Appendix Q

Geochemistry Assessment

Balranald Mineral Sands Project
Geochemistry Assessment

prepared for

Iluka Resources Limited

by

EARTH SYSTEMS
Environment · Water · Sustainability

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EXECUTIVE SUMMARY

Iluka Resources Limited (Iluka) proposes to develop a mineral sands mine in south-western New South Wales (NSW), known as the Balranald Mineral Sands Project (the Balranald Project). The Balranald Project includes construction, mining and rehabilitation of two linear mineral sand deposits, known as West Balranald and Nepean. These mineral sand deposits are located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald.

Earth Systems was commissioned to undertake a geochemistry assessment for the State significant development (SSD) application for the Balranald Project. The geochemistry assessment specifically relates to the potential for acid and metalliferous drainage (AMD) impacts on water quality associated with sulfide oxidation in mine materials, and has been carried out to address the Secretary's environmental assessment requirements (SEARs) and in accordance with leading practice guidelines, and with reference to other national and state level standards, guidelines and policies where relevant.

A detailed review of the regulatory framework applicable to geochemistry assessment for the Balranald Project was conducted, and various information and data were reviewed on the site geochemistry, water balance, mine plan, hydrogeology and other studies being conducted in parallel for the Environmental Impact Statement (EIS). A description of the project is provided in Section 2, and the environmental setting of the project area is described in Section 3, including local climate, hydrology, geology, hydrogeology, water quality, environmental values and water resource use. Background information on AMD is included in Section 4, which provides important context for the geochemistry assessment.

Following the review of existing information, geochemical characterisation of mine materials was then conducted, utilising available data from a preliminary geochemical test work program conducted by KCB (2012 and 2013) and supplementary geochemical test work conducted by Earth Systems (2015). The KCB (2012 and 2013) studies were relatively broad in scope, encompassing the West Balranald and Nepean deposits, and provided limited representative samples for the various mine site domains and associated lithologies (the study was limited to ore materials and two categories of overburden). The Earth Systems (2015) study was based on a more extensive sampling program and provided a comprehensive characterisation of mine materials and lithologies to be disturbed or dewatered at the West Balranald deposit. Samples of product and mining by-product (MBP) streams were also assessed.

The results summarised below and documented throughout this report incorporate the key findings from both KCB (2012 and 2013) and Earth Systems (2015) and contribute to the fulfilment of the following Secretary's environmental assessment requirements (SEARs) for the Balranald Project:

- A waste (overburden, tailings, etc.) management strategy, dealing with NSW Environment Protection Authority (EPA) requirements.
- A water management strategy, dealing with the EPA's and NSW Office of Water's requirements.
- A rehabilitation strategy, dealing with NSW Trade and Investment's requirements.
- An assessment of the likely impacts of the development on the quality of the region's surface and groundwater resources, having regard to the EPA's and NSW Office of Water's requirements and the NSW Aquifer Interference Policy.

- An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.
- A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.
- A detailed description of the management of concentrate and back-loaded waste material during transport, storage and handling.

Other studies conducted in parallel with this geochemistry assessment, which also contribute to fulfilling the above SEARs (aspects beyond the scope of geochemical characterisation and AMD impact assessment / management) include the Water Assessment (EMM, 2015a), Soil Resources Assessment (EMM, 2015b), Radiation Risk Assessment (Iluka, 2015) and Rehabilitation and Closure Strategy (EMM, 2015c) for the Balranald Project.

Results of the mine material geochemical characterisation and classification are presented in Section 6, with the key findings summarised below:

- The non-saline and saline overburden materials (NSOB and SOB) at West Balranald were all (63 samples) classified as non acid forming (NAF) as they have minimal, if any, sulfide content. These materials are not considered to represent an AMD risk and were therefore not assessed further.
- The organic overburden (OOB) at the West Balranald deposit is almost entirely (52 of 53 samples) classified as potentially acid forming (PAF). This material has an average sulfide-sulfur content of 1.01 wt.% S, relatively minor Acid Neutralising Capacity (ANC), and a maximum pyrite oxidation rate (POR) of up to 2.5 wt.% FeS_2/week under fully oxidising conditions (ie. full exposure to atmospheric oxygen). The thickness of the OOB layer ranges from 3-20 metres. At an in situ density of 1.8 t/m^3, the estimated tonnage of overburden from the West Balranald deposit is around 397 million tonnes, of which around 57 million tonnes (14%) is classified as OOB.
- At the Nepean deposit, 95% of the NSOB samples tested (22 of 23 samples) were classified as NAF and the one PAF sample of NSOB was classified as having a low potential for acid generation (AG4) based on a low sulfur content and low ANC.
- The ore material from West Balranald was all classified as PAF (16 samples). This material has significant potential to generate AMD, with an average sulfide-sulfur content of 1.09 wt.% S, relatively minor ANC, and a maximum POR of up to 2.2 wt.% FeS_2/week under fully oxidising conditions. The thickness of the ore layer ranges from 5-6 metres. At any time, the quantity of ore stockpiled at the operating West Balranald Mining Unit Plant (MUP) is estimated at up to around 1.2 million tonnes.
- Unlike at West Balranald, all of the Nepean ore samples tested (5 samples) were NAF.
- Kinetic geochemical test work indicates that air entry to stockpiled or in situ OOB and ore materials is unlikely to exceed 2 metres, and therefore limited supply of oxygen will be the key control on acidity generation rate from these sources, rather than the total tonnage of unsaturated (stockpiled or dewatered) material.
- All of the MBPs and products tested were classified as PAF.
- Of the MBPs tested, the Balranald Modified Co-Disposal by-product or “ModCod” (from pre-concentrator and wet concentrator plants) and float plant tails and Hyti (leucoxene) from the

Hamilton mineral separation plant (MSP) in particular have significant potential to generate AMD. The Balranald ModCod has an average sulfide-sulfur content of 1.6 wt.% S, no detectable ANC, and a maximum POR of up to 1.6 wt.% FeS_2/week under fully oxidising conditions. Balranald ModCod is estimated to be generated at a rate of around 1.2 million tonnes per year. These results are based on ModCod generated from processing of the West Balranald ore during bench-scale metallurgical test work.

- The Hamilton float plant tails and Hyti (leucoxene) have an average sulfide-sulfur content of 15 wt.% S and 7.3 wt.S, respectively, and no detectable ANC (POR currently unknown) but will be generated in relatively small quantities (each less than 10,000 tonnes per year).
- The other Hamilton by-products are expected to represent a lower AMD risk than the float plant tails and Hyti (leucoxene) based on their lower sulfide-sulfur content (in the case of PDC ilmenite, combined monazite reject and combined zircon wet tails) or their relatively small proportion of the total by-product stream (in the case of rutile wet circuit concentrate and PDC conductors oversize +410 µm).
- The Balranald sand tails have a relatively low sulfide-sulfur content of 0.3 wt.% S but high POR (up to 2.4 wt.% FeS_2/week under fully oxidising conditions) and therefore also represent a significant AMD risk. Balranald sand tails are estimated to be generated at a rate of around 1.1 million tonnes per year (in addition to those contained in ModCod). Similarly, the magnetic rejects are expected to represent an AMD risk based on preliminary geochemical test work on Wet High Intensity Magnetic Separation (WHIMS) plant magnetics material, which has comparable sulfide-sulfur content and POR to the Balranald sand tails. However, the magnetic rejects will be generated in relatively small quantities (less than 100,000 tonnes per year). These results are based on sand tails and WHIMS plant magnetics streams generated from processing of the West Balranald ore during bench-scale metallurgical test work.
- The HMC product (non-magnetic stream from the Balranald WHIMS plant) has significant potential to generate AMD, with an average sulfide-sulfur content of 0.8 wt.% S, no detectable ANC, and a POR of up to 1.2 wt.% FeS_2/week under fully oxidising conditions. The ilmenite product (the key component of the magnetic stream from the Balranald WHIMS plant) also has potential to generate AMD, based on preliminary geochemical test work on WHIMS magnetics material, which has an average sulfide-sulfur content of 0.4 wt.% S, relatively minor ANC, and a POR of up to 2.4 wt.% FeS_2/week under fully oxidising conditions. However, the extent of AMD generation from these products will be limited assuming they will not be stockpiled for more than 2 weeks. These results are based on the WHIMS plant streams generated from processing of the West Balranald ore during bench-scale metallurgical test work.
- Potential elements of environmental significance in leachate from sulfidic mine materials include iron, aluminium, manganese, cadmium, chromium, cobalt, copper, nickel, lead and zinc.
- There are currently insufficient data for comprehensive geochemical characterisation of the Nepean deposit. However, limited available data indicate this deposit represents a lower AMD risk than West Balranald.

The geochemical characterisation results were used in combination with site water balance estimates (WRM, 2015) and hydrogeology modelling outputs (Jacobs, 2015) as summarised in Section 7, to assess the potential water quality impacts of the project relating to oxidation of sulfidic mine materials and associated AMD generation. Potential water quality impacts, in the absence of AMD management measures, were quantified where possible in terms of estimated acidity generation rates[1], with the key results summarised below (refer to detailed assumptions throughout Sections 8 to 12):

- Overburden
  - Stockpiled OOB could generate a maximum acidity load of up to 250 tonnes H_2SO_4 per week (without mitigation) over a period of approximately 2 months during the construction phase.
  - Backfilled OOB within the West Balranald pit could generate a maximum acidity load of up to 60 tonnes H_2SO_4 per week (without mitigation) during operations. No further acidity generation from the backfilled OOB would occur post-closure as this will be covered with MBPs and backfilled SOB.
- Ore
  - Stockpiled ore (from West Balranald) could generate a maximum acidity load of up to 100 tonnes H_2SO_4 per week (without mitigation) during operations.
- MBPs
  - Up to 30 ha of ModCod may be exposed to oxidising conditions at any time in the Tailings Storage Facility (TSF), which could generate a maximum acidity load of up to 1,000 tonnes H_2SO_4 per week (without mitigation) during operations. Stockpiled sand tails, magnetic rejects and Hamilton by-products, could generate a maximum of around 40 tonnes H_2SO_4 per week (combined) during operations.
  - Backfilled MBPs within the West Balranald pit could generate a maximum acidity load of up to 100 tonnes H_2SO_4 per week (without mitigation) during operations. No further acidity generation from the MBPs would occur post-closure as they will be covered with backfilled SOB.
- Pit walls / benches / floors
  - In situ OOB and ore in the exposed surfaces of the West Balranald pit could generate a maximum acidity load of up to 190 tonnes H_2SO_4 per week (without mitigation) during the construction and operations phases. No further acidity generation from the pit wall / bench / floor material would occur post-closure as this will be covered with backfilled SOB (and MBPs).
  - Based on estimated quantities of in situ OOB and ore surrounding the dewatering bores at the West Balranald pit that may become exposed to oxidising conditions, relatively minor acidity loads are anticipated from these sources (less than 30 tonnes H_2SO_4 per week, without mitigation).
- Products
  - Stockpiled HMC and ilmenite (from processing of West Balranald ore) could generate a combined estimated acidity load of up to 20 tonnes H_2SO_4 per week (without mitigation) during operations.

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[1] "Acidity" is, used as a measure of acid and metal concentrations. Acidity generation rates refer to the "acidity load" that has the potential to be generated upon exposure of sulfidic mine materials to oxidising conditions. This is expressed as a mass of sulfuric acid equivalent per unit time (eg. tonnes H_2SO_4 per week). Acidity generation rates are therefore equivalent to pollutant generation rates.

For each potential impact, the likelihood, consequence and resulting impact rating was assessed with reference to a standard impact assessment matrix developed by Iluka specifically for the Balranald Project. Residual impact ratings were then determined, taking into account Iluka's currently planned AMD management approaches.

The impact ratings take into consideration the unique environmental setting at Balranald, which is expected to limit the spatial extent of project impacts associated with any local water quality changes. In particular:

- Groundwater from the project area will drain to the Shepparton Formation and LPS Formation aquifers. Baseline groundwater quality data indicates that these aquifers are generally unsuitable for agricultural and stock water uses due to their high salinity concentrations.
- Of the 26 landholder bores nearest to the project area identified by Jacobs (2015), 3 bores are screened in the Shepparton Formation and 1 bore is screened in the LPS Formation. The 3 bores in the Shepparton Formation are located approximately 10-15 km west of the northern end of the West Balranald deposit (Jacobs, 2015; Appendix F)[2].
- Groundwater modelling for these landholder bores conducted by Jacobs (2015) indicates that there will be no drawdown in the Shepparton Formation bores and minimal drawdown in the LPS Formation bores (0.02 metres).
- GDEs in the vicinity of the project area are either unlikely to be significant groundwater users (based on groundwater salinity and/or depth to the water table) or unlikely to experience groundwater drawdown in excess of 3-5 metres in the Shepparton Formation.
- Further to the above points, the rate of groundwater flow away from the project area is expected to be low under natural conditions based on existing regional hydraulic gradients and modelling conducted by Jacobs (2015).
- Uncontrolled releases of mine affected water are predicted to be rare (less than a 1% chance occurring in any year of the mine life) and low volume.
- Natural drainage lines in the vicinity of the project area are generally dry throughout the year based on historic anecdotal evidence.
- There are no surface water users in the immediate vicinity of the project area. The nearest reliable and significant surface water resource is the Murrumbidgee River, approximately 30 km south-west of the project area.

Results of the impact assessment, including potential impacts, management measures and residual impacts of the Balranald Project on groundwater and surface water, relating to the potential for sulfide oxidation and associated AMD generation from mine materials, are presented in Sections 8 to 12. A summary of these results is consolidated in Section 13 and the key findings are summarised below.

During the construction phase of the project, the highest potential AMD impact, and key residual impact, is:

- Runoff or seepage of AMD from temporary OOB stockpile (from box cut) into surface water / groundwater at the West Balranald site.

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[2] The location of 2 additional landholder bores screened in the Shepparton Formation, identified by LWC (2014f) study, and 1 bore screened in the LPS Formation (Jacobs, 2015), is still to be confirmed.

During the operations phase of the project, the highest potential AMD impacts, and key residual impacts, are:

- Runoff or seepage of AMD from stockpiled ore at the West Balranald site into surface water / groundwater.
- Release of AMD via supernatant water overflow from the TSF to Box Creek.

During the post-closure phase of the project, the highest potential AMD impacts, and key residual impacts, are:

- Release of AMD from backfilled overburden at West Balranald into void / groundwater due to sulfide oxidation between the time of OOB dewatering and final inundation below groundwater.
- Release of AMD from backfilled MBPs at West Balranald below final (natural) groundwater level, into void / groundwater due to sulfide oxidation between the time of MBP generation and inundation below groundwater.
- Release of AMD from dewatered in situ material at West Balranald into void / groundwater due to sulfide oxidation between the time of mine dewatering and inundation below groundwater.

Key components of Iluka's current AMD management strategy to address the above impacts include:

- During the operations phase, return OOB directly to its final storage location as low as possible in the backfill profile below the final (natural) groundwater level in the West Balranald pit, and rapidly cap (within 1-2 days) backfilled OOB with at least 5 metres of SOB or inert clay-rich material.
- Incorporate sufficient quantity of limestone into backfilled OOB and MBPs, allowing for 3 times the theoretical neutralisation requirement to address AMD generated from both backfilled and in situ sources, during the operations phase. The limestone requirement associated with backfilled OOB will be substantially lowered by implementation of the above strategy (direct backfill and capping within 1-2 days).
- Traffic compact backfilled limestone-blended OOB, and cover as soon as practicable.
- Routine monitoring and segregation of OOB during the construction and operations phases of the project.
- Installation of a low permeability liner, incorporating limestone, beneath the OOB stockpile (construction phase) and stockpiled ore (operations phase).
- Surface water drainage control around the OOB stockpile (construction phase) and stockpiled ore (operations phase).
- Minimise the surface area of stockpiled OOB (relocate to pit as soon as possible during the construction phase).
- Incorporate sufficient quantity of limestone in OOB stockpile (construction phase) and stockpiled ore (operations phase), allowing for 3 times the theoretical neutralisation requirement[3]. Alternatively or in combination with this strategy:

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[3] Factor of 3 is conservative as it is based on use of coarse-grained limestone aggregate. There is potential to lower this quantity if an ultra-fine grained limestone material is used.

  - Collect, treat and/or reuse any acidic runoff or seepage from stockpiled ore.
  - Treat any residual AMD in ore slurry by hydrated lime addition at the process plant site.
- Backfill oversize material directly to West Balranald pit.
- Minimise the surface area of stockpiled ore.
- Routine monitoring and characterisation of MBPs to inform neutralisation requirements.
- No disposal of MBPs in the Nepean pit.
- Co-dispose Balranald thickener underflow and sand tails as ModCod material, to facilitate handling and trafficability of backfilled material.
- Return sand tails, magnetic rejects and Hamilton by-products directly, if possible, to the West Balranald pit. If this is not possible:
  - Stockpile by-products on low permeability pads comprising a limestone liner (eg. ultra-fine grained limestone) with surface water drainage control at the MUP site.
  - Alternatively, consider temporary stockpiling of by-products below ground level so that drainage reports to the pit sump.
- Traffic compact backfilled limestone-blended MBPs and cover with SOB as soon as practicable.
- Where overburden is exposed in bench lags, maintain a layer of in situ SOB as long as possible (eg. minimum 5 metres) before disturbing OOB.
- Collect, treat and/or reuse any acidic runoff or seepage from OOB stockpile (construction phase), backfilled OOB, backfilled MBPs and pit walls / benches / floor (operations phase).
- Incorporate AMD considerations into MUP dam design, operation and emergency response procedures.
- Regular surface and groundwater monitoring at the pit sump, MUP dam, OOB and ore stockpiles during the construction and operations phases of the project.

Further detail on the above management measures, and other components of Iluka's AMD management strategy to address potential impacts rated as "medium" or "low", are presented throughout Sections 8 to 12.

If the AMD management strategy outlined in the this report is adopted, it is considered that the Balranald Project will not present a high AMD risk to the receiving environment, including water resource use, aquatic ecosystems and riparian land, in the short to medium term (during construction and operations) as well as the long term (post-closure).

RECOMMENDATIONS

The following are recommended for effective site-wide management of AMD issues associated with the Balranald Project:

- Develop a detailed AMD Management Plan. The Plan should detail the AMD management strategies outlined in this assessment and encompass construction, operations and post-closure phases of the project and include procedures for materials characterisation / classification, materials segregation / handling / stockpiling, void water / stockpile leachate / TSF seepage management (eg. collection / treatment), blending procedures, active and passive treatment measures. This should be regularly reviewed and updated throughout the project life.
- During detailed project design, investigate blending options for PAF mine materials. For the preferred option/s, optimise the blending method and develop operating protocols for materials management (including segregation, handling, stockpiling, blending, backfilling and covering) as part of the AMD Management Plan. Establish detailed QA/QC procedures to ensure effective implementation of these operating protocols.
- Incorporate monitoring requirements for construction, operations and post-closure, in the AMD Management Plan. This will need to include geological / geochemical monitoring, water quality monitoring (surface / groundwater / void water / seepage / pore water) and water level monitoring (surface water in TSF / groundwater below TSF / void water, seepage flow rates.
- Integrate AMD management and monitoring (above) with site rehabilitation and closure planning.
- Incorporate AMD considerations into emergency response planning for the project.

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FIGURES

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ATTACHMENTS

Attachment A	Acid and Metalliferous Drainage (AMD), Acidity and Acidity Load
Attachment B	Regulatory Context
Attachment C	NSW EPA Waste Classification Results for Hamilton MSP Mining By-Products

GLOSSARY

ABA	Acid Base Accounting
AEP	Annual Exceedence Probability
AGR	Acidity Generation Rate
AMD	Acid and Metalliferous Drainage
ANC	Acid Neutralising Capacity
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPA	Environment Protection Authority (NSW)
EP&A Act	Environmental Planning and Assessment Act
EP&A Regulation	Environmental Planning and Assessment Regulation
EPBC Act	Environment Protection and Biodiversity Conservation Act
GDE	Groundwater dependent ecosystem
GMC	Gravimetric Moisture Content
HMC	Heavy Mineral Concentrate
ISP	Ilmenite Separation Plant
LOR	Limit of reporting
ModCod	Modified Co-Disposal
MPA	Maximum Potential Acidity
MUP	Mining Unit Plant
NAF	Non Acid Forming
NAG	Net Acid Generation
NAGR	Net Acidity Generation Rate
NAPP	Net Acid Production Potential
NOW	NSW Office of Water
NMD	Neutral Metalliferous Drainage
NPR	Neutralisation Potential Ratio
NSOB	Non Saline Overburden
NSW	New South Wales
OOB	Organic Overburden
PAF	Potentially Acid Forming
PDC	Primary Dry Circuit

PCP	Pre-Concentrator Plant
POR	Pyrite Oxidation Rate
PSD	Particle Size Distribution
SEARs	Secretary’s Environmental Assessment Requirements
SFE	Shake Flask Extraction
SOB	Saline Overburden
SPLP	Synthetic Precipitation Leaching Procedure
SSD	State Significant Development
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
TUF	Thickener Underflow (slimes)
WCP	Wet Concentrator Plant
WHIMS	Wet High Intensity Magnetic Separation Plant
XRD	X-Ray Diffraction

1.0 Introduction

1.1 Overview

Iluka Resources Limited (Iluka) proposes to develop a mineral sands mine in south-western New South Wales (NSW), known as the Balranald Mineral Sands Project (the Balranald Project). The Balranald Project includes construction, mining and rehabilitation of two linear mineral sand deposits, known as West Balranald and Nepean. These mineral sand deposits are located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald (Figure 1).

Iluka is seeking development consent under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Balranald Project, broadly comprising:

- open cut mining of the West Balranald and Nepean deposits, referred to as the West Balranald and Nepean mines, including progressive rehabilitation;
- processing of extracted ore to produce heavy mineral concentrate (HMC) and ilmenite;
- road transport of HMC and ilmenite to Victoria;
- backfilling of the mine voids with overburden and tailings, including transport of by-products from the processing of HMC in Victoria for backfilling in the West Balranald mine void;
- return of hypersaline groundwater extracted prior to and during mining to its original aquifer by a network of injection borefields;
- an accommodation facility for the construction and operational workforce;
- gravel extraction from local sources for construction requirements; and
- a water supply pipeline from the Murrumbidgee River and groundwater from the Olney Formation to provide fresh water during construction and operation.

Separate approvals are being sought for:

- the construction of a transmission line to supply power to the Balranald Project; and
- project components located within Victoria.

1.2 Approval Process

In NSW, the Balranald Project requires development consent under Part 4, Division 4.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). Part 4 of the EP&A Act relates to development assessment. Division 4.1 specifically relates to the assessment of development deemed to be State Significant Development (SSD). The Balranald Project is a mineral sands mining development which meets the requirements for SSD.

An application for SSD must be accompanied by an environmental impact statement (EIS), prepared in accordance with the NSW *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation).

An approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is required for the Balranald Project (the transmission line will be subject to a separate

EPBC Act referral process). A separate EIS will be prepared to support an application in accordance with the requirements of Part 8 of the EPBC Act.

1.3 Secretary's Environmental Assessment Requirements

This EIS has been prepared to address specific requirements provided in the Secretary's environmental assessment requirements (SEARs) for the SSD application, issued on 2 December 2014.

This geochemistry assessment report has been prepared to address specific requirements that are relevant to acid and metalliferous drainage (AMD) and water impact assessment and management, as listed in the SEARs and summarised in Table 1.

Table 1: Relevant SEARs for the geochemistry assessment.

Requirement	Section addressed
A waste (overburden, tailings, etc.) management strategy, dealing with the Environmental Protection Authority's (EPA's) requirements.	Sections 8.1.3, 8.2.3 and 8.3.3 address aspects relating to the management of AMD from overburden during construction, operations and post-closure. Sections 10.1.3, 10.2.3 and 10.3.3 address aspects relating to the management of AMD from tailings (and other MBPs) during construction, operations and post-closure. Other aspects of the AMD management strategy for the project (relating to ore, pit walls / benches / floors, and products, are addressed in Sections 9, 11 and 12.
A water management strategy, dealing with the EPA's and NSW Office of Water's requirements	Sections 8.1.3, 8.2.3, 8.3.3, 9.1.3, 9.2.3, 9.3.3, 10.1.3, 10.2.3, 10.3.3, 11.1.3, 11.2.3, 11.3.3, 12.1.3, 12.2.3 and 12.3.3 address aspects relating to the management of AMD during construction, operations and post-closure.
A rehabilitation strategy, dealing with NSW Trade and Investment's requirements	Sections 8.2.3, 8.3.3, 9.2.3, 9.3.3, 10.2.3, 10.3.3, 11.2.3, 11.3.3, 12.2.3 and 12.3.3 address aspects relating to the management of AMD during operations and post-closure, which are integral to the rehabilitation strategy for the project.
An assessment of the likely impacts of the development on the quality of the region's surface and groundwater resources, having regard to the EPA's and NSW Office of Water's requirements and the NSW Aquifer Interference Policy.	Section 8-12 addresses aspects relating to the potential impacts of AMD during construction, operations and post-closure. Section 13 provides a summary of potential and residual impacts relating to AMD.
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.	As above.
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	Section 8-12 addresses aspects relating to the management and monitoring of AMD during construction, operations and post-closure.
A detailed description of the management of concentrate and back-loaded waste material during transport, storage and handling.	As above.

1.4 Purpose of this Report

Earth Systems was commissioned to undertake a geochemistry assessment for the SSD application for the Balranald Project. The geochemistry assessment has been carried out to address the SEARs and with reference to the following standards, guidelines and policies:

- *Commonwealth EPBC Act 1999;*
- *Commonwealth Water Act 2007;*
- NSW State Environment Planning Policy (Mining, Petroleum Production & Extractive Industries);
- *NSW Mining Act 1992;*
- *NSW Water Act 1912;*
- *NSW Water Management Act 2000*;
- NSW Aquifer Interference Policy 2012;
- Leading Practice Sustainable Development Program for the Mining Industry: Managing Acid and Metalliferous Drainage (Department of Industry, Tourism and Resources, 2007);
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC / ARMCANZ, 2000);
- Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC / ARMCANZ, 2000);
- Guidelines for Groundwater Protection in Australia (ANZECC / ARMCANZ, 1995);
- ANZECC Guidelines and Water Quality Objectives in NSW (Department of Environment and Conservation, 2006);
- NSW Water Quality and River Flow Objectives (Department of Environment, Climate Change and Water, 2006);
- NSW State Groundwater Policy Framework Document (Department of Land & Water Conservation, 1997);
- NSW State Groundwater Quality Protection Policy (Department of Land & Water Conservation, 1998);
- Guidelines for the Assessment and Management of Groundwater Contamination (Department of Environment and Conservation, 2007);
- NSW Waste Classification Guidelines (Department of Environment, Climate Change and Water, 2009);
- NSW Acid Sulfate Soils Assessment Guidelines (Acid Sulfate Soils Management Advisory Committee, 1998);
- Prediction & Kinetic Control of Acid Mine Drainage (AMIRA, 2002); and
- Global Acid Rock Drainage Guide (INAP, 2012).

1.5 Scope of Works

The scope of works included:

- Review of available data and literature relating to mine materials and products geochemistry, surface water and groundwater at the Balranald Project site.
- Summarise relevant project information including environmental setting and the project design.
- Compilation of all geochemical characterisation data for the West Balranald and Nepean deposits and associated product and by-product streams.
- Review of site water balance and hydrogeology impact assessment.
- Identification of potential impacts related to AMD from the mine materials, products and by-products over the project lifetime including construction, operations and post-closure.
- Identification of management actions to minimise potential impacts related to AMD from the mine materials, products and by-products during construction, operations and post-closure.
- Identification of residual impacts related to the potential for AMD from the mine materials, products and by-products over the project lifetime including construction, operations and post-closure.
- Demonstration that the relevant SEARs for the project have been addressed.
- Liaison with the Balranald Project team and consultants completing the surface water and groundwater technical studies and the EIS to ensure that the findings from each study are accounted for, where relevant.
- Participation in government consultation (including presentation to NSW Office of Water (NOW) and EPA in Wagga Wagga on 18 November 2014).

This geochemistry assessment addresses the potential water quality impacts (including impacts to water end-users) related to AMD from the mine materials, products and by-products over the project lifetime including construction, operations and post-closure.

As part of the EIS, separate studies are being conducted to address potential impacts related to soil geochemistry, radiation, other water quality issues (eg. salinity, turbidity, nutrients, hazardous chemicals) and site rehabilitation (EMM, 2015a-c; Iluka, 2015a).

The results of this assessment will feed directly into the Water Assessment (EMM, 2015a) and the Rehabilitation and Closure Strategy (EMM, 2015c).

2.0 Project Description

2.1 Project Schedule

The Balranald Project will have a life of approximately 15 years, including construction, mining, backfilling of all overburden material rehabilitation and decommissioning.

Construction of the Balranald Project will commence at the West Balranald mine, and is expected to take about 2.5 years. Operations will commence at the West Balranald mine in Year 1 of the operations phase, which will overlap with approximately the last six months of the construction. The operations phase will include mining and associated ore extraction, processing and transport activities, and will take approximately nine years. This will include completion of backfilling overburden into the pits at both the West Balranald and Nepean mines. Construction of infrastructure at the Nepean mine will commence in approximately Year 5 of the operational phase, with mining of ore starting in Year 6, and being complete by approximately Year 8.

Rehabilitation and decommissioning is expected to take a further two to five years following Year 9 of the operations phase.

2.2 Project Area

All development for the Balranald Project that is the subject of the SSD application is within the project area. The project area is approximately 9,964 ha, and includes the following key project elements, described in subsequent sections (Figure 1 to Figure 6):

- West Balranald and Nepean mines;
- West Balranald access road;
- Nepean access road;
- injection bore fields;
- gravel extraction;
- water supply pipeline (from the Murrumbidgee River); and
- accommodation facility.

Within the project area, the land directly disturbed for the Balranald Project is referred to as the disturbance area. For some project elements in the project area, a larger area has been surveyed than would actually be disturbed. This enables some flexibility to account for changes that may occur during detailed design and operation. The project area and disturbance area for each project element are in Table 2.

Table 2: Proposed project area and disturbance area.

Project element	Project area (ha)	Disturbance area (ha)
West Balranald mine	3,059	3,059
Nepean mine	805	805
West Balranald access road	128	52 [1]
Nepean access road	173	156 [2]
Injection bore fields	5,721	1,214 [3]
Gravel extraction	42	42
Water supply pipeline	29	11 [4]
Accommodation facility	7	7
Total	9,964	5,346

Notes: 1. 60 m wide corridor within project area.
2. 40-50 m wide corridor within project area.
3. 100 m wide corridors within project area.
4. 15 m wide corridor within project area.

2.2.1 West Balranald and Nepean Mines

The West Balranald and Nepean mines and associated facilities will include:

- open cut mining areas (ie pit/mine void) that will be developed using conventional dry mining methods to extract the ore;
- soil and overburden stockpiles;
- ore stockpiles and Mining Unit Plant (MUP) locations;
- product and MBP (to be backfilled) stockpiles;
- a processing area (at the West Balranald mine), including a mineral processing plant, tailings storage facility (TSF), maintenance areas and workshops, product stockpiles, truck load-out area, administration offices and amenities);
- groundwater management infrastructure, including dewatering, injection and monitoring bores and associated pumps and pipelines;
- surface water management infrastructure;
- services and utilities infrastructure (eg electricity infrastructure);
- haul roads for heavy machinery and service roads for light vehicles; and
- other ancillary equipment and infrastructure.

The location of infrastructure at the West Balranald and Nepean mines will vary over the life of the Balranald Project according to the stage of mining.

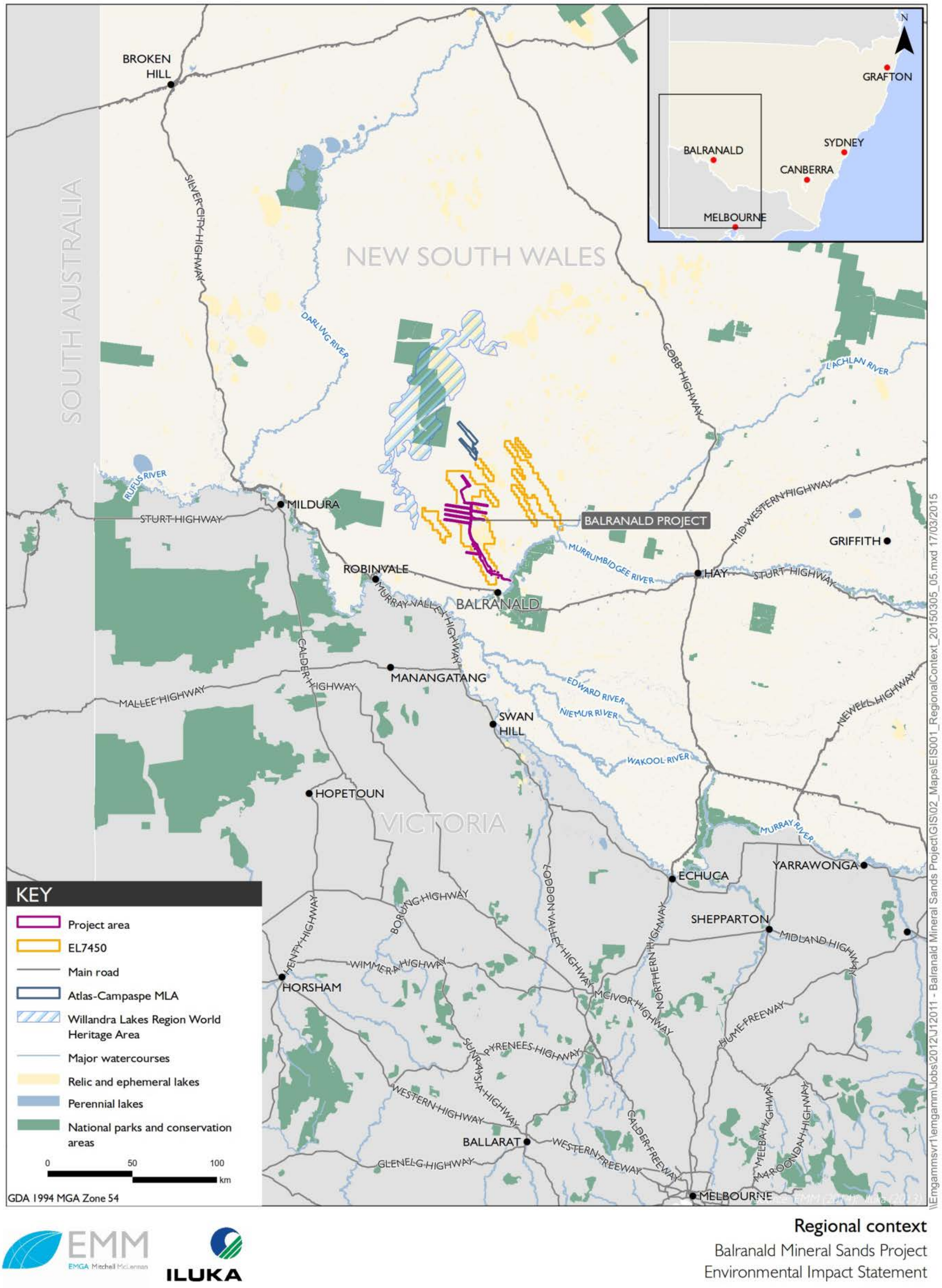

Figure 1: Regional context (EMM, 2015d).

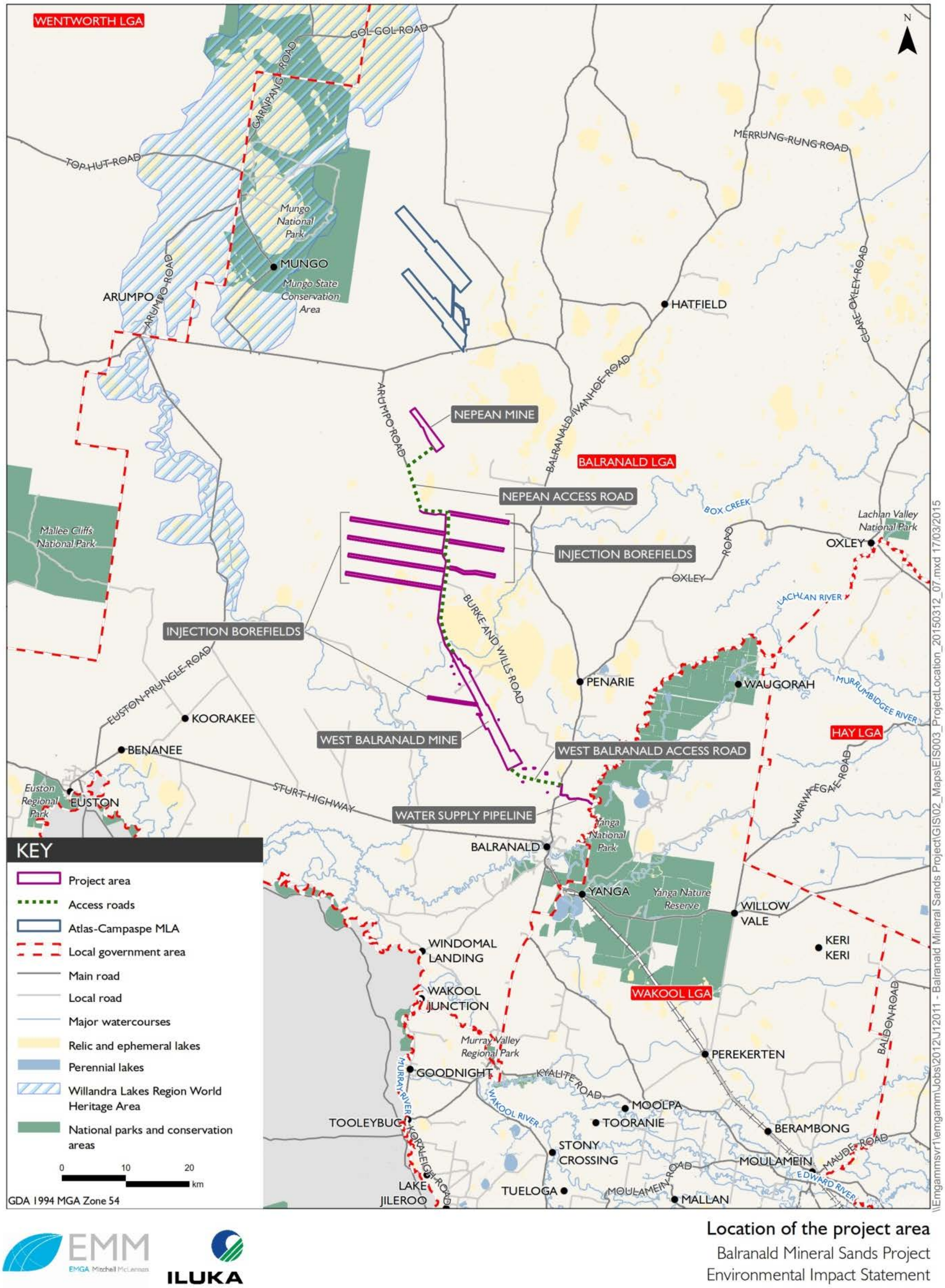

Figure 2: Location of the project area (EMM, 2015d).

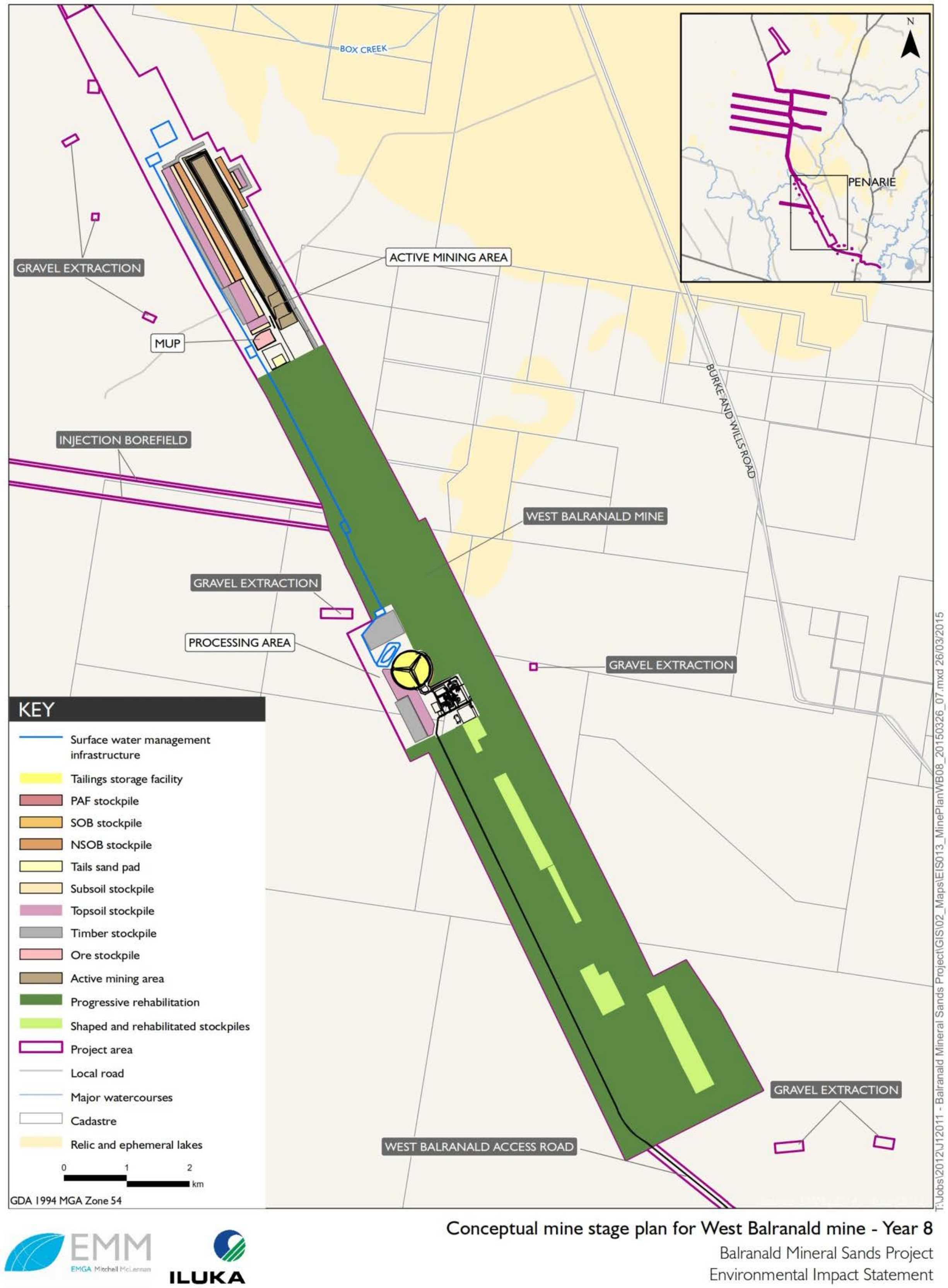

Figure 3: Proposed West Balranald mine layout Year 8 (EMM, 2015d).

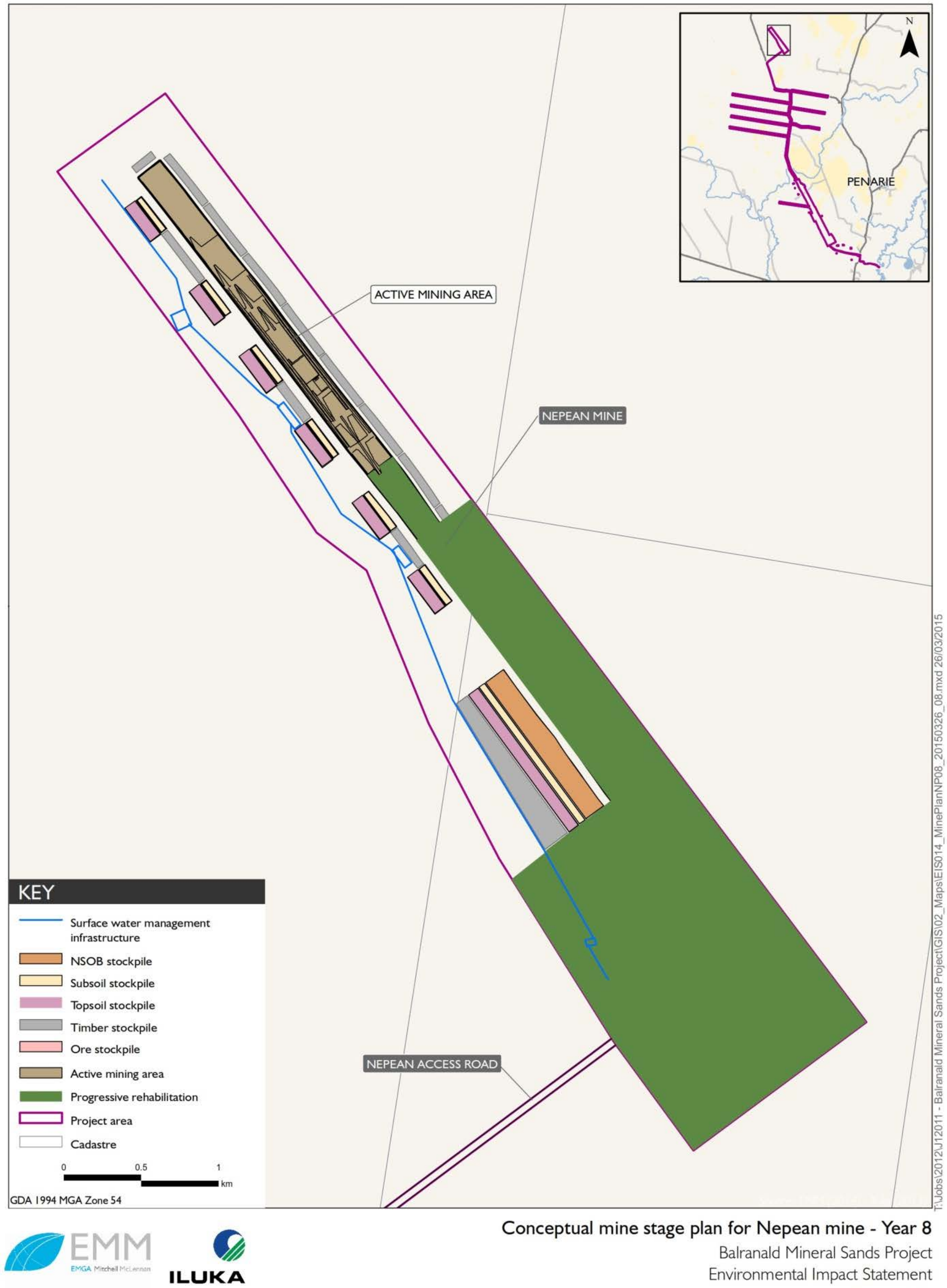

Figure 4: Proposed Nepean mine layout Year 8 (EMM, 2015d).

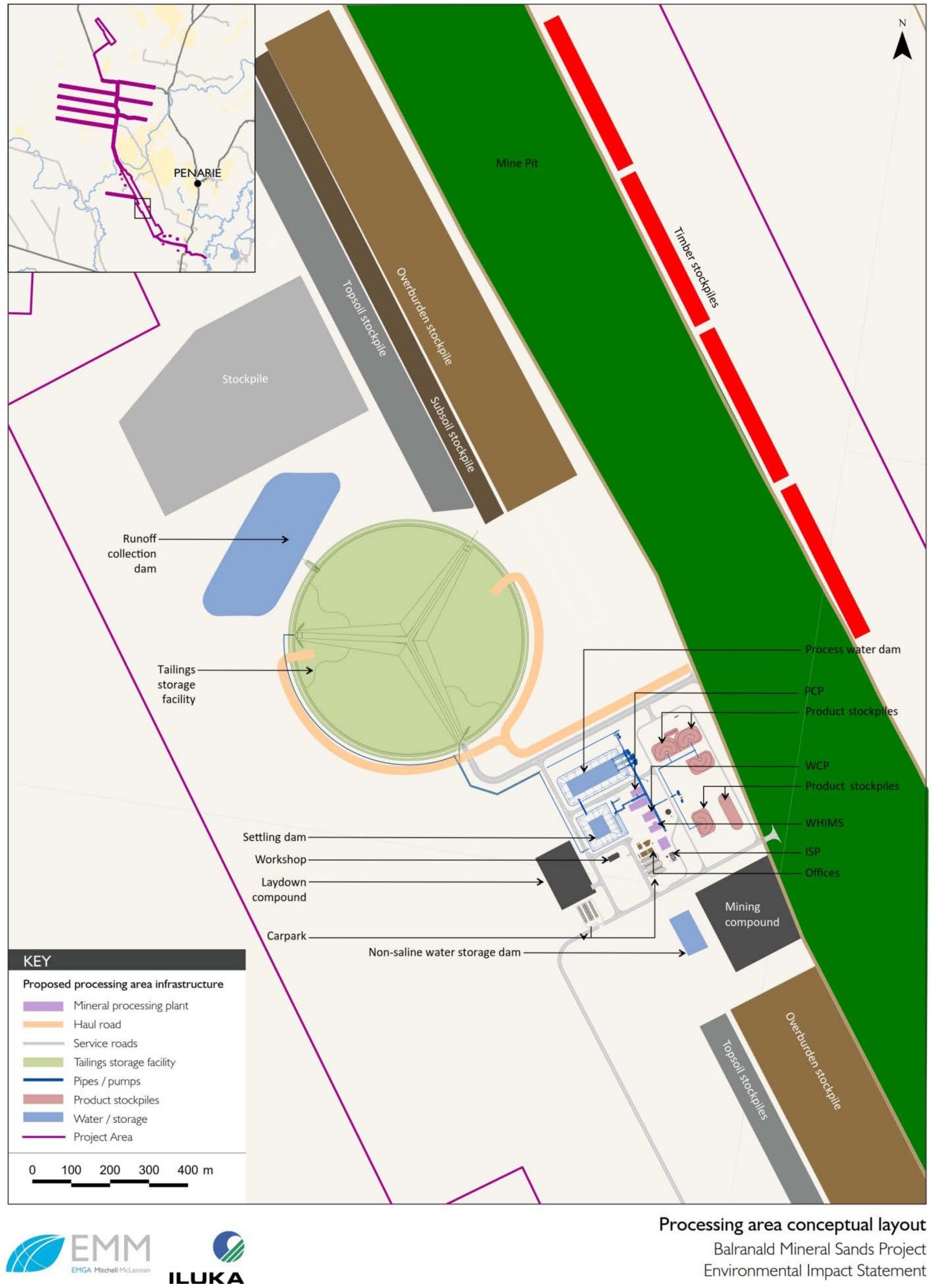

Figure 5: Processing area conceptual layout (EMM, 2015d).

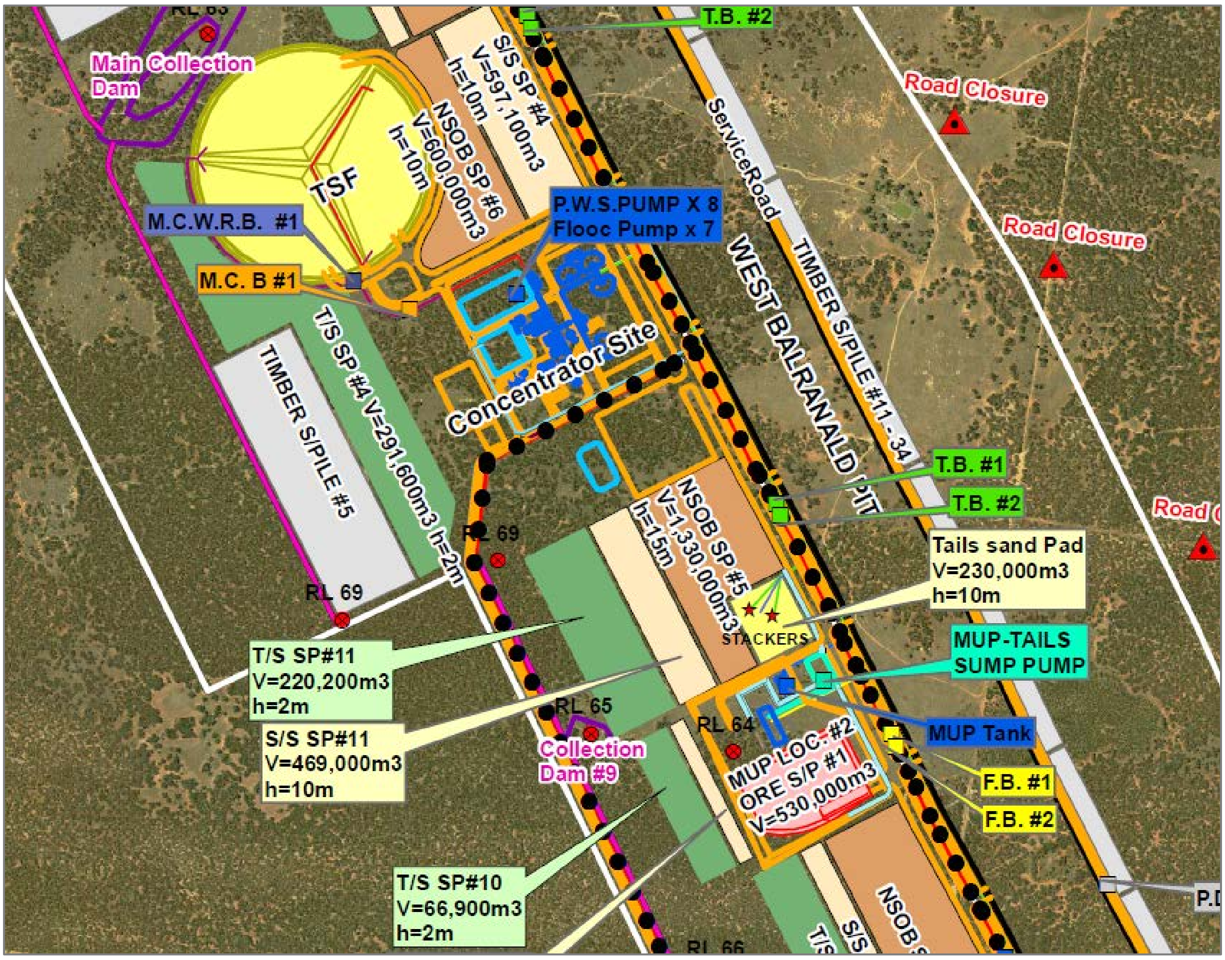

Figure 6: Proposed TSF and MUP layout including associated ore and overburden stockpiles (Iluka, 2014a).

2.2.2 *Injection Borefields*

The Balranald Project requires a network of injection borefields in the project area for the return of groundwater to the hypersaline Loxton Parilla Sands (LPS) aquifer (defined in Section 3.4). Within each borefield, infrastructure will generally be located in two 50 m wide corridors (approximately 350 m apart) and typically comprises:

- a network of pipelines with a graded windrow on either side;
- access roads for vehicle access during construction and operation;
- rows of injection wells, with wells spaced at approximately 100 m intervals; and
- a series of water storage dams to store water during well development.

2.2.3 Access Roads

Two proposed primary access roads within the project area to will provide access to the Balranald Project:

- West Balranald access road – a private access road to be constructed from the Balranald Ivanhoe Road to the West Balranald mine.
- Nepean access road – a route comprising private access roads and existing public roads. A private access road will be constructed from the southern end of the West Balranald mine to the Burke and Wills Road. The middle section of the route will be two public roads, Burke and Wills Road and Arumpo Road. A private access road will be constructed from Arumpo Road to the Nepean mine.

The West Balranald access road would be the primary access point to the project area, and will be used by heavy vehicles transporting HMC and ilmenite. The Nepean access road would primarily be used by heavy vehicles transporting ore mined at the Nepean mine to the processing area at the West Balranald mine.

During the initial construction phase, existing access tracks through the project area from the local road network may also be used temporarily until the West Balranald and Nepean access roads and internal access roads within the project are established.

2.2.4 Accommodation Facility

An accommodation facility will be constructed for the Balranald Project workforce. It will operate throughout the construction and operation phases of the project. It will be located adjacent to the West Balranald mine near the intersection of the West Balranald access road with the Balranald Ivanhoe Road.

2.2.5 Water Supply Pipeline

A water supply pipeline will be constructed to supply water from the Murrumbidgee River for the Balranald Project. Groundwater from the Olney formation will be used for project water supply during construction.

2.2.6 Gravel Extraction

Gravel will be required during the construction and operational phases of the Balranald Project. Local sources of gravel (borrow pits) have been included in the project area to provide gravel during the construction phase. During the construction phase, gravel will be required for the construction of the West Balranald access road, internal haul roads and service roads, and hardstand areas for infrastructure. Processing operations, such as crushing and screening activities (if required) will also be undertaken at the borrow pits. Gravel for the operational phase would be obtained from external sources.

3.0 Environmental Setting

3.1 Climate

Data collected at the Australian Bureau of Meteorology's (BoM) weather station located in the nearby town of Balranald, NSW indicates that the climate of the project area is characterised by cold winters and hot summers, with an average annual minimum temperature of 10.0°C and an average annual maximum temperature of 24.3°C (see Figure 7).

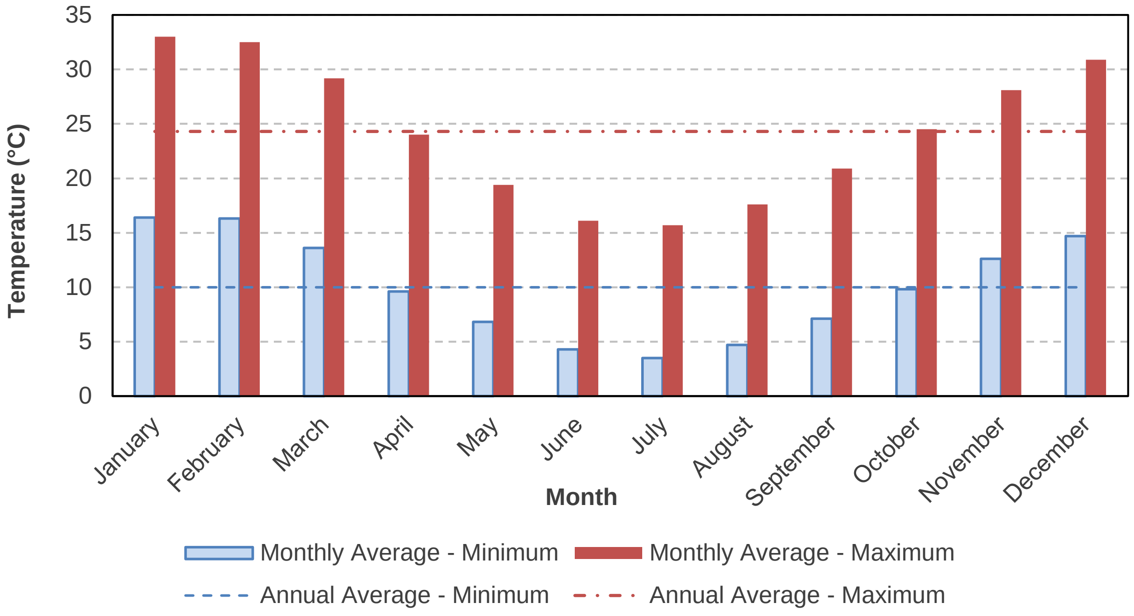

Figure 7: Average monthly temperature at Balranald and average number of rainy days (>1mm) from 1907 to 2012 (BOM, 2014).

The median annual rainfall (based on records from 1907 to 2012) is 324.7 mm. Median monthly rainfall is fairly uniformly distributed throughout the year, with slightly higher rainfall and higher number of rainy days during the winter and spring months (see Figure 8).

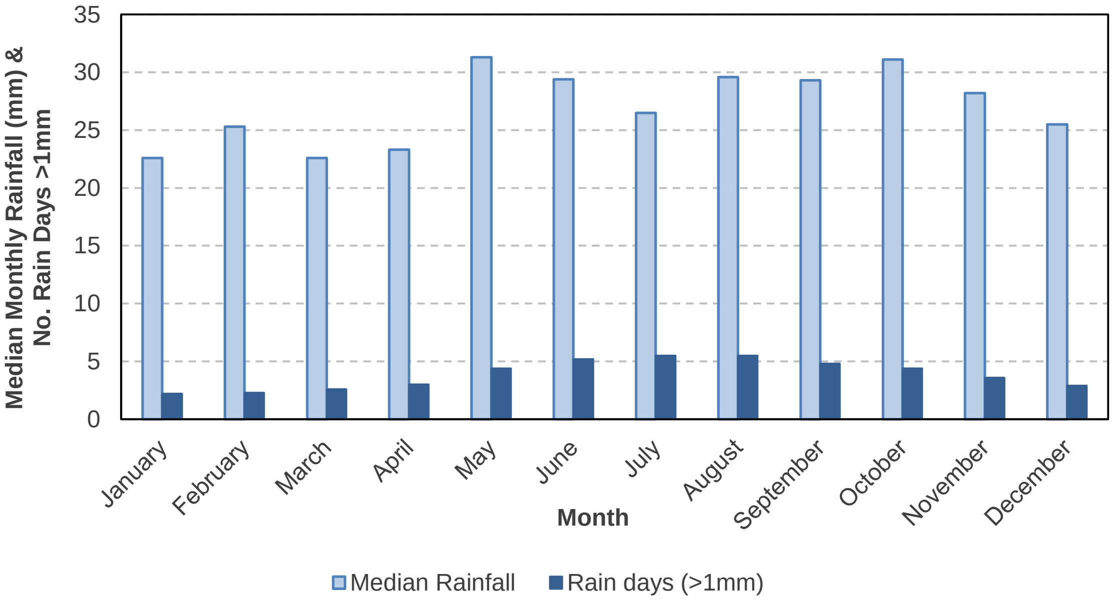

Figure 8: Median monthly rainfall at Balranald and average number of rainy days (>1mm) from 1907 to 2012 (BOM, 2012).

Evaporation data were not available for the town of Balranald. However, long term evaporation data were available for the towns of Ouyen (approximately 125 km from Balranald), between 1972 and 1987, and Mildura (approximately 145 km from Balranald), between 1965 and 2014 (see Figure 9). Average annual evaporation (Class A pan evaporation) was 1,424 mm at Ouyen and 2,190 mm at Mildura Airport, both significantly exceeding median annual rainfall of 325 mm at Balranald. Bureau of Meteorology average annual pan evaporation isohyets (see Figure 10), developed based on records between 1995 and 2005, indicate annual evaporation at Balranald is approximately 2,000 mm. This indicates the Mildura Airport evaporation data is likely to be more reflective of evaporation at the project site than the Ouyen evaporation data.

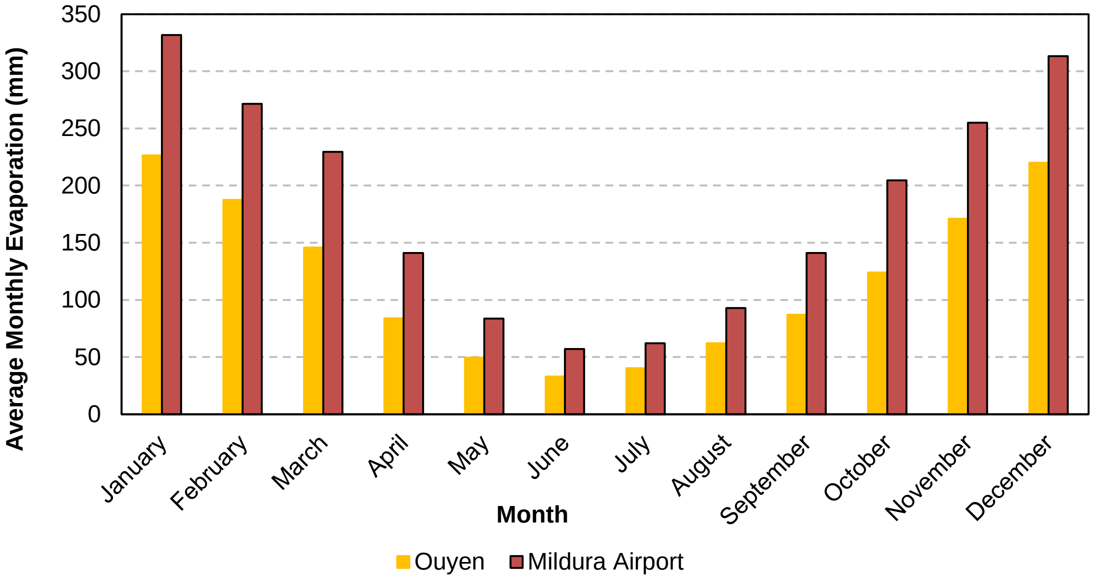

Figure 9: Average monthly pan evaporation (mm/month) at Ouyen (1972-1987) and Mildura Airport (1965-2014; BOM, 2014).

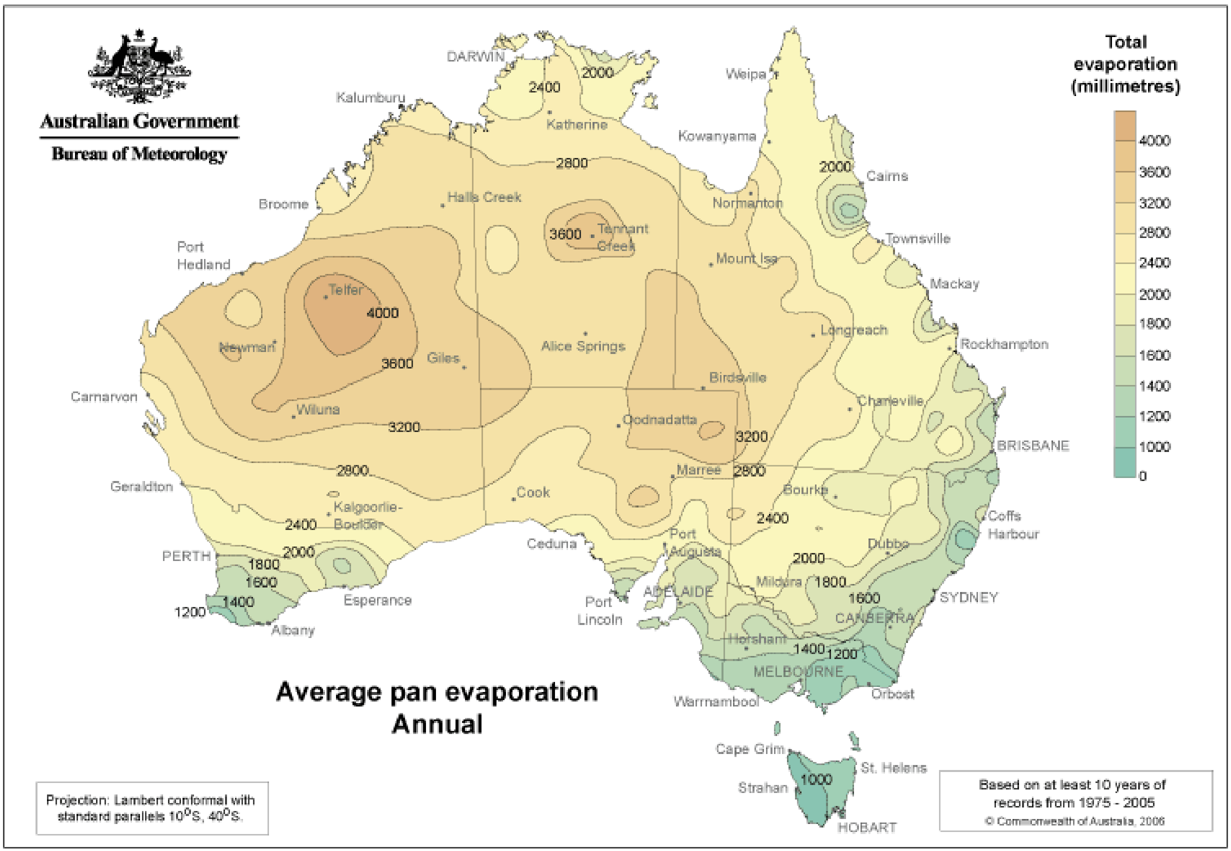

Figure 10: Average annual pan evaporation isohyets for Australia based on the last 10 years of records from 1975-2005 (BOM, 2014).

Rainfall intensity information was not available, however a series of intensity-frequency-duration (IFD) curves were generated using the Bureau of Meteorology IFD tool (BOM, 2014). Figure 11 provides the estimated IFD curves which show that for a 10 year ARI rainfall event, the rainfall intensity approximately doubles relative to a 1 year ARI event of equivalent duration.

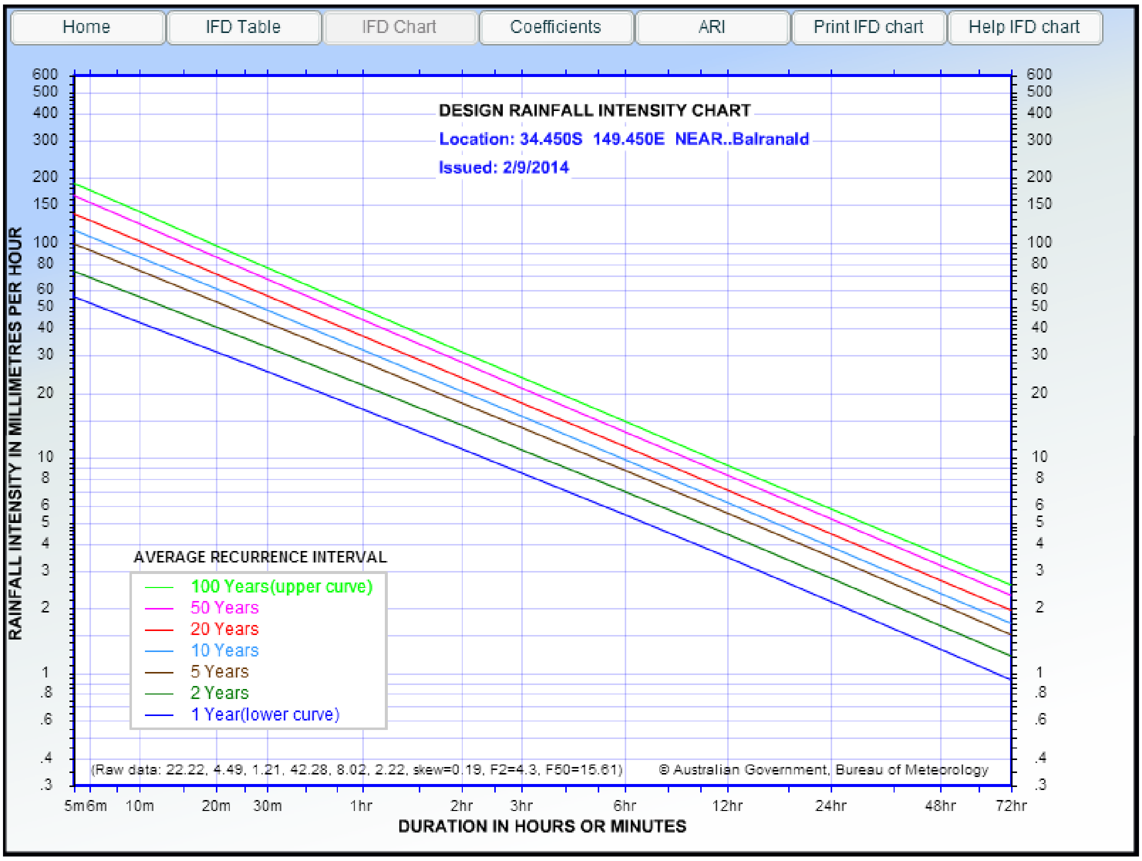

Figure 11: Calculated IFD curves for Balranald based on the BOM IFD tool (BOM, 2014).

3.2 Hydrology

The Lachlan, Murrumbidgee and Murray rivers are the major permanent surface water features in the vicinity of the project area, shown in Figure 12. The Lachlan River flows south-west, terminating at Great Cumbung Swamp, a 16,000 ha swamp dependent on flows from the Lachlan River, approximately 80 km east of the project area. The Great Cumbung Swamp joins the Murrumbidgee River to the south and becomes part of the Lowbidgee Floodplain (EMM, 2015d).

Flows within these rivers are regulated by major dams in their headwaters, and by local regulating structures such as Balranald Weir and the Paika levee, which divert water for irrigation purposes. A number of ancient lakes that would be otherwise dry (eg. Waldaira, Yanga and Paika Lakes) are artificially filled for irrigation water storage (WRM, 2015).

Permanent surface water flows are confined to the major rivers and their associated backwaters and billabongs which are outside of the project area. The catchments within the project area do not contribute to flows of the major permanent surface water features in the vicinity of the project area, except under extreme flood conditions (WRM, 2015).

Local drainage is poorly defined with the exception of Muckee, Pitarpunga and Tin Tin lakes, and Box Creek downstream of the confluence with Arumpo Creek.

Muckee, Pitarpunga and Tin Tin lakes are dry relic lake beds that are subject to agricultural activities including cropping and grazing.

As described by WRM (2015), the proposed Nepean access road, which joins the West Balranald and Nepean mines, passes through the western edge of Tin Tin Lake, and the proposed injection borefields that extend west from the Nepean access road cross a series of small unnamed dry lakes that appear to overflow towards Arumpo Creek.

The main surface water course within the project area is Box Creek, which is an ephemeral creek that traverses the proposed haul road and groundwater injection borefield infrastructure.

Identifying local drainage catchments and flowpaths is complicated due to the dunal landforms, which result in numerous small depression storages and small dry lakes. Under existing conditions it is likely that any runoff from the project area would drain via shallow overland sheet flow, before being captured by the dry lakes or depressions evident in the topography (WRM, 2015).

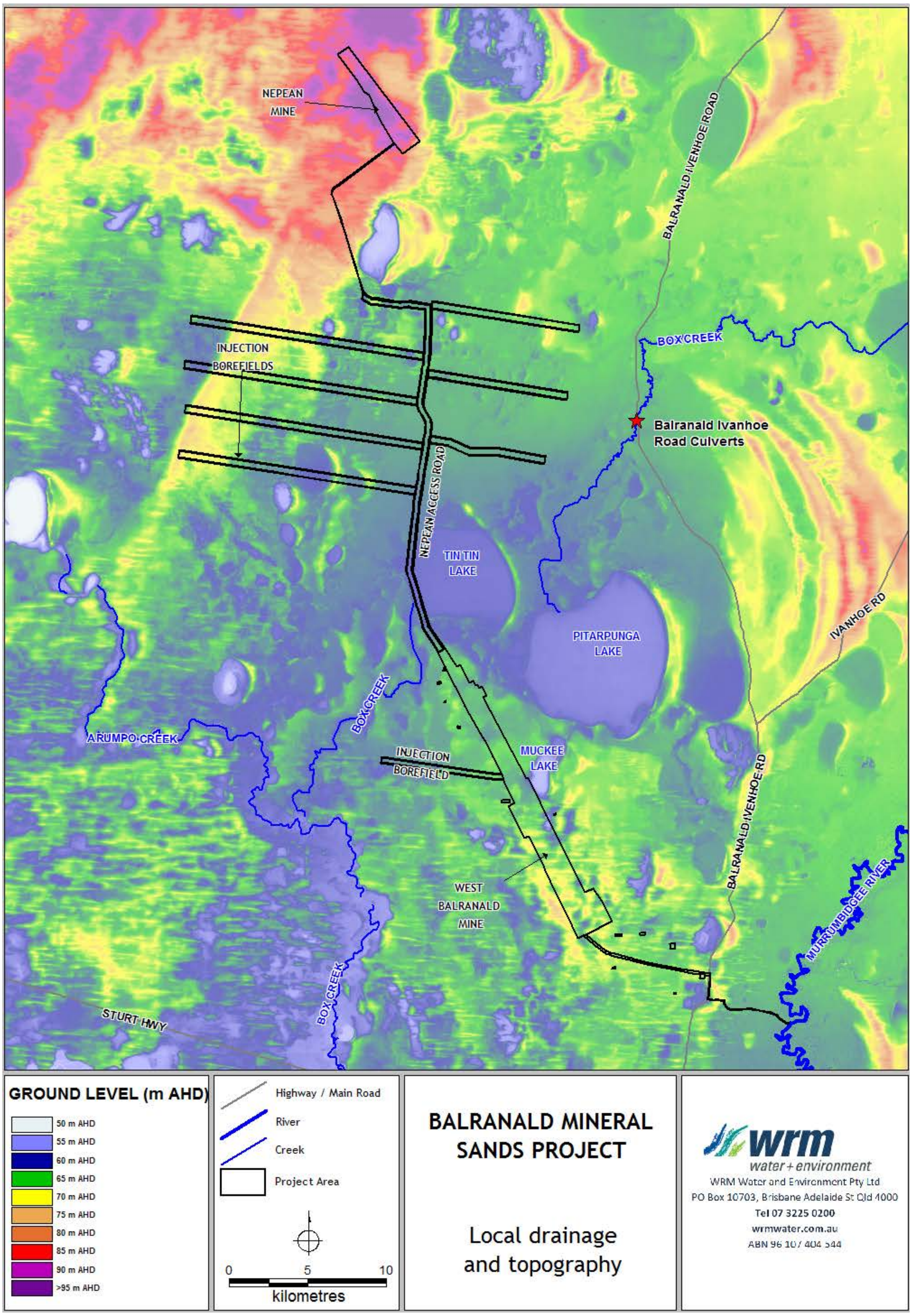

Figure 12: Drainage lines surrounding the Balranald Project area (WRM, 2015).

3.3 Geology

The following lithologies have been identified for the Balranald Project (Figure 13):

- Topsoil and subsoil.
- Non-saline overburden (NSOB), defined as overburden located above the water table.
- Saline overburden (SOB).
- Organic overburden (OOB)[4].
- Ore.

Descriptions of the West Balranald and Nepean deposit geology presented in the sections below are from EMM (2015d). The geology is also illustrated schematically in Figure 14.

3.3.1 West Balranald

At the West Balranald deposit, the Shepparton Formation consists of a thick layer of unconsolidated to poorly consolidated clays and silty clays with inter-bedded sand lenses. The strata unit is highly variable across the West Balranald deposit and drilling has defined two dense clay layers (locally up to 4- 6 metres thick). Moderately to strongly indurated iron cemented rock layers are also present within the sand-dominant lenses between the clay layers. The thickness of the unit varies from approximately 19 metres at the northern end to more than 36 metres through the central and southern areas of the deposit. The strata strikes in a north-west to south-east direction.

The upper Loxton-Parilla Sands marine sequence (LPS 1) varies in thickness along the strike of the deposit from 16-20 metres in the north to more than 60 metres at the southern end. The sequence typically consists of three upper beach facies: foreshore, surf zone and lower shore. A marine transgression marks the boundary between the LPS 1 and the lower (older) marine sequence of Loxton Parilla Sands (LPS 2). The lower marine sequence (LPS 2) is host to the West Balranald deposit and also consists of three facies (foreshore, surf zone and lower shore), with the mineral sands deposit lying within the foreshore facies of LPS 2. Explorative drilling along the length of the West Balranald deposit confirmed the presence of Geera Clay along the strike of the West Balranald deposit below the LPS 2.

3.3.2 Nepean

The Nepean deposit has the same stratigraphic units and strike as the West Balranald deposit (Loxton Parilla Sands and Shepparton Formations) with differing local features. The Shepparton Formation across the extent of the Nepean deposit consists of an upper layer which contains the consistently high clay contents of the typical Shepparton Formation. Underlying this at the northern and southern ends of the deposit are additional fluvio-lacustrine sediments of the Shepparton Formation, which have highly variable clay content relative to that typically seen in the region. These sediments are interpreted to be derived from material eroded from the uplifted Iona Ridge and a broad paleo-channel immediately adjacent to the southern edge of the Iona Ridge. In the south, this unit is 80 metres thick, including up to 60 metres of the highly variable sediments beneath the typical Shepparton Formation sediments.

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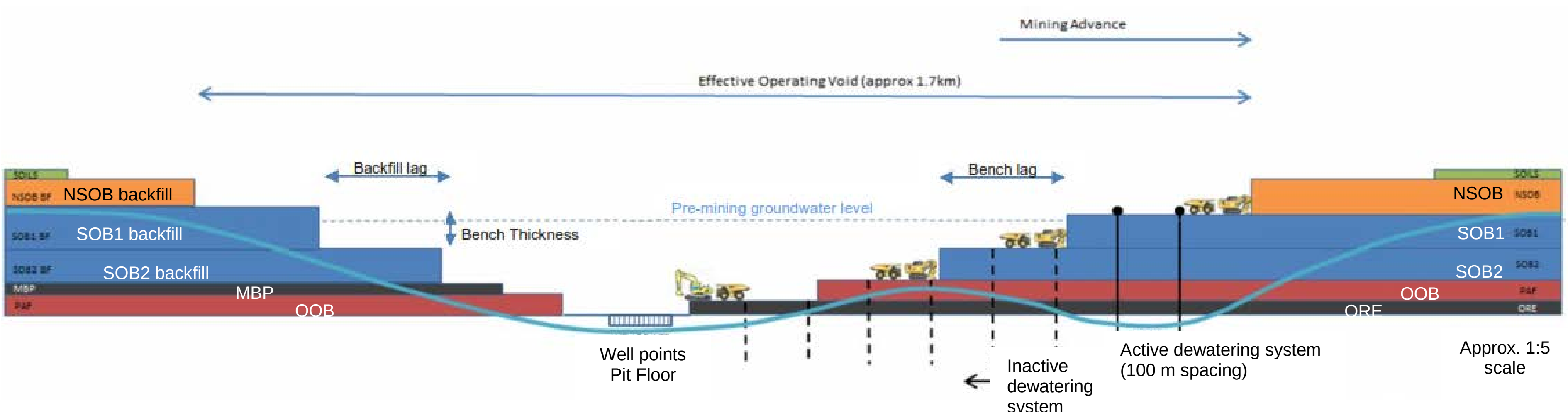
[4] The OOB is also saline but is distinguished from the SOB lithology due to the presence of organic matter and other differences in geochemical properties.

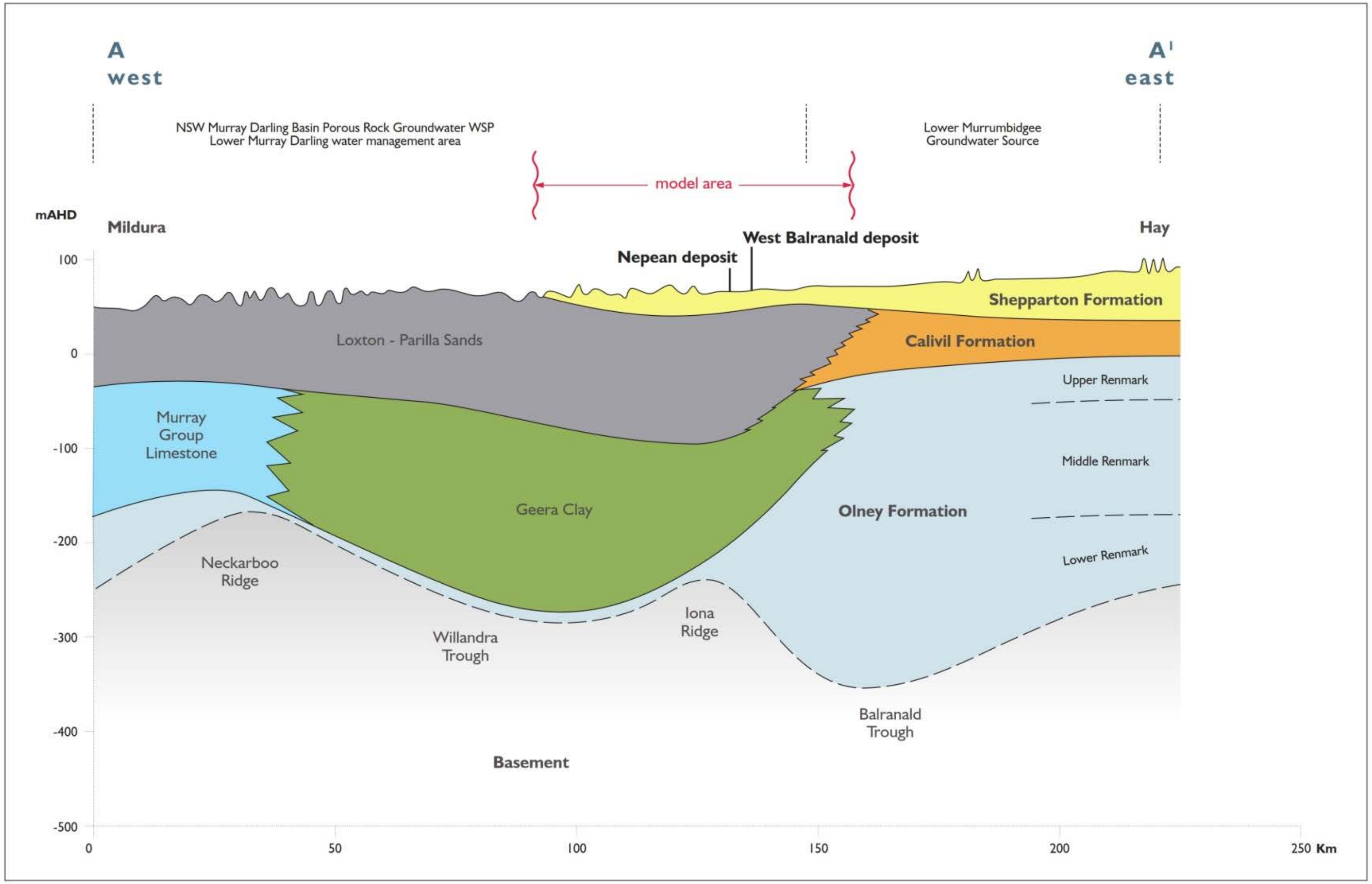
Within the Loxton Parilla Sands Formation, unlike the West Balranald deposit, the contact between the LPS 2 and the overlying LPS 1 regressive sequence is impossible to delineate as the LPS 1 sequence is incomplete. Similar to West Balranald, the lower marine sequence (LPS 2) is host to the Nepean deposit and is also located within the foreshore facies, often immediately above the poorly sorted coarser surf zone sands. Below the LPS 2 at Nepean is the Geera Clay unit.



Mine Material	Thickness	Bench lag	Backfill lag	Batter Angle
	m	m	m	Degrees
Soils	1	300	200	35
NSOB	12	300	200	35
SOB[2]	32*	200	200	35
OOB	20	200	200	35
MBP	2.5	200	200	35
Ore	5	200	n/a	35
Pit floor	n/a	200[3]	n/a	n/a

Notes: 1. Green shading in cross-section. 2. *SOB split into two 16m benches. 3. Pit floor dimensions of 80m wide and 200m long assumed.

Figure 13: Conceptual long section of mine progression and tabulated pit geometry (Iluka, 2014b).



EMM
EMGA Mitchell McLennan

Conceptual geology of the Murray Basin
Balranald Miner Sands Project
Water Assessment

Figure 14: Conceptual geological cross section (EMM, 2015d).

3.4 Hydrogeology

Two main aquifers are present in the vicinity of the project area including the Shepparton Formation aquifer and the LPS Formation aquifer. The water table occurs in the Shepparton Formation at West Balranald deposit and the LPS Formation at the Nepean deposit (Jacobs, 2015). The following information on the hydrogeology of the region surrounding the deposits was extracted from the *Balranald Project DFS1 Groundwater Modelling* (Jacobs, 2015).

3.4.1 Shepparton Formation Aquifer

In the vicinity of the West Balranald deposit, the Shepparton Formation ranges in thickness from 20 to 40 metres from north to south, decreasing to around 25 metres in the vicinity of the Nepean deposit. The formation comprises unconsolidated sediments of sandy clay and clayey sand with bands of fine grained sand. The horizontal stratification of bands of material with higher / lower clay and silt content results in anisotropy, with a higher hydraulic conductivity in the horizontal direction along the bands of higher sand content. A significant clay layer has been identified and is expected to act as a barrier to flow between the Shepparton Formation and the LPS Formation, providing confinement to the LPS Formation aquifer. The extent of this clay layer on a regional scale is unknown.

Literature indicates a regional horizontal conductivity in the order of 1 m/day to 2 m/day. The presence of interbedded fine material and, in particular the presence of an ironstone layer and a 2-3 metre thick clay layer towards the base of many of Iluka’s bore logs, suggest the vertical conductivity will be low. This is consistent with results of hydraulic testing carried out by Iluka in which the Shepparton Formation typically displays poor hydraulic connection to the underlying LPS Formation.

3.4.2 LPS Formation Aquifer

The LPS Formation Aquifer underlies the Shepparton Formation and contains the ore zone, at both the West Balranald and Nepean deposits. Through the West Balranald deposit, the LPS Formation ranges in thickness from 40 to 60 metres and is fully saturated throughout. Through the Nepean deposit, the LPS Formation is partially saturated and is between 25 to 40 metres thick.

The LPS Formation is composed of fine grained sand with some horizons of coarser grained sand with interspersed bands of clay and sandy clay. Clay layers are indicated to be less prevalent in the LPS Formation compared with the Shepparton Formation. The Iluka geological model for the LPS Formation divides the formation into repeating cycles of a facies stack that move upwards from offshore to lower shore to surf zone to foreshore facies.

Most estimates of bulk horizontal hydraulic conductivity indicate a range of generally between 2 and 5 m/day. Within the LPS 1 and LPS 2 sequences, the different facies (foreshore, surf zone and lower shore) have varying horizontal hydraulic conductivities. The surf zones consistently display significantly higher hydraulic conductivity (15-25 m/day). The foreshore and lower shore sediments, consist of finer material, typically have a hydraulic conductivity of 1-3 m/day. The stratification both within and between the sub-units of the LPS Formation is likely to cause significant horizontal to vertical anisotropy in hydraulic conductivity.

3.5 Water Quality

There are no background surface water quality data available for any watercourses or waterbodies in the Box Creek catchment (WRM, 2015).

Groundwater in the Shepparton Formation is generally near-neutral (pH from 6.6 to 8.1) and saline to hypersaline, with total dissolved solids (TDS) concentrations ranging from 19,700 - 57,200 mg/L. The underlying LPS Formation aquifer is also near-neutral and saline to hypersaline, but with slightly lower TDS concentrations (8,870 to 47,300 mg/L).

Bores screened in the deeper Olney Formation generally have lower salinity (TDS up to 7,114 mg/L) and near-neutral to alkaline pH (6.4 to 9.3), as reported in EMM (2015a).

URS (2012) suggested that this separation in salinity concentration supports the conceptualisation of a strong aquitard limiting hydraulic connection between the Shepparton Formation and LPS Formation and the underlying Lower Renmark Aquifer. Groundwater is less saline near the Murrumbidgee River and lower again near the Murray River.

Recent groundwater quality data (LWC, 2014a-e) are provided in Table 3.

Table 3: Selected groundwater chemistry results for the Shepparton and LPS Formation aquifers LWC between November 2013 and 2014 (LWC, 2014a-e). Minimum and maximum values presented.

Parameter	Unit	Shepparton Formation Aquifer*	LPS Formation Aquifer
Laboratory pH	pH units	6.6 - 8.1	6.2 - 8.2
TDS	mg/L	19,700 - 57,200	8,870 - 47,300
Sodium	mg/L	7,170 - 16,100	3,200 - 13,900
Magnesium	mg/L	710 - 2,550	225 - 1,930
Calcium	mg/L	340 - 832	105 – 848
Potassium	mg/L	19 - 115	12 – 110
Chloride	mg/L	12,400 - 30,500	5,240 - 25,400
Sulfate	mg/L	1,860 - 9,309	510 - 6,170
Bicarbonate	mg $CaCO_3$/L	177 - 570	207 – 940
Dissolved arsenic	mg/L	<LOR - 0.06	<LOR - 0.16
Dissolved cadmium	mg/L	<LOR - 0.0011	<LOR - 0.0001
Dissolved chromium	mg/L	<LOR - 0.01	<LOR - 0.001
Dissolved cobalt	mg/L	<LOR - 0.321	<LOR - 0.06
Dissolved copper	mg/L	<LOR - 0.071	<LOR - 0.058
Dissolved Iron	mg/L	<LOR - 10.4	<LOR - 12.3
Dissolved Ferrous iron (Fe^{2+})	mg/L	<LOR - 10.3	<LOR -11.5
Dissolved lead	mg/L	<LOR - 0.07	<LOR - 0.004
Dissolved nickel	mg/L	<LOR - 0.168	<LOR - 0.129
Dissolved aluminium	mg/L	<LOR - 28.9	<LOR - 0.34
Dissolved manganese	mg/L	<LOR - 5.07	0.064 - 1.55
Dissolved uranium	mg/L	<LOR - 0.2	<LOR - 0.025
Dissolved zinc	mg/L	<LOR - 0.244	<LOR - 1.1

Notes: TDS = TDSTotal Dissolved Solids; LOR = Limit of reporting.

*One borehole (GW040247-1) consistently had an acidic pH of around 3.9 over the monitoring events (LWC, 2014a-e).

3.6 Environmental Values and Water Resource Use

3.6.1 Surface Water

The three major rivers located in the vicinity of the Balranald Project are the Murrumbidgee River, to the south of the project, the Lachlan River, to the east of the project area and the Murray River, to the south-west of the project area.

The project area is located almost entirely within the catchment of Box Creek, which is an ephemeral water course and a distributary of the Lachlan River, and typically only flows after heavy local rainfall and during large flood events in the Lachlan River (WRM, 2015). Box Creek drains into the Murrumbidgee River, approximately 30 km south-west of the project area, after merging with Arumpo Creek (WRM, 2015).

The Murrumbidgee River is a permanent surface water feature and is a nationally significant river that is home to many sites of international, national and regional environmental importance (EMM, 2015a). It is a critical water source for communities that live on and rely on river water for irrigation and potable water supply (EMM, 2015a). Further downstream of the project area, the Murrumbidgee River flows into the Murray River, a major surface water resource for town water supply and irrigation.

The predominant land use in the project area is grazing. However, due to the ephemeral nature of surface water flows, there are no surface water users in the immediate vicinity of the project area. Water use in the project area is therefore principally through groundwater access, usually for stock watering (Section 3.6.2). There are also a number of lakes that would be naturally dry (eg. Waldaira, Yanga and Paika Lakes) but are periodically used to store water for irrigation (EMM, 2015a). These are located outside of the project area.

3.6.2 Groundwater Use by Landholders

Based on NSW Office of Water (NOW) records (EMM, 2015a):

- Privately owned bores surrounding the project area are predominantly registered for stock and/or domestic use. The location of these installations is shown in Figure 15.
- The majority of the landholder bores were installed into the Shepparton Formation (60), with 35 bores screening the Olney Formation, 9 bores screening the Geera Clay, 7 bores screening the LPS Formation and one bore screening basement.

LWC (2014f) undertook a groundwater use study within the project area, which involved interviewing available landholders on the status and use of any bores on their property. A total of 16 bores were identified. Key results of the LWC (2014f) study, as summarised by EMM (2015a) are:

- Consistent with NOW records for the region, the majority of the landholder bores in the project area are registered for stock and/or domestic use.
- In most cases, bore water is the only source of stock water, with the exception of intermittent surface water runoff.
- All the bores utilised by the landholders interviewed (16 bores) are used for stock water, with one bore used for both stock and domestic purposes.

- Ten of the 16 landholder bores identified are screened in the lower Olney Formation, with 5 bores screened in the Shepparton Formation and the screen depth of the remaining bore unknown.
- Artesian conditions were observed in 4 bores screened in the Olney Formation.
- Salinity was variable (ranging from 350 mg/L to 5,300 mg/L TDS), with comparable salinity data for bores intersecting the Olney Formation and the Shepparton Formation. Regional salinity concentrations in the Shepparton Formation aquifer are considerably higher (Section 3.5).
- The bores were mostly low yielding, typically around 0.4 L/s.

Groundwater modelling was conducted by Jacobs (2015) for 26 landholder bores potentially susceptible to groundwater level changes relating to mine dewatering, including 19 bores screened in the Olney Formation, 3 bores screened in the Shepparton Formation, 3 bores screened in the Geera Clay and 1 bore screened in the LPS Formation (EMM, 2015a; Table 14.1).

The 3 landholder bores screened in the Shepparton Formation are located approximately 10-15 km west of the northern end of the West Balranald deposit (Jacobs, 2015; Appendix F). The location of the additional 2 landholder bores screened in the Shepparton Formation, as identified in the LWC (2014f) study, and 1 bore screened in the LPS Formation (Jacobs, 2015), is still to be confirmed.

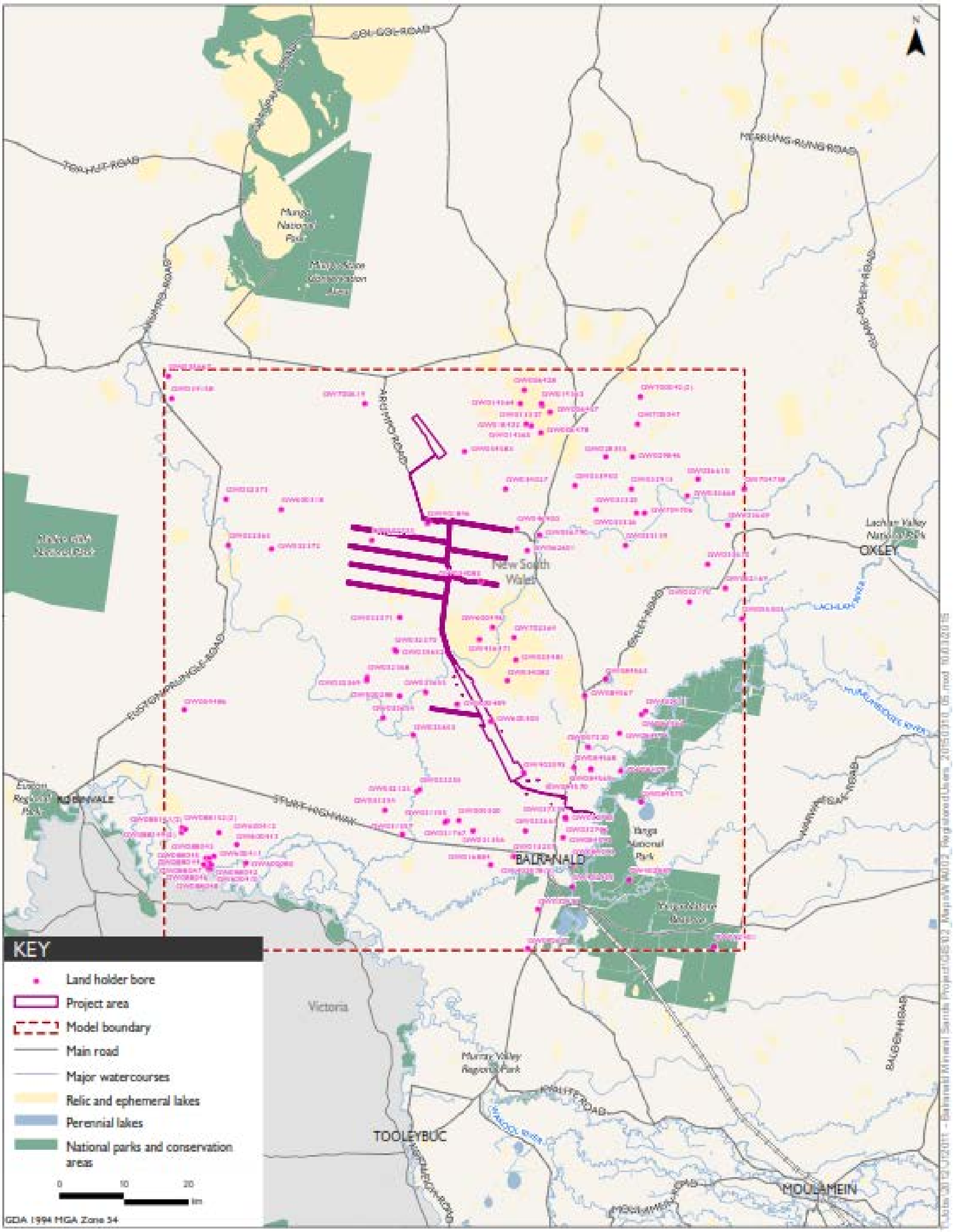


Figure 15: NSW Office of Water landholder bores in the Project region (EMM, 2015a).

3.6.3 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDE) are ecological communities whose extent and life processes are dependent on groundwater. The major potential GDE types surrounding the project area include (CDM Smith, 2015):

- Wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments.
- Vegetation (primarily Black Box trees) outside the floodplain and permanent streams, in topographic depressions where the water table may be shallow enough and not too saline.

CDM Smith (2015) developed conceptual models for these GDEs, to ascertain whether an exposure pathway exists between the water-related effects of the project and the hydrological regime that supports these GDEs, and found that:

- No exposure pathways exist in relation to runoff and surface inundation for potential GDEs.
- Exposure pathways related to groundwater may occur if water table is affected by drawdown or mounding.

Drawdown may cause reduced water availability to vegetation that uses groundwater (CDM Smith, 2015). It may also lead to desaturation of sulfidic materials, which could potentially generate AMD and therefore adversely affect local groundwater quality and associated GDEs. In both cases, the sensitivity of potential GDEs will vary according to the extent that they use groundwater.

As noted by CDM Smith (2015):

- Previous studies (eg. Jacobs, 2014) have shown that the groundwater use of vegetation in the region is influenced by two main factors: the depth of the water table and groundwater salinity.
- The highest level of groundwater use occurs where the water table is shallow and of a low salinity. Negligible groundwater use occurs where the water table is too deep to be accessible to roots (say, >15 m) or is too saline (>35,000 mg/L).

A classification system for the indicative level of groundwater use was developed by CDM Smith (2015) based on a consideration of groundwater salinity and the depth of the water table (Figure 16). The GDE classes vary according to likely groundwater use, from very high (Class 1) to negligible (Class 5), such that Class 1 GDEs will be very sensitive to groundwater level drawdown and Class 5 GDEs will be insensitive to groundwater level drawdown.

Key observations from Figure 16 include:

- The nearest GDEs to the project area are located approximately 0.5 km from the northern extent of the West Balranald deposit and are generally defined as Class 4 (likely to be low level of groundwater use).
- The next closest GDEs to the project area are located approximately 4 km from the southern extent of the West Balranald deposit and are generally defined as Class 3 (likely to be moderate level of groundwater use).
- All Class 2 GDEs identified were located more than 6 km the project area, and no Class 1 GDEs were identified.

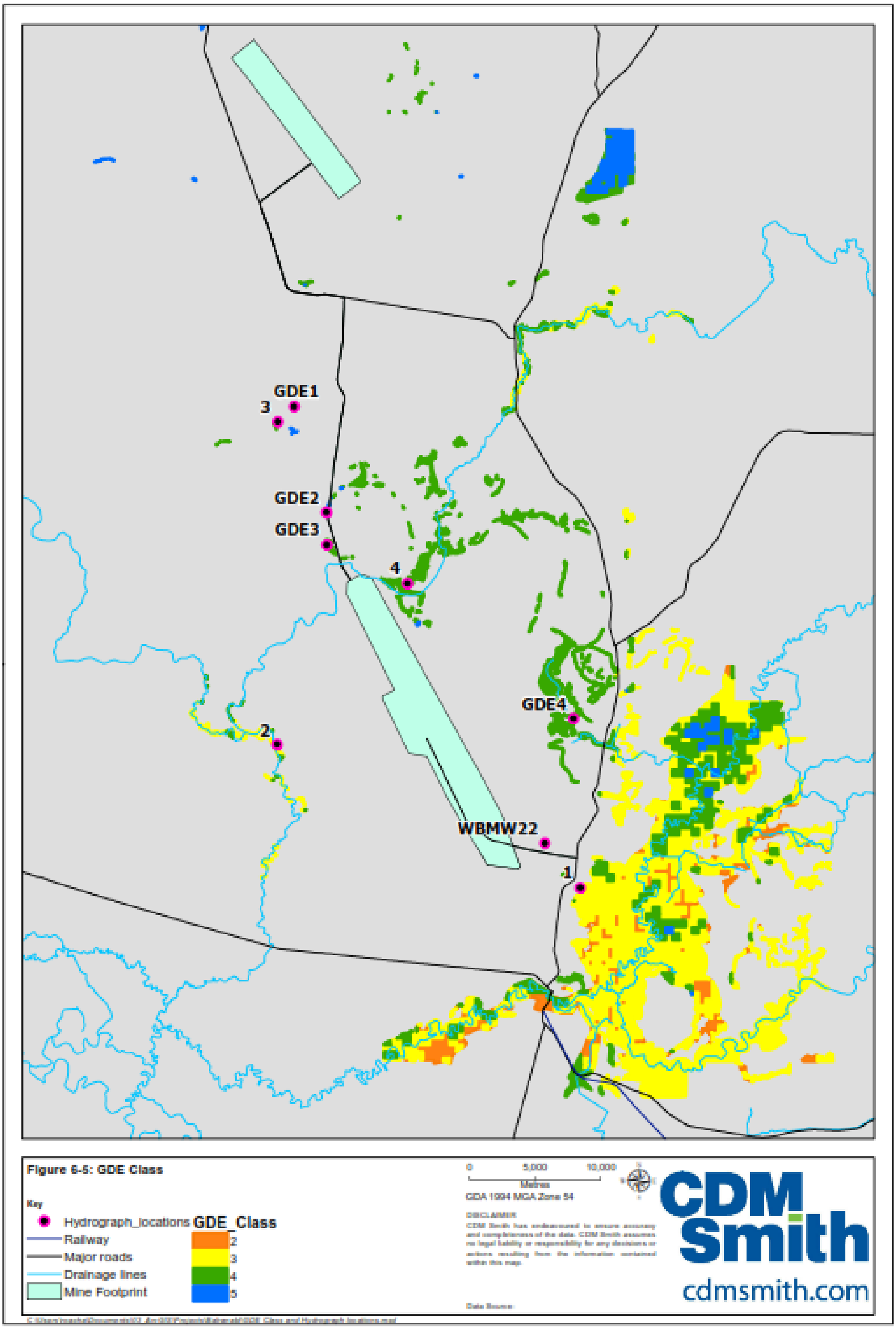


Figure 16: GDEs in the Project region (CDM Smith, 2015). GDE classes refer to the likely level of groundwater use (Class 1 = Very High; Class 2 = High; Class 3 = Moderate; Class 4 = Low; Class 5 = Negligible).

4.0 Background to AMD

4.1 Key Geochemical Principles for Environmental Management

In order to understand AMD and associated risks, it is important to consider the mechanism of AMD generation in some detail. AMD refers to the acidic, saline and metalliferous water that can occur as drainage from mine waste stockpiles, TSFs, pit walls, underground workings (if any) and potentially other mine infrastructure such as Run Of Mine (ROM) pads and road embankments. AMD is a common problem for mines worldwide and one of the most significant obstacles to pollution prevention and minimisation during operations and post-closure.

AMD commonly occurs when previously water-saturated sulfide mineral bearing rocks or sediments are excavated and stored in an unsaturated setting, as is typical in mining operations that store mine waste materials and tailings in unsaturated or partially unsaturated piles and impoundments. Desaturation of in-situ rocks / sediments (eg. associated with mine dewatering) can also generate AMD.

The key terms and processes involved in the generation, release and treatment of AMD are described in the following sections. Detailed information on key AMD generation and neutralisation reactions is provided in Attachment A.

4.2 Sulfide Oxidation

AMD can be produced when reactive sulfide minerals such as pyrite (iron sulfide, FeS_2) are disturbed or dewatered as part of mine operations. Many sulfide minerals, particularly pyrite but also chalcopyrite (copper sulfide, $CuFeS_2$), pyrrhotite (iron sulfide, FeS) and some others, naturally undergo oxidation when exposed to atmospheric oxygen and moisture. Oxidation of sulfides results in decomposition of the mineral to release sulfur in the form of sulfuric acid (H_2SO_4), and soluble metals such as iron, which contribute to ‘mineral acidity’. The acid conditions and soluble iron generated during pyrite oxidation can attack and dissolve other minerals, resulting in elevated soluble concentrations of other metals such as aluminium, manganese, copper, lead, zinc, nickel, cobalt, cadmium, chromium, arsenic, antimony and mercury.

Under oxidising conditions, sulfide oxidation continues until all reactive sulfides have been converted to acid and metals. Different sulfides oxidise at different rates. It is not unusual for sulfide oxidation (and hence AMD issues) to persist for hundreds of years. The amount of acid produced by sulfide oxidation per year tends to decrease over time as the bulk concentration of source sulfides decreases (eg. within an overburden pile).

Some sulfide minerals, such as galena (PbS), sphalerite (ZnS), arsenopyrite (FeAsS) and stibnite (Sb_2S_3), are relatively geochemically stable (unreactive) and slow to oxidise. However, these minerals can be dissolved by exposure to acid conditions and dissolved iron, resulting in the release of soluble metals, which contribute to acidity.

4.3 Secondary Acid Sulfate Minerals

Acidity generated as a result of sulfide oxidation can react with silicate minerals to form secondary acid sulfate salts such as melanterite, jarosite and alunite. Melanterite is highly soluble in water, jarosite is sparingly soluble, and alunite is approximately ten times less soluble than jarosite. Acidity stored in these minerals is released by dissolution in water, and is not sensitive to oxygen availability.

Depending on the rate of sulfide oxidation, jarosite (or alunite) formation as a result of sulfide oxidation can proceed faster than the rate of jarosite dissolution, resulting in an accumulation of jarosite in stockpiles of potentially acid forming (PAF) materials. Melanterite, if formed, is highly soluble and does not tend to accumulate in non-arid environments.

4.4 Acid Neutralisation

Certain carbonate minerals, primarily calcium- and magnesium-bearing carbonates such as calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), can neutralise the acidity produced by sulfide oxidation. The neutralisation potential of a rock or sediment as determined through test work is referred to as its acid neutralisation capacity (ANC). Iron- and manganese-bearing components of carbonates have no net contribution to ANC, as the metals oxidise and hydrolyse, thereby contributing to acidity.

Acid produced by sulfide oxidation can also react (slowly) with common silicate minerals, partially neutralising acidity and storing some acidity in precipitated secondary minerals such as jarosite or alunite. Due to the slow rate of reaction, relatively long acidity contact times are required to induce silicate neutralisation, which can be achieved by ensuring slow water migration rates.

4.5 Acid and Acidity

In determining AMD risk, it is important to take into account both acid (H^+) and dissolved metals (latent mineral acidity) concentrations as a combined measurement of ‘acidity’ in units of milligrams of calcium carbonate (equivalent) per litre (mg $CaCO_3$/L). The measurement of acidity is equivalent to the amount of neutralising agent (such as calcium carbonate) that would need to be added to the affected water to raise the pH to 8.3. Observations of pH alone, while a reasonable qualitative indicator of water quality, are insufficient to estimate total acidity. For example, water with a pH of 3.0 can have an acidity of as low as 50 mg $CaCO_3$/L and as high as 10,000 mg $CaCO_3$/L or more.

4.6 Kinetics of Sulfide Oxidation

Sulfide oxidation occurs at a rate that is determined by the intrinsic geochemical and physical properties of the sulfide minerals (eg. mode of formation, geological history and crystal size), the grain size of the rock, temperature, moisture availability, oxygen availability and bacterial activity.

Sulfide oxidation is a first-order decay reaction that can be described in terms of a percentage of the sulfides that oxidises each year. For example, if the sulfide oxidation rate is 50 wt.% sulfide / year, half of the sulfide exposed to atmospheric oxygen would be oxidised (to form acid and soluble metal ions) in the first year, and then half of the remaining sulfide (25% of the starting total) would be oxidised in the second year. The rate of acid generated by this process decays over time accordingly. The rate of oxidation can be determined through kinetic geochemical tests such as oxygen consumption cell tests and column leach tests.

The kinetics of sulfide oxidation can therefore be used to estimate the duration or longevity of sulfide oxidation and acid generation (before neutralisation reactions).

For materials or sediments of the same geological characteristics (ie. from the same lithological unit) and grain size, the rate of sulfide oxidation is largely uniform and independent of absolute sulfide concentration. This means that oxidation rates (in wt.% sulfide/year) determined through kinetic geochemical test work can be applied to rocks of the same lithology for any sulfide-sulfur content. The sulfide oxidation rate is typically normalised to pyrite equivalent units for convenience (ie. wt.% FeS_2 / year).

4.7 Lag Period

Once the sulfide oxidation rate has been determined, the annual acidity generation rate (AGR) and ANC can be used to determine the lag time before the onset of acid conditions. In materials or sediments that contain reactive carbonate minerals (as ANC), any acidity generated as a result of sulfide oxidation will be neutralised until the effective ANC has been exhausted.

If the ANC of the material is less than the total acid generating potential of the sulfides, acid conditions will eventually develop. The net acidity generation rate (NAGR) is the amount of acidity released after neutralisation reactions. The evolution of NAGR can be predicted over time using the sulfide oxidation rate and ANC.

Depending on the balance of Maximum Potential Acidity (MPA) and ANC, sulfidic materials or sediments can display three general lag-related behaviours:

- No lag period with immediate onset of acid conditions (ANC = 0 , MPA > 0).
- A discrete lag period followed by the onset of acid conditions (MPA > ANC).
- Onset of acid conditions unlikely to occur (ANC >> MPA).

In the second case described above, drainage will be near-neutral, but may be metalliferous and / or saline, during the lag phase. This is referred to as neutral metalliferous drainage (see Section 4.8) or saline drainage (see Section 4.9).

4.8 Neutral Metalliferous Drainage (NMD)

Neutral metalliferous drainage (NMD), also referred to as or neutral mine drainage, can occur when there is sufficient ANC to neutralise the acidity produced by sulfide oxidation, but the drainage still contains elevated dissolved and/or total metal concentrations and (sulfate) salinity.

Some metals, particularly manganese (Mn), cadmium (Cd) and arsenic (As), as well as others, remain in solution even at elevated pH. Neutralisation of AMD by carbonates can raise the pH of the drainage to near-neutral levels (eg. pH 6–8), but this can be insufficient to precipitate all metals, leaving a certain metalliferous component in solution. This is referred to as NMD.

Furthermore, some metals in some scenarios, such as zinc, can precipitate at elevated pH, but can remain suspended in drainage and resist sedimentation. This can result in elevated total metal concentrations, with implications for regulatory compliance.

4.9 Saline Drainage

Saline drainage can occur when there is sufficient ANC to neutralise the acidity produced by sulfide oxidation and the resulting drainage does not contain metals at toxic concentrations. The sulfate salinity of the neutralised drainage depends on the relative proportions of calcium and magnesium in the neutralising minerals. Due to the high solubility of magnesium sulfate, higher salinity is likely to occur in deposits where magnesium is a significant component of the neutralising material. Conversely, if calcium is the dominant component of the neutralising material, gypsum precipitation may contribute to lower salinity (sulfate) levels.

5.0 Method

5.1 Review of Existing Information

The information reviewed, including the regulatory framework in Attachment B, is summarised in Table 4.

Table 4: Information reviewed for the Balranald Project Geochemistry Assessment.

Data / Report Title	Author	Date
Geochemistry		
Iluka Balranald Mineral Sands Geochemistry, Preliminary Static Testing Results	KCB	May 2012
Balranald Pre-Feasibility Study – Overburden, Ore and Mining Byproducts: Draft Kinetic Geochemical Testing Report	KCB	January 2013
Review of Geochemical Testwork and Preliminary Assessment of AMD Management Strategies for the Balranald Mineral Sands Project	Earth Systems	December 2013
Acid and Metalliferous Drainage Risk and Management Implications for Mining and Closure of the West Balranald Mineral Sands Deposit (Draft)	Earth Systems	February 2015
Site water balance		
Balranald Mineral Sands Project: Surface Water Management Report	WRM	March 2015
Environmental Impact Statement		
Draft EIS Chapters 1-9, 11, 15-17, 21-22, 29-30.Appendices C-D	EMM	June 2013
Water Assessment	EMM	March 2015
Groundwater Dependent Ecosystems Assessment Report	CDM Smith	February 2015
Project infrastructure and mine development data		
Balranald DFS1 Truck and Shovel Mining Study	Iluka	May 2014
Hamilton Mineral Separation Plant – mass balance data	Iluka	February 2015
Hydrogeology		
Balranald PFS Hydrogeological Study	URS	July 2012
Pre-Mining Quarterly Groundwater Monitoring Event (November, 2013)	LWC	March 2014
Pre-Mining Quarterly Groundwater Monitoring Event (February, 2014)	LWC	May 2014
Pre-Mining Quarterly Groundwater Monitoring Event (May, 2014)	LWC	July 2014
Pre-Mining Quarterly Groundwater Monitoring Event (August, 2014)	LWC	October 2014
Pre-Mining Quarterly Groundwater Monitoring Event (November, 2014)	LWC	December 2014
Balranald Project DFS1 Groundwater Assessment	Jacobs	February 2015

5.2 Geochemical Characterisation of Mine Materials

Two geochemical characterisation programs were conducted for the Balranald Project. A preliminary geochemical characterisation program aimed at obtaining a spatial representation of materials along the deposit strike and adjacent to the proposed mining void was conducted by KCB (2012; 2013). A supplementary geochemical characterisation program was conducted by Earth Systems (2015) to increase the sampling density for geochemical characterisation of the NSOB, SOB and OOB materials and to assess the AMD potential of the dewatered and sulfidic pit walls and benches, in particular the OOB material (Earth Systems, 2015). Samples of product and MBP streams were also provided by Iluka for characterisation.

The sampling and geochemical characterisation of the overburden (including NSOB, SOB and OOB) allowed for the assessment of AMD risk associated with overburden stockpiles, backfill material and de-saturated pit wall / bench / floor material.

The sampling and geochemical characterisation of the ore allowed for the assessment of AMD risk associated with key domains on-site including ore stockpiles and oversize backfill.

Geochemical characterisation of the product and MBP streams allowed for the assessment of AMD risk associated with key domains on-site including product and MBP stockpiles, TSF and backfill material.

The sampling and laboratory test work programs were developed with reference to the following industry standard methods and guidelines:

- Australian Leading Practice Sustainable Development Program for the Mining Industry: Managing Acid and Metalliferous Drainage (DITR, 2007).
- New South Wales Acid Sulfate Soils (ASS) Assessment Guidelines (ASSMAV, 1998).
- AMD Test Handbook – Prediction and Kinetic Control of Acid Mine Drainage (AMIRA, 2002).
- Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Colombia (Price, 1997).
- Requirements in Metal Leaching / Acid Rock Drainage Assessment and Mitigation, Mining Environmental Neutral Drainage (MEND) Report 5.10E (MEND, 2005).
- Prediction Manual for Drainage Chemistry from Sulfidic Geological Materials, MEND Report 1.20.1 (MEND, 2009).
- The Global Acid Rock Drainage Guide, International Network for Acid Prevention (INAP, 2012).

5.2.1 Sampling Program

Overburden and Ore

The sampling program for the preliminary geochemical characterisation program was conducted by KCB (2012) and included both the West Balranald and Nepean deposits. Drill holes for inclusion in the program were selected by Iluka staff, for a resource definition program, and were along strike, with exception of two holes that were off-strike (KCB, 2012). Refer to Table 5, Figure 17 and Figure 18.

Samples were collected in plastic sleeves for the overburden and lexan liners for the ore zone. Sub-samples were selected from the sleeves in the field. A suite of field geochemical tests (field pH, oxidised pH, and metal content using a field x-ray fluorescence (XRF)) were undertaken at the time of sampling on every one metre of core. Sub-samples were stored in ice boxes in the field and refrigerated during storage prior to shipping to an external laboratory for analysis (see Section 5.2.2 for details). Samples were classified as overburden (ie. NSOB and SOB), OOB and ore. A total of 101 sub-samples (73 from West Balranald and 28 from Nepean) were analysed for static geochemical test work as part of the preliminary geochemical program (KCB, 2012).

Table 5: Sampling drill holes for the West Balranald and Nepean deposits for the preliminary geochemical characterisation program (KCB, 2012).

Deposit	Drill Hole ID	Drill Hole Depth (m)	Length of Ore Captured (m)	Length of Overburden Captured (m)
West Balranald	WBSCH5	57	12	45
	WBSCH8	63	12	51
	WBSCH9	57	12	45
	WBSCH11	63	9	54
	WBSCH12	66	12	54
	WBSCH13	68	11	57
	WBSCH15	72	12	60
	WBSCH17	75	12	63
	WBSCH19	79.5	10.5	69
	WBSCH21	70	0	70
	WBSCH22	70	0	70
Nepean	NEPSCH1	48	21	27
	NEPSCH2	52	16	36
	NEPSCH3	58	21	37
	NEPSCH4	52	0	52
	NEPSCH5	52	0	52

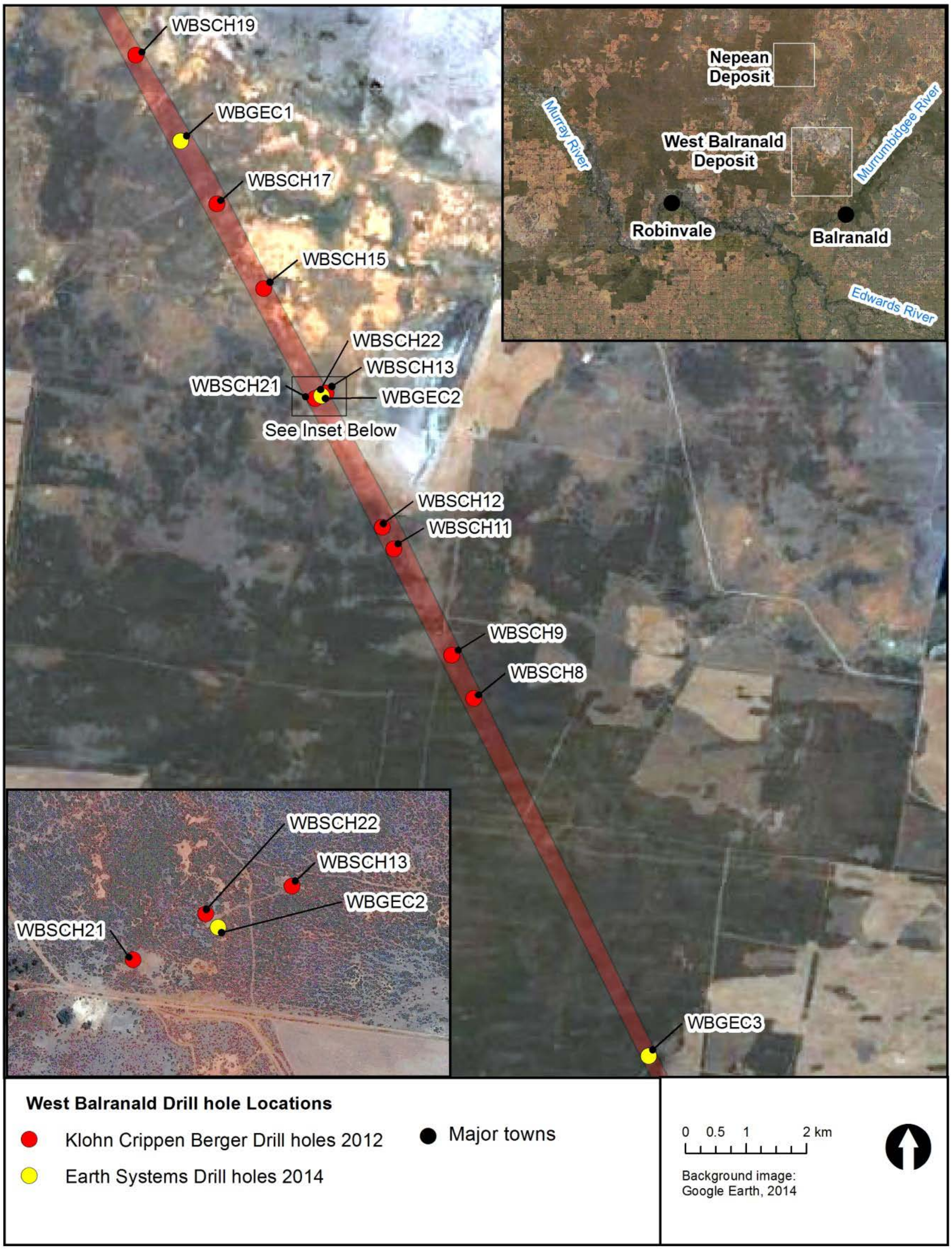


Figure 17: Location of sampling drill holes for the West Balranald preliminary geochemical characterisation program (KCB, 2012) and supplementary geochemical characterisation program (Earth Systems, 2015).

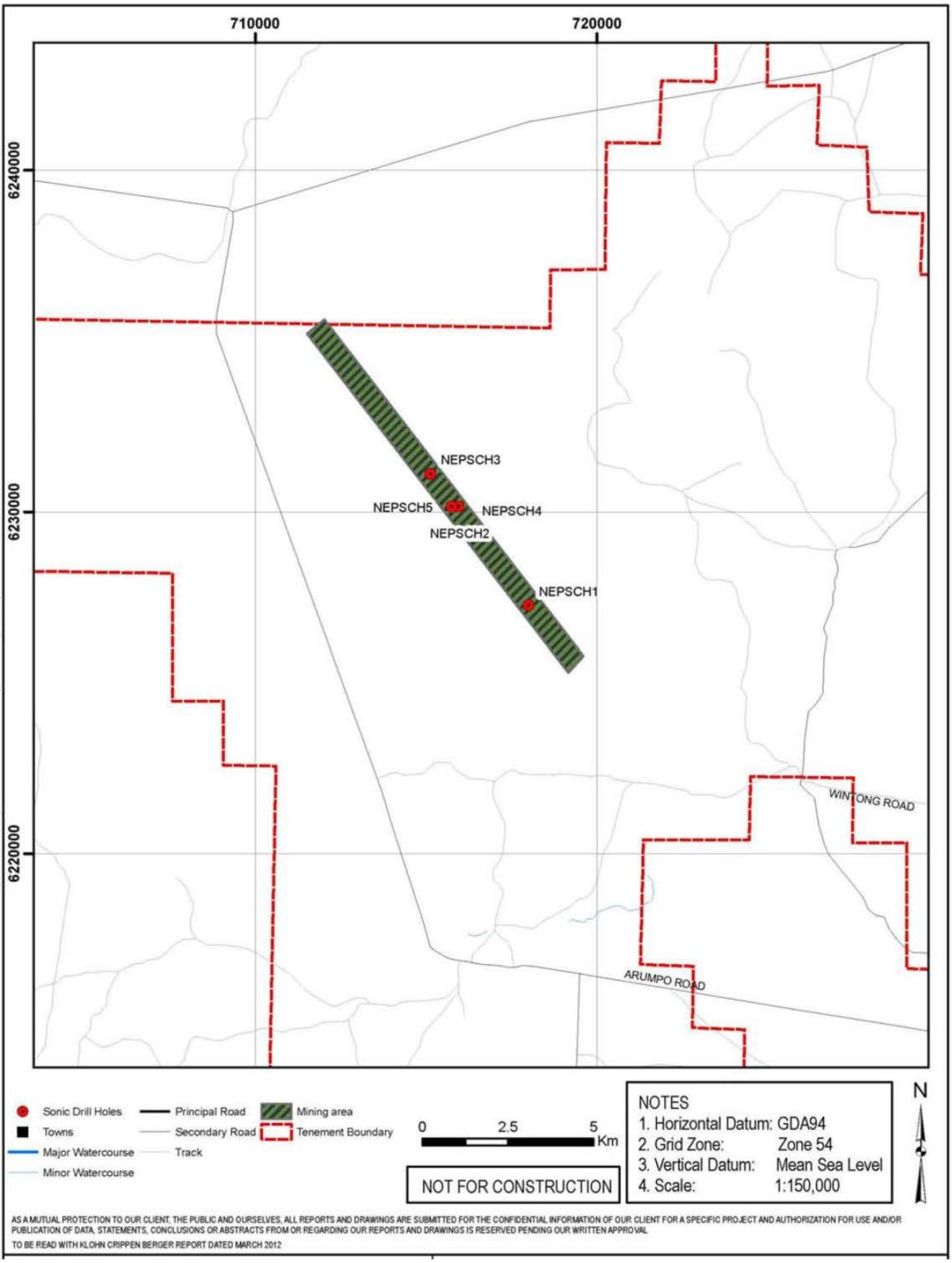


Figure 18: Location of sampling drill holes for the Nepean preliminary geochemical characterisation program (KCB, 2012).

Three drill hole locations (WBGEC-1, WBGEC-2, and WBGEC-3; see Figure 17), located along the strike of the West Balranald Deposit, were selected by Iluka for the supplementary geochemical characterisation program (Earth Systems, 2015). WBGEC-3 was located at the southern end of the deposit, south of a fault striking perpendicular to the deposit. Drilling was conducted by Star Drilling using a sonic drill rig that utilises high frequency (approximately 10 kHz) vibrations and rotation to drive a casing and core sleeve into the ground (Earth Systems, 2015). Core samples were recovered in polytetrafluoroethylene (PTFE) bags. Cores were geologically logged in the field and sub-divided into the following mine materials:

- Top-soil;
- Non-saline overburden (NSOB), classified as overburden above the water table;
- Saline overburden (SOB);
- Organic overburden (OOB); and
- Ore.

Samples for static geochemical analysis were collected at approximately 2 m intervals (or where there was a natural break in lithology). These samples were collected from the centre of the recovered cores[5] from the full 2 m interval to form a bulk sample. Each bulk sample was thoroughly mixed then representatively sub-sampled (approximately 1 kg) for laboratory analysis. Sub-samples were stored in ice boxes and later refrigerated for transport to an external laboratory (see Section 5.2.2 for details). 89 samples from the West Balranald deposit were submitted to an external analytical laboratory for static geochemical test work as part of the supplementary geochemical test work program.

Bulk samples of SOB (approximately 100 kg), OOB (approximately 300 kg) and ore (approximately 200 kg) were also collected for kinetic geochemical test work (see Section 5.2.2 for details). OOB and ore samples were vacuum sealed in PTFE within approximately 30 minutes of surface recovery to inhibit sulfide oxidation.

Bulk samples of ore and OOB were composites of the vacuum sealed drill core samples for oxygen diffusion test work. The bulk ore sample was composed from all of the ore collected from WBGEC-1 (37 vol.% of bulk sample), WBGEC-2 (34 vol.% of bulk sample) and WBGEC-3 (29 vol.% of bulk sample). The OOB bulk sample was a composite of WBGEC-1 intervals 48.5-65.5 m (45 vol.% of bulk sample) and WBGEC-2 intervals 48-59 m (55 vol.% of bulk sample).

Mining By-Products and Products

The sampling and geochemical characterisation of the MBPs and products allowed for the assessment of the AMD risk associated with key domains on-site including the TSF, MBP stockpiles, backfill material and product (ie. HMC and ilmenite) stockpiles.

Samples of the following Balranald mining-by products (MBPs) and products (Figure 33) were prepared by Iluka and provided to KCB and/or Earth Systems for geochemical characterisation:

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[5] A sampling method was employed to avoid chemical contamination from drilling muds and from the physical effects of the sonic drilling.

- Sand tails.
- Co-disposal slurry (ModCod slurry of sand tails (85 wt.% solids) and thickener underflow (15 wt.% solids))[6].
- Thickener underflow.
- The wet high intensity magnetic separation plant (WHIMS plant) process streams including:
  - WHIMS magnetics (comprised of predominantly ilmenite product and some non-magnetics).
  - WHIMS non-magnetics (HMC product) which will be transported to the Hamilton Mineral Separation Plant (MSP) for further processing.

Samples of the following Hamilton by-products were prepared by Iluka and provided to Earth Systems (numbers in brackets represent the relative proportions of each by-product stream):

- Primary Dry Circuit (PDC) ilmenite (53 wt.%).
- Combined monazite reject (10.5 wt.%).
- Hyti (leucoxene; 11.7 wt.%).
- Combined zircon wet tails (8.6 wt.%).
- Rutile wet concentrate circuit (0.9 wt.%).
- PDC conductors oversize (+410 µm; relative proportion not quantified).
- Float plant tails (11.3 wt.%).

5.2.2 Laboratory Test Work Programs

Laboratory test work conducted in the preliminary and supplementary geochemical characterisation programs included:

- Mineralogical test work to clarify the distribution of primary sulfides, secondary acid sulfate generating mineral species and carbonate minerals within the ore and overburden.
- Static geochemical test work to understand the potential magnitude of the AMD risk associated with key mine materials.
- Kinetic geochemical test work to characterise the potential rate of AMD generation associated with key mine materials.
- Test work to characterise the physical properties and potential reactivity of the key mine materials.
- Test work for classification of the Hamilton by-products with respect to NSW EPA waste classification guidelines.

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[6] Comparable proportions of sand tails and thickener underflow are expected to be produced during processing.

Analytical test work was conducted by NATA accredited laboratories including ALS Laboratories (Melbourne and Brisbane) and SGS Laboratories (Perth and Cairns). OxCon kinetic geochemical test work was undertaken at Earth Systems' laboratory in Melbourne.

A summary of the preliminary and supplementary laboratory test work is provided in Table 6 and Table 7. The various components of the programs are described in the following sections.

Table 6: Laboratory test work program employed for the preliminary geochemical characterisation program (KCB, 2012 and 2013).

Parameter category	Parameter suite	Sample numbers													
		West Balranald Deposit				Nepean Deposit			Balranald MBPs			Balranald Products		Hamilton MSP
		NSOB	SOB	OOB	Ore	NSOB	SOB	Ore	Thickener Underflow (slimes)	Sand Tails	ModCod	WHIMS Magnetics	WHIMS Non-Magnetics	Float Plant Tails
Preliminary geochemical test work program														
Static geochemical test work	1:5 Leach pH/EC	12		31	13	21		5	1	1	1	1	1	-
	Acid Base Accounting (ABA)[1]	12		31	13	21		5	1	1	1	1	1	-
	Net Acid Generation pH (NAG$_{pH}$)	12		31	13	21		5	1	1	1	1	1	-
	Chromium reducible sulfur (S$_{Cr}$)	12		31	13	21		5	1	1	1	1	1	-
	Major cations (Ca, Mg, Na, K)	12		31	13	21		5	1	1	1	1	1	-
	Major anions (SO$_4$, Cl, F)	12		31	13	21		5	1	1	1	1	1	-
	Standard metal suite (30 metals)	12		31	13	21		5	1	1	1	1	1	-
	Exchangable Cations	3		7	5	3		2	-	-	-	-	-	-
	Kinetic NAG	3		6	5	3		2	-	-	-	-	-	-
	X-Ray Diffraction (XRD)	4		10	6	5		3	1	1	1	1	1	-
	Shake Flask Extraction (SFE)	4		8	4	4		3	1	1	1	1	1	-
	Synthetic Precipitation Leaching Procedure (SPLP)	-		-	-	-		-	1	1	1	1	1	1

Parameter category	Parameter suite	Sample numbers												
		West Balranald Deposit				Nepean Deposit			Balranald MBPs			Balranald Products		Hamilton MSP
		NSOB	SOB	OOB	Ore	NSOB	SOB	Ore	Thickener Underflow (slimes)	Sand Tails	ModCod	WHIMS Magnetics	WHIMS Non-Magnetics	Float Plant Tails
	Toxicity Characteristic Leaching Procedure (TCLP)	-		-	-	-		-	-	-	-	-	-	1
Kinetic geochemical test work	Humidity Cells	1		4	3	2		2	1	1	1	1	1	-
	Humidity Cells (De-ionised Water Leach)	1		4	3	2		2	1	1	1	1	1	-
	Humidity Cells (Saline Leach)	1		1	2	1		1	-	1		-	-	-
Physical / Geotechnical Parameters	Particle Size Distribution (PSD)	4		6	5	3		2	-	-	-	-	-	-
	PSD Sieve Analysis	4		6	5	3		2	-	-	-	-	-	-
	Sieve Sedimentation Hydrometer	4		6	5	3		2	-	-	-	-	-	-

Notes: 1. Total S, ANC, MPA, Net Acid Production Potential (NAPP) and Neutralisation Potential Ratio (NPR).

Table 7: Laboratory test work program employed for the supplementary geochemical characterisation program (Earth Systems, 2015).

Parameter category	Parameter suite (refer to text for more details)	Sample numbers														
		West Balranald Deposit			West Balranald MBPs			West Balranald Products			Hamilton MSP					
		NSOB	SOB	OOB	Ore	Thickener Underflow	Sand Tails	Mod-Cod	WHIMS Magnetics	WHIMS Non-Magnetics	PDC Ilmenite	Combined monazite reject	Hyti (leuc-oxene)	Combined ziron wet tails	Rutile wet concentrate circuit	Float plant tails
Static AMD Test work	Net Acid Production Potential (NAPP) Suite[1]	11	43	32	8	1	1	1	1	1	1	1	1	1	1	1
	Net Acid Generation (NAG) Suite[2]	11	43	32	8	1	1	1	1	1	-	-	-	-	-	-
	Sulfur Speciation[3]	-	43	-	-	1	1	1	1	1	-	-	-	-	-	-
	Carbon Speciation[4]	-	-	32	8	1	1	1	1	1	-	-	-	-	-	-
	X-Ray Diffraction (XRD)	-	1	1	3	1	1	1	1	1	-	-	-	-	-	-
Kinetic AMD Test work	Oxygen consumption method (OxCon)[5]	-	1	5	5	1	1	1	1	1	-	-	-	-	-	-
	Oxygen diffusion profile[5]	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Physical / Geotechnical Parameters	Particle Size Distribution (PSD)	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-
	Physical Parameters (bulk density, particle density, porosity)	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-

Notes:
1. Total S, ANC and NAPP.
2. NAG pH, NAG 4.5 and NAG 7.0.
3. Sulfate-S, S_{CR} and S_{TOS}.
4. TOC, Total C and TIC.
5. Refer to Section 5.3 for kinetic test work methods.

Physical test work

Particle size distribution (by sieves and hydrometer) was analysed at SGS' Perth Laboratory for selected samples (Table 6) in the preliminary geochemical characterisation program in order to understand the potential chemical reactivity of the materials (KCB, 2012).

In the supplementary geochemical test work program (Earth Systems, 2015; Table 7), the physical properties of the bulk OOB and ore were analysed to support the kinetic test work interpretation and the development of AMD management options. Representative sub-samples collected from the bulk OOB and ore samples were submitted to ALS' Brisbane Laboratory for analysis of:

- Particle size distribution.
- Particle density (γ_p).
- Soil water content (θ, gravimetric).

Additional physical properties were measured by Earth Systems' Melbourne Laboratory (bulk density, porosity) and calculated during the OxCon kinetic test work program (discussed below).

Static geochemical test work

Representative sub-samples of material from the preliminary geochemical characterisation program (Table 6) were submitted for X-Ray Diffraction (XRD) by Microanalysis Australia (KCB, 2012) for mineralogical analysis.

Representative sub-samples of SOB, OOB and ore materials were also analysed by XRD by Federation University in Ballarat for the supplementary geochemical test work program (Earth Systems, 2015; Table 7). Mineralogical data assisted with the identification and quantification of relative proportions of key acid generating and acid neutralising minerals as well as weathering processes affecting the mobilisation of heavy metals and acidity.

As part of the preliminary geochemical program (KCB, 2012), samples were analysed for:

- 1:5 leach pH and electrical conductivity (EC);
- Net Acid Producing Potential including:
  - Sulfur (S) determination, including sulfate S, sulfide S and total S;
  - Chromium reducible S (S_{cr});
  - Maximum Potential Acidity (MPA = Total S x 30.6, kg H_2SO_4 / tonne);
  - Acid Neutralising Capacity (ANC, kg H_2SO_4 / tonne);
  - Net Acid Producing Potential (NAPP = MPA - ANC, kg H_2SO_4 / tonne); and
  - Neutralisation Potential Ratio (NPR).
- pH after oxidation (NAG pH, pH units);
- Major cations and ions (Ca, Mg, Na, K, Cl, F and SO_4)
- Elemental composition (aqua regia digest) for trace metals by ICP-MS or ICP-AES (Ag, As, Ba, Be, Bi, Cd, Co, Cr, Cs, Cu, Fe, Li, Mn, Mo, Nb, Ni, Pb, Rb, Sb, Se, Sn, Sr, Te, Th, Tl, U, W, Zn and Zr).

Selected samples (Table 6) were analysed for:

- Shake flask extraction (SFE) to determine the readily leachable materials and the likelihood of leaching, by simulating dissolution of soluble mineral phases.
- Kinetic NAG, to provide a first order indication of the kinetics of sulfide oxidation, acid generation and ANC in the sample.

The Balranald MBPs (thickener underflow, ModCod and sand tails), products (WHIMS magnetics and non-magnetics) and float plant tails derived from the Hamilton MSP, were analysed for synthetic precipitation leaching procedure (SPLP). The Hamilton float plant tails were also analysed for the toxicity characteristic leaching procedure (TCLP).

As part of the supplementary geochemical test work program (Earth Systems, 2015; Table 7), samples were analysed for:

- Net Acid Producing Potential including:
    - Total sulfur (Total S);
    - MPA;
    - ANC;
    - NAPP.
- NAG including:
    - pH after oxidation (NAG pH, pH units);
    - Net Acid Generation at pH 4.5 (NAG4.5, kg H_2SO_4 / tonne);
    - Net Acid Generation at pH 7.0 (NAG7.0, kg H_2SO_4 / tonne).

OOB and ore samples were also analysed for carbon speciation to characterise the carbon content, which has potential to assist in promoting chemical reducing conditions in unsaturated material and may play an important role in AMD management. Carbon speciation test work included:

- Total Carbon (TC, wt.% C).
- Total Organic Carbon (TOC, wt.% C).
- Total Inorganic Carbon (TIC = TC - TOC, wt.% C).

SOB samples were also analysed for sulfur speciation (at lower detection levels than XRD) to better define the nature of the sulfur bearing minerals within the samples. Sulfur speciation test work included:

- Chromium reducible sulfur (S_{Cr}, wt.% S).
- Sulfate sulfur (by HCl digestion, reported as wt.% S-equivalent).

Sub-samples of SOB, OOB and ore bulk samples were subjected to additional analyses to support kinetic test work as follows:

- Elemental composition by XRF (for Al, Ca, Ba, Cr, Fe, K, Mg, Mn, Na, P, Si, S, Sr, Ti, V, Zn, and Zr).
- Elemental composition (aqua regia digest) for trace metals by ICP-MS (for Sb, As, Be, B, Cd, Co, Cu, Pb, Mo, Ni, Se, Ag, and Sn).

- NAG leachate major and trace element composition (for Al, Sb, As, Bi, B, Ca, Cd, Cl, Cr, Co, Cu, F, Fe, Pb, Hg, Mg, Mn, Mo, Ni, P, K, Se, Ag, Na, SO_4, Te, Tl, Sn, U, V and Zn).

Summary laboratory methods for key static geochemical test work parameters are provided in Earth Systems (2015).

Quality Assurance / Quality Control (QA / QC)

In addition to the quality assurance / quality control (QA/QC) procedures implemented by the external laboratories, the following QA/QC protocols were implemented as part of the supplementary geochemical characterisation program (Earth Systems, 2015):

- Three duplicate samples were submitted to ALS' Brisbane Laboratory (NATA accredited) and analysed for the same parameter suite as the corresponding primary samples.
- Four duplicate SOB samples were submitted to SGS laboratories in Cairns (NATA accredited) for analysis of chromium reducible sulfur (S_{Cr}). S_{Cr} is considered a key parameter in assessment of the AMD risk of the SOB, hence these samples were analysed to increase confidence in S_{Cr} results.
- One sample of crustal material from the edge of the recovered sonic drill core was collected and analysed for Total Organic Carbon, to investigate the potential for sample contamination from drilling muds.

Kinetic Geochemical Test Work – Humidity Cell Method

Significant kinetic test work was conducted on OOB and ore via humidity cell test work (KCB, 2013). One SOB sample was also tested. The humidity cells were established and conducted by SGS's Perth laboratory, for selected samples (Table 6), in accordance with the standard procedure outline by Price (MEND, 2009) and the GARD Guide (INAP, 2009). Leaches were conducted with deionised water; duplicate leaches were conducted for selected samples using saline groundwater for materials expected to be backfilled to the mine voids.

Humidity cell set-up included (KCB, 2013):

- Approximately 1 kg of test sample was placed in the cell and arranged with a flat surface.
- The test samples were wetted and flushed / rinsed during the 1st week. This was followed by a weekly cycle of dry air (3 days), humid air (3 days) and flushing (7th day flushed with 500 ml of distilled water), which was repeated.
- Leachate water collected from the outlet at the bottom of the test cell for analysis.
- Analysis of leachate for pH, sulfate, EC, acidity, alkalinity and metals.
- Humidity cells were operated for a period of 20 weeks.

Pyrite oxidation rates (PORs) were calculated based on acidity and sulfate release rates from the humidity cell results. Leachable elements that may have adverse impacts on receiving water quality were also identified from the humidity cell results.

Kinetic Geochemical Test Work – Oxygen Consumption Method

Kinetic test work via an oxygen consumption method (OxCon) was conducted at Earth Systems' Melbourne Laboratory on SOB, OOB, ore and MBPs, to supplement the KCB (2013) data, in order to:

- Confirm the static geochemical characterisation results for SOB.
- Support assessment of the AMD risk of OOB in pit walls and stockpiled ore.
- Quantify the AMD risk associated with MBPs prior to and during disposal.
- Investigate the role of the oxidation of organic carbon in minimising sulfide oxidation.
- Develop an understanding of the time before the on-set of acidic conditions (i.e. the lag-time) and the expected duration of sulfide oxidation processes.
- Inform the development of appropriate management strategies on site.

The OxCon method was chosen as it was able to generate results within the project timeframe and allowed for more accurate measurement of the POR and the behaviour of organic carbon within the sample.

The oxygen consumption rate (when CO_2 is removed) is measured and converted to the POR of a sample[7]. There are various sample characteristics that influence the POR, including the sulfide mineralogy, particle size distribution, moisture content, pH and bacterial activity. The time frame at which sufficient acidity is generated to exhaust the amount of available ANC of a sample is referred to as the 'lag time' (see Section 4.7).

Representative sub-samples (approximately 5 kg) of SOB, OOB and ore, collected from the respective material bulk samples and were each placed in an OxCon apparatus (Figure 19) and the oxygen concentration measured over time. As these samples contain organic carbon, carbon dioxide released during oxidation of the organic carbon was also measured to allow for the dilution of oxygen concentration within the apparatus.

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[7] Pyrite oxidation rates can be expressed as a weight percent of exposed pyrite oxidised per unit time (eg. wt.% FeS_2/year or wt.% FeS_2/week) or other commonly used intrinsic oxidation rate units such as kilograms of oxygen consumed per kilogram of material per second (kg O_2/kg/sec) or kilograms of sulfur oxidised per kilogram of material per year (kg S/kg/year). Expressing the POR in wt.% FeS_2 per unit time (eg. wt.% FeS_2/year or wt.% FeS_2/week), normalised to the samples sulfide content, allows comparison of results between samples with different sulfide contents and also allows simple application of the results to estimate annual acidity generation rates for representative rocks with differing sulfide contents.

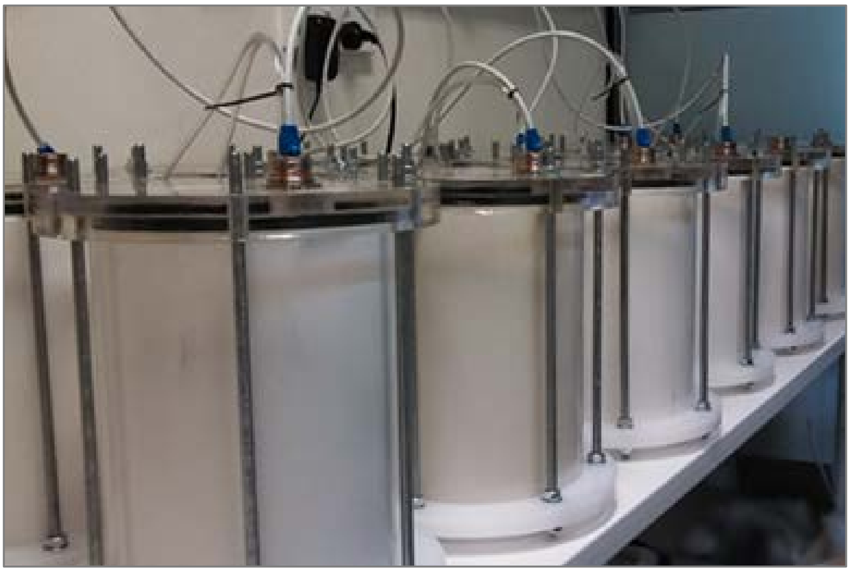

Figure 19: Photograph of OxCon apparatus.

As part of OxCon test work, a sub-sample of each of the materials for the OxCon tests was leached via a bottle roll test with deionised water for 24 hours. A sub-sample of leachate was collected for each OxCon sample and dispatched to ALS laboratories in Melbourne for analysis of the following parameters:

- pH.
- Electrical conductivity (EC).
- Alkalinity (mg $CaCO_3$/L equivalent).
- Major cations: Na, K, Ca, Mg.
- Major anions: Cl, $SO_{4.}$
- Dissolved metals: Al, Sb, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, Se, Ag and Zn.

Additional oxygen consumption test work was undertaken to identify the effect of moisture content on sulfide mineral oxidation within the ore and OOB, to support the investigation into the AMD potential of these materials. The moisture content can have a key role in limiting oxygen flux into a soil by partially filling void spaces with water, which lowers the gas permeability of the material.

Six representative sub-samples of both ore and OOB were collected from the respective material bulk samples. The moisture content of the samples was modified to simulate moisture contents between the field capacity (as received) and relatively dry conditions. Samples were oven dried at 40 °C so as not to significantly enhance sulfide decomposition, until their target moisture content was achieved. Ore sub-samples were tested at 13.8 (as collected), 12, 10, 8, 6 and ~0.1 wt.% water. OOB samples were tested at 19.9 (as collected), 16, 8, 6, 4 and 1.1 wt.% water.

OxCon test work was also undertaken for the Balranald MBPs and products. Three sub-samples of thickener Underflow were tested at 8, 21, and 57 wt.% (as received) water, and seven sub-samples of ModCod was tested at a range of water contents between 2 and 25 wt.% (as received) water and also at depths within the vessel to investigate the degree of oxidation as a function of sample depth in fine grained materials.

POR with depth was also measured for five sub-samples of sand tails (5, 10, 15 and 20 cm depth). Both WHIMS magnetic and non-magnetic stream samples were tested as received at 14 wt.% water. The WHIMS non-magnetic stream samples were also tested at two sample depths (2 and 6 cm depth). The different depths were examined to conduct an initial assessment of oxygen depth penetration into these materials.

Table 8: Summary table of the Balranald MBPs and products contents tested using the OxCon method.

Material	Sample Depth Tested (cm)	Sample Gravimetric Moisture Content (GMC)
Balranald MBPs		
Sand tails	5	19 wt.% water
	10	
	15	
	20	
Thickener underflow (slimes)	N/A	8 wt.% water
		21 wt.% water
		57 wt.% water
ModCod	5	25 wt.% water
	8	
	17	
	5	10 wt.% water
	8	
	17	
	5	1 wt.% water
	8	3 wt.% water
Balranald Products		
WHIMS magnetics	N/A	14 wt.% water
WHIMS non-magnetics	2	14 wt.% water
	8	

Kinetic Geochemical Test Work – Oxygen Diffusion Profiles

A laboratory test work program was developed to measure the oxygen consumption and reactive depth of the ore and OOB materials under free draining conditions to simulate conditions that will be encountered upon dewatering and exposure of the material to atmospheric oxygen. The scenarios tested were:

- Pit walls containing OOB.
- Ore stockpiles.

Two tests were commissioned to measure the oxygen concentration gradients within a bulk sample of OOB and ore. Bulk samples were composed from the vacuum sealed drill core samples. The bulk ore sample was composed of ore material collected from WBGEC-1 (37 vol.% of bulk sample), WBGEC-2 (34 vol.% of bulk sample) and WBGEC-3 (29 vol.% of bulk sample). The OOB bulk sample was composed of WBGEC-1 intervals 48.5-65.5 m (45 vol.% of bulk sample) and WBGEC-2 intervals 48-59 m (55 vol.% of bulk sample). Each bulk sample was thoroughly mixed then compacted to the maximum practicable wet bulk density achievable, to approximate the in-situ undisturbed density of the materials. The physical properties of the bulk samples, as used for testing, are shown in Table 9.

Table 9: Physical properties of bulk ore and OOB samples used for oxygen diffusion profile laboratory test work (Earth Systems, 2015).

Parameter	Unit	Ore	OOB	Basis
Bulk Sample Mass (wet)	kg	175	140	Measured
Bulk Sample Mass (dry)	kg	155	118	Calculated
Bulk density (wet)	t/m^3	2.5	2.0	Measured
Bulk density (dry)	t/m^3	2.21	1.68	Calculated
Particle density	t/m^3	3.2	2.65	Calculated
Porosity	-	22%	26%	Measured
Moisture Content (as received)	wt.% water (GMC)[2]	13%	19%	Measured
	% saturation	>95%	>95%	Calculated

Notes: 1. Particle density calculated based on mineralogy results and mineral densities obtained from literature.
2. GMC = Gravimetric Moisture Content.

5.2.3 AMD Risk Classification

Earth Systems used AMDact v4.03[8] to assign AMD risk classifications to the materials based on the reported acid-base accounting data (Total S, ANC, NAPP, NAG_{pH}, $NAG_{4.5}$ and $NAG_{7.0}$). The samples were classified by AMDact into the general and detailed categories outlined in Table 10.

A series of graphs of measured parameters were also generated to identify key trends including indicative sulfur cut-off values that separate PAF and NAF materials and to identify relationships between lithologies and AMD risk classification.

Table 10: AMD risk classifications determined by AMDact.

General AMD Risk Classification	Detailed AMD Risk Classification	
	Description	Detailed AMD Risk Classification ID
Potentially Acid Forming (PAF)	High Potential for Acid Generation	Category 1 (AG1)
	Moderate / High Potential for Acid Generation	Category 2 (AG2)
	Moderate Potential for Acid Generation	Category 3 (AG3)
	Low Potential for Acid Generation	Category 4 (AG4)
Non Acid Forming (NAF)	Unlikely to be Acid Generating	UAG
	Likely to be Acid Consuming	LAC

5.3 Site Water Balance and Hydrogeology

A site water balance and surface water management report was prepared by WRM (2015). The project water balance figures (operations and post-closure) were assessed in order to understand the movement and management of water around the project area during operations and post-closure. The water balance figures were used in this geochemistry assessment in the preparation of estimates for the movement of solute loads (derived from project materials geochemistry only) around site and off-site during operations and post-closure.

Groundwater modelling was conducted by Jacobs (2015) including an assessment of dewatering rates and the extent of groundwater drawdown surrounding the mine voids. This data provides an indication of volumes of material likely to be de-saturated during operations and post-closure. Assumptions regarding the penetration of oxygen into de-saturated materials (based on test work as described in Section 5.2.2) were made to determine the volume of de-saturated material that has the potential to generate AMD during operations and post-closure.

The groundwater modelling results were reviewed in this geochemistry assessment to provide a general indication of the potential rate of migration of solute loads (associated with AMD from sulfidic mine materials only) through the groundwater system during operations and post-closure.

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[8] Acid and Metalliferous Drainage Assessment and Classification Tool (AMDact) v.4.03 produced by Earth Systems.

5.4 Impact Assessment

An assessment of potential AMD impacts on surface and groundwater quality was completed for the three phases of the Balranald Project: construction, operations and post-closure.

Table 11 and Table 12 outline the definitions of the likelihood and consequences used to assess the level of potential AMD related impacts. Table 13 outlines the matrix used to assign impact ratings for each potential impact.

Iluka's current management approaches to mitigate potential AMD related impacts have been identified in this report. Additional management options are also identified that are primarily intended to improve the efficiency and cost-effectiveness of AMD management for Iluka, and may assist with further lowering the residual AMD risks associated with the project.

The residual impacts have been quantified, assuming that Iluka's current AMD management approaches are fully and effectively implemented throughout all phases of project development. The overall score for the residual impacts for each potential source of AMD were calculated using the likelihood / consequence definitions and matrix in Table 11, Table 12 and Table 13.

The impact ratings are based on estimated AMD generation rates, where available, and the subsequent implications for water resource use, aquatic ecosystems or riparian land. Hence, for the purpose of this assessment, AMD generation itself is not considered an impact; an "impact" refers to AMD generation that leads to acidity dissolution in surface water or groundwater to the extent that the receiving environment may be adversely affected.

The impact assessment considers both the West Balranald and Nepean deposits (as well as other project facilities) but has a focus on West Balranald based on the following:

- Preliminary geochemical data indicates that the Nepean deposit does not contain significant quantities of sulfidic minerals, and therefore is likely to represent a lower AMD risk than the West Balranald deposit (refer to Section 6).
- The Nepean deposit is closer to the surface and considerably smaller than the West Balranald deposit. Therefore, the extent of disturbance and duration of mining at Nepean will be less than at West Balranald.

This impact assessment excludes all potential impacts to surface water and groundwater quality that are not related to sulfide oxidation (eg. salinity, turbidity, nutrients, hydrocarbons, organics, process chemicals and radioactivity as these are addressed elsewhere in the EIS (EMM, 2015d).

Table 11: Definitions used to assign likelihoods for each potential and residual AMD impact (Iluka, 2015b).

Rating	Description	Likelihood of occurrence	Frequency
A	Almost Certain	Recurring event during the life of the mine	Likely to occur more than twice a year
B	Likely	Event that may occur frequently during the life of the mine	Likely to occur once or twice a year
C	Possible	Event that may occur during the life of the mine	Might occur once a decade
D	Unlikely	Event that is unlikely to occur during the life of the mine but may occur following mine closure	Possibility to occur once a century
E	Very unlikely	Event that is very unlikely to occur during the life of the mine and is unlikely to occur following mine closure	Unlikely to occur within a century

Table 12: Definitions used to assign consequences for each potential and residual AMD impact (Iluka, 2015b).

Rating	Description	Health and Safety	Environment	Community	Project Interruption	Reputation and Image
1	Insignificant	Local treatment with short recovery-minor short term health effects	Onsite release, containable with minimal damage	No damage to external property, infrastructure or water assets	Negligible Critical systems unavailable for less than one hour	Negligible impact
2	Minor	Medical treatment required for short term acute health effects	Major onsite release with some damage, no offsite damage Remediation in terms of days	Minor damage to external property, infrastructure or water assets	Inconvenient Critical systems unavailable for several hours	Adverse local media coverage only
3	Moderate	Lost Time Injury (off work recovery required) or short/medium term health issues	Offsite release, no significant environmental damage Remediation in terms of weeks	Moderate damage to external property, infrastructure or water assets	Critical systems unavailable for less than one day	Adverse capital city media coverage
4	Major	Extensive injuries or chronic health issues	Major offsite release, short to medium term environmental damage to nationally significant ecosystem Remediation in terms of months	Major damage to external property, infrastructure or water assets	Critical systems unavailable for one day or a series of prolonged outages	Adverse and extended national media coverage
5	Catastrophic	Single fatality or permanent disability	Major offsite release, long term environmental damage to nationally or internationally significant ecosystem Remediation in terms of years	Irreparable damage to external property, infrastructure or water assets	Critical systems unavailable for more than a day (at a crucial time)	Demand for government inquiry

Table 13: Matrix used to assign impact ratings for each potential and residual AMD impacts (Iluka, 2015b).

		Consequence				
		1 - Insignificant	2 - Minor	3 - Moderate	4 - Major	5 - Catastrophic
Likelihood	A - Almost Certain	Medium	Medium	High	High	High
	B - Probable	Low	Medium	Medium	High	High
	C - Possible	Low	Medium	Medium	Medium	High
	D - Unlikely	Low	Low	Medium	Medium	High
	E - Very Unlikely	Low	Low	Low	Medium	Medium

1. Since the impact assessment was completed, Iluka has revised their impact assessment categories. Any future work in assessing the impacts associated with AMD will be completed using the updated categories.

6.0 Characterisation of Mine Materials

This section presents the mine material characterisation results for overburden (Section 6.1), ore (Section 6.2), MBPs (Section 6.3) and products (Section 6.4). These results are based on geochemistry characterisation reports by KCB (2012; 2013) and Earth Systems (2015) and laboratory reports contained therein.

A summary of the key results is presented in Section 6.5.

6.1 Overburden

Overburden materials, including NSOB, SOB and OOB, will form part of the following project domains:

- Overburden stockpiles;
- Overburden material backfilled to the mine void;
- Exposed and de-saturated pit wall / bench material; and
- De-saturated material surrounding dewatering bores.

The physical properties for the bulk OOB and SOB samples are provided in Table 14. The particle size distribution of SOB and OOB bulk samples used for kinetic geochemical test work are provided in Figure 20. These results show that the SOB and OOB had very similar characteristics and are characterised as fine to medium sands with minor silt content.

Table 14: Particle size and density results.

Sample[1]	Particle Density (g / cm^3)	Classification	D10 (µm)	D50 (µm)	D90 (µm)
OOB	2.65	Sand and silt	62	212	395
SOB	2.67	Sand	78	208	425
Ore	3.37	Sand and silt	56	131	230

Notes: 1. Physical test work was carried out on one composite sub-sample for each material.

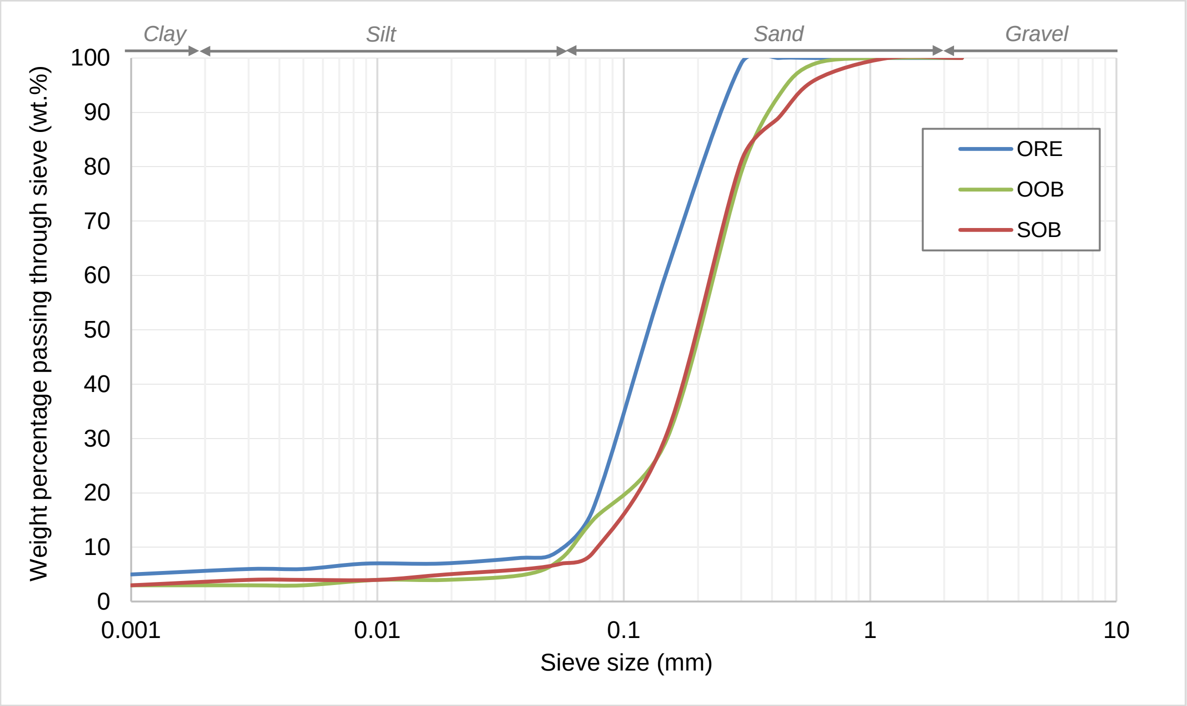

Figure 20: Particle size distribution for SOB, OOB and ore bulk samples used for kinetic geochemical test work.

The results of the static and kinetic geochemical characterisation test work for the overburden materials from the West Balranald and Nepean deposits are described in detail in Section 6.1.1 to 6.1.3. Static and kinetic geochemical laboratory results are provided in Earth Systems (2015).

The AMD risk classifications, based on static geochemical test work, for West Balranald and Nepean deposit overburden, are summarised in Table 15 and Table 16.

Key results from the AMD risk classification of overburden samples from the West Balranald deposit include:

- All of the NSOB and SOB samples tested were classified as NAF.
- 98% of the OOB samples tested (52 of 53 samples) were classified as PAF.
- Of the PAF OOB samples:
  - Approximately 12% of samples were classified as having a high potential for acid generation (AG1) based on high sulfur contents and low ANC.
  - Approximately 23% of samples were classified as having a moderate potential for acid generation (AG3) based on moderately elevated sulfur contents and low ANC.
  - Approximately 65% of samples were classified as having a low potential for acid generation (AG4) based on low sulfur contents and low ANC.

Table 15: AMD risk classification for overburden materials at the West Balranald deposit.

General AMD Risk Classification	Detailed AMD Risk Classification		Number of samples		
	Description	Detailed AMD Risk Classification ID	NSOB	SOB	OOB
Potentially Acid Forming (PAF)	High Potential for Acid Generation	Category 1 (AG1)	-	-	6
	Moderate / High Potential for Acid Generation	Category 2 (AG2)	-	-	-
	Moderate Potential for Acid Generation	Category 3 (AG3)	-	-	12
	Low Potential for Acid Generation	Category 4 (AG4)	-	-	34
Total number of PAF Samples			-	-	52
Non Acid Forming (NAF)	Unlikely to be Acid Generating	UAG	13	50	1
	Likely to be Acid Consuming	LAC	-	-	-
Total number of NAF Samples			13	50	1

Key results from the AMD risk classification of overburden samples from the Nepean deposit include:

- 95% of the NSOB samples tested (22 of 23 samples) were classified as NAF.
- The one PAF sample of NSOB was classified as having a low potential for acid generation (AG4) based on a low sulfur content and low ANC.

Table 16: AMDrisk classification for overburden at the Nepean deposit.

General AMD Risk Classification	Detailed AMD Risk Classification		Number of samples
	Description	Detailed AMD Risk Classification ID	NSOB
Potentially Acid Forming (PAF)	High Potential for Acid Generation	Category 1 (AG1)	-
	Moderate / High Potential for Acid Generation	Category 2 (AG2)	-
	Moderate Potential for Acid Generation	Category 3 (AG3)	-
	Low Potential for Acid Generation	Category 4 (AG4)	1
Total number of PAF Samples			1
Non Acid Forming (NAF)	Unlikely to be Acid Generating	UAG	22
	Likely to be Acid Consuming	LAC	-
Total number of NAF Samples			22

6.1.1 Non-Saline Overburden

West Balranald

Field pH_{paste} and NAG pH profiles for West Balranald are graphed in Figure 21. Summary statistics for the West Balranald NSOB static geochemistry laboratory results are presented in Table 17. Key results of the field and laboratory test work programs include:

- Field pH_{paste} results ranged from approximately 5.6 to 8.8, indicating that the NSOB contains no appreciable acid-storing secondary salts (eg. jarosite) that can be common reaction products of AMD generation and neutralisation reactions.
- Total S is low for the NSOB with an average value of 0.06 wt.% S (see Table 17). This sulfur is likely present as secondary sulfate salts, rather than primary sulfide minerals, in the NSOB. This is supported by the very low S_{Cr} values reported for NSOB (average 0.009 wt.% S).
- The average sulfate (SO_4) S value for the NSOB was 0.031 wt.% S. This sulfate is likely attributed to sulfate present in the groundwater that remained in the sample as pore water.
- Total Oxidisable Sulfur (S_{TOS}) values are very low in the NSOB (average 0.034 mg/L). S_{TOS} should equal the S_{Cr} value as these laboratory methods both determine the sulfide-sulfur content of a sample. The reason for the poor correlation between these two parameters is not clear, however it may be attributed to incomplete digestion of sparingly soluble alunite in some samples, or a matrix interference during S_{Cr} test work.
- The average Total S concentration equates to an average MPA value of 1.7 kg H_2SO_4/t for the NSOB.
- ANC values are low throughout the NSOB. The highest ANC values in the deposit were in the NSOB, and are thought to be due to carbonate formation in the topsoil layers. The average ANC for the NSOB was 2.9 kg H_2SO_4/t.
- Average NAPP for the NSOB was -1.7 kg H_2SO_4/t (ie. NAF) when based on S_{TOS} which can be considered more conservative than using S_{Cr} and more realistic than NAPP when based on Total S. NAG results support the NAPP data, with no NAG pH values below 4.5 and an average NAG pH value for the NSOB of 7.1.

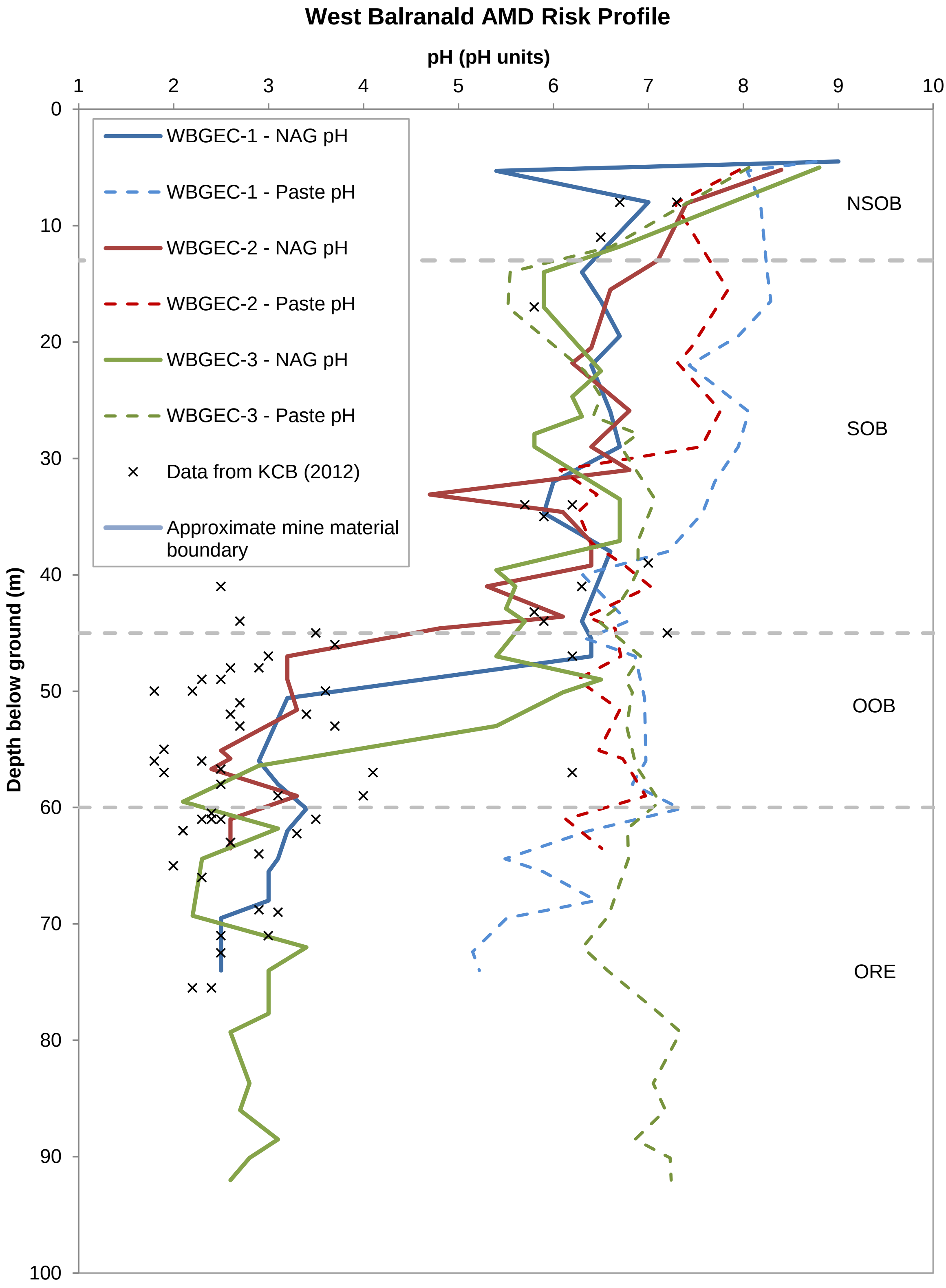

Figure 21: NAG pH and Paste pH (field) profile for the West Balranald deposit. Note that material intersections shown are approximate as these will vary with the strike of the deposit (Earth Systems, 2015).

Table 17: Field pH, Sulfur speciation, carbon speciation, acid-base accounting and NAG statistics for the West Balranald NSOB from the KBC (2013) and Earth Systems (2015) geochemical characterisation programs.

Statistic	Field Parameters		Sulfur Speciation				Carbon Speciation			Acid-Base Accounting						Net Acid Generation		
	Paste pH (1:5)	pH_{fox}	Total S	S_{Cr}	S as Sulfate	S_{TOS}	Total C	Total Organic Carbon (TOC)	Total Inorganic Carbon (TIC)	MPA (based on Total S)	MPA (based on S_{TOS})	ANC	NAPP (based on Total S)	NAPP (based on S_{TOS})	ANC / MPA Ratio	NAG pH	NAG 4.5	NAG 7.0
	pH units	pH units	wt.%S	wt.%S	wt.%S-eq	wt.%S	wt.% C	wt.% C	wt.% C	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	-	-	kg H_2SO_4/t	kg H_2SO_4/t
Count	12	13	13	3	3	3	-	-	-	13	3	13	13	3	13	13	13	13
Minimum	5.55	3.10	0.03	0.006	0.020	0.008	-	-	-	0.9	0.2	0.3	-6.0	-3.7	0.1	5.4	0.1	0.1
Maximum	8.77	7.88	0.09	0.011	0.050	0.071	-	-	-	2.8	2.2	7.5	1.6	0.8	9.8	9.0	0.3	1.6
Average	7.61	6.22	0.06	0.009	0.031	0.034	-	-	-	1.7	1.0	2.9	-1.1	-1.7	2.5	7.1	0.1	0.4
Median	7.80	6.58	0.06	0.011	0.022	0.023	-	-	-	1.8	0.7	2.0	-0.8	-2.2	1.5	7.0	0.1	0.3
Standard Deviation	0.85	1.49	0.02	0.003	0.017	0.033	-	-	-	0.6	1.0	2.4	2.3	2.3	2.9	1.1	0.1	0.5
Relative Standard Deviation (RSD)	11%	24%	36%	31%	54%	97%	-	-	-	36%	97%	84%	207%	133%	113%	15%	91%	126%

Nepean

Summary statistics for the Nepean NSOB static geochemistry laboratory results are presented in Table 18**Error! Reference source not found.**. Key results of the field and laboratory test work programs include (KCB, 2012):

- Both NSOB samples were dominated by quartz (SiO_2). The shallow overburden sample (sample depth 5.1 – 5.3 m) also contained zircon ($ZrSiO_4$) (4.9 wt.%), kaolinite ($Al_2Si_2O_5(OH)_4$) (2.8 wt.%), chamosite ($(Fe,Mg)_5Al(AlSi_3O_{10})$) (1.4 wt.%) and rutile (TiO_2) (1.0 wt.%).
- Total S was low for the NSOB samples with an average value of 0.03 wt.% S. The sulfur is likely present as secondary sulfate salts in the non-saline portion of the overburden. This assertion is supported by the very low S_{Cr} values reported for these materials (average 0.03 wt.% S for the overburden).
- The average Total S concentration equates to the very low average MPA value of 0.7 H_2SO_4/t.
- The average Sulfate (SO_4) concentration for NSOB was 330 mg SO_4/kg (approximately 0.03 wt.% S equivalent).
- ANC values are low throughout the Nepean NSOB, with an average of 3.7 kg H_2SO_4/t. Two high ANC values were observed, one at 5 metres below ground level (mbgl) and the second at 46.8 mbgl. The high ANC value of the shallow sample is thought to be due to carbonate formation in the topsoil layers.
- The average NAPP value was -3.0 kg H_2SO_4/t, when based on S_{TOS} which can be considered more conservative than using S_{Cr} and more realistic than NAPP based on Total S. NAG results support the NAPP, with an average NAG pH value of 6.0.
- The one PAF sample had a NAPP of only 1.3 kg H_2SO_4/t and a NAG pH of 4.5.

Table 18: Sulfur speciation, carbon speciation, acid-base accounting and NAG statistics for the Nepean NSOB from the KCB (2012) geochemical characterisation program.

Statistic	Sulfur Speciation				Acid-Base Accounting				Net Acid Generation		
	Total S	S_{Cr}	S as Sulfate	S_{TOS}	MPA (based on S_{TOS})	ANC	NAPP (based on S_{TOS})	ANC/MPA Ratio	NAG pH	NAG 4.5	NAG 7.0
	wt.%S	wt.%S	wt.%S-eq	wt.%S	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	-	-	kg H_2SO_4/t	kg H_2SO_4/t
Count	23	1	23	23	23	23	23	23	23	23	23
Minimum	0.01	0.030	0.005	0.01	0.3	0.5	-26	0.3	4.5	0.3	0.3
Maximum	0.09	0.030	0.10	0.06	1.9	26	1.3	49	9.5	0.3	1.3
Average	0.03	0.030	0.030	0.02	0.7	3.7	-3.0	5.2	6.0	0.3	0.4
Median	0.03	0.030	0.017	0.02	0.6	1.4	-0.8	2.1	5.7	0.3	0.3
Standard Deviation	0.02	-	280	0.01	0.4	6.8	6.7	10	1.0	0.0	0.3
Relative Standard Deviation	63%	-	92%	60%	60%	181%	-222%	194%	16%	0%	69%

Results from the kinetic geochemical characterisation of the NSOB conducted by KCB (2013) are provided in Table 19. This includes PORs, estimated by Earth Systems, calculated from the humidity cell test work (KCB, 2013). Key results include:

- Sulfate release rates for both the NSOB materials were low.
- Sulfate release rates were comparable to the West Balranald overburden samples.
- The calculated PORs ranged from 0.2-2.3 wt.% FeS_2 per week, indicating that the trace levels of sulfide present within the overburden, when exposed to atmospheric oxygen, will fully oxidise in somewhere between one to ten years.
- Concentrations of chromium (Cr) in the NSOB samples were elevated relative to average crustal abundance.
- Under the test conditions (neutral pH and an oxidising environment) no significant leaching of metals from the NSOB samples was observed. This was despite the elevated concentrations of Cr detected in the samples.

Table 19: Kinetic geochemical test results for NSOB based on humidity cell test work conducted by KCB (2013).

Material	Average Total S	Calculated average weekly sulfate release[1]	Indicative pyrite oxidation rate (POR)[3]
	wt.% S	mg SO_4 / kg / week	wt.% FeS_2 / week
NEPSCH3_5.1-5.3m	0.057	38.3	2.3%
NEPSCH1_30-31.5m	0.017	1.13	0.2%

Notes: 1. Values extracted from KCB (2013) – Figure 3-33 p. 41.

2. Calculated by Earth Systems based on pH and dissolved metals in humidity cell leachate.

3. POR: Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content) estimated by Earth Systems.

6.1.2 Saline Overburden

West Balranald

Mineralogy results for the West Balranald SOB material are presented in Table 20. Key results include:

- No primary or secondary acid generating minerals were present in levels above the detection limit (0.1 wt.%).
- No carbonate minerals were detected in the samples.
- Low quantities of the potassium (K) bearing mineral muscovite (<1 wt.%) were found in the SOB. Muscovite is sparingly acid consuming as its dissolution is thought to provide the potassium for the formation of alunite.

Table 20: Mineralogy results for composite SOB samples at West Balranald (Earth Systems, 2015).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)[1]
Albite	$NaAlSi_3O_8$	-	<1
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	-
Ilmenite	$FeTiO_3$	-	-
Kaolinite	$Al_2Si_2O_5(OH)_4$	-	1
Monazite	$(Ce,La)PO_4$	-	-
Muscovite	$KAl_2(Si_3Al)O_{10}(F,OH)_2$	Sparingly acid consuming	<1
Pseudorutile	$Fe_2Ti_3O_9$	-	-
Pyrite	FeS_2	Primary acid generating	-
Quartz	SiO_2	-	97
Rutile	TiO_2	-	-
Sodium Chloride	NaCl	-	<1
Zircon	$ZrSiO_4$	-	<1

Notes: 1. Mineralogy results are considered semi-quantitative and include only crystalline phases. The results are normalised to 100% of the crystalline phases present in the sample. Hence, the amorphous organic carbon is not included in the mineralogy results. Organic carbon only represents <1-5 wt.% of the samples on average.

Field pH_{paste} and NAG pH profiles for West Balranald are graphed in Figure 21. Summary statistics for the West Balranald SOB static geochemistry laboratory results are presented in Table 21. Key results of the field and laboratory test work programs include (KCB, 2012; Earth Systems, 2015):

- Field pH_{paste} results ranged from approximately 5.5 to 8.3, indicating that the SOB contained no appreciable acid-storing secondary salts (eg. jarosite) that can be common reaction products of AMD generation and neutralisation reactions.
- Total S is low for the SOB with an average value of 0.04 wt.% S. This sulfur is likely present as secondary sulfate salts and/or evaporatively concentrated sulfate from the groundwater. This is supported by the very low S_{Cr} values (average 0.00 wt.%S).

- The average sulfate-sulfur value for the SOB was 0.022 wt.% S. This is likely attributed to sulfate in the groundwater that remained in the sample as pore water.
- The average Total S concentration equates to a low average MPA value of 1.2 kg H_2SO_4/t.
- ANC values are low throughout the SOB, with an average of 0.8 kg H_2SO_4/t.
- The average NAPP value for the SOB was -0.2 kg H_2SO_4/t, when based on S_{TOS}, which can be considered more conservative than using S_{Cr} and more realistic than NAPP based on Total S. NAG results support the NAPP data for the SOB with no NAG pH values below 4.5 and a slightly acidic average NAG pH value of 6.1.

Table 21: Field pH, sulfur speciation, carbon speciation, acid-base accounting and NAG statistics for SOB at West Balranald (KCB, 2012; Earth Systems, 2015).

Statistic	Field Parameters		Sulfur Speciation				Carbon Speciation			Acid-Base Accounting						Net Acid Generation		
	Paste pH (1:5)	pH_{fox}	Total S	S_{Cr}	S as Sulfate	S_{TOS}	Total C	Total Organic Carbon (TOC)	Total Inorganic Carbon (TIC)	MPA (based on Total S)	MPA (based on S_{TOS})	ANC	NAPP (based on Total S)	NAPP (based on S_{TOS})	ANC/MPA Ratio	NAG pH	NAG 4.5	NAG 7.0
	pH units	pH units	wt.%S	wt.%S	wt.%S-eq	wt.%S	wt.% C	wt.% C	wt.% C	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	-	-	kg H_2SO_4/t	kg H_2SO_4/t
Count	43	49	50	49	49	49	-	-	-	50	49	50	50	49	50	50	50	50
Minimum	5.52	2.13	0.02	0.003	0.002	0.005	-	-	-	0.6	0.2	0.3	-1.1	-2.1	0.2	4.7	0.1	0.2
Maximum	8.29	7.89	0.07	0.012	0.045	0.046	-	-	-	2.1	1.4	2.3	1.6	0.9	1.9	7.2	0.3	6.0
Average	6.98	6.82	0.04	0.003	0.022	0.017	-	-	-	1.2	0.5	0.8	0.4	-0.2	0.7	6.1	0.1	1.1
Median	6.86	7.17	0.04	0.003	0.022	0.016	-	-	-	1.2	0.5	0.5	0.5	0.02	0.6	6.3	0.1	0.6
Standard Deviation	0.62	1.05	0.01	0.002	0.009	0.007	-	-	-	0.3	0.2	0.6	0.6	0.7	0.5	0.5	0.1	1.3
RSD	9%	15%	28%	65%	44%	43%	-	-	-	28%	43%	82%	132%	274%	68%	9%	90%	119%

The kinetic geochemical test work results are provided in Table 22 for the West Balranald SOB samples. SOB material is not expected to be encountered at the Nepean deposit. Key results from these data are:

- The trace levels of sulfide minerals present within the SOB are oxidising at a rate of 0.37-0.48 wt.% FeS_2 per week. Despite this, there is likely to be sufficient ANC (albeit low) to neutralise this acid as this material is classified as NAF.
- Significant carbon dioxide was released from the samples, which is likely due to the oxidation of some organic carbon, however it could also be due to the neutralisation of acid generated against the trace amounts of carbonate minerals that may be present. Carbon dioxide generation is likely to be beneficial, at least by diluting oxygen concentrations, thereby limiting potential for acid generation (Earth Systems, 2015).

The key results from leachate chemistry data for SOB samples irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that AMD was not released from the SOB sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was near-neutral (pH 7.4) with low dissolved metal concentrations. This data is consistent with the NAF classification.
- Elevated (sulfate) salinity, as indicated by an electrical conductivity (EC) of 9.2 mS/cm and sulfate concentration of 608 mg/L, is therefore primarily attributed to salinity from the groundwater (pore water) leaching from the sample (Earth Systems, 2015). This interpretation is consistent with the trends in EC and sulfate concentrations, and metal release rates, observed in leachate from humidity cell tests.

Table 22: Kinetic geochemical test work results for the SOB at West Balranald (KCB, 2013; Earth Systems, 2015).

Sample ID	Data Source	Total sulfur	Sulfide sulfur (S_{TOS})	MPA	ANC	GMC	Pyrite oxidation rate (POR)[1]	Indicative time to oxidise 90% of pyrite in exposed material[2]	Estimated lag time to onset of acid conditions[3]	Acid Generation Rate (AGR)
		wt.% S	wt.% S	kg H_2SO_4/t	kg H_2SO_4/t	wt.% H_2O	wt.%/week FeS_2	years	weeks	kg H_2SO_4/t/year
SOB	Earth Systems (2015)	0.05	0.02	2	<0.1	10.0	0.37	20 years	no lag time	0.01
WBSCH5_42.5-44m[5]	KCB (2013)[4]	0.02	-	-	-	-	0.48	-	-	-

Notes - 1. Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content).

2. POR follows an exponential decay curve as reported in Earth Systems (2015).

3. Calculated lag time before the onset of acid conditions, calculated from the acidity generation rate and available ANC.

4. Calculated by Earth Systems based on pH and dissolved metals in humidity cell leachate using data from KCB (2013) – Appendix I.

5. Sample described as “Overburden” (not distinguished as NSOB or SOB) but assumed to be SOB based on sample depth 42.5-44 metres.

6.1.3 Organic Overburden

West Balranald

Mineralogy results for the West Balranald OOB samples are presented in Table 23. Key results include:

- Less than 1 wt.% pyrite was detected by XRD in the OOB.
- No carbonate minerals were detected.
- Potassium (K) bearing mineral muscovite (3 wt.%) were found in the OOB. Muscovite is sparingly acid soluble as its dissolution is thought to provide the potassium for the formation of alunite.

Table 23: Mineralogy results for composite OOB samples (Earth Systems, 2015).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)[1]
Albite	$NaAlSi_3O_8$	-	<1
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	-
Ilmenite	$FeTiO_3$	-	-
Kaolinite	$Al_2Si_2O_5(OH)_4$	-	2
Monazite	$(Ce,La)PO_4$	-	-
Muscovite	$KAl_2(Si_3Al)O_{10}(F,OH)_2$	Sparingly acid consuming	3
Pseudorutile	$Fe_2Ti_3O_9$	-	-
Pyrite	FeS_2	Primary acid generating	<1
Quartz	SiO_2	-	93
Rutile	TiO_2	-	1
Sodium Chloride	NaCl	-	<1
Zircon	$ZrSiO_4$	-	<1

Notes: 1. Mineralogy results are considered semi-quantitative and include only crystalline phases. The results are normalised to 100% of the crystalline phases present in the sample. Hence, the amorphous organic carbon is not included in the mineralogy results. Organic carbon only represents <1-5 wt.% of the samples on average.

Field pH_{paste} and NAG pH profiles for West Balranald are graphed in Figure 21. Summary statistics for the West Balranald OOB static geochemistry laboratory results are presented in Table 24. Key results of the field and laboratory test work programs include (KCB, 2012; Earth Systems, 2015):

- Total S is significantly higher for the OOB with an average of 0.94 wt.% S, and a maximum value of 4.32 wt.%. Elevated Total S values typically occur below 45 mbgl. S_{Cr} values are also elevated for OOB with an average value of 0.9 wt.% S indicating that a significant proportion (50-70 wt.% in general) of the Total S is present in the form of primary sulfide minerals, presumably pyrite (or marcasite) as detected by XRD.
- The average sulfate-sulfur value for the OOB was 0.028 wt.% S. This is likely attributed to sulfate in the groundwater that remained in the sample as pore water.

- The average Total S concentration equates to an average MPA value of 29 kg H_2SO_4/t for the OOB.
- The OOB contains little ANC (average 1.1 kg H_2SO_4/t).
- Average Total C is 4.8 wt.% C for the OOB. The Total C is dominated by the organic carbon fraction (TOC) with only minor contributions from inorganic carbon (TIC).
- The highest carbon values are associated with lignite layers in the OOB.
- The low TIC values correlate well with the low ANC values.
- The average NAPP for the OOB was 31 kg H_2SO_4/t, when based on S_{TOS}. NAG pH results ranged from 1.8 to 6.2 and average NAG7.0 for the OOB was 27 H_2SO_4/t, which are consistent with the NAPP data.

Table 24: Field pH, sulfur speciation, carbon speciation, acid-base accounting and NAG statistics for West Balranald OOB (KCB, 2012; Earth Systems, 2015).

Statistic	Field Parameters		Sulfur Speciation				Carbon Speciation			Acid-Base Accounting						Net Acid Generation		
	Paste pH (1:5)	pH_{fox}	Total S	S_{Cr}	S as Sulfate	S_{TOS}	Total C	Total Organic Carbon (TOC)	Total Inorganic Carbon (TIC)	MPA (based on Total S)	MPA (based on S_{TOS})	ANC	NAPP (based on Total S)	NAPP (based on S_{TOS})	ANC/MPA Ratio	NAG pH	NAG 4.5	NAG 7.0
	pH units	pH units	wt.%S	wt.%S	wt.%S-eq	wt.%S	wt.% C	wt.% C	wt.% C	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	-	-	kg H_2SO_4/t	kg H_2SO_4/t
Count	44	59	61	34	34	34	27	27	27	61	34	61	61	34	61	61	61	61
Minimum	4.00	1.15	0.08	0.020	0.006	0.061	0.04	0.03	0.01	3	2	0.3	2	1	0.0	1.8	0.3	0.3
Maximum	7.34	5.99	4.32	3.50	0.047	4.28	62.8	62.8	1.60	132	131	13.4	132	130	0.3	6.2	189	285
Average	6.47	2.62	0.94	0.685	0.028	1.014	4.83	4.68	0.15	29	31	1.1	28	31	0.1	2.9	20	27
Median	6.70	2.13	0.59	0.465	0.028	0.656	0.47	0.47	0.03	18	20	0.5	17	20	0.0	2.9	7	11
Standard Deviation	0.71	1.33	1.04	0.757	0.010	1.046	13.09	13.03	0.32	32	32	2.5	31	32	0.1	0.8	33	43
RSD	11%	51%	111%	111%	35%	103%	271%	278%	219%	111%	103%	230%	113%	105%	124%	27%	163%	163%

The kinetic geochemical test work results for OOB samples are provided in Table 25. For comparison, Table 25 also provides PORs in equivalent units, calculated from previously conducted humidity cell test work (KCB, 2013). Key results from these data are:

- The measured PORs for the OOB ranged from approximately 1.3-2.5 wt.% FeS_2 equivalent per week, indicating that pyrite in the OOB, when exposed to atmospheric oxygen will fully oxidise in somewhere between several months to approximately 3 years.
- The sample water content did not significantly change the oxidation rate until the sample was very dry (see Figure 22) which may be due to the limited water available for the oxidation reaction. This relationship has been seen previously in similar materials (Earth Systems, 2010; Hollings et al., 2001) and implies that the POR may not increase as conditions dry within the pit wall / bench profile, even though lower pore-water may result in greater oxygen entry into the profile.
- Significant carbon dioxide was released from all samples which is likely due to the oxidation of some organic carbon, however it could also be due to the neutralisation of acid generated against the trace amounts of carbonate minerals that may be present. Carbon dioxide generation is likely to be beneficial, at least by diluting oxygen concentrations (Earth Systems, 2015).
- PORs measured using the oxygen consumption method were within a factor of two (generally higher) from average PORs calculated from previous measurements using humidity cell test work, although the range of OOB PORs measured previously is not known. The higher oxidation rates may be due to the consumption of oxygen by organic carbon oxidation within the oxygen consumption tests, however it is more likely that the leachate was saturated with respect to jarosite and did not represent the entire sulfate flux associated with pyrite oxidation. Based on the above, the higher PORs measured have been adopted for this study as they are considered more accurate, and also represent a slightly more conservative approach. A POR of 2.5 wt.% FeS_2/week has been adopted for the OOB for subsequent acidity load estimates in the impact assessment.

Table 25: Kinetic geochemical test work results for West Balranald OOB using oxygen consumption and humidity cell methods (KCB, 2013; Earth Systems, 2015).

Sample ID	Data Source	Total sulfur	Sulfide sulfur (S_{TOS})	MPA	ANC	GMC	Pyrite oxidation rate (POR)[1]	Indicative time to oxidise 90% of pyrite in exposed material	Estimated lag time to onset of acid conditions	Acid Generation Rate (AGR)
	-	wt.% S	wt.% S	kg H_2SO_4/t	kg H_2SO_4/t	wt.% H_2O	wt.%/week FeS_2	years	weeks	kg H_2SO_4/t/year
OOB	Earth Systems (2015)	0.62	0.55	19	<0.1	16.0	2.5	3 years	no lag time	0.48
OOB (average 4 samples)[5]	KCB (2013)	1.4	-	-	-	-	1.3	-	-	-

Notes - 1. Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content).

2. POR follows an exponential decay curve as reported in Earth Systems (2015).

3. Calculated lag time before the onset of acid conditions, calculated from the acidity generation rate and available ANC.

4. Calculated average weekly sulfate release rates of 552 mg/kg/week and average weekly acidity release rates of 659 mg $CaCO_3$/kg/week.

5. Calculated by Earth Systems based on pH and dissolved metals in humidity cell leachate using data from KCB (2013) – Appendix 1.

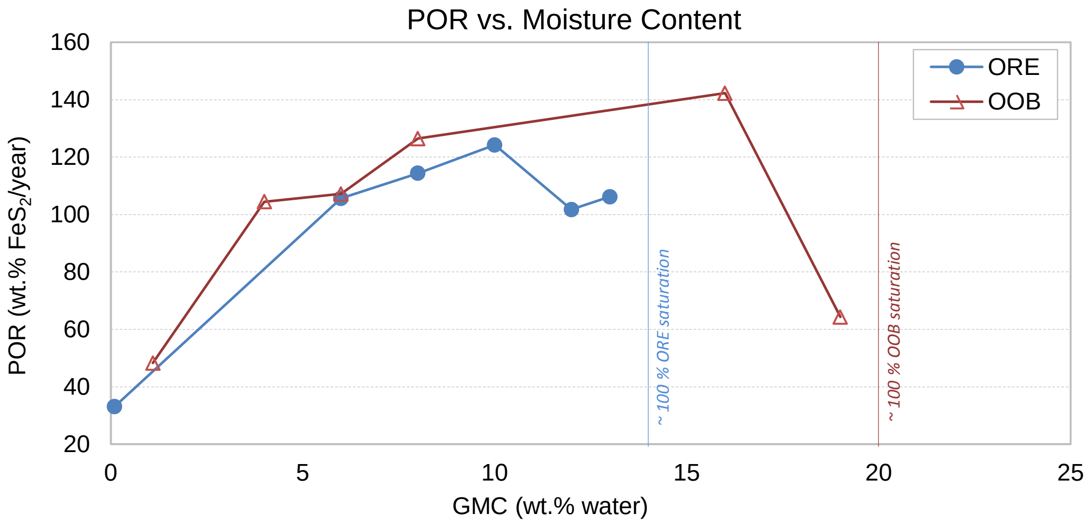

Figure 22: Pyrite oxidation rate (POR) for OOB and ore samples from the West Balranald deposit tested at various moisture contents (Earth Systems, 2015).

The oxygen concentration profile for the OOB sample is plotted in Figure 23. The time-series oxygen concentrations at each depth interval are provided in Figure 24. These figures show that:

- Upon commissioning, the sulfidic material and organic carbon in both samples rapidly consumed oxygen within pore-spaces. Steep oxygen concentration gradients developed rapidly, between atmospheric concentrations at the surface (20.9 vol.%) to zero oxygen at depths of approximately 50-60 cm. Hence, despite unconstrained air entry at the surface, oxygen consumption via sulfide oxidation and carbon oxidation fully depleted atmospheric oxygen at shallow depths within the OOB. This indicates that oxygen consumption is proceeding faster that oxygen supply at depths of greater than 50-60 cm. In essence, the supply of oxygen to sulfide and carbon sources is being limited to diffusional processes. While acidity generation is limited to depths of less than 50-60 cm, it has been halted by a lack of oxygen at greater depths.
- For the purposes of impact assessment, a conservative estimate of the maximum oxygen penetration depth of 2 metres has been assumed for in-situ / compacted OOB, based on the test work conducted to date. This assumption allows for the possibility of increased oxygen diffusion rates in backfill material that may be less compacted than the material tested in the laboratory.

The key results from leachate chemistry data for OOB samples irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that AMD was released from the OOB sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was acidic (pH 5.1) with high levels of dissolved zinc and cobalt, and moderate levels of dissolved chromium, cadmium, boron, arsenic and nickel. This data is consistent with the PAF classification.
- Exposure of OOB to oxidising conditions over several weeks can be expected to generate even more acidic conditions, with pH values approaching 2 and associated increases in dissolved metal concentrations.

- Elevated (sulfate) salinity, as indicated by an electrical conductivity (EC) of 13 mS/cm and sulfate concentration of 1,030 mg/L, is attributed to a combination of sulfide oxidation and existing salinity from the groundwater (pore water) leaching from the sample. This interpretation is consistent with the trends in EC and sulfate concentrations, and metal release rates, observed in leachate from humidity cell tests.

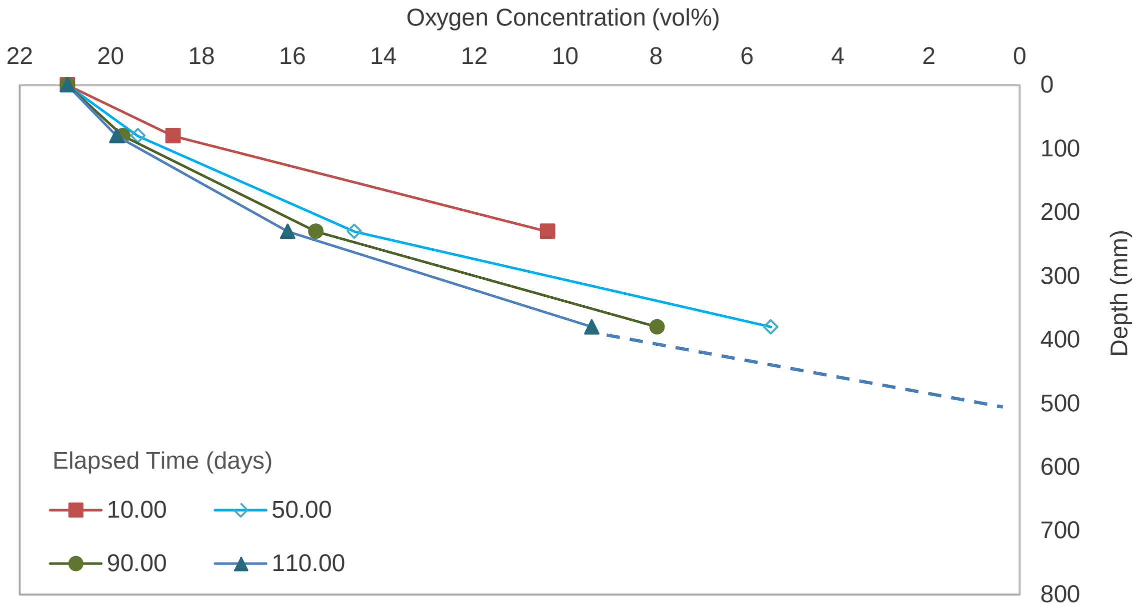

Figure 23: Oxygen diffusion profile for the OOB (Earth Systems, 2015). The dashed blue line shows the inferred trend.

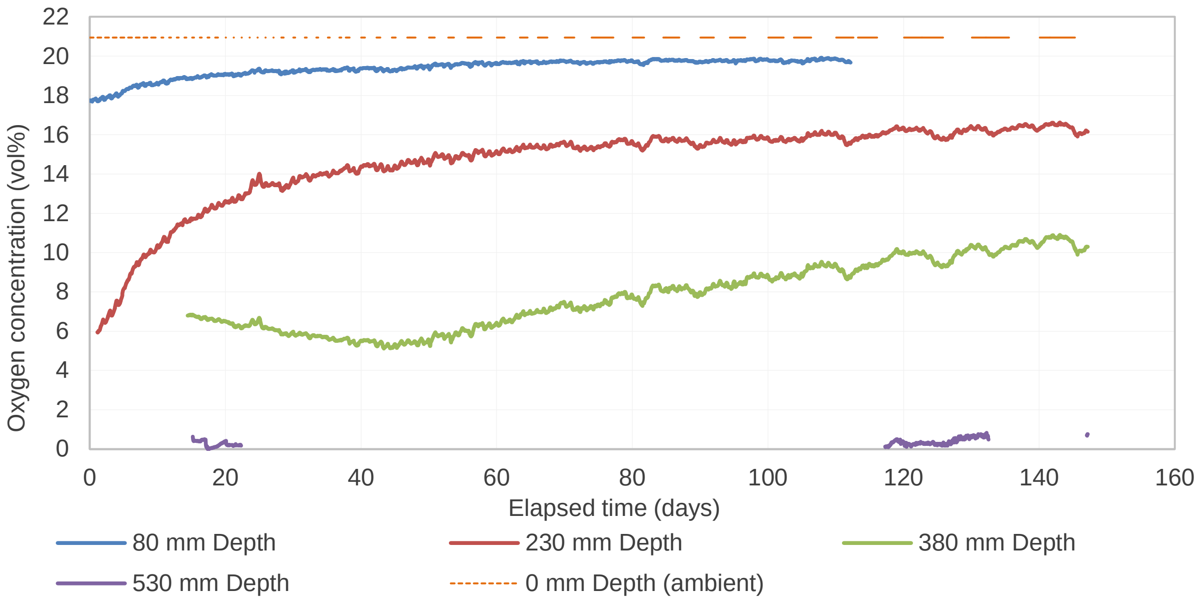

Figure 24: Oxygen concentration at various depth intervals in the OOB. See Figure 23 for profile trends at various times (Earth Systems, 2015).

6.2 Ore

Ore material from the West Balranald and Nepean deposits will form part of the following project domains:

- Ore stockpiles; and
- Oversize stockpiles (if applicable, to be backfilled).

The physical properties for the bulk ore sample are provided in Table 14. The particle size distribution of the ore bulk samples used for kinetic geochemical test work is provided in Figure 20. The higher particle density of the ore relative to the SOB and OOB reflects its heavy mineral content. The ore was slightly finer than the SOB and OOB samples.

The AMD risk classification, based on static geochemical test work, for the West Balranald and Nepean deposit ore materials are summarised in Table 26.

Key results from the AMD risk classification of ore samples from the West Balranald and Nepean deposits include:

- All of the Nepean ore samples tested (5 samples) were classified as NAF.
- All of the West Balranald ore samples tested (16 samples) were classified as PAF.
- Of the PAF West Balranald ore samples:
  - Approximately 6% of samples were classified as having a high potential for acid generation (AG1) based on high sulfur contents and low ANC.
  - Approximately 44% of samples were classified as having a moderate potential for acid generation (AG3) based on moderately elevated sulfur contents and low ANC.
  - Approximately 50% of samples were classified as having a low potential for acid generation (AG4) based on low sulfur contents and low ANC.

Table 26: AMD risk classification for ore samples from the West Balranald (WB) and Nepean deposits (KCB, 2012; Earth Systems, 2015).

General AMD Risk Classification	Detailed AMD Risk Classification		Ore	
	Description	Detailed AMD Risk Classification ID	WB	Nepean
Potentially Acid Forming (PAF)	High Potential for Acid Generation	Category 1 (AG1)	1	-
	Moderate / High Potential for Acid Generation	Category 2 (AG2)	-	-
	Moderate Potential for Acid Generation	Category 3 (AG3)	7	-
	Low Potential for Acid Generation	Category 4 (AG4)	8	-
Total number of PAF Samples			16	-
Non Acid Forming (NAF)	Unlikely to be Acid Generating	UAG	-	5
	Likely to be Acid Consuming	LAC	-	-
Total number of NAF Samples			-	5

6.2.1 West Balranald

Mineralogy results for the West Balranald ore are presented in Table 27. Key results include:

- The composite ore sample contained high concentrations of ilmenite (14 wt.%), rutile (9 wt.%), pseudorutile (3 wt.%) and zircon (3 wt.%), as well as trace levels of monazite (Table 27). The ore sample also contained the highest concentrations of pyrite (2 wt.%) and alunite (3 wt.%), which is an acid-storing secondary mineral, of all the materials tested.
- No carbonate minerals were detected in the sample.

Table 27: Mineralogy results for composite West Balranald ore sample (Earth Systems, 2015).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)[1]
Albite	$NaAlSi_3O_8$	-	-
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	3
Ilmenite	$FeTiO_3$	-	14
Kaolinite	$Al_2Si_2O_5(OH)_4$	-	1
Monazite	$(Ce,La)PO_4$	-	<1
Muscovite	$KAl_2(Si_3Al)O_{10}(F,OH)_2$	Sparingly acid consuming	<1
Pseudorutile	$Fe_2Ti_3O_9$	-	3
Pyrite	FeS_2	Primary acid generating	2
Quartz	SiO_2	-	63
Rutile	TiO_2	-	9
Sodium Chloride	NaCl	-	<1
Zircon	$ZrSiO_4$	-	3

Notes: 1. Mineralogy results are considered semi-quantitative and include only crystalline phases. The results are normalised to 100% of the crystalline phases present in the sample. Hence, the amorphous organic carbon is not included in the mineralogy results. Organic carbon only represents <1-5 wt.% of the samples on average.

Field pH_{paste} and NAG pH profiles for West Balranald are graphed in Figure 21. Summary statistics for the West Balranald ore static geochemistry laboratory results are presented in Table 28. Key results include:

- Average total S for the ore (1.1 wt.% S) is similar to the OOB. The maximum value recorded was 2.7 wt.% S. S_{Cr} values are also elevated with an average value of 0.63 wt.% S, indicating that a significant proportion (50-70% in general) of the Total S is present in the form of sulfide minerals, presumably pyrite (or marcasite) as detected by XRD (see Table 27).
- Average sulfate-sulfur for the ore is 0.014 wt.% S.
- S_{TOS} values are similar to Total S due to the low concentrations of sulfate relative to Total S.
- Average Total S concentrations equate to an average MPA value of 34 kg H_2SO_4/t for the ore, hence the ore has slightly higher overall potential for AMD generation than the OOB.

- The ore effectively contains no ANC.
- Average Total C for the ore is 0.2 wt.% C. Most of this is organic carbon, with Total Inorganic Carbon making up only 0.03 wt.% C.
- In general, the ore and OOB (Table 24) have similar NAPP and NAG characteristics.
- NAPP values were typically similar to MPA values due to the low ANC (ie. very low carbonate content) throughout the ore.
- The average NAPP for the ore was 33 kg H_2SO_4/t, when based on S_{TOS}. The NAG pH ranged from 1.9 to 4.1 and average NAG7.0 for the ore was 23 kg H_2SO_4/t. These values are similar to the OOB (Table 24).
- In general, NAG7.0 values were very close to the NAPP values, based on S_{TOS}, indicating that S_{TOS} appears to be a reasonable estimate of acid generating capacity due to relatively low SO_4-S and minimal ANC. Hence, S_{TOS} is favoured over S_{Cr} and has been adopted for estimation of acidity loads from the ore material as part of the impact assessment (Section 8 onwards).

Table 28: Field pH, sulfur speciation, carbon speciation, acid-base accounting and NAG statistics for West Balranald ore (KCB, 2012; Earth Systems, 2015).

Statistic	Field Parameters		Sulfur Speciation				Carbon Speciation			Acid-Base Accounting						Net Acid Generation		
	Paste pH (1:5)	pH_{fox}	Total S	S_{Cr}	S as Sulfate	S_{TOS}	Total C	Total Organic Carbon (TOC)	Total Inorganic Carbon (TIC)	MPA (based on Total S)	MPA (based on S_{TOS})	ANC	NAPP (based on Total S)	NAPP (based on S_{TOS})	ANC/ MPA Ratio	NAG pH	NAG 4.5	NAG 7.0
	pH units	pH units	wt.%S	wt.%S	wt.%S-eq	wt.%S	wt.% C	wt.% C	wt.% C	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	-	-	kg H_2SO_4/t	kg H_2SO_4/t
Count	9	19	20	13	13	13	7	7	7	20	13	20	20	13	20	20	20	20
Minimum	5.15	1.10	0.38	0.26	0.002	0.379	0.09	0.08	0.01	12	12	0.3	11	11	0.0	1.9	4.9	8.0
Maximum	7.90	3.00	2.72	1.80	0.024	2.70	0.36	0.31	0.06	83	83	1.6	83	82	0.0	4.1	60	68
Average	6.61	1.78	1.10	0.63	0.014	1.09	0.20	0.17	0.03	34	33	0.5	33	33	0.0	2.6	19	23
Median	7.23	1.70	1.18	0.41	0.015	1.20	0.14	0.13	0.03	36	37	0.5	35	36	0.0	2.6	14	18
Standard Deviation	0.42	0.48	0.57	0.43	0.008	0.67	0.10	0.08	0.02	17	21	0.3	17	21	0.0	0.5	13	14
Relative Standard Deviation	6%	27%	52%	67%	54%	62%	52%	49%	69%	52%	62%	58%	53%	62%	61%	18%	69%	62%

The kinetic geochemical test work results for the ore samples are provided in Table 29. For comparison, Table 29 also provides PORs in equivalent units, calculated from previously conducted humidity cell test work (KCB, 2013). Key results from these data are:

- The measured PORs for the ore were similar to the OOB, and ranged from approximately 1.3-2.2 wt.% FeS_2 per week, indicating that pyrite in the ore, when exposed to atmospheric oxygen will fully oxidise in somewhere between several months to approximately 4 years.
- As with the OOB, the ore sample water content did not significantly change the oxidation rate until the sample was very dry (see Figure 22) which may be due to the limited water available for the oxidation reaction. This relationship has been seen previously in similar materials (Earth Systems, 2010; Hollings et al., 2001), and implies that the POR may not increase as conditions dry within the pit wall / bench profile.
- Significant carbon dioxide was released from all samples which is likely due to the oxidation of some organic carbon, however it could also be due to the neutralisation of acid generated against the trace amounts of carbonate minerals that may be present. Carbon dioxide generation is likely to be beneficial, at least by diluting oxygen concentrations (Earth Systems, 2015).
- POR's measured using the oxygen consumption method were within a factor of two (generally higher) from average PORs calculated from previous measurements using humidity cell test work. Note that the range of ore PORs measured previously is not known.
- Based on the above, the higher PORs measured have been adopted for this study as they are considered more accurate, and also represent a slightly more conservative approach. A POR of 2.2 wt.% FeS_2/week has been adopted for ore for acidity load estimates for the impact assessment.

The oxygen concentration profile for ore material is plotted in Figure 25. The time-series oxygen concentrations for the ore sample are provided in Figure 26. These figures show that:

- Similar to the OOB sample, the ore sample rapidly consumed the oxygen within its pore-spaces. Steep oxygen concentration gradients developed rapidly.
- The oxygen concentration profile in the ore exhibited a circum-linear temporal trend decreasing steadily from approximately 40 to 50 cm depth (to zero oxygen) over 130 days of test work as shown in Figure 25, slightly less deep than then OOB sample.
- For the purposes of impact assessment, a conservative estimate of the maximum oxygen penetration depth of 2 metres has been assumed for in-situ / compacted ore, based on the test work conducted to date. This is consistent with the approach adopted for OOB, as described in further detail in Section 6.1.3.

Table 29: Kinetic geochemical test work results for West Balranald ore samples using the oxygen consumption and humidity cell methods (KCB, 2013; Earth Systems, 2015).

Sample ID	Data Source	Total sulfur	Sulfide sulfur (S_{TOS})	MPA	ANC	GMC	Pyrite oxidation rate (POR)[1]	Indicative time to oxidise 90% of pyrite in exposed material	Estimated lag time to onset of acid conditions	Acid Generation Rate (AGR)
		wt.% S	wt.% S	kg H_2SO_4/t	kg H_2SO_4/t	wt.% H_2O	wt.%/week FeS_2	years	weeks	kg H_2SO_4/t/year
Ore	Earth Systems (2015)	0.96	0.89	29	<0.1	13.8	2.18	4 years	no lag time	0.64
Ore (average of 3 samples)[5]	KCB (2013)	0.94	-	-	-	-	1.32	-	-	-

Notes - 1. Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content).

2. POR follows an exponential decay curve as reported in Earth Systems (2015).

3. Calculated lag time before the onset of acid conditions, calculated from the acidity generation rate and available ANC.

4. Calculated average weekly sulfate release rates were 376 mg/kg/week and calculated average weekly acidity release rates were 340 mg $CaCO_3$/kg/week.

5. Calculated by Earth Systems based on pH and dissolved metals in humidity cell leachate using data from KCB (2013) – Appendix 1.

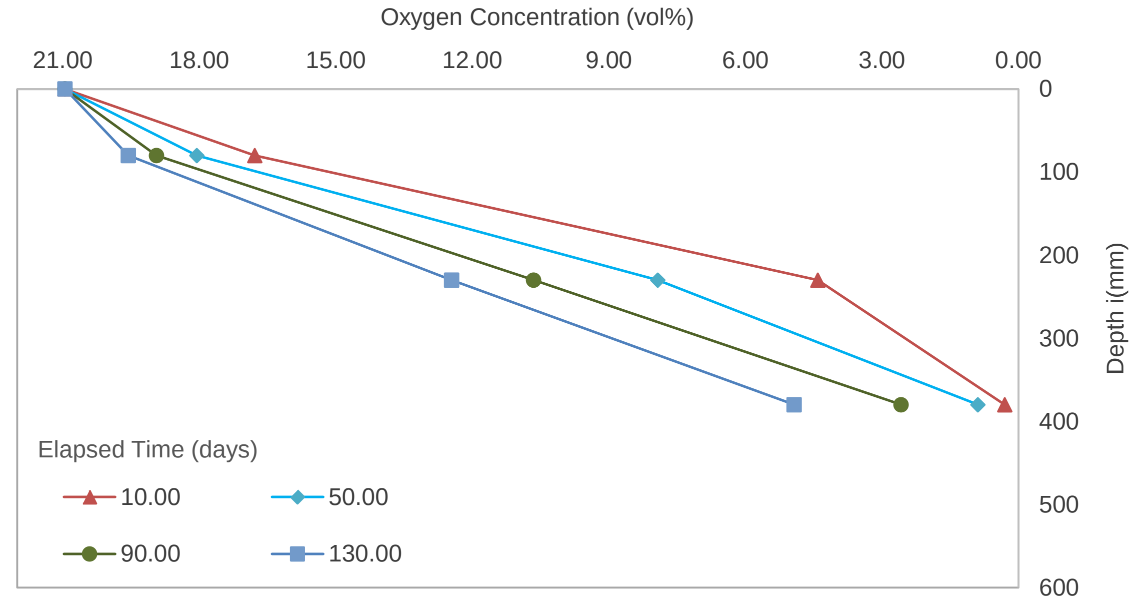

Figure 25: Oxygen diffusion profile in the ore.

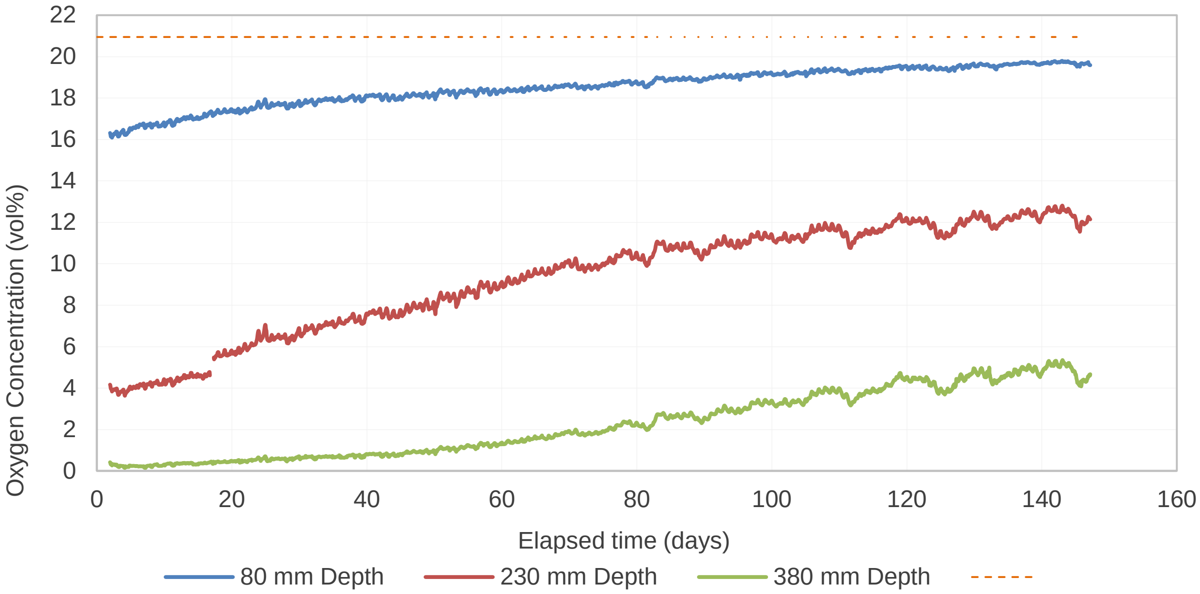

Figure 26: Oxygen concentration at various depth intervals in the ore.

The key results from leachate chemistry data for the West Balranald ore samples irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that AMD was released from the ore sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was acidic (pH 4.7) with high levels of dissolved cobalt and zinc, and elevated levels of dissolved boron, nickel and arsenic. This data is consistent with the PAF classification.
- Long term exposure of ore to oxidising conditions over several weeks can be expected to generate even more acidic conditions, with pH values approaching 2 and associated increases in dissolved metal concentrations.
- Elevated (sulfate) salinity, as indicated by an electrical conductivity (EC) of 6.8 mS/cm and sulfate concentration of 899 mg/L, is attributed to a combination of sulfide oxidation and existing salinity from the groundwater (pore water) leaching from the sample. This interpretation is consistent with the trends in EC and metal release rates observed in leachate from humidity cell tests.

6.2.2 Nepean

Mineralogy results for the Nepean ore are presented in Table 30. Key results include (KCB, 2012):

- The ore sample from Channel 1 (NEPSCH1_39-40.5m) contained high concentrations of rutile (58 wt.%), zircon (5 wt.%), and ilmenite (4 wt.%) as well as trace levels of iron oxide.
- The ore sample from Channel 3 (NEPSCH3_46.5_48m) contained mostly quartz (96 wt.%) as well as rutile (2 wt.%), zircon (2 wt.%), and traces of ilmenite.
- The XRD test work did not report pyrite, suggesting that pyrite levels were below the limits of reporting for XRD analysis.
- Neither of the ore samples contained significant amounts of acid generating minerals.

Table 30: Mineralogy results for Nepean ore samples (KCB, 2012).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)[1, 2]	
			NEPSCH1_39-40.5m	NEPSCH3_46.5-48m
Calcite	$CaCO_3$	Acid consuming	-	-
Chamosite	$Fe_3Si_2O_5(OH_4)$	-	-	-
Illmenite	$FeTiO_3$	-	4	-
Illmenite (Mg)	$(Fe,Mg)(Ti,Fe)O_3$	-	-	<1
Iron Oxide	Fe_2O_3	-	<1	-
Kaolinite	$Al_2Si_2O_5(OH)_4$	-	-	-
Quartz	SiO_2	-	33	96
Rutile	TiO_2	-	58	2
Zircon	$ZrSiO_4$	-	5	2

Notes: 1. Mineralogy results are considered semi-quantitative and include only crystalline phases. The results are normalised to 100% of the crystalline phases present in the sample. Hence, the amorphous organic carbon is not included in the mineralogy results.

2. Values obtained from KCB (2012) – Table 4.1 p.4

Summary statistics for the Nepean ore static geochemistry laboratory results are presented in Table 31. Key results of the field and laboratory test work programs include (KCB, 2012):

- Total S is low for the ore samples with an average value of 0.03 wt.% S. The sulfur is likely present as evaporatively concentrated sulfate from the groundwater for the saline portion. This assertion is supported by the very low S_{Cr} values (average <0.005 wt.%S for the ore).
- The average Total S concentration equates to an average MPA value of 0.8 kg H_2SO_4/t for the ore. The ore exhibited very low MPA values.
- All sample materials from the Nepean Deposit had Total S concentrations less than 0.1 wt.% S suggesting that the materials are NAF.
- Average sulfate-sulfur concentrations were 0.029 wt.% S for the ore samples. This is likely attributed to sulfate in the groundwater that remained in the sample as pore water.

- S_{TOS} values are similar to Total S due to the low concentrations of sulfate relative to Total S. Hence S_{TOS} values are very low in the ore. S_{TOS} should equal the S_{Cr} value as these laboratory methods both determine the sulfide-sulfur content of a sample. Static data for S_{Cr} suggest that there is no sulfur present as sulfide however S_{TOS} suggests trace sulfides.
- ANC values are low throughout the deposit, with an average value of 2.0 kg H_2SO_4/t for the ore samples.
- The average NAPP value for the Nepean ore was -1.2 kg H_2SO_4/t, when based on S_{TOS}. NAG results support the NAPP, with no NAG pH values below 6.1 and an average NAG pH of 6.4.

Table 31: Sulfur speciation, carbon speciation, acid-base accounting and NAG statistics for Nepean ore samples (KCB, 2012).

Statistic	Sulfur Speciation[1]				Acid-Base Accounting[2]				Net Acid Generation[3]		
	Total S	S_{Cr}	S as Sulfate	S_{TOS}	MPA (based on S_{TOS})	ANC	NAPP (based on S_{TOS})	ANC/MPA Ratio	NAG pH	NAG 4.5	NAG 7.0
	wt.%S	wt.%S	wt.% S equiv.	wt.%S	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	-	-	kg H_2SO_4/t	kg H_2SO_4/t
Count	5	5	5	5	5	5	5	5	5	5	5
Minimum	0.03	<0.005	0.021	0.02	0.7	0.5	-2.5	0.7	6.1	0.25	0.3
Maximum	0.04	<0.005	0.043	0.03	0.9	3.4	0.3	3.9	6.7	0.25	2.9
Average	0.03	<0.005	0.029	0.03	0.8	2.0	-1.2	2.4	6.4	0.25	0.8
Median	0.04	<0.005	0.023	0.03	0.8	1.4	-0.7	1.9	6.3	0.25	0.3
Standard Deviation	0.00	0.000	0.010	0.00	0.1	1.3	1.3	1.4	0.2	0.00	1.2
RSD	11%	0%	36%	8%	8%	67%	-109%	61%	3%	0%	152%

Results from the kinetic geochemical characterisation of the Nepean ore, conducted via humidity cell test work by KCB (2013), are provided in Table 32. This includes PORs estimated by Earth Systems. Key results include (KCB, 2013):

- In contrast to the static test work, the cumulative sulfate production test work suggests that sulfides are present in some samples.
- Sulfate production rates for the ore materials were low.
- Cumulative sulfate production rates for Nepean ore samples were significantly lower than the West Balranald ore samples.
- PORs for the two ore samples ranged from approximately 0-0.4 wt.% FeS_2 per week. The results suggest that the oxidation of trace levels of sulfide present in the ore will occur over a number of years.
- Total concentrations of As, Cr, Th, U and Zr in the Nepean ore samples were elevated with respect to average crustal abundance.
- Despite elevated total concentrations of As, Cr, Th, U and Zr, the Nepean ore samples did not exhibit significant metals leaching.
- The available (limited) leachate chemistry data are consistent with the NAF classification.

Table 32: Indicative pyrite oxidation rates (PORs) for Nepean ore samples, based on humidity cell test work conducted by KCB (2013).

Material	Average Total S	Calculated average weekly sulfate release[1]	Indicative pyrite oxidation rate (POR)[2]
	wt.% S	mg SO_4 / kg / week	wt.% FeS_2 equiv./ week
NEPSCH1_39-40.5m	0.032	4.3	0.4%
NEPSCH3_46.5-48m	0.036	Not detected	Not detected

Notes: 1. Values extracted from KCB (2013) – Figure 3-33 p. 41.
2. Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content).

6.3 Mining By-Products

MBPs from the West Balranald and Nepean deposits and by-products from the Hamilton MSP will form part of the following project domains:

- By-product stockpiles;
- Tailings storage facility (TSF); and
- Backfilled material to the mine voids.

The results of the static and kinetic geochemical characterisation test work for each of the by-product streams are described below.

6.3.1 Balranald Sand Tails

Mineralogy results for the Balranald sand tails are presented in Table 33. Key results include (KCB, 2013; Earth Systems, 2015):

- The sand tails are composed almost entirely of quartz (>90 wt.%). Both rutile and ilmenite are present at trace concentrations (approximately 2 wt.%).
- Minor concentrations of marcasite (<1 wt.%) and pyrite (<1 wt.%), primary acid generating sulfidic minerals, were detected.
- No carbonate minerals were detected in the samples by XRD.

Table 33: Mineralogy results for Balranald sand tails (KCB, 2013; Earth Systems, 2015).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)	
Source			*KCB*	*Earth Systems*
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	-	<1
Anatase*	TiO_2		-	<1
Birnessite, sodian	$(Na_{0.3}Ca_{0.1}K_{0.1})(Mn^{4+},Mn^{3+})_2O_4 \cdot 1.5 H_2O$		-	-
Coalingite*	$Mg_{10}Fe_2(CO_3)(OH)_{24} \cdot 2H_2O$		-	-
Goethite	$FeO(OH)$		-	<1
Gypsum	$CaSO_4 \cdot 2(H_2O)$		-	<1
Halite	$NaCl$		<1	<1
Ilmenite	$FeTiO_3$		-	2
Jarosite	$KFe_3(SO_4)_2(OH)_6$	Secondary acid generation	-	-
Kaolinite	$Al_2(Si_2O_5)(OH)_4$		-	-
Marcasite	FeS_2	Primary acid generation	-	<1
Monazite	$(Ce,La,Nd,Th)PO_4$		-	-
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	Sparingly acid consuming	-	-
Pseudorutile*	$Fe_2Ti_3O_9$		-	-
Pyrite	FeS_2	Primary acid generation	<1	<1
Quartz	SiO_2		98	93

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)	
Rutile (some leucoxene)	TiO_2		-	2
Sodalite	$Na_8Al_6Si_6O_{24}Cl_2$		<1	-
Zircon	$ZrSiO_4$		<1	<1

* Inferred presence.

Static geochemistry laboratory results for the sand tails are presented in Table 34. Key results include:

- Both sand tails samples were classified as PAF, with NAPP values ranging between 11 and 12 kg H_2SO_4/t and NAG pH values of 2.6.
- Total sulfur values for the sand tails were relatively low, ranging between 0.35 and 0.47 wt.% S.
- ANC was below detection limit in both sand tails samples.
- Sand tails NAG7.0 values were the lowest of the MBPs, ranging between 11 and 20 kg H_2SO_4/t.

Kinetic test work results for the sand tails are provided in Table 35 and plotted in Figure 27. The PORs for sand tails were measured as received at a GMC of approximately 19 wt.% water at numerous depths within the test apparatus. The sand tails had a sulfide-sulfur (S_{TOS}) content of approximately 0.4 wt.%.S and had measured PORs ranging from 1.7 to 2.4 wt.% FeS_2/week, indicating very high reactivity in all samples. Similar PORs for sand tails were calculated based on humidity cell test work conducted by KCB (2013) as shown in Table 36.

Table 34: Static geochemical characteristics of the Balranald sand tails (KCB, 2013; Earth Systems, 2015).

MBP	Sand Tails	
Source	*KCB*	*Earth Systems*
Total S (wt.%)	0.47	0.35
Cr Reducible S (wt.%)	0.35	0.25
Total Oxidisable S (wt.%)	0.4	0.31
Sulfate as SO_4^{2-} (wt.%S)	0.12	0.0074
MPA (kg H_2SO_4/t) based on S_{TOS} / Total S	12	11
ANC (kg H_2SO_4/t)	<1	<0.5
ANC (kg $CaCO_3$/t)	<1	<0.5
NAPP (kg H_2SO_4/t) based on S_{TOS} / Total S	12	11
NAG pH	2.6	2.6
NAG 4.5 (kg H_2SO_4/t)	17	7.8
NAG 7.0 (kg H_2SO_4/t)	20	11
AMD Risk Classification	PAF	PAF

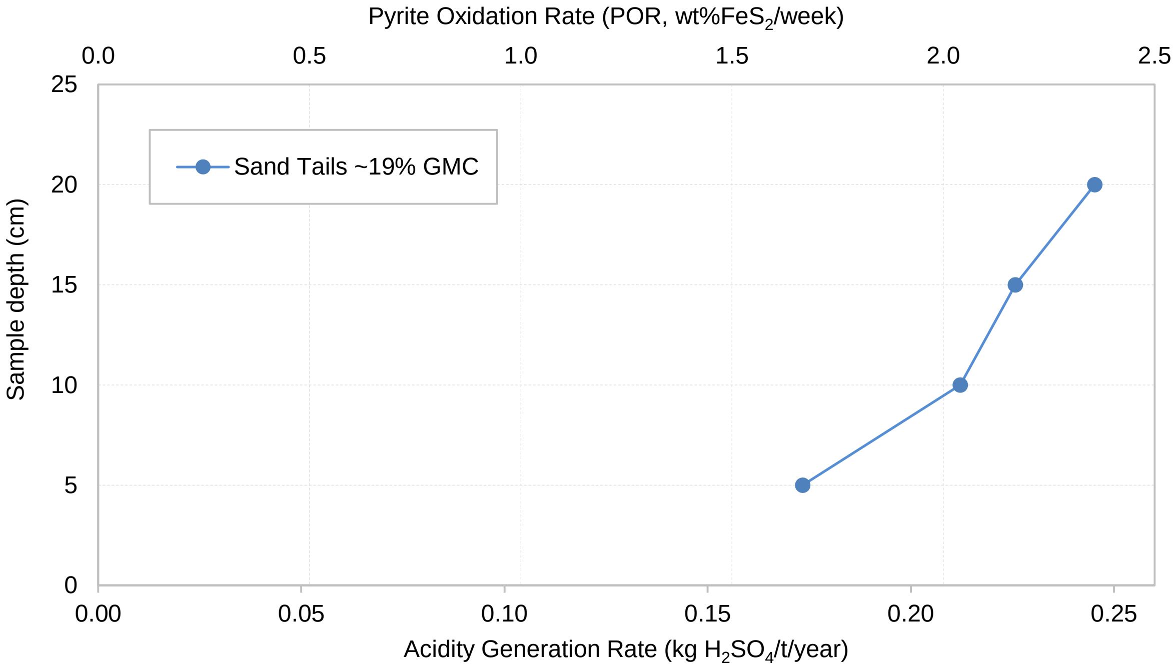

Figure 27: Sample depth vs. pyrite oxidation rates (POR) and acidity generation rates (AGR) for sand tails samples.

Table 35: Summary of kinetic geochemical test work results for the Balranald MBPs using the oxygen consumption method (Earth Systems, 2015).

Sample ID	Description	Total sulfur	Sulfide sulfur (S_{TOS})	MPA[1]	ANC	GMC	Pyrite oxidation rate (POR) [2]	Indicative time to oxidise 90% of pyrite in exposed material	Estimated lag time to onset of acid conditions	Acid Generation Rate (AGR)
		wt.% S	wt.% S	kg H_2SO_4/t	kg H_2SO_4/t	wt.% H_2O	wt.%/week FeS_2	years	weeks	kg H_2SO_4/t/year
ST-19WT%H2O-5CM	Sand Tailings - Blended Wet Concentrator Plant (WCP) and pre-concentrator plant (PCP) at 19 wt.% water and 5 cm thickness	0.35	0.31	11	<0.5	19.0	1.67	5 years	no lag time	0.18
ST-19WT%H2O-10CM	Sand Tailings - Blended WCP and PCP at 19 wt.% water and 10 cm thickness	0.35	0.31	11	<0.5	19.0	2.04	4 years	no lag time	0.22
ST-19WT%H2O-15CM	Sand Tailings - Blended WCP and PCP at 19 wt.% water and 15 cm thickness	0.35	0.31	11	<0.5	19.0	2.17	4 years	no lag time	0.23
ST-19WT%H2O-20CM	Sand Tailings - Blended WCP and PCP at 19 wt.% water and 20 cm thickness	0.35	0.31	11	<0.5	19.0	2.36	4 years	no lag time	0.25
TUF-8WT%H2O	TUF - Thickener underflow from the PCP at 8 wt.% water	7.86	7.25	241	<0.5	8.0	3.19	3 years	no lag time	7.69

Sample ID	Description	Total sulfur	Sulfide sulfur (S_{TOS})	MPA[1]	ANC	GMC	Pyrite oxidation rate (POR) [2]	Indicative time to oxidise 90% of pyrite in exposed material	Estimated lag time to onset of acid conditions	Acid Generation Rate (AGR)
		wt.% S	wt.% S	kg H_2SO_4/t	kg H_2SO_4/t	wt.% H_2O	wt.%/week FeS_2	years	weeks	kg H_2SO_4/t/year
TUF-21WT%H2O	TUF - Thickener underflow from the PCP at 21 wt.% water	7.86	7.25	241	<0.5	21.0	0.79	10 years	no lag time	1.91
TUF-57WT%H2O	TUF - Thickener underflow from the PCP at 57 wt.% water	7.86	7.25	241	<0.5	57.0	0.09	85 years	no lag time	0.21
ModCod-25WT%H2O-5CM	ModCod - Mixture of sand tailings and thickener underflow at 25 wt. % water and 5 cm depth	1.72	1.57	53	<0.5	25.0	0.24	32 years	no lag time	0.12
ModCod-25WT%H2O-8CM	ModCod - Mixture of sand tailings and thickener underflow at 25 wt.% water and 8 cm depth	1.72	1.57	53	<0.5	25.0	0.14	53 years	no lag time	0.07
ModCod-25WT%H2O-17CM	ModCod - Mixture of sand tailings and thickener underflow at 25 wt.% water and 17 cm depth	1.72	1.57	53	<0.5	25.0	0.11	67 years	no lag time	0.06

Sample ID	Description	Total sulfur	Sulfide sulfur (S_{TOS})	MPA[1]	ANC	GMC	Pyrite oxidation rate (POR) [2]	Indicative time to oxidise 90% of pyrite in exposed material	Estimated lag time to onset of acid conditions	Acid Generation Rate (AGR)
		wt.% S	wt.% S	kg H_2SO_4/t	kg H_2SO_4/t	wt.% H_2O	wt.%/week FeS_2	years	weeks	kg H_2SO_4/t/year
ModCod-10WT%H2O-5cm	ModCod - Mixture of sand tailings and thickener underflow at 10 wt.% water and 5 cm depth	1.72	1.57	53	<0.5	10.0	1.59	5 years	no lag time	0.84
ModCod-10WT%H2O-8cm	ModCod - Mixture of sand tailings and thickener underflow at 9 wt.% water and 8 cm depth.	1.72	1.57	53	<0.5	9.0	1.20	7 years	no lag time	0.63
ModCod-2WT%H2O-5cm	ModCod - Mixture of sand tailings and thickener underflow at 1 wt.% water and 5 cm depth	1.72	1.57	53	<0.5	1.0	0.38	20 years	no lag time	0.20
ModCod-2WT%H2O-8cm	ModCod - Mixture of sand tailings and thickener underflow at 3 wt.% water and 8 cm depth	1.72	1.57	53	<0.5	3.0	0.72	10 years	no lag time	0.38

Notes: 1. The maximum potential acidity that can be generated from the sample if all of the sulfur were to oxidise.

2. PORs are calculated based on the oxygen consumption and then normalised to the sample sulfur content. These are expressed in terms of the percentage of the remaining pyrite that is oxidised per unit time. POR follows an exponential decay curve as reported in Earth Systems (2015).

3. Mass Ratio of limestone required to neutralise the acidity generated from each tonne of material exposed to oxidising conditions per week. A stoichiometric ratio of 3:1 for the mass of ($CaCO_3$) limestone relative to the mass of (H_2SO_4) acidity generated is recommended to allow for limestone impurities, passivation reactivity limitations.

4. Mass Ratio of hydrated lime required to neutralise the acidity generated from each tonne of material exposed to oxidising conditions per week. A stoichiometric ratio of 1:1 for the mass of hydrated lime relative to the mass of acidity generated is provided based on the assumption that only the soluble acidity in process water stream is to be treated.

Table 36: Indicative pyrite oxidation rates (PORs) for the Balranald MBPs based on humidity cell test work conducted by KCB (2013).

Material	Average Total S	Calculated average weekly sulfate release[1]	Calculated average weekly acidity release[2]	Indicative pyrite oxidation rate (POR)[3]
	wt.% S	mg/kg/week	mg $CaCO_3$ /kg/week	wt.% FeS_2 equiv. /week
Thickener underflow	14	424	1741	0.1%
ModCod	1.9	97	377	0.2%
Sand tails	0.47	337	51	2.4%

Notes: 1. Values obtained from KCB (2013) – Table 4-2 p.82 and Appendix 1.

2. Calculated based on pH and dissolved metals in humidity cell leachate data from KCB (2013) – Appendix 1.

3. POR: Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content).

The key results from leachate chemistry data for Balranald sand tails irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that AMD was released from the Balranald sand tails sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was acidic (pH 4.4) with elevated concentrations of dissolved iron, aluminium, boron, cobalt, nickel and zinc. This data is consistent with the PAF classification.
- Long term exposure of Balranald sand tails to oxidising conditions over several weeks can be expected to generate even more acidic conditions, with pH values approaching 2 and associated increases in dissolved metal concentrations.
- Elevated (sulfate) salinity, as indicated by an electrical conductivity (EC) of 9.1 mS/cm and sulfate concentration of 790 mg/L, is attributed to a combination of sulfide oxidation and existing salinity from the groundwater (pore water) leaching from the sample. This interpretation is consistent with the trends in sulfate and metal release rates observed in leachate from humidity cell tests.

6.3.2 Balranald Thickener Underflow

Mineralogy results for the thickener underflow are presented in Table 37. Key results include (KCB, 2013; Earth Systems, 2015):

- Pyrite is concentrated in the thickener underflow, at approximately 20 wt.%.
- Alunite, a secondary acid generating mineral, is also concentrated in this MBP (30 wt.% (KCB)/ 15 wt.% (Earth Systems)).
- No carbonate minerals were detected in the samples by XRD.
- The thickener underflow also contains significant ilmenite (24 wt.%), quartz (17 wt.%), and rutile (6 wt.%).

Table 37: Mineralogy results for the Balranald thickener underflow (KCB, 2013).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)	
Source			*KCB*	*Earth Systems*
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	31	15
Anatase*	TiO_2		-	2
Birnessite, sodian	$(Na_{0.3}Ca_{0.1}K_{0.1})(Mn^{4+},Mn^{3+})_2O_4 \cdot 1.5\ H_2O$		12	-
Coalingite*	$Mg_{10}Fe_2(CO_3)(OH)_{24} \cdot 2H_2O$		-	-
Goethite	$FeO(OH)$		-	1
Gypsum	$CaSO_4 \cdot 2(H_2O)$		-	<1
Halite	$NaCl$		-	3
Ilmenite	$FeTiO_3$		-	24
Jarosite	$KFe_3(SO_4)_2(OH)_6$	Secondary acid generating	-	-
Kaolinite	$Al_2(Si_2O_5)(OH)_4$		-	5
Marcasite	FeS_2	Primary acid generating	-	<1
Monazite	$(Ce,La,Nd,Th)PO_4$		-	-
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	Sparingly acid consuming	-	1
Pseudorutile*	$Fe_2Ti_3O_9$		-	<1
Pyrite	FeS_2	Primary acid generating	19	20
Quartz	SiO_2		26	17
Rutile (some leucoxene)	TiO_2		-	6
Sodalite	$Na_8Al_6Si_6O_{24}Cl_2$		-	-
Zircon	$ZrSiO_4$		13	2

* Inferred presence.

Summary static geochemical statistics for the Balranald thickener underflow are presented in Table 38. Key results include (KCB, 2013; Earth Systems, 2015):

- Positive NAPP values and NAG pH values below 4.5 indicate the thickener underflow is PAF.
- NAPP values for the thickener underflow samples were the highest of the MBPs and ranged between 240 and 400 kg H_2SO_4/t.
- NAG pH values are similar between all MBP's, and were 1.9-2.2 for the thickener underflow samples.
- Total S was highest for the thickener underflow, of all the MBPs, ranging between 7.9 and 14 wt.% S.
- S_{Cr} values (5.2-7.5 wt.% S) for the thickener underflow samples were high, indicating a significant proportion of S is contained in sufide minerals in these samples, such as pyrite.
- ANC values were below detection limit.
- Total C is highest in the thickener underflow (1.7 wt.% C), however this is likely to be organic carbon as ANC was not detected in any of the MBP samples.
- Thickener underflow NAG7.0 values were the highest of the MBPs, ranging between 170 and 370 kg H_2SO_4/t.
- Results from the two studies display the same general characteristics for the thickener underflow, and the difference in the results does not affect the material's AMD risk classification or AMD management implications.

Table 38: Static geochemical characteristics of the Balranald thickener underflow (KCB, 2013; Earth Systems, 2015).

MBP	Thickener Underflow	
Source	*KCB*	*Earth Systems*
Total S (wt.%)	14	7.9
Cr Reducible S (wt.%)	7.5	5.23
Total Oxidisable S (wt.%)	13	7.7
Sulfate as SO_4^{2-} (wt.%S)	0.860	0.159
MPA (kg H_2SO_4/t) based on S_{TOS} / Total S	398	240
ANC (kg H_2SO_4/t)	<1	<0.5
ANC (kg $CaCO_3$/t)	<1	<0.5
NAPP (kg H_2SO_4/t) based on S_{TOS} / Total S	397	240
NAG pH	1.9	2.2
NAG 4.5 (kg H_2SO_4/t)	320	150
NAG 7.0 (kg H_2SO_4/t)	370	165
AMD Risk Classification	PAF	PAF

Kinetic test work results for thickener underflow are provided in Table 35 and plotted in Figure 28. The PORs for thickener underflow were measured at three GMCs ranging from 8 wt.% to 57 wt.% water, the latter being the as-received moisture content. This material is expected to be highly reactive due to its concentrated sulfide-sulfur content (7.9 wt.%S) and fine grained texture. The measured POR was very low (0.09 wt.% FeS_2/week) for the sample tested as received (57 wt.% water). However the POR increased by one order of magnitude (0.79 wt.% FeS_2/week) for the sample tested at 21 wt.% water and then increased to 3.2 wt.% FeS_2/week) for the relatively dry sample tested at 8 wt.% water.

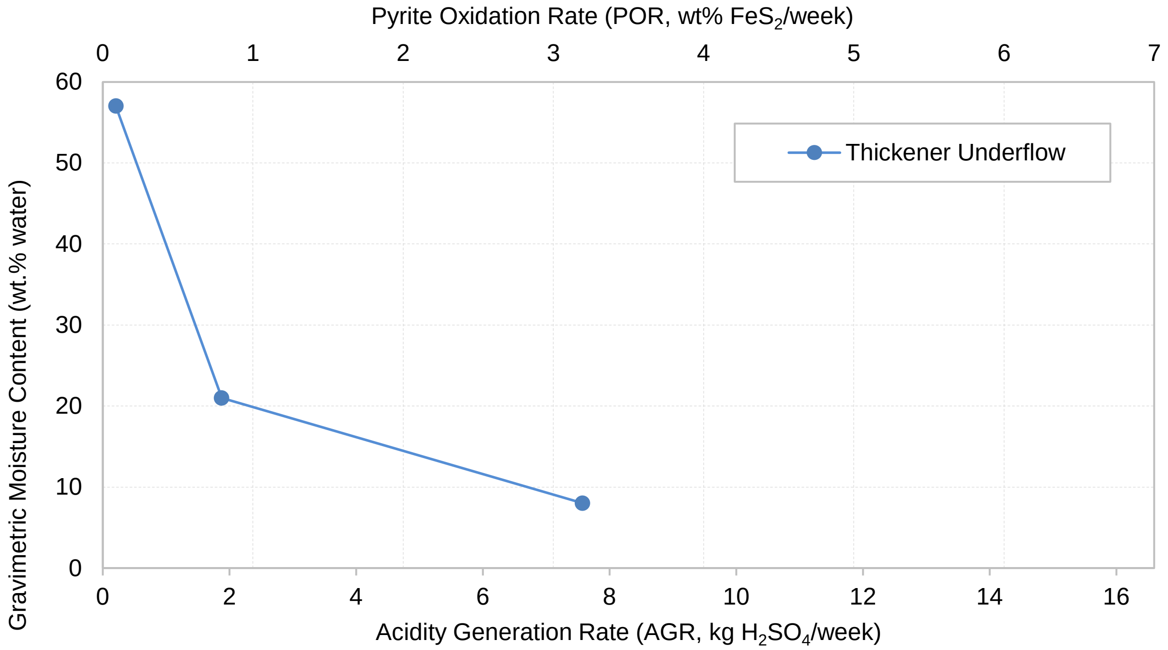

Figure 28: Pyrite oxidation rate (POR) and acidity generation rates (AGR) vs. gravimetric moisture content (GMC) for Balranald thickener underflow samples, showing inferred trend (Earth Systems, 2015).

The key results from leachate chemistry data for Balranald thickener underflow irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that significant AMD was released from the Balranald thickener underflow sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was acidic (pH 4.2) with elevated concentrations of dissolved iron, aluminium, manganese, boron, cadmium, chromium, cobalt, copper, nickel and zinc. These data are consistent with the PAF classification.
- Long term exposure of Balranald thickener underflow to oxidising conditions over several weeks can be expected to generate even more acidic conditions, with pH values approaching 2 and associated increases in dissolved metal concentrations.
- Highly elevated (sulfate) salinity, as indicated by an EC of 49 mS/cm and sulfate concentration of 6,800 mg/L, is attributed to a combination of sulfide oxidation and existing salinity from the groundwater (pore water) leaching from the sample. This interpretation is consistent with the trends in EC and sulfate concentrations, and metal release rates, observed in leachate from humidity cell tests.

6.3.3 Balranald ModCod

Mineralogy results for the Balranald ModCod are presented in Table 39. Key results include (KCB, 2013):

- The ModCod Slurry is almost entirely quartz (97 wt.%) with some halite (2 wt.%) and pyrite (<1 wt.%).
- No carbonate minerals were detected in the sample by XRD.

Table 39: Mineralogy results for the Balranald ModCod (KCB, 2013).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	-
Anatase	TiO_2		-
Birnessite, sodian	$(Na_{0.3}Ca_{0.1}K_{0.1})(Mn^{4+},Mn^{3+})_2O_4 \cdot 1.5 H_2O$		-
Coalingite*	$Mg_{10}Fe_2(CO_3)(OH)_{24} \cdot 2H_2O$		-
Goethite	$FeO(OH)$		-
Gypsum	$CaSO_4 \cdot 2(H_2O)$		-
Halite	$NaCl$		2
Ilmenite	$FeTiO_3$		-
Jarosite	$KFe_3(SO_4)_2(OH)_6$	Secondary acid generating	-
Kaolinite	$Al_2(Si_2O_5)(OH)_4$		-
Marcasite	FeS_2	Primary acid generating	-
Monazite	$(Ce,La,Nd,Th)PO_4$		-
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	Sparingly acid consuming	-
Pseudorutile	$Fe_2Ti_3O_9$		-
Pyrite	FeS_2	Primary acid generating	<1
Quartz	SiO_2		97
Rutile (some leucoxene)	TiO_2		-
Sodalite	$Na_8Al_6Si_6O_{24}Cl_2$		<1
Zircon	$ZrSiO_4$		<1

* Inferred presence.

Static geochemistry laboratory results for the Balranald ModCod are presented in Table 40. Key results include (KCB, 2013; Earth Systems, 2015):

- Positive NAPP values and NAG pH values below 4.5 indicate the ModCod samples are PAF.
- NAPP values for the ModCod samples ranged between 53 and 55 kg H_2SO_4/t.
- NAG pH values are similar between all MBP's, and were 2.2-2.6 for the ModCod samples.
- Total S for the ModCod samples ranged between 1.7 and 1.9 wt.% S.
- S_{Cr} values (0.57-1.1 wt.% S) for the ModCod samples were similar to Total S, indicating a significant proportion of S is present as sulfide minerals in these samples, such as pyrite.
- ANC values were below detection limit.
- ModCod NAG7.0 values were approximately 38 kg H_2SO_4/t.

Table 40: Static geochemical characteristics of the Balranald ModCod (KCB, 2013; Earth Systems, 2015).

MBP	ModCod	
Source	*KCB*	*Earth Systems*
Total S (wt.%)	1.9	1.72
Cr Reducible S (wt.%)	0.57	1.14
Total Oxidisable S (wt.%)	1.8	1.57
Sulfate as SO_4^{2-} (wt.%S)	0.230	0.0385
MPA (kg H_2SO_4/t) based on S_{TOS} / Total S	55	53
ANC (kg H_2SO_4 /t)	<1	<0.5
ANC (kg $CaCO_3$ /t)	<1	<0.5
NAPP (kg H_2SO_4/t) based on S_{TOS} / Total S	55	53
NAG pH	2.2	2.6
NAG 4.5 (kg H_2SO_4/t)	31	33.9
NAG 7.0 (kg H_2SO_4/t)	38	38.1
AMD Risk Classification	PAF	PAF

Kinetic test work results are provided in Table 35 and plotted in Figure 29 and Figure 30, which show that:

- The ModCod sample contained 1.7 wt.% S and was tested at GMCs ranging from 25 wt.% water (as received) down to 1 wt.% water. PORs for the ModCod samples ranged from moderate (0.11 wt.% FeS_2/week) to very high (1.6 wt.% FeS_2/week).
- The highest PORs were associated with the samples tested at 10 wt.% water. The saturated conditions at 25 wt.% water are thought to significantly inhibit the POR, as are the very dry conditions, where water limitations are thought to prevent pyrite oxidation from progressing to completion.
- The PORs generally decreased with increasing sample depth, indicating that diffusion processes (as opposed to advection) are likely to be limiting the rate of oxidation. The depth of oxygen diffusion could not be extracted from the trend using the available data.

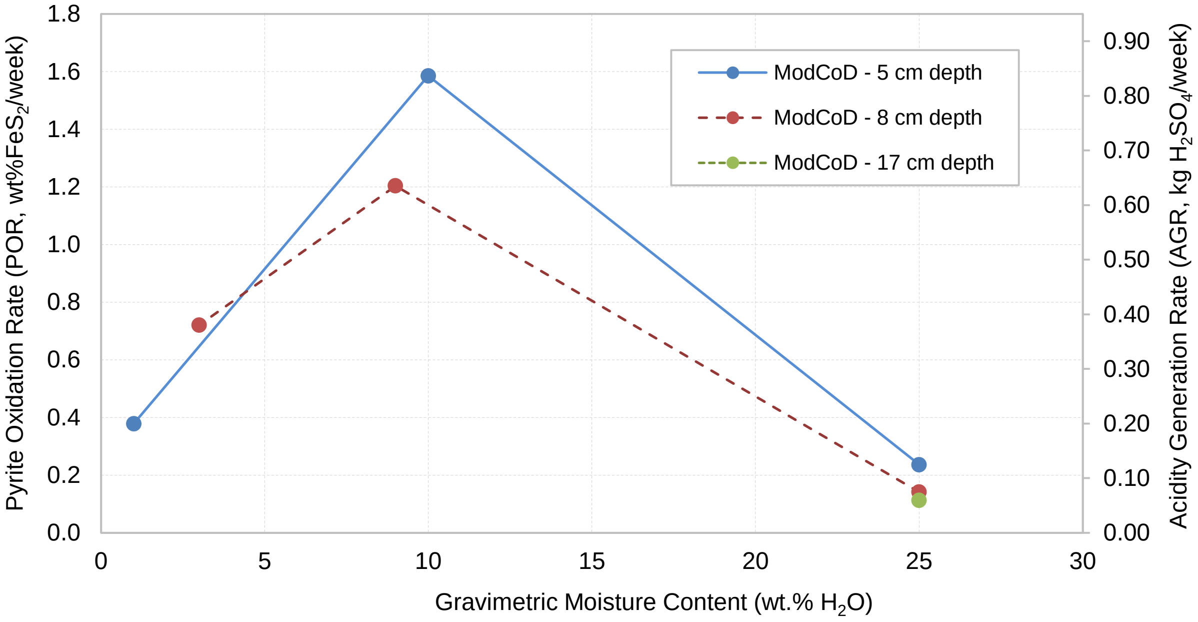

Figure 29: Pyrite oxidation rate (POR) vs. gravimetric moisture content (GMC) for ModCod samples, showing the inferred trend.

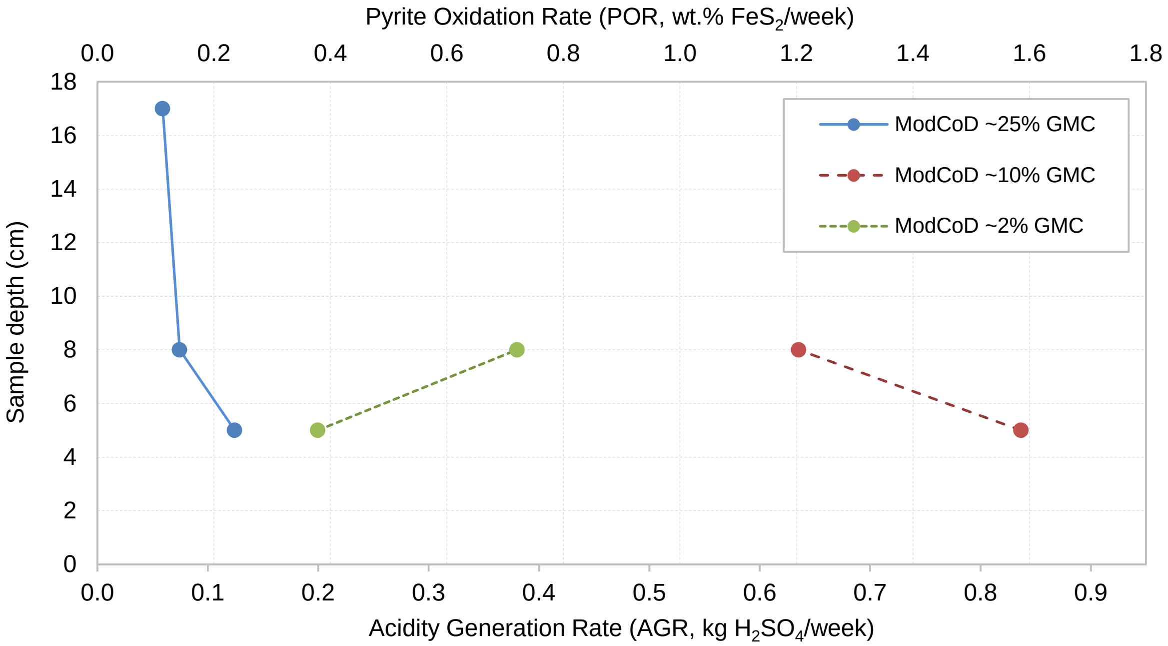

Figure 30: Sample depth vs. pyrite oxidation rates (POR) and acidity generation rates (AGR) for ModCod samples for samples tested at various moisture contents.

The key results from leachate chemistry data for Balranald ModCod irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that significant AMD was released from the Balranald ModCod sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was acidic (pH 3.3) with elevated concentrations of dissolved iron, aluminium, arsenic, boron, cadmium, chromium, cobalt, nickel, uranium and zinc. This data is consistent with the PAF classification.
- Long term exposure of Balranald ModCod to oxidising conditions over several weeks can be expected to generate even more acidic conditions, with pH values approaching 2 and associated increases in dissolved metal concentrations.
- Highly elevated (sulfate) salinity, as indicated by an electrical conductivity (EC) of 20 mS/cm and sulfate concentration of 2,700 mg/L, is attributed to a combination of sulfide oxidation and existing salinity from the groundwater (pore water) leaching from the sample. This interpretation is consistent with the trends in sulfate and metal release rates observed in leachate from humidity cell tests.

6.3.4 Hamilton Mineral Separation Plant By-Products

Static geochemistry test work results for Hamilton MSP by-product samples are presented in Table 41. These results show that:

- Sulfide is concentrated within the Rutile Wet Circuit Concentrate, Float Plant Tails, PDC Conductors oversize (ranging from 14 to 21.6 wt.%S) and to a lesser extent the Hyti (leucoxene) MBP which contained 9.3 wt.%S.
- PDC Ilmenite, combined Zircon Wet Tails and the Combined Monazite Reject MBPs had significantly lower Total Sulfur, ranging from 0.14 to 1.03 wt.%S.
- The majority of the Total Sulfur measured in all samples was in the form of sulfide minerals, based on the S_{Cr} results.
- No ANC was detected in the samples, which is consistent with the lack of ANC in the source material (WHIMS non magnetics).

Table 41: Static geochemistry test work results for Hamilton MSP by-product samples.

Hamilton MSP By-Product	Total S	S_{Cr}	ANC		NAPP	Proportion of total waste produced[1]
	wt.%	wt.%	kg H_2SO_4	% $CaCO_3$	kg H_2SO_4/t	wt.%
PDC Ilmenite	1.0	0.78	<0.5	<0.5	31.5	53
Combined Monazite Reject	0.14	0.058	<0.5	<0.5	4.3	10.5
Hyti (leucoxene)	9.3	7.3	<0.5	<0.5	284	11.7
Combined Zircon Wet Tails	0.36	0.21	<0.5	<0.5	11	8.6
Rutile Wet Circuit Concentrate	22	17	<0.5	<0.5	661	0.9
Float Plant Tails	20	15	<0.5	<0.5	618	11.3
PDC Conductors oversize +410µm	14	11	<0.5	<0.5	428	- [2]
Weighted average	4.3	3.3	<0.5	<0.5	132	n/a

Notes: 1. The remaining 4% of by-products are recycled through the Hamilton MSP.
2. Likely to represent ~0.1 wt.% of the total waste, however may not be produced.

Test work results for classification of the Hamilton by-products with respect to NSW EPA waste classification guidelines are provided in Attachment C. The key results are summarised below:

- Based on Part 3 of the guidelines relating to wastes containing radioactive material, the combined monazite reject is likely to be classified as Hazardous Solid Waste.
- Based on Part 3 of the guidelines relating to wastes containing radioactive material, the PDC ilmenite, Hyti, combined zircon wet tails, rutile wet concentrate circuit, PDC conductors oversize and float plant tails by-product streams are likely to be classified as Restricted Solid Waste.
- Notwithstanding the classification of the Hamilton by-products by the guidelines relating to wastes containing radioactive material:
  - Based on Part 1, Step 5 of the guidelines relating to chemical classification of solid wastes, the combined zircon wet tails would be classified as Restricted Solid Waste.
  - Based on Part 1, Step 5 of the guidelines relating to chemical classification of solid wastes, the PDC conductors oversize would be classified as Restricted Solid Waste.

6.4 Products

Potential sources of AMD from mining products generated at the Balranald Project process plant will include:

- HMC product stockpile (non-magnetics stream from WHIMS process plant at Balranald); and
- Ilmenite product stockpile (major component of WHIMS magnetics stream at Balranald).

Static and kinetic geochemical test work results for these products are described below.

6.4.1 Heavy Mineral Concentrate

Mineralogy results for the HMC (WHIMS non-magnetics) are presented in Table 42. Key results include (KCB, 2013; Earth Systems, 2015):

- The HMC is composed of predominantly zircon (65 wt.% (KCB, 2013) / 38 wt.% (Earth Systems, 2015)) and rutile (32 wt.% (KCB, 2013) / 44 wt.% (Earth Systems, 2015)), with some quartz (10 wt.%)
- No carbonate minerals were detected by XRD.

Table 42: Mineralogy results for the HMC (KCB, 2013, Earth Systems, 2015).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)	
Source			*KCB*	*Earth Systems*
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	-	-
Anatase*	TiO_2		2	<1
Birnessite, sodian	$(Na_{0.3}Ca_{0.1}K_{0.1})(Mn^{4+},Mn^{3+})_2O_4 \cdot 1.5\ H_2O$		-	-
Coalingite*	$Mg_{10}Fe_2(CO_3)(OH)_{24} \cdot 2H_2O$		1	-
Goethite	$FeO(OH)$		-	-
Gypsum	$CaSO_4 \cdot 2(H_2O)$		-	-
Halite	$NaCl$		-	-
Ilmenite	$FeTiO_3$		-	3
Jarosite	$KFe_3(SO_4)_2(OH)_6$	Secondary acid generating	-	-
Kaolinite	$Al_2(Si_2O_5)(OH)_4$		-	<1
Marcasite	FeS_2	Primary acid generating	-	<1
Monazite	$(Ce,La,Nd,Th)PO_4$		-	<1
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	Sparingly acid consuming	-	2
Pseudorutile*	$Fe_2Ti_3O_9$		-	1
Pyrite	FeS_2	Primary acid generating	-	1
Quartz	SiO_2		-	10
Rutile (some leucoxene)	TiO_2		32	44
Sodalite	$Na_8Al_6Si_6O_{24}Cl_2$		-	-
Zircon	$ZrSiO_4$		65	38

* Inferred presence.

Static geochemistry results for the HMC are presented in Table 43. Key results include (KCB, 2013; Earth Systems, 2015):

- Positive NAPP values and NAG pH values below 4.5 indicate the HMC samples are PAF.
- NAPP values for the HMC samples ranged between 28.4 and 33 kg H_2SO_4/t.
- NAG pH values were 2.3-2.5 for the HMC samples.
- Total S for the HMC samples ranged between 0.93 and 1.1 wt.% S.
- S_{Cr} values (0.25-0.87 wt.% S) for the HMC samples were similar to Total S, indicating a significant proportion of S is present as sulfide minerals, such as pyrite.
- ANC values were below the detection limit.
- NAG7.0 values for the HMC samples were between 36-40 kg H_2SO_4/t.

Table 43: Static geochemical characteristics of the HMC (KCB, 2013; Earth Systems, 2015).

Product	Heavy Mineral Concentrate (WHIMS Non-Magnetics)	
Source	*KCB*	*Earth Systems*
Total S (wt.%)	1.1	0.93
Cr Reducible S (wt.%)	0.25	0.868
Total Oxidisable S (wt.%)	1.1	0.84
Sulfate as SO_4^{2-} (wt.%S)	0.044	0.026
MPA (kg H_2SO_4/t) based on S_{TOS} / Total S	34	28
ANC (kg H_2SO_4 / t)	<1	<0.5
ANC (kg $CaCO_3$ / t)	<1	<0.5
NAPP (kg H_2SO_4/t) based on S_{TOS} / Total S	33	28
NAG pH	2.3	2.5
NAG 4.5 (kg H_2SO_4/t)	35	27
NAG 7.0 (kg H_2SO_4/t)	40	36.2
AMD Risk Classification	PAF	PAF

Kinetic test work results for the HMC samples are provided in Table 44. These samples contained 0.93 wt.% S, whereas the ilmenite sample (WHIMS magnetics) contained 0.48 wt.% S. Both HMC and ilmenite samples were tested as received at a GMC of 14 wt.% water.

PORs for the two HMC samples were 1.1-1.2 wt.% FeS_2/week and did not vary as a function of sample depth, indicating full exposure of the samples to oxidising conditions. Note that only limited sample quantity was available hence the maximum sample depth was 6 cm.

For comparison, indicative PORs based on humidity cell test work (KCB, 2013) are shown in Table 45.

Table 44: Kinetic geochemical test work results relevant to HMC and ilmenite using the oxygen consumption method (Earth Systems, 2015).

Sample ID	Description	Total sulfur	Sulfide sulfur (S_{TOS})	MPA[1]	ANC	GMC	Pyrite oxidation rate (POR)[2]	Indicative time to oxidise 90% of pyrite in exposed material	Estimated lag time to onset of acid conditions	Acid Generation Rate (AGR)
		wt.% S	wt.% S	kg H_2SO_4/t	kg H_2SO_4/t	wt.% H_2O	wt.%/week FeS_2	years	weeks	kg H_2SO_4/t/year
WHIMS-MAG	WHIMS-MAG - Magnetic fraction from the WHIMS plant at 14% wt. water	0.48	0.42	15	<0.5	14.0	2.43	4 years	no lag time	0.36
WHIMS-NONMAG-2CM	WHIMS-NONMAG - Non-Magnetic WHIMS fraction at 2 cm thickness and 14 wt.% water	0.93	0.84	28	<0.5	14.0	1.11	7 years	no lag time	0.32
WHIMS-NONMAG-6CM	WHIMS-NONMAG - Non-Magnetic WHIMS fraction at 6 cm thickness and 14 wt.% water	0.93	0.84	28	<0.5	14.0	1.22	7 years	no lag time	0.35

Notes: 1. The maximum potential acidity that can be generated from the sample if all of the sulfur were to oxidise.

2. PORs are calculated based on the oxygen consumption and then normalised to the sample sulfur content. These are expressed in terms of the percentage of the remaining pyrite that is oxidised per unit time.

3. Mass Ratio of limestone required to neutralise the acidity generated from each tonne of material exposed to oxidising conditions per week. A stoichiometric ratio of 3:1 for the mass of ($CaCO_3$) limestone relative to the mass of (H_2SO_4) acidity generated is recommended to allow for limestone impurities, passivation reactivity limitations.

4. Mass Ratio of hydrated lime required to neutralise the acidity generated from each tonne of material exposed to oxidising conditions per week. A stoichiometric ratio of 1:1 for the mass of hydrated lime relative to the mass of acidity generated is provided based on the assumption that only the soluble acidity in process water stream is to be treated.

Table 45: Indicative pyrite oxidation rates (PORs) relevant to mining products based on humidity cell test work conducted by KCB (2013).

Material	Average Total S	Calculated average weekly sulfate release[1]	Calculated average weekly acidity release[2]	Indicative pyrite oxidation rate (POR)[3]
	wt.% S	mg/kg/week	mg $CaCO_3$ /kg/week	wt.% FeS_2/week
Ilmenite (WHIMS magnetics)	0.71	207	54	1.0
HMC (WHIMS non magnetics)	1.1	106	417	0.3

Notes: 1. Values obtained from KCB (2013) – Table 4-2 p.82 and Appendix 1.

2. Calculated based on pH and dissolved metals in humidity cell leachate data from KCB (2013) – Appendix 1.

3. Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content).

The key results from leachate chemistry data for the HMC samples irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that AMD was released from the HMC sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was acidic (pH 3.8) with elevated concentrations of dissolved iron, aluminium, boron, chromium, cobalt, nickel and zinc. This data is consistent with the PAF classification.
- Long term exposure of HMC to oxidising conditions over several weeks can be expected to generate even more acidic conditions, with pH values approaching 2 and associated increases in dissolved metal concentrations.
- Elevated (sulfate) salinity, as indicated by an EC of 7.2 mS/cm and sulfate concentration of 710 mg/L, is attributed to a combination of sulfide oxidation and existing salinity from the groundwater (pore water) leaching from the sample. This interpretation is consistent with the trends in EC and sulfate concentrations, and metal release rates, observed in leachate from humidity cell tests.

6.4.2 Ilmenite

Mineralogy results for the Balranald ilmenite samples (WHIMS magnetics) are presented in Table 46. Key results for this material include (KCB, 2013; Earth Systems, 2015):

- The product is comprised of predominantly ilmenite (85 wt.%) with a smaller amount of with rutile (15 wt.% (KCB, 2013) / 8 wt.% (Earth Systems, 2015) and some non-magnetics.
- No carbonate minerals were detected by XRD.

Table 46: Mineralogy results for the ilmenite product (KCB, 2013; Earth Systems, 2015).

Mineral Name	Mineral Formula	AMD Significance	Mineral composition (wt.%)	
Source			*KCB***	*Earth Systems*
Alunite	$KAl_3(SO_4)_2(OH)_6$	Secondary acid generating	-	-
Anatase*	TiO_2		-	<1
Birnessite, sodian	$(Na_{0.3}Ca_{0.1}K_{0.1})(Mn^{4+},Mn^{3+})_2O_4 \cdot 1.5 H_2O$		-	-
Coalingite*	$Mg_{10}Fe_2(CO_3)(OH)_{24} \cdot 2H_2O$		-	-
Goethite	$FeO(OH)$		-	1
Gypsum	$CaSO_4 \cdot 2(H_2O)$		-	<1
Halite	$NaCl$		-	<1
Ilmenite	$FeTiO_3$		85	85
Jarosite	$KFe_3(SO_4)_2(OH)_6$	Secondary acid generating	-	-
Kaolinite	$Al_2(Si_2O_5)(OH)_4$		-	-
Marcasite	FeS_2	Primary acid generating	-	<1
Monazite	$(Ce,La,Nd,Th)PO_4$		-	<1
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	Sparingly acid consuming	-	-
Pseudorutile*	$Fe_2Ti_3O_9$		-	<1
Pyrite	FeS_2	Primary acid generating	-	1
Quartz	SiO_2		-	<1
Rutile (some leucoxene)	TiO_2		15	8
Sodalite	$Na_8Al_6Si_6O_{24}Cl_2$		-	-
Zircon	$ZrSiO_4$		-	2

* Inferred presence.

** Ilmenite-rich fraction.

Static geochemistry for the Balranald ilmenite samples are presented in Table 47. Key results include (KCB, 2013; Earth Systems, 2015):

- Positive NAPP values and NAG pH values below 4.5 indicate the ilmenite product is PAF.
- NAPP values for the ilmenite samples ranged between 9.3 and 15 kg H_2SO_4/t.
- NAG pH values were 2.5 for the ilmenite samples.
- Total S for the ilmenite samples ranged between 0.48 and 0.71 wt.% S.
- S_{Cr} values (0.35-0.55 wt.% S) for the ilmenite samples were similar to Total S, indicating a significant proportion of S is present as sulfide minerals in these samples, such as pyrite.
- ANC values ranged between below detection limit (<0.5 kg H_2SO_4/t) and 10 kg H_2SO_4/t.
- WHIMS magnetics NAG7.0 values were between 14-24 kg H_2SO_4/t.

The POR for the WHIMS magnetic stream sample was approximately twice that of the non-magnetic stream samples at 2.4 wt.% FeS_2/week.

Table 47: Static geochemical characteristics of the ilmenite product (KCB, 2013; Earth Systems, 2015).

Product	Ilmenite	
Source	*KCB*	*Earth Systems*
Total S (wt.%)	0.71	0.48
Cr Reducible S (wt.%)	0.55	0.35
Total Oxidisable S (wt.%)	0.63	0.42
Sulfate as SO_4^{2-} (wt.%S)	0.13	0.011
MPA (kg H_2SO_4/t) based on S_{TOS}	19	15
ANC (kg H_2SO_4/t)	10	<0.5
ANC (kg $CaCO_3$/t)	10	<0.5
NAPP (kg H_2SO_4/t) based on S_{TOS}	9.3	15
NAG pH	2.5	2.5
NAG 4.5 (kg H_2SO_4/t)	20	10.9
NAG 7.0 (kg H_2SO_4/t)	24	13.5
AMD Risk Classification	PAF	PAF

The key results from leachate chemistry data for the ilmenite samples irrigated with de-ionised water are summarised below (Earth Systems, 2015; KCB, 2013):

- Leachate chemistry data indicate that some AMD was released from the ilmenite sample after exposure to oxidising conditions at the completion of the OxCon test. The leachate was slightly acidic (pH 6.6) with elevated dissolved boron (0.39 mg/L). This data is consistent with the PAF classification.
- Long term exposure of ilmenite product to oxidising conditions over several weeks can be expected to generate even more acidic conditions, with pH values approaching 2 and associated increases in dissolved metal concentrations.
- Elevated (sulfate) salinity, as indicated by an electrical conductivity (EC) of 7.1 mS/cm and sulfate concentration of 520 mg/L, is primarily attributed to existing salinity from the groundwater (pore water) leaching from the sample. This interpretation is consistent with the trends in EC and sulfate concentrations, and metal release rates, observed in leachate from humidity cell tests.

6.5 Summary

A summary of the key geochemical characteristics and AMD risk classifications for each mine material, which are used throughout the impact assessment in Sections 8 to 12, is presented in Table 48.

Table 48: Summary of static and kinetic geochemical characteristics of mine materials at the Balranald Project.

Material	Average Acid-Base Accounting Data			Pyrite Oxidation Rate Data		Leachate Chemistry Data					AMD Risk Classification[4]
	S_{TOS}	ANC	NAPP[1]	Indicative POR[2]	Indicative time to oxidise 90% of pyrite in exposed material[3]	Leachate pH	Leachate SO_4	Leachate pH[5]	Leachate SO_4	Leachate elements of environmental significance	
	wt.%S	kg H_2SO_4/t	kg H_2SO_4/t	Wt.%/week FeS_2	years	pH units	mg/L SO_4	pH units	mg/L SO_4		
Data Source	Earth Systems (2015) and KCB (2013)					Earth Systems (2015)		KCB (2013)[5]		Earth Systems (2015)	
NSOB											
WB	0.034	2.9	-1.7	no data	n/a	n/a	n/a	n/a	n/a	n/a	Unlikely to be acid generating
Nepean	0.02	3.7	-3.0	0.2 - 2.3	n/a	n/a	n/a	~6.0 - 8.0	TBC	n/a	
SOB											
WB	0.02	0.8	-0.2	0.4 - 0.5	~20	7.4	608	~6.8 - 7.0	TBC	n/a	Unlikely to be acid generating
Nepean	No SOB present at Nepean										
OOB											
WB	1.01	1.1	31	1.3 - 2.5	~3	5.1	1,030	~2.0 - 3.0	TBC	Fe, Al, Mn, Cd, Cr, Co, Cu, Ni, Zn	Low potential for acid generation
Nepean	No OOB present at Nepean										
ORE											
WB	1.09	<1	33	1.3 - 2.2	~4	4.7	899	~2.5 - 3.2	TBC	Fe, Al, Mn, Cr, Co, Cu, Ni, Zn	Moderate potential for acid generation
Nepean	0.03	2	-1.2	0.4	n/a	n/a	n/a	~6.3 - 8.5	TBC	n/a	
Balranald MBPs – acid base accounting and pyrite oxidation rate data from Earth Systems (2015) assumed to be most representative											
Sand Tails	0.31	<0.5	11	up to 2.4	4 years	4.4	786	~2.3 - 3.0	~200 - 2,000	Fe, Al, Mn, Cr, Co, Cu, Ni, Zn	Low potential for acid generation
ModCod	1.57	<0.5	53	up to 1.6	5 years	3.3	2,670	~2.0 - 3.0	~200 - 3,000	Fe, Al, Mn, Cd, Cr, Co, Cu, Ni, Zn	Moderate potential for acid generation
Thickener underflow	7.7	<0.5	240	up to 3.2	3 years	4.2	6,770	~2.0 - 3.0	~2,000 - 8,000	Fe, Al, Mn, Cd, Cr, Co, Cu, Ni, U, Zn	High potential for acid generation
Magnetic rejects	Not tested, refer to WHIMS magnetics below.										n/a

Material	Average Acid-Base Accounting Data			Pyrite Oxidation Rate Data		Leachate Chemistry Data					AMD Risk Classification(4)
	S_{TOS}	ANC	NAPP(1)	Indicative POR(2)	Indicative time to oxidise 90% of pyrite in exposed material(3)	Leachate pH	Leachate SO_4	Leachate pH(5)	Leachate SO_4	Leachate elements of environmental significance	
	wt.%S	kg H_2SO_4/t	kg H_2SO_4/t	Wt.%/week FeS_2	years	pH units	mg/L SO_4	pH units	mg/L SO_4		
Data Source	Earth Systems (2015) and KCB (2013)					Earth Systems (2015)		KCB (2013)(5)		Earth Systems (2015)	
Hamilton by-products											
PDC Ilmenite	0.78(6)	<0.5	31.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Moderate / High Potential for Acid Generation
Combined Monazite Reject	0.058(6)	<0.5	4.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Unlikely to be Acid Generating
Hyti (leucoxene)	7.3(6)	<0.5	284	n/a	n/a	n/a	n/a	n/a	n/a	n/a	High Potential for Acid Generation
Combined Zircon Wet Tails	0.21(6)	<0.5	11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Moderate Potential for Acid Generation
Rutile Wet Circuit Concentrate	17(6)	<0.5	661	n/a	n/a	n/a	n/a	n/a	n/a	n/a	High Potential for Acid Generation
Float Plant Tails	15(6)	<0.5	618	n/a	n/a	n/a	n/a	n/a	n/a	n/a	High Potential for Acid Generation
PDC Conductors oversize +410µm	11(6)	<0.5	428	n/a	n/a	n/a	n/a	n/a	n/a	n/a	High Potential for Acid Generation
Balranald products – acid base accounting and pyrite oxidation rate data from Earth Systems (2015) assumed to be most representative											
WHIMS non-magnetics (HMC)	0.84	<0.5	28	up to 1.2	7 years	3.8	706	~2.5 - 2.8	~800 - 2,000	Fe, Al, Mn, Cr, Co, Cu, Pb, Ni, Zn	Moderate / high potential for acid generation
WHIMS magnetics (ilmenite)	0.42	<0.5	15	up to 2.4	4 years	6.6	515	~2.5 - 3.0	~200 - 900	Fe, Al, Mn, Cr, Co, Cu, Ni, Zn	Low potential for acid generation

Notes:
1. NAPP is calculated based on S_{TOS}.
2. Weight percentage of available pyrite oxidised per unit time (ie. normalised with respect to pyrite content).
3. POR follows an exponential decay curve as reported in Earth Systems (2015).
4. Refer to Table 10 for classification scheme.
5. Indicative values based on plotted humidity cell leachate trends in KCB (2013).
6. S_{Cr} value as S_{TOS} not reported.

7.0 Site Water Balance and Hydrogeology

7.1 Construction

Water supply for pre-mining / construction will be sourced from the Olney formation. It is proposed that groundwater will be sourced from local borefields at a rate of up to 150 ML/year during the construction phase (Jacobs, 2015).

7.2 Operations

A schematic of the proposed water management strategy for the operations phase of the project is provided in Figure 31. The philosophy of the proposed water management strategy for the project is to maintain separation between sources of water with expected differences in water chemistry and prevent the release of mine affected waters from the Project (WRM, 2015). Key aspects of the project water management strategy during operations include (WRM, 2015):

- Surface water run-off from undisturbed catchments will be diverted around project infrastructure for environmental release, where feasible.
- Hypersaline groundwater from the LPS Formation aquifer will be extracted via dewatering bores in the vicinity of the West Balranald deposit to allow for mining below the current water table.
- Some of the extracted groundwater will be used for mine water supply, however most of the groundwater will be reinjected to the LPS Formation aquifer via the injection borefield. A network of eight injection borefields in the project area will be required for the return of hypersaline groundwater to the LPS Formation aquifer. Water will be stored in a series water storage dams during well development.
- There will be no surface discharge of hypersaline groundwater from the project area.
- Seepage, groundwater and surface water run-off contributions to the West Balranald mine void will be collected in on-site storages and used for mine water supply.
- Surface water run-off from the MUP area and processing area, and the SOB and PAF stockpiles will be collected in on-site storages and used for mine water supply.
- Surface water run-off from NSOB stockpiles, the open cut mining area and ROM pad at the Nepean mine will be captured and treated in sediment dams and/or used for dust suppression, or potentially released from the site via spillway discharges during rainfall events that exceed the sediment basin design criteria.
- Water will be pumped from the Murrumbidgee River (up to 450 ML/year[9]) for raw water supply for use in dust suppression on sensitive areas and filtered water demands.
- Potable water will be trucked into the project area and stored in a tank for reticulation and consumption.

Groundwater modelling has predicted an average dewatering rate of 746 L/s for the six years of mining and an average of 95 L/s during the two years of backfilling for the West Balranald deposit (Jacobs,

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[9] To be confirmed.

2015). The predicted groundwater drawdown cone of depression extends along the length of the deposit and up to approximately 10 km laterally from the strike of the deposit for the Shepparton Formation (Jacobs, 2015). In the LPS Formation, the drawdown is predicted to extend up to approximately 15 km laterally from the West Balranald deposit (Jacobs, 2015).

The drawdown cone of depression for the Nepean deposit is predicted to extend no further than 2 km from the deposit in both the Shepparton and LPS Formations (Jacobs, 2015) with an average dewatering rate of 100 L/s for the 1.5 years of mining and a peak dewatering rate of 186 L/s (Jacobs, 2015).

Water produced by dewatering operation would be reinjected into the LPS Formation via on-path injection wells at West Balranald and an off-path injection borefield, located on and accessed from the Nepean access road (Jacobs, 2015). The off-path injection borefield would receive the majority of water produced from dewatering (Jacobs, 2015). Groundwater injection is expected to peak at approximately 1,300 L/s. The injection borefield has been designed to ensure the water table remains a minimum of 3 metres below the ground surface (Jacobs, 2015).

Post-mining of the West Balranald deposit, when groundwater produced from dewatering activities is insufficient to meet plant make-up and dust suppression water requirements, Iluka also proposes operation of a groundwater supply from the LPS aquifer (Jacobs, 2015).

Uncontrolled releases of mine affected water are predicted to be rare (less than a 1% chance occurring in any year of the mine life) and low volume, and it is expected that any uncontrolled releases could be contained by bunds and sumps, preventing the release of mine affected water from the project area (WRM, 2015).

7.3 Post-Closure

At closure, saline water from water storage dams, process water dams and the TSF will be injected to the LPS Formation aquifer via the injection borefield.

WRM (2014) prepared a water balance for the final void at West Balranald. The model was run for a period of 125 years in order to investigate the long term water management strategy for the final void at the West Balranald deposit (WRM, 2015). A schematic of the water balance for the West Balranald final void is provided in Figure 32. Key aspects of the West Balranald final void include (WRM, 2015; Jacobs, 2015):

- Surface water run-off will be diverted around the area surrounding the final void, limiting the catchment area (approximately 52 ha) and the amount of water reporting the final void.
- The invert level of the final void (52 m AHD) will be approximately 13.5 m below existing ground levels (65.5 m AHD) and will be 4 metres above the pre-mining water table elevation in the LPS Formation aquifer at this location of 48 m AHD. No groundwater is expected to enter the final void post-closure (ie. the final void will not act as a groundwater sink).
- Surface water run-off from the catchment of the final void will collect at the base of the void and evaporate or percolate through the floor of the void to the LPS Formation aquifer.

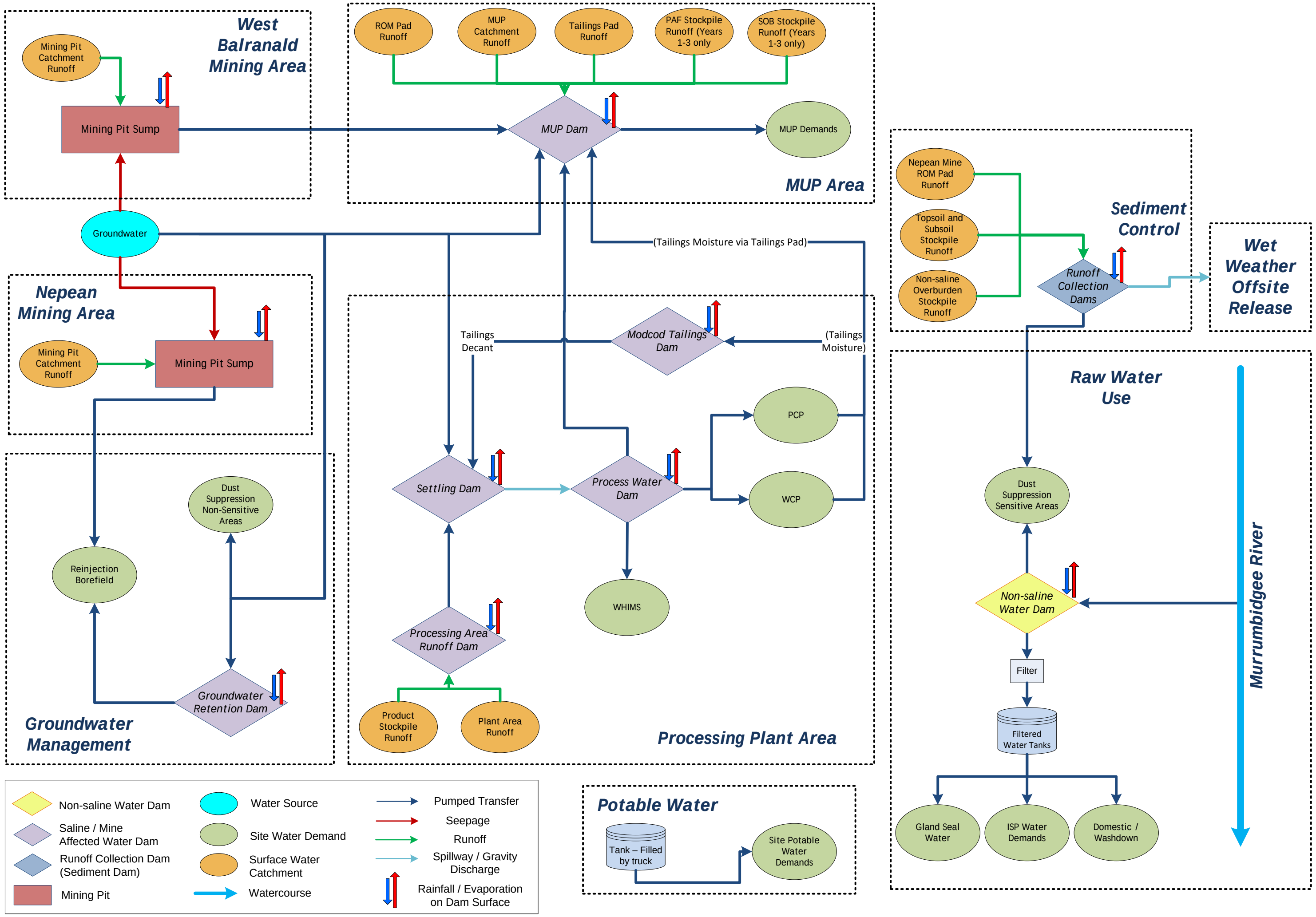

Figure 31: Balranald Project conceptual water management system (WRM, 2015).

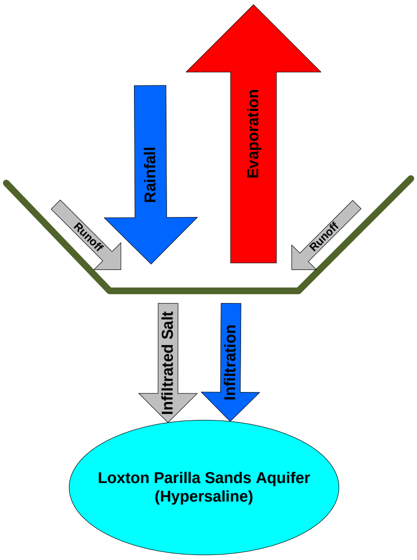

Figure 32: Water balance model for the West Balranald final mine void (WRM, 2015).

No modelling was conducted for the Nepean final void as the void is not expected to intercept groundwater (WRM, 2015). It is expected that surface water run-off in the final void will collect and either evaporate or percolate through the floor of the final void to the LPS Formation aquifer.

The Shepparton and LPS Formation aquifers were modelled to have residual groundwater level drawdown and mounding of up to 1 m at West Balranald and the off-path borefield respectively (Jacobs, 2015). No residual impact of dewatering at Nepean is expected (Jacobs, 2015).

8.0 Impact Assessment – Overburden

8.1 Construction

8.1.1 Context

During construction, overburden stockpiles (as well as soil stockpiles) will be generated from excavation of the box cut at the West Balranald deposit.

The box cut volume at West Balranald will be approximately 9.5 million m^3, comprising 0.5 million m^3 of soils and 9.0 million m^3 of overburden.

NSOB, SOB and OOB will be segregated within the overburden stockpile areas. Total volumes of each overburden component at the West Balranald box cut are estimated at 4.1 million m^3, 4.7 million m^3 and 0.2 million m^3, respectively. At an in situ density of 1.8 t/m^3, the estimated tonnage of overburden from the West Balranald box cut is 16.1 million tonnes, of which 0.3 million tonnes (1.8%) is classified as OOB and has significant potential to generate AMD. Refer to Table 49.

Table 49: Material quantities in the West Balranald box cut.

West Balranald Box Cut Material	Volume (million m^3)	In Situ Density (t/m^3)	Mass	
			Million tonnes	%
NSOB	4.1	1.8	7.3	45%
SOB	4.7	1.8	8.5	53%
OOB	0.2	1.8	0.3	1.8%
Total	9.0	1.8	16.1	100%

The OOB has an average sulfide-sulfur (S_{TOS}) content of 1.01 wt.% S and relatively minor ANC (Table 24) and a maximum POR of 2.5 wt.% FeS_2/week (Table 25) under fully oxidising conditions (full exposure to atmospheric oxygen)[10]. The thickness of the OOB layer across the deposit ranges from 3-20 metres, increasing along strike from south to north, and is therefore expected to be around 3 metres in the vicinity of the box cut.

The NSOB and SOB materials at West Balranald have minimal, if any, sulfide-sulfur content. These materials are not considered to represent an AMD risk and are therefore not assessed further in this study.

There are insufficient quantities of ANC for the NSOB and SOB to be classified as "*Likely to be Acid Consuming*" (Table 15) hence there is no obvious potential to utilise these materials as a resource for AMD neutralisation. However, geochemical test work indicates that SOB has the potential to consume oxygen (refer to Section 6.1.2)[11] and may therefore present opportunities for AMD prevention or

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[10] Up to 2.5 wt.% of all pyrite that is fully exposed to atmospheric oxygen will decompose to form sulfuric acid each week.

[11] While oxygen consumption occurs via sulfide oxidation in the SOB, the material is still classified as NAF due to its relatively low sulfide content and an excess of ANC.

minimisation by lowering air entry to PAF mine materials and associated sulfide oxidation (Earth Systems, 2015).

There will be no box cut development or mining of the Nepean deposit during the construction phase.

The assessment of each potential impact on surface water / groundwater in the following section also takes into consideration the following:

- Groundwater from the project area will drain to the Shepparton Formation and LPS Formation aquifers (refer to Section 3.4). Baseline groundwater quality data indicates that these aquifers are generally unsuitable for agricultural and stock water uses due to their high salinity concentrations.
- Of the 26 landholder bores nearest to the project area identified by Jacobs (2015), 19 bores are screened in the Olney Formation, 3 bores are screened in the Shepparton Formation, 3 bores are screened in the Geera Clay and 1 bore is screened in the LPS Formation. The 3 landholder bores screened in the Shepparton Formation are located approximately 10-15 km west of the northern end of the West Balranald deposit (Jacobs, 2015; Appendix F)[12]. Refer to Section 3.6.2.
- Groundwater modelling conducted by Jacobs (2015) indicates that the extent of groundwater drawdown in local landholder bores is not likely to exceed 0.07 metres. Maximum drawdown in the Olney Formation bores is estimated at 0.07 metres, with relatively minor drawdown predicted for the other bores (Shepparton Formation 0 metres; Geera Clay 0.06 metres; LPS Formation (0.02 metres).
- GDEs in the vicinity of the project area are either unlikely to be significant groundwater users (based on groundwater salinity and/or depth to the water table) or unlikely to experience groundwater drawdown in excess of 3-5 metres in the Shepparton Formation (CDM Smith, 2015; Figure 7-3). For example, the nearest GDEs are located approximately 0.5 km from the northern extent of the West Balranald deposit and are generally defined as Class 4 (likely to be low level of groundwater use). These GDEs are predicted to experience groundwater drawdown not exceeding 3-5 metres. The next closest GDEs are located approximately 4 km from the southern extent of the West Balranald deposit and are generally defined as Class 3 (likely to be moderate level of groundwater use) but are predicted to experience negligible groundwater drawdown. No Class 1 or 2 GDEs are present in the vicinity of the project area. Refer to Figure 16 in Section 3.6.3.
- Further to the above points, the rate of groundwater flow away from the project area is expected to be low under natural conditions based on existing regional hydraulic gradients and modelling conducted by Jacobs (2015). In particular, there is expected to be a significant hydraulic gradient towards the centre of each pit during mine development. At the end of mining, full groundwater rebound is expected to take more than 100 years at the West Balranald and 30-100 years at Nepean. Thereafter, groundwater flows will be subject to considerably lower hydraulic gradients relative to those experienced during groundwater rebound, with a regional hydraulic gradient in the order of around 0.00025 (5 metres per 20 km; from east to west) under natural conditions (Jacobs, 2015).

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[12] The location of 2 additional landholder bores screened in the Shepparton Formation, as identified in the LWC (2014f) study, and 1 bore screened in the LPS Formation (Jacobs, 2015), is still to be confirmed.

- Uncontrolled releases of mine affected water are predicted to be rare (less than a 1% chance occurring in any year of the mine life) and low volume, and it is expected that any uncontrolled releases could be contained by bunds and sumps, preventing the release of mine affected water from the project area. Refer to Section 7.2.
- Natural drainage lines in the vicinity of the project area are generally dry throughout the year based on historic anecdotal evidence as reported in WRM (2015) and Section 3.2. For example, flows in Box Creek have been observed on several occasions (only) over the last 60 years (once in 1956, several times in the 1970s and in 2010-11). Thus, any impacts on surface water (or riparian land) would be associated with extremely high rainfall conditions, locally and/or in the upper catchment of these drainage lines.
- Due to the ephemeral nature of surface water flows, there are no surface water users in the immediate vicinity of the project area. The nearest reliable and significant surface water resource is the Murrumbidgee River, approximately 30 km south-west of the project area. Refer to Section 3.6.1.

The above considerations apply throughout the following sections of this geochemistry assessment, and are not repeated hereafter.

8.1.2 Potential Impacts

Potential construction phase AMD impacts relating to overburden materials from the West Balranald and Nepean deposits are summarised in Table 50.

Table 50: Potential (Unmitigated) AMD Impacts from Overburden Material during the Construction Phase.

Project Element	Potential AMD Impact	Description
Overburden material stockpiled above ground level – West Balranald deposit	Runoff or seepage of AMD from temporary OOB stockpile (from box cut) into surface water / groundwater	The quantity of OOB from the box cut at the West Balranald deposit to be temporarily stockpiled is estimated at up to 0.3 million tonnes, although only the outer 2 metre layer is expected to be exposed to oxidising conditions. This is based on key findings from kinetic geochemical test work which indicate that air entry to stockpiled OOB materials is unlikely to exceed 2 metres, and this is the key control on acidity generation rate, rather than the total tonnage of unsaturated (stockpiled) material (see Section 6.1.3). With an average sulfide-sulfur content of 1.01 wt.% S, relatively minor ANC, a POR of 2.5 wt.% FeS_2/week (Section 8.1.1), and assuming one stockpile only, this could generate an estimated acidity load of up to around 80 tonnes H_2SO_4 per week or around 600 tonnes H_2SO_4 in total during the construction phase, assuming that the duration of stockpiling is 2 months . The timing of acidity fluxes from the temporary OOB stockpile will tend to be associated with rainfall events. Based on site rainfall characteristics, localised acidity fluxes to surface water or groundwater could occur at various times throughout the year. Surface water would be collected and contained on site under most conditions, with less than 2% chance of an uncontrolled release during a 1-2 year construction phase, based on water balance estimates provided in WRM (2015). Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. In the absence of AMD management measures, the potential impact is considered HIGH (consequence – major; likelihood – probable).

Project Element	Potential AMD Impact	Description
Overburden material stockpiled above ground level – Nepean deposit	Runoff or seepage of AMD from temporary overburden stockpiles into surface water / groundwater	Not applicable during the construction phase.
Overburden material used for site construction works	Runoff or seepage of AMD from any overburden materials used for site construction works (eg. access roads, hardstand areas, dam embankments) into surface water / groundwater	The quantity of overburden or other borrow material required for site construction works is currently unknown. The seepage could be affected by AMD if OOB is inadvertently used for site construction works. As with stockpiled OOB, localised acidity fluxes to surface water or groundwater could occur at various times throughout the year based on site rainfall characteristics. Surface water would be collected and contained on site under most conditions, with less than 2% chance of an uncontrolled release during a 1-2 year construction phase, based on water balance estimates provided in WRM (2015). Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – major; likelihood – very unlikely).
Overburden material backfilled in pit - West Balranald deposit	Release of AMD from backfilled overburden into void / groundwater or surface water (due to pit dewatering) due to sulfide oxidation between the time of OOB dewatering and final inundation below groundwater	Not applicable during the construction phase.
Overburden material backfilled in pit - Nepean deposit	As above	Not applicable during the construction phase.

8.1.3 *Proposed Management Approach*

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from overburden materials into surface water / groundwater during construction includes:

- Confirm the suitability of a field-based (eg. visual) method for identification of PAF versus NAF overburden.
- Upon confirmation of PAF versus NAF classification method, conduct routine geological / geochemical assessment of overburden extracted during box cut development to enable segregation of OOB and selective handling / reuse according to potential AMD risk and to confirm that other overburden materials are NAF. Available data indicates that regular visual inspection and field-based NAG pH tests could be used to inform OOB handling requirements (Earth Systems, 2015).
- Stockpile OOB on a low permeability pad comprising a limestone liner (eg. ultra-fine grained limestone) with surface water drainage control (upstream cutoff drains), within the designated stockpile area at the MUP site. Direct any runoff or seepage (if any) from the OOB stockpile to the MUP dam.

- Minimise the surface area of stockpiled OOB by relocating this material to the West Balranald pit, as low as possible in the backfill profile, and covering with MBPs and then SOB, as soon as possible during the operations phase.
- Blend or apply thin layers of a sufficient quantity of limestone into the temporary OOB stockpile (from the box cut) to address AMD generated between OOB dewatering and full inundation below groundwater. Based on available static and kinetic geochemical test work data, and the expected duration of exposure to oxidising conditions during construction, neutralisation requirements are estimated at up to 2,000 tonnes $CaCO_3$ equivalent. This allows for 3 times the theoretical neutralisation requirement based on stoichiometry[13]. Refer to additional neutralisation requirements to address long term AMD generation (during operations) in Section 8.2 (Overburden) and Section 11.2 (Pit Walls, Benches and Floors). Blending may be achieved through various methods, with the preferred method to be selected and optimised during detailed project design. Operating protocols will be developed for the selected blending method, including QA/QC, prior to commencing construction.
- Ensure that any acidic runoff or seepage (if any) from the OOB stockpile or MUP dam is collected, treated and/or reused on site. During construction, treatment may be achieved within the MUP dam (in situ), if required. However this is unlikely to be necessary if limestone blending is effective.
- Design the MUP dam to withstand up to a 1 in100 Annual Exceedence Probability (AEP) event, and develop operating protocols to maintain/create sufficient storage to contain this design event, including rainfall forecasting to identify when the MUP dam may be vulnerable to overtopping.
- Conduct regular monitoring of water level and chemistry in the MUP dam, and any surface runoff from the OOB stockpile.
- Conduct regular monitoring of groundwater level and chemistry down gradient of the OOB stockpile and MUP dam.
- In the event of any seepage from the OOB stockpile or MUP dam, conduct opportunistic monitoring of seepage flow rate and chemistry.
- Develop an emergency response plan, incorporating AMD considerations, to address the risk of MUP dam water overflow, uncontrolled seepage, or percolation to groundwater, from the OOB stockpile or MUP dam.
- Do not use OOB for site construction works.
- If any overburden is to be used as a construction material (eg. TSF embankment, access roads, plant foundations), characterise and classify the material to ensure that it is both NAF and non-saline.

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[13] Factor of 3 is conservative as it is based on use of coarse-grained limestone aggregate. There is potential to lower this quantity if an ultra-fine grained limestone material is used.

8.1.4 Residual Impacts

Based on the proposed management approach outlined in Section 8.1.3, the residual water quality impacts associated with potential AMD generation from the overburden materials during the construction phase are generally considered to be **LOW**.

The key exception to this relates to the potential for runoff or seepage of AMD from the temporary OOB stockpile into surface water / groundwater (**MEDIUM** residual impact).

The residual impacts are summarised in Section 13.

8.2 Operations

8.2.1 Context

During operations, the temporary OOB stockpile from excavation of the box cut at the West Balranald deposit will be relocated to the pit.

NSOB, SOB and OOB will continue to be segregated as mining progresses along the length of the West Balranald deposit.

Based on the current project design, OOB will be directly deposited at its final storage location in the pit below the final (natural) groundwater level, SOB will also be directly deposited within the pit, and NSOB will be either directly deposited within the pit, or temporarily stockpiled ex- pit. Backfill materials will be placed in the following order (from depth to surface) – organic overburden, MBPs, SOB, NSOB – prior to soil placement and rehabilitation.

Total in situ volumes of NSOB, SOB and organic overburden for the West Balranald deposit are estimated at around 53 million m^3, 136 million m^3 and 32 million m^3, respectively (Table 51).

At an in situ density of 1.8 t/m^3, the estimated tonnage of overburden from the West Balranald deposit is around 397 million tonnes, of which around 57 million tonnes (14%) is classified as OOB and has significant potential to generate AMD. The OOB has an average sulfide-sulfur (S_{TOS}) content of 1.01 wt.% S and relatively minor ANC (Table 24) and a maximum POR of 2.5 wt.% FeS_2/week (Table 25) under fully oxidising conditions. The thickness of the OOB layer ranges from 3-20 metres.

As previously noted, the NSOB and SOB materials at West Balranald are not considered to represent an AMD risk, but have no obvious potential to be utilised as a neutralisation resource.

Unlike the construction phase, there will be no above-ground OOB stockpile during the operations phase, due to the backfilling of temporary stockpiles (from the box cut) and ongoing direct placement of newly disturbed OOB within the pit.

For the Nepean deposit, proposed overburden materials to be disturbed are outlined in Table 51. Geology data indicates that OOB is not expected to be encountered at the Nepean deposit. This is consistent with available geochemical data, which indicates relatively low sulfide-sulfur content (hence low AMD risk) for the overburden material at Nepean.

Table 51: Soil and overburden material quantities in the West Balranald and Nepean mines.

Material	West Balranald				Nepean			
	Volume (million m^3)	In Situ Density (t/m^3)	Mass		Volume (million m^3)	In Situ Density (t/m^3)	Mass	
			Million tonnes	%			Million tonnes	%
NSOB	53	1.8	95	24%	38	1.8	68	100%
SOB	136	1.8	245	62%	-	1.8	-	-
OOB	32	1.8	57	14%	-	1.8	-	-
Total	221	1.8	397	100%	38	1.8	68	100%

8.2.2 Potential Impacts

Potential operations phase AMD impacts relating to overburden materials from the West Balranald and Nepean deposits are summarised in Table 52.

Table 52: Potential (Unmitigated) AMD Impacts from Overburden Material during the Operations Phase.

Project Element	Potential AMD Impact	Description
Overburden material stockpiled above ground level – West Balranald deposit	Runoff or seepage of AMD from temporary OOB stockpile (from box cut) into surface water / groundwater	Not applicable during the operations phase as the temporary OOB stockpile from the box cut will be relocated to the pit. All other OOB will be directly transferred to its final storage location within the pit, to avoid the need for temporary above-ground or in pit stockpiling.
Overburden material stockpiled above ground level – Nepean deposit	Runoff or seepage of AMD from temporary overburden stockpiles into surface water / groundwater	OOB is not expected to be encountered at the Nepean deposit, and currently available (limited) geochemical data indicate that there is low, if any, potential for AMD generation from for overburden at this deposit. More extensive geochemical assessment for the Nepean deposit is required to verify this. In the interim, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).
Overburden material used for site construction works	Runoff or seepage of AMD from any overburden materials used for site construction works (eg. access roads, hardstand areas, dam embankments) into surface water / groundwater	The quantity of overburden or other borrow material required for site construction works is currently unknown. The seepage could be affected by AMD if OOB is inadvertently used for site construction works. Any AMD impacts during construction could extend into the operations phase. In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – major; likelihood – very unlikely).
Overburden material backfilled in pit - West Balranald deposit	Release of AMD from backfilled overburden into void / groundwater or surface water (due to pit dewatering) as a result of sulfide oxidation between the time of OOB dewatering and final inundation below groundwater	OOB mined during the operations phase will be directly backfilled to its final storage location in the pit, below the final (natural) groundwater level. The outer 2 metres of backfilled OOB is expected to be temporarily exposed to oxidising conditions within the pit, at any time during the operations phase. With an average sulfide-sulfur content of 1.01 wt.% S, relatively minor ANC, and a POR of 2.5 wt.% FeS_2/week (Section 8.2.1), this could generate an estimated acidity load of around 60 tonnes H_2SO_4 per week. The above estimates are based on findings from kinetic geochemical test work which indicate that air entry to backfilled OOB materials is unlikely to exceed 2 metres, and this is the key control on acidity generation rate, rather than the total tonnage of unsaturated material (see Section 6.1.3).

Project Element	Potential AMD Impact	Description
		The backfilled OOB (and MBPs) will be progressively covered with SOB material and inundated with groundwater as mining progresses along the orebody. Thus, the potential rate of acidity generation will be relatively constant over time in accordance with the pit dimensions. Acidity generation would continue until the OOB (and MBPs) is covered with SOB to a thickness of at least 5 metres (nominally). Any AMD from backfilled OOB could drain to the pit sump, from where it may be pumped to the MUP dam for use on site, or directly infiltrate to groundwater. Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. However, groundwater contaminants are not expected to migrate significantly from the project area over the mine life, as there will generally be a local hydraulic gradient towards the centre of the West Balranald pit (Jacobs, 2015). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – possible).
Overburden material backfilled in pit - Nepean deposit	As above	OOB is not expected to be encountered at the Nepean deposit, and currently available (limited) geochemical data indicate that there is low, if any, potential for AMD generation from for overburden at this deposit. More extensive geochemical assessment for the Nepean deposit is required to verify this. In the interim, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).

8.2.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from OOB into surface water / groundwater during operations is outlined below. Most of these measures are intended to not only address operational phase risks but also to pre-emptively manage the potential post-closure impacts identified in Section 8.3.2.

- Continue routine geological / geochemical assessment of overburden extracted during mining, to enable segregation of OOB and selective handling / reuse according to potential AMD risk and to confirm that other overburden materials are NAF.
- Ensure that OOB is directly placed to its final storage location as low as possible in the backfill profile, to avoid the need for temporary stockpiling of this material above-ground or within the pit and hence minimise the extent of AMD generation by minimising the duration of exposure to oxidising conditions.
- Rapidly (within 1-2 days) cap backfilled OOB with at least 5 metres of SOB or inert clay-rich material sourced from the aquitard separating the Shepparton and LPS Formations. Geochemical test work indicates that SOB will assist with lowering air entry to underlying OOB (and MBPs).
- Blend or apply thin layers of a sufficient quantity of limestone into the OOB as it is progressively mined, to address any residual AMD generated between OOB dewatering and full inundation below groundwater. Based on available static and kinetic geochemical test work data, and the

expected duration of exposure to oxidising conditions, neutralisation requirements are estimated at up to 200 tonnes $CaCO_3$ equivalent per week[14]. This allows for 3 times the theoretical neutralisation requirement based on stoichiometry[15]. This is in addition to neutralisation requirements outlined in Section 8.1 (Overburden - construction phase) and Section 11.2 (Pit Walls, Benches and Floors). Blending may be achieved through various methods, with the preferred method to be selected and optimised during detailed project design. Operating protocols will be developed for the selected blending method, including QA/QC, prior to commencing construction.

- Traffic-compact backfilled limestone-blended OOB as soon as practicable after placement. This will lower the extent of AMD generation by minimising the duration of exposure to oxidising conditions (ie. minimising the potential for air entry to sulfide minerals) and ensure this material remains as far as possible below the final groundwater rebound level.
- Ensure that backfilled limestone-blended OOB is covered as soon as practicable after placement and traffic compaction.
- Ensure that any acidic runoff or seepage (if any) from backfilled OOB is collected, treated and/or reused on site. Treatment may be achieved within the pit sump or MUP dam (in situ) or through a hydrated lime treatment plant at the MUP site, if required. However this is unlikely to be necessary if limestone blending is effective.
- Design the MUP dam to withstand up to a 1 in100 AEP event, and develop operating protocols to maintain/create sufficient storage to contain this design event, including rainfall forecasting to identify when the MUP dam may be vulnerable to overtopping.
- Conduct regular monitoring of water level and chemistry in the pit sump and MUP dam, and opportunistic monitoring of any surface runoff or seepage from backfilled OOB.
- Conduct regular monitoring of groundwater level and chemistry down gradient of the MUP dam.
- In the event of any seepage from the MUP dam, conduct opportunistic monitoring of seepage flow rate and chemistry.
- Conduct regular monitoring of groundwater level and chemistry in dewatering bores.
- Develop an emergency response plan, incorporating AMD considerations, to address the risk of MUP dam water overflow, uncontrolled seepage, or percolation to groundwater, from the MUP dam.
- Conduct more extensive geochemical assessment of overburden materials for the Nepean deposit to verify that this material presents a low AMD risk.

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[14] This is a conservative estimate as it does not take into account the AMD prevention / minimisation measure listed above (rapid capping within 1-2 days) that will substantially lower the extent of acidity generation and neutralisation requirement.

[15] Factor of 3 is conservative as it is based on use of coarse-grained limestone aggregate. There is potential to lower this quantity if an ultra-fine grained limestone material is used.

8.2.4 Residual Impacts

Based on the proposed management approach outlined in Section 8.2.3, the residual water quality impacts associated with potential AMD generation from the overburden materials during the operations phase are considered to be **LOW**.

The residual impacts are summarised in Section 13.

8.3 Post-Closure

8.3.1 Context

Post-closure, all OOB from the West Balranald deposit will have been relocated to its final storage location in the pit.

As noted in Section 8.2.1, the estimated tonnage of OOB from the West Balranald deposit is around 57 million tonnes (14% of total overburden tonnage), based on an initial in situ density of 1.8 t/m^3. A lower in situ density can be expected after backfilling, leading to an expected volume increase of around 3% (excluding that associated with any limestone blending).

The OOB, with an average sulfide-sulfur (S_{TOS}) content of 1.01 wt.% S and relatively minor ANC (Table 24) and a maximum POR of 2.5 wt.% FeS_2/week (Table 25) under fully oxidising conditions, will be overlain by MBPs, SOB, NSOB and then subsoil and topsoil.

Hydrogeological modelling conducted by Jacobs (2015) indicates that the groundwater table will take more than 100 years after mine closure to fully rebound to its existing level at the West Balranald deposit, and 30-100 years at the Nepean deposit.

As per the operations phase, there will be no above-ground OOB stockpile post-closure, due to the backfilling of the temporary stockpile (from the West Balranald box cut) and direct placement of newly disturbed OOB within the pit during mining operations.

8.3.2 Potential Impacts

Potential post-closure AMD impacts relating to overburden materials from the West Balranald and Nepean deposits are summarised in Table 53.

Table 53: Potential (Unmitigated) AMD Impacts from Overburden Material during the Post-Closure Phase.

Project Element	Potential AMD Impact	Description
Overburden material stockpiled above ground level – West Balranald deposit	Runoff or seepage of AMD from temporary OOB stockpile (from box cut) into surface water / groundwater	Not applicable during the post-closure phase.
Overburden material stockpiled above ground level – Nepean deposit	Runoff or seepage of AMD from temporary overburden stockpiles into surface water / groundwater	Not applicable during the post-closure phase.
Overburden material used for site construction works	Runoff or seepage of AMD from any overburden materials used for site construction works (eg. access roads, hardstand areas, dam embankments) into surface water / groundwater	The quantity of overburden or other borrow material required for site construction works is currently unknown. The seepage could be affected by AMD if OOB is inadvertently used for site construction works. However, any AMD impacts during construction and operations are unlikely to extend into the post-closure phase due to the high POR of the OOB. The potential impact is considered LOW (consequence – minor; likelihood – very unlikely).
Overburden material backfilled in pit - West Balranald deposit	Release of AMD from backfilled overburden into void / groundwater due to sulfide oxidation between the time of OOB dewatering and final inundation below groundwater	OOB mined during the operations phase will be directly backfilled to its final storage location in the pit, below the final (natural) groundwater level. Prior to groundwater inundation, the OOB will have been exposed to oxidising conditions during above-ground stockpiling (box cut material) and during the backfill process. Refer to acidity load estimates for the Construction and Operations phase in Table 50 and Table 52, respectively. No further acidity generation from the OOB would occur post-closure as this will have been covered with MBPs and several metres of backfilled SOB. However, flushing of acid salts (acidity fluxes) from the OOB may continue until this material returns to a saturated state following groundwater rebound. The groundwater table is expected to take more than 100 years after mine closure to fully rebound to its existing level (Jacobs, 2015). Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. After groundwater rebound, any AMD from backfilled OOB could migrate away from the pit. Groundwater flows will be subject to considerably lower hydraulic gradients relative to those experienced during groundwater rebound, with a regional hydraulic gradient of around 0.00025 from east to west across the length of the West Balranald mine under natural conditions (Jacobs, 2015). The potential impact is considered HIGH (consequence – major; likelihood – probable).
Overburden material backfilled in pit - Nepean deposit	As above	OOB is not expected to be encountered at the Nepean deposit, and currently available (limited) geochemical data indicate that there is low, if any, potential for AMD generation from overburden at this deposit. More extensive geochemical assessment for the Nepean deposit is required to verify this. In the interim, the potential impact is considered MEDIUM (consequence – major; likelihood – unlikely).

8.3.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from backfilled OOB into surface water / groundwater post-closure is to:

- Pre-emptively manage this risk during operations by implementing the measures outlined in Section 8.2.3 (Operations).
- Monitor the rate of groundwater rebound and pore water chemistry in backfilled OOB until the final (natural) groundwater level has been achieved, to confirm that sufficient neutralising capacity has been added to prevent residual acid salts from contaminating the groundwater system.
- Use dewatering bores to facilitate post-closure monitoring of groundwater rebound, prior to full decommissioning.

8.3.4 Residual Impacts

Based on the proposed management approach outlined in Section 8.3.3, the residual water quality impacts associated with potential AMD generation from the overburden materials during the post-closure phase are generally considered to be **LOW**.

The key exception to this relates to the potential for release of AMD from backfilled overburden into void / groundwater / surface water due to sulfide oxidation between the time of OOB dewatering and final inundation below groundwater (**MEDIUM** residual impact).

The residual impacts are summarised in Section 13.

9.0 Impact Assessment – Ore

9.1 Construction

9.1.1 Context

No ore from the West Balranald or Nepean deposits will be mined during the construction phase.

9.1.2 Potential Impacts

Not applicable during the construction phase.

9.1.3 Proposed Management Approach

Not applicable during the construction phase.

9.1.4 Residual Impacts

Not applicable during the construction phase.

9.2 Operations

9.2.1 Context

The total volume of ore material to be extracted during the Balranald Project is estimated at 12.9 million m^3, comprising 10.2 million m^3 from the West Balranald pit and 2.7 million m^3 from the Nepean pit. At an in situ density of around 2.2 t/m^3, this corresponds to a total ore mass of 28.4 million tonnes (22.5 million tonnes at West Balranald and 5.9 million tonnes at Nepean). Ore extracted from the Nepean mine will be transported to the West Balranald site via a 39 km long road.

At any time, the quantity of ore stockpiled at the operating West Balranald MUP is estimated at up to around 1.2 million tonnes. This is equivalent to approximately 4 months supply of ore feed on the ROM pad at any time, based on an ore processing rate of 475 tonnes per hour and a rougher head feed of 440 tph. The ore stockpile will have a maximum height of 10 metres and a footprint of approximately 1 ha.

Extracted ore will initially be stockpiled on a ROM pad adjacent to the MUP. From there, ore will be screened to remove oversize material (>2.5 mm). The screened ore will then be slurried with water from the MUP dam and pumped via pipeline to the Pre-Concentrator Plant (PCP), while oversize material will be returned to the pit.

The ore material from West Balranald has significant potential to generate AMD, with an average sulfide-sulfur content (S_{TOS}) of 1.09 wt.% S and relatively minor ANC (Table 28) and a maximum POR of 2.2 wt.% FeS_2/week under fully oxidising conditions (Table 29). The thickness of the ore layer ranges from 5-6 metres.

Available geochemical data for the Nepean ore material indicates relatively low sulfide-sulfur content (hence low AMD risk) (see Section 6.2.2).

9.2.2 Potential Impacts

Potential operations phase AMD impacts relating to ore material are summarised in Table 54.

Table 54: Potential (Unmitigated) AMD Impacts from Ore Material during the Operations Phase.

Project Element	Potential AMD Impact	Description
Ore material stockpiled at MUP – from West Balranald deposit	Runoff or seepage of AMD from stockpiled ore into surface water / groundwater	The quantity of ore from the West Balranald deposit to be stockpiled at the West Balranald MUP at any time is estimated at 1.2 million tonnes, although only the outer 2 metre layer is expected to be exposed to oxidising conditions (see Section 6.2.1). With an average sulfide-sulfur content of 1.09 wt.% S, relatively minor ANC, a POR of 2.2 wt.% FeS_2/week (Section 9.2.1) and assuming one stockpile only, this could generate an estimated acidity load of up to 100 tonnes H_2SO_4 per week. The timing of acidity fluxes from the ore stockpile will tend to be associated with rainfall events. Based on site rainfall characteristics, localised acidity fluxes to surface water or groundwater could occur at various times throughout the year. Acidity generation and flux would continue throughout the operations phase until the completion of ore processing. Surface water would be collected and contained on site under most conditions, with less than 10% chance of an uncontrolled release during the mine life,

Project Element	Potential AMD Impact	Description
		based on water balance estimates provided in WRM (2015). Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. However, groundwater contaminants are not expected to migrate significantly from the project area over the mine life, as there will generally be a local hydraulic gradient towards the centre of the West Balranald pit (Jacobs, 2015). In the absence of AMD management measures, the potential impact is considered HIGH (consequence – major; likelihood – probable).
Ore material stockpiled at MUP – from Nepean deposit	As above	Currently available (limited) geochemical data for ore samples from the Nepean deposit indicate that there is low, if any, potential for AMD generation from this material. More extensive geochemical assessment for the Nepean deposit is required to verify this. In the interim, the potential impact is considered MEDIUM (consequence – moderate; likelihood –unlikely).
Process plant water	Uncontrolled release of process plant water affected by AMD from ore material	As noted above, stockpiled ore from the West Balranald deposit could generate an estimated acidity load of up to 100 tonnes H_2SO_4 per week. Any acidity that is not flushed from the ore stockpile during rainfall events will remain in the pore spaces of the ore material. As the ore slurry is generated and pumped to the process plant, this residual acidity in the pore spaces would dissolve into the process water stream. Any uncontrolled release or spill of acidic process water could then result in a localised acidity flux to surface water or groundwater. Surface water would be collected and contained on site under most conditions, with less than 10% chance of an uncontrolled release during the mine life, based on water balance estimates provided in WRM (2015). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).
Pipeline failure while pumping ore slurry from MUP to PCP (eg. due to rupture)	Runoff or seepage of AMD from ore slurry into surface water / groundwater	An ore slurry pipeline failure leading to uncontrolled release of ore during operations is conceivable, if not well managed. This could lead to localised but chronic impacts on water quality and vegetation (long term AMD generation). Based on the average sulfide-sulfur content and POR values noted above, an ore pump rate of 440 tonnes per hour, the total potential acidity released from spilled ore, in the event of a pipeline spill up to 1 hour in duration, would be in the order of 10-20 tonnes H_2SO_4 in total, or less than 500 kg H_2SO_4 if the spilled ore is cleaned up within days of such an accident. In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – possible).
Transport accident on haul road between Nepean and West Balranald deposits leading to spill of Nepean ore	Runoff or seepage of AMD from Nepean ore into surface water / groundwater	A transport accident leading to uncontrolled release of ore is conceivable. However, currently available (limited) geochemical data for ore samples from the Nepean deposit indicate that there is low, if any, potential for AMD generation from this material. The potential impact is considered LOW (consequence – minor; likelihood – unlikely).

9.2.3 *Proposed Management Approach*

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from ore material into surface water / groundwater during operations includes:

- Directly backfill oversize material to the West Balranald pit.
- Backfilled oversize material in the same manner as backfilled OOB. In particular:
  - Ensure that oversize material is backfilled to a final storage location above (or mixed within) the backfilled OOB but below NAF materials in the backfill profile as soon as practicable, to minimise the duration of stockpiling (duration of exposure to oxidising conditions) above-ground.
  - Blend or apply thin layers of a sufficient quantity of limestone into oversize material as it is backfilled, to address AMD generated between the time of dewatering and full inundation below groundwater.
  - Traffic compact backfilled limestone-blended oversize material as soon as practicable after placement, in order to lower the extent of AMD generation and ensure this material remains as far as possible below the final groundwater rebound level.
  - Ensure that backfilled limestone-blended oversize material is covered rapidly after placement.
- Stockpile ore on a low permeability pad comprising a limestone liner (eg. ultra-fine grained limestone) with surface water drainage control (upstream cutoff drains), within the designated ROM pad area at the active MUP site.
- Minimise the surface area of stockpiled ore, and process this material as soon as possible to minimise the duration of exposure to oxidising conditions, during the operations phase.
- Blend or apply thin layers of a sufficient quantity of limestone into the stockpiled ore to address AMD generated between ore dewatering and the time of processing. Based on available static and kinetic geochemical test work data, and the expected duration of ore stockpiling, neutralisation requirements are estimated at up to 200 tonnes $CaCO_3$ equivalent per week. This allows for 3 times the theoretical neutralisation requirement based on stoichiometry[16]. This is in addition to neutralisation requirements outlined in Section 10 (MBPs) and Section 12 (Products). Blending may be achieved through various methods, with the preferred method to be selected and optimised during detailed project design. Operating protocols will be developed for the selected blending method, including QA/QC, prior to commencing construction.
- As an alternative to, or in combination with limestone blending (see above):
  - Ensure that any acidic runoff or seepage (if any) from stockpiled ore and the MUP dam is collected, treated and/or reused on site. Treatment may be achieved within the MUP dam (in situ) or through a centralised water treatment system using a hydrated lime treatment plant at the MUP site, if required.
  - Treat any residual AMD in ore slurry by hydrated lime addition at the process plant site.

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[16] Factor of 3 is conservative as it is based on use of coarse-grained limestone aggregate. There is potential to lower this quantity if an ultra-fine grained limestone material is used.

However the above measures are unlikely to be necessary if limestone blending is effective.

- Design the MUP dam to withstand up to the 1 in 100 AEP event, and develop operating protocols to maintain/create sufficient storage to contain a 1 in 100 AEP event, including rainfall forecasting to identify when the MUP dam may be vulnerable to overtopping.
- Conduct regular monitoring of water level and chemistry in the MUP dam, and opportunistic monitoring of any surface runoff from stockpiled ore.
- Conduct regular monitoring of groundwater level and chemistry down gradient of the stockpiles and dam.
- In the event of any seepage from the stockpiled ore or MUP dam, conduct opportunistic monitoring of seepage flow rate and chemistry.
- Incorporate bunding around the process plant area, with sufficient storage capacity and designed in accordance with leading practice standards, and develop an emergency response plan to address the risk of uncontrolled overflow of process water that may be affected by AMD from the ore material.
- Develop an emergency response plan, incorporating AMD considerations, to address the risk of MUP dam water overflow, uncontrolled seepage, or percolation to groundwater, from the stockpiled ore or MUP dam.
- To prevent the failure of the ore slurry pipeline (eg. due to rupture, bushfire) leading to the release of sulfidic ore / AMD to surface water or groundwater:
  - Install bunding and ore slurry collection sump(s) along the pipeline alignment in accordance with leading practice standards.
  - Clear vegetation along pipeline alignment to minimise bushfire risk, and ensure that fire control pipelines, hydrants, fittings and storages are in place before pipeline operation commences.
  - Install isolation valves along pipeline.
  - Ensure ore transfer is shut-down during any bushfire event in the vicinity of the slurry pipeline.
  - Install a pipeline leak detection system (eg. pressure transmitter at the pump end of the ore slurry pipeline to alarm at high and low pressures, which may indicate line blockages or breaks, respectively).
  - Conduct regular pipeline maintenance and inspection.
- In the event of potential pipeline failure or transport accident involving a spill of ore material, recover spilled material as soon as practicable.
- Incorporate AMD considerations into emergency response procedures for potential pipeline failure or transport accident involving a spill of ore material.
- Conduct more extensive geochemical assessment of ore materials for the Nepean deposit to verify that this material presents a low AMD risk.
- To minimise the risk of a transport accident on the haul road from Nepean to West Balranald construct internal roads within the project area to minimise interaction between mining equipment and haul trucks, and general light vehicle traffic on site.

9.2.4 Residual Impacts

Based on the proposed management approach outlined in Section 9.2.3, the residual water quality impacts associated with potential AMD generation from the ore materials during the operations phase are generally considered to be **LOW**.

The key exception to this relates to the potential for runoff or seepage of AMD from stockpiled ore into surface water / groundwater (**MEDIUM** residual impact).

The residual impacts are summarised in Section 13.

9.3 Post-Closure

9.3.1 Context

No stockpiled ore will remain post-closure.

9.3.2 Potential Impacts

Not applicable during the post-closure phase.

9.3.3 Proposed Management Approach

Not applicable during the post-closure phase.

9.3.4 Residual Impacts

Not applicable during the post-closure phase.

10.0 Impact Assessment – Mining By-Products

10.1 Construction

10.1.1 Context

No processing of ore from the West Balranald or Nepean deposits will occur, and hence there will be no MBPs generated, during the construction phase.

10.1.2 Potential Impacts

Not applicable during the construction phase.

10.1.3 Proposed Management Approach

Not applicable during the construction phase.

10.1.4 Residual Impacts

Not applicable during the construction phase.

10.2 Operations

10.2.1 Context

During operations, MBPs will be generated from processing West Balranald and Nepean ore at the processing plant at the West Balranald mine. Key facilities at the processing plant site include the Mining Unit Plant (MUP), Pre-Concentrator Plant (PCP), Wet Concentrator Plant (WCP), Wet High Intensity Magnetic Separation Plant (WHIMS) and Ilmenite Separate Plant (ISP). In addition, by-products will be generated from the processing of HMC at the MSP in Hamilton. Refer to the process flow diagram in Figure 33. Based on the current project design, all MBPs will be placed in the West Balranald pit.

MBPs generated at the PCP and WCP will include sand tails and thickener underflow (also referred to as slimes)[17]. The selected method of Balranald MBPs disposal is a combination of Modified Co-Disposal (ModCod) and sand stacking. Modified co-disposal involves slurrying sand tails with thickener underflow, and placement in the TSF. The blended waste stream is referred to as “ModCod”.

A centralised multi-cell ex-pit TSF, with a storage capacity of around 1 million m^3 (EMM, 2015d), and total surface area of 30 ha (3 x 10 ha cells), will be located at the processing area (where the PCP, WCP, WHIMS and ISP are located) at the West Balranald mine. Sand tails and thickener underflow will be combined to create a ModCod mixture with an approximate ratio 15:85 (wt.% thickener underflow / wt.% sand tails) and initially pumped as a slurry to a single cell within the TSF. When the cell is full, ModCod will be directed to the next empty cell while the first cell dries and consolidates. Dried ModCod will be excavated and trucked back to the West Balranald pit. TSF cells that have been excavated will then be ready to be refilled. Each TSF cell will undergo a 12 month cycle, with ModCod discharging to a new cell every 4 months. Each cell will undergo 4 months of drying, followed by 4 months transfer of dried ModCod to the pit. Decant water will be recovered from the TSF and pumped to the settling dam at the process plant site.

Excess sand tails that are not required for ModCod will be pumped as a slurry to a sand stacking pad adjacent to the ore stockpile at the MUP. When the sand tails are dry, they will be backfilled to the West Balranald pit.

The WHIMS plant will generate a magnetic process stream, referred to as WHIMS magnetics, that will feed into the ISP at Balranald. The ISP will generate two product streams (refer to Section 12) and magnetic rejects will form a by-product stream. Magnetic rejects will be blended with dried WCP sand tails and backfilled into the pit. For the purposes of this impact assessment, it is assumed that the magnetic rejects will initially be stockpiled for drying at the MUP site for up to 2 weeks.

The average annual production rate of Balranald MBPs is outlined below:

- Thickener underflow – 0.26 million tonnes per annum. This will be fully incorporated into ModCod (below).
- ModCod – 1.24 million tonnes per annum, with an approximate density of 1.5 t/m^3.
- Sand tails (excess) – 1.05 million tonnes per annum, with an approximate density of 1.7 t/m^3.
- Magnetic rejects – assumed to be less than 100,000 tonnes per annum.

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[17] Oversize material generated at the MUP is covered in Section 9.2.1 (Ore).

Hamilton by-products are expected to be generated at a rate of around 82,000 tonnes per year, throughout the operations phase. The relative proportions of each Hamilton by-product are outlined in Table 41.

The by-product streams from Hamilton will be blended at the MSP prior to road transport to Iluka's Douglas operations or Balranald. If transported to Balranald, the Hamilton by-products will be temporarily stockpiled at the MUP, blended with the Balranald MBPs, then backfilled in the West Balranald pit.

For the purposes of this impact assessment, it is assumed that the Hamilton by-products have an average sulfide-sulfur content of 3.3 wt.% S (Table 41) and will initially be stockpiled for drying at the MUP site for up to 2 weeks.

All dried MBPs will be trucked from the MUP to the lower levels of the backfill dump/face to provide a cover for the OOB backfill material.

Iluka has estimated the volume of MBPs to be generated, as a percentage of the original ore volume, at 83%, based on experience at similar sites. Hence, the volume of by-products after backfilling and consolidation is assumed to represent a decrease of around 17% relative to the original in situ ore material (excluding volume increases associated with any limestone blending). It is understood that this represents an "average" volume decrease for both deposits, although the West Balranald pit will receive all of the backfilled MBPs based on the current mine plan.

The Balranald ModCod, Hamilton float plant tails and Hyti (leucoxene) in particular have significant potential to generate AMD. The Balranald ModCod has an average sulfide-sulfur content (S_{TOS}) of 1.6 wt.% S, no detectable ANC, and a maximum POR of up to 1.6 wt.% FeS_2/week (Table 35) under fully oxidising conditions, while the Hamilton float plant tails and Hyti (leucoxene) have an average sulfide-sulfur content of 15 wt.% S and 7.3 wt.% S, respectively (Table 41) and no detectable ANC (POR currently unknown).

The other Hamilton by-products are expected to represent a lower AMD risk than the float plant tails and Hyti (leucoxene) based on their lower sulfide-sulfur content (in the case of PDC Ilmenite, Combined monazite reject and Combined zircon wet tails) or their relatively small proportion of the total by-product stream (in the case of Rutile wet circuit concentrate and PDC Conductors oversize +410 µm).

The Balranald sand tails have a relatively low sulfide-sulfur (S_{TOS}) content of 0.3 wt.% S but high POR (up to 2.4 wt.% FeS_2/week under fully oxidising conditions) and therefore also represent a significant AMD risk (Table 35). Similarly, the magnetic rejects are expected to represent an AMD risk based on preliminary geochemical test work on WHIMS magnetics material, which has comparable sulfide-sulfur content and POR to the Balranald sand tails.

Based on the available geochemical data for the Nepean deposit, the sulfide-sulfur content (hence AMD risk) of MBPs associated with the Nepean deposit can reasonably be assumed to be lower than at West Balranald.

The Balranald MBPs and (potentially) by-products from processing at Hamilton will ultimately be relocated to their final storage location in the West Balranald pit, above the OOB but below the final (natural) groundwater level. The MBPs will be overlain by SOB and then NSOB, prior to soil placement and rehabilitation.

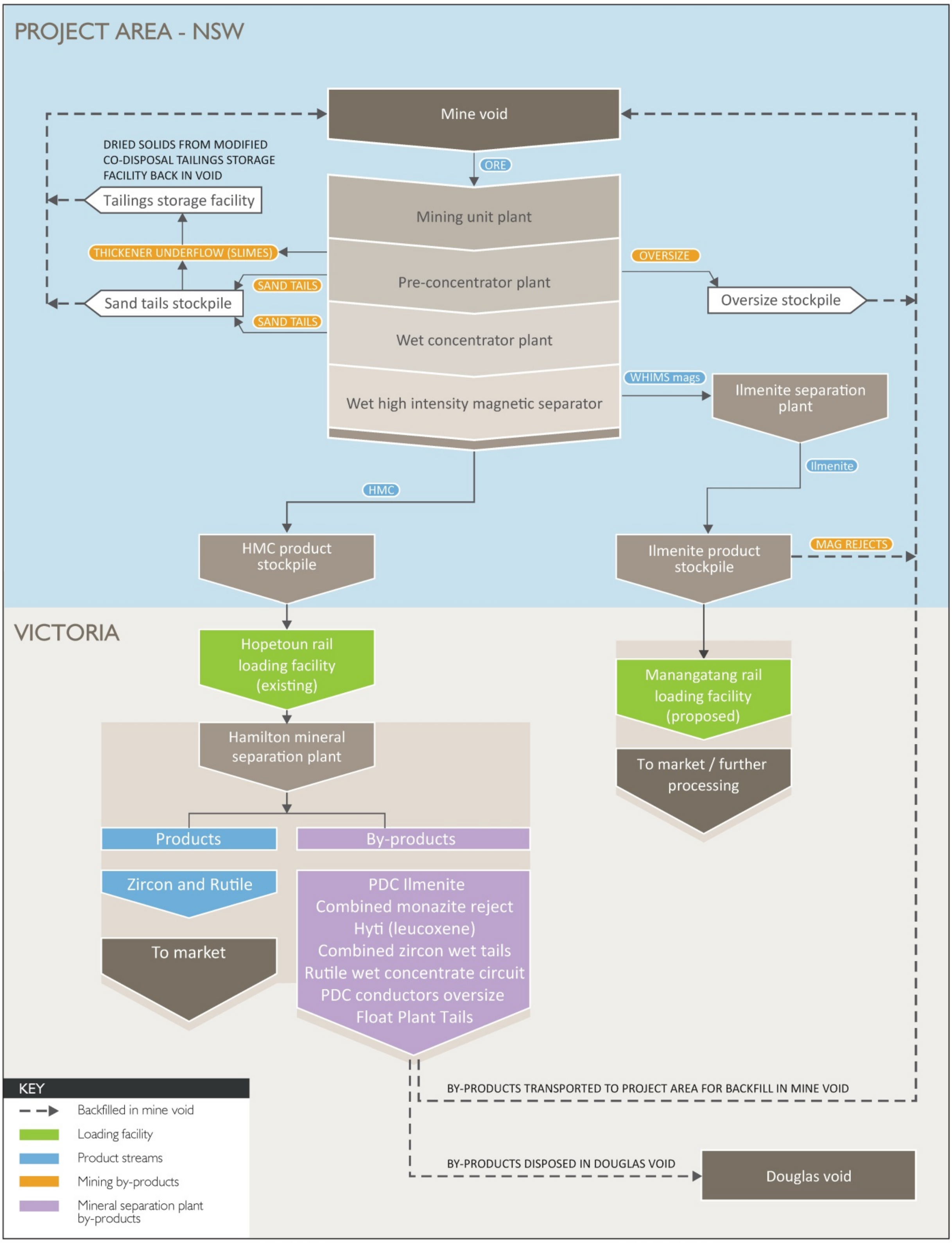

Figure 33: Mineral processing plant process flow diagram (EMM, 2015d).

10.2.2 Potential Impacts

Potential operations phase AMD impacts relating to MBPs are summarised in Table 55.

Table 55: Potential (Unmitigated) AMD Impacts from MBPs during the Operations Phase.

Project Element	Potential AMD Impact	Description
MBPs stored above ground level (eg. sand tails, ModCod, magnetic rejects, Hamilton by-products)	Release of AMD via supernatant water overflow from TSF to Box Creek	AMD generation is likely to occur within the upper layer of unsaturated ModCod within the TSF. The surface area of ModCod to be exposed to oxidising conditions at any time is estimated at up to 30 ha, based on a TSF comprising 3 cells, each with a surface area of 10 ha. With an average sulfide-sulfur content of 1.6 wt.% S, no detectable ANC, and a maximum POR of up to 1.6 wt.% FeS_2/week under fully oxidising conditions (Section 10.2.1), this could generate an estimated acidity load of up to 1,000 tonnes H_2SO_4 per week within the TSF. Acidity generation could continue until the ModCod is returned to the pit and covered with at least 5 metres of SOB (nominally). AMD generation within the TSF could have a significant impact on supernatant water quality. It is unlikely that water would overflow from the TSF during normal operating conditions based on the current site water management strategy (WRM, 2015). It is also assumed that, in the event of TSF overflow, surface water would be collected and contained on site under most conditions, with less than 10% chance of an uncontrolled release during the mine life, based on water balance estimates provided in WRM (2014). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – major; likelihood – possible).
	Seepage of AMD from TSF into groundwater	Some seepage of tailings pore water can be expected. The seepage quality is likely to be dominated by a process water signature during operations, at least initially, but given the high POR of the ModCod material it is possible that TSF seepage may also be affected by AMD. Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. However, groundwater contaminants are not expected to migrate significantly from the project area over the mine life, as there will generally be a local hydraulic gradient towards the centre of the West Balranald pit (Jacobs, 2015). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – minor; likelihood – possible).
	TSF embankment failure leading to release of sulfidic MBPs / AMD to surface water / groundwater	TSF embankment failure is unlikely but could potentially occur in the event of extreme rainfall conditions or seismic activity. In the unlikely event of TSF embankment failure, there would be a major impact on downstream water quality. AMD impacts may be acute (release of contaminated water) and/or chronic (release of ModCod leading to significant AMD generation over several months to years). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – major; likelihood – unlikely).

Project Element	Potential AMD Impact	Description
	Runoff or seepage of AMD from temporary MBP stockpiles (eg. sand tails, magnetic rejects, Hamilton by-products) into surface water / groundwater	The quantity of sand tails to be temporarily stockpiled is estimated at up to 230,000 m^3, equivalent to around 135,000 tonnes. With an average sulfide-sulfur content of 0.3 wt.% S, no detectable ANC, and a POR of up to 2.4 wt.% FeS_2/week (Section 10.2.1), this could generate an estimated acidity load of up to 30 tonnes H_2SO_4 per week. The quantity of magnetic rejects to be temporarily stockpiled is estimated at up to 4,000 tonnes. Based on geochemical characteristics of the WHIMS magnetics stream, this could generate an estimated acidity load in the order of 2 tonnes H_2SO_4 per week. The quantity of Hamilton by-products to be temporarily stockpiled is estimated at around 3,000 tonnes. With an average sulfide-sulfur content of 3.3 wt.% S (Section 10.2.1), this could generate an estimated acidity load in the order of 10 tonnes H_2SO_4 per week. The timing of acidity fluxes from temporary MBP stockpiles will tend to be associated with rainfall events. Based on site rainfall characteristics, localised acidity fluxes to surface water or groundwater could occur at various times throughout the year. Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. However, groundwater contaminants are not expected to migrate significantly from the project area over the mine life, as there will generally be a local hydraulic gradient towards the centre of the West Balranald pit (Jacobs, 2015). If pyrite is not fully depleted, acidity generation would continue until the temporarily stockpiled MBPs are returned to the pit and covered with at least 5 metres of SOB (nominally). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – likely).
MBPs placed below ground level in West Balranald pit (eg. sand tails, thickener underflow or ModCod from PCP / WCP at Balranald; by-products from Hamilton MSP)	Release of AMD from backfilled MBPs below final (natural) groundwater level, into void / groundwater or surface water (due to pit dewatering) as a result of sulfide oxidation between the time of MBP generation and inundation below groundwater	MBPs generated during the operations phase will be backfilled to their final storage location in the West Balranald pit, below the final (natural) groundwater level. Prior to groundwater inundation, the quantity of backfilled MBPs to be temporarily exposed to oxidising conditions within the pit is estimated at around 117,000 tonnes at any time during the operations phase. Based on ModCod geochemical characteristics (to be conservative), with an average sulfide-sulfur content of 1.6 wt.% S, no detectable ANC, and a POR of 1.6 wt.% FeS_2/week (Section 10.2.1), this could generate an estimated acidity load of around 100 tonnes H_2SO_4 per week. The backfilled MBPs will be progressively covered with SOB material and inundated with groundwater as mining progresses along the orebody. Thus, the potential rate of acidity generation will be relatively constant over time in accordance with the pit dimensions. Any AMD from backfilled MBPs could drain to the pit sump, from where it may be pumped to the MUP dam for use on site, or directly infiltrate to groundwater. Acidity generation could continue until the MBPs are covered with at least 5 metres of SOB (nominally). Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads.

Project Element	Potential AMD Impact	Description
		However, groundwater contaminants are not expected to migrate significantly from the project area over the mine life, as there will generally be a local hydraulic gradient towards the centre of the West Balranald pit (Jacobs, 2015). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – possible).
MBP pipelines: • ModCod pipeline to TSF. • Sand tails pipeline to MUP.	Failure of MBP pipeline (eg. due to rupture, bushfire) leading to release of sulfidic MBPs / AMD to surface water / groundwater	A pipeline failure leading to uncontrolled release of MBPs during operations is conceivable, if not well managed. This could lead to localised but significant impacts on water quality and vegetation (due to the high POR). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – possible).
Return water pipeline (TSF decant water pipeline to process plant)	Failure of return water pipeline (eg. due to rupture, bushfire) leading to release of AMD to surface water / groundwater	A pipeline failure leading to uncontrolled release return water during operations is conceivable, if not well managed. This could lead to localised short-term impacts on water quality and vegetation. In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – possible).
Hamilton by-product transport to West Balranald mine for final disposal (off site)	Transport accident (off site) leading to release of sulfidic MBPs and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	A transport accident leading to uncontrolled release of Hamilton by-products is conceivable. Based on the average sulfide-sulfur content noted above of Hamilton float plant tails (to be conservative) and mass of up to 40 tonnes per truck load, the potential acidity released from spilled material, in the event of an accident, would be around 20 tonnes H_2SO_4. In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).
MBP transport on site: • Hamilton by-products. • Dried ModCod transport from TSF to MUP. • Dried magnetic rejects transport from process plant to MUP. • Blended MBPs from MUP to West Balranald pit.	Transport accident (on site) leading to release of sulfidic MBPs and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	A transport accident leading to uncontrolled release of MBPs is conceivable. A spill of dried ModCod, magnetic rejects or blended MBPs during transport on site would have less impact than a spill of Hamilton by-products (see above) as these materials will remain within the site boundaries at all times. The potential impact is considered LOW (consequence – minor; likelihood – unlikely).

10.2.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from MBPs into surface water / groundwater during operations is outlined below. Most of these measures are intended to not only address operational phase risks but also to pre-emptively manage the potential post-closure impacts identified in Section 10.3.2.

- Install clay liner across TSF embankment and floor and ensure that any seepage is collected and pumped back to the TSF, or treated and reused on site.
- Return sand tails, magnetic rejects and Hamilton by-products directly if possible, to their final storage location above the backfilled OOB but below NAF materials in the backfill profile, in the West Balranald pit.
- If sand tails, magnetic rejects and Hamilton by-products cannot be directly backfilled to the West Balranald pit:
    - Stockpile MBPs and Hamilton by-products on low permeability pads comprising a limestone liner (eg. ultra-fine grained limestone) with surface water drainage control (upstream cutoff drains), within the designated stockpile area at the MUP site.
    - Alternatively, consider temporary stockpiling of these materials below ground level so that drainage reports to the pit sump.
- Minimise the surface area of by-product stockpiles, and minimise the duration of exposure to oxidising conditions, by relocating this material to the West Balranald pit, above the backfilled OOB but below NAF materials in the backfill profile, as soon as possible during the operations phase.
- No disposal of by-product in the Nepean pit.
- Co-dispose Balranald thickener underflow and sand tails as ModCod material, to facilitate handling and trafficability of backfilled material.
- Minimise the duration of ModCod exposure to oxidising conditions by relocating this material to the pit, above the backfilled OOB but below NAF materials in the backfill profile, as soon as practicable.
- Transport the Hamilton by-products back to the mine site as frequently as possible (eg. at least weekly) to minimise AMD generation prior to backfilling of the by-products, and associated neutralisation requirements.
- Blend or apply thin layers of a sufficient quantity of limestone into ModCod and MBP stockpiles (prior to backfilling) to address AMD generated between by-product generation and full inundation below groundwater. Based on available static and kinetic geochemical test work data, and the expected duration of exposure to oxidising conditions, neutralisation requirements are estimated at up to 3,500 tonnes $CaCO_3$ equivalent per week. This allows for 3 times the theoretical neutralisation requirement based on stoichiometry[18]. Blending may be achieved through various methods, with the preferred method to be selected and optimised during

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[18] Factor of 3 is conservative as it is based on use of coarse-grained limestone aggregate. There is potential to lower this quantity if an ultra-fine grained limestone material is used.

detailed project design[19]. Operating protocols will be developed for the selected blending method, including QA/QC, prior to commencing construction.

- Conduct routine geological / geochemical assessment of each MBP stream, to monitor variability and more accurately inform neutralisation requirements. This particularly applies to magnetic rejects as WHIMS magnetics have been characterised as a composite sample only.
- Monitor the profile of gaseous oxygen concentrations in the upper 2 metres of dried ModCod within the TSF to verify or refine acidity load estimates (and neutralisation requirements) based on kinetic geochemical test work.
- Ensure that any acidic runoff or seepage (if any) from MBP stockpiles, TSF or MUP dam is collected, treated and/or reused on site. Treatment may be achieved within the TSF or MUP dam (in situ) or through a centralised water treatment system using a hydrated lime treatment plant at the MUP or process plant site, if required. However this is unlikely to be necessary if limestone blending is effective.
- Design TSF to withstand extreme events (probable maximum precipitation and maximum credible earthquake) in accordance with ANCOLD guidelines, and develop operating protocols to maintain/create sufficient storage to contain the design rainfall event, including rainfall forecasting to identify when the TSF may be vulnerable to overtopping.
- Design the MUP dam to withstand up to the 1 in 100 AEP event, and develop operating protocols to maintain/create sufficient storage to contain the design rainfall event, including rainfall forecasting to identify when the MUP dam may be vulnerable to overtopping.
- Conduct regular monitoring of water level and chemistry in the TSF, MUP and any surface runoff from MBP stockpiles.
- Conduct regular monitoring of groundwater level and chemistry down gradient of the TSF and stockpiles.
- In the event of any seepage from the TSF, MUP or MBP stockpiles, conduct opportunistic monitoring of seepage flow rate and chemistry.
- Develop an emergency response plan, incorporating AMD considerations, to address the risk of TSF or MUP water overflow, uncontrolled seepage, or percolation to groundwater, from the TSF, MUP or MBP stockpiles.
- Traffic compact backfilled limestone-blended MBPs as soon as practicable after placement, in order to ensure this material remains as far as possible below the final groundwater rebound level, and to lower the extent of AMD generation by minimising the duration of exposure to oxidising conditions (ie. minimising the potential for air entry to sulfide minerals).
- Ensure that backfilled limestone-blended MBPs are covered with SOB as soon as practicable after placement and traffic compaction.
- To prevent the failure of ModCod, sand tails slurry or return water pipelines (eg. due to rupture, bushfire) leading to the release of sulfidic ore / AMD to surface water or groundwater:

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[19] For example, this could be achieved by limestone addition to the ore stockpile such that an excess of alkalinity is incorporated into the mining by-product streams.

  - Install bunding and slurry / return water collection sump(s) along the pipeline alignment in accordance with leading practice standards.
  - Clear vegetation along pipeline alignment to minimise bushfire risk, and ensure that fire control pipelines, hydrants, fittings and storages are in place before pipeline operation commences.
  - Install isolation valves along pipeline.
  - Ensure MBP / return water transfer is shut-down during any bushfire event in the vicinity of the pipelines.
  - Install a pipeline leak detection system (eg. pressure transmitter at the pump end of the MBP and return water pipelines to alarm at high and low pressures, which may indicate line blockages or breaks, respectively).
  - Conduct regular pipeline maintenance and inspection.
- In the event of potential pipeline failure or transport accident involving a spill of MBPs, recover spilled material as soon as practicable.
- Incorporate AMD considerations into emergency response procedures for potential pipeline failure or transport accident involving a spill of MBPs.

10.2.4 Residual Impacts

Based on the proposed management approach outlined in Section 10.2.3, the residual water quality impacts associated with potential AMD generation from the MBPs during the operations phase are generally considered to be **LOW**.

The key exception to this relates to the potential for release of AMD via supernatant water overflow from the TSF to Box Creek (**MEDIUM** residual impact).

The residual impacts are summarised in Section 13.

10.3 Post-Closure

10.3.1 Context

Post-closure, all MBPs from the West Balranald and Nepean mines (including associated by-products from processing at Hamilton) will have been relocated to their final storage location in the West Balranald pit.

Hydrogeological modelling conducted by Jacobs (2015) indicates that the groundwater table will take more than 100 years after mine closure to fully rebound to its existing level at the West Balranald deposit, and 30-100 years at the Nepean deposit.

There will be no above-ground storage of MBPs post-closure, due to the progressive relocation of these materials to the West Balranald pit during mining operations.

10.3.2 Potential Impacts

Potential post-closure phase AMD impacts relating to MBPs are summarised in Table 56.

Table 56: Potential (Unmitigated) AMD Impacts from MBPs during the Post-Closure Phase.

Project Element	Potential AMD Impact	Description
MBPs stored above ground level (eg. sand tails, thickener underflow or ModCod from PCP / WCP at Balranald)	Release of AMD via supernatant water overflow from TSF to Box Creek	Not applicable post-closure.
	Seepage of AMD from MBPs into groundwater and then surface water	Not applicable post-closure.
	TSF embankment failure leading to release of sulfidic MBPs / AMD to surface water / groundwater	Not applicable post-closure.
	Runoff or seepage of AMD from temporary MBPs stockpiles (eg. sand tails, magnetic rejects, Hamilton by-products) into surface water / groundwater	Not applicable post-closure.
MBPs placed below ground in West Balranald pit (eg. sand tails, thickener underflow or ModCod from PCP / WCP at Balranald; by-products from Hamilton MSP)	Release of AMD from backfilled MBPs below final (natural) groundwater level, into void / groundwater due to sulfide oxidation between the time of MBP generation and inundation below groundwater	During the operations phase, MBPs generated will have been directly backfilled to their final storage location in the West Balranald pit, below the final (natural) groundwater level. Prior to groundwater inundation, the MBPs will have been exposed to oxidising conditions during above-ground stockpiling and during the backfill process. Refer to acidity load estimates for the Operations phase in Table 55. No further acidity generation from the MBPs would occur post-closure as they will have been covered with several metres of backfilled SOB. However, flushing of acid salts (acidity fluxes) from the MBPs may continue until this material returns to a saturated state following groundwater rebound. The groundwater table is expected to take more than 100 years after mine closure to fully rebound to its existing level (Jacobs, 2015).

Project Element	Potential AMD Impact	Description
		Groundwater quality would be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. After groundwater rebound, any AMD from backfilled MBPs could migrate away from the pit. Groundwater flows will be subject to considerably lower hydraulic gradients relative to those experienced during groundwater rebound, with a regional hydraulic gradient of around 0.00025 from east to west across the length of the West Balranald mine under natural conditions (Jacobs, 2015). In the absence of AMD management measures, the potential impact is considered HIGH (consequence – major; likelihood – probable).
MBP pipelines	Failure of MBP pipeline (eg. due to rupture, bushfire) leading to release of sulfidic MBPs / AMD to surface water / groundwater	Not applicable post-closure.
Return water pipeline (TSF decant water pipeline to process plant)	Failure of return water pipeline (eg. due to rupture, bushfire) leading to release of AMD to surface water / groundwater	Not applicable post-closure.
Hamilton by-product transport to West Balranald mine for final disposal (off site)	Transport accident (off site) leading to release of sulfidic MBPs and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	Not applicable post-closure.
MBP transport on site	Transport accident (on site) leading to release of sulfidic MBPs and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	Not applicable post-closure.

10.3.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from backfilled MBPs into surface water / groundwater post-closure is to:

- Pre-emptively manage this risk during operations by implementing the measures outlined in Section 10.2.3 (Operations).
- Monitor the rate of groundwater rebound and pore water chemistry in backfilled MBPs until the final (natural) groundwater level has been achieved, to confirm that sufficient neutralising capacity has been added to prevent residual acid salts from contaminating the groundwater system.
- Use dewatering bores to facilitate post-closure monitoring of groundwater rebound, prior to full decommissioning.

10.3.4 Residual Impacts

Based on the proposed management approach outlined in Section 10.3.3, the residual water quality impacts associated with potential AMD generation from the MBPs during the post-closure phase are generally considered to be **LOW**.

The key exception to this relates to the potential for release of AMD from backfilled MBPs below final (natural) groundwater level, into void / groundwater / surface water due to sulfide oxidation between the time of MBP generation and inundation below groundwater (**MEDIUM** residual impact).

The residual impacts are summarised in Section 13.

11.0 Impact Assessment – Pit Walls, Benches and Floors

11.1 Construction

11.1.1 Context

During construction, dewatering of groundwater will be required to enable box cut development (via dry mining methods) at the West Balranald deposit. This will lead to the desaturation of in situ overburden and ore materials to varying extents in the vicinity of the box cut. Excavation of the box cut will further increase the potential for air entry to these materials.

The box cut dimensions will be around 1.4 km long, 300 metres wide and 50-90 metres deep.

No specific geochemical test work was conducted on in situ unsaturated materials in the box cut walls. Nevertheless it can be assumed that these materials will include sulfides within the OOB and ore. The AMD potential of sulfides in these (in situ) unsaturated materials is unknown, but can be conservatively assumed to be similar to those measured for equivalent (ex situ) overburden and ore samples.

The degree of exposure of sulfides in dewatered in situ OOB and ore materials will depend on both the extent of the dewatering 'cone of depression' and the extent of air entry within the dewatered (unsaturated) zone.

Based on kinetic geochemical test work conducted to date, the primary pathway for air entry to the dewatered in situ OOB and ore materials will be through the exposed pit walls, benches and floors, whereas air entry through the overlying in situ overburden material is likely to be negligible in comparison.

Key aspects of the dewatering program during construction are summarised below[20]:

- Dewatering will commence several months in advance of box cut development and will be conducted primarily via ex-pit bores (Jacobs, 2015) which will be drilled to an indicative maximum depth of 130 metres.
- Dewatering bores will be installed in two parallel lines located around 25 metres either side of the box cut, with an approximate bore spacing along each line of 100 metres (Jacobs, 2015).
- There may be additional groundwater flow to the box cut, estimated at 50 L/s (WRM, 2015), that may not be intercepted by dewatering bores. This will be collected in a sump at the base of the box cut, for later transfer to the MUP dam (during operations).
- The total dewatering flow rate at the West Balranald deposit is estimated at around 750 L/s during the construction phase (Jacobs, 2015).
- For the purposes of this impact assessment, it is assumed that up to around 30 bores will be active at any time, with a flow rate of approximately 25 L/s per bore.

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[20] Dewatering program details are considered to be indicative only and will be optimised at a later stage (Jacobs, 2015).

Another potential source of AMD during box cut dewatering is the in situ OOB and ore materials in the immediate vicinity of each dewatering bore.

The estimated mass of in situ OOB and ore to be exposed in the walls of West Balranald pit at any time during operations is (based on 2 metre thickness of air entry zone) is 192,000 tonnes and 122,000 tonnes, respectively. Smaller tonnages will be exposed in the box cut.

The estimated mass of OOB and ore to be exposed in materials surrounding the dewatering bores (based on 2 metre thickness of air entry zone) is 15,000 tonnes and 7,000 tonnes, respectively.

Relatively minor dewatering (average 100 L/s; peak 186 L/s) will be required at the Nepean deposit (Jacobs, 2015).

11.1.2 Potential Impacts

Potential construction phase AMD impacts relating to pit wall / bench / floor material are summarised in Table 57.

Table 57: Potential (Unmitigated) AMD Impacts from Pit Wall / Bench / Floor Material during the Construction Phase.

Project Element	Potential AMD Impact	Description
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – West Balranald deposit	Release of AMD from dewatered in situ material into void / groundwater or surface water (due to pit dewatering) as a result of sulfide oxidation between the time of mine dewatering and inundation below groundwater	The quantity of in situ OOB in the exposed surfaces of the box cut at the West Balranald deposit to be dewatered and exposed to oxidising conditions is conservatively estimated at up to 192,000 tonnes (based on estimated dimensions of the pit during operations, which will be larger than the box cut), assuming that air entry will be limited to 2 metres from the exposed pit surfaces. With an average sulfide-sulfur content of 1.01 wt.% S and relatively minor ANC (Table 24) and a maximum POR of 2.5 wt.% FeS_2/week (Table 25) under fully oxidising conditions, this could generate an estimated acidity load of up to 120 tonnes H_2SO_4 per week. The corresponding estimate for in situ ore material is an acidity load of up to 70 tonnes H_2SO_4 per week, based on up to 122,000 tonnes of desaturated ore at 1.09 wt.% S (S_{TOS}; Table 28) and a maximum POR of 2.2 wt.% FeS_2/week under fully oxidising conditions (Table 29). This is also based on estimated dimensions of the pit during operations, which will be larger than the box cut. The timing of acidity fluxes from box cut surface runoff or seepage will tend to be associated with rainfall events. Based on site rainfall characteristics, localised acidity fluxes to surface water or groundwater could occur at various times throughout the year. The estimated acidity influxes would significantly exceed alkalinity inputs from groundwater based on inflow rates to the box cut sump of 10 L/s at 200 mg/L $CaCO_3$ equivalent (1 tonne $CaCO_3$ per week). Any AMD from in-situ pit wall / bench / floor material could drain to the box cut sump or directly infiltrate to groundwater. Sump water from the box cut can be collected / treated on site during construction if necessary. In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – major; likelihood – possible).

Project Element	Potential AMD Impact	Description
	Release of AMD from dewatered in situ material into groundwater injection aquifer due to sulfide oxidation during mine dewatering	The quantity of in situ OOB surrounding the dewatering bores that may become exposed to oxidising conditions is estimated at up to 15,000 tonnes, assuming the box cut dewatering bore network comprises up to 30 bores intercepting a PAF layer of nominal thickness 20 metres and with air entry limited to 2 metres radially from the centre of each bore. With an average sulfide-sulfur content of 1.01 wt.% S and relatively minor ANC (Table 24), and a maximum POR of 2.5 wt.% FeS_2/week under fully oxidising conditions (Table 25), this could generate an estimated acidity load of less than 10 tonnes H_2SO_4 per week. The corresponding estimate for in situ ore material is an acidity load of less than 5 tonnes H_2SO_4 per week, based on 7,000 tonnes of desaturated ore at 1.09 wt.% S (S_{TOS}; Table 28) and a maximum POR of 2.2 wt.% FeS_2/week under fully oxidising conditions (Table 29). At dewatering rates in the order of 750 L/s with groundwater alkalinity of 200 mg/L $CaCO_3$ equivalent, representing around 90 tonnes $CaCO_3$ per week, this would be more than sufficient to neutralise the estimated acidity fluxes. The potential impact is considered LOW (consequence – minor; likelihood – unlikely).
	Failure of pipeline between dewatering and injection sites (eg. due to rupture, bushfire) leading to release of AMD to surface water / groundwater	AMD release associated with a potential pipeline failure is not expected to be an issue, based on the comments above. The potential impact is considered LOW (consequence – minor; likelihood – unlikely).
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – Nepean deposit	Release of AMD from dewatered in situ material into void / groundwater / surface water due to sulfide oxidation between the time of mine dewatering and inundation below groundwater	Relatively minor dewatering (average 100 L/s; peak 186 L/s) will be required at the Nepean deposit. Furthermore, currently available (limited) geochemical data for overburden and ore samples from the Nepean deposit indicate that there is low, if any, potential for AMD generation from this material. More extensive geochemical assessment for the Nepean deposit is required to verify this. In the interim, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).

11.1.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from pit wall / bench / floor material into surface water / groundwater during construction includes:

- Ensure that any acidic runoff or seepage (if any) from pit surfaces is collected in the box cut sump and treated and/or reused on site. Treatment may be achieved within the box cut sump or MUP dam (in situ) or through a centralised water treatment system using a hydrated lime treatment plant at the MUP site, if required.
- Direct any AMD affected groundwater from mine dewatering to the treatment plant, if required.
- Design the MUP dam to withstand up to the 1 in100 AEP event, and develop operating protocols to maintain/create sufficient storage to contain this design event, including rainfall forecasting to identify when the MUP dam may be vulnerable to overtopping.

- Conduct regular monitoring of water level and chemistry in the box cut sump and MUP dam, and pump flow rates from the box cut sump to the MUP dam.
- Conduct regular monitoring of groundwater level and chemistry down gradient of the MUP dam.
- In the event of any seepage from the MUP dam, conduct opportunistic monitoring of seepage flow rate and chemistry.
- Develop an emergency response plan, incorporating AMD considerations, to address the risk of MUP dam water overflow, uncontrolled seepage, or percolation to groundwater, from the MUP dam.
- Routinely monitor groundwater chemistry during dewatering and injection, to confirm that receiving groundwater in the injection aquifer will not be adversely affected.
- Conduct more extensive geochemical assessment of overburden materials (in situ) for the Nepean deposit to verify that this material presents a low AMD risk.

11.1.4 Residual Impacts

Based on the proposed management approach outlined in Section 11.1.3, the residual water quality impacts associated with potential AMD generation from the pit wall / bench / floor material during the construction phase are considered to be **LOW**.

The residual impacts are summarised in Section 13.

11.2 Operations

11.2.1 Context

During operations, ongoing dewatering of groundwater will be required to enable mining of the West Balranald deposits. This will lead to the desaturation of in situ overburden and ore materials to varying extents in the vicinity of the pit. Excavation of the pit will further increase the potential for air entry to these materials.

As per the construction phase:

- The AMD potential of sulfides in these (in situ) unsaturated materials is conservatively assumed to be similar to those measured for equivalent (ex situ) overburden and ore samples.
- The primary pathway for air entry to the dewatered in situ OOB and ore materials will be through the exposed pit surfaces, whereas air entry through the overlying in situ overburden material is likely to be negligible in comparison.

The active mine area at any time will be around 2-2.5 km long, 300 metres wide and 50-90 metres deep. The pit will advance rate of 8-10 m/day to the north.

Key aspects of the dewatering program during operations are summarised below[21]:

- Dewatering will be conducted primarily via ex-pit bores (Jacobs, 2015) which will be drilled to an indicative maximum depth of 130 metres.
- Dewatering bores will be installed in two parallel lines located around 25 metres either side of the pit, with an approximate bore spacing along each line of 100 metres (Jacobs, 2015).
- Bores will be constructed and decommissioned along the length of the pit as the mine progresses.
- There may be additional groundwater flow to the pit, estimated at 50 L/s (WRM, 2015) that may not be intercepted by dewatering bores. This will be collected in a sump at the base of the pit and transferred to the MUP dam.
- Two methods of groundwater injection have been considered – on path (along the mine pit, ahead of mining operations) and off path injection (5-10 km away from mining operations), with the latter option currently preferred by Iluka.
- Off path injection bores will be designed to ensure that only the target aquifer zone/s is affected. Bore casing (both surface and production) will be fully cement sealed to prevent upward migration of injection water.
- Total dewatering flow rates will average around 750 L/s and peak at up to 1,300 L/s during the operations phase (Jacobs, 2015)
- For the purposes of this impact assessment, it is assumed that 375-400 bores will be required at West Balranald over the course of mining, with up to around 50 bores active at any time, and each bore will have a flow rate of approximately 25 L/s.

The estimated mass of OOB and ore to be exposed in the walls of West Balranald pit at any time (based on 2 metre thickness of air entry zone) is 192,000 tonnes and 122,000 tonnes, respectively.

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[21] Dewatering program details are considered to be indicative only and will be optimised at a later stage (Jacobs, 2015).

The estimated mass of OOB and ore to be exposed in materials surrounding the dewatering bores (based on 2 metre thickness of air entry zone) is 25,000 tonnes and 13,000 tonnes, respectively.

Relatively minor dewatering (average 100 L/s; peak 186 L/s) will be required at the Nepean deposit (Jacobs, 2015).

11.2.2 Potential Impacts

Potential operations phase AMD impacts relating to pit wall / bench / floor material are summarised in Table 58.

Table 58: Potential (Unmitigated) AMD Impacts from Pit Wall / Bench / Floor Material during the Operations Phase.

Project Element	Potential AMD Impact	Description
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – West Balranald deposit	Release of AMD from dewatered in situ material into void / groundwater or surface water (due to pit dewatering) as a result of sulfide oxidation between the time of mine dewatering and inundation below groundwater	At any time, the quantity of in situ OOB in the exposed surfaces of the West Balranald pit to be dewatered and exposed to oxidising conditions is estimated at up to 192,000 tonnes, assuming that air entry will be limited to 2 metres from the pit surface. This is based on an operating pit length of up to 2,500 metres and width of 300 metres. With an average sulfide-sulfur content of 1.01 wt.% S, relatively minor ANC, and a maximum POR of 2.5 wt.% FeS_2/week under fully oxidising conditions, this could generate an estimated acidity load of around 120 tonnes H_2SO_4 per week. The corresponding estimate for in situ ore material is an acidity load of up to 70 tonnes H_2SO_4 per week (based on 122,000 tonnes of desaturated ore at 1.09 wt.% S and a maximum POR of 2.2 wt.% FeS_2/week under fully oxidising conditions). The timing of acidity fluxes from pit surface runoff or seepage will tend to be associated with rainfall events. Based on site rainfall characteristics, localised acidity fluxes to surface water or groundwater could occur at several times throughout the year. The estimated acidity influxes would significantly exceed alkalinity inputs from groundwater based on inflow rates to the pit of 10 L/s at 200 mg/L $CaCO_3$ equivalent (1 tonne $CaCO_3$ per week). Any AMD from in-situ pit wall / bench / floor material could drain to the pit sump, from where it may be pumped to the MUP dam for use on site, or directly infiltrate to groundwater. Acidity generation would continue until the temporarily dewatered in situ OOB is covered with at least 5 metres of backfilled SOB (nominally). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – major; likelihood – possible).
	Release of AMD from dewatered in situ material into groundwater injection aquifer due to sulfide oxidation during mine dewatering	The quantity of in situ OOB surrounding the dewatering bores that may become exposed to oxidising conditions is estimated at up to 25,000 tonnes, assuming the dewatering bore network comprises up to 50 bores intercepting a PAF layer of nominal thickness 20 metres and with air entry limited to 2 metres radially from the centre of each bore. With an average sulfide-sulfur content of 1.01 wt.% S and relatively minor ANC (Table 24) and a POR of 2.5 wt.% FeS_2/week (Table 25), this could generate an estimated acidity load of less than 20 tonnes H_2SO_4 per week.

Project Element	Potential AMD Impact	Description
		The corresponding estimate for in situ ore material is an acidity load of less than 10 tonnes H_2SO_4 per week, based on 13,000 tonnes of desaturated ore at 1.09 wt.% S (S_{TOS}; Table 28) and a maximum POR of 2.2 wt.% FeS_2/week under fully oxidising conditions (Table 29). Acidity generation and flushing of acid salts (acidity fluxes) would continue until the cessation of groundwater pumping. At dewatering rates in the order of 1300 L/s with groundwater alkalinity of 200 mg/L $CaCO_3$ equivalent, representing around 150 tonnes $CaCO_3$ per week, this would be more than sufficient to neutralise the estimated acidity fluxes. The potential impact is considered LOW (consequence – minor; likelihood – unlikely).
	Failure of pipeline between dewatering and injection sites (eg. due to rupture, bushfire) leading to release of AMD to surface water / groundwater	AMD release associated with a potential pipeline failure is not expected to be an issue, based on the comments above. The potential impact is considered LOW (consequence – minor; likelihood – unlikely).
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – Nepean deposit	Release of AMD from dewatered in situ material into void / groundwater / surface water due to sulfide oxidation between the time of mine dewatering and inundation below groundwater	Relatively minor dewatering (average 100 L/s; peak 186 L/s) will be required at the Nepean deposit. Furthermore, currently available (limited) geochemical data for overburden and ore samples from the Nepean deposit indicate that there is low, if any, potential for AMD generation from this material. More extensive geochemical assessment for the Nepean deposit is required to verify this. In the interim, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).

11.2.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from pit wall / bench / floor material into surface water / groundwater during operations is outlined below. Most of these measures are intended to not only address operational phase risks but also to pre-emptively manage the potential post-closure impacts identified in Section 11.3.2.

- Where overburden is exposed in bench lags, maintain a layer of in situ SOB as long as possible (eg. minimum cover 5 metres over in situ OOB) before disturbing OOB, during mining.
- Blend or apply thin layers of a sufficient quantity of limestone into the backfill material, to address AMD generated between in situ OOB dewatering and full inundation below groundwater. Based on available static and kinetic geochemical test work data, and the expected duration of exposure to oxidising conditions, neutralisation requirements are estimated at up to 210 tonnes $CaCO_3$ equivalent per week. This allows for 3 times the theoretical neutralisation requirement based on stoichiometry[22]. This is in addition to

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[22] Factor of 3 is conservative as it is based on use of coarse-grained limestone aggregate. There is potential to lower this quantity if an ultra-fine grained limestone material is used.

neutralisation requirements associated with the backfill material itself (Section 6 and Section 8). Blending may be achieved through various methods, with the preferred method to be selected and optimised during detailed project design. Operating protocols will be developed for the selected blending method, including QA/QC, prior to commencing construction.

- Ensure that any acidic runoff or seepage (if any) from pit surfaces is collected in the pit sump and treated and/or reused on site. Treatment may be achieved within the pit sump or MUP dam (in situ) or through a centralised water treatment system using a hydrated lime treatment plant at the MUP site, if required. However this is unlikely to be necessary if limestone blending is effective.
- Direct any AMD affected groundwater from mine dewatering to the treatment plant, if required.
- Design the MUP dam to withstand up to the 1 in100 AEP event, and develop operating protocols to maintain/create sufficient storage to contain this design rainfall event, including rainfall forecasting to identify when the MUP dam may be vulnerable to overtopping.
- Conduct regular monitoring of water level and chemistry in the pit sump and MUP dam, and pump flow rates from the pit sump to the MUP dam.
- Conduct regular monitoring of groundwater level and chemistry down gradient of the MUP dam.
- In the event of any seepage from the MUP dam, conduct opportunistic monitoring of seepage flow rate and chemistry.
- Develop an emergency response plan, incorporating AMD considerations, to address the risk of MUP dam water overflow, uncontrolled seepage, or percolation to groundwater, from the MUP dam.
- Routinely monitor groundwater chemistry during dewatering and injection, to confirm that receiving aquifer in the injection borefields will not be adversely affected.
- Conduct more extensive geochemical assessment of overburden and ore materials (in situ) for the Nepean deposit to verify that this material presents a low AMD risk.

11.2.4 Residual Impacts

Based on the proposed management approach outlined in Section 9.2.3, the residual water quality impacts associated with potential AMD generation from the pit wall / bench / floor material during the operations phase are considered to be **LOW**.

The residual impacts are summarised in Section 13.

11.3 Post-Closure

11.3.1 Context

Post-closure, all in situ OOB and any residual ore in the walls of the backfilled West Balranald pit will have been covered with backfilled overburden and MBPs.

The degree of exposure of sulfides in dewatered in situ OOB and any residual ore materials, and hence the potential for ongoing AMD generation, will depend on both the extent of the dewatering 'cone of depression' and the extent of air entry within the dewatered (unsaturated) zone.

Based on kinetic test work, air entry to dewatered in situ OOB and any residual ore materials will be relatively minor post-closure due to coverage with backfilled overburden and soils. This is expected to be the key control on acidity generation potential, rather than rate of groundwater rebound.

The key AMD risk relates therefore relates to the flushing of any residual acid salts generated during the operations phase (prior to backfill) as groundwater rebounds post-closure.

Pit dewatering will have ceased post-closure and there will be no potential for additional AMD generation from the in situ OOB or any residual ore materials in the immediate vicinity of dewatering bores.

Hydrogeological modelling conducted by Jacobs (2015) indicates that the groundwater table will take more than 100 years after mine closure to fully rebound to its existing level at the West Balranald deposit, and 30-100 years at the Nepean deposit.

11.3.2 Potential Impacts

Potential post-closure phase AMD impacts relating to pit wall / bench / floor material are summarised in Table 59.

Table 59: Potential (Unmitigated) AMD Impacts from Pit Wall / Bench / Floor Material during the Post-Closure Phase.

Project Element	Potential AMD Impact	Description
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – West Balranald deposit	Release of AMD from dewatered in situ material into void / groundwater due to sulfide oxidation between the time of mine dewatering and inundation below groundwater	Prior to groundwater inundation, the in situ OOB and any residual ore in the pit wall / bench / floor material will have been exposed to oxidising conditions during dewatering. Refer to acidity load estimates for the Construction and Operations phase. No further acidity generation from the pit wall / bench / floor material would occur post-closure as the in situ OOB and any residual ore material will have been covered with several metres of backfilled SOB (and MBPs). However, flushing of acid salts (acidity fluxes) from the in situ OOB may continue until this material returns to a saturated state following groundwater rebound. The timing of acidity fluxes from pit wall / bench / floor material into groundwater will be determined by the rate of groundwater rebound. During groundwater rebound, the estimated acidity influxes would significantly exceed alkalinity inputs from groundwater. The groundwater table is expected to take more than 100 years after mine closure to fully rebound to its existing level (Jacobs, 2015).

Project Element	Potential AMD Impact	Description
		After groundwater rebound, any AMD from pit wall / bench / floor material could migrate away from the pit. Groundwater flows will be subject to considerably lower hydraulic gradients relative to those experienced during groundwater rebound, with a regional hydraulic gradient of around 0.00025 from east to west across the length of the West Balranald mine under natural conditions (Jacobs, 2015). In the absence of AMD management measures, the potential impact is considered HIGH (consequence – major; likelihood – probable).
	Release of AMD from dewatered in situ material into groundwater injection aquifer due to sulfide oxidation during mine dewatering	Not applicable during post-closure phase.
	Failure of pipeline between dewatering and injection sites (eg. due to rupture, bushfire) leading to release of AMD to surface water / groundwater	Not applicable during post-closure phase.
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – Nepean deposit	Release of AMD from dewatered in situ material into void / groundwater / surface water due to sulfide oxidation between the time of mine dewatering and inundation below groundwater	Relatively minor dewatering (average 100 L/s; peak 186 L/s) will be required at the Nepean deposit. Furthermore, currently available (limited) geochemical data for overburden and ore samples from the Nepean deposit indicate that there is low, if any, potential for AMD generation from this material. More extensive geochemical assessment for the Nepean deposit is required to verify this. In the interim, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).

11.3.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from pit wall / bench / floor material into surface water / groundwater post-closure is to:

- Pre-emptively manage this risk during operations by implementing the measures outlined in Section 11.2.3 (Operations).
- Monitor the rate of groundwater rebound and pore water chemistry in re-saturated pit wall material until the final (natural) groundwater level has been achieved, to confirm that sufficient neutralising capacity has been added to prevent residual acid salts from contaminating the groundwater system.
- Use dewatering bores to facilitate post-closure monitoring of groundwater rebound, prior to full decommissioning.

11.3.4 Residual Impacts

Based on the proposed management approach outlined in Section 11.3.3, the residual water quality impacts associated with potential AMD generation from the pit wall / bench / floor material during the post-closure phase are generally considered to be **LOW**.

The key exception to this relates to the potential for release of AMD from dewatered in situ material into void / groundwater / surface water due to sulfide oxidation between the time of mine dewatering and inundation below groundwater (**MEDIUM** residual impact).

The residual impacts are summarised in Section 13.

12.0 Impact Assessment – Products

12.1 Construction

12.1.1 Context

No processing of ore from the West Balranald or Nepean deposits will occur, and hence there will be no mining products generated, during the construction phase.

12.1.2 Potential Impacts

Not applicable during the construction phase.

12.1.3 Proposed Management Approach

Not applicable during the construction phase.

12.1.4 Residual Impacts

Not applicable during the construction phase.

12.2 Operations

12.2.1 Context

Ore slurry from the MUP site will be pumped to the process plant for further processing through the PCP, WCP, WHIMS and ISP.

The WHIMS plant will separate magnetic material, referred to as WHIMS magnetics (containing ilmenite) from non-magnetic material (HMC). The WHIMS plant will have a feed rate of around 185 tonnes per hour, and generate roughly equal proportions of WHIMS magnetics and HMC.

WHIMS magnetics will feed into the ISP, which will generate two product streams (sulfate and chloride ilmenite products) and one by-product stream (magnetic rejects). Refer to the process flow diagram in Figure 33. Magnetic rejects will be blended with other MBPs and backfilled into the pit (refer to Section 10).

The processes described above will achieve annual average production rates of 500,000 tonnes per year of HMC and 650,000 tonnes per year of ilmenite. The HMC and ilmenite products will be temporarily stored on site in separate stockpiles located at the process plant area, prior to off-site transport. For the purposes of this impact assessment, the size of each product stockpile is expected to be equivalent to no more than 2 weeks production, which corresponds to 20,000 tonnes HMC and 25,000 tonnes ilmenite.

The HMC product has significant potential to generate AMD, with an average sulfide-sulfur (S_{TOS}) content of 0.8 wt.% S, no detectable ANC, and a maximum POR of up to 1.2 wt.% FeS_2/week under fully oxidising conditions (Table 44).

The ilmenite product is also expected to represent an AMD risk based on preliminary geochemical test work on WHIMS magnetics material, which has an average sulfide-sulfur content of 0.4 wt.% S, relatively minor ANC, and a maximum POR of up to 2.4 wt.% FeS_2/week under fully oxidising conditions (Table 44).

HMC and ilmenite will be progressively transported off site. Up to 150 B-Double truck movements (comprising HMC and ilmenite) would be generated each day associated with product haulage.

12.2.2 Potential Impacts

Potential operations phase AMD impacts relating to mining products are summarised in Table 60.

Table 60: Potential (Unmitigated) AMD Impacts from Mining Products during the Operations Phase.

Project Element	Potential AMD Impact	Description
Mining products – during temporary storage at West Balranald process plant	Runoff or seepage of AMD from stockpiled HMC product into surface water / groundwater	The quantity of HMC to be exposed to oxidising conditions is estimated at 20,000 tonnes. With an average sulfide-sulfur content of 0.8 wt.% S, no detectable ANC, and a maximum POR of up to 1.2 wt.% FeS_2/week under fully oxidising conditions (Table 44), this could generate an estimated acidity load of around 10 tonnes H_2SO_4 per week. The above estimate is conservative, assuming that all material is fully exposed to oxidising conditions. The actual acidity generation rate may be less than 10 tonnes H_2SO_4 per week as kinetic geochemical test work indicates that air entry to stockpiled materials is unlikely to exceed 2 metres, and this is the key control on acidity generation rate, rather than the total tonnage of unsaturated (stockpiled) material. The timing of acidity fluxes from the stockpile will tend to be associated with

Project Element	Potential AMD Impact	Description
		rainfall events. Based on site rainfall characteristics, localised acidity fluxes to surface water or groundwater could occur at various times throughout the year. Acidity generation and flux would continue until the product stockpile is removed off site. Groundwater quality could be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. However, groundwater contaminants are not expected to migrate significantly from the project area over the mine life, as there will generally be a local hydraulic gradient towards the centre of the West Balranald pit (Jacobs, 2015). In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – minor; likelihood – possible).
	Runoff or seepage of AMD from stockpiled ilmenite product into surface water / groundwater	The quantity of ilmenite to be exposed to oxidising conditions is estimated at 25,000 tonnes. Based on WHIMS magnetics geochemical characteristics, with an average sulfide-sulfur content of 0.4 wt.% S, relatively minor ANC, and a maximum POR of 2.4 wt.% FeS_2/week under fully oxidising conditions (Table 44), this could generate an estimated acidity load of around 10 tonnes H_2SO_4 per week. The above estimate is conservative, assuming that all material is fully exposed to oxidising conditions. The actual acidity generation rate may be less than 10 tonnes H_2SO_4 per week as kinetic geochemical test work indicates that air entry to stockpiled materials is unlikely to exceed 2 metres, and this is the key control on acidity generation rate, rather than the total tonnage of unsaturated (stockpiled) material. The timing of acidity fluxes from the stockpile will tend to be associated with rainfall events. Based on site rainfall characteristics, localised acidity fluxes to surface water or groundwater could occur at various times throughout the year. Acidity generation and flux would continue until the product stockpile is removed off site. Groundwater quality could be affected locally (within the mine site) as there would be insufficient natural alkalinity to neutralise the potential acidity loads. However, groundwater contaminants are not expected to migrate significantly from the project area over the mine life, as there will generally be a local hydraulic gradient towards the centre of the West Balranald pit (Jacobs, 2015). The potential impact is considered MEDIUM (consequence – minor; likelihood – possible).
Mining products – during off site transport	Transport accident (off-site) leading to release of HMC product and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	A transport accident leading to uncontrolled release of HMC is conceivable. However, based on the average sulfide-sulfur content of HMC noted above, and mass of up to 20 tonnes per truck load, the potential acidity released from spilled material, in the event of an accident, would be less than 500 kg H_2SO_4. In the absence of AMD management measures, the potential impact is considered MEDIUM (consequence – moderate; likelihood – unlikely).
	Transport accident (off-site) leading to release of ilmenite product and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	A transport accident leading to uncontrolled release of ilmenite is conceivable. However, based on the average sulfide-sulfur content of WHIMS magnetics noted above, and mass of up to 20 tonnes per truck load, the potential acidity released from spilled material, in the event of an accident, would be less than 250 kg H_2SO_4. The potential impact is considered MEDIUM (consequence –moderate; likelihood – unlikely).

12.2.3 Proposed Management Approach

Iluka's proposed approach to minimise and monitor the risk of AMD runoff or seepage from mining products into surface water / groundwater during operations includes:

- Stockpile mining products on low permeability pads comprising a limestone liner (eg. ultra-fine grained limestone) with surface water drainage control (upstream cutoff drains), within the designated stockpile area at the plant site.
- Minimise surface area of stockpiled mining products.
- Frequent transport of mining products off site.
- Ensure that any acidic runoff or seepage (if any) from mining product stockpiles is collected, treated and/or reused on site. Treatment may be achieved within the settling dam (in situ) or through a centralised water treatment system using a hydrated lime treatment plant at the process plant site, if required.
- Conduct regular monitoring of any surface runoff (including flow rate and chemistry) from the mining product stockpiles, and groundwater level and chemistry down gradient of the stockpiles.
- In the event of any seepage from stockpiles, conduct opportunistic monitoring of seepage flow rate and chemistry.
- In the event of a transport accident involving a spill of mining products, recover spilled material as soon as practicable.
- Incorporate AMD considerations into emergency response procedures for transport accident involving a spill of mining product.

12.2.4 Residual Impacts

Based on the proposed management approach outlined in Section 12.2.3, the residual water quality impacts associated with potential AMD generation from the product materials during the operations phase are considered to be **LOW**.

12.3 Post-Closure

12.3.1 Context

Post-closure, all mining products from the West Balranald and Nepean deposits will have been transported off site, hence there will be no residual HMC or ilmenite stockpiles remaining on site and no associated AMD risks.

12.3.2 Potential Impacts

Not applicable during the post-closure phase.

12.3.3 Proposed Management Approach

Not applicable during the post-closure phase.

12.3.4 Residual Impacts

Not applicable during the post-closure phase.

13.0 Impact Assessment Summary

A summary of the potential impacts, management measures and residual impacts of the Balranald Project on groundwater and surface water, relating to the potential for sulfide oxidation and associated AMD generation from mine materials, is presented in Table 61 to Table 65. This section consolidates the key findings presented throughout Sections 8 to 12.

As previously described, the impact ratings are based on estimated AMD generation rates, where available, and the subsequent implications for the receiving environment including water resource use, aquatic ecosystems or riparian land. Hence, in this assessment, AMD generation itself is not considered an “impact”. An “impact” refers to AMD generation that leads to acidity dissolution in surface water or groundwater to the extent that the receiving environment may be adversely affected.

To this end, the impact ratings take into consideration the unique environmental setting at Balranald, which is expected to limit the spatial extent of project impacts associated with any local water quality changes. In particular:

- Groundwater from the project area will drain to the Shepparton Formation and LPS Formation aquifers (refer to Section 3.4). Baseline groundwater quality data indicates that these aquifers are generally unsuitable for agricultural and stock water uses due to their high salinity concentrations.
- Of the 26 landholder bores nearest to the project area identified by Jacobs (2015), 3 bores are screened in the Shepparton Formation and 1 bore is screened in the LPS Formation. The 3 bores in the Shepparton Formation are located approximately 10-15 km west of the northern end of the West Balranald deposit (Jacobs, 2015; Appendix F)[23]. Refer to Section 3.6.2.
- Groundwater modelling for these landholder bores conducted by Jacobs (2015) indicates that there will be no drawdown in the Shepparton Formation bores and minimal drawdown in the LPS Formation bores (0.02 metres).
- Groundwater modelling conducted by Jacobs (2015) indicates that the extent of groundwater drawdown in local landholder bores is not likely to exceed 0.07 metres. Refer to Section 3.6.2.
- GDEs in the vicinity of the project area are either unlikely to be significant groundwater users (based on groundwater salinity and/or depth to the water table) or unlikely to experience groundwater drawdown in excess of 3-5 metres in the Shepparton Formation (CDM Smith, 2015). Refer to Section 3.6.3.
- Further to the above points, the rate of groundwater flow away from the project area is expected to be low under natural conditions based on existing regional hydraulic gradients and modelling conducted by Jacobs (2015).
- Uncontrolled releases of mine affected water are predicted to be rare (less than a 1% chance occurring in any year of the mine life) and small in volume (WRM, 2015; Section 7.2).
- Natural drainage lines in the vicinity of the project area are generally dry throughout the year based on historic anecdotal evidence (WRM, 2015; Section 3.2).

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[23] The location of 2 additional landholder bores screened in the Shepparton Formation, as identified in the LWC (2014f) study, and 1 bore screened in the LPS Formation (Jacobs, 2015), is still to be confirmed.

- There are no surface water users in the immediate vicinity of the project area. The nearest reliable and significant surface water resource is the Murrumbidgee River, approximately 30 km south-west of the project area (WRM, 2015; Section 3.6.1).

The residual impact ratings outlined in Table 61 to Table 65 are based on Iluka's proposed AMD management approaches.

Table 61: Summary of geochemistry assessment results for the Balranald Project – OVERBURDEN.

Potential Impacts						Iluka's proposed management approach (see Section 8 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
Overburden material stockpiled above ground level – West Balranald deposit	Runoff or seepage of AMD from temporary OOB stockpile (from box cut) into surface water / groundwater	Construction	Major	Probable	High	Confirm field-based (eg. visual) method for identification of PAF versus NAF overburden. Routine monitoring and segregation of OOB. Low permeability liner, incorporating limestone, beneath OOB stockpile. Surface water drainage control around OOB stockpile. Minimise surface area of OOB stockpile (relocate to pit as soon as possible). Incorporate sufficient quantity of limestone in OOB stockpile, allowing for 3 times the theoretical neutralisation requirement. Collect, treat and/or reuse any acidic runoff or seepage from OOB stockpile. Incorporate AMD considerations into MUP dam design, operation and emergency response procedures. Regular surface and groundwater monitoring at MUP dam and OOB stockpile.	Major	Unlikely	Medium
		Operations	n/a	n/a	-	Not required.	n/a	n/a	-
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
Overburden material stockpiled above ground level – Nepean deposit	Runoff or seepage of AMD from temporary overburden stockpiles into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Unlikely	Medium	More extensive geochemical assessment of overburden materials for the Nepean deposit.	Minor	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
Overburden material used for site construction works	Runoff or seepage of AMD from any overburden materials used for site construction works (eg. access roads, hardstand areas, dam embankments) into surface water / groundwater	Construction	Major	Very unlikely	Medium	Avoid use of OOB for site construction works. If any overburden is to be used as a construction material (eg. TSF embankment, access roads, plant foundations) characterise and classify the material to ensure that it is both NAF and non-saline.	Moderate	Very unlikely	Low
		Operations	Major	Very unlikely	Medium	As above.	Moderate	Very unlikely	Low
		Post-closure	Minor	Very unlikely	Low	As above.	Minor	Very unlikely	Low

Potential Impacts						Iluka's proposed management approach (see Section 8 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
Overburden material backfilled in pit - West Balranald deposit	Release of AMD from backfilled overburden into void / groundwater or surface water (due to pit dewatering) as a result of sulfide oxidation between the time of OOB dewatering and final inundation below groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Possible	Medium	Continue routine monitoring and segregation of OOB. Return OOB directly to its final storage location as low as possible in the backfill profile, and rapidly cap (within 1-2 days) backfilled OOB with at least 5 metres of SOB or inert clay-rich material. To address any residual acidity, incorporate sufficient quantity of limestone into backfilled OOB, allowing for 3 times the theoretical neutralisation requirement. The limestone requirement for backfilled OOB will be substantially lowered by implementing the above strategy (direct backfill and capping within 1-2 days). Traffic compact backfilled limestone-blended OOB, and cover as soon as practicable. Collect, treat and/or reuse any acidic runoff or seepage from backfilled OOB. Incorporate AMD considerations into MUP dam design, operation and emergency response procedures. Regular surface and groundwater monitoring at pit sump and MUP dam. Regular groundwater monitoring from dewatering bores.	Minor	Unlikely	Low
		Post-closure	Major	Probable	High	As per operations phase management approach (most of these measures listed above are intended to not only address operational phase risks but also to pre-emptively manage the potential post-closure impacts. Monitor the rate of groundwater rebound and pore water chemistry in backfilled OOB until the final (natural) groundwater level has been achieved, to confirm that sufficient neutralising capacity has been added to prevent residual acid salts from contaminating the groundwater system. Use dewatering bores to facilitate post-closure monitoring of groundwater rebound, prior to full decommissioning.	Moderate	Unlikely	Medium
Overburden material backfilled in pit - Nepean deposit	As above	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Unlikely	Medium	More extensive geochemical assessment of overburden materials for the Nepean deposit.	Minor	Very unlikely	Low
		Post-closure	Major	Unlikely	Medium	More extensive geochemical assessment of overburden materials for the Nepean deposit.	Minor	Very unlikely	Low

Table 62: Summary of geochemistry assessment results for the Balranald Project – ORE.

Potential Impacts						Iluka's proposed management approach (see Section 9 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
Ore material stockpile from West Balranald deposit	Runoff or seepage of AMD from stockpiled ore into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Major	Probable	High	Backfill oversize material directly to West Balranald pit. Backfill oversize material to the pit in the same manner as backfilled OOB. Low permeability liner, incorporating limestone, beneath stockpiled ore. Surface water drainage control around stockpiled ore. Minimise surface area of ore stockpile. Incorporate sufficient quantity of limestone in stockpiled ore, allowing for 3 times the theoretical neutralisation requirement. As an alternative or in combination with limestone blending (see above): • Collect, treat and/or reuse any acidic runoff or seepage from stockpiled ore. • Treat any residual AMD in ore slurry by hydrated lime addition at the process plant site. Incorporate AMD considerations into MUP dam design, operation and emergency response procedures. Regular surface and groundwater monitoring at MUP dam and ore stockpile/s.	Major	Unlikely	Medium
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
Ore material stockpile from Nepean deposit	As above	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Unlikely	Medium	More extensive geochemical assessment of ore materials for the Nepean deposit.	Minor	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
Process plant water	Uncontrolled release of process plant water affected by AMD from ore material	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Unlikely	Medium	Incorporate bunding around the process plant area and develop an emergency response plan to address the risk of uncontrolled overflow of process water that may be affected by AMD from the ore material.	Moderate	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-

Potential Impacts						Iluka's proposed management approach (see Section 9 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
Pipeline failure while pumping ore slurry from MUP to PCP (eg. due to rupture, bushfire)	Runoff or seepage of AMD from ore slurry into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Possible	Medium	Install bunding and ore slurry collection sump(s) along the pipeline alignment. Clear vegetation along pipeline alignment and ensure fire control systems are in place before commencing pipeline operation. Install isolation valves along pipeline. Shut-down ore transfer during any bushfire event in the vicinity of the slurry pipeline. Install a pipeline leak detection system. Regular pipeline maintenance and inspection. Recover any spilled material as soon as practicable. Incorporate AMD considerations into emergency response procedures for potential pipeline failure.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
Transport accident on haul road between Nepean and West Balranald deposits leading to spill of Nepean ore	Runoff or seepage of AMD from Nepean ore into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Minor	Unlikely	Low	Recover any spilled ore as soon as practicable. Incorporate AMD considerations into emergency response procedures for potential transport accident involving a spill of ore material. More extensive geochemical assessment of ore materials for the Nepean deposit. Construct internal roads within the project area to minimise interaction between mining equipment and haul trucks, and general light vehicle traffic on site.	Minor	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-

Table 63: Summary of geochemistry assessment results for the Balranald Project – MINING BY-PRODUCTS.

Potential Impacts						Iluka's proposed management approach (see Section 10 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
MBPs stored above ground level (eg. sand tails, ModCod, magnetic rejects, Hamilton by-products)	Release of AMD via supernatant water overflow from TSF to Box Creek	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Major	Possible	Medium	Develop TSF operating protocols to maintain/create sufficient storage to contain the design rainfall event (eg. probable maximum precipitation). Incorporate sufficient quantity of limestone in ModCod, allowing for 3 times the theoretical neutralisation requirement. Routine monitoring and characterisation of ModCod to inform neutralisation requirements. Regular surface water monitoring at TSF. Field-based kinetic geochemical test work (oxygen diffusion profiles) to refine acidity load estimates / neutralisation requirements. Incorporate AMD considerations into TSF emergency response procedures.	Major	Unlikely	Medium
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
	Seepage of AMD from TSF into groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Minor	Possible	Medium	Install clay liner across TSF embankment and floor. Ensure that any seepage is collected and pumped back to the TSF or treated and re-used on site. Regular seepage water monitoring at TSF.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
	TSF embankment failure leading to release of sulfidic MBPs / AMD to surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Major	Unlikely	Medium	TSF design to withstand extreme rainfall / earthquake events in accordance with ANCOLD guidelines. Develop TSF operating protocols to maintain/create sufficient storage to contain the design rainfall event (eg. probable maximum precipitation). Regular surface water monitoring at TSF. Incorporate AMD considerations into TSF emergency response procedures.	Moderate	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-

Potential Impacts						Iluka's proposed management approach (see Section 10 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
	Runoff or seepage of AMD from temporary MBPs stockpiles (eg. sand tails, magnetic rejects, Hamilton by-products) into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Probable	Medium	Transport the Hamilton by-products back to the mine site as frequently as possible (eg. at least weekly) to minimise AMD generation at the processing plant and associated neutralisation requirements. Return sand tails, magnetic rejects and Hamilton by-products directly, if possible, to the West Balranald pit. Low permeability liner, incorporating limestone, beneath by-product stockpiles. Consider temporary stockpiling below ground level so drainage reports to the pit sump. Surface water drainage control around stockpiled by-products. Minimise surface area of by-product stockpiles. Incorporate sufficient quantity of limestone in stockpiled by-products, allowing for 3 times the theoretical neutralisation requirement. Routine monitoring and characterisation of each by-product stream to inform neutralisation requirements. Collect, treat and/or reuse any acidic runoff or seepage from stockpiled by-products. Incorporate AMD considerations into MUP dam design, operation and emergency response procedures. Regular surface and groundwater monitoring at MUP dam and by-product stockpile/s.	Moderate	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
MBPs placed below ground in West Balranald pit (eg. sand tails, thickener underflow or ModCod from PCP / WCP at Balranald; by-products from Hamilton MSP)	Release of AMD from backfilled MBPs below final (natural) groundwater level, into void / groundwater or surface water (due to pit dewatering) as a result of sulfide oxidation between the time of MBP generation and inundation below groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Possible	Medium	Routine monitoring and characterisation of MBPs to inform neutralisation requirements. No disposal of MBPs in the Nepean pit. Co-dispose Balranald thickener underflow and sand tails as ModCod material, to facilitate handling and trafficability of backfilled material. Backfill MBPs directly if possible, in particular float plant tails, to their final storage location above the backfilled OOB but below NAF materials in the backfill profile. Incorporate sufficient quantity of limestone into backfilled MBPs, allowing for 3 times the theoretical neutralisation requirement. Traffic compact backfilled limestone-blended MBPs and cover with SOB as soon as practicable. Collect, treat and/or reuse any acidic runoff or seepage from backfilled MBPs. Incorporate AMD considerations into MUP dam design, operation and emergency response procedures. Regular surface and groundwater monitoring at pit sump and MUP dam.	Minor	Unlikely	Low

Potential Impacts						Iluka's proposed management approach (see Section 10 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
		Post-closure	Major	Probable	High	As per operations phase management approach (most of these measures listed above are intended to not only address operational phase risks but also to pre-emptively manage the potential post-closure impacts. Monitor the rate of groundwater rebound and pore water chemistry in backfilled MBPs until the final (natural) groundwater level has been achieved, to confirm that sufficient neutralising capacity has been added to prevent residual acid salts from contaminating the groundwater system. Use dewatering bores to facilitate post-closure monitoring of groundwater rebound, prior to full decommissioning.	Moderate	Unlikely	Medium
MBP pipelines: · ModCod pipeline to TSF. · Sand tails pipeline to MUP.	Failure of MBP pipeline (eg. due to rupture, bushfire) leading to release of sulfidic MBPs / AMD to surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Possible	Medium	Install bunding and slurry collection sump(s) along the pipeline alignment. Clear vegetation along pipeline alignment and ensure fire control systems are in place before commencing pipeline operation. Install isolation valves along pipeline. Shut-down MBP transfer during any bushfire event in the vicinity of the pipelines. Install a pipeline leak detection system. Regular pipeline maintenance and inspection. Recover any spilled material as soon as practicable. Incorporate AMD considerations into emergency response procedures for potential pipeline failure.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
Return water pipeline (TSF decant water pipeline to process plant)	Failure of return water pipeline (eg. due to rupture, bushfire) leading to release of AMD to surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Possible	Medium	Install bunding and return water collection sump(s) along the pipeline alignment. Clear vegetation along pipeline alignment and ensure fire control systems are in place before commencing pipeline operation. Install isolation valves along pipeline. Shut-down return water transfer during any bushfire event in the vicinity of the pipeline. Install a pipeline leak detection system. Regular pipeline maintenance and inspection. Recover any spilled material as soon as practicable. Incorporate AMD considerations into emergency response procedures for potential pipeline failure.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-

Potential Impacts						Iluka's proposed management approach (see Section 10 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
Hamilton by-product transport to West Balranald mine for final disposal (off site)	Transport accident (off site) leading to release of sulfidic by-products and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Unlikely	Medium	Recover any spilled material as soon as practicable. Incorporate AMD considerations into emergency response procedures for transport accident involving a spill of MBPs.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
MBP transport on site: • Hamilton by-products. • Dried ModCod transport from TSF to MUP. • Dried magnetic rejects transport from process plant to MUP. • Blended MBPs from MUP to West Balranald pit.	Transport accident (on site) leading to release of sulfidic MBPs and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Minor	Unlikely	Low	Recover any spilled material as soon as practicable. Incorporate AMD considerations into emergency response procedures for transport accident involving a spill of MBPs.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-

Table 64: Summary of geochemistry assessment results for the Balranald Project – PIT WALLS / BENCHES / FLOORS.

Potential Impacts						Iluka's proposed management approach (see Section 11 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – West Balranald deposit	Release of AMD from dewatered in situ material into void / groundwater or surface water (due to pit dewatering) as a result of sulfide oxidation between the time of mine dewatering and inundation below groundwater	Construction	Major	Possible	Medium	Collect, treat and/or reuse any acidic runoff or seepage from box cut walls / benches / floor. Direct any AMD affected groundwater from mine dewatering to treatment plant, if required. Incorporate AMD considerations into MUP dam design, operation and emergency response procedures. Regular surface and groundwater monitoring at box cut sump and MUP dam. Routinely monitor groundwater chemistry during dewatering.	Minor	Unlikely	Low
		Operations	Major	Possible	Medium	Where overburden is exposed in bench lags, maintain a layer of in situ SOB as long as possible (eg. minimum 5 metres) before disturbing OOB. Incorporate sufficient quantity of limestone into backfilled overburden to address AMD generation from in situ materials (in addition to backfill), allowing for 3 times the theoretical neutralisation requirement. Collect, treat and/or reuse any acidic runoff or seepage from pit walls / benches / floor. Direct any AMD affected groundwater from mine dewatering to treatment plant, if required. Incorporate AMD considerations into MUP dam design, operation and emergency response procedures. Regular surface and groundwater monitoring at pit sump and MUP dam. Routinely monitor groundwater chemistry during dewatering.	Minor	Unlikely	Low
		Post-closure	Major	Probable	High	As per operations phase management approach (most of these measures listed above are intended to not only address operational phase risks but also to pre-emptively manage the potential post-closure impacts. Monitor the rate of groundwater rebound and pore water chemistry until the final (natural) groundwater level has been achieved, to confirm that sufficient neutralising capacity has been added to prevent residual acid salts from contaminating the groundwater system. Use dewatering bores to facilitate post-closure monitoring of groundwater rebound, prior to full decommissioning.	Moderate	Unlikely	Medium
	Release of AMD from dewatered in situ material into groundwater injection aquifer due to sulfide oxidation during mine dewatering	Construction	Minor	Unlikely	Low	Routinely monitor groundwater chemistry during dewatering and injection, to confirm that receiving groundwater in the injection aquifer will not be adversely affected.	Minor	Unlikely	Low
		Operations	Minor	Unlikely	Low	As per construction phase management approach.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-

Potential Impacts						Iluka's proposed management approach (see Section 11 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
	Failure of pipeline between dewatering and injection sites (eg. due to rupture, bushfire) leading to release of AMD to surface water / groundwater	Construction	Minor	Unlikely	Low	Not required.	Minor	Unlikely	Low
		Operations	Minor	Unlikely	Low	Not required.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
In-situ pit wall / bench / floor material that is unsaturated due to mine dewatering – Nepean deposit	Release of AMD from dewatered in situ material into void / groundwater / surface water due to sulfide oxidation between the time of mine dewatering and inundation below groundwater	Construction	Moderate	Unlikely	Medium	More extensive geochemical assessment of overburden and ore materials for the Nepean deposit.	Minor	Very unlikely	Low
		Operations	Moderate	Unlikely	Medium	More extensive geochemical assessment of overburden and ore materials for the Nepean deposit.	Minor	Very unlikely	Low
		Post-closure	Moderate	Unlikely	Medium	Not required.	Minor	Very unlikely	Low

Table 65: Summary of geochemistry assessment results for the Balranald Project – PRODUCTS.

Potential Impacts						Iluka's proposed management approach (see Section 12 for details)	Residual Impacts		
Element	Impact	Phase	Conseq.	L'hood	Impact		Conseq.	L'hood	Impact
Mining products – during temporary storage at West Balranald process plant	Runoff or seepage of AMD from stockpiled HMC product into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Minor	Possible	Medium	Low permeability liner, incorporating limestone, beneath HMC product stockpile. Surface water drainage control around HMC product stockpile. Minimise surface area of HMC product stockpiling. Frequent transport of mining products off site. Collect, treat and/or reuse any acidic runoff or seepage from HMC product stockpile. Regular surface and groundwater monitoring at HMC product stockpile.	Minor	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
	Runoff or seepage of AMD from stockpiled ilmenite product into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Minor	Possible	Medium	As per HMC product stockpile during operations phase (see above).	Minor	Very unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
Mining products – during off site transport	Transport accident (off-site) leading to release of HMC product and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Unlikely	Medium	Recover any spilled material as soon as practicable. Incorporate AMD considerations into transport accident emergency response procedures.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-
	Transport accident (off-site) leading to release of ilmenite product and subsequent runoff or seepage of AMD from spilled material into surface water / groundwater	Construction	n/a	n/a	-	Not required.	n/a	n/a	-
		Operations	Moderate	Unlikely	Medium	Recover any spilled material as soon as practicable. Incorporate AMD considerations into transport accident emergency response procedures.	Minor	Unlikely	Low
		Post-closure	n/a	n/a	-	Not required.	n/a	n/a	-

14.0 Conclusions

The key conclusions from mine material geochemical characterisation and classification are summarised below:

- The NSOB and SOB at West Balranald were all (63 samples) classified as NAF as they have minimal, if any, sulfide content. These materials are not considered to represent an AMD risk.
- The OOB at the West Balranald deposit is almost entirely (52 of 53 samples) classified as PAF. This material has an average sulfide-sulfur content of 1.01 wt.% S, relatively minor ANC, and a maximum POR of up to 2.5 wt.% FeS_2/week under fully oxidising conditions. The estimated tonnage of overburden from the West Balranald deposit is around 397 million tonnes, of which around 57 million tonnes (14%) is classified as OOB.
- At the Nepean deposit, 95% of the NSOB samples tested (22 of 23 samples) were classified as NAF and the one PAF sample of NSOB was classified as having a low potential for acid generation (AG4) based on a low sulfur content and low ANC.
- The ore material from West Balranald was all classified as PAF (16 samples). This material has significant potential to generate AMD, with an average sulfide-sulfur content of 1.09 wt.% S, relatively minor ANC, and a maximum POR of up to 2.2 wt.% FeS_2/week under fully oxidising conditions. At any time, the quantity of ore stockpiled during operations is estimated at up to around 1.2 million tonnes.
- Unlike at West Balranald, all of the Nepean ore samples tested (5 samples) were NAF.
- Kinetic geochemical test work indicates that air entry to stockpiled or in situ OOB and ore materials is unlikely to exceed 2 metres, and therefore limited supply of oxygen will be the key control on acidity generation rate from these sources.
- All of the MBPs and products tested were classified as PAF.
- Of the MBPs tested, the Balranald ModCod and Hamilton float plant tails and Hyti (leucoxene), in particular, have significant potential to generate AMD. The Balranald ModCod has an average sulfide-sulfur content of 1.6 wt.% S, no detectable ANC, and a maximum POR of up to 1.6 wt.% FeS_2/week under fully oxidising conditions. Balranald ModCod is estimated to be generated at a rate of around 1.2 million tonnes per year.
- The Hamilton float plant tails and Hyti (leucoxene) have an average sulfide-sulfur content of 15 wt.% S and 7.3 wt.S, respectively, and no detectable ANC (POR currently unknown) but will be generated in relatively small quantities (each less than 10,000 tonnes per year).
- The other Hamilton by-products are expected to represent a lower AMD risk than the float plant tails and Hyti (leucoxene) based on their lower sulfide-sulfur content and/or relatively small proportion of the total by-product stream.
- The Balranald sand tails have a relatively low sulfide-sulfur content of 0.3 wt.% S but high POR (up to 2.4 wt.% FeS_2/week under fully oxidising conditions) and therefore also represent a significant AMD risk. Balranald sand tails are estimated to be generated at a rate of around 1.1 million tonnes per year (in addition to those contained in ModCod).
- The magnetic rejects are expected to represent an AMD risk based on preliminary geochemical test work on WHIMS plant magnetics material, which has comparable sulfide-sulfur content and

POR to the Balranald sand tails. However, the magnetic rejects will be generated in relatively small quantities (less than 100,000 tonnes per year).

- The HMC product has significant potential to generate AMD, with an average sulfide-sulfur content of 0.8 wt.% S, no detectable ANC, and a POR of up to 1.2 wt.% FeS_2/week under fully oxidising conditions. The ilmenite product also has potential to generate AMD, based on preliminary geochemical test work on WHIMS magnetics material, which has an average sulfide-sulfur content of 0.4 wt.% S, relatively minor ANC, and a POR of up to 2.4 wt.% FeS_2/week under fully oxidising conditions. However, the extent of AMD generation from these products will be limited assuming they will not be stockpiled for more than 2 weeks.
- Potential elements of environmental significance in leachate from sulfidic mine materials include iron, aluminium, manganese, cadmium, chromium, cobalt, copper, nickel, lead and zinc.
- There are currently insufficient data for comprehensive geochemical characterisation of the Nepean deposit. However, limited available data indicate this deposit represents a lower AMD risk than West Balranald.

The potential water quality impacts of the project relating to oxidation of sulfidic mine materials and associated AMD generation, in the absence of AMD management measures, include:

- Stockpiled OOB could generate a maximum acidity load of up to 250 tonnes H_2SO_4 per week over approximately 2 months during construction.
- Backfilled OOB within the West Balranald pit could generate a maximum acidity load of up to 60 tonnes H_2SO_4 per week during operations. No further acidity generation from backfilled OOB would occur post-closure as this will be covered with MBPs and SOB.
- Stockpiled ore (from West Balranald) could generate a maximum acidity load of up to 100 tonnes H_2SO_4 per week during operations.
- Up to 30 ha of ModCod may be exposed to oxidising conditions at any time in the Tailings Storage Facility (TSF), which could generate a maximum acidity load of up to 1,000 tonnes H_2SO_4 per week during operations. Other stockpiled by-products, could generate a maximum of around 40 tonnes H_2SO_4 per week during operations.
- Backfilled MBPs within the West Balranald pit could generate a maximum acidity load of up to 100 tonnes H_2SO_4 per week during operations. No further acidity generation from MBPs would occur post-closure as they will be covered with backfilled SOB.
- In situ OOB and ore in the exposed surfaces of the West Balranald pit could generate a maximum acidity load of up to 190 tonnes H_2SO_4 per week during construction and operations. No further acidity generation from this material would occur post-closure as it will be covered with backfilled SOB (and MBPs).
- Relatively minor acidity loads are anticipated from in situ OOB and ore surrounding the dewatering bores at the West Balranald pit (less than 30 tonnes H_2SO_4 per week).
- Stockpiled HMC and ilmenite (from processing of West Balranald ore) could generate a combined estimated acidity load of up to 20 tonnes H_2SO_4 per week (without mitigation) during operations.

For each potential water quality impact relating to oxidation of sulfidic mine materials and associated AMD generation, the likelihood, consequence and resulting impact rating was assessed with reference to Iluka's standard impact assessment matrix. Residual impact ratings were determined, taking into account Iluka's currently planned AMD management approaches. The impact ratings take into consideration the unique environmental setting at Balranald, which is expected to limit the spatial extent of project impacts associated with any local water quality changes. A summary of the impact assessment results is presented in Section 13, and the key conclusions are provided below.

- During construction, the highest potential AMD impact, and key residual impact, is:
    - Runoff or seepage of AMD from temporary OOB stockpile (from box cut) into surface water / groundwater at the West Balranald site.
- During operations, the highest potential AMD impacts, and key residual impacts, are:
    - Runoff or seepage of AMD from stockpiled ore at the West Balranald site into surface water / groundwater.
    - Release of AMD via supernatant water overflow from the TSF to Box Creek.
- Post-closure, the highest potential AMD impacts, and key residual impacts, are:
    - Release of AMD from backfilled overburden at West Balranald into void / groundwater due to sulfide oxidation between the time of OOB dewatering and final inundation below groundwater.
    - Release of AMD from backfilled MBPs at West Balranald below final (natural) groundwater level, into void / groundwater due to sulfide oxidation between the time of MBP generation and inundation below groundwater.
    - Release of AMD from dewatered in situ material at West Balranald into void / groundwater due to sulfide oxidation between the time of mine dewatering and inundation below groundwater.

Iluka's AMD management strategy for the project is presented throughout Sections 8 to 12.

If the AMD management strategy outlined in the this report is adopted, it is considered that the Balranald Project will not present a high AMD risk to the receiving environment, including water resource use, aquatic ecosystems and riparian land, in the short to medium term (during construction and operations) as well as the long term (post-closure).

15.0 Recommendations

The following are recommended for effective site-wide management of AMD issues associated with the Balranald Project:

- Develop a detailed AMD Management Plan. The Plan should detail the AMD management strategies outlined in this assessment and encompass construction, operations and post-closure phases of the project and include procedures for materials characterisation / classification, materials segregation / handling / stockpiling, void water / stockpile leachate / TSF seepage management (eg. collection / treatment), blending procedures, active and passive treatment measures, etc. This should be regularly reviewed and updated throughout the project life.
- During detailed project design, investigate blending options for PAF mine materials. For the preferred option/s, optimise the blending method and develop operating protocols for materials management (including segregation, handling, stockpiling, blending, backfilling and covering) as part of the AMD Management Plan. Establish detailed QA/QC procedures to ensure effective implementation of these operating protocols.
- Incorporate monitoring requirements for construction, operations and post-closure, in the AMD Management Plan. This will need to include geological / geochemical monitoring, water quality monitoring (surface / groundwater / void water / seepage / pore water), water level monitoring (surface water in TSF / groundwater below TSF / void water, seepage flow rates, etc.
- Integrate AMD management and monitoring (above) with site rehabilitation and closure planning.
- Incorporate AMD considerations into emergency response planning for the project.

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Attachment A

Acid and Metalliferous Drainage (AMD), Acidity and Acidity Load

ACID AND METALLIFEROUS DRAINAGE (AMD), ACIDITY AND ACIDITY LOAD

When sulfidic material is exposed to oxidising conditions, sulfides begin to oxidise and water subsequently transports reaction products including acidity, sulfate, iron and other metals into surface water and groundwater. This water is referred to as *acid and metalliferous drainage (AMD).*

AMD can display one or more of the following chemical characteristics:

- Low pH (typically < 4)
- High soluble metal concentrations (eg. iron, aluminium, manganese, copper, lead, zinc, cadmium, arsenic)
- Elevated total acidity (eg. 100 – 15,000 mg/L $CaCO_3$ equivalent)
- High sulfate salinity (sulfate typically 500 – 10,000 mg/L)
- High salinity (1000 – 20,000 µS/cm)
- Low dissolved oxygen concentrations (commonly < 6 mg/L)
- Low turbidity or total suspended solids (TSS) (combined with one or more of the above).

Acid and metal production associated with pyrite oxidation is shown in Reactions 1 to 4. An initial oxidation reaction involves the oxidation of pyrite to produce ferrous ions (Fe^{2+}), sulfate and acid, as shown in Reaction 1.

$$\underset{\textit{pyrite}}{FeS_2} + \underset{\textit{oxygen}}{7/2\ O_2} + \underset{\textit{water}}{H_2O} \rightarrow \underset{\textit{ferrous ion}}{Fe^{2+}} + \underset{\textit{sulfate}}{2\ SO_4^{2-}} + \underset{\textit{acid}}{2\ H^+} \qquad \text{[Reaction 1]}$$

The ferrous ions (Fe^{2+}) released by pyrite oxidation may be further oxidised to ferric ions (Fe^{3+}) consuming some acid (Reaction 2). Notice that this reaction does not involve pyrite.

$$\underset{\textit{ferrous ion}}{Fe^{2+}} + \underset{\textit{oxygen}}{1/4\ O_2} + \underset{\textit{acid}}{H^+} \rightarrow \underset{\textit{ferric ion}}{Fe^{3+}} + \underset{\textit{water}}{1/2\ H_2O} \qquad \text{[Reaction 2]}$$

The ferric ions then react with water to form ferric hydroxide ($Fe(OH)_3$), which precipitates out of solution, producing additional acid (Reaction 3).

$$\underset{\substack{\textit{ferric ion}\\ \textit{(orange precipitate)}}}{Fe^{3+}} + \underset{\textit{water}}{3\ H_2O} \rightarrow \underset{\textit{ferric hydroxide}}{Fe(OH)_3} + \underset{\textit{acid}}{3\ H^+} \qquad \text{[Reaction 3]}$$

As shown in Reaction 3, the precipitation of ferric hydroxide is a key acid producing stage. Once sulfide minerals have oxidised and released Fe^{2+} ions, it is extremely difficult to prevent ferrous ions oxidising to ferric ions with concomitant iron hydroxide precipitation and further acid generation.

A summary reaction of the complete oxidation of pyrite (by oxygen) in mine waste materials may be expressed as follows (Reactions 1-3 combined):

FeS_2	+	$15/4\ O_2$	+	$7/2\ H_2O$	$\rightarrow$	$2\ SO_4^{2-}$	+	$4\ H^+$	+	$Fe(OH)_3$			[Reaction 4]
pyrite		*oxygen*		*water*		*sulfate*		*acid*		*ferric hydroxide*			

Furthermore, the presence of ferric ions (Fe^{3+}) can accelerate the oxidation of pyrite, generating additional sulfate and acid, as shown in Reaction 5.

FeS_2	+	$14\ Fe^{3+}$	+	$8\ H_2O$	$\rightarrow$	$15\ Fe^{2+}$	+	$2\ SO_4^{2-}$	+	$16\ H^+$		[Reaction 5]
pyrite		*ferric ion*		*water*		*ferrous ion*		*sulfate*		*acid*		

Note that in Reaction 5, 16 moles of acid are produced per mole of pyrite oxidised, as compared with 4 moles of acid generated when pyrite is oxidised by molecular oxygen (Reaction 4). Whether pyrite oxidation proceeds through Reaction 4 or 5 depends on the chemical conditions in solution at the pyrite surface. Reaction 5 suggests that soluble ferric ions can play a significant role in promoting sulfide oxidising reactions that result in AMD.

Two distinct processes, both promoted by oxidation of sulfide minerals, are responsible for decreasing the pH of an aqueous solution:

1. Acid (H^+) is directly generated by the oxidation of sulfur (Reaction 1).
2. Acid (H^+) is generated by the precipitation of metal hydroxides (eg. $Fe(OH)_3$, $Mn(OH)_4$: Reaction 3) during oxidation / neutralisation / dilution reactions.

While process 1 is controlled only by the availability of oxygen and water, process 2 depends on the solubility of the metal aqueous species, which in turn is controlled by the factors such as pH of the solution and oxidation state of the metal. In other words, the generation of acid through process 1 is limited by the sulfide oxidation rate, while the generation of acid through process 2 is delayed until metals can precipitate from solution (thus the term “latent acidity” or “mineral acidity”).

The term “acid” quantifies only the actual amount of H^+ present in solution and is generally expressed as pH. The term “acidity”, on the other hand, accounts for both the actual H^+ concentration of the aqueous solution and the potential for acid generation due to mineral or latent acidity (ie. H^+ produced by process 2).

In general acidity increases as pH decreases, but there is not always a direct relationship between acidity and pH. Based on earlier descriptions of metalliferous drainage, it is possible to have AMD with an elevated acidity but near neutral pH values. It is therefore important to quantify the contributions of both hydrogen ion concentrations (acid) and mineral contributions (latent acidity) in order to determine the total acidity of a water sample. Acidity is generally expressed as a mass of calcium carbonate ($CaCO_3$) equivalent per unit volume (eg. mg/L $CaCO_3$).

Acidity is either measured in the field or laboratory by titration or estimates of acidity can be made from water chemistry data (pH and dissolved metal concentrations) using shareware such as ABATES.

Acidity load refers to the product of the total acidity (acid plus latent acidity) and flow rate (or volume) and is expressed as a mass of $CaCO_3$ equivalent per unit time (or mass of $CaCO_3$ for a given volume of water).

$$\underset{\text{tonnes CaCO}_3\text{ eq. per year}}{\text{Acidity load}} = \underset{\text{conversion factor}}{10^{-3}} \times \underset{\text{ML/yr}}{\text{Flow volume per year}} \times \underset{\text{mg/L}}{\text{Acidity}} \qquad \text{[Equation 1]}$$

Occasionally, the acid drainage produced via Reactions 4 and 5 is completely neutralised by dissolution reactions with naturally occurring carbonate minerals such as calcite, dolomite, ankerite and magnesite. This neutralisation process can result in the precipitation of metals such as aluminium, copper and lead which have solubilities that are pH dependent. Other metals, such as zinc, arsenic and cadmium are still relatively soluble at near neutral pH and so concentrations of these metals may remain elevated. Sulfate concentrations are not affected by these carbonate dissolution reactions and so remain elevated. This resultant near-neutral, high sulfate salinity and variably metalliferous drainage is commonly referred to as *neutral metalliferous drainage (NMD)*. While NMD still indicates the oxidation of sulfidic materials, it is less common due to the requirements for specific sulfide minerals (eg. sphalerite, arsenopyrite) and a local excess of carbonate minerals.

In some environments the NMD may contain little or no soluble metals as a result of the reaction with available neutralising materials. In these environments the only indication of sulfide oxidation is high sulfate salinity or *saline drainage (SD).* The concentration of sulfate within this saline drainage is dependent on the relative proportions of calcium and magnesium in the neutralising carbonate materials. If magnesium is the dominant component of the neutralising material, high salinity is more likely to be an issue, due to the high solubility of magnesium sulfate. Conversely, if calcium is the dominant component, then the formation of gypsum precipitates will contribute to lower salinity levels.

Saline drainage generated specifically as a result of sulfide oxidation is relatively rare, in comparison with acid and/or metalliferous drainage. Nevertheless, sulfate salinity can be an important indicator of AMD issues at mine sites, and may require similar management strategies (that is, control of sulfide oxidation).

Attachment B

Regulatory Context

REGULATORY CONTEXT

There is a range of applicable legislation, policies and strategies that have been established for the protection of water resources. As potential geochemical impacts relate to water quality, the legislation, policies and strategies discussed in this Section are relevant to this Geochemistry Assessment for the Balranald Project.

Commonwealth Legislation

Environment Protection and Biodiversity Conservation Act 1999

The principal Commonwealth legislation is the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), which provides for the protection of the environment in matters of national environmental significance (NES). These include:

- World heritage properties;
- National heritage places;
- Ramsar wetlands of international importance;
- Nationally threatened animal and plant species and ecological communities;
- Internationally protected migratory species;
- Commonwealth land and marine areas; and
- Nuclear actions.

The proposed Balranald Project was referred to the Department of Sustainability, Environment, Water, Population and Communities (now Department of Environment) on 20 August 2012 to obtain a decision on whether the project required formal assessment and approval under the EPBC Act. On the 25th of October 2012, the minister determined that the project was a controlled action due to the potential to impact world heritage properties, places listed on the National Heritage Register, listed threatened species and ecological communities and listed migratory species. The Commonwealth provided guidelines for the content of a Draft EIS on the 22nd of November 2012. The guidelines that are relevant to this Geochemistry Assessment for the Balranald Project include:

- Any technical data and other information used to assess impacts including:
    - Details of any by-products that may be disposed of (including in the mine void), including the chemical composition of the material, radio-activity levels (note, radioactivity addressed by a separate assessment), proposed method of disposal (including the final depth of disposed materials), the potential for materials or their constituents to become re-mobilised, and the potential for the materials to cause short-term or long-term harm to the environment, including matters of NES.

EPBC Act amendment – Water trigger 2013

The EPBC Act was amended in June 2013, to provide for water resources that are a matter of national environmental significance, in relation to coal seam gas and large coal mining development. The water trigger allows the impacts of proposed coal seam gas and large coal mining developments on water resources to be comprehensively assessed at a national level.

Approval from the Australian Government Environment Minister is required if the proposed action is likely to have a significant impact on a water resource or if there is a real or not remote chance or possibility that it will directly or indirectly result in a change to the:

- Hydrology of a water resource.
- Water quality of a water resource.

The change must be of sufficient scale or intensity as to reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.

Whilst this legislation applies only to coal or coal seam gas developments, this report has considered the potential for the Balranald Project to generate AMD to an extent that local or regional water resource quality may be significantly impacted.

Water Act 2007

The Murray-Darling Basin Authority (MDBA) was established under the Commonwealth *Water Act 2007* to undertake activities that support the sustainable and integrated management of the water resources of the Murray-Darling Basin in a manner that best meets the social, economic and environmental needs of the Basin and its communities.

The *Water Act 2007* requires the MDBA to perform the following functions:

- Construct and operate River Murray assets such as dams and weirs;
- Advise the Commonwealth Minister for Water (now the Minister for the Environment) on the accreditation of state water resource plans;
- Develop a water rights information sharing service to facilitate water trading across the Basin;
- Manage water sharing between the states;
- Manage all aspects of Basin water resources, including water, organisms and other components and ecosystems that contribute to the physical state and environmental value of the Basin's water resources;
- Measure and monitor water resources in the Basin;
- Gather information and undertake research; and
- Engage and educate the community in the management of the Basin's resources.

The *Water Act 2007* requires the MDBA to prepare a strategic plan (the *Basin Plan*) for the management of water resources within the Basin. A key aspect of the *Basin Plan* that is relevant to this Geochemistry Assessment is the specification of water quality objectives for the Basin water resources.

New South Wales Legislation

Environmental Planning and Assessment Act 1979 and Environmental Planning and Assessment Regulation 2000

The NSW Government *Environmental Planning and Assessment Act 1979* and *Environmental Planning and Assessment Regulation 2000* are the key legislation governing environmental assessment in NSW. Section 78A (8A) of the *Environmental Planning and Assessment Act 1979* requires that an EIS is prepared to accompany Development Application for any State Significant Development.

Before preparing an EIS, the proponent must request the Secretary's Environmental Assessment Requirements (SEARs) (formerly Director General Requirements (DGRs)), which outline the key issues to be addressed by the EIS.

The DGRs were first issued for the Balranald Project by the NSW Director of Mining and Industry Projects on 25th May 2012. Updated SEARs for the Balranald Project EIS were received on 2nd December 2014. The SEARs that are relevant to this Geochemistry Assessment include:

Directly Relevant

- A waste (overburden, tailings, etc.) management strategy, dealing with the EPA's requirements.

Relevant to the Water Impact Assessment and partially relevant to this Geochemistry Assessment

- **Water Resources** – including:
    - An assessment of the likely impacts of the development on the quality of the region's surface and groundwater resources, having regard to the EPA's and NSW Office of Water's requirements and the NSW Aquifer Interference Policy;
    - An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users;
    - A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.

Relevant to the Transport Assessment and partially relevant to this Geochemistry Assessment

- **Hazards and Risks** – including:
    - A detailed description of the management of concentrate and back-loaded waste material during transport, storage and handling.

State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007

This State Environmental Planning Policy (SEPP) aims to provide for the proper management and development of mineral, petroleum and extractive material resources for the purpose of promoting the social and economic welfare of the State of New South Wales. Sections of this Policy that are relevant to this Geochemistry Assessment include:

- Clause 14 requires the determining authority to consider natural resources management, and states:
    1. Before granting consent for development for the purposes of mining, petroleum production or extractive industry, the consent authority must consider whether or not the consent should

be issued subject to conditions aimed at ensuring that the development is undertaken in an environmentally responsible manner, including conditions to ensure the following:

a) That impacts on significant water resources, including surface and groundwater resources, are avoided, or are minimised to the greatest extent practicable;

- Clause 17 requires the determining authority to consider rehabilitation. It states:

1. Before granting consent for development for the purposes of mining, petroleum production or extractive industry, the consent authority must consider whether or not the consent should be issued subject to conditions aimed at ensuring the rehabilitation of land that will be affected by the development.
2. In particular, the consent authority must consider whether conditions of the consent should:

a) Require the preparation of a plan that identifies the proposed end use and landform of the land once rehabilitated, or
b) Require waste generated by the development or the rehabilitation to be dealt with appropriately, or
c) Require any soil contaminated as a result of the development to be remediated in accordance with relevant guidelines (including guidelines under Section 145C of the Act and the Contaminated Land Management Act 1997), or
d) Require steps to be taken to ensure that the state of the land, while being rehabilitated and at the completion of the rehabilitation, does not jeopardise public safety.

Mining Act 1992

The aims of the *Mining Act* are to encourage and facilitate the discovery and development of mineral resources in New South Wales, having regard to the need to encourage ecologically sustainable development. The objectives of the Act that are relevant to this Geochemistry Assessment include:

- To ensure effective rehabilitation of disturbed land and water; and
- To ensure mineral resources are identified and developed in ways that minimise impacts on the environment.

Water Act 1912 and Water Management Act 2000

The *Water Act* regulates the issue and trade of licences for water sources in NSW where water sharing plans have not yet commenced. The Act includes provisions for the licence holder to protect both the quantity and quality of water flowing in, to, or from, or being in any river or lake. The Act also provides for the licence holder to take measures or precautions for the protection of the quality and prevention of pollution or contamination of any sub-surface water in any restricted sub-surface water area.

The *Water Management Act* governs the issue and trade of water licences and allocations for those water sources (including rivers, lakes and groundwater) in NSW where water sharing plans have commenced. The objectives of the Act that are relevant to this Geochemistry Assessment include:

- Protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality.

NSW Aquifer Interference Policy 2012

The *Aquifer Interference Policy* aims to protect underground water resources in NSW and to balance multiple water users and their requirements. The policy requires that aquifer interference activities obtain the relevant approvals under the *Water Act* and *Water Management Act.*

The following requirements of the *Aquifer Interference Policy* are relevant to this Geochemistry Assessment including:

- Details of potential water quality impacts on nearby water users who are exercising their right to take water under a basic landholder right. Consideration will need to be given to any relevant distance requirements that may be specified in any relevant water sharing plan or any remediation measures to address these impacts;
- Details of potential water quality impacts on nearby licensed water users in connected groundwater and surface water sources;
- Details of potential water quality impacts on groundwater dependent ecosystems; and
- Details of potential for increased saline or contaminated water inflows to aquifers and highly connected river systems.

Attachment C

NSW EPA Waste Classification Results for Hamilton MSP Mining By-Products

EARTH SYSTEMS
Environment | Water | Sustainability
Australian Business Number 42 120 062 544

NSW WASTE CLASSIFICATION OF HAMILTON MINING BY-PRODUCTS

Prepared for

ILUKA RESOURCES LIMTED

April 2015

INTRODUCTION

The Balranald Project is comprised of two linear mineral sands deposits, the West Balranald and Nepean deposits, which are located ~12 km and 66 km north-west of Balranald, NSW, respectively. It is proposed that the two deposits will be mined for heavy minerals, primarily rutile (TiO_2) over an expected mine life of approximately 8 years. A heavy mineral concentrate (HMC) produced at the Balranald process plant will be transported to Hamilton, Victoria, for further processing at Iluka's Hamilton mineral separation plant (MSP). It is understood that mining by-products (MBPs), including reactive pyritic material, will be generated as waste during open cut mining and mineral processing at the Balranald Project and the Hamilton MSP.

Non-saleable MBPs associated with the processing of HMC at the Hamilton MSP are expected to be managed as part of Iluka's Murray Basin operations in Victoria, which includes placement of MBPs from the Hamilton MSP in the mine void of Iluka's Douglas Mine (EMGA, 2015). However, if this is not possible, the MBPs will be transported back to the Balranald mine site by road for placement in the West Balranald mine void (EMGA, 2015).

The NSW Department of Planning and Environment (DPE) Secretary's Environmental Assessment Requirements (SEARs) for the Environmental Impact Statement (EIS) for the Balranald Project outline a requirement to assess the MBPs against the NSW Environment Protection Authority (NSW EPA) *Waste Classification Guidelines* (hereafter referred to as the *NSW Guidelines*).

Earth Systems was engaged by Iluka Resources Ltd. to conduct a laboratory testwork program to classify the Hamilton MBPs in accordance with New South Wales (NSW) government waste classification guidelines.

RELEVANT NSW LEGISLATION, GUIDELINES AND STANDARDS

In NSW, industrial wastes are regulated under the amended *Protection of the Environment Operations Act* (1997) and the *Protection of the Environment Operations (Waste) Regulation* (2014). The *NSW Guidelines* were prepared by the NSW Government Department of Environment, Climate Change and

Water to provide guidance on the implementation of sampling, analytical and classification protocols and the management of industrial wastes.

The sections contained within the *NSW Guidelines* that are relevant to the classification of the Hamilton MBPs include:

- *Classifying Waste* (Part 1); and
- *Waste Containing Radioactive Material* (Part 3).

Relevant strategies and regulations that are referred to in the *NSW Guidelines* include:

- *Radiation Control Act (1990)*; and
- *Radiation Control Regulation (2013).*

Under Part 1 of the *NSW Guidelines*, ‘Special Wastes’, ‘Liquid Waste’ and ‘Pre-classified’ wastes do not require any further assessment.

Part 1, Step 5 (*Determining a waste’s classification using chemical assessment*) of the *NSW Guidelines* outlines the procedure for determining a solid waste’s classification using chemical assessment. The analytical requirements include:

- Specific contaminant concentration (SCC) of any chemical contaminant in the waste, expressed as mg/kg; and
- Leachable concentration of any chemical contaminant using the toxicity characteristic leaching procedure (TCLP), expressed in mg/L.

To establish the waste’s classification using both SCC and TCLP tests, the analytical results are compared with the threshold values outlined in Tables A1 and A2 of the *NSW Guidelines* (Attachment A). If either the SCC or TCLP threshold values for a contaminant are exceeded for ‘general solid waste’, the waste must be classified as ‘restricted solid waste’. If either the SCC or TCLP threshold values for a contaminant are exceeded for ‘restricted solid waste’, the waste must be classified as ‘hazardous solid waste’. In the absence of TCLP data, a solid waste may also be classified against more conservative (ie. lower) SCC threshold values as outlined in Table 1 of Part 1 of the *NSW Guidelines*.

Part 3 of the *NSW Guidelines* outlines the classification requirements for solid and liquid wastes containing radionuclides. Radioactive waste is regulated in accordance with the *Radiation Control Act* (1990) and the *Radiation Control Regulation* (2003). Part 3 of the guidelines stipulate that wastes with a specific activity greater than 100 Bq/g and consisting of, or containing more than, the prescribed activity of a radioactive element in Schedule 1 of the *Radiation Control Regulation* (2003) must be classified as hazardous waste. The Specific Activity and Total Activity ratios are then used to determine whether the waste is classified as ‘restricted solid waste’ or whether it is to be classified in accordance with Part 1 of the *NSW Guidelines*. If the Specific Activity or Total Activity ratios are greater than one, then non-liquid wastes must be classified as ‘restricted solid waste’ unless:

- Other characteristics of the waste mean that the waste must be classified as ‘hazardous waste’ (eg. via Step 3 of Part 1 of the *NSW Guidelines*); or
- It may contain chemical contaminants that will lead to its assessment as ‘hazardous waste’ (eg. via Step 5 of Part 1 of the *NSW Guidelines*).

Where the Specific Activity and Total Activity ratios are equal to or less than one, the waste must be classified according to its other characteristics in line with Part 1 of the *NSW Guidelines*.

METHOD

Samples of each of the Hamilton MBP streams were provided to Earth Systems from Iluka's pilot scale metallurgical testwork. The MBPs and the percentage that each waste stream represents of the total MBP mass produced at the Hamilton MSP are provided in Table 1.

All samples were submitted for radionuclide and chemical analyses.

Table 1: Hamilton MBPs, sample mass and the percentage that each by-product represents of the total waste produced at the Hamilton MSP.

MBP	Percentage of total waste produced (wt.%)[1]
PDC Ilmenite	53
Combined monazite reject	10.5
Hyti	11.7
Combined zircon wet tails	8.6
Rutile wet concentrate circuit	0.9
PDC conductors oversize (+410 µm)[2]	-
Float Tails	11.3

1: The remaining 4 % of waste material is recycled through the Hamilton MSP.

2: This stream represents 0.1 wt.% of the Hamilton MSP feed and may not be produced as it makes very little difference to the grade of the products.

Radionuclide Analytical Testwork

A representative sub-sample of each of the MBPs was also submitted to Australian Nuclear Science and Technology Organisation (ANSTO) Minerals Department for analysis and classification in accordance with Part 3 of the *NSW Guidelines*. Analyses conducted include:

- Gamma spectrometry for U-238 and Th-232 decay progeny and U-235 and its decay progeny;
- Delayed neutron activation (DNA) analysis or fusion / acid digest followed by ICP-MS for parent U-238 (method depends on available mass of sample material);
- Neutron activation analysis (NAA) or fusion / acid digest followed by ICP-MS for parent Th-232 (method depends on available mass of sample material);
- Alpha spectrometry for Po-210; and
- X-ray fluorescence spectrometry (XRF) analysis for elemental content for self-absorption corrections in gamma spectrometry.

The Specific Activity was determined for each of the MBPs and for MBPs with a specific activity of <100 Bq/g, the Total Activity ratio and Specific Activity ratios were calculated using the following expressions:

$$\text{Total Activity ratio} = (A1 \times 10^{-3}) + (A2 \times 10^{-4}) + (A3 \times 10^{-5}) + (A4 \times 10^{-6})$$

Where A1 to A4 are the total activity of Group 1 to Group 4 radionuclides, as set out in Column 1 of Schedule 1 of the Radiation Control Regulation (2013).

$$\text{Specific Activity ratio} = SA1 + (SA2 \times 10^{-1}) + (SA3 \times 10^{-2}) + (SA4 \times 10^{-3})$$

Where SA1 to SA4 are the specific activity (of the material) of Group 1 to Group 4 radionuclides, as set out in Column 1 of Schedule 1 of the Radiation Control Regulation (2013).

Chemical Analytical Testwork

The samples were also submitted to a NATA accredited laboratory for the following analyses (detection limits in brackets) in accordance with Step 5 of the *NSW Guidelines* (Part 1):

- Total concentrations of:
    - Metals including arsenic (5 mg/kg), beryllium (1 mg/kg), cadmium (1 mg/kg), chromium (VI) (0.5 mg/kg), lead (5 mg/kg), mercury (0.1 mg/kg), molybdenum (2 mg/kg), nickel (2 mg/kg), selenium (5 mg/kg) and silver (2 mg/kg).
    - Total fluoride (40 mg/kg).
    - Cyanide including weak acid dissociable (1 mg/kg) and total cyanide (1 mg/kg).
    - Total polychlorinated biphenyls (PCB) (0. 1 mg/kg).
    - Triazines including atrazine (0.05 mg/kg) (NSW parameter only) and simazine (0.05 mg/kg).
    - Fipronil (0.05 mg/kg) and fenitrothion (0.05 mg/kg).
    - Monocyclic aromatic hydrocarbons including benzene (0.2 mg/kg), toluene (0.5 mg/kg), ethylbenzene (0.5 mg/kg), meta- & para-xylene (0.5 mg/kg), ortho-xylene (0.5 mg/kg), total xylenes (calculated) and styrene (0.5 mg/kg).
    - Polynuclear aromatic hydrocarbons including naphthalene (0.5 mg/kg), acenaphthylene (0.5 mg/kg), acenaphthene (0.5 mg/kg), fluorene (0.5 mg/kg), phenanthrene (0.5 mg/kg), anthracene (0.5 mg/kg), fluoranthene (0.5 mg/kg), pyrene (0.5 mg/kg), benz(a)anthracene (0.5 mg/kg), chrysene (0.5 mg/kg), benzo (b+j) & benzo(k)fluoranthene (0.5 mg/kg), benzo(a)pyrene (0.5 mg/kg), indeno(1.2.3.cd)pyrene (0.5 mg/kg), dibenz(a,h)anthracene (0.5 mg/kg) and benzo(g.h.i)perylene (0.5 mg/kg).
    - C6-C9 petroleum hydrocarbons (10 mg/kg).
    - C10-C36 petroleum hydrocarbons (50 mg/kg).
    - 2-butanone (methyl ethyl ketone) (5 mg/kg).
    - Halogenated aliphatic compounds including vinyl chloride (4 mg/kg), 1,1-dichloroethylene (0.5 mg/kg), methylene chloride (dichloromethane) (0.5 mg/kg), 1,1,1-trichloroethane (0.5 mg/kg), carbon tetrachloride (0.5 mg/kg), 1,2-dichloroethane (0.5 mg/kg), trichloroethylene (0.5 mg/kg), 1,1,2-trichloroethane (0.5 mg/kg) (NSW parameter only), tetrachloroethylene (0.5 mg/kg), 1,1,1,2-tetrachloroethane (0.5 mg/kg), and 1,1,2,2-tetrachloroethane (0.5 mg/kg).
    - Chlorobenzene (0.5 mg/kg).
    - Chloroform (0.5 mg/kg).
    - Isodrin (0.5 mg/kg).

  - Phenolic compounds including phenol (0.5 mg/kg), 2-methylphenol (o-cresol) (0.5 mg/kg), 3 (m-cresol) - & 4- (p-cresol) methylphenol (0.5 mg/kg), 4-chloro-3-methylphenol (0.5 mg/kg), 2-chlorophenol (0.5 mg/kg), 2,4,5-trichlorophenol (0.5 mg/kg), 2,4,6-trichlorophenol (0.5 mg/kg), 2,3,4,6-tetrachlorophenol (0.5 mg/kg) and pentachlorophenol (0.5 mg/kg).
  - Plasticiser compounds including bis(2-ethylhexyl)phthalate (0.5 mg/kg).
  - Nitroaromatics and ketones including nitrobenzene (0.5 mg/kg), 2,4-dinitrotoluene (0.5 mg/kg).
  - Chlorinated aromatic hydrocarbons including 1,2-dichlorobenzene (0.5 mg/kg), 1,4-dichlorobenzene (0.5 mg/kg), 1,2,4-trichlorobenzene (0.5 mg/kg), 1,3,5-trichlorobenzene (0.5 mg/kg), 1,2,3-trichlorobenzene (0.5 mg/kg), 1,2,3,4-tetrachlorobenzene (0.5 mg/kg), 1,2,3,5- & 1,2,4,5-tetrachlorobenzene (0.5 mg/kg) and pentachlorobenzene (0.5 mg/kg).
  - Organochlorine pesticides including hexachlorobenzene (0.05 mg/kg), alpha-BHC (0.05 mg/kg), beta-BHC (0.05 mg/kg), gamma-BHC (0.05 mg/kg), delta-BHC (0.05 mg/kg), heptachlor (0.05 mg/kg), aldrin (0.05 mg/kg), heptachlor epoxide (0.05 mg/kg), alpha-endosulfan (0.05 mg/kg), beta-endosulfan (0.05 mg/kg), endosulfan sulfate (0.05 mg/kg), total endosulfan (calculated), 4,4`-DDE (0.05 mg/kg), trans-chlordane (0.05 mg/kg), cis-chlordane (0.05 mg/kg), total chlordane (calculated), dieldrin (0.05 mg/kg), endrin (0.05 mg/kg), endrin aldehyde (0.05 mg/kg), 4,4`-DDD (0.05 mg/kg), and 4,4`-DDT (0.2 mg/kg).
  - Organophosphorus pesticides including dichlorvos (0.05 mg/kg), dimethoate (0.05 mg/kg), chlorpyrifos-methyl (0.05 mg/kg), malathion (0.05 mg/kg), fenthion (0.05 mg/kg), parathion-methyl (0.2 mg/kg), chlorpyrifos (0.05 mg/kg) and ethion (0.05 mg/kg).
  - Synthetic pyrethroids including bifenthrin (0.05 mg/kg), lambda-cyhalothrin (0.05 mg/kg), permethrin (0.05 mg/kg), cyfluthrin (0.05 mg/kg), cypermethrin (0.05 mg/kg), deltamethrin & tralomethrin (0.05 mg/kg).
  - Hexachlorophene (10 µg/kg).
  - Thiodicarb (0.02 mg/kg).
  - Phenoxyacetic acid herbicides including 2,4-D (0.02 mg/kg), triclopyr (0.02 mg/kg) , 2,4,5-TP (0.02 mg/kg), 2,4,5-T (0.02 mg/kg), picloram (0.02 mg/kg), fluroxypyr (0.02 mg/kg).
  - Glyphosate (0.5 mg/kg).
- Leachable concentrations (after TCLP) of the following analytes:
  - The initial pH of the sample leach was determined using 5 g of the waste material and 96.5 mL of deionised water to determine the leaching protocol to be used in the TCLP. This pH value was also used to assess the approximate pH of the waste solids.
  - Metals including arsenic (0.1 mg/L), beryllium (0.05 mg/L), cadmium (0.05 mg/L), chromium (VI) (0.01 mg/L), lead (0.1 mg/L), mercury (0.001 mg/L), molybdenum (0.1 mg/L), nickel (0.1 mg/L), selenium (0.05 mg/L) and silver (0.1 mg/L).

  - Total fluoride (0.1 mg/L);
  - Cyanide including weak acid dissociable (0.004 mg/L) and total cyanide (0.004 mg/L).
  - Monocyclic aromatic hydrocarbons including benzene (0.001 mg/L), toluene (0.002 mg/L), ethylbenzene (0.002 mg/L), meta- & para-xylene (0.002 mg/L), ortho-xylene (0.002 mg/L), total xylenes (calculated) and styrene (0.005 mg/L).
  - 2-butanone (methyl ethyl ketone) (0.05 mg/L).
  - Halogenated aliphatic compounds including vinyl chloride (0.05 mg/L), 1,1-dichloroethylene (0.005 mg/L), methylene chloride (dichloromethane) (0.005 mg/L), 1,1,1-trichloroethane (0.005 mg/L), carbon tetrachloride (0.005 mg/L), 1,2-dichloroethane (0.005 mg/L), trichloroethylene (0.005 mg/L), 1,1,2-trichloroethane (0.005 mg/L), tetrachloroethylene (0.005 mg/L), 1,1,1,2-tetrachloroethane (0.005 mg/L), and 1,1,2,2-tetrachloroethane (0.005 mg/L).
  - Chlorobenzene (0.005 mg/L).
  - Chloroform (0.005 mg/L).
  - Phenolic compounds including phenol (0.002 mg/L), 2-methylphenol (o-cresol) (0.002 mg/L), 3 (m-cresol) - & 4- (pcresol) methylphenol (0.002 mg/L), 2-chlorophenol (0.002 mg/L), 2,4,5-trichlorophenol (0.002 mg/L) and 2,4,6-trichlorophenol (0.002 mg/L).
  - Plasticiser compounds including bis(2-ethylhexyl)phthalate (0.005 mg/L).
  - Nitroaromatics and ketones including nitrobenzene (0.002 mg/L), 2,4-dinitrotoluene (0.004 mg/L).
  - Chlorinated aromatic hydrocarbons including 1,2-dichlorobenzene (0.002 mg/L), 1,4-dichlorobenzene (0.002 mg/L), 1,2,4-trichlorobenzene (0.002 mg/L), 1,3,5-trichlorobenzene (0.002 mg/L) and 1,2,3,4-tetrachlorobenzene (0.0002 mg/L).
  - Organochlorine pesticides including alpha-endosulfan (0.0005 mg/L), beta-endosulfan (0.0005 mg/L), endosulfan sulfate (0.0005 mg/L), total endosulfan (calculated).
  - Organophosphorus pesticides including chlorpyrifos (0.0005 mg/L).
  - Synthetic pyrethroids including bifenthrin (0.0005 mg/L), lambda-cyhalothrin (0.0005 mg/L), permethrin (0.0005 mg/L), cyfluthrin (0.0005 mg/L), cypermethrin (0.0005 mg/L), deltamethrin and tralomethrin (0.0005 mg/L).
  - Phenoxyacetic acid herbicides including 2,4-D (0.01 mg/L), triclopyr (0.01 mg/L), picloram (0.01 mg/L), fluroxypyr (0.01 mg/L).
  - Tebuconazole (0.00001 mg/L).

Classification

The MBP samples were assumed to be solid wastes, and were then classified based on the results of the analytical testwork, the threshold values for chemical classification of solid wastes (Attachment A) and the threshold values for waste containing radioactive material outlined in the *Relevant NSW Legislation, Guidelines and Standards* Section of this report.

MBP CLASSIFICATION

Table 2 outlines the classification of the Hamilton MBPs against Part 1, Step 5 (ie. chemical classification) and Part 3 (ie. radioactivity classification) of the *NSW Guidelines*. Results are described in the sections below.

Table 2: Classification of Hamilton MBPs against Part 1, Step 5 and Part 3 of the *NSW Guidelines*.

MBP Stream	Preliminary Waste Classification	Clause Triggering Waste Classification
PDC Ilmenite	Restricted Solid Waste	PDC Ilmenite sample had a Specific Activity Ratio of 1.9, exceeding the threshold value of 1 outlined in Part 3 of the *NSW Guidelines*.
Combined monazite reject	Hazardous Solid Waste	Combined monazite reject sample had a Specific Activity of 938 Bq/g and a waste disposal mass of 87 g would result in a Prescribed Activity, of a radioactive element in Schedule 1 of the Radiation Control Regulation (2013), greater than 40 kBq. These exceed the threshold values outlined in Part 3 of the *NSW Guidelines*.
Hyti	Restricted Solid Waste	Hyti sample had a Specific Activity Ratio of 10, exceeding the threshold value of 1 outlined in Part 3 of the *NSW Guidelines*.
Combined zircon wet tails	Restricted Solid Waste	Combined zircon wet tails sample had a Specific Activity Ratio of 7.7, exceeding the threshold value of 1 outlined in Part 3 of the *NSW Guidelines*. Combined zircon wet tails sample had a total fluoride concentration of 3,980 mg/kg, exceeding the threshold value of 1,000 mg/kg for ‘General Solid Waste’ outlined in Part 1, Step 5 of the *NSW Guidelines*.
Rutile wet concentrate circuit	Restricted Solid Waste	Rutile wet concentrate circuit sample had a Specific Activity Ratio of 8.8, exceeding the threshold value of 1 outlined in Part 3 of the *NSW Guidelines*.
PDC conductors oversize (+410 µm)	Restricted Solid Waste	PDC conductors oversize sample had a Specific Activity Ratio of 10, exceeding the threshold value of 1 outlined in Part 3 of the *NSW Guidelines*. PDC conductors oversize sample had a total nickel concentration of 50 mg/kg, exceeding the threshold value (for classification without TCLP) of 40 mg/kg for ‘General Solid Waste’ outlined in Part 1, Step 5 of the *NSW Guidelines*.
Float Tails	Restricted Solid Waste	Float tails sample had a Specific Activity Ratio of 3.8, exceeding the threshold value of 1 outlined in Part 3 of the *NSW Guidelines*.

Comparison of results with radionuclide thresholds

The results of the analysis of the Hamilton MBPs against *NSW Guidelines* for radioactive material are provided in Attachment B. Key results include (ANSTO Minerals, 2015):

- The Specific Activity for all MBP streams, with the exception of the combined monazite reject, was below the 100 Bq/g threshold value for the *NSW Guidelines*.
- The Specific Activity for the combined monazite reject (938 Bq/g) exceeded the 100 Bq/g threshold value. The Total Activity of the Group 1 radionuclides was 460 Bq/g, meaning a waste disposal mass of ≥87 g will also exceed the Prescribed Activity for Group 1 radionuclides in Schedule 1 of the *Radiation Control Regulation 2013* (40 kBq), resulting in a Hazardous Solid Waste classification.
- The Specific Activity ratios of the PDC ilmenite (1.9), Hyti (10), Combined zircon wet tails (7.7), rutile wet circuit concentrate (8.8), float tails (3.8) and PDC conductors oversize (+410 µm) were greater than 1 resulting in a Restricted Solid Waste classification under the NSW *Guidelines*.

Comparison of results with SCC thresholds

The results of the analysis of the Hamilton MBPs against specific contaminant concentration thresholds are provided in Table A1 (Attachment A). Key results include:

- Total fluoride concentrations for the combined zircon wet tails sample were 3,980 mg/kg, exceeding the specific contaminant concentration threshold value of 1,000 mg/kg for General Waste.
- As leachate data is not available for the PDC Conductor's Oversize (+410 µm) waste stream, this was assessed against the maximum contaminant threshold values for classification without TCLP. All reported values were below the specific contaminant concentration threshold values for general waste with the exception of nickel at 50 mg/kg, which was above the maximum contaminant concentration threshold value of 40 mg/kg for 'General Waste'.
- All other reported values were below the specific contaminant concentration threshold values for general waste.
- Total arsenic concentrations (454 mg/kg) for the rutile wet concentrate circuit are close to, but do not exceed, the specific contaminant concentration threshold value for general waste (500 mg/kg).
- The NSW EPA requires chemical classification testwork for the contaminants that are expected to be present in the samples. The following analytes were not reported by the analytical laboratory and are not expected to be present in the sample solids based on the source material composition and an assessment of the process flow diagram for the Hamilton MSP:
  - Some of the moderately harmful pesticide contaminants;
  - Di-2-ethyl-hexyl adipate; and
  - Tebuconazole.

Comparison of results with TCLP thresholds

The results of the analysis of the Hamilton MBPs against leachable contaminant concentration thresholds are provided in Table A2 (Attachment A). Key results include:

- pH values for a deionised water leach of the MBPs (5 g sample to 96.5 mL of deionised water) were around 4, above the pH 2 threshold value which results in classification of the material as corrosive and hazardous under the *Australian Code for the Transport of Dangerous Goods by Road & Rail* (2014).
- No reported values were above the leachable contaminant concentration threshold values for general waste.
- Although total fluoride concentrations of 3,980 mg/kg for the combined zircon wet tails material exceed the specific contaminant concentration threshold value for general waste of 1,000 mg/kg, leachable concentrations of fluoride (0.3 mg/L) were well below the leachable contaminant concentration threshold value for general waste (150 mg/L).
- The following analytes were not reported by the analytical laboratory, however are not expected to be present in the sample leachate based on an assessment of the process flow diagram for the Hamilton MSP:
    - Di-2-ethyl-hexyl adipate; and
    - 1,2,3,4-tetrachlorobenzene.

CONCLUSIONS

Key conclusions from the classification testwork of the MBP samples include:

1. Based on Part 3 of the *NSW Guidelines* relating to wastes containing radioactive material, the Combined Monazite Reject is likely to be classified as Hazardous Solid Waste.
2. Based on Part 3 of the *NSW Guidelines* relating to wastes containing radioactive material, the PDC Ilmenite, Hyti, Combined Zircon Wet Tails, Rutile Wet Concentrate Circuit, PDC Conductors Oversize and Float Tails MBP streams are likely to be classified as Restricted Solid Waste.
3. Not withstanding the classification of the Hamilton MBPs by the *NSW Guidelines* relating to wastes containing radioactive material:
    a. Based on Part 1, Step 5 of the *NSW Guidelines* relating to chemical classification of solid wastes, the Combined Zircon Wet Tails would be classified as Restricted Solid Waste.
    b. Based on Part 1, Step 5 of the *NSW Guidelines* relating to chemical classification of solid wastes, the PDC Conductors Oversize would be classified as Restricted Solid Waste.

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Department of Environment, Climate Change and Water (2009). *Waste Classification Guidelines: Part 3: Waste Containing Radioactive Material*. New South Wales State Government.

Attachment A

NSW Waste Classification Analytical Laboratory Results

Table A1: Hamilton MBPs specific contaminant concentrations against the general and restricted solid waste thresholds (DECCW, 2009). Yellow shading indicates an exceedance of general solid waste threshold and brown shading indicates an exceedance of both general and restricted solid waste thresholds (light and dark shading respectively if printed in black and white).

Contaminant	CAS Registry Number	General Solid Waste	Restricted Solid Waste	Hamilton Mining By-Product Contaminant Concentration (mg/kg)						
		SCC1 (mg/kg)	SCC2 (mg/kg)	PDC Ilmenite	Combined Monazite Reject	Hyti	Combined Zircon Wet Tails	Rutile Wet Circuit Concentrate	PDC Conductors O/size +410µm	Float Tails
Arsenic		500	2,000	<5	16	31	<5	454	79	357
Benzene	71-43-2	18	72	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(a)pyrene[3]	50-32-8	10	23	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.5
Beryllium		100	400	<1	<1	<1	<1	<1	<1	<1
Cadmium		100	400	<1	<1	<1	<1	<1	<1	<1
Carbon tetrachloride	56-23-5	18	72	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chlorobenzene	108-90-7	3,600	14,400	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chloroform	67-66-3	216	864	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chlorpyrifos	2921-88-2	8	30	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium (VI)[6]		1,900	7,600	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	<0.5
m-cresol	108-39-4	7,200	28,800	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-cresol	95-48-7	7,200	28,800	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
p-cresol	106-44-5	7,200	28,800	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cresol (total)	1319-77-3	7,200	28,800	-	-	-	-	-	-	
Cyanide (amenable)[7, 8]		300	1,200	<1	<1	<1	<1	<1	<1	<1
Cyanide (total)[7]		5,900	23,600	<1	<1	<1	<1	<1	<1	<1
2,4-D	94-75-7	360	1,440	<0.02	<0.02	<0.04	<0.02	<0.02	<0.02	<0.04

Contaminant	CAS Registry Number	General Solid Waste	Restricted Solid Waste	Hamilton Mining By-Product Contaminant Concentration (mg/kg)						
		SCC1 (mg/kg)	SCC2 (mg/kg)	PDC Ilmenite	Combined Monazite Reject	Hyti	Combined Zircon Wet Tails	Rutile Wet Circuit Concentrate	PDC Conductors O/size +410µm	Float Tails
1,2-Dichlorobenzene	95-50-1	155	620	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,4-Dichlorobenzene	106-46-7	270	1,080	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,2-Dichloroethane	107-06-2	18	72	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,1-Dichloroethylene	75-35-4	25	100	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dichloromethane	75-09-2	310	1,240	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2,4-Dinitrotoluene	121-14-2	5	19	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.5
Endosulfan[9]		108	432							
alpha-endosulfan	*959-98-8*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
beta-endosulfan	*33213-65-9*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Endosulfan-sulfate	*1031-07-8*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ethylbenzene	100-41-4	1,080	4,320	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoride		1,000	40,000	<40	550	<40	3,980	<40	<40	<40
Fluroxypyr	69377-81-7	75	300	<0.02	<0.02	<0.04	<0.02	<0.02	<0.02	<0.04
Lead		1,500	6,000	28	17	133	<5	412	49	288
Mercury		50	200	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Methyl ethyl ketone	78-93-3	7,200	28,800	<5	<5	<5	<5	<5	<5	<5
Moderately Harmful Pesticides[11]		250	1,000							
Atrazine	*1912-24-9*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Azoxystrobin	*131860-33-8*			NR	NR	NR	NR	NR	NR	NR

Contaminant	CAS Registry Number	General Solid Waste	Restricted Solid Waste	Hamilton Mining By-Product Contaminant Concentration (mg/kg)						
		SCC1 (mg/kg)	SCC2 (mg/kg)	PDC Ilmenite	Combined Monazite Reject	Hyti	Combined Zircon Wet Tails	Rutile Wet Circuit Concentrate	PDC Conductors O/size +410μm	Float Tails
Bifenthrin	*82657-04-3*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR
Brodifacoum	*56073-10-0*			NR	NR	NR	NR	NR	NR	NR
Carboxin	*5234-68-4*			NR	NR	NR	NR	NR	NR	NR
Copper naphthenate	*1338-02-9*			NR	NR	NR	NR	NR	NR	NR
Cyfluthrin	*68359-37-5*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR
Cyhalothrin	*68085-85-8*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR
Cypermethrin	*52315-07-08*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR
Deltamethrin	*52918-63-5*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR
Dichlofluanid	*1085-98-9*			NR	NR	NR	NR	NR	NR	NR
Dichlorvos	*62-73-7*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Difenoconazole	*119446-68-3*			NR	NR	NR	NR	NR	NR	NR
Dimethoate	*60-51-5*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Diquat dibromide	*85-00-7*			NR	NR	NR	NR	NR	NR	NR
Emamectin benzoate	*137515-75-4 & 155569-918*			NR	NR	NR	NR	NR	NR	NR
Ethion	*563-12-2*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fenthion	*55-38-9*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fenitrothion	*122-14-5*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR
Fipronil	*120068-37-3*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR

Contaminant	**CAS Registry Number**	**General Solid Waste**	**Restricted Solid Waste**	**Hamilton Mining By-Product Contaminant Concentration (mg/kg)**						
		SCC1 (mg/kg)	**SCC2 (mg/kg)**	**PDC Ilmenite**	**Combined Monazite Reject**	**Hyti**	**Combined Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**	**PDC Conductors O/size +410µm**	**Float Tails**
Fluazifop-P-butyl	*79241-46-6*			NR	NR	NR	NR	NR	NR	NR
Fluidioxonil	*131341-86-1*			NR	NR	NR	NR	NR	NR	NR
Glyphosate	*1071-83-6*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Imidacloprid	*138261-41-3*			NR	NR	NR	NR	NR	NR	NR
Indoxacarb	*173584-44-6*			NR	NR	NR	NR	NR	NR	NR
Malathion	*121-75-5*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Metalaxyl	*57837-19-1*			NR	NR	NR	NR	NR	NR	NR
Metalaxyl-M	70630-17-0			NR	NR	NR	NR	NR	NR	NR
Methidathion	950-37-8			NR	NR	NR	NR	NR	NR	NR
3-Methyl-4-chlorophenol	59-50-7			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Methyl chlorpyrifos	*5598-13-0*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
N-Methyl pyrrolidone	*872-50-4*			NR	NR	NR	NR	NR	NR	NR
2-octylthiazol-3-one	*26530-20-1*			NR	NR	NR	NR	NR	NR	NR
Oxyfluorfen	*42874-03-3*			NR	NR	NR	NR	NR	NR	NR
Paraquat dichloride	*1910-42-5*			NR	NR	NR	NR	NR	NR	NR
Parathion methyl	*298-00-0*			<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Permethrin	*52645-53-1*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NR
Profenofos	*41198-08-7*			NR	NR	NR	NR	NR	NR	NR
Prometryn	*7287-19-6*			NR	NR	NR	NR	NR	NR	NR
Propargite	*2312-35-8*			NR	NR	NR	NR	NR	NR	NR
Pentachloronitrobenzene	*82-68-8*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Contaminant	**CAS Registry Number**	**General Solid Waste**	**Restricted Solid Waste**	**Hamilton Mining By-Product Contaminant Concentration (mg/kg)**						
		SCC1 (mg/kg)	**SCC2 (mg/kg)**	**PDC Ilmenite**	**Combined Monazite Reject**	**Hyti**	**Combined Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**	**PDC Conductors O/size +410µm**	**Float Tails**
Simazine	*122-34-9*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Thiabendazole	*148-79-8*			NR	NR	NR	NR	NR	NR	NR
Thiamethoxam	*153719-23-4*			NR	NR	NR	NR	NR	NR	NR
Thiodicarb	*59669-26-0*			<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thiram	*137-26-8*			NR	NR	NR	NR	NR	NR	NR
Molybdenum		1000	4000	<2	<2	<2	<2	6	<2	4
Nickel		1050	4200	9	3	31	<2	38	50	50
Nitrobenzene	98-95-3	72	288	<0.5	<0.50	<0.5	<0.5	<0.5	<0.5	<0.5
C6-C9 petroleum hydrocarbons[13]		650	2600	<10	<10	<10	<10	<10	<10	<10
C10-C36 petroleum hydrocarbons[13]		10000	40000	<50	<50	<50	<50	<50	<50	<50
Phenol (non-halognated)	108-95-2	518	2073	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Picloram	1918-02-1	110	440	<0.02	<0.02	<0.04	<0.02	<0.02	<0.02	<0.04
Plasticiser compounds[15]		600	2,400							
di-2-ethyl hexyl phthalate	*117-81-7*	---	---	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
di-2-ethyl hexyl adipate	*103-23-1*			NR	NR	NR	NR	NR	NR	NR
Polychlorinated biphenyls[12]	1336-36-3	<50	<50	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Polycyclic aromatic hydrocarbons (total)[16]		200	800							
Acenaphthene	*83-32-9*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthylene	*208-96-8*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Contaminant	**CAS Registry Number**	**General Solid Waste**	**Restricted Solid Waste**	**Hamilton Mining By-Product Contaminant Concentration (mg/kg)**						
		SCC1 (mg/kg)	**SCC2 (mg/kg)**	**PDC Ilmenite**	**Combined Monazite Reject**	**Hyti**	**Combined Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**	**PDC Conductors O/size +410µm**	**Float Tails**
Anthracene	*120-12-7*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)anthracene	*56-55-3*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene	*50-32-8*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b)fluoranthene	*205-99-2*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.05
Benzo(ghi)perylene	*191-24-2*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(k)fluoranthene	*207-08-9*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	*218-01-9*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dibenzo(a,h)anthracene	*53-70-3*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	*206-44-0*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	*86-73-7*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-cd)pyrene	*193-39-5*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	*91-20-3*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	*85-01-8*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	*129-00-0*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Scheduled Chemicals[17]		<50	<50							
Aldrin	*309-00-2*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Alpha-BHC	*319-84-6*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Beta-BHC	*319-85-7*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Gamma-BHC	*58-89-9*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Contaminant	CAS Registry Number	General Solid Waste	Restricted Solid Waste	Hamilton Mining By-Product Contaminant Concentration (mg/kg)						
		SCC1 (mg/kg)	SCC2 (mg/kg)	PDC Ilmenite	Combined Monazite Reject	Hyti	Combined Zircon Wet Tails	Rutile Wet Circuit Concentrate	PDC Conductors O/size +410µm	Float Tails
Delta-BHC	*319-86-8*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
trans-chlordane	*5103-74-2*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
cis-chlordane	*5103-71-9*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
DDD	*72-54-8*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
DDE	*72-55-9*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
DDT	*50-29-3*			<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dieldrin	*60-57-1*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Endrin	*72-20-8*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Endrin aldehyde	*7421-93-4*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Heptachlor	*76-44-8*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Heptachlor epoxide	*1024-57-3*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hexachlorobenzene	*118-74-1*			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hexachlorophene	*70-30-4*			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Isodrin	*465-73-6*			<3	<3	<3	<3	<3	<3	<0.5
Pentachlorobenzene	*608-93-5*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pentachloronitrobenzene	*82-68-8*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pentachlorophenol	*87-86-5*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,2,4,5-Tetrachlorobenzene	*95-94-3*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2,3,4,6 Tetrachlorophenol	*58-90-2*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,2,4-Trichlorobenzene	*120-82-1*			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2,4,5-Trichlorophenoxyyacetic acid, salts and esters	*93-76-5*			<0.02	<0.02	<0.04	<0.02	<0.02	<0.02	<0.04

Contaminant	**CAS Registry Number**	**General Solid Waste**	**Restricted Solid Waste**	**Hamilton Mining By-Product Contaminant Concentration (mg/kg)**						
		SCC1 (mg/kg)	**SCC2 (mg/kg)**	**PDC Ilmenite**	**Combined Monazite Reject**	**Hyti**	**Combined Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**	**PDC Conductors O/size +410µm**	**Float Tails**
Selenium		50	200	<5	<5	<5	<5	<5	<5	<5
Silver		180	720	<2	<2	<2	<2	<2	<2	<2
Styrene (vinyl benzene)	100-42-5	108	432	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tebuconazole	107534-96-3	230	920	NR	NR	NR	NR	NR	NR	NR
1,2,3,4-tetrachlorobenzene	634-66-2	18	72	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.5
1,1,1,2-tetrachloroethane[5]	630-20-6	360	1440	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,1,2,2-tetrachloroethane[5]	79-34-5	46.8	187.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tetrachloroethylene	127-18-4	25.2	100.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	108-88-3	518	2073	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5
1,1,1-trichloroethane	71-55-6	1080	4320	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,1,2-trichloroethane	79-00-5	43.2	172.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Trichloroethylene	79-01-6	18	72	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2,4,5-trichlorophenol	95-95-4	14400	57600	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2,4,6-trichlorophenol	88-06-2	72	288	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Triclopyr	55335-06-3	75	300	<0.02	<0.02	<0.04	<0.02	<0.02	<0.02	<0.04
Vinyl chloride	75-01-4	7.2	28.8	<4	<4	<4	<4	<4	<4	<4
Xylenes (total)	1330-20-7	1800	7200							
meta- & para-xylene				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Contaminant	**CAS Registry Number**	**General Solid Waste**	**Restricted Solid Waste**	**Hamilton Mining By-Product Contaminant Concentration (mg/kg)**						
		SCC1 (mg/kg)	**SCC2 (mg/kg)**	**PDC Ilmenite**	**Combined Monazite Reject**	**Hyti**	**Combined Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**	**PDC Conductors O/size +410µm**	**Float Tails**
ortho-xylene				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

1. Values are the same for general solid waste (putrescible) and general solid waste (nonputrescible).

2. See Hazardous Waste Management System: Identification and Listing of Hazardous Waste – Toxicity Characteristics Revisions, Final Rule (USEPA 1990) for TCLP levels.

3. There may be a need for the laboratory to concentrate the sample to achieve the TCLP limit value for benzo(a)pyrene with confidence. Waste Classification Guidelines 20 Part 1: Classifying waste (December 2009)

4. Calculated from Hazardous Waste: Identification and Listing – Proposed Rule (USEPA 1995)

5. Calculated from ‘Beryllium’ in The Health Risk Assessment and Management of Contaminated Sites (DiMarco & Buckett 1996)

6. These limits apply to chromium in the +6 oxidation state only.

7. Taken from the Land Disposal Restrictions for Newly Identified and Listed Hazardous Wastes and Hazardous Soil: Proposed Rule (USEPA 1993)

8. Analysis for cyanide (amenable) is the established method used to assess the potentially leachable cyanide. DECCW may consider other methods if it can be demonstrated that these methods yield the same information.

9. Endosulfan (CAS Registry Number 115-29-7) means the total of Endosulfan I (CAS Registry Number 959-98-8), Endosulfan II (CAS Registry Number 891-86-1) and Endosulfan sulfate (CAS Registry Number 1031-07-8).

10. Calculated from Australian Drinking Water Guidelines (NHMRC 1994)

11. The following moderately harmful pesticides (CAS Registry Number) are to be included

in the total values specified: Atrazine (1912-24-9), Azoxystrobin (131860-33-8), Bifenthrin (82657-04-3), Brodifacoum (56073-10-0), Carboxin (5234-68-4), Copper naphthenate (1338-02-9),

Cyfluthrin (68359-37-5), Cyhalothrin (68085-85-8), Cypermethrin (52315-07-08), Deltamethrin (52918-63-5), Dichlofluanid (1085-98-9), Dichlorvos (62-73-7), Difenoconazole (119446-68-3), Dimethoate (60-51-5), Diquat dibromide (85-00-7), Emamectin benzoate (137515-75-4 & 155569-91-8), Ethion (563-12-2), Fenthion (55-38-9), Fenitrothion (122-14-5), Fipronil (120068-37-3), Fluazifop-P-butyl (79241-46-6), Fludioxonil (131341-86-1), Glyphosate (1071-83-6), Imidacloprid (138261-41-3), Indoxacarb (173584-44-6), Malathion (Maldison) (121-75-5), Metalaxyl (57837-19-1), Metalaxyl-M (70630-17-0), Methidathion (950-37-8), 3-Methyl-4-chlorophenol (59-50-7), Methyl chlorpyrifos (5598-13-0), N-Methyl pyrrolidone (872-50-4), 2-octylthiazol-3-one (26530-20-1), Oxyfluorfen (42874-03-3), Paraquat dichloride (1910-42-5), Parathion methyl (298-00-0), Permethrin (52645-53-1), Profenofos (41198-08-7), Prometryn (7287-19-6), Propargite (2312-35-8), Pentachloronitrobenzene (Quintozene) (82-68-8), Simazine (122-34-9), Thiabendazole (148-79-8),Thiamethoxam (153719-23-4), Thiodicarb (59669-26-0) and Thiram (137-26-8).

12. No TCLP analysis is required. Moderately harmful pesticides, petroleum hydrocarbons, polychlorinated biphenyls, polycyclic aromatic hydrocarbons and scheduled chemicals are assessed using SCC1 and SCC2.

13. Approximate range of petroleum hydrocarbon fractions: petrol C6-C9, kerosene C10-C18, diesel C12-C18, and lubricating oils above C18. Laboratory results are reported as four different fractions: C6-C9, C10-C14, C15-C28 and C29-C36. The results of total petroleum hydrocarbons (C10-C36) analyses are reported as a sum of the relevant three fractions. Please note that hydrocarbons are defined as molecules that only contain carbon and hydrogen atoms. Prior to TPH (C10-C36) analysis, cleanup may be necessary to remove non-petroleum hydrocarbon compounds. Where the presence of other materials that will interfere with the analysis may be present, such as oils and fats from food sources, you are advised to treat the extract that has been solvent exchanged to hexane with silica gel as described in USEPA Method 1664A (USEPA 1999).

14. Proposed level for phenol and toluene in Hazardous Waste Management System: Identification and Listing of Hazardous Waste – Toxicity Characteristics Revisions, Final Rule (USEPA 1990)

15. Plasticiser compounds means the total of di-2-ethyl hexyl phthalate (CAS Registry Number 117-81-7) and di-2-ethyl hexyl adipate (CAS Registry Number 103-23-1) contained within a waste.

16. The following polycyclic aromatic hydrocarbons (CAS number) are assessed as the total concentration of 16 USEPA Priority Pollutant PAHs, as follows: Polycyclic aromatic hydrocarbons (total) (PAH name, CAS Registry Number) Acenaphthene 83-32-9 Chrysene 218-01-9 Acenaphthylene 208-96-8 Dibenzo(a,h)anthracene 53-70-3 Anthracene 120-12-7 Fluoranthene 206-44-0 Benzo(a)anthracene 56-55-3 Fluorene 86-73-7 Benzo(a)pyrene 50-32-8 Indeno(1,2,3-cd)pyrene 193-39-5 Benzo(b)fluoranthene 205-99-2 Naphthalene 91-20-3 Benzo(ghi)perylene 191-24-2 Phenanthrene 85-01-8 Benzo(k)fluoranthene 207-08-9 Pyrene 129-00-0

17. The following Scheduled Chemicals (CAS Registry Number) are to be included in the total values specified: Aldrin (309-00-2), Alpha-BHC (319-84-6), Beta-BHC (319-85-7), Gamma-BHC (Lindane) (58-89-9), Delta-BHC (319-86-8), Chlordane (57-74-9), DDD (72-54-8), DDE (72-55-9), DDT (50-29-3), Dieldrin (60-57-1), Endrin (72-20-8), Endrin aldehyde (7421-93-4), Heptachlor (76-44-8), Heptachlor epoxide (1024-57-3), Hexachlorobenzene (118-74-1), Hexachlorophene (70-30-4), Isodrin (465-73-6), Pentachlorobenzene (608-93-5), Pentachloronitrobenzene (82-68-8), Pentachlorophenol (87-86-5), 1,2,4,5-Tetrachlorobenzene (95-94-3), 2,3,4,6 Tetrachlorophenol (58-90-2), 1,2,4-Trichlorobenzene (120-82-1), 2,4,5-Trichlorophenoxyacetic acid, salts and esters (93-76-5).

18. Calculated from Guidelines for Drinking Water Quality (WHO 1993).

NR Parameter not reported by analytical laboratory.

Table A2: Hamilton MBPs leachable contaminant concentrations against the general and restricted solid waste thresholds (DECCW, 2009). Yellow shading indicates an exceedance of general solid waste threshold and brown shading indicates an exceedance of both general and restricted solid waste thresholds (light and dark shading respectively if printed in black and white).

Contaminant	CAS Registry Number	General Solid Waste	Restricted Solid Waste	Hamilton Mining By-Product Leachable Contaminant Concentration (mg/L)						
		TCLP1 (mg/L)	TCLP22 (mg/L)	PDC Ilmenite	Combined Monazite Reject	Hyti	Combined Zircon Wet Tails	Rutile Wet Circuit Concentrate	PDC Conductors O/size +410µm	Float Tails
pH[19]	-	-	-	4.3	3.7	3.7	4.6	3.5	4.2	3.6
Arsenic		5.0 [2]	20	<0.1	<0.1	<0.1	<0.1	<0.1	INS	<0.1
Benzene	71-43-2	0.5 [2]	2	<0.001	< 0.001	< 0.001	< 0.001	< 0.001	INS	INS
Benzo(a)pyrene[3]	50-32-8	0.04 [2]	0.16	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
Beryllium		1 [5]	4	<0.05	<0.05	<0.05	<0.05	<0.05	INS	<0.05
Cadmium		1 [2]	4	<0.05	<0.05	<0.05	<0.05	<0.05	INS	<0.05
Carbon tetrachloride	56-23-5	0.5 [2]	2	<0.005	< 0.005	< 0.005	< 0.005	< 0.005	INS	INS
Chlorobenzene	108-90-7	100 [2]	400	<0.005	< 0.005	< 0.005	< 0.005	< 0.005	INS	INS
Chloroform	67-66-3	6 [2]	24	<0.005	< 0.005	< 0.005	< 0.005	< 0.005	INS	INS
Chlorpyrifos	2921-88-2	0.2	0.8	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	INS	<0.0005
Chromium (VI)[6]		5 [2]	20	<0.01	<0.01	<0.01	<0.01	<0.01	INS	<0.01
m-cresol	108-39-4	200 [2]	800	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
o-cresol	95-48-7	200 [2]	800	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
p-cresol	106-44-5	200 [2]	800	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
Cresol (total)	1319-77-3	200 [2]	800							
Cyanide (amenable)[7, 8]		3.5 [7]	14	<0.004	<0.004	<0.004	<0.004	<0.004	INS	NR

Contaminant	**CAS Registry Number**	**General Solid Waste**	**Restricted Solid Waste**	**Hamilton Mining By-Product Leachable Contaminant Concentration (mg/L)**						
		TCLP1 (mg/L)	**TCLP22 (mg/L)**	**PDC Ilmenite**	**Combined Monazite Reject**	**Hyti**	**Combined Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**	**PDC Conductors O/size +410µm**	**Float Tails**
Cyanide (total)[7]		16 [7]	64	<0.004	<0.004	<0.004	<0.004	<0.004	INS	NR
2,4-D	94-75-7	10 [2]	40	<0.01	<0.01	<0.01	<0.01	<0.01	INS	<0.01
1,2-Dichlorobenzene	95-50-1	4.3 [2]	17.2	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
1,4-Dichlorobenzene	106-46-7	7.5 [2]	30	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
1,2-Dichloroethane	107-06-2	0.5 [2]	2	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
1,1-Dichloroethylene	75-35-4	---	---	<0.005	<0.005	<0.005	<0.005	<0.006	INS	INS
Dichloromethane	75-09-2	8.6 [2]	34.4	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
2,4-Dinitrotoluene	121-14-2	0.13 [2]	0.52	<0.004	<0.004	<0.004	<0.004	<0.004	INS	<0.004
Endosulfan[9]		3	12							
alpha-endosulfan	*959-98-8*			<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
beta-endosulfan	*33213-65-9*			<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Endosulfan-sulfate	*1031-07-8*			<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ethylbenzene	100-41-4	30 [10]	120	<0.002	<0.002	<0.002	<0.002	<0.002	INS	INS
Fluoride		150 [10]	600	0.3	0.2	0.3	0.3	0.2	INS	0.1
Fluroxypyr	69377-81-7	2	8	<0.01	<0.01	<0.01	<0.01	<0.01	INS	<0.01
Lead		5 [2]	20	<0.1	<0.1	<0.1	<0.1	<0.1	INS	<0.1
Mercury		0.2 [2]	0.8	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	INS	<0.0010
Methyl ethyl ketone	78-93-3	200 [2]	800	<0.05	<0.05	<0.05	<0.05	<0.05	INS	INS
Molybdenum		5 [10]	20	<0.1	<0.1	<0.1	<0.1	<0.1	INS	<0.1

Contaminant	**CAS Registry Number**	**General Solid Waste**	**Restricted Solid Waste**	**Hamilton Mining By-Product Leachable Contaminant Concentration (mg/L)**						
		TCLP1 (mg/L)	**TCLP22 (mg/L)**	**PDC Ilmenite**	**Combined Monazite Reject**	**Hyti**	**Combined Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**	**PDC Conductors O/size +410µm**	**Float Tails**
Nickel		2 [10]	8	<0.1	0.1	0.4	<0.1	0.1	INS	0.3
Nitrobenzene	98-95-3	2 [2]	8	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
Phenol (non-halognated)	108-95-2	14.4 [14]	57.6	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
Picloram	1918-02-1	3	12	<0.01	<0.01	<0.01	<0.01	<0.01	INS	<0.01
Plasticiser compounds[15]		1	4							
di-2-ethyl hexyl phthalate	*117-81-7*	---	---	0.006	<0.005	<0.005	0.026	<0.005	INS	<0.005
di-2-ethyl hexyl adipate	*103-23-1*			NR	NR	NR	NR	NR	NR	NR
Selenium		1 [2]	4	<0.05	<0.05	<0.05	<0.05	<0.05	INS	<0.05
Silver		5 [2]	20	<0.1	<0.1	<0.1	<0.1	<0.1	INS	<0.1
Styrene (vinyl benzene)	100-42-5	3 [10]	12	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
Tebuconazole	107534-96-3	6.4	25.6	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	INS	<0.01
1,2,3,4-tetrachlorobenzene	634-66-2	0.5	2	<0.01	NR	NR	NR	NR	INS	INS
1,1,1,2-tetrachloroethane[5]	630-20-6	10 [2]	40	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
1,1,2,2-tetrachloroethane[5]	79-34-5	1.3 [2]	5.2	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
Tetrachloroethylene	127-18-4	0.7 [2]	2.8	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
Toluene	108-88-3	14.4 [14]	57.6	<0.002	<0.002	0.006	<0.002	<0.002	INS	INS
1,1,1-trichloroethane	71-55-6	30 [2]	120	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS

Contaminant	CAS Registry Number	General Solid Waste	Restricted Solid Waste	Hamilton Mining By-Product Leachable Contaminant Concentration (mg/L)						
		TCLP1 (mg/L)	TCLP22 (mg/L)	PDC Ilmenite	Combined Monazite Reject	Hyti	Combined Zircon Wet Tails	Rutile Wet Circuit Concentrate	PDC Conductors O/size +410µm	Float Tails
1,1,2-trichloroethane	79-00-5	1.2 [2]	4.8	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
Trichloroethylene	79-01-6	0.5 [2]	2	<0.005	<0.005	<0.005	<0.005	<0.005	INS	INS
2,4,5-trichlorophenol	95-95-4	400 [2]	1600	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
2,4,6-trichlorophenol	88-06-2	2 [2]	8	<0.002	<0.002	<0.002	<0.002	<0.002	INS	<0.002
Triclopyr	55335-06-3	2	8	<0.01	<0.01	<0.01	<0.01	<0.01	INS	<0.01
Vinyl chloride	75-01-4	0.2 [2]	0.8	<0.05	<0.05	<0.05	<0.05	<0.05	INS	INS
Xylenes (total)	1330-20-7	50 [18]	200							
meta- & para-xylene	*108-38-3* *106-42-3*			<0.002	<0.002	<0.002	<0.002	<0.002	INS	INS
ortho-xylene	*95-47-6*			<0.002	<0.002	<0.002	<0.002	<0.002	INS	INS

1. Values are the same for general solid waste (putrescible) and general solid waste (nonputrescible).

2. See Hazardous Waste Management System: Identification and Listing of Hazardous Waste – Toxicity Characteristics Revisions, Final Rule (USEPA 1990) for TCLP levels.

3. There may be a need for the laboratory to concentrate the sample to achieve the TCLP limit value for benzo(a)pyrene with confidence. Waste Classification Guidelines 20 Part 1: Classifying waste (December 2009)

4. Calculated from Hazardous Waste: Identification and Listing – Proposed Rule (USEPA 1995)

5. Calculated from ‘Beryllium’ in The Health Risk Assessment and Management of Contaminated Sites (DiMarco & Buckett 1996)

6. These limits apply to chromium in the +6 oxidation state only.

7. Taken from the Land Disposal Restrictions for Newly Identified and Listed Hazardous Wastes and Hazardous Soil: Proposed Rule (USEPA 1993)

8. Analysis for cyanide (amenable) is the established method used to assess the potentially leachable cyanide. DECCW may consider other methods if it can be demonstrated that these methods yield the same information.

9. Endosulfan (CAS Registry Number 115-29-7) means the total of Endosulfan I (CAS Registry Number 959-98-8), Endosulfan II (CAS Registry Number 891-86-1) and Endosulfan sulfate (CAS Registry Number 1031-07-8).

10. Calculated from Australian Drinking Water Guidelines (NHMRC 1994)

11. The following moderately harmful pesticides (CAS Registry Number) are to be included

in the total values specified: Atrazine (1912-24-9), Azoxystrobin (131860-33-8), Bifenthrin (82657-04-3), Brodifacoum (56073-10-0), Carboxin (5234-68-4), Copper naphthenate (1338-02-9),

Cyfluthrin (68359-37-5), Cyhalothrin (68085-85-8), Cypermethrin (52315-07-08), Deltamethrin (52918-63-5), Dichlofluanid (1085-98-9), Dichlorvos (62-73-7), Difenoconazole (119446-68-3), Dimethoate (60-51-5), Diquat dibromide (85-00-7), Emamectin benzoate (137515-75-4 & 155569-91-8), Ethion (563-12-2), Fenthion (55-38-9), Fenitrothion (122-14-5), Fipronil (120068-37-3), Fluazifop-P-butyl (79241-46-6), Fludioxonil (131341-86-1), Glyphosate (1071-83-6), Imidacloprid (138261-41-3), Indoxacarb (173584-44-6), Malathion (Maldison) (121-75-5), Metalaxyl (57837-19-1), Metalaxyl-M (70630-17-0), Methidathion (950-37-8), 3-Methyl-4-chlorophenol (59-50-7), Methyl chlorpyrifos (5598-13-0), N-Methyl pyrrolidone (872-50-4), 2-octylthiazol-3-one (26530-20-1), Oxyfluorfen (42874-03-3), Paraquat dichloride (1910-42-5), Parathion methyl (298-00-0), Permethrin (52645-53-1), Profenofos (41198-08-7), Prometryn (7287-19-6), Propargite (2312-35-8), Pentachloronitrobenzene (Quintozene) (82-68-8), Simazine (122-34-9), Thiabendazole (148-79-8),Thiamethoxam (153719-23-4), Thiodicarb (59669-26-0) and Thiram (137-26-8).

12. No TCLP analysis is required. Moderately harmful pesticides, petroleum hydrocarbons, polychlorinated biphenyls, polycyclic aromatic hydrocarbons and scheduled chemicals are assessed using SCC1 and SCC2.

13. Approximate range of petroleum hydrocarbon fractions: petrol C6-C9, kerosene C10-C18, diesel C12-C18, and lubricating oils above C18. Laboratory results are reported as four different fractions: C6-C9, C10-C14, C15-C28 and C29-C36. The results of total petroleum hydrocarbons (C10-C36) analyses are reported as a sum of the relevant three fractions. Please note that hydrocarbons are defined as molecules that only contain carbon and hydrogen atoms. Prior to TPH (C10-C36) analysis, cleanup may be necessary to remove non-petroleum hydrocarbon compounds. Where the presence of other materials that will interfere with the analysis may be present, such as oils and fats from food sources, you are advised to treat the extract that has been solvent exchanged to hexane with silica gel as described in USEPA Method 1664A (USEPA 1999).

14. Proposed level for phenol and toluene in Hazardous Waste Management System: Identification and Listing of Hazardous Waste – Toxicity Characteristics Revisions, Final Rule (USEPA 1990)

15. Plasticiser compounds means the total of di-2-ethyl hexyl phthalate (CAS Registry Number 117-81-7) and di-2-ethyl hexyl adipate (CAS Registry Number 103-23-1) contained within a waste.

16. The following polycyclic aromatic hydrocarbons (CAS number) are assessed as the total concentration of 16 USEPA Priority Pollutant PAHs, as follows: Polycyclic aromatic hydrocarbons (total) (PAH name, CAS Registry Number) Acenaphthene 83-32-9 Chrysene 218-01-9 Acenaphthylene 208-96-8 Dibenzo(a,h)anthracene 53-70-3 Anthracene 120-12-7 Fluoranthene 206-44-0 Benzo(a)anthracene 56-55-3 Fluorene 86-73-7 Benzo(a)pyrene 50-32-8 Indeno(1,2,3-cd)pyrene 193-39-5 Benzo(b)fluoranthene 205-99-2 Naphthalene 91-20-3 Benzo(ghi)perylene 191-24-2 Phenanthrene 85-01-8 Benzo(k)fluoranthene 207-08-9 Pyrene 129-00-0

17. The following Scheduled Chemicals (CAS Registry Number) are to be included in the total values specified: Aldrin (309-00-2), Alpha-BHC (319-84-6), Beta-BHC (319-85-7), Gamma-BHC (Lindane) (58-89-9), Delta-BHC (319-86-8), Chlordane (57-74-9), DDD (72-54-8), DDE (72-55-9), DDT (50-29-3), Dieldrin (60-57-1), Endrin (72-20-8), Endrin aldehyde (7421-93-4), Heptachlor (76-44-8), Heptachlor

epoxide (1024-57-3), Hexachlorobenzene (118-74-1), Hexachlorophene (70-30-4), Isodrin (465-73-6), Pentachlorobenzene (608-93-5), Pentachloronitrobenzene (82-68-8), Pentachlorophenol (87-86-5), 1,2,4,5-Tetrachlorobenzene (95-94-3), 2,3,4,6 Tetrachlorophenol (58-90-2), 1,2,4-Trichlorobenzene (120-82-1), 2,4,5-Trichlorophenoxyacetic acid, salts and esters (93-76-5).

18. Calculated from Guidelines for Drinking Water Quality (WHO 1993)

19. Initial pH of the sample determined using 5 g of the waste material and 96.5 mL of deionised water.

NR Parameter not reported by analytical laboratory.

INS Insufficient sample available to report parameter.

Attachment B

Analytical Laboratory Reports

CERTIFICATE OF ANALYSIS

Work Order	: **EB1447303**	Page	: 1 of 17
Client	: **EARTH SYSTEMS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR NIC BOURGEOT	Contact	: Customer Services EB
Address	: SUITE 17 79-83 HIGH STREET KEW VIC, AUSTRALIA 3101	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: nic.bourgeot@earthsystems.com.au	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 03 9810 7500	Telephone	: +61-7-3243 7222
Facsimile	: +61 03 9853 5030	Facsimile	: +61-7-3243 7218
Project	: ILUKA1485	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 28-Nov-2014 09:05
C-O-C number	: ----	Date Analysis Commenced	: 01-Dec-2014
Sampler	: NIC BOURGEOT	Issue Date	: 15-Dec-2014 17:55
Site	: ----		
		No. of samples received	: 6
Quote number	: ----	No. of samples analysed	: 6

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Alex Rossi	Organic Chemist	Sydney Organics
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Merrin Avery	Supervisor - Inorganic	Newcastle - Inorganics
Pabi Subba	Senior Organic Chemist	Sydney Organics
Phalak Inthakesone	Laboratory Manager - Organics	Sydney Organics
Ryan Story	2IC Organic Instrument Chemist	Brisbane Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

- **Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero, for 'TEQ 1/2LOR' are treated as half the reported LOR, and for 'TEQ LOR' are treated as being equal to the reported LOR. Note: TEQ 1/2LOR and TEQ LOR will calculate as 0.6mg/Kg and 1.2mg/Kg respectively for samples with non-detects for all of the eight TEQ PAHs.**
- **EG005T (Total Metals) Sample EB1447303002 shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection**
- **EP201: Poor matrix spike recoveries due to matrix effects.**
- **EP202: Particular samples required dilution due to matrix interferences. LOR values have been adjusted accordingly.**
- **Results for all samples have been reported on an "as received" basis. Moisture calculations and corrections have not been applied. Due to the nature of the samples' matrices (sands) moisture content is expected to be small or negligible.**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Ilmenite**	**Combinded Monazite Reject**	**Hyti**	**Combinded Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**
			Client sampling date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-001**	**EB1447303-002**	**EB1447303-003**	**EB1447303-004**	**EB1447303-005**
				Result	Result	Result	Result	Result
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	**16**	**31**	<5	**454**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Lead	7439-92-1	5	mg/kg	**28**	**17**	**133**	<5	**412**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	**6**
Nickel	7440-02-0	2	mg/kg	**9**	**3**	**31**	<2	**38**
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EG048: Hexavalent Chromium (Alkaline Digest)								
Hexavalent Chromium	18540-29-9	0.5	mg/kg	<0.5	**0.7**	<0.5	<0.5	<0.5
EK026SF: Total CN by Segmented Flow Analyser								
Total Cyanide	57-12-5	1	mg/kg	<1	<1	<1	<1	<1
EK028SF: Weak Acid Dissociable CN by Segmented Flow Analyser								
Weak Acid Dissociable Cyanide	----	1	mg/kg	<1	<1	<1	<1	<1
EK040T: Fluoride Total								
Fluoride	16984-48-8	40	mg/kg	<40	**550**	<40	**3980**	<40
EN33: TCLP Leach								
Initial pH	----	0.1	pH Unit	**4.3**	**3.7**	**3.7**	**4.6**	**3.5**
After HCl pH	----	0.1	pH Unit	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Extraction Fluid Number	----	1	-	**1**	**1**	**1**	**1**	**1**
Final pH	----	0.1	pH Unit	**5.0**	**5.0**	**4.9**	**5.0**	**5.0**
EP066: Polychlorinated Biphenyls (PCB)								
^ **Total Polychlorinated biphenyls**	----	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EP068C: Triazines								
Atrazine	1912-24-9	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Simazine	122-34-9	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
EP068F: Miscellaneous Pesticides								
Fipronil	120068-37-3	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Fenitrothion	122-14-5	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
EP071 SG: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Silica gel cleanup								
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Ilmenite**	**Combinded Monazite Reject**	**Hyti**	**Combinded Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**
			Client sampling date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-001**	**EB1447303-002**	**EB1447303-003**	**EB1447303-004**	**EB1447303-005**
				Result	Result	Result	Result	Result
EP071 SG: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Silica gel cleanup - Continued								
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP071 SG-S: Total Petroleum Hydrocarbons in Soil - Silica gel cleanup								
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP074A: Monocyclic Aromatic Hydrocarbons								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	**0.6**	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Styrene	100-42-5	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP074B: Oxygenated Compounds								
2-Butanone (MEK)	78-93-3	5	mg/kg	<5	<5	<5	<5	<5
EP074E: Halogenated Aliphatic Compounds								
Vinyl chloride	75-01-4	4	mg/kg	<4	<4	<4	<4	<4
1.1-Dichloroethene	75-35-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Methylene chloride	75-09-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.1.1-Trichloroethane	71-55-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon Tetrachloride	56-23-5	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.2-Dichloroethane	107-06-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Trichloroethene	79-01-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.1.2-Trichloroethane	79-00-5	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Tetrachloroethene	127-18-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.1.1.2-Tetrachloroethane	630-20-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.1.2.2-Tetrachloroethane	79-34-5	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP074F: Halogenated Aromatic Compounds								
Chlorobenzene	108-90-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP074G: Trihalomethanes								
Chloroform	67-66-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP075K: Miscellaneous Compounds								
Isodrin	465-73-6	0.5	mg/kg	<3	<3	<3	<3	<3

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Ilmenite**	**Combinded Monazite Reject**	**Hyti**	**Combinded Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**
			Client sampling date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-001**	**EB1447303-002**	**EB1447303-003**	**EB1447303-004**	**EB1447303-005**
				Result	Result	Result	Result	Result
EP076A: Phenolic Compounds (Chlorinated)								
Phenol	108-95-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
2-Methylphenol	95-48-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
3- & 4-Methylphenol	1319-77-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
4-Chloro-3-methylphenol	59-50-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
2.4.5-Trichlorophenol	95-95-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
2.4.6-Trichlorophenol	88-06-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
2.3.4.6-Tetrachlorophenol	58-90-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Pentachlorophenol	87-86-5	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP076B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthylene	208-96-8	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	83-32-9	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	86-73-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	85-01-8	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	120-12-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	206-44-0	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	129-00-0	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Benz(a)anthracene	56-55-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	218-01-9	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b+j) & Benzo(k)fluoranthene	205-99-2 207-08-9	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene	50-32-8	0.5	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Indeno(1.2.3.cd)pyrene	193-39-5	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Dibenz(a.h)anthracene	53-70-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(g.h.i)perylene	191-24-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP076C: Phthalate Esters								
bis(2-ethylhexyl) phthalate	117-81-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP076E: Nitroaromatics and Ketones								
Nitrobenzene	98-95-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
2.4-Dinitrotoluene	121-14-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Pentachloronitrobenzene	82-68-8	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP076G: Chlorinated Hydrocarbons (Aromatic)								
1.4-Dichlorobenzene	106-46-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.2-Dichlorobenzene	95-50-1	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Ilmenite**	**Combinded Monazite Reject**	**Hyti**	**Combinded Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**
			Client sampling date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-001**	**EB1447303-002**	**EB1447303-003**	**EB1447303-004**	**EB1447303-005**
				Result	Result	Result	Result	Result
EP076G: Chlorinated Hydrocarbons (Aromatic) - Continued								
1.2.4-Trichlorobenzene	120-82-1	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.2.3.4-Tetrachlorobenzene	634-66-2	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	634-90-2/95-94-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Pentachlorobenzene	608-93-5	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP076I: Organochlorine Pesticides								
Hexachlorobenzene (HCB)	118-74-1	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
alpha-BHC	319-84-6	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
beta-BHC	319-85-7	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
gamma-BHC	58-89-9	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
delta-BHC	319-86-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Heptachlor	76-44-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Aldrin	309-00-2	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Heptachlor epoxide	1024-57-3	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
alpha-Endosulfan	959-98-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
4.4`-DDE	72-55-9	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
trans-Chlordane	5103-74-2	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Dieldrin	60-57-1	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Endrin	72-20-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
cis-Chlordane	5103-71-9	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
beta-Endosulfan	33213-65-9	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
4.4`-DDD	72-54-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Endosulfan sulfate	1031-07-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
4.4`-DDT	50-29-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Endrin aldehyde	7421-93-4	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
EP076J: Organophosphorus Pesticides								
Dichlorvos	62-73-7	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Dimethoate	60-51-5	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Chlorpyrifos-methyl	5598-13-0	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Malathion	121-75-5	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Fenthion	55-38-9	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Parathion-methyl	298-00-0	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Chlorpyrifos	2921-88-2	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Ethion	563-12-2	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
EP080/071: Total Petroleum Hydrocarbons								

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Ilmenite**	**Combinded Monazite Reject**	**Hyti**	**Combinded Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**
			Client sampling date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-001**	**EB1447303-002**	**EB1447303-003**	**EB1447303-004**	**EB1447303-005**
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons - Continued								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
EP094A: Synthetic Pyrethroids								
Bifenthrin	82657-04-3	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Lambda-cyhalothrin	68085-85-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Permethrin	52645-53-1	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Cyfluthrin	68359-37-5	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Cypermethrin	52315-07-8	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Deltamethrin & Tralomethrin	62229-77-0/66841-25-	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
EP132A: Phenolic Compounds								
Hexachlorophene	70-30-4	10	µg/kg	<10	<10	<10	<10	<10
EP201: Carbamate Pesticides by LCMS								
Thiodicarb	59669-26-0	0.02	mg/kg	<0.02	<0.02	<0.02	<0.02	<0.02
EP202A: Phenoxyacetic Acid Herbicides by LCMS								
2.4-D	94-75-7	0.02	mg/kg	<0.02	<0.02	<0.04	<0.02	<0.02
Triclopyr	55335-06-3	0.02	mg/kg	<0.02	<0.02	<0.04	<0.02	<0.02
2.4.5-TP (Silvex)	93-72-1	0.02	mg/kg	<0.02	<0.02	<0.04	<0.02	<0.02
2.4.5-T	93-76-5	0.02	mg/kg	<0.02	<0.02	<0.04	<0.02	<0.02
Picloram	1918-02-1	0.02	mg/kg	<0.02	<0.02	<0.04	<0.02	<0.02
Fluroxypyr	69377-81-7	0.02	mg/kg	<0.02	<0.02	<0.04	<0.02	<0.02
EP204: Glyphosate and AMPA								
ø **Glyphosate**	1071-83-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP066S: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.1	%	**62.2**	**62.9**	**75.0**	**61.3**	**72.0**
EP068S: Organochlorine Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.05	%	**105**	**102**	**123**	**106**	**111**
EP068T: Organophosphorus Pesticide Surrogate								
DEF	78-48-8	0.05	%	**89.2**	**88.4**	**63.5**	**84.8**	**78.3**
DEF	78-48-8	0.05	%	**111**	**114**	**108**	**106**	**104**
EP074S: VOC Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.5	%	**117**	**118**	**118**	**122**	**120**
Toluene-D8	2037-26-5	0.5	%	**112**	**114**	**108**	**116**	**110**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Ilmenite**	**Combinded Monazite Reject**	**Hyti**	**Combinded Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**
			Client sampling date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-001**	**EB1447303-002**	**EB1447303-003**	**EB1447303-004**	**EB1447303-005**
				Result	Result	Result	Result	Result
EP074S: VOC Surrogates - Continued								
4-Bromofluorobenzene	460-00-4	0.5	%	**114**	**116**	**113**	**121**	**114**
EP076S: Acid Extractable Surrogates								
2-Fluorophenol	367-12-4	0.05	%	**121**	**121**	**124**	**90.8**	**116**
Phenol-d6	13127-88-3	0.05	%	**108**	**122**	**112**	**119**	**89.9**
2-Chlorophenol-D4	93951-73-6	0.05	%	**127**	**106**	**91.9**	**125**	**102**
2.4.6-Tribromophenol	118-79-6	0.05	%	**121**	**108**	**131**	**120**	**80.9**
EP076T: Base-Neutral Surrogate Compounds								
Nitrobenzene-D5	4165-60-0	0.05	%	**121**	**117**	**122**	**122**	**112**
1.2-Dichlorobenzene-D4	2199-69-1	0.05	%	**116**	**117**	**127**	**112**	**105**
2-Fluorobiphenyl	321-60-8	0.05	%	**118**	**104**	**129**	**119**	**104**
Anthracene-d10	1719-06-8	0.05	%	**113**	**116**	**24.4**	**112**	**24.6**
4-Terphenyl-d14	1718-51-0	0.05	%	**110**	**124**	**105**	**104**	**127**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**111**	**112**	**114**	**118**	**114**
Toluene-D8	2037-26-5	0.2	%	**115**	**122**	**110**	**119**	**116**
4-Bromofluorobenzene	460-00-4	0.2	%	**115**	**118**	**108**	**119**	**110**
EP094S: Pesticide Surrogate								
DEF	78-48-8	0.05	%	**89.2**	**88.4**	**63.5**	**84.8**	**78.3**
EP132S: Acid Extractable Surrogates								
2-Fluorophenol	367-12-4	10	%	**82.2**	**68.9**	**64.8**	**73.8**	**84.1**
Phenol-d6	13127-88-3	10	%	**86.5**	**72.3**	**62.9**	**79.2**	**81.6**
2-Chlorophenol-D4	93951-73-6	10	%	**88.2**	**71.5**	**70.3**	**81.4**	**86.7**
2.4.6-Tribromophenol	118-79-6	10	%	**96.9**	**80.3**	**75.7**	**80.2**	**86.5**
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	**78.3**	**73.1**	**69.6**	**80.7**	**80.2**
Anthracene-d10	1719-06-8	10	%	**91.8**	**40.9**	**42.2**	**73.2**	**57.8**
4-Terphenyl-d14	1718-51-0	10	%	**110**	**102**	**82.4**	**102**	**103**
EP201S: Carbamate Surrogate								
4-Bromo-3.5-dimethylphenyl-N-methylcarbamate	672-99-1	0.02	%	**91.3**	**89.7**	**92.4**	**88.3**	**79.2**
EP202S: Phenoxyacetic Acid Herbicide Surrogate								
2.4-Dichlorophenyl Acetic Acid	19719-28-9	0.02	%	**71.9**	**114**	**99.1**	**84.1**	**93.2**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Conductors O/seze + 410µm**	**----**	**----**	**----**	**----**
			Client sampling date / time	[11-Nov-2014]	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-006**	**--------**	**--------**	**--------**	**--------**
				Result	Result	Result	Result	Result
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	**79**	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	----	----	----	----
Lead	7439-92-1	5	mg/kg	**49**	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	----	----	----	----
Nickel	7440-02-0	2	mg/kg	**50**	----	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	----	----	----	----
Silver	7440-22-4	2	mg/kg	<2	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	----	----	----
EG048: Hexavalent Chromium (Alkaline Digest)								
Hexavalent Chromium	18540-29-9	0.5	mg/kg	<0.5	----	----	----	----
EK026SF: Total CN by Segmented Flow Analyser								
Total Cyanide	57-12-5	1	mg/kg	<1	----	----	----	----
EK028SF: Weak Acid Dissociable CN by Segmented Flow Analyser								
Weak Acid Dissociable Cyanide	----	1	mg/kg	<1	----	----	----	----
EK040T: Fluoride Total								
Fluoride	16984-48-8	40	mg/kg	<40	----	----	----	----
EN33: TCLP Leach								
Initial pH	----	0.1	pH Unit	**4.2**	----	----	----	----
After HCl pH	----	0.1	pH Unit	**1.0**	----	----	----	----
Extraction Fluid Number	----	1	-	**1**	----	----	----	----
Final pH	----	0.1	pH Unit	**5.0**	----	----	----	----
EP066: Polychlorinated Biphenyls (PCB)								
^ **Total Polychlorinated biphenyls**	----	0.1	mg/kg	<0.1	----	----	----	----
EP068C: Triazines								
Atrazine	1912-24-9	0.05	mg/kg	<0.05	----	----	----	----
Simazine	122-34-9	0.05	mg/kg	<0.05	----	----	----	----
EP068F: Miscellaneous Pesticides								
Fipronil	120068-37-3	0.05	mg/kg	<0.05	----	----	----	----
Fenitrothion	122-14-5	0.05	mg/kg	<0.05	----	----	----	----
EP071 SG: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Silica gel cleanup								
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	----	----	----	----
>C16 - C34 Fraction	----	100	mg/kg	<100	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Conductors O/seze + 410µm**	----	----	----	----
			Client sampling date / time	[11-Nov-2014]	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-006**	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EP071 SG: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Silica gel cleanup - Continued								
>C34 - C40 Fraction	----	100	mg/kg	<100	----	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg	<50	----	----	----	----
EP071 SG-S: Total Petroleum Hydrocarbons in Soil - Silica gel cleanup								
C10 - C14 Fraction	----	50	mg/kg	<50	----	----	----	----
C15 - C28 Fraction	----	100	mg/kg	<100	----	----	----	----
C29 - C36 Fraction	----	100	mg/kg	<100	----	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg	<50	----	----	----	----
EP074A: Monocyclic Aromatic Hydrocarbons								
Benzene	71-43-2	0.2	mg/kg	<0.2	----	----	----	----
Toluene	108-88-3	0.5	mg/kg	<0.5	----	----	----	----
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	----	----	----	----
Styrene	100-42-5	0.5	mg/kg	<0.5	----	----	----	----
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	----	----	----	----
EP074B: Oxygenated Compounds								
2-Butanone (MEK)	78-93-3	5	mg/kg	<5	----	----	----	----
EP074E: Halogenated Aliphatic Compounds								
Vinyl chloride	75-01-4	4	mg/kg	<4	----	----	----	----
1.1-Dichloroethene	75-35-4	0.5	mg/kg	<0.5	----	----	----	----
Methylene chloride	75-09-2	0.5	mg/kg	<0.5	----	----	----	----
1.1.1-Trichloroethane	71-55-6	0.5	mg/kg	<0.5	----	----	----	----
Carbon Tetrachloride	56-23-5	0.5	mg/kg	<0.5	----	----	----	----
1.2-Dichloroethane	107-06-2	0.5	mg/kg	<0.5	----	----	----	----
Trichloroethene	79-01-6	0.5	mg/kg	<0.5	----	----	----	----
1.1.2-Trichloroethane	79-00-5	0.5	mg/kg	<0.5	----	----	----	----
Tetrachloroethene	127-18-4	0.5	mg/kg	<0.5	----	----	----	----
1.1.1.2-Tetrachloroethane	630-20-6	0.5	mg/kg	<0.5	----	----	----	----
1.1.2.2-Tetrachloroethane	79-34-5	0.5	mg/kg	<0.5	----	----	----	----
EP074F: Halogenated Aromatic Compounds								
Chlorobenzene	108-90-7	0.5	mg/kg	<0.5	----	----	----	----
EP074G: Trihalomethanes								
Chloroform	67-66-3	0.5	mg/kg	<0.5	----	----	----	----
EP075K: Miscellaneous Compounds								
Isodrin	465-73-6	0.5	mg/kg	<3	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Conductors O/seze + 410µm**	----	----	----	----
			Client sampling date / time	[11-Nov-2014]	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-006**	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EP076A: Phenolic Compounds (Chlorinated)								
Phenol	108-95-2	0.5	mg/kg	<0.5	----	----	----	----
2-Methylphenol	95-48-7	0.5	mg/kg	<0.5	----	----	----	----
3- & 4-Methylphenol	1319-77-3	0.5	mg/kg	<0.5	----	----	----	----
4-Chloro-3-methylphenol	59-50-7	0.5	mg/kg	<0.5	----	----	----	----
2.4.5-Trichlorophenol	95-95-4	0.5	mg/kg	<0.5	----	----	----	----
2.4.6-Trichlorophenol	88-06-2	0.5	mg/kg	<0.5	----	----	----	----
2.3.4.6-Tetrachlorophenol	58-90-2	0.5	mg/kg	<0.5	----	----	----	----
Pentachlorophenol	87-86-5	0.5	mg/kg	<0.5	----	----	----	----
EP076B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	0.5	mg/kg	<0.5	----	----	----	----
Acenaphthylene	208-96-8	0.5	mg/kg	<0.5	----	----	----	----
Acenaphthene	83-32-9	0.5	mg/kg	<0.5	----	----	----	----
Fluorene	86-73-7	0.5	mg/kg	<0.5	----	----	----	----
Phenanthrene	85-01-8	0.5	mg/kg	<0.5	----	----	----	----
Anthracene	120-12-7	0.5	mg/kg	<0.5	----	----	----	----
Fluoranthene	206-44-0	0.5	mg/kg	<0.5	----	----	----	----
Pyrene	129-00-0	0.5	mg/kg	<0.5	----	----	----	----
Benz(a)anthracene	56-55-3	0.5	mg/kg	<0.5	----	----	----	----
Chrysene	218-01-9	0.5	mg/kg	<0.5	----	----	----	----
Benzo(b+j) & Benzo(k)fluoranthene	205-99-2 207-08-9	0.5	mg/kg	<0.5	----	----	----	----
Benzo(a)pyrene	50-32-8	0.5	mg/kg	<0.50	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	0.5	mg/kg	<0.5	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	0.5	mg/kg	<0.5	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	0.5	mg/kg	<0.5	----	----	----	----
EP076C: Phthalate Esters								
bis(2-ethylhexyl) phthalate	117-81-7	0.5	mg/kg	<0.5	----	----	----	----
EP076E: Nitroaromatics and Ketones								
Nitrobenzene	98-95-3	0.5	mg/kg	<0.5	----	----	----	----
2.4-Dinitrotoluene	121-14-2	0.5	mg/kg	<0.5	----	----	----	----
Pentachloronitrobenzene	82-68-8	0.5	mg/kg	<0.5	----	----	----	----
EP076G: Chlorinated Hydrocarbons (Aromatic)								
1.4-Dichlorobenzene	106-46-7	0.5	mg/kg	<0.5	----	----	----	----
1.2-Dichlorobenzene	95-50-1	0.5	mg/kg	<0.5	----	----	----	----
1.2.4-Trichlorobenzene	120-82-1	0.5	mg/kg	<0.5	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL)**			*Client sample ID*	**PDC Conductors O/seze + 410µm**	----	----	----	----
			Client sampling date / time	[11-Nov-2014]	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-006**	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EP076G: Chlorinated Hydrocarbons (Aromatic) - Continued								
1.2.3.4-Tetrachlorobenzene	634-66-2	0.5	mg/kg	<0.5	----	----	----	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	634-90-2/95-94-3	0.5	mg/kg	<0.5	----	----	----	----
Pentachlorobenzene	608-93-5	0.5	mg/kg	<0.5	----	----	----	----
EP076I: Organochlorine Pesticides								
Hexachlorobenzene (HCB)	118-74-1	0.05	mg/kg	<0.05	----	----	----	----
alpha-BHC	319-84-6	0.05	mg/kg	<0.05	----	----	----	----
beta-BHC	319-85-7	0.05	mg/kg	<0.05	----	----	----	----
gamma-BHC	58-89-9	0.05	mg/kg	<0.05	----	----	----	----
delta-BHC	319-86-8	0.05	mg/kg	<0.05	----	----	----	----
Heptachlor	76-44-8	0.05	mg/kg	<0.05	----	----	----	----
Aldrin	309-00-2	0.05	mg/kg	<0.05	----	----	----	----
Heptachlor epoxide	1024-57-3	0.05	mg/kg	<0.05	----	----	----	----
alpha-Endosulfan	959-98-8	0.05	mg/kg	<0.05	----	----	----	----
4.4`-DDE	72-55-9	0.05	mg/kg	<0.05	----	----	----	----
trans-Chlordane	5103-74-2	0.05	mg/kg	<0.05	----	----	----	----
Dieldrin	60-57-1	0.05	mg/kg	<0.05	----	----	----	----
Endrin	72-20-8	0.05	mg/kg	<0.05	----	----	----	----
cis-Chlordane	5103-71-9	0.05	mg/kg	<0.05	----	----	----	----
beta-Endosulfan	33213-65-9	0.05	mg/kg	<0.05	----	----	----	----
4.4`-DDD	72-54-8	0.05	mg/kg	<0.05	----	----	----	----
Endosulfan sulfate	1031-07-8	0.05	mg/kg	<0.05	----	----	----	----
4.4`-DDT	50-29-3	0.2	mg/kg	<0.2	----	----	----	----
Endrin aldehyde	7421-93-4	0.05	mg/kg	<0.05	----	----	----	----
EP076J: Organophosphorus Pesticides								
Dichlorvos	62-73-7	0.05	mg/kg	<0.05	----	----	----	----
Dimethoate	60-51-5	0.05	mg/kg	<0.05	----	----	----	----
Chlorpyrifos-methyl	5598-13-0	0.05	mg/kg	<0.05	----	----	----	----
Malathion	121-75-5	0.05	mg/kg	<0.05	----	----	----	----
Fenthion	55-38-9	0.05	mg/kg	<0.05	----	----	----	----
Parathion-methyl	298-00-0	0.2	mg/kg	<0.2	----	----	----	----
Chlorpyrifos	2921-88-2	0.05	mg/kg	<0.05	----	----	----	----
Ethion	563-12-2	0.05	mg/kg	<0.05	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Conductors O/seze + 410µm**	----	----	----	----
			Client sampling date / time	[11-Nov-2014]	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-006**	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	----	----	----	----
EP094A: Synthetic Pyrethroids								
Bifenthrin	82657-04-3	0.05	mg/kg	<0.05	----	----	----	----
Lambda-cyhalothrin	68085-85-8	0.05	mg/kg	<0.05	----	----	----	----
Permethrin	52645-53-1	0.05	mg/kg	<0.05	----	----	----	----
Cyfluthrin	68359-37-5	0.05	mg/kg	<0.05	----	----	----	----
Cypermethrin	52315-07-8	0.05	mg/kg	<0.05	----	----	----	----
Deltamethrin & Tralomethrin	62229-77-0/66841-25-	0.05	mg/kg	<0.05	----	----	----	----
EP132A: Phenolic Compounds								
Hexachlorophene	70-30-4	10	µg/kg	<10	----	----	----	----
EP201: Carbamate Pesticides by LCMS								
Thiodicarb	59669-26-0	0.02	mg/kg	<0.02	----	----	----	----
EP202A: Phenoxyacetic Acid Herbicides by LCMS								
2.4-D	94-75-7	0.02	mg/kg	<0.02	----	----	----	----
Triclopyr	55335-06-3	0.02	mg/kg	<0.02	----	----	----	----
2.4.5-TP (Silvex)	93-72-1	0.02	mg/kg	<0.02	----	----	----	----
2.4.5-T	93-76-5	0.02	mg/kg	<0.02	----	----	----	----
Picloram	1918-02-1	0.02	mg/kg	<0.02	----	----	----	----
Fluroxypyr	69377-81-7	0.02	mg/kg	<0.02	----	----	----	----
EP204: Glyphosate and AMPA								
ø **Glyphosate**	1071-83-6	0.5	mg/kg	<0.5	----	----	----	----
EP066S: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.1	%	**62.4**	----	----	----	----
EP068S: Organochlorine Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.05	%	**104**	----	----	----	----
EP068T: Organophosphorus Pesticide Surrogate								
DEF	78-48-8	0.05	%	**90.2**	----	----	----	----
DEF	78-48-8	0.05	%	**104**	----	----	----	----
EP074S: VOC Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.5	%	**122**	----	----	----	----
Toluene-D8	2037-26-5	0.5	%	**117**	----	----	----	----
4-Bromofluorobenzene	460-00-4	0.5	%	**122**	----	----	----	----
EP076S: Acid Extractable Surrogates								

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**PDC Conductors O/seze + 410µm**	----	----	----	----
			Client sampling date / time	[11-Nov-2014]	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-006**	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EP076S: Acid Extractable Surrogates - Continued								
2-Fluorophenol	367-12-4	0.05	%	**118**	----	----	----	----
Phenol-d6	13127-88-3	0.05	%	**117**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	0.05	%	**112**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	0.05	%	**104**	----	----	----	----
EP076T: Base-Neutral Surrogate Compounds								
Nitrobenzene-D5	4165-60-0	0.05	%	**108**	----	----	----	----
1.2-Dichlorobenzene-D4	2199-69-1	0.05	%	**110**	----	----	----	----
2-Fluorobiphenyl	321-60-8	0.05	%	**112**	----	----	----	----
Anthracene-d10	1719-06-8	0.05	%	**126**	----	----	----	----
4-Terphenyl-d14	1718-51-0	0.05	%	**104**	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**115**	----	----	----	----
Toluene-D8	2037-26-5	0.2	%	**120**	----	----	----	----
4-Bromofluorobenzene	460-00-4	0.2	%	**119**	----	----	----	----
EP094S: Pesticide Surrogate								
DEF	78-48-8	0.05	%	**90.2**	----	----	----	----
EP132S: Acid Extractable Surrogates								
2-Fluorophenol	367-12-4	10	%	**71.8**	----	----	----	----
Phenol-d6	13127-88-3	10	%	**76.9**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	10	%	**77.9**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	10	%	**72.7**	----	----	----	----
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	**73.4**	----	----	----	----
Anthracene-d10	1719-06-8	10	%	**85.0**	----	----	----	----
4-Terphenyl-d14	1718-51-0	10	%	**99.0**	----	----	----	----
EP201S: Carbamate Surrogate								
4-Bromo-3.5-dimethylphenyl-N-methylcarbamate	672-99-1	0.02	%	**86.0**	----	----	----	----
EP202S: Phenoxyacetic Acid Herbicide Surrogate								
2.4-Dichlorophenyl Acetic Acid	19719-28-9	0.02	%	**91.4**	----	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**PDC Ilmenite**	**Combinded Monazite Reject**	**Hyti**	**Combinded Zircon Wet Tails**	**Rutile Wet Circuit Concentrate**
			Client sampling date / time	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]	[11-Nov-2014]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1447303-001**	**EB1447303-002**	**EB1447303-003**	**EB1447303-004**	**EB1447303-005**
				Result	Result	Result	Result	Result
EP068F: Miscellaneous Pesticides								
Fipronil	120068-37-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Fenitrothion	122-14-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP094A: Synthetic Pyrethroids								
Bifenthrin	82657-04-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Lambda-cyhalothrin	68085-85-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Permethrin	52645-53-1	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Cyfluthrin	68359-37-5	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Cypermethrin	52315-07-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Deltamethrin & Tralomethrin	62229-77-0/66841-25-	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP068T: Organophosphorus Pesticide Surrogate								
DEF	78-48-8	0.5	%	**22.0**	**106**	**85.3**	**105**	**107**
EP094S: Pesticide Surrogate								
DEF	78-48-8	0.5	%	**22.0**	**106**	**85.3**	**105**	**107**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**PDC Conductors O/seze + 410µm**	**----**	**----**	**----**	**----**
			Client sampling date / time	[11-Nov-2014]	----	----	----	----
Compound	CAS Number	LOR	Unit	**EB1447303-006**	**--------**	**--------**	**--------**	**--------**
				Result	Result	Result	Result	Result
EP068F: Miscellaneous Pesticides								
Fipronil	120068-37-3	0.5	µg/L	<0.5	----	----	----	----
Fenitrothion	122-14-5	0.5	µg/L	<0.5	----	----	----	----
EP094A: Synthetic Pyrethroids								
Bifenthrin	82657-04-3	0.5	µg/L	<0.5	----	----	----	----
Lambda-cyhalothrin	68085-85-8	0.5	µg/L	<0.5	----	----	----	----
Permethrin	52645-53-1	0.5	µg/L	<0.5	----	----	----	----
Cyfluthrin	68359-37-5	0.5	µg/L	<0.5	----	----	----	----
Cypermethrin	52315-07-8	0.5	µg/L	<0.5	----	----	----	----
Deltamethrin & Tralomethrin	62229-77-0/66841-25-	0.5	µg/L	<0.5	----	----	----	----
EP068T: Organophosphorus Pesticide Surrogate								
DEF	78-48-8	0.5	%	**108**	----	----	----	----
EP094S: Pesticide Surrogate								
DEF	78-48-8	0.5	%	**108**	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EM1413773**	Page	: 1 of 15
Amendment	: **1**		
Client	: **EARTH SYSTEMS PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MR NIC BOURGEOT	Contact	: Client Services
Address	: SUITE 17 79-83 HIGH STREET KEW VIC, AUSTRALIA 3101	Address	: 4 Westall Rd Springvale VIC Australia 3171
E-mail	: nic.bourgeot@earthsystems.com.au	E-mail	: Melbourne.Enviro.Services@alsglobal.com
Telephone	: +61 03 9810 7500	Telephone	: +61-3-8549 9600
Facsimile	: +61 03 9853 5030	Facsimile	: +61-3-8549 9601
Project	: ILUKA1485	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 24-DEC-2014
Sampler	: NB	Issue Date	: 10-FEB-2015
Site	: ----		
		No. of samples received	: 1
Quote number	: MEBQ/112/14	No. of samples analysed	: 1

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key :	CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
	LOR = Limit of reporting
	^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA033 (CRS Suite): ANC not required because pH KCl less than 6.5**
- **ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.**
- **Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero, for 'TEQ 1/2LOR' are treated as half the reported LOR, and for 'TEQ LOR' are treated as being equal to the reported LOR. Note: TEQ 1/2LOR and TEQ LOR will calculate as 0.6mg/Kg and 1.2mg/Kg respectively for samples with non-detects for all of the eight TEQ PAHs.**
- **Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero.**
- **Due to insufficient sample ZHE Leach Prep (EN33Za) and Leachate Volatile Compounds (EP074) was not able to be reported.**
- **EP075: 'Sum of PAH' is the sum of the USEPA 16 priority PAHs**
- **EP202: Particular samples required dilution due to matrix interferences. LOR values have been adjusted accordingly.**
- **EP202: Poor matrix spike recoveries due to matrix effects.**
- **Fluoride (EK040T) conducted by ALS Newcastle, NATA accreditation no. 825, site no 1656.**
- **This report has been amended and re-released to allow the reporting of additional analytical data. 5/2/15**
- **ZHE Leach Prep (EN33Za), Leachate Volatile Compounds (EP074), Semi-Volatiles Compounds (EP075k/76), Hexachlorophene (EP132), Thiodicarb (EP201), Glyphosate (EP204), Herbicides (EP202), PCB (EP066), Triazines (EP068) and Tebuconazole (EP234) conducted by ALS Sydney, NATA accreditation no. 825, site no 10911.**

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics
Gaston Allende	R&D Chemist	Sydney Organics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Phalak Inthakesone	Laboratory Manager - Organics	Sydney Organics
Ryan Story	2IC Organic Instrument Chemist	Brisbane Organics
Satishkumar Trivedi	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	23-DEC-2014 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**3.4**	----	----	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	**73**	----	----	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	**0.12**	----	----	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**15.7**	----	----	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**9800**	----	----	----	----
EA033-D: Retained Acidity								
KCl Extractable Sulfur (23Ce)	----	0.02	% S	**0.48**	----	----	----	----
HCl Extractable Sulfur (20Be)	----	0.02	% S	**0.75**	----	----	----	----
Net Acid Soluble Sulfur (20Je)	----	0.02	% S	**0.28**	----	----	----	----
acidity - Net Acid Soluble Sulfur (a-20J)	----	10	mole H+ / t	**129**	----	----	----	----
sulfidic - Net Acid Soluble Sulfur (s-20J)	----	0.02	% pyrite S	**0.21**	----	----	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	----	----	----	----
Net Acidity (sulfur units)	----	0.02	% S	**16.0**	----	----	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	**10000**	----	----	----	----
Liming Rate	----	1	kg CaCO3/t	**750**	----	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**18.2**	----	----	----	----
EG005T: Total Metals by ICP-AES								
Antimony	7440-36-0	5	mg/kg	<5	----	----	----	----
Arsenic	7440-38-2	5	mg/kg	**357**	----	----	----	----
Barium	7440-39-3	10	mg/kg	**20**	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
Boron	7440-42-8	50	mg/kg	<50	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	----	----	----	----
Copper	7440-50-8	5	mg/kg	**37**	----	----	----	----
Lead	7439-92-1	5	mg/kg	**288**	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	**4**	----	----	----	----
Nickel	7440-02-0	2	mg/kg	**50**	----	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	23-DEC-2014 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EG005T: Total Metals by ICP-AES - Continued								
Silver	7440-22-4	2	mg/kg	<2	----	----	----	----
Zinc	7440-66-6	5	mg/kg	**62**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	----	----	----
EG048: Hexavalent Chromium (Alkaline Digest)								
Hexavalent Chromium	18540-29-9	0.5	mg/kg	<0.5	----	----	----	----
EK026SF: Total CN by Segmented Flow Analyser								
Total Cyanide	57-12-5	1	mg/kg	<1	----	----	----	----
EK028SF: Weak Acid Dissociable CN by Segmented Flow Analyser								
Weak Acid Dissociable Cyanide	----	1	mg/kg	<1	----	----	----	----
EK040T: Fluoride Total								
Fluoride	16984-48-8	40	mg/kg	<40	----	----	----	----
EN33: TCLP Leach								
Initial pH	----	0.1	pH Unit	**3.6**	----	----	----	----
Extraction Fluid Number	----	1	-	**1**	----	----	----	----
Final pH	----	0.1	pH Unit	**4.9**	----	----	----	----
EP066: Polychlorinated Biphenyls (PCB)								
Total Polychlorinated biphenyls	----	0.1	mg/kg	<0.1	----	----	----	----
EP068C: Triazines								
Atrazine	1912-24-9	0.05	mg/kg	<0.05	----	----	----	----
Simazine	122-34-9	0.05	mg/kg	<0.05	----	----	----	----
EP071 SG: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Silica gel cleanup								
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	----	----	----	----
>C16 - C34 Fraction	----	100	mg/kg	<100	----	----	----	----
>C34 - C40 Fraction	----	100	mg/kg	<100	----	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg	<50	----	----	----	----
EP071 SG-S: Total Petroleum Hydrocarbons in Soil - Silica gel cleanup								
C10 - C14 Fraction	----	50	mg/kg	<50	----	----	----	----
C15 - C28 Fraction	----	100	mg/kg	<100	----	----	----	----
C29 - C36 Fraction	----	100	mg/kg	<100	----	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg	<50	----	----	----	----
EP074A: Monocyclic Aromatic Hydrocarbons								
Benzene	71-43-2	0.2	mg/kg	<0.2	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

			Client sample ID	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	23-DEC-2014 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EP074A: Monocyclic Aromatic Hydrocarbons - Continued								
Toluene	108-88-3	0.5	mg/kg	<0.5	----	----	----	----
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	----	----	----	----
Styrene	100-42-5	0.5	mg/kg	<0.5	----	----	----	----
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	----	----	----	----
EP074B: Oxygenated Compounds								
2-Butanone (MEK)	78-93-3	5	mg/kg	<5	----	----	----	----
EP074E: Halogenated Aliphatic Compounds								
Vinyl chloride	75-01-4	4	mg/kg	<4	----	----	----	----
1.1-Dichloroethene	75-35-4	0.5	mg/kg	<0.5	----	----	----	----
Methylene chloride	75-09-2	0.5	mg/kg	<0.5	----	----	----	----
1.1.1-Trichloroethane	71-55-6	0.5	mg/kg	<0.5	----	----	----	----
Carbon Tetrachloride	56-23-5	0.5	mg/kg	<0.5	----	----	----	----
1.2-Dichloroethane	107-06-2	0.5	mg/kg	<0.5	----	----	----	----
Trichloroethene	79-01-6	0.5	mg/kg	<0.5	----	----	----	----
1.1.2-Trichloroethane	79-00-5	0.5	mg/kg	<0.5	----	----	----	----
Tetrachloroethene	127-18-4	0.5	mg/kg	<0.5	----	----	----	----
1.1.1.2-Tetrachloroethane	630-20-6	0.5	mg/kg	<0.5	----	----	----	----
1.1.2.2-Tetrachloroethane	79-34-5	0.5	mg/kg	<0.5	----	----	----	----
EP074F: Halogenated Aromatic Compounds								
Chlorobenzene	108-90-7	0.5	mg/kg	<0.5	----	----	----	----
EP074G: Trihalomethanes								
Chloroform	67-66-3	0.5	mg/kg	<0.5	----	----	----	----
EP075K: Miscellaneous Compounds								
Isodrin	465-73-6	0.5	mg/kg	<0.5	----	----	----	----
EP076A: Phenolic Compounds (Chlorinated)								
2-Chlorophenol	95-57-8	0.5	mg/kg	<0.5	----	----	----	----
Phenol	108-95-2	0.5	mg/kg	<0.5	----	----	----	----
2-Methylphenol	95-48-7	0.5	mg/kg	<0.5	----	----	----	----
3- & 4-Methylphenol	1319-77-3	0.5	mg/kg	<0.5	----	----	----	----
2.4-Dichlorophenol	120-83-2	0.5	mg/kg	<0.5	----	----	----	----
4-Chloro-3-methylphenol	59-50-7	0.5	mg/kg	<0.5	----	----	----	----
2.4.5-Trichlorophenol	95-95-4	0.5	mg/kg	<0.5	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

			Client sample ID	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	23-DEC-2014 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EP076A: Phenolic Compounds (Chlorinated) - Continued								
2.4.6-Trichlorophenol	88-06-2	0.5	mg/kg	<0.5	----	----	----	----
2.3.4.6-Tetrachlorophenol	58-90-2	0.5	mg/kg	<0.5	----	----	----	----
Pentachlorophenol	87-86-5	0.5	mg/kg	<0.5	----	----	----	----
EP076B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	0.5	mg/kg	<0.5	----	----	----	----
Acenaphthylene	208-96-8	0.5	mg/kg	<0.5	----	----	----	----
Acenaphthene	83-32-9	0.5	mg/kg	<0.5	----	----	----	----
Fluorene	86-73-7	0.5	mg/kg	<0.5	----	----	----	----
Phenanthrene	85-01-8	0.5	mg/kg	<0.5	----	----	----	----
Anthracene	120-12-7	0.5	mg/kg	<0.5	----	----	----	----
Fluoranthene	206-44-0	0.5	mg/kg	<0.5	----	----	----	----
Pyrene	129-00-0	0.5	mg/kg	<0.5	----	----	----	----
Benz(a)anthracene	56-55-3	0.5	mg/kg	<0.5	----	----	----	----
Chrysene	218-01-9	0.5	mg/kg	<0.5	----	----	----	----
Benzo(b+j) & Benzo(k)fluoranthene	205-99-2 207-08-9	0.5	mg/kg	<0.5	----	----	----	----
Benzo(a)pyrene	50-32-8	0.50	mg/kg	<0.50	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	0.5	mg/kg	<0.5	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	0.5	mg/kg	<0.5	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	0.5	mg/kg	<0.5	----	----	----	----
EP076C: Phthalate Esters								
bis(2-ethylhexyl) phthalate	117-81-7	0.5	mg/kg	<0.5	----	----	----	----
EP076E: Nitroaromatics and Ketones								
Nitrobenzene	98-95-3	0.5	mg/kg	<0.5	----	----	----	----
2.4-Dinitrotoluene	121-14-2	0.5	mg/kg	<0.5	----	----	----	----
Pentachloronitrobenzene	82-68-8	0.5	mg/kg	<0.5	----	----	----	----
EP076G: Chlorinated Hydrocarbons								
Hexachlorobutadiene	87-68-3	0.05	mg/kg	<0.05	----	----	----	----
EP076G: Chlorinated Hydrocarbons (Aromatic)								
1.4-Dichlorobenzene	106-46-7	0.5	mg/kg	<0.5	----	----	----	----
1.2-Dichlorobenzene	95-50-1	0.5	mg/kg	<0.5	----	----	----	----
1.3.5-Trichlorobenzene	108-70-3	0.5	mg/kg	<0.5	----	----	----	----
1.2.4-Trichlorobenzene	120-82-1	0.5	mg/kg	<0.5	----	----	----	----
1.2.3-Trichlorobenzene	87-61-6	0.5	mg/kg	<0.5	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	23-DEC-2014 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EP076G: Chlorinated Hydrocarbons (Aromatic) - Continued								
1.2.3.4-Tetrachlorobenzene	634-66-2	0.5	mg/kg	<0.5	----	----	----	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	634-90-2/95-94-3	0.5	mg/kg	<0.5	----	----	----	----
Pentachlorobenzene	608-93-5	0.5	mg/kg	<0.5	----	----	----	----
EP076I: Organochlorine Pesticides								
Hexachlorobenzene (HCB)	118-74-1	0.05	mg/kg	<0.05	----	----	----	----
alpha-BHC	319-84-6	0.05	mg/kg	<0.05	----	----	----	----
beta-BHC	319-85-7	0.05	mg/kg	<0.05	----	----	----	----
gamma-BHC	58-89-9	0.05	mg/kg	<0.05	----	----	----	----
delta-BHC	319-86-8	0.05	mg/kg	<0.05	----	----	----	----
Heptachlor	76-44-8	0.05	mg/kg	<0.05	----	----	----	----
Aldrin	309-00-2	0.05	mg/kg	<0.05	----	----	----	----
Heptachlor epoxide	1024-57-3	0.05	mg/kg	<0.05	----	----	----	----
alpha-Endosulfan	959-98-8	0.05	mg/kg	<0.05	----	----	----	----
4.4`-DDE	72-55-9	0.05	mg/kg	<0.05	----	----	----	----
trans-Chlordane	5103-74-2	0.05	mg/kg	<0.05	----	----	----	----
Dieldrin	60-57-1	0.05	mg/kg	<0.05	----	----	----	----
Endrin	72-20-8	0.05	mg/kg	<0.05	----	----	----	----
cis-Chlordane	5103-71-9	0.05	mg/kg	<0.05	----	----	----	----
beta-Endosulfan	33213-65-9	0.05	mg/kg	<0.05	----	----	----	----
4.4`-DDD	72-54-8	0.05	mg/kg	<0.05	----	----	----	----
Endosulfan sulfate	1031-07-8	0.05	mg/kg	<0.05	----	----	----	----
4.4`-DDT	50-29-3	0.2	mg/kg	<0.2	----	----	----	----
Endrin aldehyde	7421-93-4	0.05	mg/kg	<0.05	----	----	----	----
EP076J: Organophosphorus Pesticides								
Dichlorvos	62-73-7	0.05	mg/kg	<0.05	----	----	----	----
Dimethoate	60-51-5	0.05	mg/kg	<0.05	----	----	----	----
Chlorpyrifos-methyl	5598-13-0	0.05	mg/kg	<0.05	----	----	----	----
Malathion	121-75-5	0.05	mg/kg	<0.05	----	----	----	----
Fenthion	55-38-9	0.05	mg/kg	<0.05	----	----	----	----
Parathion-methyl	298-00-0	0.2	mg/kg	<0.2	----	----	----	----
Chlorpyrifos	2921-88-2	0.05	mg/kg	<0.05	----	----	----	----
Ethion	563-12-2	0.05	mg/kg	<0.05	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Client sample ID	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	23-DEC-2014 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	**EM1413773-001**	**----**	**----**	**----**	**----**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	----	----	----	----
EP132A: Phenolic Compounds								
Hexachlorophene	70-30-4	10	µg/kg	<10	----	----	----	----
EP201: Carbamate Pesticides by LCMS								
Thiodicarb	59669-26-0	0.02	mg/kg	<0.02	----	----	----	----
EP202A: Phenoxyacetic Acid Herbicides by LCMS								
2.4-D	94-75-7	0.02	mg/kg	<0.04	----	----	----	----
Triclopyr	55335-06-3	0.02	mg/kg	<0.04	----	----	----	----
2.4.5-TP (Silvex)	93-72-1	0.02	mg/kg	<0.04	----	----	----	----
2.4.5-T	93-76-5	0.02	mg/kg	<0.04	----	----	----	----
Picloram	1918-02-1	0.02	mg/kg	<0.04	----	----	----	----
Fluroxypyr	69377-81-7	0.02	mg/kg	<0.04	----	----	----	----
EP204: Glyphosate and AMPA								
Glyphosate	1071-83-6	0.5	mg/kg	<0.5	----	----	----	----
EP066S: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.1	%	**108**	----	----	----	----
EP068S: Organochlorine Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.1	%	**72.8**	----	----	----	----
EP068T: Organophosphorus Pesticide Surrogate								
DEF	78-48-8	0.1	%	**71.2**	----	----	----	----
EP074S: VOC Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**83.4**	----	----	----	----
Toluene-D8	2037-26-5	0.1	%	**86.7**	----	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**86.7**	----	----	----	----
EP076S: Acid Extractable Surrogates								
2-Fluorophenol	367-12-4	0.1	%	**114**	----	----	----	----
Phenol-d6	13127-88-3	0.1	%	**90.6**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	**94.6**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	**106**	----	----	----	----
EP076T: Base-Neutral Surrogate Compounds								
Nitrobenzene-D5	4165-60-0	0.1	%	**108**	----	----	----	----

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Client sample ID	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	23-DEC-2014 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	**EM1413773-001**	----	----	----	----
EP076T: Base-Neutral Surrogate Compounds - Continued								
1.2-Dichlorobenzene-D4	2199-69-1	0.1	%	**95.9**	----	----	----	----
2-Fluorobiphenyl	321-60-8	0.1	%	**104**	----	----	----	----
Anthracene-d10	1719-06-8	0.1	%	**109**	----	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	**130**	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**90.0**	----	----	----	----
Toluene-D8	2037-26-5	0.1	%	**88.4**	----	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**82.1**	----	----	----	----
EP132S: Acid Extractable Surrogates								
2-Fluorophenol	367-12-4	0.1	%	**91.8**	----	----	----	----
Phenol-d6	13127-88-3	0.1	%	**97.1**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	**89.9**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	**110**	----	----	----	----
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	**102**	----	----	----	----
Anthracene-d10	1719-06-8	0.1	%	**75.0**	----	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	**91.9**	----	----	----	----
EP201S: Carbamate Surrogate								
4-Bromo-3.5-dimethylphenyl-N-methylcarbamate	672-99-1	0.1	%	**103**	----	----	----	----
EP202S: Phenoxyacetic Acid Herbicide Surrogate								
2.4-Dichlorophenyl Acetic Acid	19719-28-9	0.1	%	**121**	----	----	----	----

Analytical Results

Sub-Matrix: **TCLP LEACHATE** (Matrix: **WATER**)			Client sample ID	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	06-JAN-2015 12:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EG005C: Leachable Metals by ICPAES								
Aluminium	7429-90-5	0.1	mg/L	**0.1**	----	----	----	----
Antimony	7440-36-0	0.01	mg/L	<0.01	----	----	----	----
Arsenic	7440-38-2	0.1	mg/L	<0.1	----	----	----	----
Barium	7440-39-3	0.1	mg/L	**0.4**	----	----	----	----
Beryllium	7440-41-7	0.05	mg/L	<0.05	----	----	----	----
Boron	7440-42-8	0.1	mg/L	**0.2**	----	----	----	----
Cadmium	7440-43-9	0.05	mg/L	<0.05	----	----	----	----
Chromium	7440-47-3	0.01	mg/L	**0.01**	----	----	----	----
Cobalt	7440-48-4	0.01	mg/L	**0.2**	----	----	----	----
Copper	7440-50-8	0.01	mg/L	**0.02**	----	----	----	----
Iron	7439-89-6	0.01	mg/L	**0.6**	----	----	----	----
Lead	7439-92-1	0.1	mg/L	<0.1	----	----	----	----
Manganese	7439-96-5	0.01	mg/L	**0.3**	----	----	----	----
Nickel	7440-02-0	0.1	mg/L	**0.3**	----	----	----	----
Selenium	7782-49-2	0.05	mg/L	<0.05	----	----	----	----
Silver	7440-22-4	0.1	mg/L	<0.1	----	----	----	----
Strontium	7440-24-6	0.1	mg/L	**0.2**	----	----	----	----
Tin	7440-31-5	0.01	mg/L	<0.01	----	----	----	----
Titanium	7440-32-6	0.01	mg/L	**0.02**	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.1	mg/L	**0.8**	----	----	----	----
Molybdenum	7439-98-7	0.1	mg/L	<0.1	----	----	----	----
EG035C: Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0010	mg/L	<0.0010	----	----	----	----
EG050G: Hexavalent Chromium by Discrete Analyser								
Hexavalent Chromium	18540-29-9	0.01	mg/L	<0.01	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.1**	----	----	----	----
EP068A: Organochlorine Pesticides (OC)								
alpha-Endosulfan	959-98-8	0.5	µg/L	<0.5	----	----	----	----
beta-Endosulfan	33213-65-9	0.5	µg/L	<0.5	----	----	----	----
Endosulfan sulfate	1031-07-8	0.5	µg/L	<0.5	----	----	----	----
EP068B: Organophosphorus Pesticides (OP)								

Analytical Results

Sub-Matrix: **TCLP LEACHATE** (Matrix: **WATER**)			*Client sample ID*	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	06-JAN-2015 12:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EP068B: Organophosphorus Pesticides (OP) - Continued								
Chlorpyrifos	2921-88-2	0.5	µg/L	<0.5	----	----	----	----
EP075A: Phenolic Compounds								
Phenol	108-95-2	2	µg/L	<2	----	----	----	----
2-Chlorophenol	95-57-8	2	µg/L	<2	----	----	----	----
2-Methylphenol	95-48-7	2	µg/L	<2	----	----	----	----
3- & 4-Methylphenol	1319-77-3	2	µg/L	<2	----	----	----	----
2.4-Dichlorophenol	120-83-2	2	µg/L	<2	----	----	----	----
2.4.6-Trichlorophenol	88-06-2	2	µg/L	<2	----	----	----	----
2.4.5-Trichlorophenol	95-95-4	2	µg/L	<2	----	----	----	----
EP075B: Polynuclear Aromatic Hydrocarbons								
Benzo(a)pyrene	50-32-8	2	µg/L	<2	----	----	----	----
EP075C: Phthalate Esters								
bis(2-ethylhexyl) phthalate	117-81-7	5	µg/L	<5	----	----	----	----
EP075E: Nitroaromatics and Ketones								
Nitrobenzene	98-95-3	2	µg/L	<2	----	----	----	----
2.4-Dinitrotoluene	121-14-2	4	µg/L	<4	----	----	----	----
EP075G: Chlorinated Hydrocarbons								
1.4-Dichlorobenzene	106-46-7	2	µg/L	<2	----	----	----	----
1.2-Dichlorobenzene	95-50-1	2	µg/L	<2	----	----	----	----
Hexachlorobutadiene	87-68-3	2	µg/L	<2	----	----	----	----
EP202A: Phenoxyacetic Acid Herbicides by LCMS								
2.4-D	94-75-7	10	µg/L	<10	----	----	----	----
Triclopyr	55335-06-3	10	µg/L	<10	----	----	----	----
Picloram	1918-02-1	10	µg/L	<10	----	----	----	----
Fluroxypyr	69377-81-7	10	µg/L	<10	----	----	----	----
EP234E: Conazole and Aminopyrimidine Fungicides								
Tebuconazole	107534-96-3	0.01	µg/L	<0.01	----	----	----	----
EP068S: Organochlorine Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.1	%	**117**	----	----	----	----
EP068T: Organophosphorus Pesticide Surrogate								
DEF	78-48-8	0.1	%	**134**	----	----	----	----
EP075S: Acid Extractable Surrogates								
2-Fluorophenol	367-12-4	0.1	%	**104**	----	----	----	----

Analytical Results

Sub-Matrix: **TCLP LEACHATE** (Matrix: **WATER**)			*Client sample ID*	**3785 Flot Conc RSV's**	----	----	----	----
			Client sampling date / time	06-JAN-2015 12:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM1413773-001**	**----**	**----**	**----**	**----**
EP075S: Acid Extractable Surrogates - Continued								
Phenol-d6	13127-88-3	0.1	%	**32.8**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	**85.6**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	**104**	----	----	----	----
EP075T: Base/Neutral Extractable Surrogates								
Nitrobenzene-D5	4165-60-0	0.1	%	**87.5**	----	----	----	----
1.2-Dichlorobenzene-D4	2199-69-1	0.1	%	**90.4**	----	----	----	----
2-Fluorobiphenyl	321-60-8	0.1	%	**111**	----	----	----	----
Anthracene-d10	1719-06-8	0.1	%	**123**	----	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	**134**	----	----	----	----
EP202S: Phenoxyacetic Acid Herbicide Surrogate								
2.4-Dichlorophenyl Acetic Acid	19719-28-9	0.1	%	**93.0**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%)	
		Low	High
EP066S: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	39	149
EP068S: Organochlorine Pesticide Surrogate			
Dibromo-DDE	21655-73-2	49	147
EP068T: Organophosphorus Pesticide Surrogate			
DEF	78-48-8	35	143
EP074S: VOC Surrogates			
1.2-Dichloroethane-D4	17060-07-0	64	130
Toluene-D8	2037-26-5	66	136
4-Bromofluorobenzene	460-00-4	60	122
EP076S: Acid Extractable Surrogates			
2-Fluorophenol	367-12-4	25	121
Phenol-d6	13127-88-3	24	113
2-Chlorophenol-D4	93951-73-6	23	134
2.4.6-Tribromophenol	118-79-6	19	122
EP076T: Base-Neutral Surrogate Compounds			
Nitrobenzene-D5	4165-60-0	23	120
1.2-Dichlorobenzene-D4	2199-69-1	32	129
2-Fluorobiphenyl	321-60-8	30	115
Anthracene-d10	1719-06-8	27	133
4-Terphenyl-d14	1718-51-0	18	137
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	72.8	133.2
Toluene-D8	2037-26-5	73.9	132.1
4-Bromofluorobenzene	460-00-4	71.6	130.0
EP132S: Acid Extractable Surrogates			
2-Fluorophenol	367-12-4	25	121
Phenol-d6	13127-88-3	24.6	121
2-Chlorophenol-D4	93951-73-6	21.3	137
2.4.6-Tribromophenol	118-79-6	19	122
EP132T: Base/Neutral Extractable Surrogates			
2-Fluorobiphenyl	321-60-8	26.9	131
Anthracene-d10	1719-06-8	35	139
4-Terphenyl-d14	1718-51-0	29.7	164
EP201S: Carbamate Surrogate			
4-Bromo-3.5-dimethylphenyl-N-methylcarbamate	672-99-1	59	137
EP202S: Phenoxyacetic Acid Herbicide Surrogate			
2.4-Dichlorophenyl Acetic Acid	19719-28-9	45	139

Sub-Matrix: **TCLP LEACHATE**

Compound	*CAS Number*	*Recovery Limits (%)* Low	*Recovery Limits (%)* High
EP068S: Organochlorine Pesticide Surrogate			
Dibromo-DDE	21655-73-2	40.4	134.4
EP068T: Organophosphorus Pesticide Surrogate			
DEF	78-48-8	41.8	143.3
EP075S: Acid Extractable Surrogates			
2-Fluorophenol	367-12-4	10.0	126.5
Phenol-d6	13127-88-3	10.0	128.8
2-Chlorophenol-D4	93951-73-6	20.3	138.1
2.4.6-Tribromophenol	118-79-6	13.7	162.7
EP075T: Base/Neutral Extractable Surrogates			
Nitrobenzene-D5	4165-60-0	34.0	139.3
1.2-Dichlorobenzene-D4	2199-69-1	10.0	128.7
2-Fluorobiphenyl	321-60-8	18.7	145.1
Anthracene-d10	1719-06-8	32.7	160.2
4-Terphenyl-d14	1718-51-0	31.5	177.3
EP202S: Phenoxyacetic Acid Herbicide Surrogate			
2.4-Dichlorophenyl Acetic Acid	19719-28-9	64	140

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MEMORANDUM

TO: Rob Piccinin and David Dettrick, Earth Systems **DATE:** 4 February 2015

FROM: Sue Brown, ANSTO Minerals **No. of Pages:** 12 inclusive

SUBJECT: Waste Classification of Mining By-Products

Earth Systems requested[1] ANSTO Minerals (AM) to undertake radioactivity analysis of mining by-products (MBP's). Seven (7) samples were received on 5 January 2015. The sample identifications, together with corresponding AM numbers, are given in **Table 1**.

Table 1
Sample Identification

Client ID	AM ID
PDC Ilmenite	ES-050115-1
Combined Monazite Reject	ES-050115-2
Hyti	ES-050115-3
Combined Zircon Wet Tails	ES-050115-4
Rutile Wet Circuit Concentrate	ES-050115-5
Float tails sample	ES-050115-6
PDC Conductors O/size +410 µm	ES-050115-7

The samples were dried to constant weight and then pulverised for assay. The following techniques were used in the analysis, depending upon the elemental content:

- Gamma spectrometry for U-238 and Th-232 decay progeny and U-235 and its decay progeny
- Delayed neutron activation (DNA) analysis or fusion/acid digest followed by ICPMS for parent U-238
- Neutron activation analysis (NAA) analysis or fusion/acid digest followed by ICPMS for parent Th-232
- Alpha spectrometry for Po-210
- X-Ray Fluorescence Spectrometry (XRF) analysis for elemental content. This data was used for self-absorption corrections in gamma spectrometry.

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[1] Email dated 18 December 2014 from D. Dettrick to S. Brown.

MEMORANDUM

The radionuclide results are given in **Table 2**. The Po-210 concentrations were low in comparison to other radionuclides in the U-238 decay chain for all samples, although the concentration of 0.34 Bq/g for the Hiti sample is within the analytical error. Polonium-210 is determined by alpha spectrometry, which is a very sensitive technique, however, because of its volatile nature, high temperature dissolution processes (e.g. fusion) cannot be used. Fusion/acid digestion procedures are preferred for dissolution of samples containing Ti and Zr and so, the low Po-210 results indicate that the samples did not completely dissolve in the standard acid digestion procedure used for Po-210 analysis. Since Po-210 will reach equilibrium with its parent, Pb-210, in ~2 years, in the geological timeframe, there is no reason to assume that Po-210 is not in secular equilibrium with its parent, Pb-210.

Table 2
Radionuclide Results (Bq/g)

Client ID	PDC Ilmenite	Combined Monazite Reject	Hyti	Combined Zircon Wet Tails	Rutile Wet Circuit Concentrate	Float Tails Sample	PDC Conductors O/size +410 µm
ANSTO ID	ES-050115-1	ES-050115-2	ES-050115-3	ES-050115-4	ES-050115-5	ES-050115-6	ES-050115-7
Th-232 Decay Chain							
Th-232	0.22 ± 0.02	77 ± 8	1.3 ± 0.2	0.56 ± 0.06	1.0 ± 0.1	0.30 ± 0.03	0.89 ± 0.09
Ra-228	0.22 ± 0.02	68 ± 7	1.2 ± 0.1	0.30 ± 0.03	0.91 ± 0.09	0.27 ± 0.03	0.86 ± 0.09
Th-228	0.19 ± 0.02	75 ± 8	1.3 ± 0.1	0.30 ± 0.03	0.90 ± 0.09	0.27 ± 0.03	0.86 ± 0.09
U-238 Decay Chain							
U-238	0.11 ± 0.05	14 ± 1	0.42 ± 0.01	1.01 ± 0.02	0.58 ± 0.02	0.48 ± 0.02	0.81 ± 0.03
Th-230	0.12 ± 0.02	17 ± 4	0.5 ± 0.1	0.78 ± 0.08	0.51 ± 0.08	< 0.30	0.9 ± 0.2
Ra-226	0.12 ± 0.01	13 ± 1	0.47 ± 0.05	0.83 ± 0.08	0.58 ± 0.06	0.39 ± 0.04	0.82 ± 0.08
Pb-210	0.14 ± 0.02	13 ± 1	0.42 ± 0.04	0.72 ± 0.07	0.47 ± 0.05	0.33 ± 0.03	0.68 ± 0.07
Po-210	0.03 ± 0.02	8.0 ± 0.7	0.34 ± 0.08	0.30 ± 0.06	0.16 ± 0.04	0.25 ± 0.07	0.31 ± 0.07
U-235 Decay Chain							
U-235	0.0051 ± 0.0023	0.65 ± 0.05	0.0194 ± 0.0005	0.0466 ± 0.0009	0.0268 ± 0.0009	0.0222 ± 0.0009	0.037 ± 0.0014
Pa-231	< 0.026	0.8 ± 0.2	< 0.069	< 0.039	< 0.043	< 0.064	< 0.13
Ac-227	< 0.0053	1.0 ± 0.1	0.028 ± 0.005	0.046 ± 0.005	0.030 ± 0.003	0.019 ± 0.003	0.047 ± 0.008
Th-227	< 0.0053	1.0 ± 0.1	0.028 ± 0.005	0.045 ± 0.005	0.030 ± 0.003	0.019 ± 0.003	0.047 ± 0.008
K-40	0.026 ± 0.007	< 0.32	0.10 ± 0.02	< 0.024	0.07 ± 0.01	< 0.044	0.30 ± 0.05

MEMORANDUM

The radionuclide results were then used to assess the MBP's in accordance with the requirements of the NSW EPA Waste Classification Guidelines, Part 3: Waste containing radioactive material (radioactive waste), based on AM understanding and interpretation of said Guidelines. It is recommended that the client confirm these classifications with the Regulator at the appropriate time.

MBP's classified as hazardous wastes[2] were identified according to Step 2 of the Guidelines.

MBP's not classified as hazardous wastes were assessed according to Step 3 of the Guidelines – "*For liquid or non-liquid wastes with a specific activity of 100 becquerels per gram or less and/or consisting of, or containing, the prescribed activity or less of a radioactive element in Schedule 1 of the Radiation Control Regulation 2013, whether natural or artificial, the total activity ratio and specific activity ratio must be calculated according to the mathematical expressions below*:

Total activity ratio = $(A1 \times 10^{-3}) + (A2 \times 10^{-4}) + (A3 \times 10^{-5}) + (A4 \times 10^{-6})$

where A1 to A4 are the total activity[3] *of Group 1 to Group 4 radionuclides, as set out in Column 1 of Schedule 1 of the Radiation Control Regulation 2013; and*

Specific activity ratio = $SA1 + (SA2 \times 10^{-1}) + (SA3 \times 10^{-2}) + (SA4 \times 10^{-3})$

where SA1 to SA4 are the specific activity (of the material) of Group 1 to Group 4 radionuclides, as set out in Column 1 of Schedule 1 of the Radiation Control Regulation 2013".

However, because no information was supplied by the client for the total masses of the respective MBP's to be disposed of, the total activities, and hence total activity ratios, could not be determined. Classification for MBP's with a specific activity < 100 Bq/g was, therefore, made based on the respective specific activity ratios. It should be noted that for one (1) gram of material, the total activities of the Group 1 to 4 radionuclides

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[2] Non-liquid wastes with a specific activity greater than 100 becquerels per gram and consisting of, or containing more than, the prescribed activity of a radioactive element in Schedule 1 of the Radiation Control Regulation 2013, whether natural or artificial.

[3] Total activity of a material means the activity of the whole of the material in which the radionuclides are essentially uniformly distributed (determined using 1-kilogram representative samples of the whole material).

(A1, A2, A3, A4) are the same as the specific activities of the Group 1 to 4 radionuclides (SA1, SA2, SA3, SA4).

It should also be noted that in all calculations, the concentration of Po-210 has been assumed to be the same as that of its parent, Pb-210.

Table 3 summarises the waste classification for each MBP. A detailed assessment for each MBP is given in **Appendix 1**. The combined monazite reject was the only sample that contained a specific activity (of the material) of > 100 Bq/g. The Guidelines (Step 2) state that "*Liquid or non-liquid wastes with a specific activity greater than 100 becquerels per gram and consisting of, or containing more than, the prescribed activity of a radioactive element in Schedule 1 of the Radiation Control Regulation 2013, whether natural or artificial, must be classified as hazardous wastes*." Since the total activity of the Group 1 radionuclides (≡ SA1) is 460 Bq/g in this sample, a material weight for disposal in excess of 87 g exceeds the prescribed activity for Group 1 radionuclides in Schedule 1 of the Radiation Control Regulation 2013 (40 kBq). The combined monazite reject was classified as hazardous.

Table 3
Waste Classification for Mining By-Products

Client ID	Classification	Specific Activity Ratio
PDC Ilmenite	restricted solid	1.9
Combined Monazite Reject	hazardous (if > 87 g is being disposed of)	-
Hyti	restricted solid	10
Combined Zircon Wet Tails	restricted solid	7.7
Rutile Wet Circuit Concentrate	restricted solid	8.8
Float tails sample	restricted solid	3.8
PDC Conductors O/size +410 µm	restricted solid	10

The remaining six MBP samples were classified as restricted solids because the respective specific activity ratios for the MBP's were > 1. The Guidelines state in Step 4 that "*Where the specific activity ratio or total activity ratio is greater than one, the waste must be classified as follows: Non-liquid wastes must be classified as restricted solid waste*."

Sue Brown,
ANSTO Minerals

MEMORANDUM

APPENDIX 1

Assessment of Waste Classification for Mining By-Products

			PDC Ilmenite				
	Emission	Group	ES-050115-1				
Th-232 Decay Chain			Bq/g				Bq/g
Th-232	alpha	1	0.22 ± 0.02	**Specific Activity (material)**			**3.7**
Ra-228	beta	1	0.22 ± 0.02				
Ac-228	beta	2	0.22 ± 0.02			Factor	
Th-228	alpha	1	0.19 ± 0.02	Specific Activity - Group 1	SA1	1	1.7
Ra-224	alpha	2	0.19 ± 0.02	Specific Activity - Group 2	SA2	10^{-1}	1.6
Rn-220	alpha	3	0.19 ± 0.02	Specific Activity - Group 3	SA3	10^{-2}	0.31
Po-216	alpha	1	0.19 ± 0.02	Specific Activity - Group 4	SA4	10^{-3}	0.12
Pb-212	beta	2	0.19 ± 0.02	**Specific Activity Ratio**			**1.9**
Bi-212 (64.07%)	beta	2	0.12 ± 0.02				
Bi-212 (35.93%)	alpha	1	0.07 ± 0.02	**Classification**			**restricted solid**
Po-212 (64.07%)	alpha	1	0.12 ± 0.02				
Tl-208 (35.93%)	beta	2	0.07 ± 0.02				
U-238 Decay Chain							
U-238	alpha	4	0.11 ± 0.05				
Th-234	beta	2	0.11 ± 0.05				
Pa-234	beta	2	0.11 ± 0.05				
U-234	alpha	1	0.11 ± 0.05				
Th-230	alpha	1	0.12 ± 0.02				
Ra-226	alpha	1	0.12 ± 0.01				
Rn-222	alpha	3	0.12 ± 0.01				
Po-218	alpha	1	0.12 ± 0.01				
Pb-214	beta	2	0.12 ± 0.01				
Bi-214	beta	2	0.12 ± 0.01				
Po-214	alpha	1	0.12 ± 0.01				
Pb-210	beta	1	0.14 ± 0.02				
Bi-210	beta	2	0.14 ± 0.02				
Po-210	alpha	2	0.14 ± 0.02				
U-235 Decay Chain							
U-235	alpha	4	0.005 ± 0.002				
Th-231	beta	3	0.005 ± 0.002				
Pa-231	alpha	1	< 0.026				
Ac-227	beta	1	< 0.0053				
Th-227 (98.62%)	alpha	1	< 0.0053				
Fr-223 (1.38%)	alpha	1	< 0.0053				
Ra-223	alpha	1	< 0.0053				
Rn-219	alpha	1	< 0.0053				
Po-215	alpha	1	< 0.0053				
Pb-211	beta	2	< 0.0053				
Bi-211	alpha	1	< 0.0053				
Tl-207	beta	2	< 0.0053				
K-40	beta	2	0.026 ± 0.007				

MEMORANDUM

			Combined Monazite Reject
	Emission	Group	ES-050115-2
Th-232 Decay Chain			Bq/g
Th-232	alpha	1	77 ± 8
Ra-228	beta	1	68 ± 7
Ac-228	beta	2	68 ± 7
Th-228	alpha	1	75 ± 8
Ra-224	alpha	2	75 ± 8
Rn-220	alpha	3	75 ± 8
Po-216	alpha	1	75 ± 8
Pb-212	beta	2	75 ± 8
Bi-212 (64.07%)	beta	2	48 ± 8
Bi-212 (35.93%)	alpha	1	27 ± 8
Po-212 (64.07%)	alpha	1	48 ± 8
Tl-208 (35.93%)	beta	2	27 ± 8
U-238 Decay Chain			
U-238	alpha	4	14 ± 1
Th-234	beta	2	14 ± 1
Pa-234	beta	2	14 ± 1
U-234	alpha	1	14 ± 1
Th-230	alpha	1	17 ± 4
Ra-226	alpha	1	13 ± 1
Rn-222	alpha	3	13 ± 1
Po-218	alpha	1	13 ± 1
Pb-214	beta	2	13 ± 1
Bi-214	beta	2	13 ± 1
Po-214	alpha	1	13 ± 1
Pb-210	beta	1	13 ± 1
Bi-210	beta	2	13 ± 1
Po-210	alpha	2	13 ± 1
U-235 Decay Chain			
U-235	alpha	4	0.65 ± 0.05
Th-231	beta	3	0.65 ± 0.05
Pa-231	alpha	1	0.8 ± 0.2
Ac-227	beta	1	1.0 ± 0.1
Th-227 (98.62%)	alpha	1	1.0 ± 0.1
Fr-223 (1.38%)	alpha	1	0.014 ± 0.001
Ra-223	alpha	1	1.0 ± 0.1
Rn-219	alpha	1	1.0 ± 0.1
Po-215	alpha	1	1.0 ± 0.1
Pb-211	beta	2	1.0 ± 0.1
Bi-211	alpha	1	1.0 ± 0.1
Tl-207	beta	2	1.0 ± 0.1
K-40	beta	2	< 0.32

			Bq/g
Specific Activity (material)			**938**
		Factor	
Specific Activity - Group 1	SA1	1	460
Specific Activity - Group 2	SA2	10^{-1}	375
Specific Activity - Group 3	SA3	10^{-2}	89
Specific Activity - Group 4	SA4	10^{-3}	15
Specific Activity Ratio			**498**
Classification			**hazardous**

MEMORANDUM

	Emission	Group	Hyti ES-050115-3
Th-232 Decay Chain			
Th-232	alpha	1	1.3 ± 0.2
Ra-228	beta	1	1.2 ± 0.1
Ac-228	beta	2	1.2 ± 0.1
Th-228	alpha	1	1.3 ± 0.1
Ra-224	alpha	2	1.3 ± 0.1
Rn-220	alpha	3	1.3 ± 0.1
Po-216	alpha	1	1.3 ± 0.1
Pb-212	beta	2	1.3 ± 0.1
Bi-212 (64.07%)	beta	2	0.8 ± 0.1
Bi-212 (35.93%)	alpha	1	0.5 ± 0.1
Po-212 (64.07%)	alpha	1	0.8 ± 0.1
Tl-208 (35.93%)	beta	2	0.5 ± 0.1
U-238 Decay Chain			
U-238	alpha	4	0.42 ± 0.01
Th-234	beta	2	0.42 ± 0.01
Pa-234	beta	2	0.42 ± 0.01
U-234	alpha	1	0.42 ± 0.01
Th-230	alpha	1	0.5 ± 0.1
Ra-226	alpha	1	0.47 ± 0.05
Rn-222	alpha	3	0.47 ± 0.05
Po-218	alpha	1	0.47 ± 0.05
Pb-214	beta	2	0.47 ± 0.05
Bi-214	beta	2	0.48 ± 0.05
Po-214	alpha	1	0.47 ± 0.05
Pb-210	beta	1	0.42 ± 0.04
Bi-210	beta	2	0.42 ± 0.04
Po-210	alpha	2	0.42 ± 0.04
U-235 Decay Chain			
U-235	alpha	4	0.0194 ± 0.0005
Th-231	beta	3	0.0194 ± 0.0005
Pa-231	alpha	1	< 0.069
Ac-227	beta	1	0.028 ± 0.005
Th-227 (98.62%)	alpha	1	0.028 ± 0.005
Fr-223 (1.38%)	alpha	1	4E-04 ± 7E-05
Ra-223	alpha	1	0.028 ± 0.005
Rn-219	alpha	1	0.028 ± 0.005
Po-215	alpha	1	0.028 ± 0.005
Pb-211	beta	2	0.028 ± 0.005
Bi-211	alpha	1	0.028 ± 0.005
Tl-207	beta	2	0.028 ± 0.005
K-40	beta	2	0.10 ± 0.02

			Bq/g
Specific Activity (material)			**19**
		Factor	
Specific Activity - Group 1	SA1	1	9.3
Specific Activity - Group 2	SA2	10^{-1}	7.9
Specific Activity - Group 3	SA3	10^{-2}	1.8
Specific Activity - Group 4	SA4	10^{-3}	0.44
Specific Activity Ratio			**10**
Classification			**restricted solid**

MEMORANDUM

	Emission	Group	Combined Zircon Wet Tails ES-050115-4
Th-232 Decay Chain			
Th-232	alpha	1	0.56 ± 0.06
Ra-228	beta	1	0.30 ± 0.03
Ac-228	beta	2	0.30 ± 0.03
Th-228	alpha	1	0.30 ± 0.03
Ra-224	alpha	2	0.30 ± 0.03
Rn-220	alpha	3	0.30 ± 0.03
Po-216	alpha	1	0.30 ± 0.03
Pb-212	beta	2	0.30 ± 0.03
Bi-212 (64.07%)	beta	2	0.19 ± 0.03
Bi-212 (35.93%)	alpha	1	0.11 ± 0.03
Po-212 (64.07%)	alpha	1	0.19 ± 0.03
Tl-208 (35.93%)	beta	2	0.11 ± 0.03
U-238 Decay Chain			
U-238	alpha	4	1.01 ± 0.02
Th-234	beta	2	1.01 ± 0.02
Pa-234	beta	2	1.01 ± 0.02
U-234	alpha	1	1.01 ± 0.02
Th-230	alpha	1	0.78 ± 0.08
Ra-226	alpha	1	0.83 ± 0.08
Rn-222	alpha	3	0.83 ± 0.08
Po-218	alpha	1	0.83 ± 0.08
Pb-214	beta	2	0.84 ± 0.08
Bi-214	beta	2	0.83 ± 0.08
Po-214	alpha	1	0.83 ± 0.08
Pb-210	beta	1	0.72 ± 0.07
Bi-210	beta	2	0.72 ± 0.07
Po-210	alpha	2	0.72 ± 0.07
U-235 Decay Chain			
U-235	alpha	4	0.0466 ± 0.0009
Th-231	beta	3	0.0466 ± 0.0009
Pa-231	alpha	1	< 0.039
Ac-227	beta	1	0.046 ± 0.005
Th-227 (98.62%)	alpha	1	0.045 ± 0.005
Fr-223 (1.38%)	alpha	1	6E-04 ± 6E-05
Ra-223	alpha	1	0.046 ± 0.005
Rn-219	alpha	1	0.046 ± 0.005
Po-215	alpha	1	0.046 ± 0.005
Pb-211	beta	2	0.046 ± 0.005
Bi-211	alpha	1	0.046 ± 0.005
Tl-207	beta	2	0.046 ± 0.005
K-40	beta	2	< 0.024

			Bq/g
Specific Activity (material)			**16**
		Factor	
Specific Activity - Group 1	SA1	1	7.0
Specific Activity - Group 2	SA2	10^{-1}	6.4
Specific Activity - Group 3	SA3	10^{-2}	1.2
Specific Activity - Group 4	SA4	10^{-3}	1.1
Specific Activity Ratio			**7.7**
Classification			**restricted solid**

MEMORANDUM

			Rutile Wet Circuit Concentrate				
	Emission	Group	ES-050115-5				
Th-232 Decay Chain							Bq/g
Th-232	alpha	1	1.0 ± 0.1	**Specific Activity (material)**			**17**
Ra-228	beta	1	0.91 ± 0.09				
Ac-228	beta	2	0.91 ± 0.09			Factor	
Th-228	alpha	1	0.90 ± 0.09	Specific Activity - Group 1	SA1	1	8.1
Ra-224	alpha	2	0.90 ± 0.09	Specific Activity - Group 2	SA2	10^{-1}	7.0
Rn-220	alpha	3	0.90 ± 0.09	Specific Activity - Group 3	SA3	10^{-2}	1.5
Po-216	alpha	1	0.90 ± 0.09	Specific Activity - Group 4	SA4	10^{-3}	0.61
Pb-212	beta	2	0.90 ± 0.09	**Specific Activity Ratio**			**8.8**
Bi-212 (64.07%)	beta	2	0.58 ± 0.09				
Bi-212 (35.93%)	alpha	1	0.32 ± 0.09	**Classification**			**restricted solid**
Po-212 (64.07%)	alpha	1	0.58 ± 0.09				
Tl-208 (35.93%)	beta	2	0.32 ± 0.09				
U-238 Decay Chain							
U-238	alpha	4	0.58 ± 0.02				
Th-234	beta	2	0.58 ± 0.02				
Pa-234	beta	2	0.58 ± 0.02				
U-234	alpha	1	0.58 ± 0.02				
Th-230	alpha	1	0.51 ± 0.08				
Ra-226	alpha	1	0.58 ± 0.06				
Rn-222	alpha	3	0.58 ± 0.06				
Po-218	alpha	1	0.58 ± 0.06				
Pb-214	beta	2	0.58 ± 0.06				
Bi-214	beta	2	0.58 ± 0.06				
Po-214	alpha	1	0.58 ± 0.06				
Pb-210	beta	1	0.47 ± 0.05				
Bi-210	beta	2	0.47 ± 0.05				
Po-210	alpha	2	0.47 ± 0.05				
U-235 Decay Chain							
U-235	alpha	4	0.0268 ± 0.0009				
Th-231	beta	3	0.0268 ± 0.0009				
Pa-231	alpha	1	< 0.043				
Ac-227	beta	1	0.030 ± 0.003				
Th-227 (98.62%)	alpha	1	0.030 ± 0.003				
Fr-223 (1.38%)	alpha	1	4E-04 ± 4E-05				
Ra-223	alpha	1	0.030 ± 0.003				
Rn-219	alpha	1	0.030 ± 0.003				
Po-215	alpha	1	0.030 ± 0.003				
Pb-211	beta	2	0.030 ± 0.003				
Bi-211	alpha	1	0.030 ± 0.003				
Tl-207	beta	2	0.030 ± 0.003				
K-40	beta	2	0.07 ± 0.01				

MEMORANDUM

			Float Tails Sample
	Emission	Group	ES-050115-6
Th-232 Decay Chain			
Th-232	alpha	1	0.30 ± 0.03
Ra-228	beta	1	0.27 ± 0.03
Ac-228	beta	2	0.27 ± 0.03
Th-228	alpha	1	0.27 ± 0.03
Ra-224	alpha	2	0.27 ± 0.03
Rn-220	alpha	3	0.27 ± 0.03
Po-216	alpha	1	0.27 ± 0.03
Pb-212	beta	2	0.27 ± 0.03
Bi-212 (64.07%)	beta	2	0.17 ± 0.03
Bi-212 (35.93%)	alpha	1	0.10 ± 0.03
Po-212 (64.07%)	alpha	1	0.17 ± 0.03
Tl-208 (35.93%)	beta	2	0.10 ± 0.03
U-238 Decay Chain			
U-238	alpha	4	0.48 ± 0.02
Th-234	beta	2	0.48 ± 0.02
Pa-234	beta	2	0.48 ± 0.02
U-234	alpha	1	0.48 ± 0.02
Th-230	alpha	1	< 0.30
Ra-226	alpha	1	0.39 ± 0.04
Rn-222	alpha	3	0.39 ± 0.04
Po-218	alpha	1	0.39 ± 0.04
Pb-214	beta	2	0.39 ± 0.04
Bi-214	beta	2	0.39 ± 0.04
Po-214	alpha	1	0.39 ± 0.04
Pb-210	beta	1	0.33 ± 0.03
Bi-210	beta	2	0.33 ± 0.03
Po-210	alpha	2	0.33 ± 0.03
U-235 Decay Chain			
U-235	alpha	4	0.0222 ± 0.0009
Th-231	beta	3	0.0222 ± 0.0009
Pa-231	alpha	1	< 0.064
Ac-227	beta	1	0.019 ± 0.003
Th-227 (98.62%)	alpha	1	0.019 ± 0.003
Fr-223 (1.38%)	alpha	1	3E-04 ± 5E-05
Ra-223	alpha	1	0.019 ± 0.003
Rn-219	alpha	1	0.019 ± 0.003
Po-215	alpha	1	0.019 ± 0.003
Pb-211	beta	2	0.019 ± 0.003
Bi-211	alpha	1	0.019 ± 0.003
Tl-207	beta	2	0.019 ± 0.003
K-40	beta	2	< 0.044

			Bq/g
Specific Activity (material)			**8.2**
		Factor	
Specific Activity - Group 1	SA1	1	3.5
Specific Activity - Group 2	SA2	10^{-1}	3.5
Specific Activity - Group 3	SA3	10^{-2}	0.68
Specific Activity - Group 4	SA4	10^{-3}	0.50
Specific Activity Ratio			**3.8**
Classification			**restricted solid**

MEMORANDUM

	Emission	Group	PDC Conductors O/size +410 µm ES-050115-7
Th-232 Decay Chain			
Th-232	alpha	1	0.89 ± 0.09
Ra-228	beta	1	0.86 ± 0.09
Ac-228	beta	2	0.86 ± 0.09
Th-228	alpha	1	0.86 ± 0.09
Ra-224	alpha	2	0.86 ± 0.09
Rn-220	alpha	3	0.86 ± 0.09
Po-216	alpha	1	0.86 ± 0.09
Pb-212	beta	2	0.86 ± 0.09
Bi-212 (64.07%)	beta	2	0.55 ± 0.09
Bi-212 (35.93%)	alpha	1	0.31 ± 0.09
Po-212 (64.07%)	alpha	1	0.55 ± 0.09
Tl-208 (35.93%)	beta	2	0.31 ± 0.09
U-238 Decay Chain			
U-238	alpha	4	0.81 ± 0.03
Th-234	beta	2	0.81 ± 0.03
Pa-234	beta	2	0.81 ± 0.03
U-234	alpha	1	0.81 ± 0.03
Th-230	alpha	1	0.9 ± 0.2
Ra-226	alpha	1	0.82 ± 0.08
Rn-222	alpha	3	0.82 ± 0.08
Po-218	alpha	1	0.82 ± 0.08
Pb-214	beta	2	0.81 ± 0.08
Bi-214	beta	2	0.83 ± 0.08
Po-214	alpha	1	0.82 ± 0.08
Pb-210	beta	1	0.68 ± 0.07
Bi-210	beta	2	0.68 ± 0.07
Po-210	alpha	2	0.68 ± 0.07
U-235 Decay Chain			
U-235	alpha	4	0.037 ± 0.001
Th-231	beta	3	0.037 ± 0.001
Pa-231	alpha	1	< 0.13
Ac-227	beta	1	0.048 ± 0.008
Th-227 (98.62%)	alpha	1	0.047 ± 0.008
Fr-223 (1.38%)	alpha	1	7E-04 ± 1E-04
Ra-223	alpha	1	0.048 ± 0.008
Rn-219	alpha	1	0.048 ± 0.008
Po-215	alpha	1	0.048 ± 0.008
Pb-211	beta	2	0.048 ± 0.008
Bi-211	alpha	1	0.048 ± 0.008
Tl-207	beta	2	0.048 ± 0.008
K-40	beta	2	0.30 ± 0.05

		Factor	Bq/g
Specific Activity (material)			**21**
Specific Activity - Group 1	SA1	1	9.5
Specific Activity - Group 2	SA2	10^{-1}	8.5
Specific Activity - Group 3	SA3	10^{-2}	1.7
Specific Activity - Group 4	SA4	10^{-3}	0.85
Specific Activity Ratio			**10**
Classification			**restricted solid**