-evidence (MLE) approach.

Together, the ANZG (2018) and DFAT (2016c) guidelines provide a site-specific and evidence-based framework appropriate for assessing mine water quality risk and, where necessary, appropriate mitigation for mining-influenced water bodies such as a pit lake. DMIRS (2020) also provides specific guidance for pit lake closure planning.

3.2.1 Aquatic Ecosystem Protection Guidance

Aquatic ecosystem protection guideline values are often, but not always, the most stringent of all water quality values, and generally ensure that other related water quality values, such as human consumption of edible fish and shellfish, and terrestrial and semi-terrestrial wildlife, are also protected. Although terrestrial and semi-terrestrial wildlife drinking water is not a value covered by the ANZG (2018) Water Quality Guidelines, in general, aquatic ecosystem protection guideline values will be sufficient to protect wildlife from detrimental effects associated with wildlife drinking contaminated water. However, livestock water quality guidelines are not satisfactory for the purpose of broader ecosystem protection for many reasons.

3.2.1.1 Non-ingestion exposure pathways

Livestock drinking guidelines are only protective of drinking and not of other wildlife interactions with pit lake waters (ANZG, 2023). These guidelines focus on parameters like water quality, quantity, and the presence of contaminants that could directly affect animal health. However, they don't necessarily account for the broader environmental impact, particularly on aquatic ecosystems.

The ANZG (2018) guidelines require consideration of water quality where wildlife might interact with waters e.g., feeding, swimming, etc. Unlike stock drinking water guidelines which are only intended to protect organisms from water-borne contaminant exposures by drinking (that is, ingestion) pathways, DGVs are designed to protect against harmful effects from chronic exposure across all relevant exposure pathways that might present. For example, for waterfowl using pit lakes as habitat additional pathways to drinking would likely include:

- Bioconcentration

Even if they are not living their entire life in water, organisms exposed to pit lake water can absorb COPC from the surrounding water directly through their skin.

- Bioaccumulation

Many mine water COPCs persist in the environment and can accumulate in organisms over time, affecting aquatic ecosystems long after. Livestock guidelines do not address the long-term environmental impact of bioaccumulating COPCs. Bioaccumulation presents an additional contaminant source for animals feeding on and around the pit lake.

- Biomagnification

Biomagnification is not accounted for by livestock drinking guidelines. Herbivorous species e.g., ducks and swans, may face exposure to bioaccumulated COPC in aquatic vegetation. Carnivorous species might face greater levels of bioaccumulation through a longer food-chain of algae to invertebrates, to crayfish or fish. Further piscivorous fish may further increase COPC concentrations in body tissues of waterfowl prey items.

3.2.1.2 Whole ecosystem protection

Livestock drinking guidelines are designed to ensure the health and productivity of livestock. However, livestock are complex organisms (multicellular eukaryotes) as birds and mammals. Complex organisms, like these higher animals, have advanced physiological systems such as specialised organs (e.g., liver and kidneys) that help detoxify and manage water ingested contaminants. Smaller and simpler organisms do not have these physiological adaptations to many COPC and may therefore be more sensitive to elevated COPC concentrations, especially in early life stages such as eggs and embryos which are directly exposed to pit lake waters. These same smaller and simpler organisms are also fundamental to the foodchain of the entire pit lake ecosystem.

3.3 Literature Review

Key background geochemistry, ecological survey and water quality reports were reviewed to provide context and information of the ecology and environmental risks expected from the lake. Further information on receptor ecology and pit lake chemistry and risk was sought from peer-reviewed literature (primarily conference proceedings and journal articles).

Information on what receptors should be considered in pit lake risk assessment were also taken from:

- ministerial requirements pertaining to specific species or receiving environments (Rio Tinto, 2024a);

- company knowledgebase of regional ecological distributions and project area survey data and associated conservation protection requirements;
- mine closure planning proposals for next land use, and;
- ongoing stakeholder engagement, especially within company, with regulators and with Traditional Owners.

3.4 Closure planning for post mining land use (PMLU)

Mined lands may be returned to pre-mining land use, post closure (ICMM, 2019a).

The majority of the Winu Project area is located on Unallocated Crown Land and intersects with the Nyangurmarta Warrarn Indigenous Protected Area (NWIPA). Sections that exist within the NWIPA are managed by the Nyangumarta people (via permits) and therefore the engagement on post-mining land use will occur with a goal to align with the IPA's promotion of biodiversity and cultural resource conservation.

Due to the remote location of the Winu Project area, post-mining land use will involve (where practicable), rehabilitation of native ecosystems. Rehabilitated areas need to be sufficiently safe, stable and non-erodible to allow for the re-establishment of native vegetation appropriate to the area. All process and non-process infrastructure will be removed up to 1 m below ground level (bgl) and disposed offsite; except where an agreement is reached for transfer of infrastructure ownership (including liability) to the Nyangumarta people or Martu people.

The pit void with a pit lake, waste rock landform and TSF will remain as permanent structures. Land use on these structures will be limited due to potential for safe access, landform stability and slow rehabilitation of these landforms. For some domains it will be unlikely that a return to a pre-mining ecosystem will be possible. Seepage from the TSF and WRL will report to the pit lake as a mine influenced water containment and management structure.

Preliminary discussions on post-mining land use have been held with the Nyangumarta people. As part of discussions Rio Tinto indicated that alternate post-closure land uses could be considered, dependent on feedback from the Nyangumarta people. These discussions will remain ongoing during life of operations and there is scope within the closure plan document to make modifications to land use as required.

3.4.1 End use values (EVs)

Environmental Values (EVs) define the uses of the water by aquatic ecosystems and for human uses e.g., drinking water, irrigation, livestock watering, aquaculture, recreation, etc. (ANZG, 2018, 2023). EVs are defined attributes for end uses of water that are required for the defined mine closure end use (Young *et al.*, 2019).

Determining water quality values is the first stage in assessing the level of environmental risk and the extent of management that may be required to reduce this risk to an acceptable level (DFAT, 2016c). Water quality values can direct environmental management toward what receptors might be impacted by COPC (Figure 5). This approach allows flexibility in applying management outcomes and criteria to be based on the geochemical and social/environmental baseline conditions relevant to a particular site.

Potential water quality values for the proposed pit lake were determined though post mining land use (PMLU) and associated closure objectives proposed for the pit lake through review of consultant and internal reports and primary literature as per DSDIP (2014); SAEPA (2016); DEHP (No date). Although no specific end use values were identified for the pit lake at time of this assessment, pit lake PMLU will form an ongoing consideration as part of the mine closure planning process.

Water quality values required from inadvertent end use guidance was specifically followed from relevant water quality management guidelines, including ANZG (2018), ANZG (2023) and WA Government scientific technical studies e.g., Department of Biodiversity, Conservation and Attractions (DBCA) and peer-reviewed primary literature. In particular, the roles of the lake for waterfowl feeding and habitat use were explored, especially for species of conservation value.

Use of Winu pit lake as a stock watering source was not identified as a planned pit lake PMLU. Although livestock drinking safety is not a closure objective or water value, and stock are also not identified as receptors in the assessment, livestock drinking water guidelines were used as a proxy for wildlife drinking consequence (sensu Bleich *et al.*, 2006), the only exceedance of stock drinking guidelines (young beef cattle) was by salinity as TDS at 200–300 years.

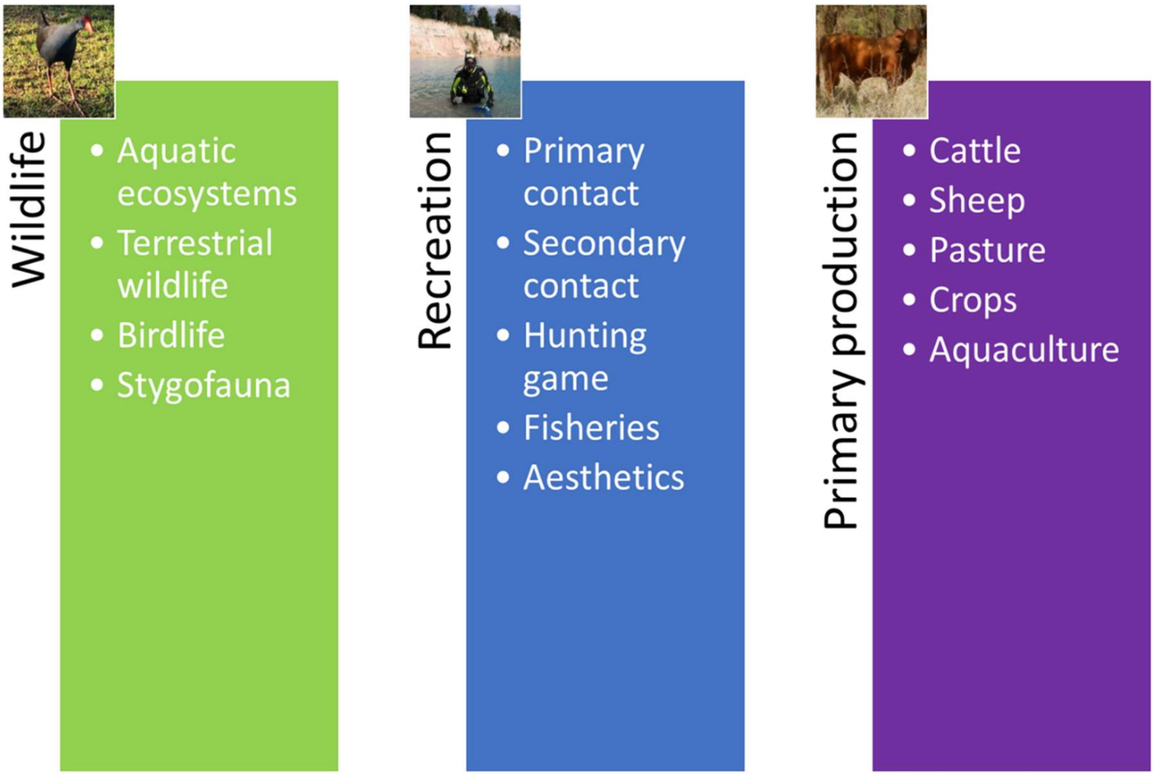

Figure 5. Definition of end use values (McCullough *et al.*, 2020).

3.5 Conceptual Model (CM)

A Conceptual Model (CM) was used as a graphical and narrative representation of the biological, physical and chemical processes that determine the movement of contaminant sources through the broader physical environment to environmental receptors. The CM formed the basis for risk assessment whilst organising information about an activity or site in an easily understandable format, thereby facilitating the identification of gaps in data and information (NTEPA, 2013). Development of the CM for the proposed pit lake was the primary planning tool to support the following environmental risk assessment and associated decision-making processes.

The first step was to understand current site conditions, establish a site definition and collate relevant background information. This information included:

- **study area boundaries** which are linked to both lake and surrounding surface and groundwater catchments;
- local **physical characteristics** including topography, geology, hydrogeology and hydrology; and

- current **water quality values and receptors** for the site and immediate surrounds including historic and contemporary impacts from other sources e.g., pastoral land uses. It was essential to consider future likely land and water use values and potential receptors.

The identification of possible sensitive receptors associated with the lake included both current and potential future receptors, the latter comprising regionally distributed or otherwise migratory vagrant species. Seasonality for this hydrologically dynamic water body feature was also accounted for as more than one model as wetted and dry hydrological conditions. Possible environmental receptors considered included:

- flora and fauna that may inhabit permanently or may intermittently use lake habitat;
- other surface water bodies located on or near the site e.g., creeks and rivers; and,
- groundwater environments beneath, or in the vicinity of the lake.

3.6 Source-Pathway-Receptor (SPR) Model

Guidance for environmental risk assessment and management of pit lake COPC advises that an SPR conceptual modelling approach be undertaken. EVs inform what receptors should be considered for management to achieve protection from unacceptably high risk. Receptors should already have been identified through the CM that was developed through review of databases and literature relevant to the lake and broader region and through discussion with stakeholders (Figure 6, left). As per Commonwealth (DFAT, 2016c), all elements (source, pathway and receptor) of the SPR model should be identified to determine if a risk is likely (Figure 6, right).

Waterfowl as receptors were assessed through considering indirect COPC contact via ingestion of lake aquatic biota. These biota may have body burdens of COPC through bioaccumulation and biomagnification (ANZG, 2018) and direct contact and ingestion of lake COPC as water and sediments.

In the SPR model, environmental risk can be managed by strategies that lead to:

- prevention of contamination to begin with;
- the lack of significant transport pathway from source to receptor; or,
- insignificant value (or tolerant) receptors being present.

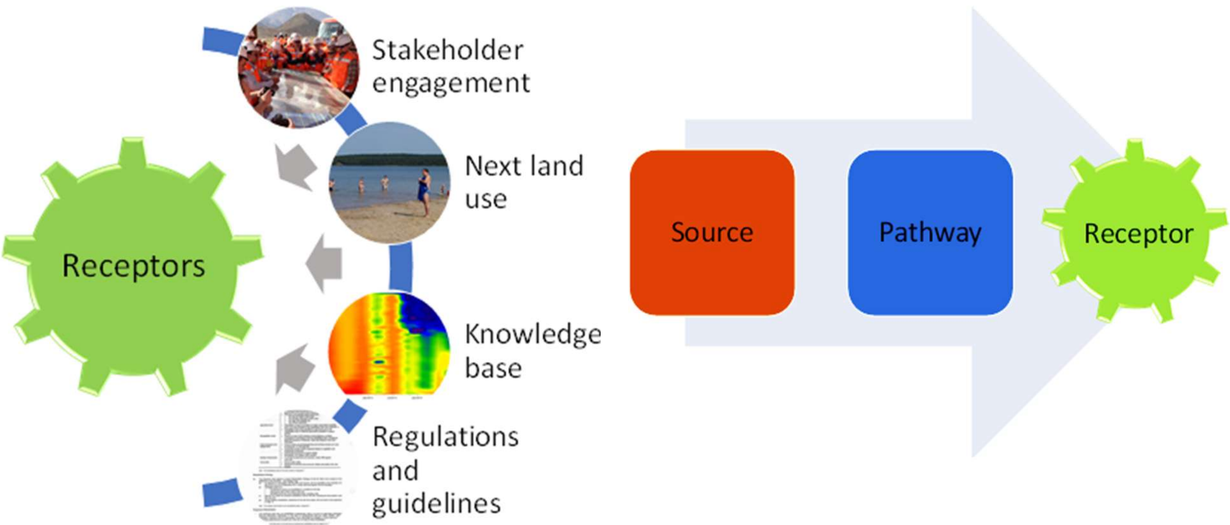

Figure 6. Recommended sources for receptor identification (left) and the source-pathway-receptor (SPR) contaminant transfer model (right).

Lists of fauna expected to occur in the study area were produced using information from a number of sources. Expected species are those that are likely to utilise the study area or be affected by changes to the study area. With some exceptions (noted), the lists excluded species recorded in the general region as vagrants or for which suitable habitat is absent. In particular, the list excluded species where the published understanding of their ecology indicated they were they were not likely to interact with lentic waterbodies.

The SPR model was presented as an interpreted graphical diagram indicating potential:

- contaminant sources;
- transport pathways; and,
- receptors.

The draft SPR model was discussed and agreed with Rio staff prior to undertaking the full risk assessment.

3.7 Environmental Risk Assessment (ERA)

Risk assessment is an accepted approach to evaluate and rank the significance of hazards (AS/NZS ISO, 2018). Environmental risk assessment (ERA) is a useful tool to understand and manage closure risk (APEC, 2018). ERA often considers a source-pathway-receptor (SPR) model that defines the potential for impacts upon defined receptors (McCullough & Sturgess, 2020).

An ERA was undertaken to provide critical consolidation and evaluation of water quality resulting from the proposed pit lake, environmental end use values and transport mechanisms to those values. The risk assessment considered the base-case site rehabilitation strategy (Rio Tinto, 2024a).

The ERA was undertaken in line with leading mine environmental risk management principles and consistent with NEPC (amended 2013), ANZG (2018) and DFAT (2016d). An assessment of expected water quality at hundreds years was considered reasonable given limitations in long-term modelling reliability (Castendyk *et al.*, 2015a; Castendyk *et al.*, 2015b), international guidance (APEC, 2018) and leading pit lake closure practice (Vandenberg *et al.*, 2022).

The risk assessment was informed by receptors whose protection was desired (Figure 6). In turn, the risk rating informed the concomitant degree of management required to protect receptors from identified risks (Figure 7).

The primary intent of the ERA was to identify:

- the environmental values and their associated stock and ecological receptors that need to be protected;
- inherent risks;
- any further environmental management actions required to further mitigate risk; and,
- the residual risk to these components, including potential source, pathway and receptors.

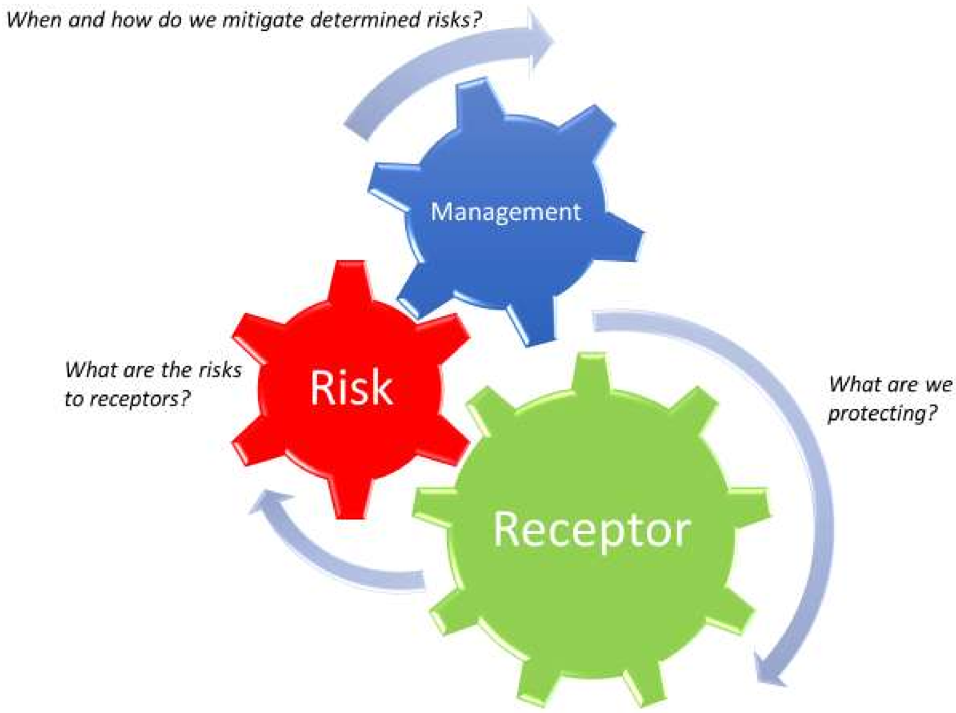

Figure 7. Interaction between receptors, risk assessment and management in mitigating environmental effects.

Good mine closure risk assessment involves company staff in a multi-disciplinary panel (ICMM, 2019a). Rio Tinto staff and associated consultants from subject matter expert areas pertaining to overall pit lake socio-environmental context and contaminant hazard sources, pathways and receptors, evaluated environmental risk at an expert workshop held on 17 May 2024, following McCullough and Sturgess (2020) (APPENDIX C– Risk Workshop Attendee Biosketches).

Key relevant disciplines providing input in the workshop were from subject matter expert (SME) areas of:

- ecology and wildlife;
- hydrogeology;
- geochemistry, and;
- stakeholder engagement.

The draft SPR model was discussed and agreed upon, then risk assessment was undertaken congruent with DIIS (2016) guidelines for managing AMD risk. Key risk assessment assumptions included the following.

- Risk to conservation-significant fauna considered individuals of the species.
- Faunal species not of an especial conservation or functional significance, were largely treated as a community e.g., waterfowl, in their risk analysis.
- Similarly, an emphasis was made on ecosystem functionality as an indicator of ecological sustainability (Kang *et al.*, 2015). As such although individual species may be lost at lower tropic levels (unless the loss of these species led to ecosystem dysfunction), then their loss was considered within ecosystem redundancy.

Pit lake water quality hazards was made through consideration of:

- direct contact and ingestion of contaminants of potential concern (CPOC) as water and sediments, and;
- indirect COPC contact via ingestion of lake aquatic biota. These biota may have body burdens of COPC through bioaccumulation and biomagnification (ANZG, 2018) and direct contact and ingestion of lake COPC as water and sediments.

3.7.1 Risk calculation

Consequence then likelihood were defined by *a priori* criteria (APPENDIX B–Risk Assessment Matrices) with weightings assigned on Likert scales from 1 to 5 (lowest to highest). The risk matrix represented 'Simple' risk (likelihood and consequence) (sensu Ross & McCullough, 2011) and excluded spatial and temporal risk distribution of the ascribed hazard's consequence (sensu DFAT, 2016c).

COPC type and concentrations were considered for consequence. Where concentrations and nature of contaminants both elicited higher toxicity; then higher consequence was allocated. Only preliminary (2015 and 2018) water quality data was available at this stage, so a conservative view of water quality was taken.

The risk assessment then determined likelihood of the *a priori* identified receptors contacting mining contaminated waters. Likelihood was defined as expected frequency of the expected occurrence of the associated hazard's consequence.

The risk rating was derived by multiplication of consequence and likelihood values with the maximum possible risk rating as 25 (i.e., 5x5). The minimum possible risk rating was always 1 (i.e., 1^x, where x is the total number of risk factors). Inherent risk was calculated first then, if unacceptably high, management was considered to reduce either likelihood or consequence terms to arrive at a reduced residual risk ranking (Figure 7).

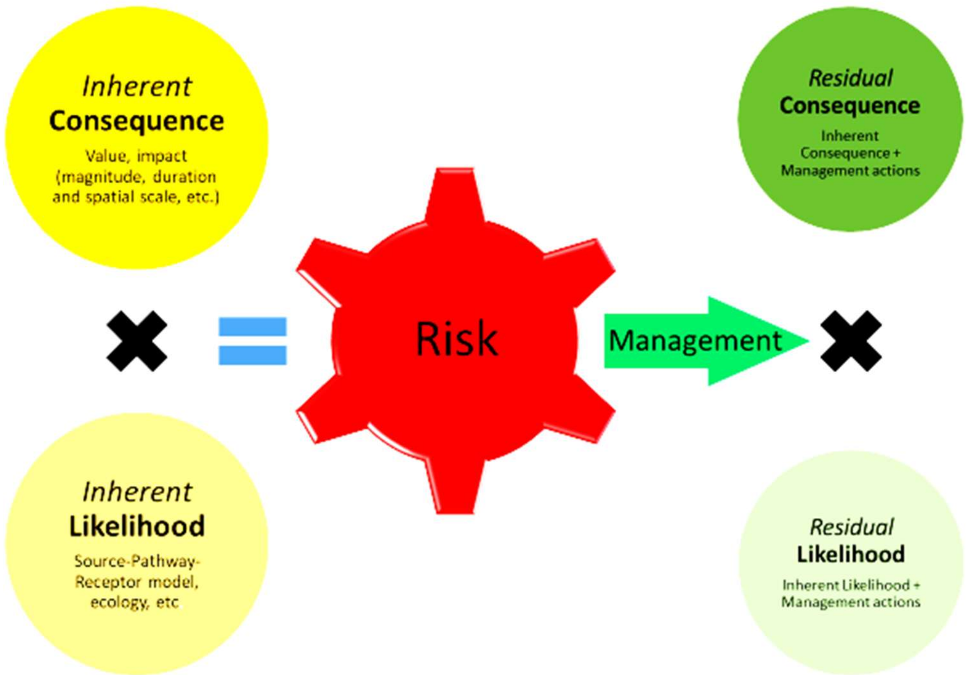

Figure 8. Understanding and managing risks to identified receptors.

4 ENVIRONMENTAL VALUES

4.1 Current and future land uses

The region is not pastoral, and the pit lake locale is not grazed by livestock. As such, there are no livestock watering values, or associated risks afforded by the pit lake as no stock will have access to the pit lake either directly through surface or groundwater pathways.

4.2 Previous disturbances

4.2.1 Regional mining and pit lake legacies

The Pilbara region of Western Australia already features many pit lakes (Germs *et al.*, 2017) predominantly from iron ore mining below groundwater. However, few pit lakes are close to the proposed Winu mine project area. The western end of the Access Road (L45/549) is located within the Wallal Downs Pastoral Station and inside the NWIPA.

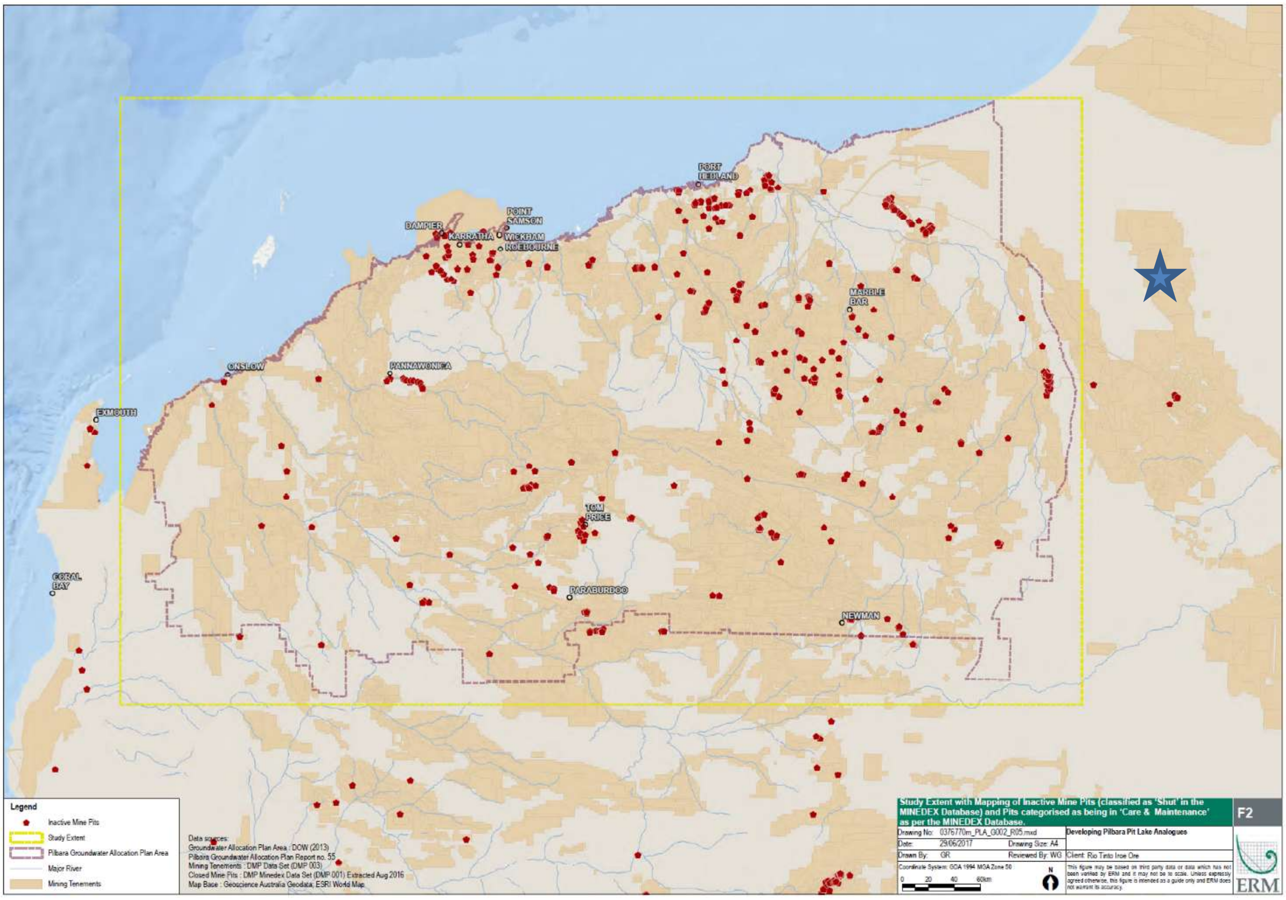

Figure 9. Existent Pilbara pit lakes (ERM, 2017). Project location shown as blue star.

4.2.2 Feral animals

Some feral animals degrade wildlife habitat values in the region, including the following introduced ground-dwelling mammals encountered in recent surveys (Biota, 2020, 2023): However, attracting pest species due to new water resource was not considered likely as the proposed pit lake is not regionally typical of regional natural waterbodies, nor is the ephemeral and eventual saline water likely to provide a drinking resource for many terrestrial animals or birds or habitat for aquatic biota (James *et al.*, 1999; McCullough & Lund, 2006; Letnic *et al.*, 2015). Regional feral species include (van Etten, 2020):

- camel (*Camelus dromedarius*);
- feral cat (*Felis catus*);
- donkeys (*Equus asinus*);
- goats (*Capra hircus*);
- rabbits (*Oryctolagus cuniculus*);
- house mouse (*Mus musculus*), and;
- red fox (*Vulpes vulpes*).

5 SOURCE-PATHWAY-RECEPTOR MODEL

5.1 Potential contaminant sources

5.1.1 Waste landforms

A key closure risk for the Winu Project is the ability to safely store waste rock and tailings to prevent emissions from acidic, metalliferous and/or saline leachate through water or wind erosion, and transport (Rio Tinto, 2024a). However, no sodic, dispersive or radioactive minerals have been identified in resource drilling completed to date. Mineralised units mined and processed as ore will variously contain both acid generating (sulfide) and acid neutralising (carbonate) minerals. A combined waste rock landform (WRL) and tailings storage facility (TSF) with multiple cells (including a high-sulfur tailings cell) will be constructed adjacent to the open pit. The TSF and top of the WRL will be capped at closure with inert and erosion resistant rock and the remaining mine facilities will be decommissioned. However, any potential seepage from these facilities will report to the pit post closure.

Figure 10. Conceptual mining and infrastructure layout (Rio Tinto, 2024a).

5.1.1.1 TSF

A tailings geochemistry study comprised of 40 samples from metallurgical test work involved acid-base accounting (ABA), whole rock assays, liquid extracts and mineralogy tests were undertaken in accordance with leading practice (AMIRA, 2002; INAP, 2009; DFAT, 2016c). In addition, there have been seven kinetic leach columns and two saturated. Sequential extractions have also been undertaken. This work has enabled the following key findings (Rio Tinto, 2024d).

- All high sulfur tailings are PAF, with limited acidification lag.
- Low sulfur tailings were classified as NAF or PAF with low capacity for acid generation.
- Acid generation potential of low sulfur tailings is variable and range up to 20 kg H_2SO_4/t. For comparison, high sulfur tailings contained over 300 kg H_2SO_4/t (excluding oxides).
- Neutralisation potential of tailings is low-nil (<20 kg H_2SO_4/t). Slow-reacting silicates are present and may assist neutralisation in the long-term seepage chemistry.
- Metal leaching at elevated concentrations was typically associated with low pH conditions (NAG pH leachate).
- Fluoride release into solution was observed for most samples.
- Cyanide concentrations into solution were generally low.
- Low and high sulfur tailings from oxide feed are NAF and barren (meaning low-nil neutralising capacity).

The closure strategy aims to maintain a high degree of saturation (>85%) of the high sulfur tailings in order to minimize oxygen ingress by use of a tension saturated cover system to decouple the shallow evapotranspiration zone from the saturated high sulfur tailings (Rio Tinto Winu, 2024). The low sulfur tailings is expected to be covered with an erosion protective cover to limit net infiltration; long term seepage estimates predict the low sulfur tailings will stabilize at 50-60% saturation (WWL, 2023).

Tailings from the processing will be classified either as lower capacity to generate acid (low sulfur tailings) or higher potential to generate acid (high sulfur tailings) and stored in separate cells within the TSF to manage potential environmental risks. The TSF will contain two high sulfur cells (HST1 and HST2) and two low sulfur cells (LST1 and LST2.

The majority (approximately 94%) of tailings will be low sulfur tailings, with a small component (approximately 6%) classified as high sulfur tailings. The High Sulfur cell will be lined with linear low-density polyethylene (LLDPE) or equivalent geomembrane with a downstream-raised zoned embankment. The High Sulfur cell will be operated with a minimum depth of 0.5m water cover during operations to reduce acid generation potential. The High Sulfur slurry will be heavily dosed with lime to ensure water pumped to the ponds and used for processing is close to neutral, or alkaline, pH. These water depths will also be maintained when the cell(s) is progressively raised. The Low Sulfur cell(s) will be lined with bitumen-impregnated liner or equivalent and upstream raises using soil with rockfill backing for closure.

5.1.1.2 WRL

An extensive geochemical characterisation program was undertaken, which included:

- 41 Oxide and overburden samples
- 86 Secondary Sulfide samples
- 115 Primary Sulfides.

Acid-base accounting (ABA), whole rock assays, liquid extracts and mineralogy tests were undertaken in accordance with leading practice (AMIRA, 2002; INAP, 2009; DFAT, 2016c). In addition, there were 21 Kinetic leach columns with some columns continuing to run after three years. Sequential extractions were also undertaken. The tests found the following.

- Material in the Upper (Oxide and Overburden) Zone is predominately NAF but does not contain significant neutralising minerals.
- PAF material is predominantly present in the Primary and Secondary Sulfide Zones.
- Pre-mineral mafic and metasediment lithologies have the highest likelihood of being PAF materials.
- 20-30% of waste rock is PAF.

During operations PAF waste rock will be handled in accordance with the Winu AMD Management Plan (Rio Tinto Winu, 2024) encapsulated within the WRL. The neutralising potential and acid-forming potential in the Primary Sulfides will be considered to designate material as PAF or NAF (Rio Tinto Winu, 2023).

5.1.2 Pit

5.1.2.1 Pit shell geology

Pit wall exposures of lithologies by elevation were extracted from the pit shell and lithologic and geometallurgy three-dimensional geologic models. Lumping of lithology and geometallurgy classes from the geologic models was performed in collaboration with Rio Tinto and resulted in 14 collated lithologies being represented in the pit lake model. The geologic and geometallurgical models provide by Rio Tinto were intersected with the pit design in the three-dimensional geologic modelling software Leapfrog (Bentley, 2024) to calculate the perpendicular surface areas each lithology in the pit wall at closure.

The three major rock types exposed in the ultimate pit wall (cover, mafic, and metasediments) were split into geometallurgical classifications based on mineralization style and sulfide content (i.e., sulfide, oxide, mixed, and leached cap). Cover materials, exclusively located above approximately 100 m AHD on the exposed pit walls, include six separate lithologies (Quaternary Sand, Permian Regolith, Permian Sandstone, Oxidized Mudstone, Reduced Mudstone, and Diamictite) which can collectively be referred to as Cover materials due to similar lithologic and geochemical characteristics between the six units. Figure 11 displays the pit wall exposure (m^2) of each lithology by each bench and Figure 12 and Figure 13 display the distribution of lithology exposure on the pit walls.

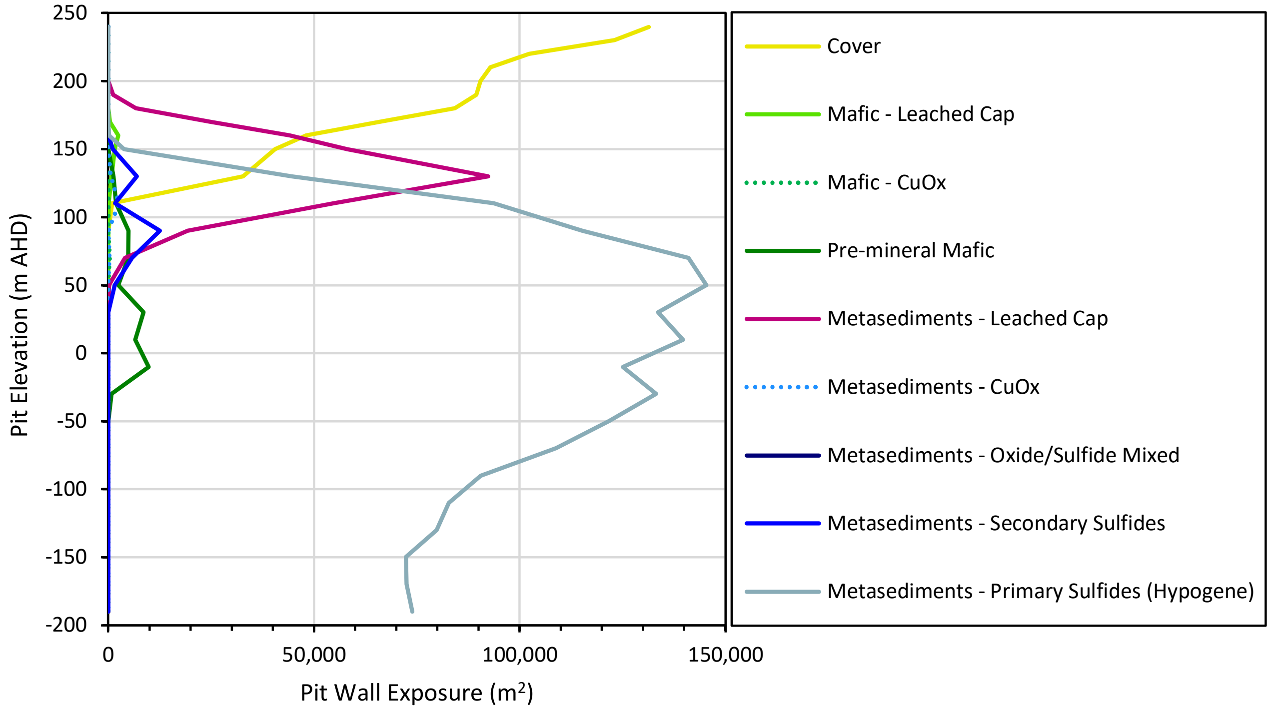

Figure 11. Pit wall exposure by bench elevation for major lithologic units (Hydrogeologica, 2024a).

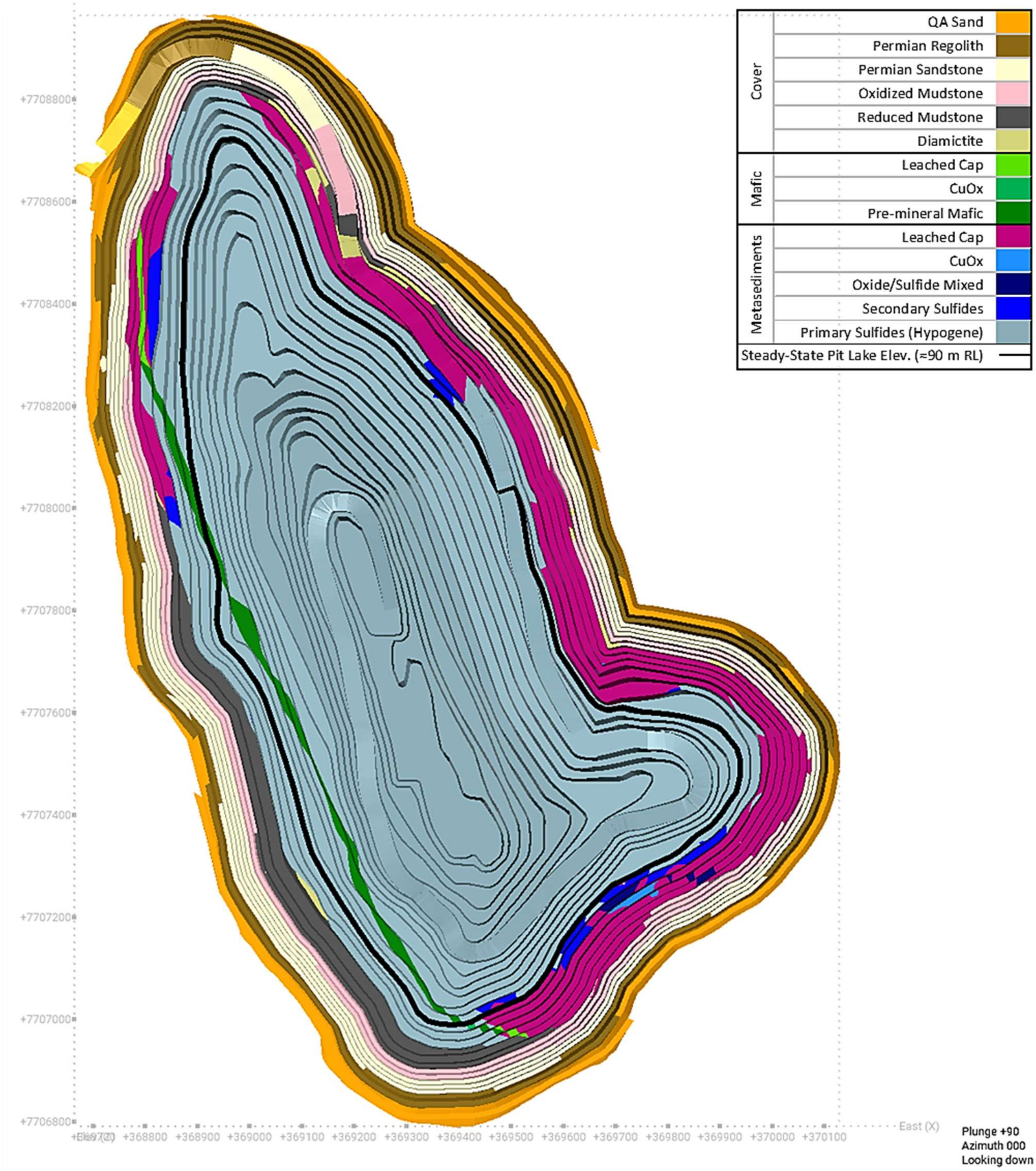

Figure 12. Pit shell exposures (plan view) (Hydrogeologica, 2024a).

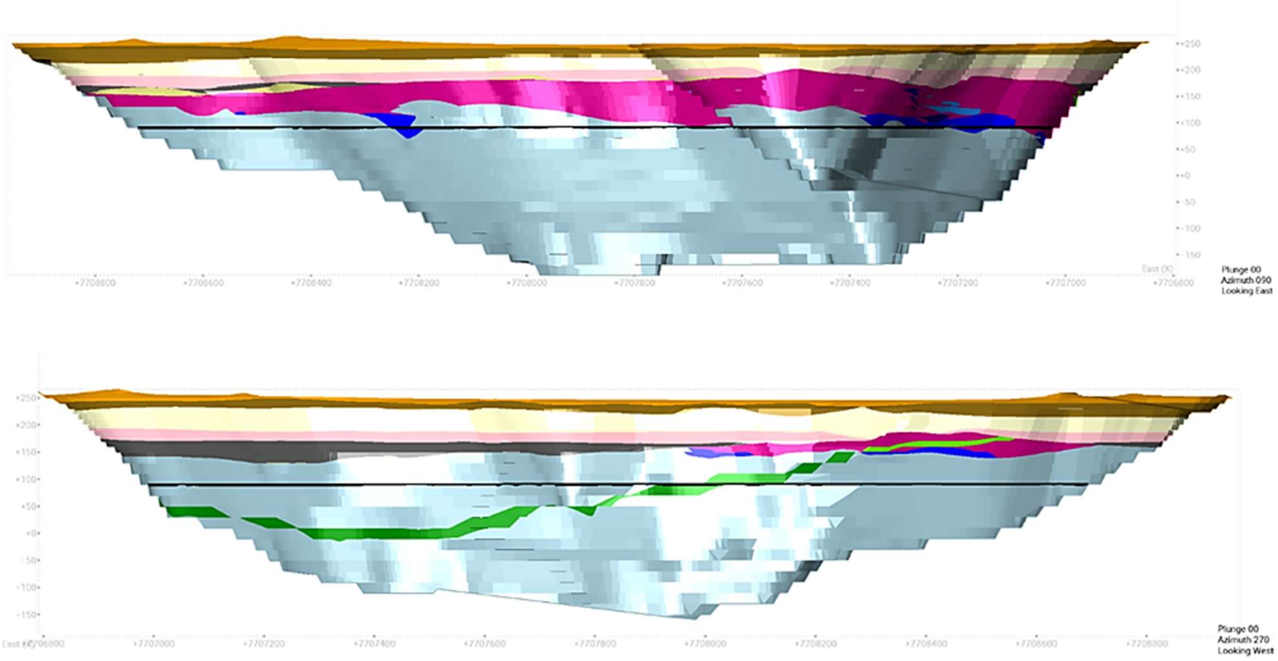

Figure 13. East wall (top) and west wall (bottom) (Hydrogeologica, 2024a).

Closure pit lake filling and geochemical modelling was performed by Hydrogeologica (2024a) using the dynamic systems modelling platform GoldSim (Goldsim, 2011) along with the geochemical modelling code PHREEQC developed by the United States Geological Survey (USGS) (Parkhurst & Appelo, 1999; Parkhurst & Appelo, 2013) coupled using a customized dynamic link library (DLL) code. GoldSim modelling of pit lake recovery during the post-closure period was developed based on existing climate and hydrogeological studies and modelling for the site, together with ultimate pit shell designs and geologic block modelling developed by Rio Tinto. Rio Tinto performed extensive geochemical testing on ore and waste materials that will be generated during mining. The results of this testing informed the development of geochemical source terms used as input to the pit lake geochemistry modelling (Rio Tinto, 2024b, c, d, e).

Geochemical mechanisms associated with pit lake development provide the basis for geochemical assumptions in the numerical modelling. Relevant geochemical mechanisms that may affect the pit lake chemistry include:

- direct rainfall onto the pit lake;
- water-rock interaction and reactions associated with pit wall runoff;
- flushing of chemical mass into the pit lake as the water level rises and inundates the damaged rock zone in the pit walls and talus accumulated on the pit wall benches (this does not provide additional water; however, it does bring chemical mass to the pit lake based on the rock type being flushed;
- seepage from the TSF;
- gas exchange between the pit lake and the atmosphere, and;
- geochemical reactions resulting in precipitation of solids, and associated solids sedimentation.

Because the primary component of pit lake filling is groundwater, groundwater chemistry is expected to dominate the chemistry of the pit lake during filling, while long-term pit lake chemistry is expected to be strongly affected by evapoconcentration.

5.1.2.1.1.1 Pit wall geochemical sources

Rising pit lake water level inundates pit wall (including damaged rock zone and talus), and labile salts and minerals which have accumulated from exposure to the atmosphere (i.e., wetting/drying cycles). These salts will be dissolved, contributing solute mass to the pit lake. These salts and minerals are assumed to be:

1. weathering products following atmospheric exposure of the pit walls over time, and/or
2. naturally present, soluble minerals or weathering products not previously flushed from the pit wall materials during runoff events.

The chemical mass loading from pit wall inundation was calculated based on the following:

- the surface area of each lithologic unit inundated during a timestep;
- a damaged rock zone thickness where inundation and mobilization will occur;
- calculated volumes of talus accumulated on benches;
- an assumed porosity for the damaged rock zone and talus;
- the number of pore volumes required to flush the damaged rock zone and talus of solutes; and,
- the chemical source term for the relevant lithologic unit.

Representative water chemistry source terms for each lithologic unit were developed from free-draining column and MEP results. Due to limited data availability for some of the 14 lithologic units, it was necessary to use some a geochemical source terms for multiple lithological units, resulting in seven unique geochemical source terms for pit wall materials. Table 2 indicates the selected geochemical source term for each lithologic unit together with its AMD classification, summary testing and pit wall exposure statistics.

Pit wall exposures of lithologies by elevation resulted in 14 lumped lithologies being represented in the pit lake model with surface areas by lithology summarized in Figure 14. Geological models were intersected with the pit design to calculate the perpendicular surface areas each lithology in the pit wall at closure with three-dimensional geologic modelling software Leapfrog (Bentley, 2024).

Geochemical properties of key lithological units are described below.

5.1.2.1.1.2 Cover/Overburden

Cover materials comprise six waste overburden lithologic units (Quaternary Sand, Permian Regolith, Permian Sandstone, Oxidized Mudstone, Reduced Mudstone, and Diamictite) that represent 29% (902,000 m^2) of the total pit wall exposure. Derivation of the geochemical source term for the cover materials was based on results from 10 MEP samples. One geochemical source term was generated for all cover materials by weighting the MEP concentrations according to their relative pit wall exposures. There are no available MEP data for Permian Regolith and Diamictite samples. 100% of cover materials are classified as NAF (Rio Tinto Winu, 2024). Additionally, nearly all cover material exposed on the pit walls is present at elevations above approximately 100 m AHD and is expected to remain above the long-term pit lake elevation. It is therefore only necessary to use this source term for runoff from exposed cover material in the pit walls, and not for inundation calculations.

5.1.2.1.1.3 Mafic Primary Sulfide

The source term for the pre-mineral mafic lithology was derived from two column tests. This lithology is overwhelmingly classified as PAF (95% (Rio Tinto Winu, 2024)), although only represents approximately 1.3% of the ultimate pit wall area. Column testing of PAF pre-mineral mafic samples indicates a lag time to the generation of acidic conditions on the order of 15 to 20 years (HGL, 2021). Column testing did not generate acidic leachate within the testing timeframe and circum-neutral column results and were used to derive the source term prior to acidification.

Results from two Mafic Secondary Sulfide columns which generated acidic leachate were used to derive a source term for this lithology post-acidification.

5.1.2.1.1.4 Mafic Secondary Sulfide

Mafic Secondary Sulfide material is not expected to intersect the pit wall or represent a small fraction and therefore is not represented in the model.

5.1.2.1.1.5 Leached Cap

The leached cap (mafic and metasediment) material is expected to represent approximately 10% of the ultimate pit wall area. This material is overwhelmingly classified as NAF (95% (Rio Tinto Winu, 2024)); therefore it is not expected that this material will generate acidic leachate. The geochemical source term for Leached Cap material was derived from results from four MEP samples (one PAF ore sample and three NAF waste samples that were appropriately weighted based on the NAF/PAF proportions according to the AMD Management Plan (Rio Tinto 2024)).

5.1.2.1.1.6 Cu-Oxide

The Cu-Oxide source term is applied to several lithologies including Cu-Oxide, Mixed Oxide/Secondary Sulfide, and Mafic Cu-Oxide. Together, these lithologies represent 0.24% of total pit wall exposure, and are overwhelmingly classified as NAF (91%) due to low sulfur content. Source terms for all Cu-Oxide materials were derived from eight MEP samples (four waste samples and four ore composites, weighted respective of NAF/PAF proportion).

5.1.2.1.1.7 Secondary sulfide

Secondary Sulfide material will be exposed on only a small proportion of the ultimate pit wall (0.97%). This lithologic unit is largely classified as PAF (62% (Rio Tinto Winu, 2024)). The source term for Metasediment Secondary Sulfide material was derived from three column tests on Metasediment Secondary Sulfide materials, including two PAF samples and one sample classified as uncertain with respect to acid formation potential. Conservative column testing results indicate the potential for the PAF material to immediately generate acidic leachate, therefore no lag time was considered.

5.1.2.1.1.8 Primary sulfide

The Primary Sulfide (Hypogene Metasediments) represent the largest lithologic unit exposed on the pit walls (58%), the majority of which (84%) is expected to be PAF (Rio Tinto Winu, 2024). In total, 11 columns of this material have been, or are currently being, tested including 5 NAF or uncertain samples and 6 PAF samples, none of which have generated acidic leachate to date. Original and updated depletion calculations agree with the Primary Sulfide columns, indicating the materials may exhibit lag times to acidification on the order of 20 to 50 years of testing under laboratory conditions. Source terms for the PAF materials pre-acidification were derived from the 11 Primary Sulfide columns which produced circum-neutral leachate, whereas source terms for the PAF material post-acidification were instead derived from acidic column results from Secondary Sulfide materials. Pre- and post-acidification source terms are calculated using the same method, averaging the leachate concentrations from the final 4 month of column data.

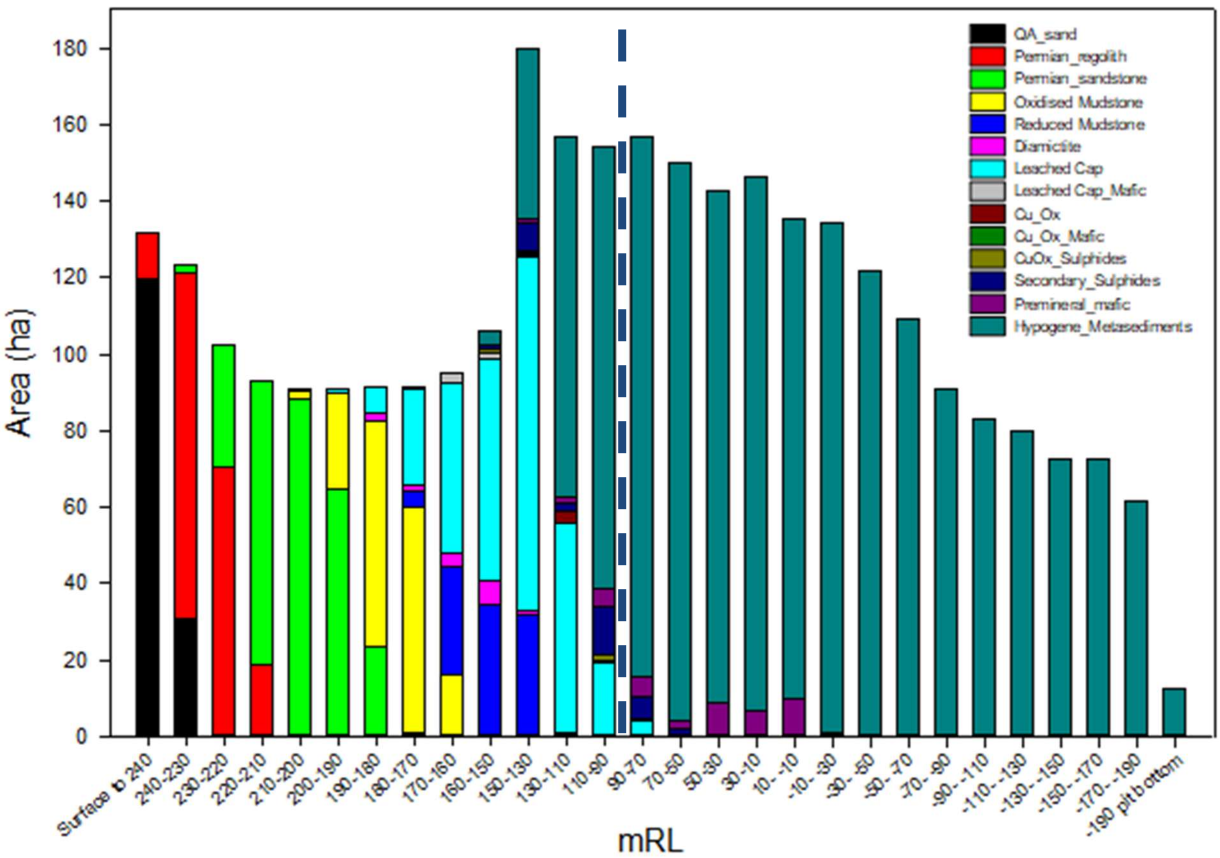

Figure 14. Total area of lithology exposed in walls relative to pit depth.

Dashed blue line indicates expected median pit lake water level.

Table 2. Summary of geochemical testing statistics, geochemical source term assignments and pit wall exposure statistics (Hydrogeologica, 2024a).

<table>
<tr><th rowspan="2">Lithology</th><th colspan="2">Area of Pit Wall Surface</th><th colspan="2">AMD Classification</th></tr>
<tr><th>m^2</th><th>%</th><th>% PAF</th><th>% NAF</th></tr>
<tr><td>QA Sand</td><td>149,814</td><td>4.9</td><td rowspan="6">0</td><td rowspan="6">100</td></tr>
<tr><td>Permian Regolith</td><td>191,048</td><td>6.2</td></tr>
<tr><td>Permian Sandstone</td><td>285,562</td><td>9.3</td></tr>
<tr><td>Oxidized Mudstone</td><td>161,552</td><td>5.3</td></tr>
<tr><td>Reduced Mudstone</td><td>98,562</td><td>3.2</td></tr>
<tr><td>Diamictite</td><td>15,518</td><td>0.51</td></tr>
<tr><td>Mafic - Leached Cap</td><td>5,426</td><td>0.18</td><td rowspan="2">5</td><td rowspan="2">95</td></tr>
<tr><td>Leached Cap</td><td>305,880</td><td>10</td></tr>
<tr><td>Pre-mineral Mafic</td><td>41,228</td><td>1.3</td><td>95</td><td>5</td></tr>
<tr><td>Mafic - CuOx</td><td>383</td><td>0.012</td><td rowspan="3">9</td><td rowspan="3">91</td></tr>
<tr><td>CuOx</td><td>3,532</td><td>0.12</td></tr>
<tr><td>Oxide/Sulfide Mixed</td><td>3,489</td><td>0.11</td></tr>
<tr><td>Secondary Sulfides</td><td>29,673</td><td>1.0</td><td>62</td><td>38</td></tr>
<tr><td>Primary Sulfides</td><td>1,778,056</td><td>58</td><td>84</td><td>16</td></tr>
</table>

* Source term derived from 2 NAF columns of Pre-Mineral Mafic and 2 PAF columns of Mafic Secondary Sulfide.
** Source term derived from 11 columns of Metasediment Primary Sulfide and 3 columns of Metasediment Secondary Sulfide.

5.1.3 Sources Summary

Contaminant sources are limited to the proposed pit lake which will entrain all COPC resulting from weathered PAF (Table 3).

Table 3. Potentially significant contaminant sources to the Winu pit lake.

Source Name	Source Location	Potential Contaminant Type(s)
Pit lake shell	Weathering pit shell in a slowly filling lake	Weathering of PAF exposures within the pit void shell and groundwater cone-of-depression forming AMD with some potentially elevated COPCs as salinity and heavy metal/metalloid concentrations. AMD neutralised by ongoing alkaline groundwater inflow but still moderate to poor water quality. Salinity and COPC concentrations increasing over time due to evapoconcentration. Initially freshwater turning brackish over 300 years.
TSF	Wholly with constructed TSF	The majority (approximately 94%) of tailings will be low sulfur tailings, with a small component (approximately 6%) classified as high sulfur tailings. All high sulfur tailings are PAF, with limited acidification lag. However, high sulfur tailings are not expected to generate AMD if saturated c.f. (Gammons, 2009; McCullough *et al.*, 2024). Acid generation potential of low sulfur tailings is variable. Neutralisation potential of tailings is low but may show long-term neutralisation. Metal leaching at elevated concentrations was typically associated with low pH conditions (NAG pH leachate). However, CN is not expected to be high.
WRL	Wholly with constructed WRL	Waste from material in the Upper (Oxide and Overburden) Zone is predominately NAF. PAF material is predominantly present in the Primary and Secondary Sulfide Zones and pre-mineral mafic and metasediment lithologies have the highest likelihood of being PAF materials with 20-30% of waste rock as PAF.

5.2 Potential contaminant pathways

5.2.1 Groundwater

5.2.1.1 TSF seepage

To reduce risk of potentially contaminated water runoff, TSF drainage will be internal. The surface water from the internal slopes of the embankments will be directed into the TSF cells. Water runoff from the outer slopes will be collected in drainage channels and directed to water ponds at the west of the facility for use as processing water (Rio Tinto, 2024a).

Flow modelling predicted potential TSF seepage rates towards the end of operations and continuing into post closure (WWL, 2023). Seepage from the entire TSF is expected to occur in the future due to progressive degradation of the 1.5 mm thick geomembrane liner system underlying the entire TSF (Figure 15). Modelling predicted upper and lower bound seepage rates from the TSF extending 250 years into post closure Infiltration rainwater quickly fills a superficial aquifer within the project area. Seepage from the TSF is then expected to report to the pit lake due to the groundwater cone of depression caused by the long-term, pit lake hydraulic sink sensu McCullough *et al.* (2013); McCullough and O'Grady (2022). These potential seepages were simulated conservatively in the model and are not predicted to adversely affect the chemistry of the pit lake at any time.

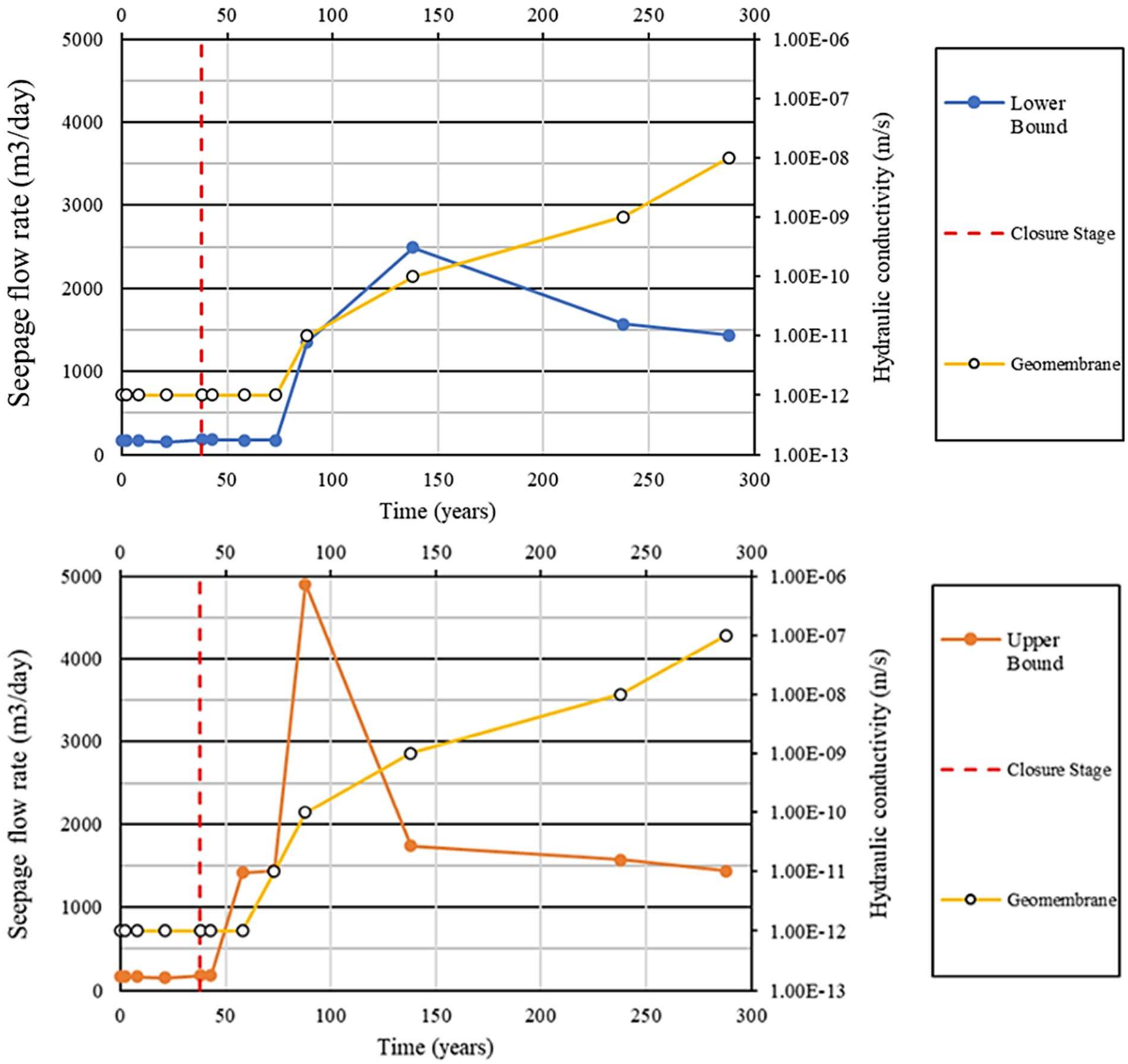

Figure 15. Predicted TSF seepage rates (WWL, 2023).

5.2.1.2 WRL seepage

The WRL to be constructed during the operations is based on the design outlined in the Winu AMD Management Plan (Rio Tinto Winu, 2024). Deep percolation of rainfall is expected to be very limited, with most of the rainfall becoming storage in the waste rock soil and evaporating.

Only one of the modelled analyses (Sensitivity 2) indicated a possibility that the uptake capacity of the WRL and vadose zone might be exceeded, suggesting the possibility of WRL seepage arriving at groundwater (Figure 16). Unless significant areas of the WRL surface are expected to remain undisturbed by truck traffic, it is considered unlikely that any seepage from the WRL to the underlying vadose zone will occur. As it will be necessary for trucks to drive on the WRL during its construction this is unlikely. Nil seepage from the WRL is therefore assumed in the pit lake modelling.

WRL Specifications	Units	Values
Total Height	m	80
Mine Life	years	26
Rate of Rise	m/yr	3.1
Mean Annual Rainfall	mm	387
Runoff Ratio for Rainfall (Overland Flow)	%	0

Interpretation Key
Seepage
No Seepage
Sensitivity
Unsaturated

		Uncompacted Waste Rock Only					0.135 m Truck Traffic Zone Only				
WRL	Units	Estimate	Sens. 1	Sens. 2	Sens. 3	Sens. 4	Estimate	Sens. 5	Sens. 6	Sens. 7	Sens. 8
Annual Rise Height	m	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Percent Infiltration (Input from Hydrus Model)	fraction	0.51	0.51	0.51	0.40	0.62	0.21	0.21	0.21	0.14	0.42
Initial Moisture Content	fraction	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Field Capacity	fraction	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Percent Preferential Flow	fraction	0.5	0.3	0.7	0.5	0.5	0.5	0.3	0.7	0.5	0.5
Deep Infiltration	mm	197	197	197	155	239	82	82	82	56	162
Uptake Capacity	mm	231	323	138	231	231	231	323	138	231	231
Seepage	mm	0	0	58	0	8	0	0	0	0	0
Percent Uptake Capacity Consumed	%	85	61	142	67	104	35	25	59	24	70

		Uncompacted Waste Rock Only					0.135 m Truck Traffic Zone Only				
Vadose Zone	Units										
Thickness	m	50	50	50	50	50	50	50	50	50	50
Annual Seepage from WRL	mm	0	0	58	0	8	0	0	0	0	0
Total LOM Seepage from WRL	mm	0	0	1518	0	214	0	0	0	0	0
Initial Moisture Capacity	fraction	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Field Capacity	fraction	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Percent Preferential Flow	fraction	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Uptake Capacity	mm	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
Seepage to Water Table	mm	0.00	0.00	268.21	0.00	0.00	0	0	0	0	0
Percent Uptake Capacity Consumed	%	0.00	0.00	121.46	0.00	17.10	0	0	0	0	0

Figure 16. Analytical WRL percolation modelling results (Hydrogeologica, 2024a).

5.2.1.3 Pit lake seepage

The likelihood of density-driven saline seepage over time (sensu McCullough *et al.*, 2013) was advised by groundwater flow modelling (Advisian, 2022) which indicates that the final pit lake elevation is likely to be significantly lower than the pre-mining groundwater elevation so, in the case of the Winu pit lake, it is anticipated that groundwater outflow will be zero at all times. Further modelling by HGL demonstrated density-corrected environmental head of the pit lake leading to outflow is not expected under any pit lake climate scenarios. TDS values in the pit lake are not sufficiently elevated to result in environmental heads in the lake approaching that of the regional groundwater head. As such, no groundwater outflow from the pit is expected. Under the scenario with the highest predicted long-term pit lake elevation (85 m AHD), theoretical TDS values would have to exceed an unrealistic concentration of 2,000 g/L in order to overcome the hydraulic gradient into the pit and induce density-driven outflow. These concentrations are likely unattainable due to expected solubility controls. Because of this exceptionally strong hydraulic gradient into the pit, no density driven groundwater outflows are expected at any point in the future despite ongoing evapoconcentration of the pit lake.

5.2.2 Pit lake discharge

No surface water outflows from the pit lake are anticipated. It would be necessary for the pit lake elevation to exceed the pre-mining groundwater level and reach the lowest point on the pit rim in order for this to occur. No reasonable storm events for the area are expected to generate sufficient pit inflows for this to occur.

5.2.3 Catchment surface waters

The mine is located in a sandy environment and rainfall infiltrates relatively quickly. Based on the current local topography, no significant catchment run-off (including creek flow) is expected to report to Winu pit void, and the pit void only receives direct rainfall and pit wall run-off (Rio Tinto, 2020b). However, this will be reviewed over the development of the project as planning of closure landform designs develops.

5.2.4 Pit lake

5.2.4.1 Pit lake water balance

A pit lake is expected to slowly develop in the Winu pit void upon cessation of mining activities and dewatering at mine closure as a result of the planned pit geometry, local climate, and groundwater hydrodynamic interaction (Rio Tinto, 2020b). Groundwater from the metasediment aquifer will be the dominant inflow to the pit lake, amongst all inflow sources. Inflow from the overlying unconfined (Permian) aquifer (into pit void) is at this stage assumed to be negligible due to the saturated thickness of the aquifer being generally less than 5 m and the aquifer being of low permeability (Golder Associates, 2021).

Pit volume and pit wall surface area relationship to elevation of the pit is shown in Figure 17. The total volume of the pit is approximately 311 Mm^3, with a total pit wall exposure of approximately 3.1 Mm^2. The pit wall surface area and two-dimensional plan view surface area were calculated from the pit shell model and used to inform the volume of damaged rock zone and the plan view catchment area for pit wall runoff, respectively.

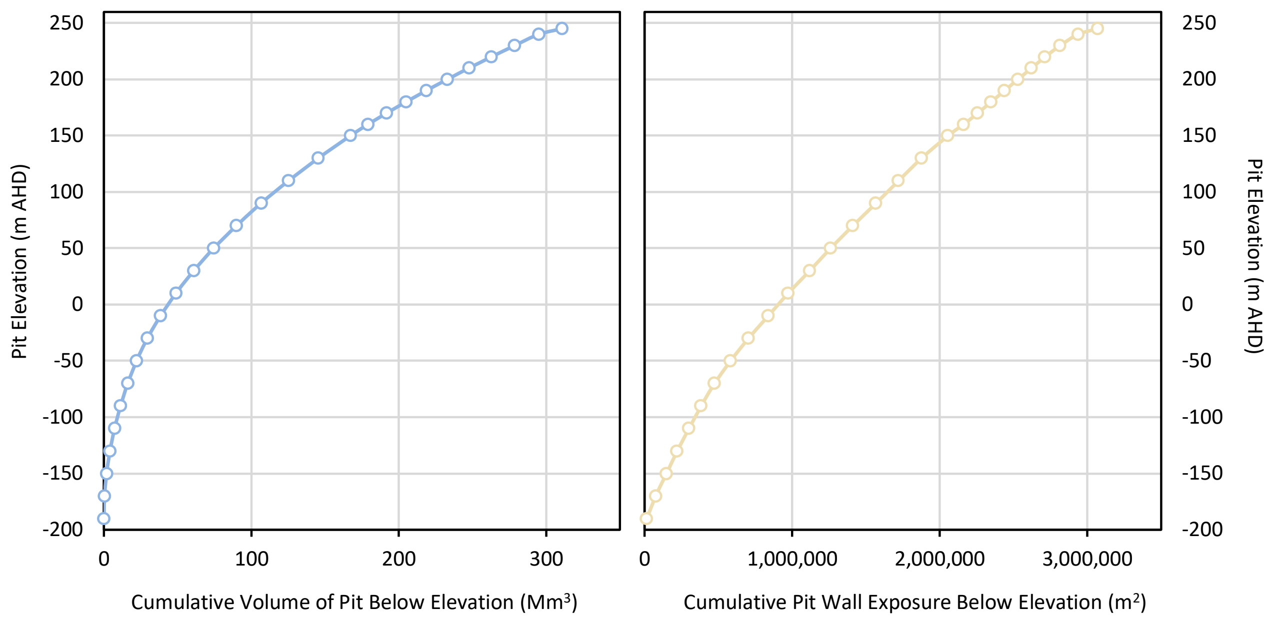

Figure 17. Cumulative volume and pit wall exposure relationships with elevation for the ultimate pit shell (Hydrogeologica, 2024b).

Modelling showed that the Winu pit lake water elevation reaches equilibrium after approximately *ca*.90 years at *ca*. 90 m AHD (110 Mm^3) (Figure 18). Although there may be some seasonal and annual variation in this level, the long-term median water level for both without (Advisian, 2022) and with addition of TSF seepage as pit inflow predict pit lake elevation (<100 m AHD) (Figure 18). That is, around 100 m lower than the pre-mining groundwater elevation (190–200 m AHD), indicating that the pit lake will likely form a terminal hydraulic sink in perpetuity sensu McCullough *et al.* (2013), where pit lake water evaporation rates exceed inflow rates in all cases. This is even under the likely less conservative assumption of a dry pan:pit lake evaporation constant of 0.7 (McJannet *et al.*, 2016; McJannet *et al.*, 2017) used in water balance modelling (Advisian, 2022).

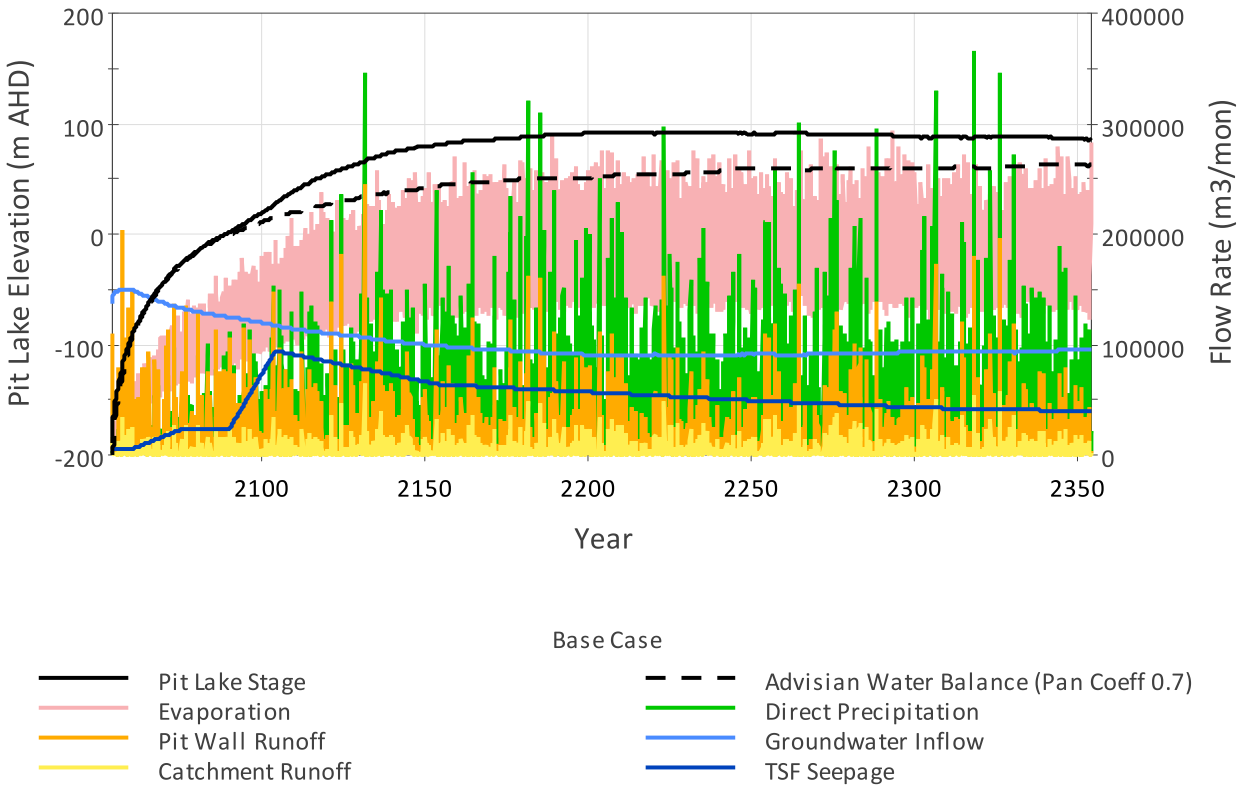

Figure 18. Predicted pit lake filling and water input rates over time for Winu pit lake base case (Hydrogeologica, 2024a).

5.2.4.2 Pit lake water quality

p(CO_2) value was based on values reported by Eary (1999) for pit lake water quality dataset largely sourced from former hard rock mines (copper and gold) in Nevada (18 of 24 pit lakes) likely most representative of the pit lake under mixed conditions (Boehrer & Schultze, 2006; Schultze *et al.*, 2016). The regional climate (hot arid) for these pit lakes also corresponds with that of Winu in the Pilbara region of WA.

Despite inputs from pit lake catchment (runoff over pit shell PAF exposures and talus), direct rainfall and seepage, pit lake water quality is expected to be initially dominated by groundwater quality. However, due to the terminal sink hydrogeological nature of the pit lake, evaporative processes will concentrate all solutes (including toxicity modifying hardness solutes (Table 5) long term as an open system. Neutralised AMD is the key source of Winu pit lake COPC to receiving water bodies then potentially to receptors.

Geochemical modelling (Hydrogeologica, 2024b) predicts that Winu pit lake will have a slightly alkaline pH of approximately 8.0–8.5 (Figure 20, top) during filling and throughout the simulated post-closure period (300 years post-closure). The pit lake is predicted to have approximately 110 to 130 mg/L as $CaCO_3$ alkalinity during early filling (Figure 20, middle), which is comparable to the median alkalinity of groundwater. During the first 75 years of modelling, alkalinity values remain at or below 130 mg/L as $CaCO_3$, at which point the concentrations steadily increases for the duration of the modelling period resulting in a final concentration of approximately 330 mg/L at the end of the simulated 300 year post-closure period. The pit lake will also have a moderate to high concentration of total dissolved solids (TDS) due to evapoconcentration, characteristic of a hydraulic Initially this is predicted to be near 500 mg/L with a gradual increase thereafter, reaching approximately 3,100 mg/L after 300 years (Figure 20, bottom).

Concentrations of several constituents, such as calcium, iron, and copper, are controlled by precipitation of secondary minerals, including calcite, ferrihydrite, and malachite (and an amorphous copper-carbonate mineral), respectively. Concentrations of these constituents either remain relatively constant through the model period or decrease (Figure 21).

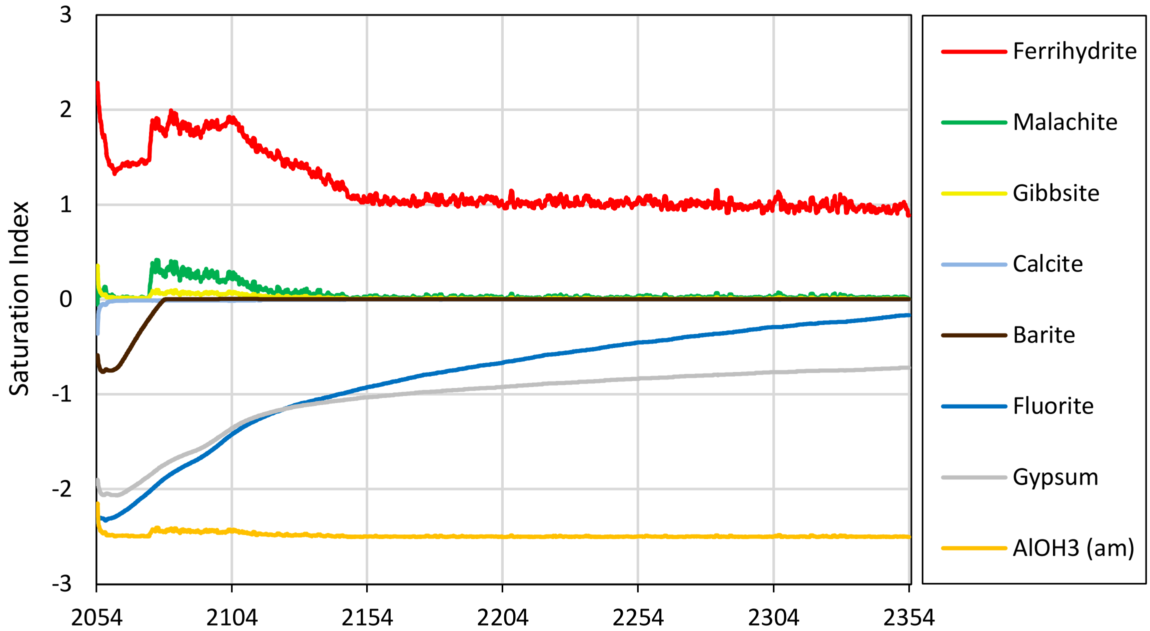

Figure 19. Predicted saturation indices for selected minerals phases for Winu pit lake base case (Hydrogeologica, 2024a).

Consistent with this evapoconcentration trend, concentrations of sulfate, sodium, chloride, and most metals and metalloids, steadily increase with time due to evapoconcentration. However, concentrations for the duration of the modelling period remain low (less than 600 mg/L) and therefore gypsum is not predicted to precipitate within the modelling timeframe (Figure 21, top left).

While predicted metals concentrations are generally low for exposed NAF material and slightly higher for exposed PAF lithologies, corresponding with results from the column and MEP datasets, metals concentrations also increase with time (Figure 21). Metals concentrations generally remain constant for the first 20 years post-closure before increasing upon acidification of the Mafic Primary Sulfide and Metasediment lithologies. Concentrations of some metal(loid)s (e.g., arsenic, chromium, cadmium, copper, lead, vanadium, and zinc) are appreciably attenuated by sorption to ferrihydrite, generally lowering the rate of increase due to evapoconcentration, relative to non-sorbing constituents. In the Base Case scenario, sulfate, cadmium, fluoride, nickel, and selenium display increasing trends through the modelling period. Concentrations of cadmium and nickel notably increase starting 20 years post closure due to the assumed onset of acidification of select lithologic units. Concentrations increase rapidly through approximately 100 years post-closure as the lake level rises and introduced additional mass loading from newly inundated pit wall material. After the steady state lake elevation is achieved, concentrations for nearly all metals slowly increase for the duration of the modelling period due to evaporation.

Exceedances in mine water by nitrate from incorporation of blasting residues are difficult to predict pre-mining when material has yet to be blasted (Reevey, 1996; Bosman, 2009). However, they are not considered in this study due to expected rapid biological transformation and uptake processes that occur in pit lakes (Axler *et al.*, 1998; Findlay *et al.*, 1999; Wendt-Potthoff *et al.*, 2012; Mori *et al.*, 2019; Navarro-Valdivia *et al.*, 2023; McCullough, 2024). Considerations of these input and transformation processes require more complex pit lake water quality models provide for (Salmon et al., 2008; Oldham et al., 2009; Oldham, 2014; Salmon et al., 2017).

Over long-term durations, Winu pit lake water quality is expected to be neutral-alkaline, fresh to brackish with elevated solute concentrations for some COPCs such as Al, some heavy metals, B and Se (Figure 20). The base case geochemical simulations predicted analyte concentrations exceeded default aquatic ecosystem protection guidelines used for screening COPCs for a number of parameters including Al, Co, Cu, Ni and Zn. B only exceeded guidelines at 200–300 years. The Cr and Se guidelines are for total COPC and will be already exceeded by the filtered concentration alone e.g., with Se proportioned across both soluble and insoluble fractions at the expected circum-neutral pH (Witczak et al., 2013). Most COPC concentrations exceeded guidelines by more than an order of magnitude. Importantly, water quality failed to meet aquatic freshwater ecosystem protection guidelines for conductivity (salinity) within only a few decades as the lake was still filling. Baseline groundwater was not considered in this assessment due to an absence of transport processes to groundwater and hence these values should not be used alone for risk assessment.

Although metal/metalloid concentrations will increase slowly over time, to an extent, so too will the protective mechanisms of calcium (and to a lesser extent magnesium) (Markich & Jeffree, 1994; Markich *et al.*, 2005) with calculated soft (mean 45 mg/L as $CaCO_3$) groundwater inflows (Hydrogeologica, 2024a) being evapoconcentrated to very hard pit lake waters over time.

However, Cd, Hg and Se was below Limit of detection (LOD) for most groundwater samples and Hg was below LOD for wall runoff. Water quality modelling used a source term of ½ the LOD for analytes below LOD as per ANZG (2018) With conservative and high rates of evapoconcentration processes over a long time, it is likely that these analytes with a conservatively estimated concentration have been overstated as a modelling artifact as a result of this approach to below LOD data.

5.2.4.3 Stratification

A relative depth greater than 20% indicates the lake is likely to be permanently stratified on the assumption that large depth/area ratios result in less wind mixing (Castendyk & Jewell, 2022). The relative depth for the Winu pit lake at Base Case steady state conditions (83 m AHD) was 25%, and ranges from 24–26% for all water balance scenarios. These screening level stratification calculations suggest there is a potential for permanent stratification in the pit lake during the post-closure period due to the pit geometry, specifically the relatively small pit lake surface area to depth ratio.

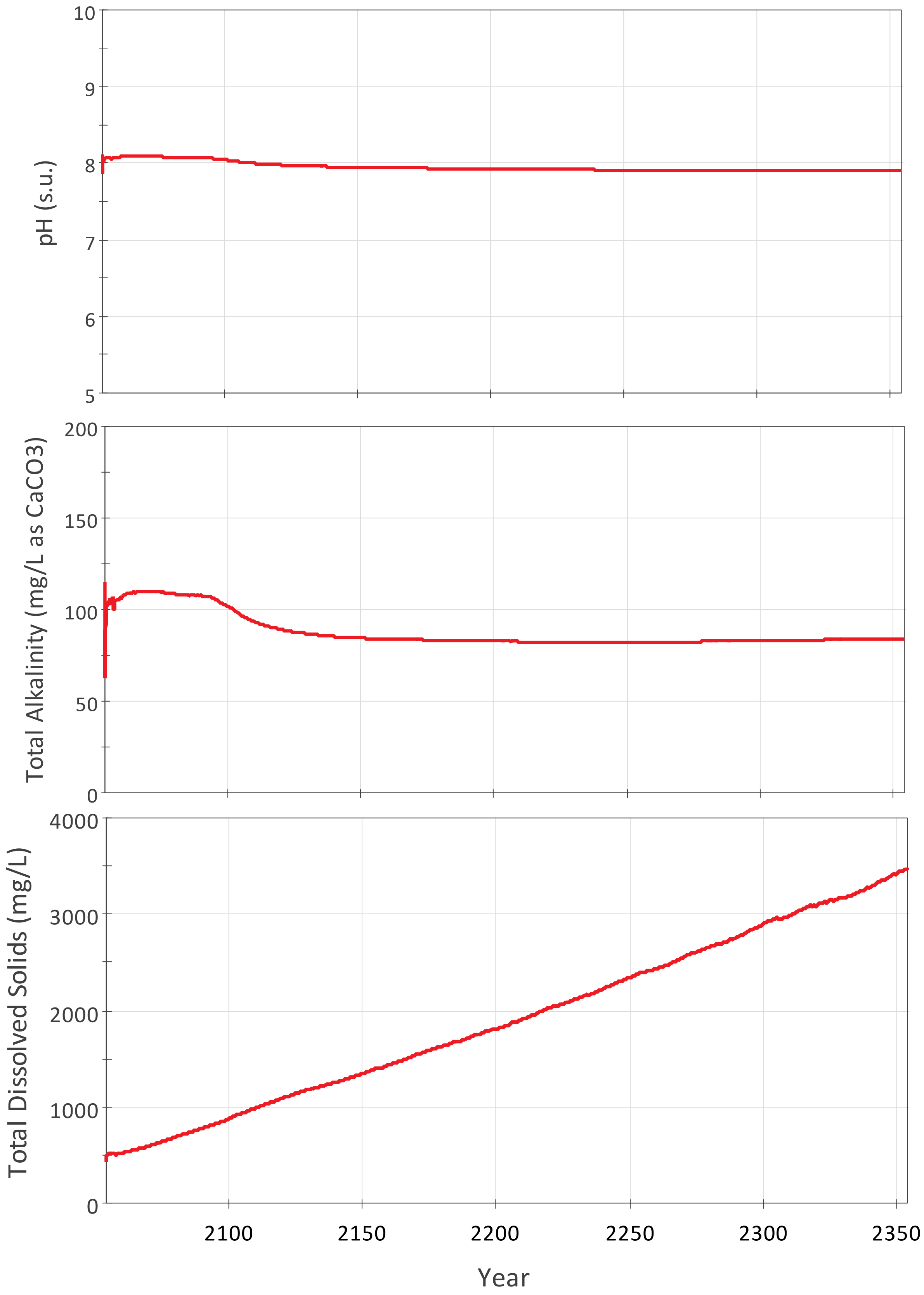

Figure 20. Predicted pH (top), alkalinity (middle) and total dissolved solids (bottom) Winu pit lake over time (Hydrogeologica, 2024a).

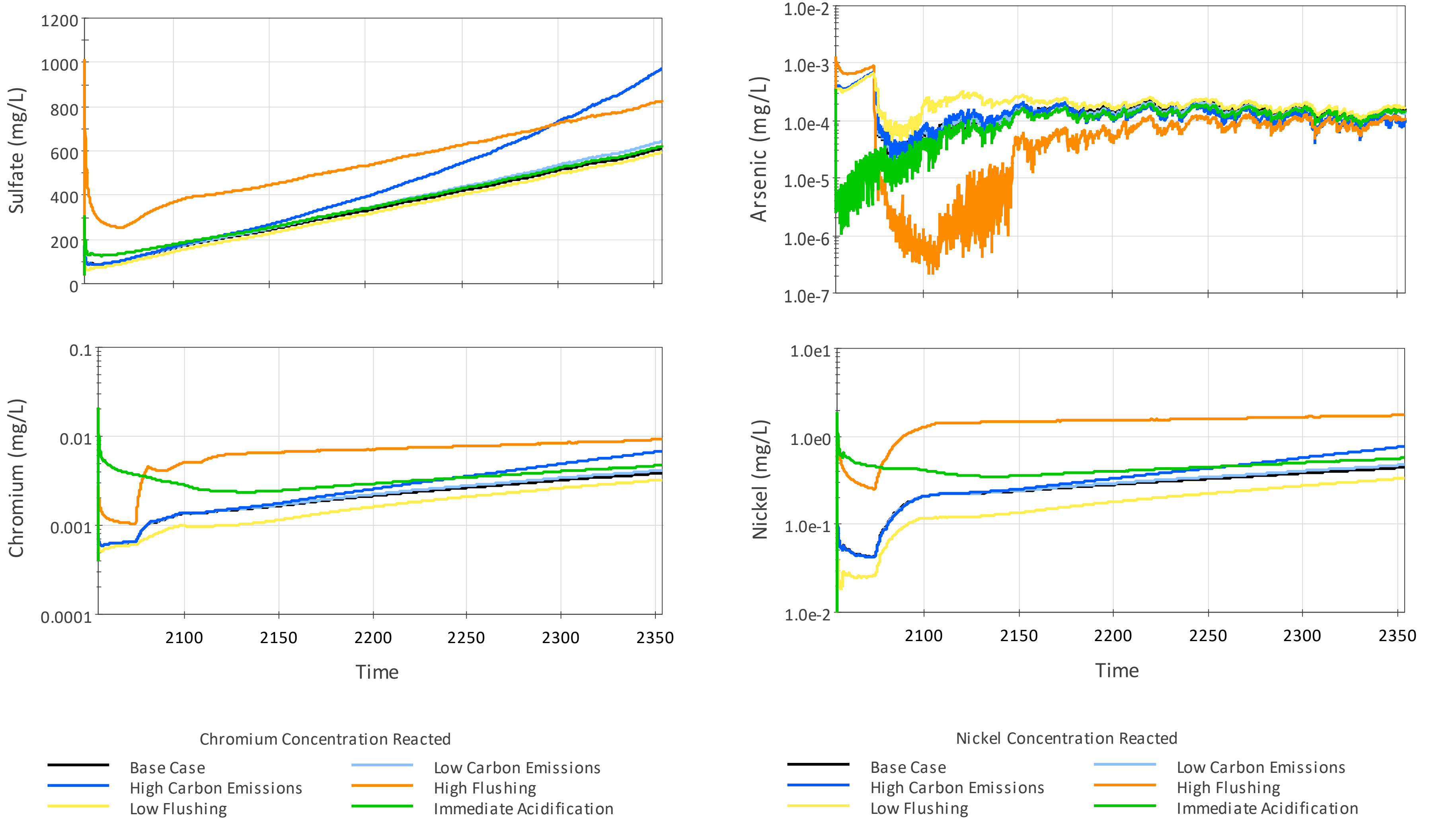

Figure 21. Predicted solute concentration in pit lake - all scenarios (Hydrogeologica, 2024a).

Table 4. Pit lake predicted median water quality for base case scenario (Hydrogeologica, 2024a) against freshwater aquatic ecosystem protection guidelines (95% DGV unless otherwise stated) (ANZG, 2018) and livestock drinking guidelines (ANZG, 2023).

Parameter	Livestock drinking	Aquatic ecosystem protection	Year 50	Year 300
pH*	6–9	**6–8[1]**	8.0	7.9
TDS	4,000	**–**	930	3,500
Ag	–	**0.05**	0.0014	0.0084
Al	5.6	**0.055**	0.013	0.011
As	0.025	**0.013**	0.00002	0.00015
B	5	**0.94**	0.15	0.843
Cd	0.01	**0.0005/0.0006[B,H]**	**0.014**	**0.030**
Co	1.0	**0.014**	**0.33**	**0.68**
Cr	0.05	**0.0024/0.0068[2,H]**	0.0011	0.0015
Cu	1.0	**0.0014**	**0.027**	**0.033**
Hg	0.002	**0.0006[B]**	0.00057	**0.0034**
Mg	400	**–[3]**	21	75
Mn	27.8	**1.9**	0.48	1.03
Mo	0.024	**0.034**	0.01	**0.051**
Ni	1.0	**0.0271/0.0798[H]**	**0.22**	**0.45**
Pb	0.1	**0.0130/0.0657[B,H]**	0.0002	0.0006
Sb	–	**0.009**	0.001	0.005
Se	0.02	**0.005[4,B]**	**0.011**	**0.039**
SO_4	704	**–**	300	1,509
U	0.2	**0.0005**	**0.0023**	**0.0064**
V	0.1	**0.006**	0.00013	0.00089
Zn	20	**0.0197/0581[H]**	**0.76**	**1.51**

Table 5. Predicted total water hardness for pit lake at 40–50 and 200–300 years (mg/L).

Years	Mg	Ca	Total hardness (as $CaCO_3$)
50	21	35	144
300	75	109	309

All values as filterable concentrations and in mg/L unless otherwise stated. Font style indicates exceedance. – indicates no data/guideline available.
*No units.
[B] Potentially bioaccumulating.
[1] Tropical Australian reservoirs and lakes.
[2] As CrVI.
[H] Site-specific hardness modified trigger value (HMTV) for 50/300 years from mean total hardness as per Warne *et al.* (2018) and calculated from total hardness as [Ca] + [Mg].
[3] Toxicity only relevant to very soft waters (Van Dam *et al.*, 2010; Mooney *et al.*, 2020).
[4] As total.

5.2.4.4 Climate change

Climate change is predicted to increase temperatures globally but will likely increase or decrease precipitation differently in different regions. With some local exceptions, precipitation is predicted to decrease over much of the equatorial belt and over most of Africa and Australia. In many regions, the climate may be more variable, regardless of long-term trends (IPCC, 2018; Shukla et al., 2019). Climate change can affect the pit lake water balance by affecting both inflows (e.g. precipitation) and outflows (e.g. evaporation), and consequently, the long-term water level (Vandenberg *et al.*, 2022). Additional effects may result from or accompany changes in water levels. Varying the water surface elevation affects groundwater discharge rates (i.e. by changing the local hydraulic gradient) as well as closure risk by changing mean and extreme pit lake water levels. The position of the water surface may also affect wall rock pore pressures and slope stability, the exposure of PAF in wall rock, and the areas of the riparian zone and littoral zone. Evapoconcentration may become more relevant to water chemistry where climate change reduces mean annual precipitation and increases net evaporation (Eary, 1998).

Two climate change scenarios were incorporated into the GoldSim model as alternative scenario was selected as providing a precautionary approach to the likelihood of pit lake decant, especially given difficulties of modelling pit lake water balances from median climate data alone (Sivapalan, 2005):

- low Carbon Emission (SSP126), and;
- moderate to High Carbon Emission (SSP370.)

The Low Carbon Emissions SSP126 and Moderate-to-High Carbon Emissions SSP370 climate scenarios exhibit lower precipitation and higher evaporation rates resulting in lower pit lake elevations. Filling curves for the Base Case and climate scenarios are displayed in Figure 22 and pit lake elevations at the end of the modelling period (300 years post closure) are summarized in Table 6. The predicted pit lake elevation under the Mod-High Carbon Emissions scenario reaches a maximum elevation of approximately 75 m AHD 90 years post-closure before decreasing to an elevation of 35 m AHD at 300 years post-closure due to increasing evaporation rates and decreasing precipitation.

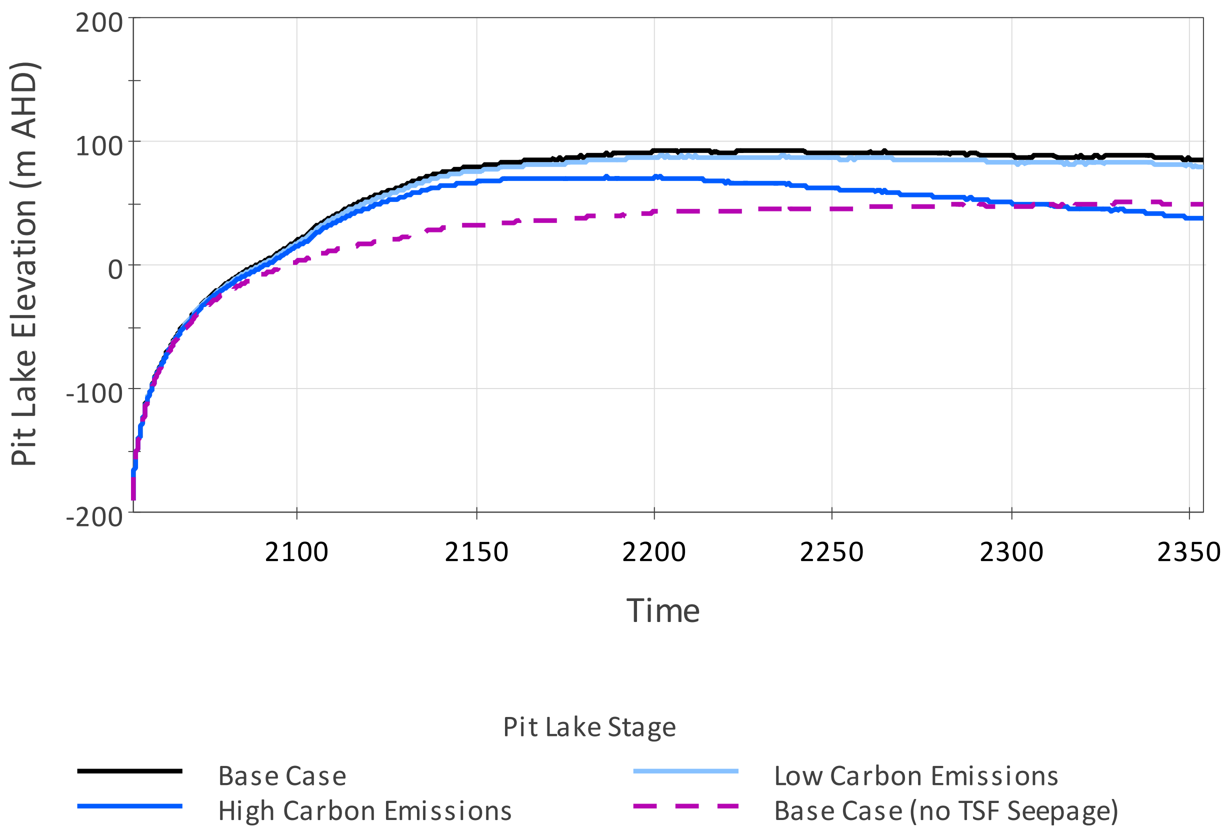

Figure 22. Predicted pit lake fillings curves for climate scenarios (Hydrogeologica, 2024b).

Table 6. Long-term pit lake elevations for all climate scenarios 300 years post-closure (Hydrogeologica, 2024b).

Scenario	Lake Elevation (m AHD)	Lake Volume (Mm^3)
Base Case	83	101
Low Carbon Emissions (SSP126)	78	96
Mod-High Carbon Emissions (SSP370)	35	64
No TSF Seepage	50	75

All scenarios are predicted to have a circum-neutral pH for the duration of the modelling period comparable to the Base Case scenario (Figure 23, top). Predicted pH values are slightly lower (approximately 0.2 pH unit) compared to all other scenarios due to the increased flushing of talus and damaged rock zone materials. In the Immediate Acidification scenario, pH values during the first few decades are also slightly lower than the Base Case scenario (approximately 0.1 pH unit). However, under all scenarios the alkalinity supplied by inflowing groundwater is sufficient to neutralize acidity generated from inundation of wall rock and pit wall runoff. Alkalinity concentrations in the pit lake for all scenarios exhibit near-stable trends at approximately 100 mg/L as $CaCO_3$ during filling. Once the steady state pit lake elevation is achieved and mass release from new talus and damaged rock zone has ceased, minor amounts of acidity loading is only contributed via pit wall runoff. Alkalinity displays increasing trends through the duration of the modelling period due inflowing groundwater and evapoconcentration (Figure 23, top).

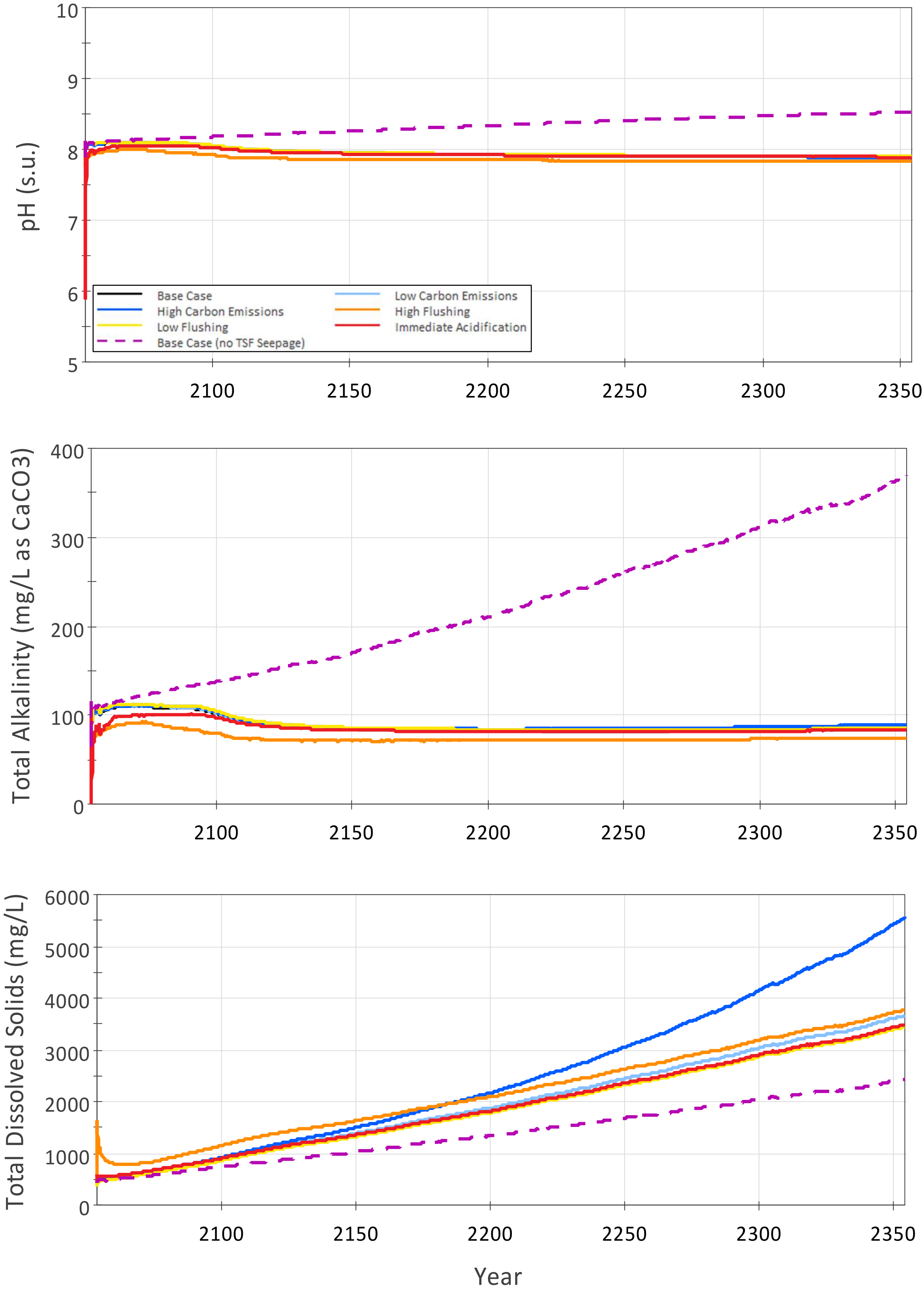

Figure 23. Predicted total pH, alkalinity and TDS of Winu pit lake - all scenarios (Hydrogeologica, 2024b).

Predicted concentrations of all constituents are elevated in the High Flushing scenario which captures the uncertainty in the solute release mechanisms of inundated talus and damaged rock zone. Aluminium and iron loading rates are higher under this scenario resulting in increased precipitation rates of iron- and aluminium-(oxy)hydroxide minerals (ferrihydrite and gibbsite, respectively) resulting in more efficient sorption and lower concentrations of some metals, specifically arsenic and lead.

Under the assumption that all PAF pit wall lithologies are expected to immediately generate acidic leachate at the start of closure, the Immediate Acidification scenario predicts elevated concentrations of select constituents associated with and leached during sulfide oxidation including sulfate, cobalt, chromium, cadmium, nickel, uranium, and zinc. However, predicted long-term concentrations of these constituents are comparable (within half an order of magnitude) to the Base Case scenario.

The High Carbon Emissions SSP370 climate scenario exemplifies the effects of increased evaporation on an evaporative sink pit lake system. Predicted concentrations during the first 100 years of pit willing are nearly equivalent to the Base Case. Once the steady-state lake elevation is achieved, evapoconcentration rates increase resulting in concentration of nearly all constituents that are not solubility controlled increasing at a more rapid rate through the end of the modelling period.

5.2.5 Potential contaminant pathways summary

In order to be meaningful, the environmental risk of Winu pit lake water quality must also be understood in the broader ecological context of the receiving ecosystem (Van Dam *et al.*, 2014). This includes accounting for anticipated ecosystem values that may be expected to be much lower in artificial water bodies (McCullough & Pearce, 2014; DIIS, 2016), such as the pit lake.

The receptors considered to spend at least part of their lifecycle within or dependent upon the aquatic environment have potential exposure to water-borne chemicals from ingestion of water (bioaccumulation), ingestion of prey (biomagnification), and dermal (ambient) exposures (bioaccumulation as bioconcentration *sensu stricto*). Biomagnification to higher orders of wildlife can occur if a lake is productive enough to support a food chain underpinning food items for the waterfowl inhabiting the area (McCullough & Lund, 2006; Miller *et al.*, 2013; DMP & EPA, 2015). These aquatic biota may then pass these body burdens onto higher food chain levels through direct ingestion of these organisms (Hoffman *et al.*, 2002; Spallholz & Hoffman, 2002).

A contaminant pathway for birdlife was considered likely. This exposure pathway was with the expectation of only short-term exposures, where birdlife receptors spend little time on the Winu pit lake, including direct contact, drinking and foraging for food from pit lake waters. This short term is due to the absence of both breeding habitat and feeding resources. In order of priority, key potential pathways are therefore as below (Table 7).

Table 7. Potentially significant contaminant pathways from the Winu pit lake.

Source Name	Pathway Type(s)	Pathway
Lake	Lake water	Direct contact
Lake	Lake water	Ingestion
Lake	Lake water	Biomagnification

5.3 Potential Receptors

Extensive and recent biological surveying has been undertaken of the greater Project most recently in 2019 (Biota, 2020) and 2023 (Biota, 2023) for a total of six fauna surveys of various types and intensity over a period of approximately four years. Survey methods used have included:

- systematic sampling (pitfall, funnel and Elliott trapping lines);
- searches of specific habitats for Schedule and Priority listed fauna species;
- searching of microhabitats for species not commonly recorded through trapping;

- avifauna surveys;
- deployment of ultrasonic sound recorders for bat species;
- deployment of autonomous recording units (ARUs) for Night Parrots;
- deployment of motion-sensor cameras;
- targeted Bilby searches;
- Marsupial Mole trenching;
- opportunistic sightings;
- nocturnal surveys including road spotting and head-torching, and;
- recording and identification of secondary trace signs including tracks, scats and diggings.

Survey results are discussed below.

5.3.1 Terrestrial habitat

Four habitat types were described for the Project (Biota, 2020) but seven in revised survey of (Biota, 2023) (Figure 24).

Shrub and spinifex on sandplain accounts for the great majority of the Project and is generally in excellent condition. Substrate consisted of red loose sand to a depth of 5 cm. Vegetation was typical of the Great Sandy Desert bioregion, comprising open hummock grasslands dominated by *Triodia schinzii* with scattered trees of *Owenia reticulata* and shrubs of mixed Acacia species.

Longitudinal sand dune ridge was also in excellent condition, with red loose sand to depth of 10 cm. The vegetation was dominated by *Corymbia chippendalei, Erythrophleum chlorostachys* and *Owenia reticulata* low woodland and scattered trees over mixed *Acacia* low open shrublands over open hummock grasslands dominated by *Triodia schinzii.*

Gravelly lateritic rise was in excellent condition and comprised a low rise of laterite gravel and pebble surface cover with sandy clay loam substrate. Vegetation comprised scattered *Grevillea wickhamii* ssp. *hispidula* over *Mirbelia viminalis* low shrubland over *Triodia brizoides* open hummock grassland.

Finally, a clayey sand plain with termitaria occurred as an isolated habitat type. Substrate comprised clayey sand to a loose depth of 2 cm. The vegetation comprised *Acacia bivenosa* shrubland over *Triodia brizoides* open hummock grassland.

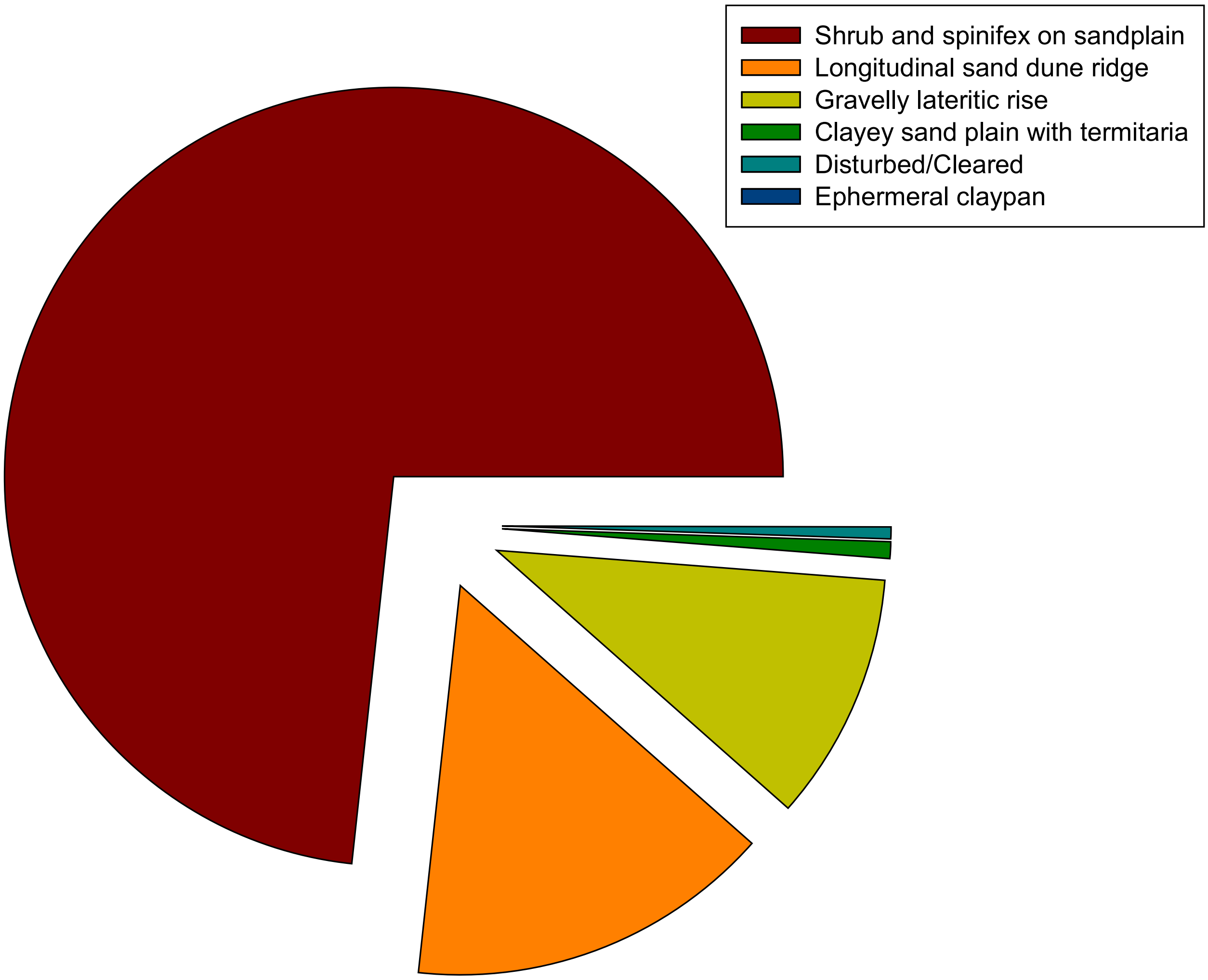

Figure 24. Major terrestrial habitat types of the Project (after (Biota, 2023).

5.3.2 Bird life

A combined total of 59 native birds are known from the Project. In addition to 7 EPBC Act Marine listed birds not of true conservation concern, native birds include the following conservation-significant species.

- Gull-billed Tern (*Gelochelidon nilotica*);
- Fork-tailed Swift (*Apus pacificus*);
- Grey Falcon (*Falco hypoleucos*);
- Oriental Plover (*Charadrius veredus*);
- Oriental Pratincole (*Glareola maldivarum*), and;
- Australian Tern (*Gelochelidon* [*nilotica*] *macrotarsa*).

Many of the bird species are listed under international migratory bird agreements. However, these species are wide ranging and do not require any special conservation considerations under localised areas (Pizzey & Knight, 2007). The birds that may be expected to make some use of the lake are predominantly waterfowl (McCullough & Lund, 2006). While waterfowl do not currently appear to frequent the project area (consistent with the current dry landscape), the presence of water in the lake may draw migratory birds and possibly territorial aquatic birds to the location.

Unlike other native animals of the semi-arid region, birds (particularly waterfowl) may be more exposed to the lake through drinking from the lake or by consuming aquatic organisms. However, drinking is expected to be a minor component of contaminant load intake for most waterfowl relative to food intake (Hoffman *et al.*, 2002; Spallholz & Hoffman, 2002; McCullough *et al.*, 2009). Consequently, food intake was considered the priority pathway for further analysis to identify potentially sensitive receptors. Furthermore, birdlife was reduced to species likely to interact with the lake e.g., feeding, breeding, roosting (Table 8).

Table 8. Conservation-significant potential receptors relevant to the Winu pit lake: birds.

Species	Conservation Status	Recordings	Description	Likelihood
Fork-tailed swift (*Apus pacificus*)	BC Act Migratory and EPBC Act	Likely to occur	Exclusively aerial within Australia and would not rely on terrestrial habitat. Invertebrate fauna are a food source. Fork-tailed Swifts are thought to be exclusively aerial in Australia as they breed in the northern hemisphere, migrating south to the Australasian region from October to April. The species is an irregular summer visitor to the Pilbara during November to early April (Johnstone & Storr, 1998).	Medium
Gull-billed tern (*Gelochelidon [nilotica] macrotarsa*)	BC Act Migratory and EPBC Act (outdated taxonomic classification)	Overflying the Winu camp on a single occasion (Australian resident population)	Nomadic and occur widely across Australia, including both coastal and inland areas. Unlikely to use the Project for breeding unless shallow wetlands form following very heavy rainfall events, however if such habitat appeared it would be of lesser importance compared to the extensive habitat at larger wetland areas in the region such as Walyarta (Mandora Marsh), located approximately 105 km north-northwest of the Project. Diet is primarily small aquatic animals, including insects, small fish, and crustaceans; sometimes catching insects in the air, but not diving, preferring to skim the surface or catching fish while standing in shallow water (Pizzey & Knight, 2007).	Medium
Peregrine Falcon (*Falco peregrinus*)	BC Act	Regional records known	The Peregrine Falcon has an almost cosmopolitan distribution, but is absent from most deserts and the Nullarbor Plain (Johnstone & Storr, 2006). Open country, especially overlooking rivers, lakes, or seacoasts; open forests and wetlands; prefers area with nearby cliffs or rock outcrops for nesting. Although core breeding habitat in the form of high cliff faces is absent from the Project, pit lake development may create this.	Medium
Oriental Pratincole (*Glareola maldivarum*)	BC Act and EPBC Act Migratory	Once locally and multiple times regionally	Non-breeding migrant to Australia present from October to May (Johnstone & Storr, 1998). Foraging habitats include short-grassed or bare plains, bare wetland margins. Take most of their insect prey aerially and will forage over a wide range of open habitat types, and occasionally over more wooded areas. Also including tidal mudflats, beaches, sewage	Medium

Species	Conservation Status	Recordings	Description	Likelihood
			ponds and freshwater wetland areas, primarily for roosting during the heat of the day. They disperse across inland northern Australia during the wet season. Suitable foraging habitat exists across most of the DE, primarily in airspace over plains habitats. There is also suitable loafing or roosting habitat in the ephemeral claypan and clayey sandplain with termitaria habitats.	
Oriental plover (*Charadrius veredus*)	BC Act Migratory and EPBC Act	Margins of the airstrip and nearby sparsely vegetated claypans	Unlike most shorebird species, they are not particularly tied to wetland and coastal habitats while in Australia. Their preferred foraging habitats are sparsely vegetated open areas, including short-grassed or bare plains, bare wetland margins, and recently burnt areas. This also includes similar man-made habitats, such as sports fields and airfields. Feeds primarily on insects and other invertebrates captured on the ground. The species will also use tidal mudflats, beaches, sewage ponds and freshwater wetland areas, primarily while on migration or for roosting during the heat of the day (Johnstone & Storr, 1998).	Medium

5.3.3 Mammals

15 native ground-dwelling mammals are known from the Project including the following five conservation-significant species:

- bilby (*Macrotis lagotis*);
- northern marsupial mole (*Notoryctes caurinus*);
- brush-tailed mulgara (*Dasycercus blythi*);
- western pebble-mound mouse (*Pseudomys chapmani*), and;
- northern quoll (*Dasyurus hallucatus*).

Of these mammals, only brush-tailed mulgara and northern quoll have an association with water bodies and is relevant as a receptor to the proposed Winu pit lake (Van Dyke & Strahan, 2008) (Table 9).

The black-footed rock wallaby is of EPBC conservation significance and is also present in the broader region with the closest known population 65 km away from Winu (Scott Young Rio Tinto, pers. comm.). However, there is no pathway for black-footed rock wallaby to get to the pit lake, as habitat surveys indicate there are no rock piles in close enough proximity to allow for travel. The black-footed rock wallaby only travels 0.5–1.0 km from its rocky habitat to forage (Kinnear *et al.*, 2010). 65 km is also a very small distance for highly mobile large macropod fauna.

Table 9. Conservation-significant potential receptors relevant to the Winu pit lake: mammals (Van Dyke & Strahan, 2008).

Species	Conservation Status	Recordings	Description	Likelihood
Brush-tailed mulgara (*Dasycercus blythi*)	Department of Biodiversity, Conservation and Attractions (DBCA) Priority 4	Project	Principal habitat is mature hummock grasslands of spinifex, especially *Triodia basedowii* and *T. pungens*. influenced by the presence of better watered areas such as paleo-drainage systems or drainage lines in sandplain or sand dune habitat. Threats include habitat alteration through changing fire regimes and increased predation by introduced predators e.g., cats and foxes.	Medium
Northern Quoll (*Dasyurus hallucatus*)	BC Act and EPBC Act	Scats in locality of rocky outcroppin g habitat type	Preys on a varied diet of small invertebrates and vertebrates, including lizards, birds, snakes, small mammals and frogs. Also known to feed on fleshy fruit and carrion. Mostly nocturnal, and crepuscular. Makes a den amongst rocks or in log and tree hollows. Many records from the Pilbara bioregion have come from mesa and breakaway features abutting large creeks (How *et al.*, 1991) which might resemble pit lake catchment. Probably occurs primarily as a transient visitor and/or at low density.	Medium

5.3.3.1.1.1 Bats

Five native bats are recorded within the Project, although these Microbats from the diverse family Vespertilionidae were not of conservation significance. The Winu pit lake could provide some feeding opportunities for carnivorous microbats in the form of aerial life stages of aquatic insects. Further, micro bats have very specific habitat requirements comprising deep humid caves (Thomson, 2002) which, although not known immediately around the lake, would likely occur in this region. Eight bat species were identified regionally from ultrasonic call recordings as follows.

- Yellow-bellied sheath-tailed Bat (*Saccolaimus flaviventris*).
- Common sheath-tailed bat (*Taphozous georgianus*).
- White-striped free-tailed bat (*Austronomus australis*).
- Greater northern free-tailed bat (*Chaerephon jobensis*).
- Northern free-tailed bat (*Ozimops lumsdenae*).
- Gould's wattled bat (*Chalinolobus gouldii*).
- Lesser long-eared bat (*Nyctophilus geoffroyi*).
- Little broad-nosed (*Scotorepens greyii*).

5.3.4 Reptiles and amphibians

72 native reptiles and one amphibian are known from the Project including the conservation-significant Dampierland plain slider (*Lerista separanda*). However, this species has no association with water bodies (Cogger, 2018) and therefore is not relevant as a receptor to the proposed Winu pit lake.

5.3.5 Groundwater resources and dependant ecosystems

Overlying the metasediments aquifer at Winu is the Wallal Aquifer (unconfined), with the Wallal Aquifer (confined) located downstream of Winu. These aquifers are considered to be major strategic groundwater resources in the West Canning Basin (DoW, 2012). Mining impacts to groundwater resources are expected to be predominantly within the metasediments aquifer and are not anticipated to impact other groundwater users or any environmental receptors. Current modelling indicates the pit lake level will be below the Permian mudstone overlying the metasediments aquifer, thus the pit lake will be predominantly connected to the metasediments aquifer and disconnected from the Wallal Aquifer.

There are no permanent surface water features within the project area, with Lake Waukarlycarly approximately 60 km south of the planned mining project which is also outside of the catchment. Investigation of the nearest known ”soaks”, Toramah and Winu Soaks indicates that surface water runoff and shallow groundwater perching likely form the soaks (Golder Associates, 2022). These regional soaks are ephemeral, with surface water or a persistently moist sub-surface only identified for Toramah Soak. Remote sensing of potential groundwater dependent ecosystems GDEs, (including soaks surrounding the project area) showed Toramah Soak had healthy vegetation on aerial photography, with a correlation between soak location and the potential for surface water persistence throughout the year and low to moderate levels of vegetation cover persistence (Rio Tinto, 2020a). However, both Toramah and Winu Soaks are located over 20 km away from the planned mining and processing areas. No vegetation detected by remote sensing or water/moisture persistence values indicating connectivity to regional scale aquifer were identified at the other three soaks (Weenoo, Djimakarra and Bulgamulgardy) and no evidence of GDEs was identified by vegetation surveys (Biota, 2020, 2023).

5.3.6 Pit lake

5.3.6.1 Habitat

The Winu pit lake void will be very deep at around 312 m and roughly elliptical (Figure 25) with the post mining lake therefore very steep sided and displaying little to no littoral habitat (Figure 26).

The water’s edge will present a long travel distance down steep and unstable terrain for terrestrial animals to travel for watering. In particular, the terrain is expected to be untraversable for large and high-ranging animals such as camel and of a long distance for more mobile but smaller animals such as feral cat and red fox.

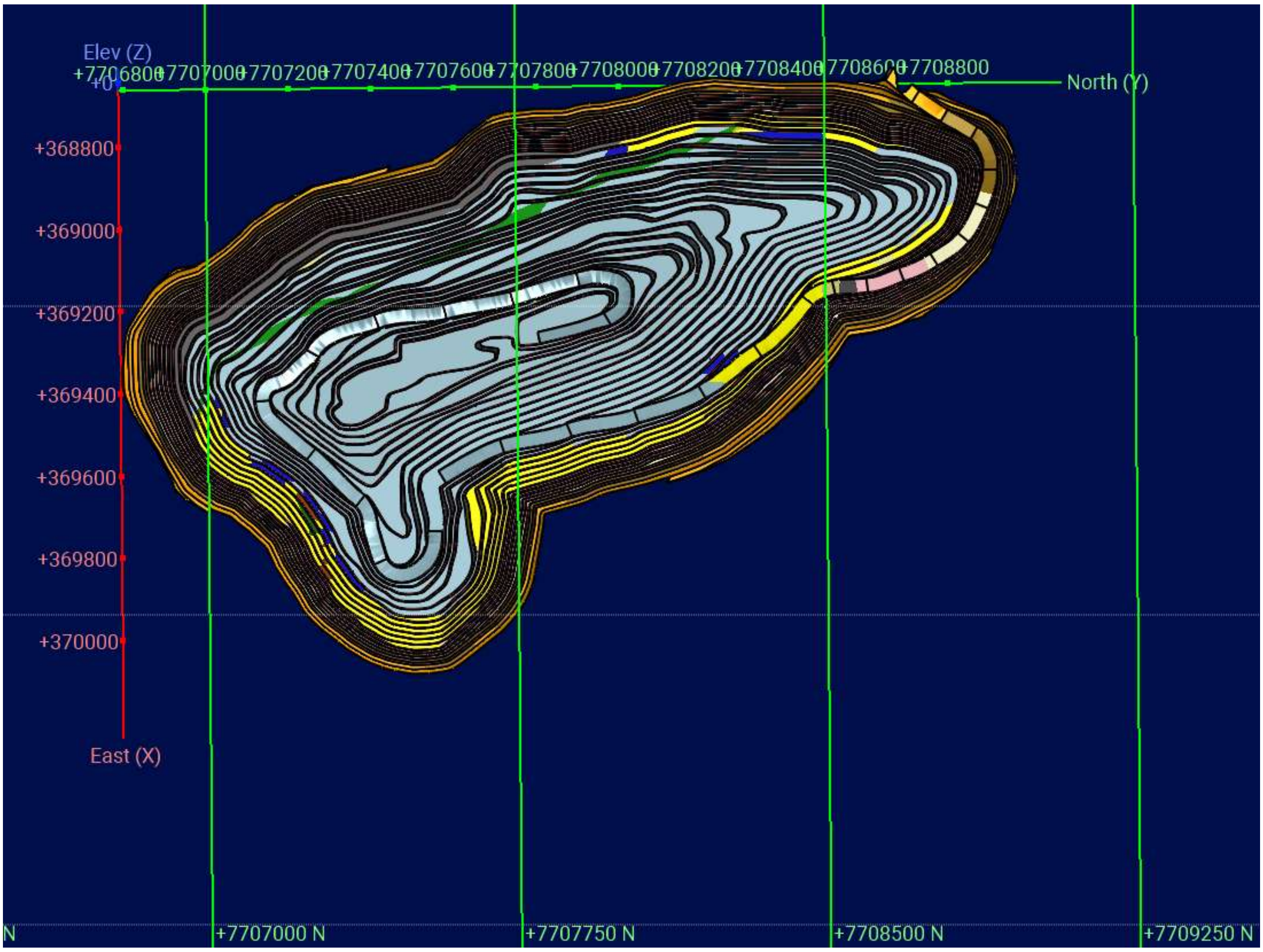

Figure 25. Plan view of the planned Winu pit void.

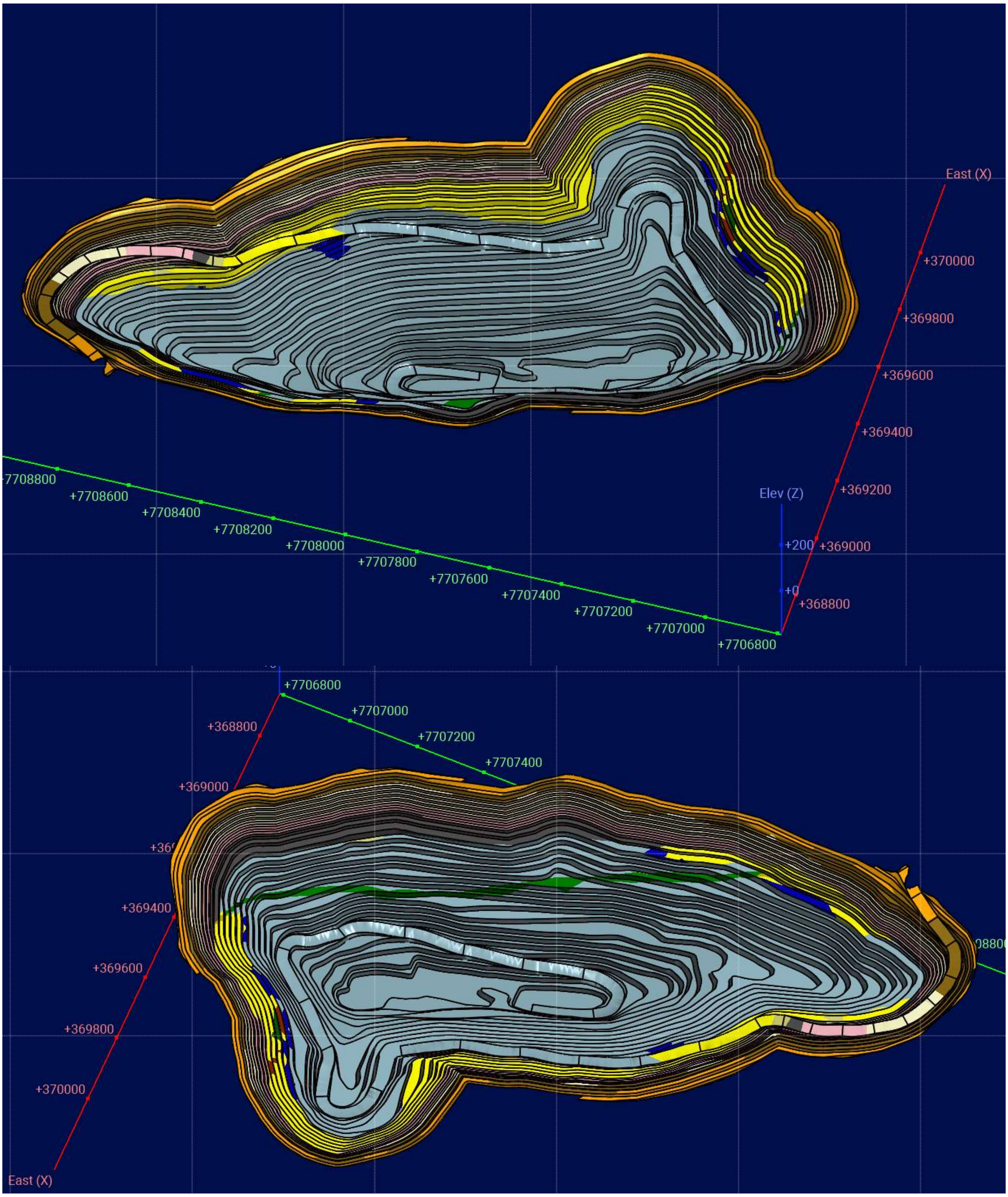

Figure 26. Orthometric views of the Winu planned pit void.

5.3.6.2 Aquatic ecosystem

There is a significant limitation to most aquatic wildlife becoming established in the pit lake due to an absence of water bodies connected to the lake e.g., creeks. There are also no regional water bodies that could directly supply aquatic biota e.g., propagules. However, waterfowl are expected to be important vectors for the introduction of phytoplankton (Santamaría & Klaassen, 2002; Tesson *et al.*, 2018) and zooplankters especially (Valls *et al.*, 2017). Furthermore, operational mine water habitats may also function as sources of aquatic invertebrates over time.

However, the foodweb expected for the pit lake is expected to be that of a lacustrine lake and not a playa wetland system more typical of the region. The lake's productivity is expected to be oligotrophic with low diversity and a short chain and dominated by a highly unproductive profundal zone (Beulker *et al.*, 2003; Bielańska-Grajner & Gładysz, 2010; Kosík *et al.*, 2011) (Figure 27). Although it is possible that fishes and macro crustacea (especially introduced *Cherax* spp. e.g., *C. quadricarinatus* (McCullough *et al.*, 2009; McCullough & Lund, 2011)) might become translocated by either water fowl or deliberate anthropogenic stocking, it is unlikely that these will form sustainable populations.

Wildlife habitat use including feeding at the Winu pit lake is expected to be opportunistic largely due to the low primary production predicted rates in the oligotrophic lake environment. Similarly, relatively sparse euphotic (and especially littoral) habitat will also greatly limit both lake foodweb primary productivity and biodiversity.

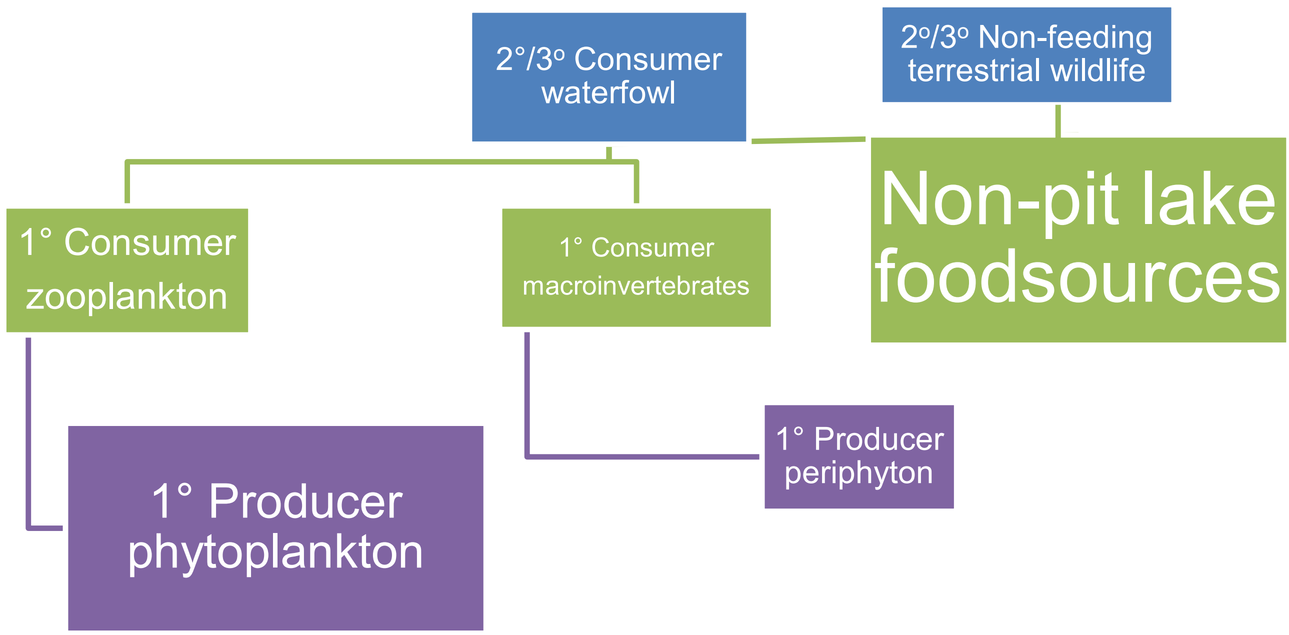

Figure 27. Conceptual aquatic food chain expected for the Winu pit lake. Font size indicates relative trophic group biomass.

5.3.7 Potential Receptor Summary

Across all supporting studies consolidated in this document, a total of 34 significant vertebrate species were returned from the database searches. Eight of these significant species were actually recorded from the DE and surrounding locality during the course of the field surveys:

- Bilby (*Macrotis lagotis*) – BC Act and EPBC Act Vulnerable;
- Brush-tailed Mulgara (*Dasycercus blythi*)– DBCA Priority 4;
- Northern Marsupial Mole (*Notoryctes caurinus*)– DBCA Priority 4;
- Western Pebble-mound Mouse (*Pseudomys chapmani*) – DBCA Priority 4;
- Dampierland Plain Slider (*Lerista separanda*) – DBCA Priority 2;

- Oriental Plover (*Charadrius veredus*) – BC Act and EPBC Act Migratory;
- Oriental Pratincole (*Glareola maldivarum*) –BC Act and EPBC Act Migratory; and
- Australian Tern (*Gelochelidon [nilotica] macrotarsa*) - BC Act and EPBC Act Migratory.

The pit lake forms a terminal sink, and is intended to function sacrificially, retaining elevated geochemistries away from the regional environment as a sacrificial terminal sink (McCullough & Lund, 2006; McCullough *et al.*, 2013). The main ecological receptors are expected to be birds and waterfowl in particular. Therefore, the likelihood of bird life as a receptor for pit lake water was only considered significant to waterfowl as these species are likely to interact directly in a regular manner with lake waters; either for drinking, habitat or feeding (DMIRS, 2020).

The pit lake is surrounded by Crown land outside of the Nyangumarta Indigenous Protection Area (IPA). Engagement with Nyangumarta will form an integral component of ongoing stakeholder engagement related to potential PMLU's associated with the pit void. However, PMLU options for the pit void at its designed closure configuration will be limited, due to safe access constraints. As such,All good; thanks Jo hunting or fishing opportunities are unlikely.

A summary of potential contaminant receptors is presented in Table 10.

Table 10. Potential contaminant receptors of the Winu pit lake.

Receptor	Receptor Location	Receptor Values(s)	Justification
Regional bird life	Highly mobile, up to hundreds of kms around Winu pit lake	Increasingly saline aquatic habitat with low ecosystem diversity and abundance. Waterfowl and other protected birdlife may make short-term use for habitat and may briefly feed and rest but unlikely to water.	Despite a paucity of aquatic and catchment habitat, some birdlife, especially waterfowl might occasionally use the lake for foraging and resting.
Terrestrial life	Primarily local, surrounds of lake but not utilising riparian or saline wetted areas.	No terrestrial habitat values from no catchment revegetation. Initially brackish an increasingly saline presenting poor drinking water resource. No foraging values from low biomass of prey items as aquatic macroinvertebrates and fishes and little to no littoral habitat.	No watering value if saline and little food value in depauperate littoral and riparian vegetation and habitat.

5.4 SPR model findings

The risk of the proposed pit lake to regional groundwater resources is considered negligible given the terminal nature of the lake. Equally, the consequence of mine water discharge to surface water receptors is considered to be small from water balance modelling indicating the comparatively small catchment and high evaporation rate (Rio Tinto, 2020b). However, both hydrogeological and water balance models require further definition to provide surety to these transport pathways.

Various non-conservation significant avifauna and terrestrial mammals such as kangaroos and other macropods (*Macropus* spp.) are likely to occur around the lake. However, they are not considered as likely direct receptors due to increasingly high-water salinity. Birds (particularly waterfowl) especially may be exposed to the lake through consuming aquatic organisms. However, mine water contaminants such as heavy metals may biomagnify through a foodweb pathway to consumers (Doupé & Lymbery, 2005; Miller *et al.*, 2013; Noller *et al.*, 2016).

Heavy metals such as cadmium (Cd) and the metalloid selenium (Se) have been considered significant risks for lakes with aquatic ecosystems (Miller *et al.*, 2013) and of significant risk for Western Australian pit lakes (DMIRS, 2020). The potential of lakes receiving mine waters to attract and impact upon waterfowl may therefore present a risk of a lake with poor water quality as a possible attractive nuisance (Doupé & Lymbery, 2005; McCullough & Lund, 2006). Se only exceeded 99% freshwater aquatic ecosystems protection guidelines advised for bioaccumulation risk (ANZG, 2018) at 200–300 years by 0.002 mg/L (0.007 mg/L compared to the 99% guidelines value of 0.05 mg/L). At 0.002 mg/L in 200–300 years, Cd exceeded the 99% bioaccumulation protection HMTV guideline of 0.001 mg/L. However, given the very low primary productivity and ecological habitat quality of the proposed pit lake, there is only a very low likelihood of biomagnification to bird life, and this risk was considered inconsequential.

5.4.1 Summary

A conceptual framework for key sources, pathways and receptors was developed (Figure 28). The model shows the following.

i) Surface water pathways are not considered significant as frequency of lake decant is expected to be extremely low. Groundwater pathways are similarly not considered significant due to poor hydrogeological conductivity and terminal lake water balance.

ii) The dominant contaminant pathway from the Winu pit lake will be through ingestion of lake aquatic biota. Key receptors are expected to be waterfowl occasionally drinking and feeding upon lake macroinvertebrates as benthic aquatic insects and small crustacea.

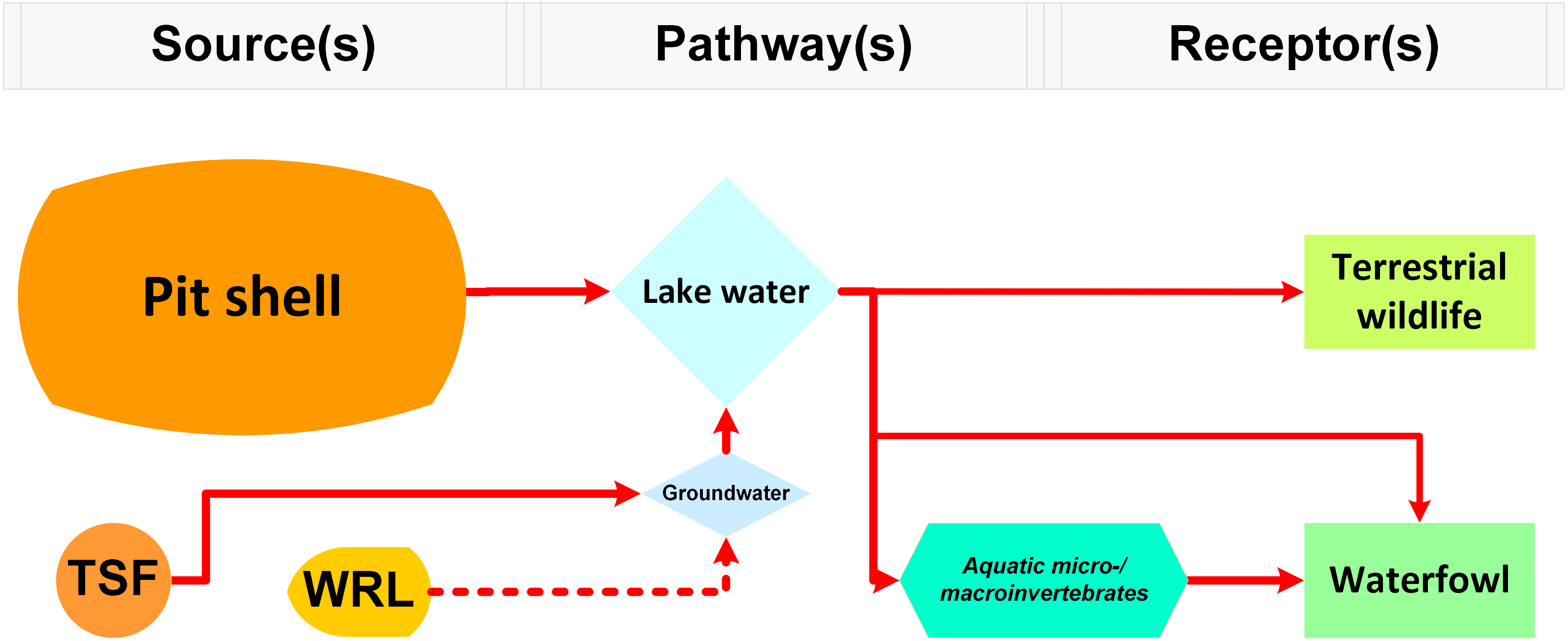

Figure 28. Conceptual source-pathway-receptor model for the Winu pit lake and surrounding environmental context.

Note: Likely potential contaminant transport pathways are shown in red and unlikely contaminant transport pathways in orange.

5.5 PIT LAKE CONCEPTUAL MODEL

In conclusion, lines-of-evidence indicated most probably that the geochemically predicted pit lake would form after acidic sumpage was neutralised by groundwater inflows. The WRL is not expected to produced leachate seepage. Although producing seepage, TSF sources are not predicted to adversely affect the chemistry of the pit lake.

As a fundamental step in determining and evaluating risk, a conceptual model (CM) summarising key COPC sources, pathways and receptors was developed (Figure 30). The CM was cognisant of both limnology and aquatic ecology of the Pilbara region but also on known physical, chemical and ecological limitations to development of pit lake aquatic ecosystems (Otahel'ová & Oťahel', 2006; Proctor & Grigg, 2006; Thomas & John, 2006; Parsons *et al.*, 2010; Kamberović & Arudanović, 2012; Pal *et al.*, 2014; Bylak *et al.*, 2019) (Figure 29).

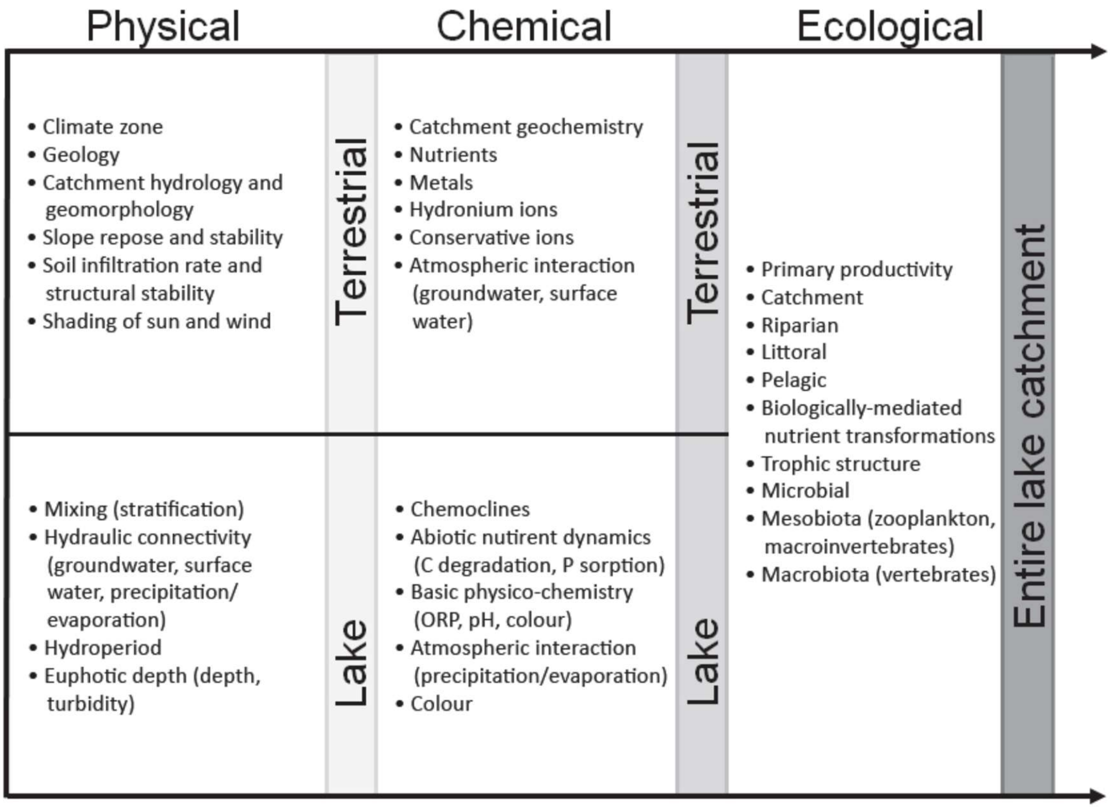

Figure 29. Influences (drivers and limitations) on pit lake ecological development (Lund & McCullough, 2011).

5.5.1 Winu pit lake CM

Winu pit lake will present as a permanent water feature in a region characterised by often extensive, but always ephemeral water bodies of typically short hydroperiods. Given the fetch, surface area, depth (Boehrer & Schultze, 2008) and tropical location (Hawkins, 1985; Kumar *et al.*, 2013) of Winu pit lake, the lake is likely to seasonally stratify when full. However, seasonally mixing (especially from cyclonic events) is also expected as per tropical analogue pit lakes (Boland & Padovan, 2002; McCullough *et al.*, 2008b). Lake organic material loading is likely to be very low (Blodau *et al.*, 2000; Oldham *et al.*, 2009; Read *et al.*, 2009).

Although regional native ecology is well adapted to make use of the (typically) salt lakes that form across the Pilbara following rainfall, this same ecology is poorly adapted to utilise permanent waterbodies; both for aquatic biota (Pinder *et al.*, 2010) and for terrestrial and avifauna (Morton *et al.*, 2011). This maladaptation is especially so for water bodies of a steep sided and deep nature (Kumar *et al.*, 2009; Larranãga *et al.*, 2010; Luek & Rasmussen, 2017; Bylak *et al.*, 2019).

The CM shows a pit lake situation where the following occurs.

- Only isolated wildlife species may make use of the lake, with some waterfowl adapted to saline lakes potentially feeding with low abundances of aquatic biota e.g., macroinvertebrates, present. Waterfowl may also use the lake as resting and foraging habitat.
- Saline pit lake water will limit what lake ecosystem is able to develop as well as act as a repellent for wildlife drinking. Terrestrial wildlife (but not on) aquatic vegetation nearby the lake but are not expected to contact the saline lake water, even for drinking as lake water is rapidly salinised.
- The lake seasonally stratifies with warmer more saline waters over the dry season and overturn over the wet season (if forcing from heavy rainfall/wind occurs).
- There is an undefined potential for groundwater to leave the lake once hypersaline hydrochemistries are reached (probably hundreds of years to millennia). However, no groundwater receptors are identified. Lake overflow is not probable; even under exceptional rainfall events.
- Bioaccumulation is not considered as foodchains are expected to be very short and upper trophic level feeding is not expected to receive a dominant proportion of food items from the pit lake.

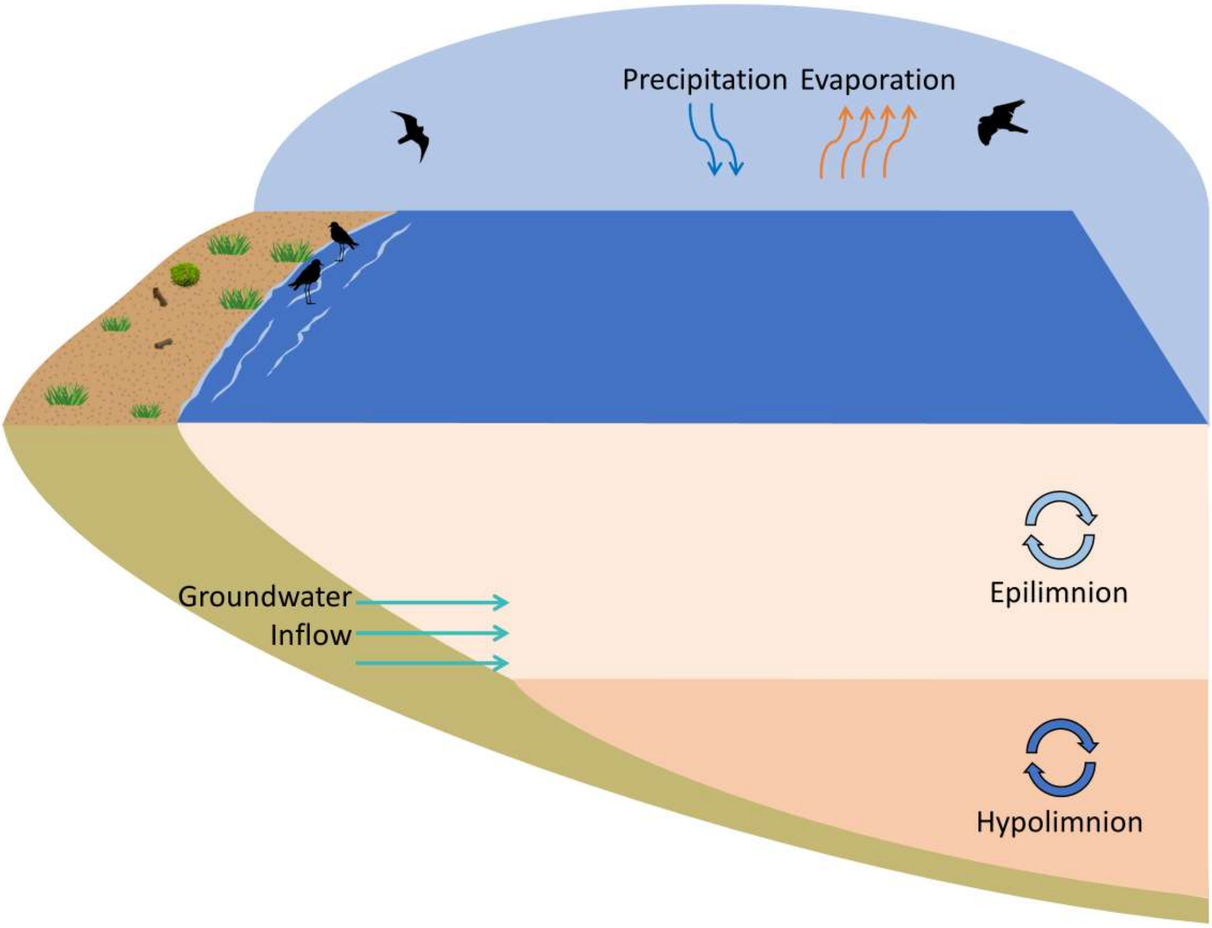

Figure 30. Conceptual Model (CM) for long-term water balance in Winu pit lake.

6 RISK ASSESSMENT

The risk assessment for Winu pit lake water quality is shown below (Table 11). Pit lakes can be an “attractive nuisance” an attractive nuisance (Parshley & Macallum, 2016). A deliberate closure strategy for the Winu pit lake domain is therefore to reduce pit lake habitat use by wildlife through not rehabilitating void vegetation or in-lake habitat.

The risk assessment found very low environmental risk given the low environmental values of the lake as a constructed water body of poor habitat value limiting native wildlife habitat values and consequent interaction frequency and duration with pit water. Constant to all risks was a low spatial influence from pit lake COPC, with contamination confined to the spatial area of the lake and concentrations declining rapidly from the pit lake source.

The lake was unlikely to be a fall hazard for wildlife due to highly competent rock climbers, such as small reptiles, being the few members of conservation-significant wildlife present. Furthermore, feral animals were unlikely to be able to make use of the saline pit lake water as a drinking resource (James *et al.*, 1999; McCullough & Lund, 2006; Letnic *et al.*, 2015); especially when requiring access by steep highwalls over hundreds of metres climbing distances.

Table 11. Semi-quantitative environmental risk assessment for Winu pit lake.

	SPR MODEL			Other		INHERENT						MANAGEMENT	RESIDUAL					
#	Source	Pathway	Receptor	Hazard	Rationale	Consequence	Likelihood	Simple	Spatial	Temporal	Complex		Consequence	Likelihood	Simple	Spatial	Temporal	Complex
1	Pit lake water	Direct contact	Terrestrial native		Inadvertent contact by few terrestrial wildlife that find access to pit lake. However, conservation-significant species not expected to use lake as habitat and therefore unlikely to contact. Little habitat from no pit lake catchment rehabilitation.	1	1	1	2	4	8	None required.	1	1	1	2	4	8
2	Pit lake water	Direct contact	Birdlife		Occasional small groups or individuals of migratory birds may be attracted to region following heavy rainfall events e.g., ARI ten years. However, regional shallow playa lakes will provide for more productive habitats and will attract most birds for feeding and resting. Similarly, regional Walyarta Marsh is extremely shallow and broad, with a massive littoral zone that provides much better birdlife habitat. Direct contact with the water is unlikely to result in adverse impacts. Some conservation-significant birds might use habitat for predator avoidance and might attempt to forage. Little habitat from no catchment rehabilitation. Shorelines at equilibrium water levels left steep.	1	5	5	3	4	60	Wetland bird site visits will be observed and recorded during operations by noting species associating with operational mine water bodies. Collecting information on the birds attracted to Winu during operations will assist in a more accurate bird-mine water ecology risk understanding and therefore future management needs and measures.	1	5	5	3	4	60
3	Pit lake water	Drinking	Terrestrial native		Native terrestrial animal water consumption low but might still be attracted. Conservation-significant species not expected to use lake as habitat. No catchment rehabilitation so as not to provide habitat. Increasingly saline water as pit lake water balance terminal; less palatable. Stock drinking guidelines as a proxy for wildlife indicate no significant health issues.	1	1	1	2	4	8	None required.	1	1	1	2	4	8
4	Pit lake water	Drinking	Birdlife		Occasional small groups or individuals of migratory birds may be attracted to region following heavy rainfall events e.g., ARI ten years. However, regional shallow playa lakes will provide for more productive habitats and will attract most birds for feeding and resting. Similarly, regional Walyarta Marsh is extremely shallow and broad, with a massive littoral zone that provides much better birdlife habitat. Direct contact with the water is unlikely to result in adverse impacts. Some conservation-significant birds might attempt to drink. However, water increasingly saline and unpalatable. Tree roosts and hollows not rehabilitated as habitat. Stock drinking guidelines as a proxy for wildlife indicate no significant health issues.	1	5	5	3	4	60	Wetland bird site will be developed during operations by noting species associating with operational mine water bodies	1	5	5	3	4	60

		SPR MODEL		Other				INHERENT				MANAGEMENT			RESIDUAL			
#	**Source**	**Pathway**	**Receptor**	**Hazard**	**Rationale**	**Consequence**	**Likelihood**	**Simple**	**Spatial**	**Temporal**	**Complex**		**Consequence**	**Likelihood**	**Simple**	**Spatial**	**Temporal**	**Complex**
5	Pit lake water	Pit lake aquatic biota	Terrestrial native		Some native terrestrial wildlife might feed upon small abundances of invertebrates such as insects with aquatic juvenile stages and small vertebrates such as amphibians that have consumed aquatic biota. However, conservation-significant species not expected to use lake as for foraging. Potentially locally resident populations. Low primary productivity limits food-chain length and thus trophic biomagnification. No woody vegetation rehabilitation within catchment restricts habitat available.	1	1	1	2	4	8	None required.	1	1	1	2	4	8
6	Pit lake water	Pit lake aquatic biota	Birdlife		Occasional small groups or individuals of migratory birds may be attracted to region following heavy rainfall events e.g., ARI ten years. However, regional shallow playa lakes will provide for more productive habitats and will attract most birds for feeding and resting. Similarly, regional Walyarta Marsh is extremely shallow and broad, with a massive littoral zone that provides much better birdlife habitat. Direct contact with the water is unlikely to result in adverse impacts. Direct consumption of pit lake aquatic biota, especially flying invertebrates with aquatic life stages and amphibians. Wading birds such as conservation-significant species identified as likely to occur in region but unlikely to feed on depauperate littoral habitat. Few food items so expected time spent is low. Highly mobile so not resident. So, pit lake aquatic biota unlikely to form significant part of diet. Low primary productivity limits food-chain length and thus trophic biomagnification. No pit lake catchment rehabilitation so as not to provide habitat.	1	3	3	3	4	36	Wetland bird site will be developed during operations by noting species associating with operational mine water bodies	1	3	3	3	4	36
7				Terrestrial native wildlife drowning	Pit lake as an attractive nuisance as they may attract even common terrestrial wildlife species so hazard of animals drowning in pit lake. Conservation significant wildlife in region limited to mammals unlikely to include pit lake habitat in range. Any impact very unlikely to influence population levels. Limited ad hoc local wildlife observations to date have not identified native terrestrial wildlife as using mining-related water sources.	1	1	1	2	4	8	Abandonment bund will limit access for some species.	1	1	1	2	4	8
8				Increased feral animal populatio ns regionally impact upon local biodiversit y values	Pit lake as an attractive nuisance. Feral animals in the region already includes foxes, cats, camels. Cats especially may use pit lake water. However, cats no feral animal likely to establish population inside very deep pit void close to water. Potential for red claw and cane toad introductions, although these will be limited by deep and unproductive lake habitat. Limited ad hoc local wildlife observations to date have identified feral animals using mining-related water sources. Only pit lake existent for many km around. ca.100 m freeboard. Drinking water quality deteriorates after decades through evaporative salinisation but remains brackish.	2	3	6	3	4	72	Feral animal monitoring and control during operations and during closure phase.	2	2	4	3	4	48

7 DISCUSSION AND CONCLUSIONS

A desktop environmental summary and gap analysis combined with preliminary expert risk assessment was undertaken to meet requirements of state and commonwealth guidelines for mine water and water resource water quality management including the following.

- ANZG (2018). Australian and New Zealand Water Quality Guidelines.
- APEC (2018). Mine Closure checklist for governments.
- AS/NZS ISO (2018). Risk management, principles and guidelines.
- DFAT (2016c). Leading practice – preventing acid and metalliferous drainage handbook.
- DMIRS (2020). Mine Closure Plan Guidance - how to prepare in accordance with Part 1 of the Statutory Guidelines for Mine Closure Plans.
- ICMM (2019a). Integrated Mine Closure: Good Practice Guide.
- NEPC (amended 2013). Schedule B5a - Guideline on ecological risk assessment.

The key aspect addressed was consideration of risk to native wildlife primarily from the Winu pit lake following mine closure. Potential contaminant sources were identified as Winu pit lake water. Key findings from modelling indicates the following.

- The pit lake is predicted to act as a long-term, evaporative hydraulic sink with no expected discharge to the environment;
- Groundwater that enters the pit post closure will have substantial alkalinity. This groundwater is the major source of water to the pit and dominates the chemistry of the pit lake during filling and post closure.
- Kinetic testing results for the PAF waste rock and ore (that also represent some of the materials remaining in the ultimate pit wall) indicate slow reactivity with very long (i.e., decades) lag times to acidification.
- Due to the long acidification lag time and the chemical nature of the groundwater, the resulting pit lake chemistry is predicted to be circumneutral with abundant buffering capacity to maintain circumneutral conditions over the long term (i.e., centuries to millennia).
- Long-term (i.e., centuries) pit lake chemistry will be driven by evapoconcentration, resulting in gradual increases in constituent concentrations through time. Concentrations of some constituents will ultimately be limited by mineral saturation and mineral precipitation. Alkalinity is predicted to increase through time, precluding any chance of late-time acidification.
- Trends in metal concentrations are driven by the mechanisms by which mass loading is handled in the numerical model, timing of acidification of PAF wall rock lithologies, and the resulting mineral saturation and associated metals sorption. Metals controlled by mineral saturation display largely constant concentration trends during the modelling period. These metals include aluminium, copper, and iron (controlled by the precipitation of gibbsite, Cu-carbonate minerals, and ferrihydrite saturation indices, respectively). Most remaining metals and metalloids exhibit increasing trends throughout the modelled period due to evapoconcentration, except for those strongly controlled by adsorption (e.g., arsenic).

Winu pit lake is expected to be poor wildlife habitat quality with no intended environmental values as an artificial constructed water body. However, a potential contaminant transport pathway exists for birdlife via water quality through ingestion for some elevated solute concentrations, along with greatly elevated water hardness and salinity as very strong toxicity modifiers and deterrents, respectively.

The CM identified that any potential impacts of the pit lake are expected to be restricted to the immediate lake area. Although Winu pit lake is likely to attract some species of waterbirds, their time spent on the lake is likely to be only relatively short periods of their life cycles across which feeding occurs. Birds are unlikely to stay for long periods due to lack of foraging habitat and little food biomass. However, this CM should be refined as additional data are gathered to allow for an improved understanding of the activity or site characteristics, contamination source characteristics, receptor exposure profiles, environmental risk rankings and resulting decision-making and COPC hazard management criteria.

Consequently, there appears to be:

- potential contaminant sources (primarily metal(loid)s Cd, Co, Cu, Ni, Se, U and Zn as solutes within mine waters);
- transport (primarily as very unlikely lake water food-chain bioaccumulation processes), and;
- potential environmental receptors, in particular waterfowl feeding upon aquatic invertebrates.

This risk assessment conservatively found that COPC risk from these elevated COPC concentrations in pit lake water to birds was the highest risk primarily through ingestion of lake water (Table 12). However, the risk assessment found a low consequence contribution to risk was primarily due to the only short-term exposures expected where birds spent little time foraging for food from depauperate Winu pit lake waters and therefore drinking and in direct contact.

Table 12. Summary of key potential Winu pit lake receptors, pathway and residual risk rating.

Receptor	Pathway	Risk ranking
Birds	Direct consumption of lake water.	Very low
Birds	Direct consumption of lake aquatic biota, especially aquatic invertebrates.	Very low

7.1 Recommendations

The revised ERA indicates that the environmental risk of the Winu pit lake is likely to be very low. However, we make some recommendations to better understand and manage these postulated risks. The following study and management actions may further provide better understanding to reduce any potential environmental risk from the Winu pit lake. Furthermore, several targeted scientific studies should be undertaken to support evidence-based practice that minimises risk to company and stakeholders. We recommend studies that improve understanding of how both native and introduced wildlife might access and use artificial water sources produced by mining at Winu.

7.1.1 End use values

The assumptions of pit lake end use values stated herein should be verified with internal and external stakeholders.

7.1.2 Pit lake aims

Pit lake closure aims should be further defined in terms of what end use values stakeholders have articulated. In particular, closure outcomes and associated criteria should be developed that meet with these aims (Young *et al.*, 2019). Water quality modelling and assessment should then relate to guidelines relevant to these specified criteria.

7.1.3 Pit lake stratification modelling

The presence or absence of vertical density gradients may be more influential toward meromictic behaviour than morphology alone (Castendyk & Jewell, 2022). However, further stratification modelling should only be undertaken to inform the pit lake water quality model on an as-required basis e.g., if and where stratification is expected to markedly change pit lake water quality as a source term from the predicted circum-neutral pH and brackish salinity.

7.1.4 Wildlife mine water usage studies

There is a need to undertake studies of native wildlife and feral animals use of mining-provided water sources. For example, dewatering and tailings storage facilities (TSFs). Collecting information on the birds attracted to Winu during operations will assist in a more accurate bird-mine water ecology risk understanding and therefore future management needs and measures.

7.1.5 Updated water balance and water quality modelling

Empirical water balance and water quality models underpinning this risk assessment should be updated as their source dataset becomes improved, especially during operations. Closure planning should ensure that operational opportunities to improve empirical modelling datasets e.g., through void inflow measurements and leachate testing of all lithologies likely to present in the final void shell are captured. In particular, when mine plans change void shape and/or size.

7.1.6 Updated ERA

DEMIRS advises that a risk assessment e.g., an ERA should be updated as the knowledge base surrounding source terms, transport mechanisms and values and receptors becomes better understood as mine planning evolves further. In particular, the ERA should be updated as more data becomes available, during operations but particularly during closure as the pit lake fills, especially as knowledge gaps of pit lake water quality are addressed.

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Why choose Mine Lakes Consulting?

We are a highly experienced and internationally active environmental consultancy specialising in mine closure and particularly mine water and the environment. We have an excellent understanding of pit lake closure and compliance guidance, having developed much of this under contract to regulators. Our scientific work has provided underpinned the global understanding of pit lake environmental management.

Our staff are the globally recognised experts for all aspects of mine pit lakes and mine closure planning. We are the trusted advisors of both leading multi-national mining houses and governments across a range of jurisdictions. Our reputation precedes us.

- Mine pit lakes are typically not well managed in closure planning. However, Mine pit lakes are Mine Lakes Consulting core business. As such, we have a much deeper understanding of the science and policy surrounding these key closure landforms.
- Dr Cherie McCullough is PhD qualified in the ecotoxicology of mine waters; the key discipline critical to understanding environmental risk and contaminated sites issues surrounding pit lakes.
- We have a broad project experience of general and other landform-specific mine closure planning, enabling us to assist with inclusion of mine pit lakes into broader closure planning and approval documents.
- Our work and advice are well-regarded by stakeholders and the scientific community through regular leading-practice industry presentation and an extensive breadth and depth of peer-reviewed industry and academic publications of the state-of-the-art of multi-disciplinary science underpinning mine pit lakes.

APPENDIX A. STUDY ASSUMPTIONS AND LIMITATIONS

Disclaimer and Statement of Limitations

This Report has been prepared on behalf of and for the exclusive use of Mine Lakes Consulting Pty Ltd's (MLC's) Client ('the Client') and persons acting on the Client's behalf and is subject to and issued in accordance with the agreement between the Client and MLC. This Report is based on the scope of services defined by the Client, budgetary and time constraints requested by the Client, the information supplied by the Client (and its agents), and methods consistent with the preceding. MLC accepts no liability or responsibility whatsoever for this Report or its contents in respect of any use of, or reliance upon, this report by any party other than the Client. MLC also disclaims all liability with respect to the use of this Report by any party for a purpose other than the purpose for which it was prepared.

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The overall conclusions of this Report should be revised if further information becomes available to inform the assumptions applied herein. The following assumptions and limitations are key to interpreting this study and its findings:

- The information contained within this report is limited by no site visit being undertaken.
- This study did not consider risk to Aboriginal or European cultural heritage, nor economic or reputational risk.
- External source documents were not critically examined other than for obvious flaws.
- Risk assessment and management was commensurate with the recommended impact assessment guidelines for AMD of DMIRS (2020) and DIIS (2016).
- The impact of water quality to stygofauna and troglofaunal environmental receptors were not considered as the lake is expected to be a terminal sink.
- There are no aquatic ecosystem data available for the lake, hence aquatic biota was assumed from professional opinion of MLC staff supported by literature where available.
- Some species that appear in the EPBC Act Protected Matters and other search tools are often not likely to occur within the specified area as the search provides an approximate guidance to matters of national significance that require further investigation. Further, some records of sightings or trappings can be outdated and could misrepresent the current range of threatened species.

APPENDIX B. Risk Assessment Matrices

Table 13. Risk matrices for environmental receptors. All variables are assigned from a scale from 1 to 5 (lowest to highest) for multi-dimensional risk components and then multiplied to yield final risk ratings after DFAT (2016c).

Weighting	Likelihood	Consequence	Extent	Duration	Simple risk	Spatio-temporal risk	Classification
1	A	I	Immediate	Days	1-5	1-75	Very Low
2	B	II	Surrounds	Months	6-10	76-120	Low
3	C	III	Local	Years	11-15	121-180	Moderate
4	D	IV	Catchment	Decades	16-20	181-240	High
5	E	V	Regional	Centuries	21-25	241-625	Extreme

Table 14. Tier A to E likelihood descriptions.

Tier	Likelihood	Definition
A	Rare	Very unlikely to occur
B	Unlikely	Unlikely to occur
C	Moderate	Possibly may occur
D	Likely	Likely to occur
E	Expected	Almost certain to occur

Table 15. Tier I to V consequence descriptions for environmental receptors (DFAT, 2016c).

Tier	Consequence	Definition
I	Low	Limited damage to minimal abundances of low conservation significance
II	Minor	Short-term impact not affecting ecosystem function
III	Moderate	Significant medium-term impact on valued species but not ecosystem function
IV	Major	Significant long-term impairment of ecosystem function or valued species
V	Catastrophic	Very significant impacts on highly valued ecosystems or components

APPENDIX C. Risk Workshop Attendee Biosketches

Table 16. Risk workshop attendee profiles.

Name, Title and Qualifications	Experience
Dr Cherie McCullough (Workshop facilitator) • Director/Principal Environmental Scientist • BSc (Freshwater Ecology), MSc (hons) (Freshwater Fisheries Ecology), PhD (Aquatic Ecotoxicology) • Fellow Australasian Institute of Mining and Metallurgy (AusIMM) Member, Certified Practitioner Environmental (CPEnv) • Ordinary Member Closure Planning Practitioners Association (OMCPPA) • Member International Mine Water Association • Member Australian Society for Limnology (ASL)	Cherie is Director of Mine Lakes Consulting and Principal Environmental Scientist. She has over 25 years' experience in consulting and research, focused on the mining industry and with water resources. Cherie's primary skills are in environmental management, ecotoxicology, ecology, geochemistry and hydrogeology. Cherie is a recognised leading international expert on pit lake sustainability, mine closure planning and rehabilitation; with project experience across Australasia, Asia, and North and South America. She has published over 100 peer-reviewed scientific journal and conference proceeding papers, book chapters, and leading practice industry guidelines, a book and international industry articles and conference presentations on pit lakes, mine closure, aquatic ecology and ecotoxicology. Cherie has helped develop guidance for mine closure, pit lakes and mine water impacts for Western Australia, South Australia, the Commonwealth of Australia, Papua New Guinea, Canada, the Asia-Pacific Economic Cooperation (APEC) and the United Nations (UN). Cherie also teaches in the AusIMM (Australasian Institute of Mining and Metallurgy) Integrated Mine Closure professional course and in part of their industry mentoring program.
Dr Ros Green • Principal Environmental Geochemist, RTC • BEng Civil and Environmental Engineering (hons), PhD Geography and Civil & Environmental Engineering (Aquatic Chemistry) • Fellow Australian Institute of Mining and Metallurgy (AusIMM) Member • Board member (Rio Tinto), International Network for Acid Prevention (INAP)	Ros is the Principal Environmental Geochemist for Rio Tinto Copper. She has been working with environmental geochemistry and mineral waste at Rio Tinto for over 19 years. This has involved all aspects of mineral waste from exploration, operations and mine closure. Ros and her team were instrumental in the pro-active identification of risk and subsequent management strategies within Rio Tinto Iron Ore. This was acknowledged in 2018 by winning the corporate division category of the INAP global best practice award for identification, planning and management of potentially reactive geological material. Ros completed a PhD in Civil and Environmental Engineering that involved building several passive and active treatment systems to treat acid sulfate soil drainage. Prior to that Ros worked for State and Local Governments and consultancies. Her involvement in the Winu study team has included oversight of the pit lake water quality modelling.
Garth Humphreys • BSc (Hons) (Zoology/Botany) • Principal Ecologist / Director, Biota Environmental Sciences	Garth is a terrestrial ecologist with over 30 years' experience in biological surveys, environmental impact assessment and ecological monitoring. He has designed and managed many large-scale ecological impact assessments spanning resource developments, major renewable energy projects, port developments, rail corridors and regional road planning. He has a demonstrated ability to manage major assessment projects with inherent approvals risk, coordinate large biological surveys, and guide teams of experienced biologists to deliver high quality outcomes. This has included

Name, Title and Qualifications	Experience
	ecological studies across Western Australia, on the Cocos-Keeling Islands and in central Africa. Garth is also an Honorary Research Associate at the WA Museum and an Adjunct Lecturer at the School of Animal Biology at the University of Western Australia. He has published multiple times in the scientific literature.
Emma McGivern • Principal Hydrogeologist, Rio Tinto Copper • BEng (Environmental Engineering) (hons), MEng (Groundwater Management) • Member International Association of Hydrogeologists	Emma is a Principal Hydrogeologist in Rio Tinto Copper. She has been working on mine water management at Rio Tinto for over 21 years, leading hydrogeological studies into mine dewatering, water supply and environmental impact assessments for government approvals and input into multi discipline teams for delivery of ore body knowledge. Her involvement in the Winu study team has included oversight of the groundwater field program, groundwater modelling, surface water modelling and water balance.
Glen Doherty • Manager Regulatory Engagement and Approvals • BCom, MBA • Certified Practicing Accountant (CPA)	Glen coordinates the Winu project's regulatory approvals processes. Engaging with all team members and external consultants, Glen gathers the necessary information for submission to the various government agencies to obtain regulatory approvals. He provides this support service through his own consultancy, which he established in 2005, and has more than 25 years' experience providing tenure, approval and land access services throughout the Western Australian mining industry including with Rio Tinto.
Rebecka Barritt • Principal Advisor, Closure SME. • BSc (Geological Sciences), MSc (Engineering Geology) • MAusIMM CP(Env) • CPPA member • GeoSoc London Fellow	Experienced closure practitioner with 16 years' experience working across a range of commodities and climates to define and develop holistic Closure planning solutions. Soil mechanics and engineering geology background with a focus on landform design and cover systems. Current role is primarily focused on working with APAC Closure assets to help reduce risk and liability through strengthening technical knowledge, specific to the site. Also involved in Closure guidance and assurance across a range of projects from M&A and exploration to conceptual studies and operations within Rio Tinto.
Ed Clarke • Principal Advisor Communities and Social Performance, RTC • BA (hons)	Ed is a Principal Advisor Communities and Social Performance for Rio Tinto Winu. He has been working in the Native Title and cultural heritage fields for over 25 years, locally and internationally pursing academic research and facilitating industrial development. Ed has been working with Rio Tinto since 2007, predominantly with Iron Ore and with the Winu Project for the past two. Ed's main focus areas for the Winu Project are cultural heritage and Native Title agreements, in particular ensuring that the social and cultural values which the project may impact are managed in the most appropriate manner and supporting the achievement of FPIC agreements.
Sharron Sutton • Manager Technical - Winu • BSc (Atmospheric Physics)	Sharron has been with CRA/Rio Tinto since graduating as an atmospheric physicist more than 30 years ago. She has worked in operational, project and technical roles across multiple commodities (coal, iron ore, diamond and copper) in Australia and across the globe. For Winu, Sharron leads the technical input to the study through to planning for operations. This technical input ranges from ore body

Name, Title and Qualifications	Experience
• Member Australasian Institute of Mining and Metallurgy (AusIMM)	knowledge, mining engineering, geotechnical engineering, hydrogeology, tailings acid mine drainage, geometallurgy, process engineering and strategic planning. Risk based approach to multi-disciplinary challenges and their mitigation and management.