

YANDAN GOLD MINE POST MINE LAND USE PLAN

PREPARED FOR
STRAITS GOLD PTY LTD

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LIST OF ABBREVIATIONS

AARC	AARC Environmental Solutions Pty Ltd
AMD	acid mine drainage
CBR	California Bearing Ratio
cm	centimetre
DES	Department of Environment and Science
EA	Environmental Authority
EHP	Department of Environment and Heritage Protection
ESD	ecologically sustainable development
FA	Financial Assurance
ha	hectare
km	kilometre
m	metre
mm	millimetre
ML	Mining Lease
PMLUP	Post Mine Land Use Plan
ROM	run of mine
Straits	Straits Gold Pty Ltd
TDS	total dissolved solids
TSF	Tailings Storage Facility

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) has been commissioned by Straits Gold Pty Ltd (Straits) to prepare a Post Mine Land Use Plan (PMLUP) for the Yandan Gold Mine (the Project). The PMLUP seeks to satisfy condition F3-1 of the Project's Environmental Authority (EA) EPML00771913 (formerly MIN100902609).

The Yandan Gold Mine is located in central Queensland, approximately 50 km west of the township of Mount Coolon and 150 km south-east of Charters Towers. The Project occupies two mining leases (MLs): ML1095 (Yandan West) and ML1096 (Yandan East).

1.1 PURPOSE

The purpose of this PMLUP is to fulfil the requirements of the Project's EA and detail the methodology by which the rehabilitation of the Project site will be undertaken. The PMLUP details the rehabilitations goals, objectives, indicators, completion criteria and success criteria to direct rehabilitation and assess progress.

The PMLUP will be reviewed and updated with each subsequent Plan of Operations.

1.2 SCOPE

In accordance with condition F3-1 of the EA, this PMLUP incorporates the following elements:

- Schematic representations of final land form inclusive of drainage features;
- Slope, cover and drainage designs;
- Erosion controls proposed on reformed land;
- Description of experimental design for monitoring of analogue and rehabilitated areas inclusive of statistical design;
- Proposed revegetation criteria, including:
 - Species diversity, abundance and composition;
 - Projective cover;
 - Dry matter production; and
 - Stocking rates to ensure self-sustaining vegetation is maintained;
- Proposed revegetation methods inclusive of plant species selection, re-profiling, re-spreading soil, soil ameliorants/amendments, surface preparation and method of propagation;
- Materials balance including available top soil and low permeability capping material;
- Research program and associated milestones;
- Geotechnical, geochemical and hydrological studies;
- Chemical, physical and biological properties of soil and water;

- Clear objectives and success criteria for the each land unit including establishment in accordance with outcomes stipulated in the Administering Authority's Guideline for Rehabilitation Requirements for Mining Projects;
- Measurable completion criteria for each rehabilitation indicator (for each land unit) that enables determination of rehabilitation success for each disturbance type (or land unit); and
- Rehabilitation monitoring program.

2.0 PROJECT DESCRIPTION

The Yandan Gold Mine is a former open cut gold mine and processing project that is currently in care and maintenance. The Project commenced in 1992 (by Ross Mining NL) and involved the mining of three open-cut pits and the operation of a process plant and heap leach. Since ceasing operations in 1998, the Project has remained in Care and Maintenance, pending final closure works.

The Project is located in the Drummond Basin in central Queensland, approximately 50 km west of the township of Mount Coolon and 150 km south-east of Charters Towers, as indicated Figure 1.

2.1 PROJECT INFRASTRUCTURE

Project operational areas / disturbances on ML 1095 and ML 1096 (Figure 2) that will or have already been rehabilitated include the following:

- Open cut pits and bunds:
 - Main pit;
 - East Hill pit;
 - Backfilled South Pit;
 - Main pit flood bund;
- Tailings Storage Facility Cells A and B;
- Dams (refer to Figure 2):
 - Runoff dam;
 - Water storage dam;
 - Mine process water dam;
 - Tailings return water dam;
 - Water harvest trench;
- Heap leach pads and ponds:
 - Heap leach stormwater pond;
 - Heap leach liquor ponds;
- Diversion structures (Yandan Creek / Suttor River);
- Topsoil stockpiles;
- Stockpile area;
- ROM pad;
- Processing plant;

- Village infrastructure (ML 1096);
- Borrow pit;
- Exploration areas;
- Infrastructure (ML 1095):
 - Plant site and office; and
 - Airstrip and roads.

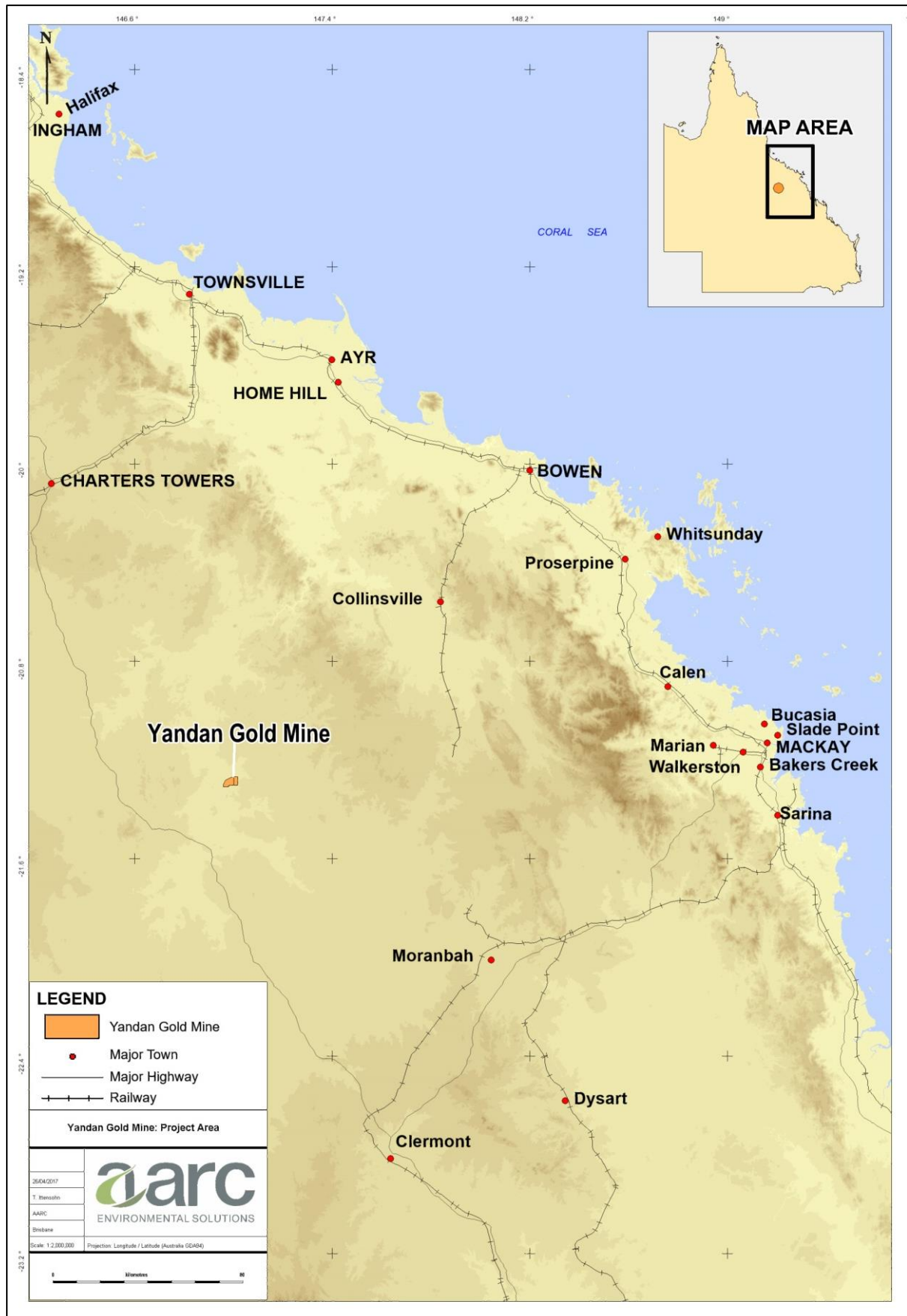


Figure 1 Project Location

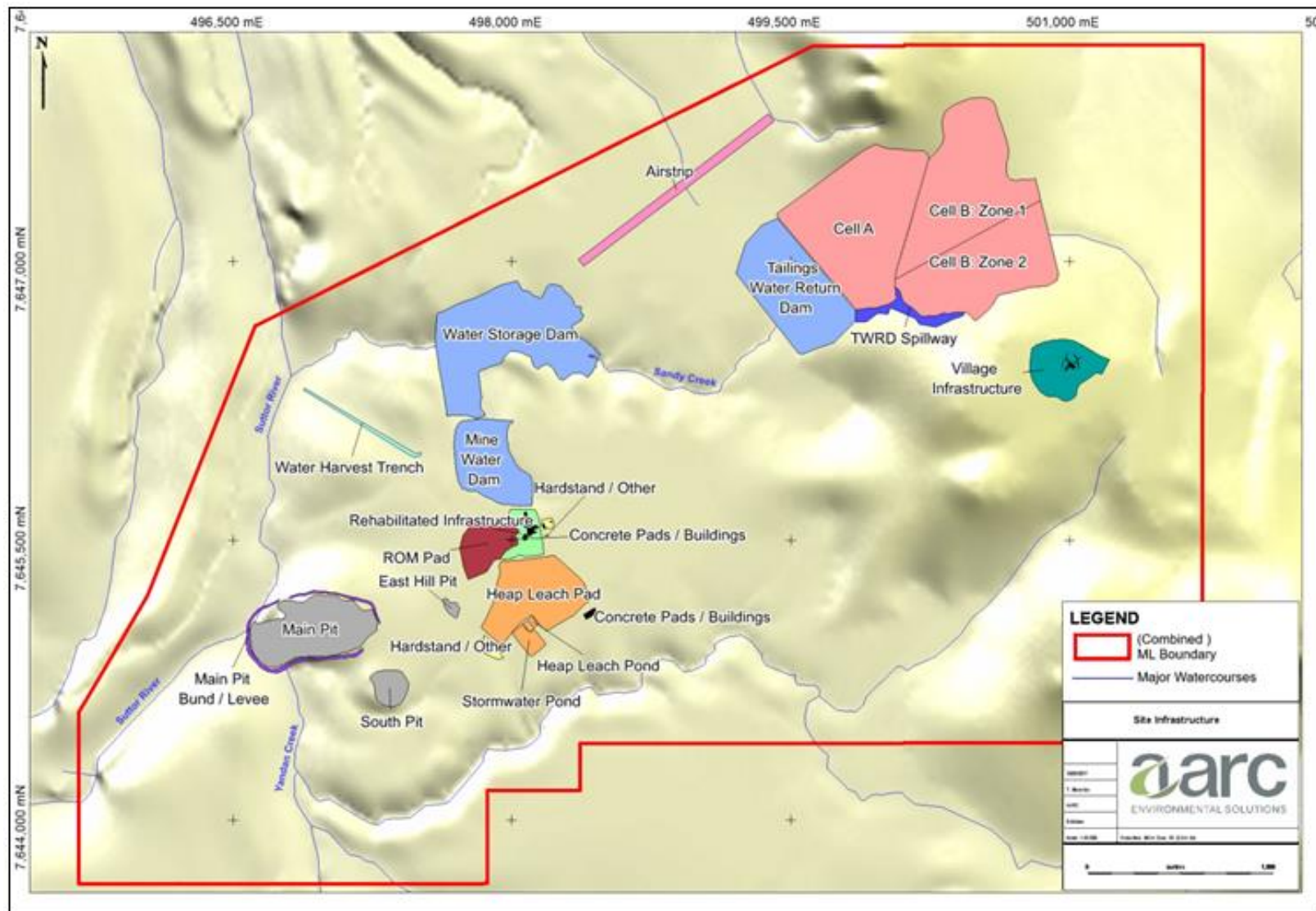


Figure 2 Yandan Gold Mine Layout

3.0 DESCRIPTION OF EXISTING ENVIRONMENT

Mine Closure Plans have previously been developed for the Yandan Gold Mine. These reports, while outdated, provide background information of the existing environment of the site. The reports include:

- Preliminary Mine Reclamation and Closure Plan Mining Leases ML 1095 & ML 1096 Yandan Gold Mine (HLA-Envirosciences Pty Ltd 2000);
- Report for Yandan Gold Mine: Mine Closure Plan (GHD 2008); and
- Yandan Gold Mine Post Mine Land Use Plan (AARC 2015).

3.1 SOIL

The north-west region of the Project site is characterised by undulating low hills and foot slopes with rocky outcrops. In contrast, the south-east of the site is characterised by clay plains with some gilgai microrelief in low areas. (GHD 2008)

Most soils within the MLs are shallow alkaline red-bleached duplex soils. Alluvial soil is present on the floodplain of the Suttor River (HLA-Envirosciences 2000). Laboratory analysis has indicated that soils exhibit a relatively low potential for dispersion. Tunnel and sheet erosion, particularly in areas where vegetation has been removed, has been noted as a historical concern for the site, “reflecting the hard-setting nature of the surface and low infiltration rate.” (GHD 2008, p.7)

GHD (2008) noted the low fertility of the soil across the site, resulting in low quality pasture and production. Historical overgrazing has also contributed to erosion and low soil productivity.

3.2 SURFACE WATER

The Project site is situated on the east bank of the Suttor River in proximity to a junction with two minor ephemeral tributaries – Yandan Creek and Sandy Creek – within the Suttor River catchment (HLA-Envirosciences 2000). Yandan Creek has a catchment of approximately 7,200 ha, while Sandy Creek has a catchment of approximately 900 ha. The Suttor River drains into Lake Dalrymple, formed by the damming of the Burdekin River (HLA-Envirosciences 2000).

3.3 GROUNDWATER

Groundwater flows west towards the Suttor River, exhibiting strong hydraulic discontinuities (GHD 2008). Historical drilling has indicated that groundwater is approximately 8 m below the bed of the Suttor River (approximately RL 158 m), with little indication of surface water / groundwater connection.

Groundwater in the region is of poor quality for stock use and generally not suitable for domestic use or use as irrigation (GHD 2008). Total dissolved solids (TDS) recorded at bores prior to Project development were in the range of 4,000 – 15,000 mg/L, while concentrations of copper, lead and zinc exceeded the respective ANZECC (2000) 95% protection trigger values for the protection of aquatic ecosystems. Concentrations of arsenic, copper, lead, sulphate and zinc remained below the ANZECC (2000) Livestock Drinking Water Quality contaminant limits (GHD 2008). More recent sampling conducted in July 2008 indicated continued high TDS and high levels of sulphate (>1,000 mg/L in some instances) (GHD 2008).

4.0 LAND USE

4.1 PRE-MINING LAND USE

Low-intensity beef cattle grazing is the primary land use for the region, with much of the naturally occurring open forest and woodlands cleared for this purpose. Limitations of the soil, together with low rainfall and high rainfall variability render the stock carrying capacity relatively low. Information obtained from the Department of Primary Industries indicated that the carrying capacity of the land is approximately one beast per 15 ha (GHD 2008).

4.2 POST-MINING LAND USE

In accordance with EA condition F2-1, land disturbed by mining activities must be rehabilitated in accordance with Table 1 and the goals, objectives, indicators and completion criteria detailed in Section 5. Table 2 explains the post mine land use classifications.

Table 1 Post Mine Land Description

EA Disturbance Class	EA Surface Area (ha)	Actual Disturbance Type (Figure 2)	Actual Disturbance area (ha)	Post Mine Land Use	Post Mine Land Classification
Backfilled pit	4	South Pit	3.1	Open pasture	VII
Tailings dam	114	Cell A Cell B (Z1 & Z2) TWRD Spillway	111.9	Open pasture	VII
Stockpile area	8.3	Topsoil Stockpile	11	Open pasture	VII
Runoff dam	16.6	Mine Water Dam	14.2	Water storage	VIII
ROM pad	3.8	ROM Pad	6.1	Low hill	VII
Processing plant	1.8	Hardstand Area	1.6	Open pasture	VII
Open pit	18.8	Open Pit	18.4	Lake	Void (Non Use Management Area)
Infrastructure	79.8	Tailings Water Return Dam Water Storage Dam Water Harvest Trench Roads Airstrip	83.8	Open pasture	VII
Heap leach	21	Heap Leach HL Ponds HL SW Dam	18.85	Low hill	VII

EA Disturbance Class	EA Surface Area (ha)	Actual Disturbance Type (Figure 2)	Actual Disturbance area (ha)	Post Mine Land Use	Post Mine Land Classification
Borrow pit	8	Borrow Pit	10	Open pasture	VII
Exploration	4.5	Exploration Areas	0	Open pasture	VII
Village Infrastructure	15	Village Infrastructure	9.5	Open pasture	VII
Total	295.6		288.45	-	-

Table 2 Land Capability Classification

Class	Description
Class I	Land suitable for all agricultural and pastoral uses
Class II	Land suitable for all agricultural uses with slight restrictions to cropping
Class III	Land suitable for all agricultural uses with moderate restrictions to cropping
Class IV	Land primarily used for pastoral uses but can be carefully cropped occasionally
Class V	Land primarily used for pastoral uses but can be carefully cropped if limitations were removed
Class VI	Land not suited to cultivation but well suited to pasture improvement
Class VII	Land not suitable for cultivation and only careful pastoral use possible
Class VIII	Land not suitable for agricultural or grazing purposes

5.0 REHABILITATION GOALS, OBJECTIVES AND CRITERIA

5.1 REHABILITATION HIERARCHY

The *Guideline: Rehabilitation Requirements for Mining Projects* (EHP 2014) defines the rehabilitation hierarchy, in order of decreasing capacity to prevent / minimise environmental harm, as the following:

1. Avoid disturbance that will require rehabilitation;
2. Reinstatement a 'natural' ecosystem as similar as possible to the original ecosystem;
3. Develop an alternative outcome with a higher economic value than the previous land use;
4. Reinstatement previous land use (e.g. grazing or cropping);
5. Develop lower value land use; and
6. Leave the site in an unusable condition or with a potential to generate future pollution or adversely affect environmental values.

5.2 REHABILITATION GOALS

The *Guideline: Rehabilitation Requirements for Mining Projects* (EHP 2014) specifies rehabilitation goals which are consistent with the National Strategy for Ecologically Sustainable Development. All land subject to mining activities must be rehabilitated to be:

- Safe to humans and wildlife;
- Non-polluting;
- Stable;
- Able to sustain the agreed post-mining land use.

5.3 REHABILITATION OBJECTIVES

5.3.1 General

Rehabilitation objectives have been developed for the Project to facilitate the realisation of the goals described above. In accordance with the *Guideline: Rehabilitation Requirements for Mining Projects* (EHP 2014), general rehabilitation objectives include:

1. Ensure mine sites are rehabilitated to sound environmental and safety standards, and to a level at least consistent with the condition of surrounding land;
2. Provide appropriate community returns for using mineral resources and achieve better environmental protection and management in the mining sector; and
3. Improve community consultation and information, improve performance in occupational health and safety, and achieve social equity objectives.

5.3.2 Site-Specific

For the purpose of determining rehabilitation indicators and completion criteria, and assessing rehabilitation success, mine sites are typically divided into domains, which encompass a number of mine features. Table 3 outlines the domains and mine features for the Project.

Table 3 Mine Domains and Mine Features

Domain	Mine Features
Mine Areas	• Open-cut Pits ◦ Backfilled pit ◦ Residual void • ROM pad • Exploration areas
Stockpiles and Waste	• Tailings dams & spillway • Topsoil stockpile
Processing Areas	• Processing plant • Heap leach pads • HL ponds & Dam • Hardstand
Dams	• Runoff dam • Mine water dam • Tailings return water dam • Water storage dam
Infrastructure	• Infrastructure Area • Village infrastructure • Office • Airstrip • Roads • Borrow pit • Water harvest trench • Bund walls

Site-specific rehabilitation objectives have been developed for the Project in order to satisfy the rehabilitation goals described in Section 5.2. Objectives include the following, however, not all objectives are relevant to all mine domains:

- Sites are safe for humans and animals now and in the foreseeable future;
- Hazardous and contaminated material adequately managed;
- Polluted runoff and seepage contained on site;
- Acid mine drainage (AMD) will not cause serious environmental harm;
- Dams to remain on closure will not contribute contaminants to the environment;

- Rehabilitated dams will not contribute contaminants to the environment;
- Establish safe and stable waterbodies with a low risk of environmental harm;
- Landform design achieves appropriate erosion rates;
- Minimal probability of wall failure or rock falls that will cause significant environmental harm;
- Adequate vegetation cover to minimise erosion;
- Very low probability of slope slippage with serious consequences;
- Soil properties that support and will continue to support desired land use; and
- Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.

Table 4 provides a comprehensive summary of Yandan Gold Mine rehabilitation objectives for each domain.

5.4 REHABILITATION INDICATORS

The EA holder maintains responsibility for determining appropriate rehabilitation indicators to achieve the objectives and goals for each mine domain.

For all indicators that are selected, the EA holder must:

- State what objective(s) the indicator relates to;
- Justify the selection of the indicator, including how the relationship between the indicator and the objective has been established (supported by references to authoritative sources or relevant monitoring data);
- State how the indicator is to be measured; and
- State how the results will be reported and interpreted.

Table 4 provides a comprehensive summary of Yandan Gold Mine rehabilitation indicators for each domain.

5.5 COMPLETION CRITERIA

Completion criteria are defined in the Guideline: Rehabilitation Requirements for Mining Projects (EHP 2014) as the standards which define successful rehabilitation. They are typically measurable benchmarks or values which can be verified by measurement or assessment of the associated rehabilitation indicator.

Table 4 provides a comprehensive summary of Yandan Gold Mine completion criteria for each domain.

Table 4 Summary of Rehabilitation Goals, Objectives, Indicators and Completion Criteria

Table 5

Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
Rehabilitation Goal: Safe Site				
Mine Areas	Pits	Final pits are safe for humans and animals now and in the foreseeable future.	Safety assessment of final landform by an appropriately qualified person.	Certification in rehabilitation report that ground is structurally sound and safe to people and animals.
			Safety barriers and signage assessed against requirements of the <i>Mining and Quarrying Safety and Health Act 1999</i> .	Evidence in rehabilitation report that all safety precautions have been implemented in accordance with the relevant legislation.
	ROM Pad	Rehabilitated ROM pad is safe for humans and animals now and in the foreseeable future.	Safety assessment of final landform by an appropriately qualified person.	Certification in rehabilitation report that ground is structurally sound and safe to people and animals.
	Exploration Areas	Exploration sites are safe for humans and animals now and in the foreseeable future.	Safety assessment of final landform by an appropriately qualified person.	Evidence in rehabilitation report that ground is structurally sound and safe.
Overburden & Waste	Tailings Dams, Topsoil Stockpiles, Stockpile Areas	Overburden and waste sites are safe for humans and animals now and in the foreseeable future.	Safety assessment of final landform by an appropriately qualified person.	Evidence in rehabilitation report that ground is structurally sound and safe.
Processing Areas	Processing Plant, Heap Leach Pads & Ponds	Sites are safe for humans and animals now and in the foreseeable future.	Safety assessment of final landform by an appropriately qualified person.	Evidence in rehabilitation report that ground is structurally sound and safe.
Dams	Runoff Dam, Water Storage Dam, Mine Process Water Dam,	Retained dam sites are safe for humans and	Safety assessment of final landform by an appropriately qualified person.	Certification in rehabilitation report that ground is structurally sound and safe to people and animals.

Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
	Tailings Return Water Dam, Water Harvest Trench	animals now and in the foreseeable future.		
Infrastructure	Village Infrastructure, Plant Site & Office, Airstrip, Roads, Borrow Pit	Infrastructure sites are safe for humans and animals now and in the foreseeable future.	Safety assessment of final landform by an appropriately qualified person.	Evidence in rehabilitation report that ground is structurally sound and safe.
Rehabilitation Goal: Non-polluting				
Mine Areas	Pits, ROM Pad, Exploration Areas	Hazardous and contaminated material adequately managed.	Contaminated land assessment and site inspection.	Evidence of remediated landform in a contaminated land assessment report.
			Rehabilitation monitoring plan in place to monitor downstream surface, groundwater and stream sediments.	Evidence in the rehabilitation report that post-closure monitoring shows the final landform is non-polluting.
		Polluted runoff and seepage contained on site.	Monitoring of surface water and groundwater.	Evidence that monitoring data meet specified criteria relevant to potential contaminants.
Overburden & Waste	Tailings Dams, Topsoil Stockpiles, Stockpile Area	Hazardous and contaminated material adequately managed.	Contaminated land assessment and site inspection.	Evidence of remediated landform in a contaminated land assessment report.
			Rehabilitation monitoring plan in place to monitor downstream surface, groundwater and stream sediments.	Evidence in the rehabilitation report that post-closure monitoring shows the final landform is compliant with limits in the relevant Environmental Protection Policies or other agreed limits.
		AMD will not cause serious environmental harm.	Technical design of barriers.	Engineer's certification of construction and maintenance to specified design performance.
			Geochemically characterisation to ensure rehabilitation facilitates a geochemically stable landform.	Evidence that rehabilitated landform will be geochemically stable and not result in serious environmental harm.
		Polluted runoff and seepage contained on site.	Monitoring of surface water and groundwater.	Evidence that monitoring data meet specified criteria relevant to potential contaminants.

Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
Processing Areas	Processing Plant, Heap Leach Pads & Ponds	Hazardous and contaminated material adequately managed.	Contaminated land assessment and site inspection.	Evidence of remediated landform in a contaminated land assessment report.
			Rehabilitation monitoring plan in place to monitor downstream surface, groundwater and stream sediments.	Evidence in the rehabilitation report that post-closure monitoring shows the final landform is compliant with limits in the relevant Environmental Protection Policies or other agreed limits.
		Polluted runoff and seepage contained on site.	Monitoring of surface water and groundwater.	Evidence that monitoring data meet specified criteria relevant to potential contaminants.
Dams	Runoff Dam, Water Storage Dam, Mine Process Water Dam, Tailings Return Water Dam, Water Harvest Trench	Dams to remain on closure will not contribute contaminants to the environment.	Rehabilitation monitoring plan in place to monitor water in the dam and downstream surface/ground water.	Evidence in the rehabilitation report that post-closure monitoring shows the final landform is compliant with limits in the relevant Environmental Protection Policies or other agreed limits.
		Hazardous and contaminated material adequately managed.	Contaminated land assessment and site inspection.	Evidence of remediated landform in a contaminated land assessment report.
			Rehabilitation monitoring plan in place to monitor downstream surface, groundwater and stream sediments.	Evidence in the rehabilitation report that post-closure monitoring shows the final landform is compliant with limits in the relevant Environmental Protection Policies or other agreed limits.
		Polluted runoff and seepage contained on site.	Monitoring of surface water and groundwater.	Evidence that monitoring data meet specified criteria relevant to potential contaminants.
Infrastructure	Village Infrastructure, Plant Site & Office, Airstrip, Roads, Borrow Pit	Hazardous and contaminated material adequately managed.	Contaminated land assessment and site inspection.	Evidence of remediated landform in a contaminated land assessment report.
			Rehabilitation monitoring plan in place to monitor downstream surface, groundwater and stream sediments.	Evidence in the rehabilitation report that post-closure monitoring shows the final landform is compliant with limits in the relevant Environmental Protection Policies or other agreed limits.
		Polluted runoff and seepage contained on site.		Evidence that monitoring data meet specified criteria relevant to potential contaminants.

Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
			Monitoring of surface water and groundwater.	
Rehabilitation Goal: Stable Landform				
Mine Areas	Residual Void	Establish safe and stable waterbody with a low risk of environmental harm.	Monitoring of water level and quality in the residual void.	Evidence in rehabilitation report that adequate water levels are maintained in the residual void.
		Landform design achieves appropriate erosion rates.	Engineer's assessment of design and construction of structures to control water flow.	Engineer certification in rehabilitation report that water management structures are sufficient to control water flow and runoff.
	Backfilled Pit, ROM Pad, Exploration Areas	Minimal probability of wall failure or rock falls that will cause significant environmental harm.	Geotechnical studies of final landform.	Evidence in rehabilitation report of geotechnical studies that confirm the final landform is stable.
			Risk assessment of final landform.	Evidence in rehabilitation report that appropriate risk assessment and control measures have been undertaken.
		Landform design achieves appropriate erosion rates.	Engineer's assessment of design and construction of structures to control water flow.	Engineer certification in rehabilitation report that decommissioned sites have the required structures to control water flow and runoff.
		Adequate vegetation cover to minimise erosion.	Vegetation assessment.	Evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites.
Overburden & Waste	Tailings Dams	Minimal probability of wall failure or rock falls that will cause significant environmental harm.	Geotechnical studies of final landform.	Evidence in rehabilitation report of geotechnical studies to determine whether final landform is stable.
			Risk assessment of final landform.	Evidence in rehabilitation report that appropriate risk assessment and control measures have been undertaken.

Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
		Very low probability of slope slippage with serious consequences.	Geotechnical, geochemical and hydrological studies of existing structures (outer batter slopes of tailings storage facilities).	Evidence in rehabilitation report that appropriate risk assessment has been undertaken and control measures are in place that will continue to meet agreed requirements.
		Landform design achieves appropriate erosion rates.	Engineer's assessment of design and construction of structures to control water flow.	Engineer certification in rehabilitation report that infrastructure sites (both remaining and decommissioned) have the required structures to control water flow and runoff.
		Adequate vegetation cover to minimise erosion.	Vegetation assessment.	Evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites.
	Topsoil Stockpiles, Stockpile Area	Landform design achieves appropriate erosion rates.	Engineer's assessment of design and construction of structures to control water flow.	Engineer certification in rehabilitation report that infrastructure sites (both remaining and decommissioned) have the required structures to control water flow and runoff.
		Adequate vegetation cover to minimise erosion.	Vegetation assessment.	Evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites.
Processing Areas	Processing Plant, Heap Leach Pads & Ponds	Landform design achieves appropriate erosion rates.	Engineer's assessment of design and construction of structures to control water flow.	Engineer certification in rehabilitation report that infrastructure sites (both remaining and decommissioned) have the required structures to control water flow and runoff.
		Adequate vegetation cover to minimise erosion.	Vegetation assessment.	Evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites.
Dams	Runoff Dam, Water Storage Dam, Mine Process Water Dam,	Establish safe and stable waterbody with a low risk of environmental harm.	Risk assessment of remaining dam landform.	Evidence in rehabilitation report that appropriate risk assessment and control measures have been undertaken.

ENVIRONMENTAL SOLUTIONS				
Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
	Tailings Return Water Dam, Water Harvest Trench	Minimal probability of wall failure or rock falls that will cause significant environmental harm.	Geotechnical studies of final landform.	Evidence in rehabilitation report of geotechnical studies to determine whether final landform is stable.
			Risk assessment of final landform.	Evidence in rehabilitation report that appropriate risk assessment and control measures have been undertaken.
		Landform design achieves appropriate erosion rates.	Engineer's assessment of design and construction of structures to control water flow.	Engineer certification in rehabilitation report that remaining infrastructure sites have the required structures to control water flow and runoff.
Infrastructure	Village Infrastructure, Plant Site & Office, Airstrip, Roads, Borrow Pit	Landform design achieves appropriate erosion rates.	Engineer's assessment of design and construction of structures to control water flow.	Engineer certification in rehabilitation report that infrastructure sites (both remaining and decommissioned) have the required structures to control water flow and runoff.
		Adequate vegetation cover to minimise erosion.	Vegetation assessment.	Evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites.
Rehabilitation Goal: Sustains Agreed Land Use				
Mine Areas	Backfilled Pit	Soil properties that support and will continue to support desired land use.	Soil monitoring program in place to ensure remaining soil is able to support post-mining land use. Monitoring of chemical, physical and biological properties of soil.	Evidence in rehabilitation report that all soil chemical, physical, and biological properties of are within acceptable limits that ensure soil is able to support post-mining land use.
		Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.	Vegetation assessment to determine: • Presence of key species; • Species type and diversity; and • Abundance of weeds.	Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate. Evidence that weed management has been successful.
	Residual Void		Hydrological studies to establish water levels and quality.	Evidence in rehabilitation report that adequate water levels will be maintained in the residual void.

Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
		Establish specified waterbody with low risk of environmental harm.	Rehabilitation monitoring plan in place to monitor void water quality.	Evidence in rehabilitation report that water quality at surface is meeting livestock contaminant limits and that no risk to wildlife exists.
			Structural report on integrity of residual void.	Evidence in report of the integrity of the final landform, certified by an engineer.
	ROM Pad, Exploration Areas	Soil properties that support and will continue to support desired land use.	Soil testing program to characterise the chemical, physical and biological properties of soil to ensure its suitability for post-mining land use prior to placement.	Evidence in rehabilitation report that all soil chemical, physical, and biological properties of are within acceptable limits that ensure soil is able to support post-mining land use.
		Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.	Vegetation assessment to determine: • Presence of key species; • Species type and diversity; and • Abundance of weeds.	Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate. Evidence that weed management has been successful.
Overburden & Waste	Tailings Dams, Topsoil Stockpiles, Stockpile Area	Soil properties that support and will continue to support desired land use.	Soil testing of chemical, physical and biological properties to ensure soil is able to support post-mining land use before placement.	Evidence in rehabilitation report that all soil chemical, physical, and biological properties of are within acceptable limits that ensure soil is able to support post-mining land use.
		Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.	Vegetation assessment to determine: • Presence of key species; • Species type and diversity; and • Abundance of weeds.	Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate. Evidence that weed management has been successful.
Process Plant	Processing Plant, Heap Leach Pads & Ponds	Soil properties that support and will continue to support desired land use.	Soil testing of chemical, physical and biological properties to ensure soil is able to support post-mining land use before placement.	Evidence in rehabilitation report that all soil chemical, physical, and biological properties of are within acceptable limits that ensure soil is able to support post-mining land use.
		Self-sustaining vegetation cover and species similar	Vegetation assessment to determine: • Presence of key species; • Species type and diversity; and	Certification within the rehabilitation report that key species are present, suitable diversity has been

Domain	Mine Feature	Rehabilitation Objective	Rehabilitation Indicator	Completion Criteria
		to adjoining undisturbed areas.	Abundance of weeds.	achieved and cover/density is adequate. Evidence that weed management has been successful.
Dams	Runoff Dam, Water Storage Dam, Mine Process Water Dam, Tailings Return Water Dam, Water Harvest Trench	Establish safe and stable water body with a low risk of environmental harm.	Water quality established by monitoring or modelling validated by monitoring.	Evidence in the rehabilitation report that the dams meet water quality guidelines.
			Structural report on integrity of structure.	Engineers certificate of structure.
Infrastructure	Village Infrastructure, Plant Site & Office, Airstrip, Roads, Borrow Pit	Soil properties that support and will continue to support desired land use.	Soil testing of chemical, physical and biological properties to ensure soil is able to support post-mining land use before placement.	Evidence in rehabilitation report that all soil chemical, physical, and biological properties of are within acceptable limits that ensure soil is able to support post-mining land use.
		Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.	Vegetation assessment to determine: - Presence of key species; - Species type and diversity; and - Abundance of weeds.	Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate. Evidence that weed management has been successful.

5.6 MAINTENANCE OF REHABILITATED AREAS

Maintenance and monitoring activities will be undertaken on rehabilitated areas. Maintenance will ensure the following:

- The stability of rehabilitated landforms;
- Continued effectiveness of erosion control measures;
- No negative effects to environmental values of any waters as a result of stormwater runoff and seepage from rehabilitated areas; and
- Evidence of healthy growth and recruitment of plants.

In addition, management of rehabilitated areas will ensure drainage lines remain stable and will aim to minimise the introduction and spread of species not consistent with the rehabilitation objectives and the post mine land use.

Ongoing rehabilitation maintenance and monitoring activities will continue until such time that completion criteria are met for three consecutive years, after which time a residual risk assessment will be conducted.

5.6.1 Assessment of Residual Risk

Meeting completion and success criteria for a number of years does not preclude the possibility of failure at a future point in time. The *Guideline: Rehabilitation Requirements for Mining Projects* (EHP 2014) recommends conducting a risk assessment to determine the 'residual risk' of rehabilitation, that is, the risk of rehabilitation failing in the future. The following factors are considered in an assessment of residual risk:

- Hazards: the components of rehabilitation that are most likely to fail the completion criteria;
- Likelihood: the likelihood that one of these components will fail; and
- Consequence: the consequences that will occur if these components of rehabilitation fail (typically in monetary terms).

The threshold for consequences of rehabilitation failure to be considered in the risk assessment is to be consistent with the definition of 'material environmental harm' – i.e. \$5,000. In accordance with *Guideline: Rehabilitation Requirements for Mining Projects* (EHP 2014), "the probability of rehabilitation failure will usually be established from estimates of the minimum time before the rehabilitation has a 50 percent probability of failure and the variance of that estimate".

A residual risk assessment will be completed at the completion of the rehabilitation works. If any significant residual risks are identified, further remedial rehabilitation works and monitoring will be undertaken, and the risk assessment updated for submission to the DES.

6.0 REHABILITATION DESIGN AND METHODOLOGY

6.1 RECOMMENDED CLOSURE STRATEGY FOR CELL A

Cell A is constructed from oxide tailings and presents a low risk source of contamination. Rehabilitation design aims to eliminate the hazards associated with the sunken central portion of Cell A by the placement of fill and creation of a water shedding landform. Fill is planned to be excavated from the TWRD, followed by topsoil and re-profiling. A water shedding landform will prevent infiltration from rainfall and unexpected capillary rise of salts into the topsoil surface. Drainage channels will be constructed around the resultant water-shedding central mound, directing water towards the existing drainage channel that exits the TSF and flows to the TWRD.

Past rehabilitation works at Cell A indicate that salt rise into the growth medium, or other contaminants in the tailings, is not a significant hazard in areas with adequate surface drainage (preventing long-term ponding of water). Much of Cell A has been successfully revegetated by seeding directly into the oxide tailings, without the use of a capillary break cover. However, the application of topsoil / growth medium across the entirety of Cell A (estimated at 42.35ha) will likely generate improved results for grazing pasture and erosion. As such, a 200mm surface layer of topsoil is proposed across the whole of Cell A (totalling 84,700 m³ of topsoil material to be carted and spread). Further to this, Cell A will also undergo earthworks to ensure all surface water is directed to the drainage system at the south west of the dam.

Source of Materials for Cell A:

The area of the central, poorly drained portion of Cell A is 4.5 Ha. To achieve a free draining contour with a slope of around 0.5% however, the area of fill placement is considerably larger. The volume estimate by a 0.1m contour level is estimated as 29,000 m³ of loose fill (Table 6). There will be approximately 35,000 m³ of sediment spoil to be removed from the TWRD and directly deposited on Cell A, so there is easily sufficient material available to achieve the re-contouring in the centre of the cell.

Table 6 Fill Quantity Estimate for Centre of Cell A

Contour	Estimated Area (m ²)	Estimated Fill Volume Placed (m ³)
190.5m RL	24,441	2,400
190.4m RL	86,294	8,600
190.3m RL	96,220	9,600
190.2m RL	56,130	5,600
190.1m RL	27,93	2,800
Totals	-	29,000

Topsoil required for Cell A will be taken from existing stockpiles located around the TSF. Topsoil requirements in excess of that contained in the stockpiles will be recovered from borrow pits located adjacent to the TSF area (if needed)

6.2 RECOMMENDED CLOSURE STRATEGY FOR CELL B

A cover design has been adopted from a preliminary conceptual cover design produced by O'Kane Consultants – an engineering firm that specialises in integrated mine waste management and closure services. This design report has been submitted to DES as an attachment to the Plan of Operations.

Geochemical Considerations for Cell B Cover Design

As part of the development of the conceptual cover system for Cell B, the results of a geochemical assessment commissioned by Straits Gold in 2014 was reviewed (RGS Environmental 2015 – noting this has been previously submitted to DES). As part of the assessment, 85 soil, oxide tailings and sulphide tailings samples from the TSF were submitted for static and kinetic geochemical testing.

Static test results for all samples had Sulphur values between 0.02- 0.53%. Results suggested that the majority of sulphur present is as sulphate sulphur. Therefore, the majority of acidity in the TSF occurs as stored acidity, which will report to the environment as a function of net percolation. Cover system design should therefore focus on reducing net percolation.

Soluble metal leach tests were used to determine the likely concentrations of major ions and trace metals in water extracts. These tests showed the majority of samples had a pH of less than 5. Salinity values were typically in the range suitable for use as irrigation water. Concentrations of metals were typically below levels for livestock drinking water, with some minor exceptions for Cd, Fe and Mn in soil samples. The report states that the levels suggest that direct surface water runoff and seepage could exceed ANZECC aquatic ecosystem guidelines (RGS, 2015). However, RGS notes that this is unlikely to be an issue due to dilution by rainfall, runoff and seepage from the TSF catchment. This opinion is supported (in the report) by water quality data from the return water dam, which shows neutral to alkaline pH and relatively low EC values.

The report also notes that ‘there has not been accumulation of soluble elements from the tailings into the trial soil cover through capillary action; if this had occurred the soluble concentrations of major ions would have been higher in the soil.’ (RGS, 2015, p.26)

Cation Exchange Capacity (CEC) tests were performed on seven samples from soil and oxide tailings. The CEC values were very low, averaging 4.7 and 2.1 meq/100g, respectively. This suggests that soils may be low in fertility and susceptible to soil acidification (RGS, 2015). RGS recommended that oxide tailings in Cell B may require soil cover prior to revegetation. Exchangeable Sodium Percentage (ESP) tests suggest samples have low sodicity and are not likely to be susceptible to erosion and dispersion. Exchangeable Ca:Mg results indicate an average ratio of 4.5, which suggests that amelioration may be required in some areas to provide a reasonable growth medium if no topsoil cover was to be placed.

Kinetic test results were found (in summary) to typically have low pH (4-5), with concentrates of most elements decreasing over time, but remaining elevated for Al, Mn and Ni. However, RGS conclude that a capillary break is not likely to be required as ‘it is considered unlikely that the tailings contain a sufficient mass of soluble ions to significantly affect the overlying soils, due to the effects of capillary rise’ (RGS, 2015, p.30). This conclusion is supported by the success of revegetation trials on Cell B.

Whilst the report concludes that a capillary break is not likely to be required, it is noted that the proposed cover system for Cell B has provided for an inert sized gravel layer between the tailings and topsoil.

Site Climate Considerations for Cell B Cover Design

The Yandan Gold Mine semi-arid tropical climate is characterised by a hot wet season and mild dry season, highly variable rainfall, high evaporation rates and low humidity. A Silo Data Drill was obtained from the Queensland government for climate data specific to the Yandan mine site. A preliminary assessment of the obtained data was performed, with the main elements presented below. For the purposes of the initial proposal, O’Kane used data dating back to 1913. Monthly averages for precipitation and potential evaporation are presented in Figure 3.

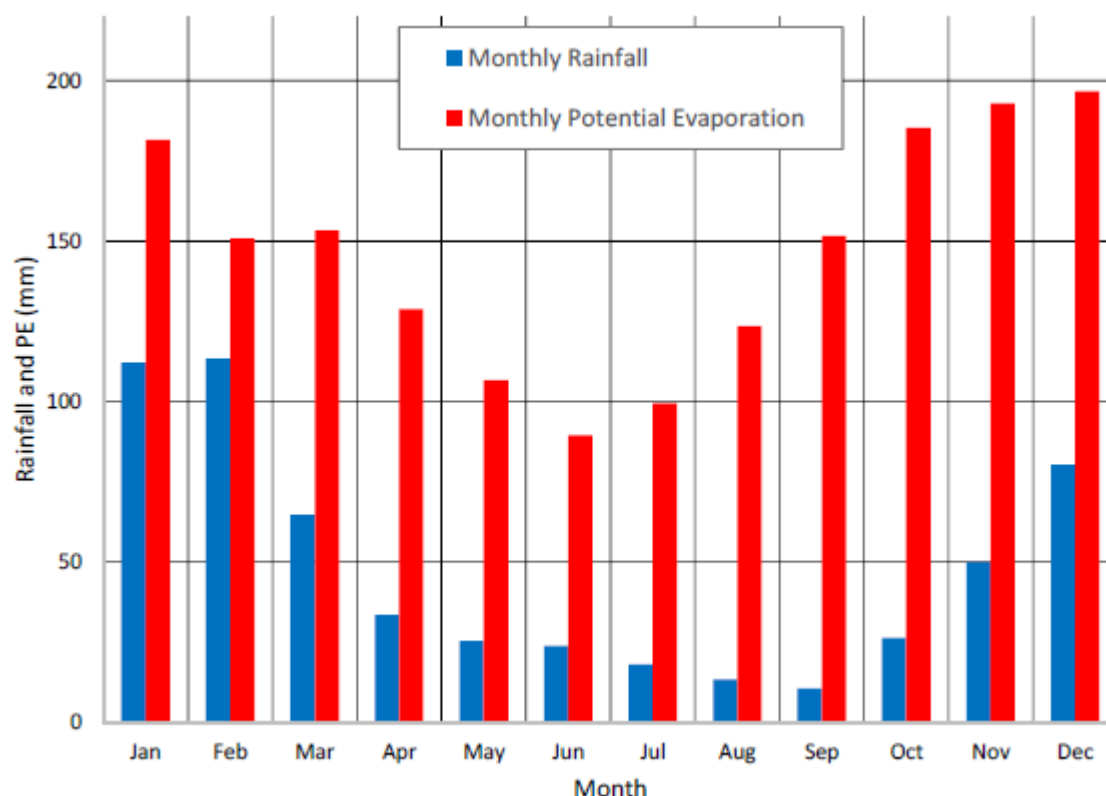


Figure 3 Yandan Site Average Monthly Rainfall and Potential Evaporation (1913 – 2014)

Average annual rainfall for the site is 559 mm (from the Bureau of Meteorology 'Bruslee' station), falling largely during the wet season (November to March). Drought is regarded as a common occurrence in the region; however, the area can be subject to heavy rainfall and flooding as tropical cyclones irregularly cross the coast and become rain-bearing depressions.

Annual rainfall regularly breaks 1,000 mm, with the maximum recorded annual rainfall being 1,157 mm. Figure 4 presents monthly rainfall and potential evaporation for 'wet years', which are defined as years when annual rainfall was over two standard deviations above the average for the entire data set.

The minimum recorded annual rainfall was 212 mm. Under the Koppen-Geiger classification system, the mine site is classified as BSh, corresponding to a hot semi-arid climate. According to current worst-case climate change scenarios (A1F1 under the IPCC SRES), this classification will remain the same for the 2076-2100 period.

Potential evaporation (PE) at the site (calculated using the FAO56 method) is approximately 1755 mm per year, which is approximately triple the average annual rainfall. PE is higher than rainfall for all months of the year. Average daily maximum temperatures range between 35°C in the summer months and 22°C in the winter months.

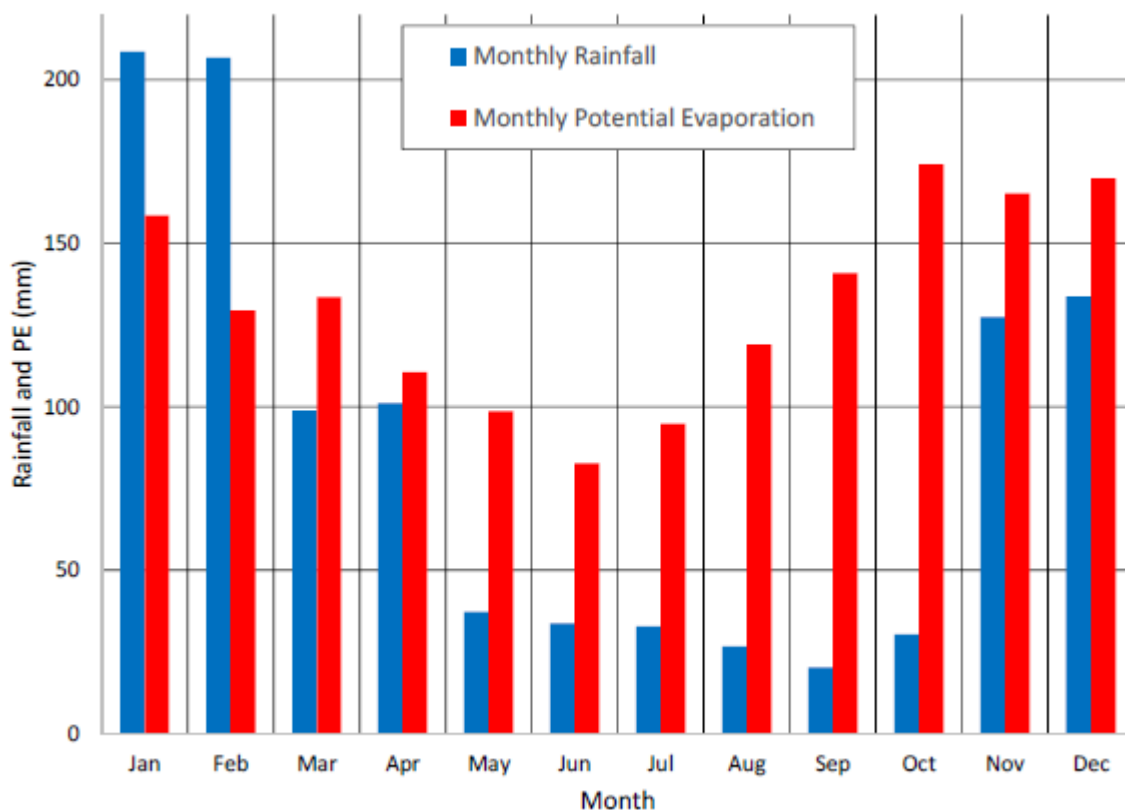


Figure 4 Yandan Site 'Wet Years' (~1 in 20) Rainfall and Potential Evaporation (1913 – 2014)

Groundwater Considerations for Cell B Cover Design

Groundwater in the area is of poor quality for stock watering, and considered unsuitable for irrigation and domestic use (GHD 2008). Groundwater flow is towards the Suttor River, on the banks of which the water table is approximately 8m below the riverbed at RL 158m. There is no known connection between the groundwater aquifer and surface water in this area.

Groundwater monitoring bores located around the TSF show the water table to be between 7m and 11m below the surface (May 2018), except to the east of Cell B where the water table is only 2.34m below the surface. This is likely due to the presence of an old creek blocked by the construction of the Cell B tailings dam. Surface water commonly pools at this location.

Design Objectives Specific to the Cover System for Cell B

The following objectives specific to the conceptual cover system have been developed. The cover system aims to:

- 1) Create clean surface runoff from the TSF Cell B surface;
- 2) Limit upward movement of oxidation products and salts;
- 3) Limit net percolation to limit flushing of stored acidity;
- 4) Form a stable landform with limited erosion; and

- 5) Support vegetation and final land use:
 - a) Cattle grazing
 - b) Avoid deep rooted vegetation (trees).

Conceptual Landform Design for Cell B

Prior to the placement of the cover system materials, the tailings surface will be reshaped and regraded to create a landform that promotes surface water runoff towards the current outlet located to the southwest of Cell B, as well as eliminating low areas that would promote water accumulation. Re-shaping the subgrade prior to construction of the cover system allows for maintaining a regular cover profile over the entire facility, with similar layer thickness throughout.

As demonstrated on previously rehabilitated areas over Cell A and the trial areas on Cell B, adequate re-sloping of the landform surface is required to promote surface runoff and avoid surface water accumulation within the TSF. It is proposed to regrade the tailings surface to create a minimum 0.5% slope towards the south.

Conceptual Cover System Design for Cell B

The cover system to be put in place will consist of two layers: a topsoil / growth medium layer at the surface; overlying a gravel drainage layer. The cover system material properties assumed for the development of the conceptual cover system design are shown in Table 7. These are assumed properties that will require verification during the detailed design of the cover system and in situ testing of the material's field saturated permeability. Detailed design has been provided for in FA calculations.

Table 7 Assumed Cover System Material Properties

Parameter	Topsoil / growth medium	Gravel	Coarse Rock	Tailings
Texture	Finer	Coarser	Very Coarse	Fine
Hydraulic Conductivity (Ksat)	10 ⁻⁴ cm/s	10 ⁻¹ cm/s	10 ⁻¹ cm/s	10 ⁻⁴ cm/s
Available Water Storage Capacity	1.5 mm/cm	n/a	n/a	n/a

The cover system design is split in two zones as per Figure 5. The separate zones are based on the potential water table within the tailings which is expected to be higher within Zone 2. This assumption stems from water levels recorded outside the TSF as part of groundwater monitoring for the site. The water table just east of the facility, within the creek area upstream of the dam wall, has been recorded at less than one metre below the surface. It is expected that the water table within the facility would range across similar levels within Zone 2.

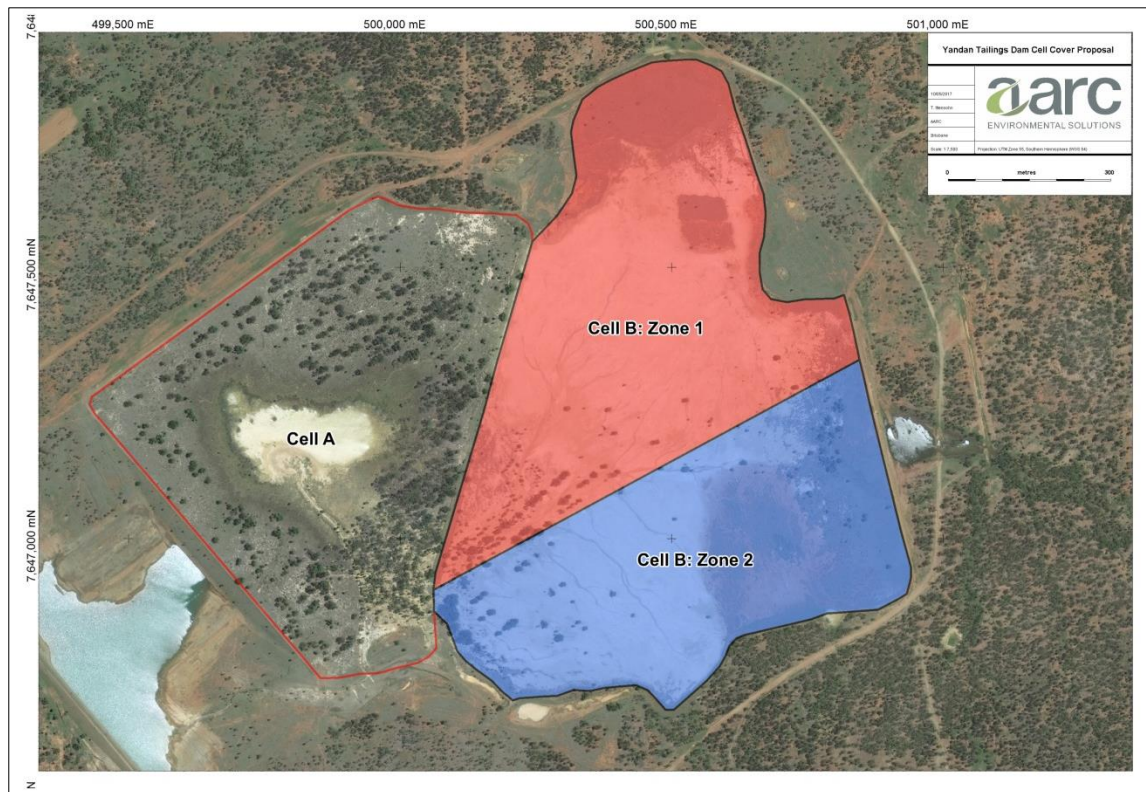


Figure 5 TSF Cell B Zoning for Cover Design

The cover systems designed for Zone 1 and Zone 2 differ in the granular material used for the drainage layer. Figure 6 shows the conceptual cover systems for Zone 1 and Zone 2, respectively.

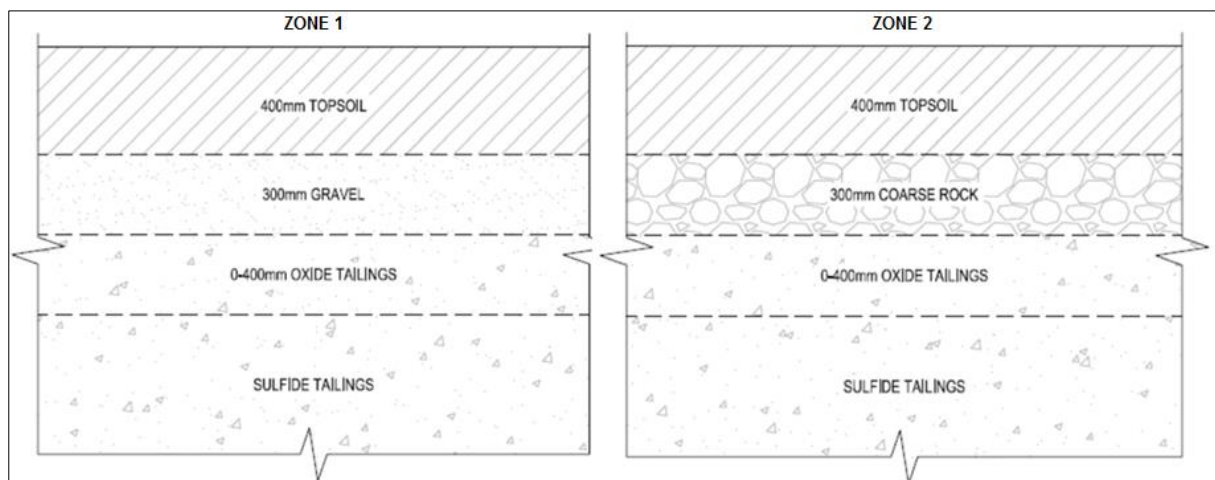


Figure 6 Conceptual Cover System Zones 1 & 2

Cover System Justification for Cell B

Meteoric water that reaches the surface of a cover system will either be intercepted by vegetation, run off, or infiltrate into the cover profile. A portion of the water that infiltrates will be stored in the 'active

zone' which refers the region of soil/growth medium near the surface; in which the water content varies due to precipitation and evapotranspiration. This water will subsequently exfiltrate back to the surface and evaporate, or be removed from within the profile by transpiration. The infiltration can also move laterally downslope, within and below the active zone. A small percentage of the infiltrating water will migrate beyond the active zone as a result of gravity overcoming the influence of atmospheric forcing (i.e. evaporation) and result in net percolation to the underlying waste material. In cases where the second granular layer (cover layer no. 2 in Figure 7) has a higher hydraulic conductivity than the underlying and overlying materials, lateral percolation would be expected within this layer as well.

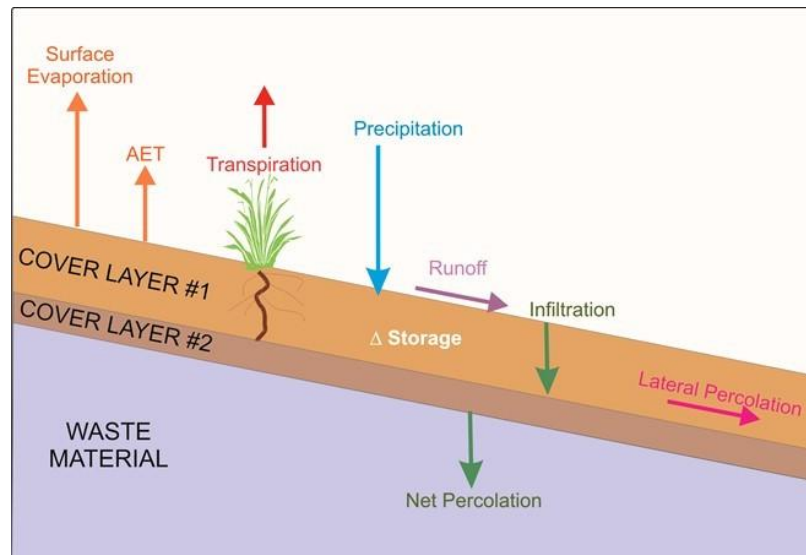


Figure 7 Schematic of hydrologic processes that influence performance of sloping mine waste cover systems

Figure 8 presents the water balance components for the conceptual model of the cover system. One goal of the cover system is to limit the amount of precipitation resulting in net percolation into the tailings material. In order to limit net percolation, the cover system promotes runoff and moisture storage within the topsoil layer while the gravel layer acts as a capillary break to limit moisture movement from the topsoil layer to the gravel layer and pore water uptake from the tailings material to the topsoil layer.

It is estimated that net percolation rates would be in the range of 10% to 15% for average annual rainfall conditions (for Yandan 1913 – 2014), and in the range of 30% to 35% for wetter years. This conceptual water balance is a broad estimate and makes conservative assumptions in regards to runoff rates (i.e. the percentage of rainfall reporting as runoff for these conditions is assumed to be relatively low at ~ 5% to 10% for an average year, and ~15% to 20% for a wetter year). It is important to note however, that this runoff will be 'clean', as it will be interacting with the topsoil surface. This is in contrast to current conditions where any runoff is adversely impacted by tailings surface conditions.

In addition to supporting vegetation for end land-use, the proposed 400 mm topsoil/growth medium layer offers a number of characteristics which support the cover system objectives presented. Conservatively, assuming the topsoil layer has a hydraulic conductivity of 10^{-4} cm/s, the infiltration rate into the topsoil layer during rainfall events would be in the range of 4 mm/hr.

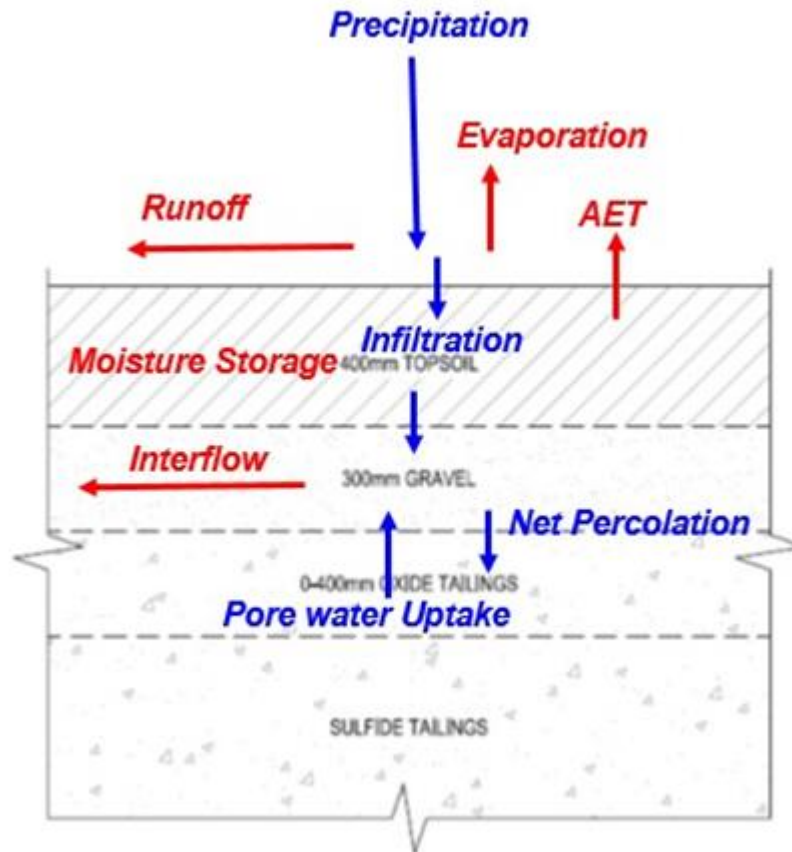


Figure 8 Conceptual Model of Cover System – Water Balance Components

As precipitation at the Yandan site is usually short and intense, it is expected that infiltration capacity may be exceeded on a regular basis, thus resulting in surface runoff. The field capacity of the topsoil, defined as the volumetric water content of the material at a soil matric suction of 33 kPa, is estimated to be 0.25. Assuming a permanent wilting point of approximately 0.10 (i.e. the volumetric water content of the material at a suction of 1,500 kPa), this equates to an available water storage capacity (AWSC) of ~1.5 mm of water per cm of soil. For a 400 mm layer of topsoil, this results in a storage capacity of 60 mm of water.

Although challenging to quantify on a conceptual basis, AWSC in the topsoil will be enhanced as a result of the textural contrast (i.e. the capillary break) at the gravel (or coarse rock) – topsoil interface. This enhancement is likely in the range of 15 to 20 mm (i.e. the field AWSC is likely to be in the range of 75 to 80 mm). This water storage capacity will be used up by vegetation and result in actual evapotranspiration (AET) while evaporation will reduce moisture storage from the soil surface. Furthermore, it is fundamental to appreciate that this water storage capacity can be utilised multiple times during the year, and particularly during the wet season. In other words, rainfall will infiltrate, be stored within the topsoil layer, and then evapotranspire repeatedly throughout the year.

If infiltration volumes into the topsoil layer exceed the field capacity of the material, gravitational flow into the gravel layer is expected. However, net percolation into the tailings material will be limited by the storage capacity of the topsoil (and enhanced by the textural contrast), the lower permeability of the tailings, the strong evaporation potential at the site, and the runoff that occurs during intense and/or extreme rainfall events. Root uptake of tailings pore-water would be limited by the presence of the

underlying textural contrast (i.e. the gravel layer) as well as provision of plant water use capacity within the topsoil layer.

Vegetation

The vegetation mix to be established on the Cell B TSF is expected to consist mainly of grasses to support the end land use of cattle grazing. As such, deep-rooted tree species are to be avoided over the area, reducing further the risk of tailings pore-water uptake from the rooting system.

Material Sources for Cell B

Coarse Rock:

Coarse rock for forming a drainage layer in Zone 2 will be sourced from the heap leach area. This is located 3.5km to the west of the TSF. Coarse rock will be recovered from the dump and screened to sort rock at approximately 50mm size. Excavation of the coarse rock will involve an excavator to take from the base of the heap and place for screening. Screen hire has been provided for in FA calculations. A tracked dozer will be required to push the dump material towards the excavator and screen. This dozing is in any case required to batter down the heap dump for final closure. Haulage of the rock by dump truck will be over a distance of 3.5km (one way) to deliver the coarse rock to the TSF.

The heap leach dump rock is Non Acid Forming (NAF) and contains lime that was dosed on the heap during processing. Analyses of 6 representative rock samples of this material shows that the pH was in the range of 8.1 to 10, EC was less than 500 $\mu\text{S}/\text{cm}$ and the Acid Neutralising Capacity (ANC) was 3.8 to 33.3 kg $\text{H}_2\text{SO}_4/\text{t}$. Net Acid Producing Potential (NAPP) was -2.9 to -32.7 kg $\text{H}_2\text{SO}_4/\text{t}$, thus this rock is classified as NAF (barren). There is approximately 1 million m^3 of material in the heap leach. Material on the heap leach is run of mine blasted rock that has not been crushed and ranges in size from sandy fines to quite large rocks. As the material is salvaged from the heap leach dump and screened via a visual check, additional Net Acid Generation (NAG) testing will determine the suitability of the leached material for use as coarse rock cover.

Gravel:

Gravel is available to be excavated from borrow pits adjacent to the TSF. On the edge of hill slopes the topsoil will be removed and stockpiled to expose the rocky gravel material. This material has already been used with great success: as the inert cover material at the test rehabilitation plots. It is rocky with high porosity but with sufficient fines to retain rainwater to support growth. The borrow pits for the rocky gravel will all be close to the TSF, so haulage distance (one way) will be less than 1000m.

Topsoil:

There are significant stockpiles of topsoil located around the TSF. The largest is located on the eastern side of Cell B. Topsoil can also be burrowed from immediately outside the TSF area.

6.2.1 Water Dams

Both the Tailings Water Return Dam (TWRD) and Mine Process Water Dam (MPWD) will be cleaned (through the removal of any contaminated sediment) to minimise the possibility of environmental harm. The closure plan is to remove up to 500mm of material from the 7 ha deepest section of the TWRD, (an area of approximately 350m x 200m adjacent to the dam wall; constituting 35,000 m^3 of material in total). The sediment and gravel will be utilised as fill on Cell A of the TSF and covered with 200mm of topsoil,

as part of the TSF rehabilitation. These dams are seasonally dry, easily accessed and do not require dewatering prior to cleaning.

The MPWD located downstream of where the old processing plant was, has received minimal sediment deposition. Sediment removal will still occur however, focused on the area close to the dam wall. Approximately 250 mm of material will be taken, from an area of 4.8 ha. Disposal of the resulting 12,000m³ of sediment, shall be achieved by placing into the nearby TSF.

The TWRD spillway area shall also require rehabilitation. This estimated surface area of the spillway is 3.1 ha. This area shall be cleared of sediment to an average depth of 0.25 m to remove any underlying contaminated sediment, with the resulting 7,750 m³ of material to be deposited in the TSF. The area will then undergo structural earthworks to manage all surface water, including any required soil conservation earthworks.

The clean dams will subsequently be allowed to fill with natural surface water and will be retained as a valuable resource for the land holder. The WSD, Runoff Dam and Water Harvest Trench are also intended to remain on the Project site following decommissioning to be used by the landholder as a highly valued asset for stock watering. No remedial works are anticipated to be required during the rehabilitation stage.

6.2.2 Leach Dump Area

The old leach dump is neutral to alkaline in nature and presents a valuable source of rock for construction and/or rehabilitation. Prior to reshaping, suitable inert material from the heap leach dump will be removed from the eastern end of the leach dump, closest to the tailings cells, to be used for capping of Zone 2 of the Cell B TSF. It is estimated that approximately 85,000 m³ shall be extracted before reshaping.

Three small ponds are present on the site adjacent to the leach dump (known as the 2 Heap Leach Ponds and the Stormwater Pond – Refer Figure 3). The water stored in the ponds will be progressively pumped to the MPWD for evaporation. The Stormwater Pond will be retained at closure, however the 2 Heap Leach Ponds will be decommissioned and rehabilitated.

The heap leach dump outside slope is to be flattened to a maximum slope of 17 degrees by dozer push. The work is all relatively high productivity down slope pushing with a dozer. Some additional pushing has been allowed to fill in and cover over the 2 Heap Leach Ponds, integrating them under the final land form.

Topsoil will be spread (200 mm), seeded and fertilised over the final land form. Topsoil stockpiles are found adjacent to the dump. A bulk dozer push of 27,400 m³ is estimated and 37,700 m³ of topsoil will be placed to complete closure of this facility. Final rehabilitated surface area is 18.85 ha.

6.2.3 Mining Pits and Main Pit Bund Wall / Levee

The Main Pit, situated adjacent to the Suttor River, will require the retention of a water layer that is sufficient to cover all potentially acid producing rock material in the pit's walls. The retention of this cover will rely on periodic inflows from the Suttor River to recharge the pit. Two spillways have been installed on the north-west and south-east walls of the pit, with the RLs of the spillways such that inflows are allowed at least once in two years.

Both spillways have been lowered to ensure inflows from the Suttor River maintain the water in the Main Pit, at levels greater than 160 m AHD. The principal spillway on the downstream side of the Main Pit is excavated in competent rock, with little erosion anticipated.

The bund wall / levee for the Main Pit is proposed to be disposed of into the Main Pit. This will be achieved by a major bulk push into the Main Pit during the dry season, allowing any resulting sedimentation time to settle before the wet season, minimising any chance of discharge into receiving waters. The bund wall / levee covers an estimated footprint of 2.1 ha and is estimated to have an average height of 5 m. The total bulk dozer push will be approximately 105,000 m³, with the footprint area then topsoiled to a depth of 200 mm and seeded with pasture species. A small safety bund will be retained around the perimeter of the pit. Topsoil shall be sourced from the nearby leach dump stockpiles.

A security fence will be constructed around the small East Hill Pit; a safety bund and stock fence is already in place. Decommissioning will involve ensuring the bund and fencing are suitable for preventing livestock and human access, as well as erecting adequate warning signage. The pit will be partially backfilled with concrete removed from the plant and infrastructure sites, as well as sediment taken from the MPWD. The pit will be left in a safe condition by short dozing of surrounding minor waste dumps into the pit. An estimated 20,000m³ of material will be required to achieve the final slope.

The South Pit has already been backfilled to blend in with the natural environment and is fully rehabilitated.

6.2.4 Infrastructure

The rehabilitation cost for the remains of the infrastructure area shall include appropriate Phase 1 contamination assessments where applicable. All remaining concrete footings (0.47 ha) will be removed and deposited in the old East Pit (for burial).

The majority of the previous buildings (such as the village accommodation camp and industrial areas) have already been removed, with areas rehabilitated (with the exception of some concrete footings). A small area of buildings utilised as the exploration camp/office (0.03 ha), and one small above-ground tank remain. These will be demolished and buried in the East Hill Pit before the underlying area is topsoiled and seeded. The residual small hardstand area will be ripped, topsoiled, and seeded with pasture species.

Approximately 4 ha of infrastructure and hardstand area has already been reshaped, topsoiled and rehabilitated. This will require only minor repairs and maintenance.

6.2.5 Borrow Pit

After being excavated as a source of gravel and topsoil material, the borrow pit area will then be reshaped, topsoiled and seeded with native grasses.

6.2.6 ROM

The ROM pad area has been previously rehabilitated and will require only minor rehabilitation repairs and maintenance. Monitoring of the rehabilitated landform is planned to demonstrate success against rehabilitation objectives.

6.2.7 Areas retained by the Landholder

By agreement with the landholder, and approval from the administrative authority, the following infrastructure shall be retained on site post closure:

- Roads
- Airstrip

- Water Storage Dam
- Tailing return dam
- Harvest Trench
- Runoff Dam

7.0 MATERIALS BALANCE

Based on available information, a materials balance has been undertaken as part of the Financial Assurance calculation for the project. This detail is provided through the FA calculator determinations and supporting material in the August 2018 Plan of Operations. In short, site supplies of the required material will substantiate final rehabilitation requirements; although a screen to grade coarse rock is required to deliver sufficient size gradients.

8.0 FURTHER STUDIES

It is a requirement of the Project's EA that the PMLUP facilitates a research program. Research to be undertaken includes further geotechnical, geochemical and hydrological studies to determine the conditions of final landforms to remain on the Project site. Much of this is occurring through ongoing rehabilitation trials. In addition, further ecology investigations will continue (through Rehabilitation Monitoring) to assess the adequacy of rehabilitation strategies and rehabilitation trials.

Completion criteria and rehabilitation strategies may be subject to change based on the results of further investigations.



YANDAN GOLD PROJECT 2023 REHABILITATION MONITORING REPORT

PREPARED FOR
STRAITS GOLD PTY LTD

14 DECEMBER 2023



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1 Introduction

AARC Environmental Solutions Pty Ltd (AARC) has been commissioned by Straits Gold Pty Ltd (Straits Gold) to conduct the 2023 Rehabilitation Monitoring Program (RMP) and prepare a summary report on the progress of rehabilitated sites and rehabilitation trials at the Yandan Gold Project (the Project, Yandan). Straits Gold is a wholly owned subsidiary of GBM Resources Ltd (GBM), who acquired the Project and the Straits Gold entity in January 2021.

1.1 Background information

The Yandan Gold Project is situated in the Drummond Basin in Central Queensland, approximately 50 km to the west of the Mount Coolon township and 150 km southeast of Charters Towers (Figure 1-1). The Project is located on mining leases (ML) 1095 and 1096, operating under Environmental Authority (EA) EPML00771913.

Ross Mining N.L. previously operated the site between 1993 - 2002, producing over 350,000 ounces (oz) of gold from heap leach operations and a Carbon in Leach (CIL) process plant. Ore was sourced from three open cut pits during operation, principally being Main Pit and South Pit, with a small pit also excavated at East Hill. During operations, low grade oxide ore (predominately clay rich) sourced from the three open cut pits was placed on the Heap Leach Pad.

Mining operations ceased in 1998, with the Heap Leach Pad remaining operational until September 2002. The site was placed into care and maintenance in April 1999, pending final closure works. The gold processing plant was later removed in 2006/2007, prior to the acquisition of the Project by Straits Gold; a wholly owned subsidiary of Aeris Resources Ltd at that time. The Project has remained in care and maintenance since ceasing operations in 1999, with some exploration activities undertaken since that time.

Rehabilitation has been progressively undertaken at Yandan since operations ceased in 2002, with some domains fully or partially rehabilitated. Rehabilitation has been completed for Cell A of the TSF, South Pit (including a complete backfill), and much of the infrastructure and mine village infrastructure areas (with the minor exception of some concrete footings and hardstands remaining). Cover trials have also been established on Cell B of the Yandan Tailings Dam, to trial the effectiveness of different cover systems proposed for the final rehabilitation of the facility. Monitoring the rehabilitated areas and the Cell B cover trials is provided by the annual rehabilitation monitoring program (RMP), with the results from the 2023 RMP event provided through this progress report.

1.2 Purpose

The purpose of the RMP is to measure the performance of rehabilitation and the TSF cover trials at the Project against the established rehabilitation objectives, indicators and completion criteria (refer to Section 2.2.4). The program also provides recommendations where necessary to ensure long-term rehabilitation success.

This Rehabilitation Monitoring Report presents the findings from the 2023 RMP event, completed 13 – 14 June 2023. The information in this report builds on the rehabilitation monitoring events previously undertaken, as outlined in Section 1.4.

This progress report has been prepared to comply with Condition F4-2 and F4-3 of the Yandan EA EPML00771913.

Conditions F4-2 and F4-3 of the Project's EA provide:

Condition F4-2: The holder of the environmental authority must conduct a Rehabilitation Monitoring Program on at least a yearly basis, which must include sufficient spatial and temporal replication to enable scientifically justifiable conclusions as established under the rehabilitation program or other methodology to the satisfaction of the administering authority.

Condition F4-3: The Rehabilitation Monitoring Program must be developed by and be implemented by a person nominated by the environmental authority holder possessing appropriate qualifications and experience in the field of mine site rehabilitation.

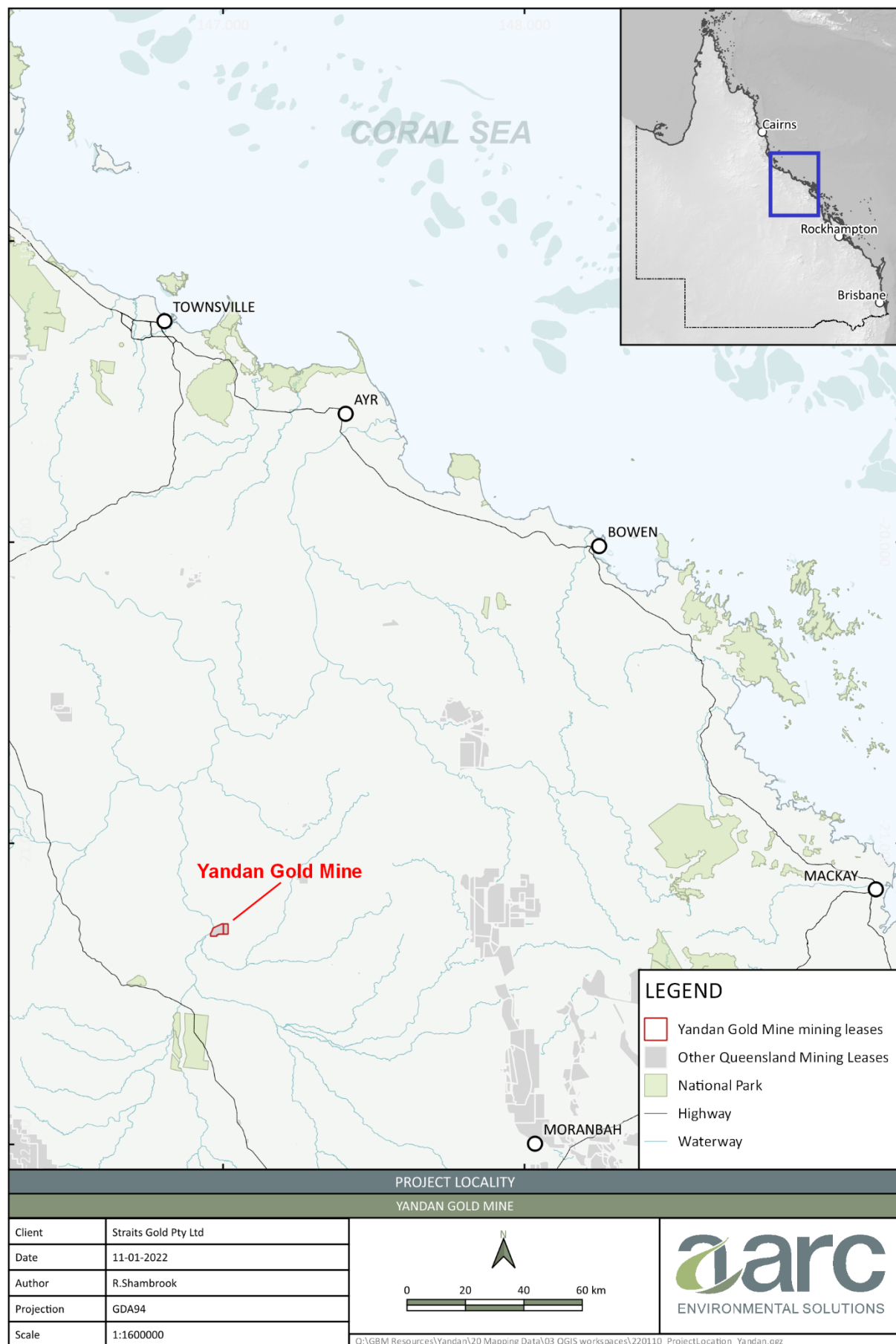


Figure 1-1: Project locality

1.3 Scope

The following scope of works was completed for the RMP:

- a field survey to evaluate the progress of site rehabilitation works, including monitoring at:
 - rehabilitation domains (ROM Pad, South Pit, Rehabilitated Infrastructure and Village Infrastructure areas);
 - the rehabilitated Cell A of the Yandan Tailings Dam;
 - the rehabilitation cover trial sites on Cell B of the Yandan Tailings Dam; and
 - three reference sites located in undisturbed portions of the Project's tenements.
- to report on the performance of the established rehabilitation methodologies with respect to attaining the relevant rehabilitation goals, objectives, and success criteria for the Project; and
- to provide recommendations to consider in the design and scheduling of future site rehabilitation works.

1.4 Previous monitoring

The dates and seasons previously surveyed are outlined below in Table 1.1. The current monitoring event (the tenth monitoring event) was undertaken during April 2023.

Table 1.1: Rehabilitation monitoring events

Monitoring Event	Season	Dates
First	Pre-wet	08 – 09 October 2014
Second	Wet	25 – 26 March 2015
Third	Post wet	10 – 11 June 2015
Fourth	Dry	13 – 14 August 2015
Fifth	Post wet	17 – 18 May 2016
Sixth	Post wet	20 – 22 July 2017
Seventh	Post wet	28 – 29 May 2018
Eighth	Post wet	25 – 26 February 2019
Ninth	Dry	24 – 26 August 2020
Tenth	Wet	15 – 19 March 2021
Eleventh	Post Wet	01 – 02 June 2022
Twelfth	Post-Wet	13 - 14 April 2023

1.6 Rainfall and seasonal influences

The Project is located within the Brigalow Belt (North) Bioregion, which is described as having a semiarid to tropical climate, with summer-dominant rainfall (DAWE 2008). Rainfall during the summer months is typically received during short and intensive storm events (Cowie *et al.* 2007).

Year-to-year variations in seasonal rainfall should be considered when comparing rehabilitation monitoring data over time. Xu Z and Zhou G (2011) and Yan *et al.* (2015) demonstrated a correlation between above ground biomass, species richness and rainfall. This correlation results from available soil moisture and higher water availability, which generally leads to increases in plant biomass and species composition (Xu Zhou 2011 & Yan *et al.* 2015). Long term annual total rainfall records for the Project region have been sourced from the Queensland Government Long Paddock SILO climate database and are presented in Figure 1-2.

The total rainfall in the three months preceding the 2023 survey was 331 mm, which was higher than the three months prior to the 2022 survey (264 mm) (Figure 1-3). Both monitoring surveys were conducted post wet season. The other most recent survey undertaken post wet season (2019) received 487 mm in the three months prior, significantly higher than the rainfall prior to the March 2021 survey (286 mm) and the May 2022 survey (264 mm). Consideration to these variations in rainfall should be given when comparing the rehabilitation data year-on-year.

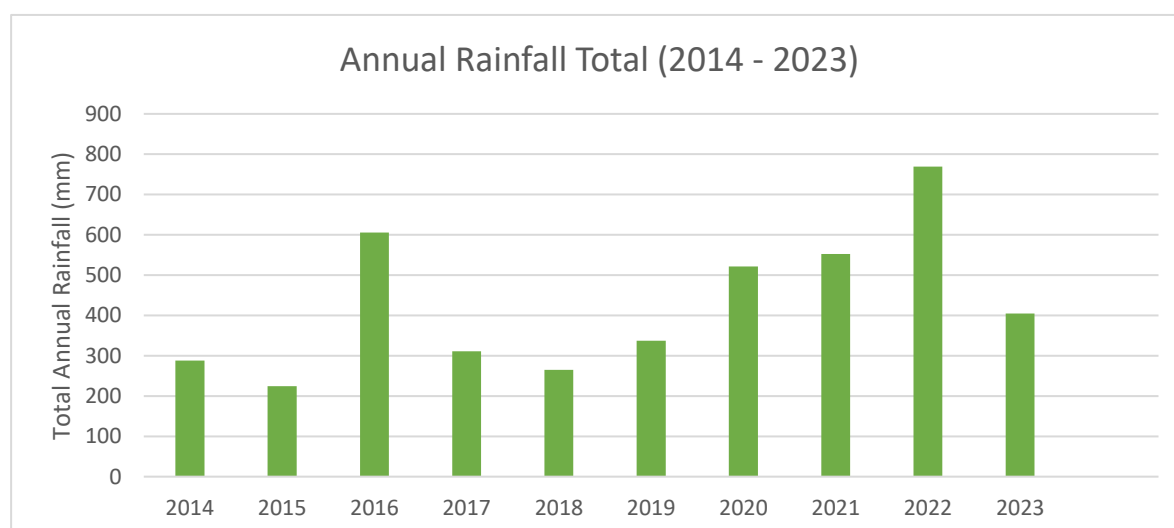


Figure 1-2: 2014 – 2023 Annual Rainfall Totals (Source: SILO climate database)

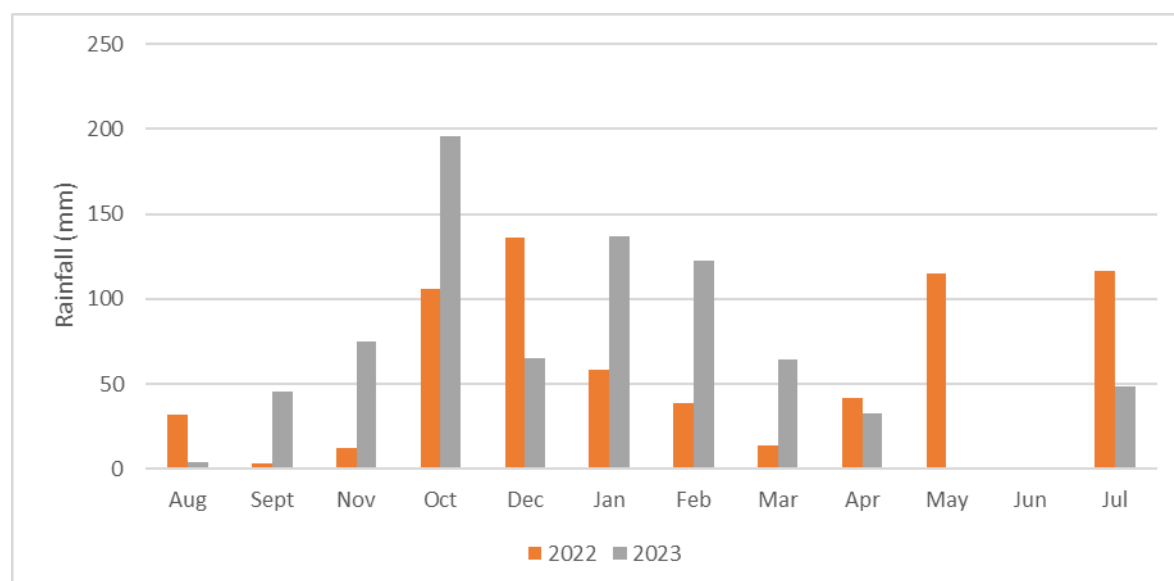


Figure 1-3 Monthly rainfall totals in lead up to 2023 RMP

2 Objectives, indicators, and completion criteria

2.1 Rehabilitation policy in Queensland

In Queensland, rehabilitation is required under the *Environmental Protection Act 1994* (EP Act). The administering authority must be satisfied with progressive rehabilitation undertaken before they can certify the progressive rehabilitation or accept the surrender of an Environmental Authority (EA) for the whole or part of a project. The administering authority must consider the relevant completion criteria when deciding whether to certify progressive rehabilitation or whether to approve a surrender application.

The government's policy objectives for rehabilitation are called rehabilitation goals to distinguish them from the rehabilitation objectives selected by mining companies in their rehabilitation strategies for a particular mine. The rehabilitation goals have been developed from the ESD policy framework, particularly in relation to intergenerational equity, the polluter pays principle, protecting biodiversity and maintaining of essential ecological processes. The four general rehabilitation goals require rehabilitating areas disturbed by mining to result in sites that are:

- 1) safe to humans and wildlife;
- 2) non-polluting;
- 3) stable; and
- 4) able to sustain an agreed post-mining land use.

It is noted that as part of amendments made to the EP Act in 2019, all mining operations are required to have a Progressive Rehabilitation and Closure Plan (PRCP) by November 2022, with existing mines required to transition from previous rehabilitation plans (including the Plan of Operations) to a PRCP. The PRCP introduces new requirements for the progressive rehabilitation and closure of mined land, establishing a schedule with time-based milestones for when activities are to be carried out, with rehabilitation criteria for each milestone. At the time of reporting, a transitional PRCP application for Yandan has been submitted (March 2022), with a decision on this application still pending subject to further information. As such, the existing rehabilitation objectives, indicators and completion criteria remain applicable for Yandan.

2.2 Site-specific rehabilitation requirements

2.2.1 EA conditions

Schedule F of the Yandan EA specifies the conditions for rehabilitation of areas disturbed by the Project.

Schedule F – Table 1 of the Yandan EA provides the post-mine land descriptions and classifications for each type of disturbance (provided as Table 2.1 below). A post-mine land classification of 'VII' (unsuitable for cultivation but suitable for grazing and forestry with severe limitations) has been approved for all areas, except for the run-off dam that has a post-mine land classification of 'VIII' (Unsuitable for cultivation grazing and forestry) (AARC 2015). The open pit areas have been classified as voids, which will be retained in the final landform as non-use management areas.

Table 2.1: Final Land Use and Rehabilitation Approval Schedule, as per Schedule F – Table 1 (Post Mine Land Description) from the Yandan EA

Tenure ID	Disturbance Type	Maximum surface area (ha)	Post mine land description	Post mine land classification
ML1095	Backfilled pit	4	Open pasture	VII
	Tailings dam	39	Open pasture	VII

Tenure ID	Disturbance Type	Maximum surface area (ha)	Post mine land description	Post mine land classification
	Stockpile area	8.3	Open pasture	VII
	Run-off dam	16.6	Water storage	VIII
	ROM pad	3.8	Low hill	VII
	Processing plant	1.8	Open pasture	VII
	Open pit	18.8	Lake	Void
	Infrastructure	79.8	Open pasture	VII
	Heap leach	21	Low hill	VII
	Borrow pit	8	Open pasture	VII
	Exploration	4.5	Open pasture	VII
ML1096	Village infrastructure	15	Open pasture	VII
	Tailings dam	75	Open pasture	VII

2.2.2 Pre-mining and post mining land uses

Cattle grazing was the predominant previous site use, and the current use of the adjoining land. This post mining land use is understood to meet relevant stakeholder and landowner expectations. Areas suitable for grazing will include improved pasture species already established on site.

2.2.3 Rehabilitation objectives

Site-specific rehabilitation objectives have been developed for the Project with the aim of returning disturbed areas to the pre-mining land use of low intensity cattle grazing. These rehabilitation objectives are established in the Post Mine Land Use Plan (PMLUP) (AARC 2018b) developed for the Project.

Rehabilitation objectives to satisfy the rehabilitation goals described in Section 2.2.1, noting that some objectives are not relevant to all domains (AARC 2018b), are:

- sites are safe for humans and animals now and in the foreseeable future;
- hazardous and contaminated materials will be adequately managed;
- polluted runoff and seepage will be contained on site;
- acid mine drainage (AMD) will not cause serious environmental harm;
- dams to remain on closure will not contribute contaminants to the environment;
- rehabilitated dams will not contribute contaminants to the environment;
- establish safe and stable waterbodies with a low risk of environmental harm;
- landform design achieves appropriate erosion rates;
- minimal probability of wall failure or rock falls that will cause significant environmental harm;
- adequate vegetation cover to minimise erosion;
- very low probability of slope slippage with serious consequences;

- soil properties that support and will continue to support desired land use; and
- self-sustaining vegetation cover and species similar to adjoining undisturbed areas, capable of supporting approved land use.

2.2.4 Rehabilitation indicators and completion criteria

To achieve the rehabilitation indicators detailed in Section 2.2.2, the PMLUP also establishes rehabilitation indicators and completion criteria (refer to Table 4 in the PMLUP) (AARC 2018b), with these summarised below in Table 2.2.

Rehabilitation indicators provide measures of progress towards rehabilitation objectives. Completion criteria are the standards that provide a clear definition of successful rehabilitation and take the form of a set of measurable benchmarks against which the rehabilitation indicators can be compared, to determine whether objectives are being met for the agreed land use. Rehabilitation is deemed successful when completion criteria for each rehabilitation goal and objective are consistently met. Parameters, monitored by the RMP, that are relevant to the established completion criteria, include:

- presence of key species;
- species type and diversity;
- adequate cover and density;
- weed abundance and diversity; and
- erosion rates.

Assessing rehabilitation success against these parameters is completed annually through the RMP. In accordance with Condition F2-7 (b) of the Yandan EA, rehabilitation is considered successful when the rehabilitation satisfies the rehabilitation goals, objectives, indicators, and completion criteria for a minimum of at least three years; in addition to some other requirements. Once rehabilitation is considered successful, progressive certification may be applied for.

Trend analysis will be used to assess if rehabilitation results are moving towards success criteria. If data is trending away from success criteria, an investigation will be undertaken to assess if there is an underlying issue and what additional maintenance is required. Monitoring may also suggest implementing a new long-term measure of success.

The completion criteria identified in this report are relevant to the monitoring and assessment of vegetation characteristics only, and additional rehabilitation objectives and completion criteria will also apply to progressively certify rehabilitation in the future. The full list of completion criteria specific to the Project is detailed in Table 4 in the 'Yandan Post Mine Land Use Plan' (AARC 2018b).

Table 2.2: Summarised objectives, rehabilitation indicators and completion criteria (AARC 2018b)

Rehabilitation objective	Rehabilitation indicator	Completion criteria
Adequate vegetation cover to minimise erosion.	Vegetation assessment.	Evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites.
Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.	Vegetation assessment to determine: • presence of key species; • species type and diversity; and • abundance of weeds.	Certification within the rehabilitation report that key species are present, suitable diversity has been achieved and cover/density is adequate. Evidence that weed management has been successful.

3 Methodology

3.1 Rehabilitation monitoring locations

Rehabilitation progress of the various rehabilitated domains and cover trial sites is monitored at established monitoring sites, as shown in Figure 3-1 and as detailed in Table 3.1 below.

Progressive rehabilitation sites are located at the following domains:

- South Pit (SP1 and SP2);
- Run-of-Mine (ROM1, ROM2, and ROM3);
- Cell A (A1 and A2);
- Rehabilitated Infrastructure (RI1 and RI2); and
- Village Infrastructure (V1 and V2).

Cover trial sites on TSF Cell B provide for monitoring of each trial cover system type, including:

- Thin Cover – 300 mm topsoil placed on the tailings surface (monitoring location 'B1' and 'B2').
- Thick Cover – 450 mm topsoil placed over oxide tailings (monitoring location 'B3' and 'B4').
- Gravel Topsoil cover – 0 – 600 mm gravelly topsoil placed over sulphide tailings (monitoring location 'B5').
- Gravel Topsoil cover – 400 mm gravelly topsoil placed over sulphide tailings (monitoring location 'B6').

Three established reference sites are located outside of the Project disturbance footprint (R1, R2, and R3). Reference data from these sites provides the benchmark for measuring the rehabilitation performance of rehabilitated sites and cover trials towards the post-mine land use of 'open pasture'.

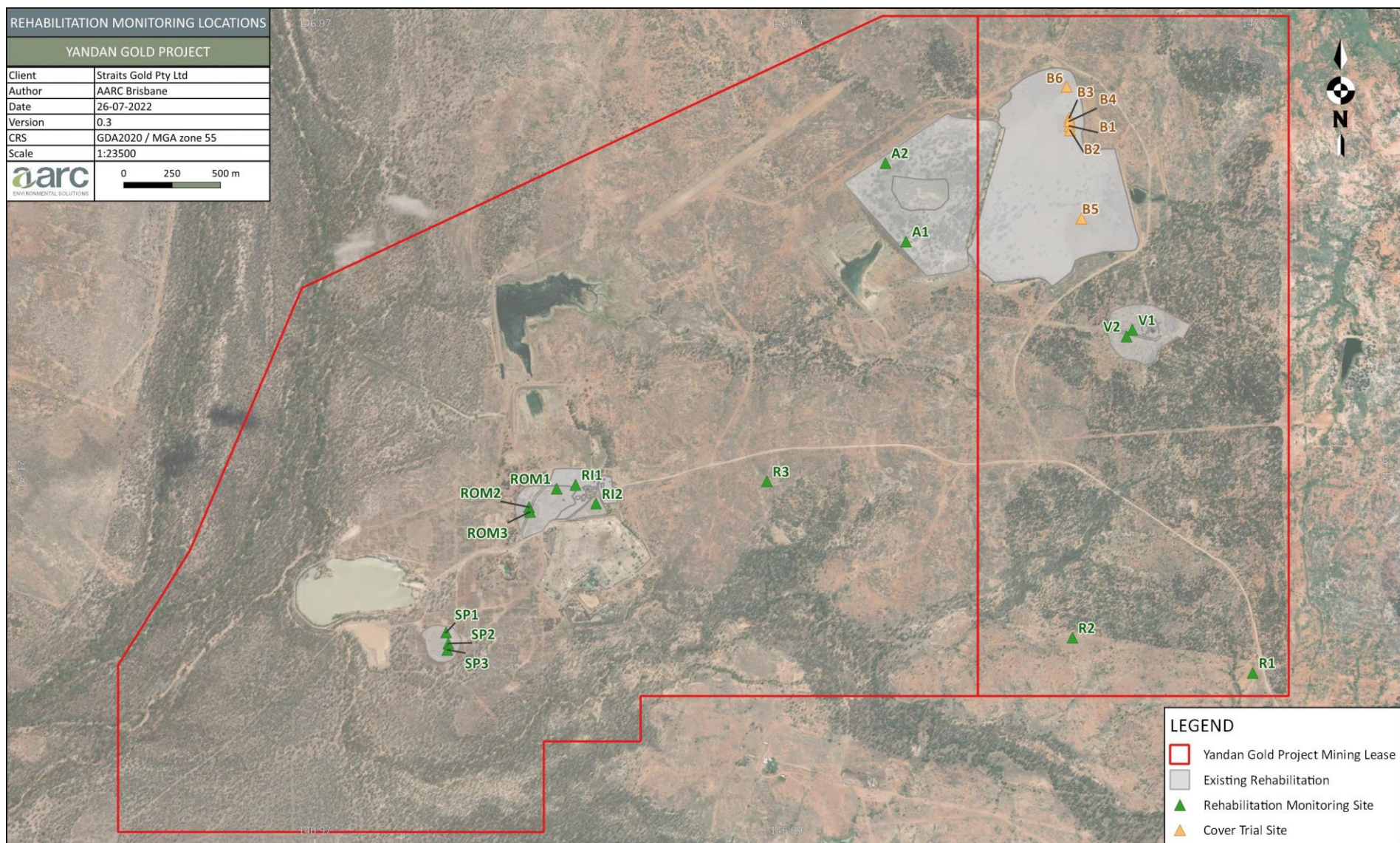


Figure 3-1: Monitoring site locations

Table 3.1: Vegetation monitoring sites

Site name	Site type	Easting	Northing	Location	Rehabilitation method	Rehabilitation classification	Year established
Reference Sites							
R1	Reference	501535	7644552	South of the village infrastructure	-	Open pasture	2014
R2	Reference	500605	7644748	South of the village infrastructure	-	Open pasture	2014
R3	Reference	499022	7645610	East of rehabilitated infrastructure	-	Open pasture	2014
Cell B Sites							
B1	TSF Cell Trial: Cell B – Thin Cover	500590	7647564	Southern trial area Cell B	300 mm topsoil placed directly on the tailings surface	Thin Cover	2014
B2	TSF Cell Trial: Cell B – Thin Cover	500591	7647544	Southern trial area Cell B	300 mm of topsoil placed directly on the tailings surface	Thin Cover	2014
B3	TSF Cell Trial: Cell B – Thick Cover	500586	7647610	Northern trial area Cell B	450 mm topsoil over oxide tailings	Thick Cover	2014
B4	TSF Cell Trial: Cell B – Thick Cover	500587	7647593	Northern trial area Cell B	450 mm topsoil over oxide tailings	Thick Cover	2014
B5	TSF Cell Trial: Cell B – Gravel Topsoil	500655	7647058	South-east area Cell B	0-600 mm gravelly topsoil over sulphide tailings	Gravelly topsoil	2014
B6	TSF Cell Trial: Cell B – Gravel Topsoil	500573	7647785	Northern end of Cell B	400 mm of gravelly topsoil over sulphide tailings	Gravelly topsoil	2014
Cell A Sites							
A1	TSF Cell Trial: Cell A	499745	7646926	South-west Cell A	Revegetation of Oxide tailings (direct seeding)	Open woodland	2014
A2	TSF Cell Trial: Cell A	499647	7647367	North-west Cell A	Revegetation of Oxide tailings (direct seeding)	Open woodland	2014
South Pit Sites							

Site name	Site type	Easting	Northing	Location	Rehabilitation method	Rehabilitation classification	Year established
SP1	Progressive rehabilitation – South Pit	497367	7644773	Top of hill. North area of pit.	Back filled pit	Rehab grassland	2017
SP2	Progressive rehabilitation – South Pit	497379	7644712	Centre of south pit	Back filled pit	Rehab grassland	2017
SP3	Progressive rehabilitation – South Pit	497373	7644677	South portion of south pit	Back filled pit	Rehab grassland	2017
ROM Pad Sites							
ROM1	Progressive rehabilitation – Run-of-Mine	497938	7645565	Eastern ROM	Rehab low slope	Rehab grassland	2017
ROM2	Progressive rehabilitation – Run-of-Mine	497795	7645464	ROM central west	Rehab slope	Rehab grassland	2017
ROM3	Progressive rehabilitation – Run-of-Mine	497800	7645437	ROM Pad Central (east of Road)	Rehab flat	Rehab grassland	2018
Rehabilitated Infrastructure Sites							
RI1	Progressive rehabilitation – Rehabilitated Infrastructure	498036	7645587	RI North	Rehab flat	Rehab grassland	2017
RI2	Progressive rehabilitation – Rehabilitated Infrastructure	498141	7645484	RI South	Rehab flat	Rehab grassland	2017
Village Infrastructure Sites							
V1	Progressive rehabilitation – Village Infrastructure	500913	7646442	North-west sector of village, north of road	Rehab flat	Rehab grassland	2017
V2	Progressive rehabilitation – Village Infrastructure	500883	7646405	SW sector of village, south of road	Rehab flat	Rehab grassland	2017

Note: Substrate information presented in this table is sourced from a tailings characterisation undertaken by Aeris Resources Pty Ltd in October 2014. GPS information provided in UTM GDA94.

3.2 Vegetation monitoring

Vegetation monitoring involves collecting quantitative data on ground cover composition, species richness, woody stem density, and canopy cover at each monitoring site. Each monitoring site is defined by a 50 m long transect and observations/ measurements are taken at 5 m intervals on both sides of the transect, thereby representing a site area of 50 m x 10 m. A star picket was installed at each end of the transect to permanently identify the transect location consistently and precisely.

Survey methodologies outlined below have been adapted from the Queensland Herbarium survey technique titled 'Methodology for Surveying and Mapping of Regional Ecosystems and Vegetation Communities in Queensland' (Version 5.1) (Neldner *et al.* 2020), and the 'Method for the Establishment and Survey of Reference Sites for BioCondition' (Eyre *et al.* 2017).

3.2.1 Ground cover monitoring

This method involved the collecting quantitative data on average ground cover (%), where the percentage of all types of ground cover within ten 1 m x 1 m quadrats was determined. The quadrat was placed every 5 m on alternating sides along the 50 m transect, commencing at 0 m on the left and the final quadrat at 45 m (refer to Figure 3-2). In each quadrat the percentage cover of rock, bare ground, organic litter, and each plant species present, was recorded. Live plant species were classified into one of the following six groups for reporting purposes:

- native pasture grass species (grass species that are palatable to stock);
- exotic pasture grass species (grass species that are palatable to stock);
- non-pasture grass species (grass species that are not palatable to stock);
- shrubs (woody plant multi-stemmed at the base or, if single-stemmed, less than 2m tall);
- forbs and other non-grass species (sedges, vines, and non-declared weeds); and,
- restricted invasive plants as listed in the Queensland *Biosecurity Act 2014*.

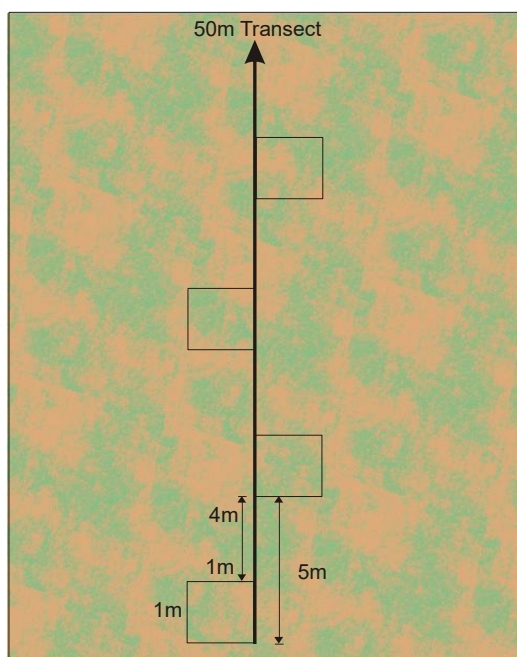


Figure 3-2: Ground cover percentage sampling

3.2.2 Species richness

Species richness was assessed using the method outlined in Eyre *et al.* (2017) where all vascular plants that occurred within a 10 m x 50 m Site area were recorded. The surveyor walked along each side of the 50 m transect centreline and recorded all trees, shrubs, forbs/other species and grasses occurring within 5 m of either side of the centreline.

Species that could not be identified within the field were collected for later identification or sent to the Queensland Herbarium for identification.

Species richness includes all species present in a monitoring Site. As shown with fractional ground cover, the time of year and seasonal rainfall impact the field observable number of species within a monitoring Site. Perennial plant species such as grasses may be identified at any time of the year depending on grazing or fire while forbs and annuals may only be visible following rain or at specific times of the year. Progress of rehabilitation is therefore assessed by functional group, compared to the mean species richness of the reference site. Species richness is presented as a proportion of reference site to indicate performance against rehabilitation targets. Values equal or greater than one represent rehabilitation with a greater species richness than the reference site average.

3.2.3 Woody stem density

Woody stem density was calculated using a methodology adapted from Eyre *et al.* (2017). All woody stems for each tree and shrub species were counted within the 10 m by 50 m site area (i.e. 5 m on both sides of each 50 m transect). From this data, both total woody stem density, as well as the density of each individual tree or shrub species, was calculated.

The density of species and growth forms on the monitoring sites is calculated using the following equation:

$$\text{Density per hectare (ha)} = \text{Number of stems recorded within the transect} \times 20$$

3.2.4 Canopy cover

Tree canopy cover can be used to characterise stand productivity and the distribution and abundance of above-ground plant biomass (Eyre *et al.* 2017). Percentage canopy cover of the living, native tree layer can be estimated along a 50 m transect, using the line intercept method (Greig-Smith *et al.* 1964). For this attribute, the vertical projection of tree canopy cover of the species making up the tree canopy cover was assessed. The vertical projection of the tree canopy over the 50 m transect was recorded as illustrated in Figure 3-3. The total length of the projected canopy of the tree canopy is divided by the total length of the transect to estimate the percentage canopy cover on the site.

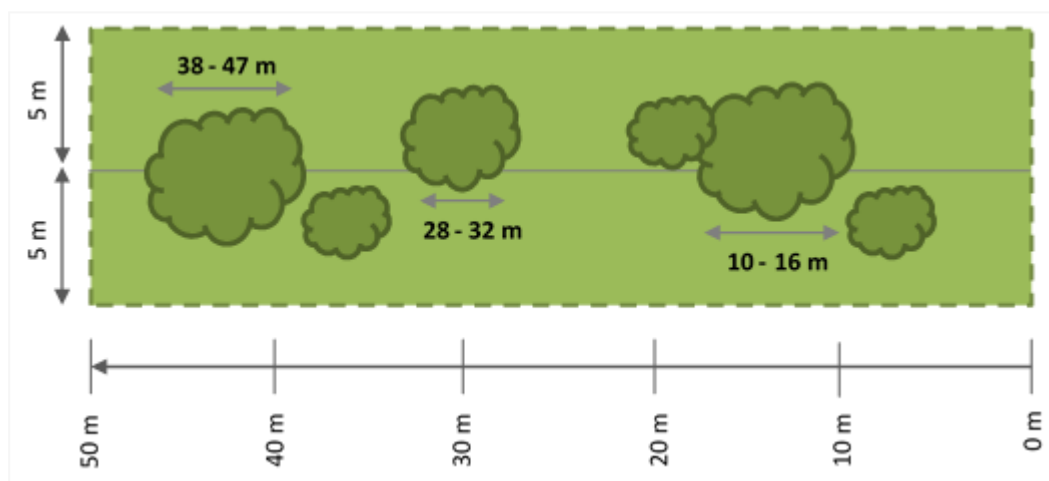


Figure 3-3: Guide to monitoring canopy cover (after Eyre *et al.* 2017)

3.2.5 Photographic monitoring

Photographic monitoring provides a visual record of the vegetation, ground cover, erosion and general appearance of each reference and rehabilitation site, allowing these sites to be compared over time.

A digital camera was used to take the photos so that a permanent record can be maintained on file for each site (Eyre *et al.* 2017). The process of collecting the monitoring photos is:

- The person taking the photograph stands at the star picket that marks the beginning of the 50 m transect at each of the sites.
- The camera is then aimed directly towards the end of the 50 m transect and a single photograph is taken. The photo is taken directly above the star picket at chest height (approximately 110 cm above the ground).
- The photographer then stands at the star picket at the opposite end of the 50 m transect.
- The camera is aimed directly towards the start of the 50 m transect and a single photograph is taken. The photo is taken directly above the star picket at chest height (approximately 110 cm above the ground).
- The digital photographs are uploaded and stored for future reference.

The photographs from each monitoring location are in Appendix D.

3.2.6 Erosion monitoring

An erosion monitoring methodology has been developed by suitably experienced AARC ecologists that considers relevant guidelines and research (Neldner *et al.* 2019, Eyre *et al.* 2017). Erosion at the survey sites is monitored by a visual assessment over time. Assessment is undertaken by traversing the 50 m transect on foot and recording the number and average depth of any erosion features or rill lines. Placing the permanent transects in a particular location does not adequately capture the level of erosion across the entire rehabilitation landforms. Observations during the surveys have also been considered in this report.

Erosion was classified (refer to Table 3.2) and recorded. The overall classification of the erosion on each transect was determined by the higher classification attributed to either the number of rills/gullies or the average depth. For example, a transect may present only one or two rills but if these are recorded as being 25 cm deep, the transect was classified as presenting a moderate erosion classification. Obvious cases of localised settlements that were not causing any subsequent erosion were not counted as instances of erosion.

In addition, the location of any severe erosion surrounding the transect (i.e. tunnels, mass wasting, large gullies) was recorded and marked with a handheld Global Positioning System (GPS), and the following information was recorded:

- GPS reading of location;
- general description of type of erosion (gully, rill line, circular failure, tunnelling etc.) and possible causes;
- depth of erosion;
- width of erosion;
- length of erosion;
- where eroded material is being deposited; and
- whether the erosion line is being stabilised by vegetation.

Table 3.2: *Erosion classifications*

Erosion Classifications	Minor	Moderate	Severe	Extreme
No. of rills ¹ / gullies	< 15	15 – 30	31-50	>50
Average depth (cm)	< 10	10 – 30	30-60	>60

¹Source: Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain 2009).

4 Results

Results from the 2023 RMP are presented in the following subsections, with results from the reference sites (Section 4.1) providing benchmarks for the assessment of rehabilitation success at the progressive rehabilitation sites (Section 4.2); and assessment of the suitability of the cover design systems trialled on Cell B of the TSF in Section 4.3. Results from the 2023 RMP have also been compared against the data collected from previous monitoring events, to determine the progress of rehabilitation and its success.

Discussion on whether the rehabilitation areas are achieving the relevant completion criteria is provided in Section 5.

4.1 Reference sites

Three reference sites provide baseline data to assess rehabilitation success. Reference sites represent vegetation that is naturally established under local climate and substrate conditions to sustainably provide the target post-mining land use. In this case, low to very low-intensity grazing.

Monitoring during the 2023 RMP continues to suggest a small background trend (<10%) in reference sites to decreasing bare ground. This trend appears correlated with increasing organic cover (all grasses, shrubs, forbs, litter) at the reference sites. However, reference site transects vary widely in proportional bare ground and organic fraction cover during most monitoring events. Across the Yandan ML tenure, the monitoring suggests a strong seasonal and more subtle decadal (approximately) cycle of total cover (green and litter) occurring. Total cover has been increasing since 2014 (Figure 4-1).

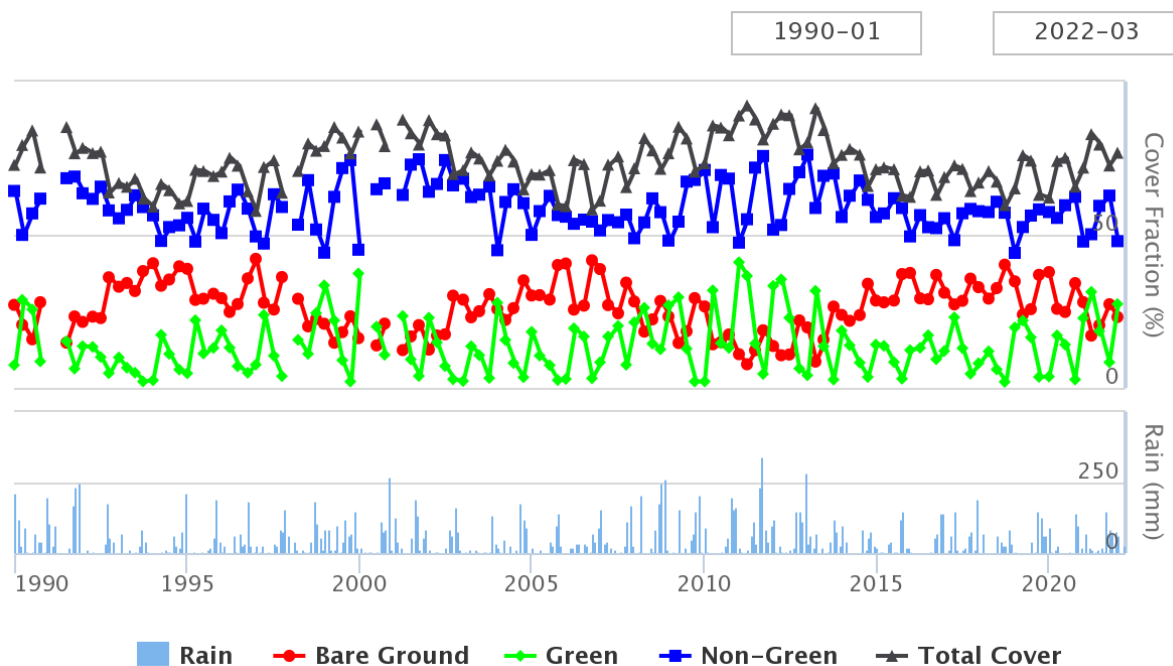


Figure 4-1: VegMachine fractional cover for Yandan tenure

4.1.1 Ground cover

Live ground cover at the reference sites was dominated by perennial grass cover (mean 86% during the 2023 RMP). Shrub cover was composed of short lived small woody species (native cottonbush) that formed a substantial cover fraction at R2 (mean 12%). The other reference sites recorded global shrub cover much less than 1% over time. Forbs represented a higher portion of cover with a global mean of 14% for all reference sites over twelve monitoring occasions (R1 7.0%, R2 31.7%, R3 3%). Stable rehabilitation with established

vegetation was therefore dominated by exotic perennial grasses with long term median cover around 30% (reference range 3.2% - 87.8%).

Total live cover (%) was variable across all years and caused variability in recordings of bare ground, organic litter, and rock within the site (Figure 4-2). Rocks made up less than 4% of the total ground cover across the years, except in 2017 (11.7%), which may be due to changes in the live cover (i.e. abundance, ground cover, species) present at the site during this time. In 2023 organic litter contributed approximately 1.2% cover. Organic litter (e.g. leaf litter) within the sites shows a high degree of variability during each of the years, ranging from 0 – 43.3%. High live groundcover has been sustained at site 'R3' since 2019, comprising exotic pasture grasses such as *Urochloa mosambicensis* (Sabi Grass), *Cenchrus ciliaris* (Buffel Grass) and *Bothriochloa pertusa* (Indian Bluegrass).

The changes in bare ground have resulted from the changes to the other variables; increases in live cover and organic litter will inherently decrease the available bare ground in the site.

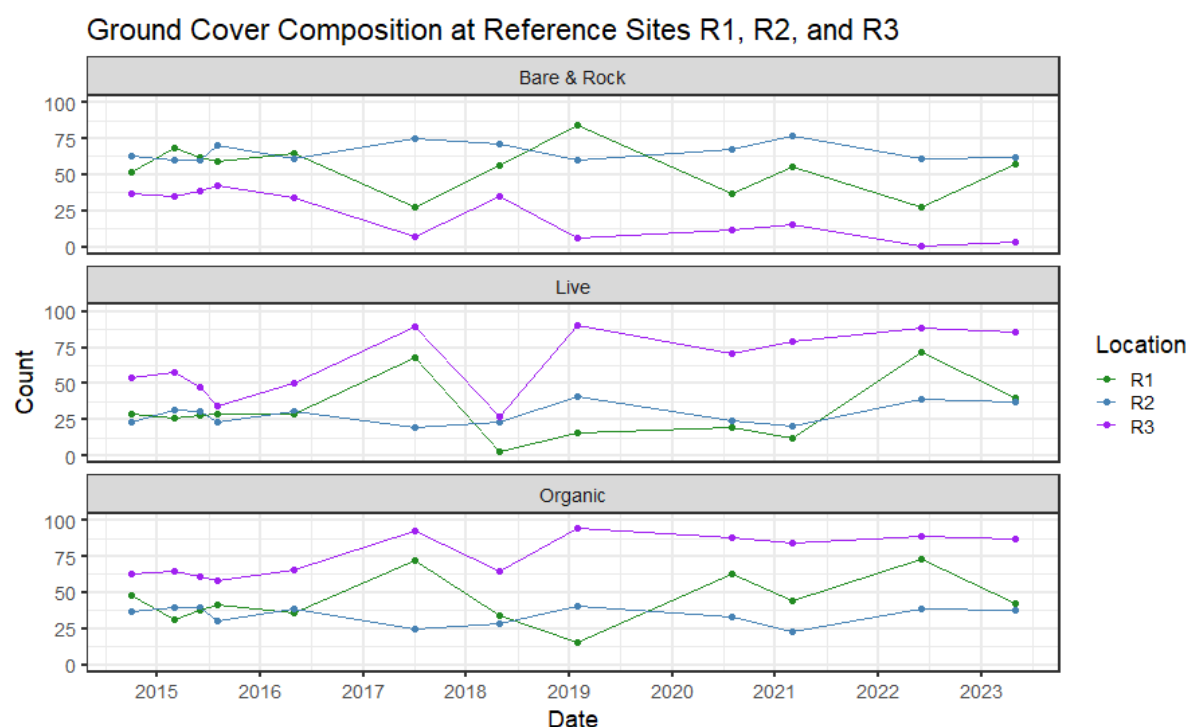


Figure 4-2: Mean ground cover at the reference sites (2015 – 2023)

4.1.1 Species richness

Since 2014, forbs have dominated total species richness in each of the reference sites, with a range of 0 – 18 species. Yearly variation between reference sites demonstrates the range of natural variation in detectable species depending on location (Figure 4-3 -bottom graph). In 2023, forb species richness of 4 - 6 was measured, with relatively stable forb species richness observed across the sites since 2017.

While grass species richness was generally lower than forbs, grasses provided a larger contribution to effective cover due to their larger size, structure and perennial or semi-perennial lifecycles. Grass species richness comprises non-pasture grasses, exotic pasture grasses, and native pasture grasses.

Pastures in the reference site locations were generally comprised of exotic (global average: 2.1 species) and native pasture grasses (global average: 1.4 species). Non-pasture grasses species richness was negligible (global average 0.2 species), as expected for actively grazed lands.

Total species richness remained in the central range of recorded values (1-31) in 2023 (R1 with 12 species, R2 with 14 species, R3 with 11 species). There were no long-term trends apparent in the species richness observed at the reference sites. The total species richness values were consistent with a sustainably managed low intensity grazing land use.

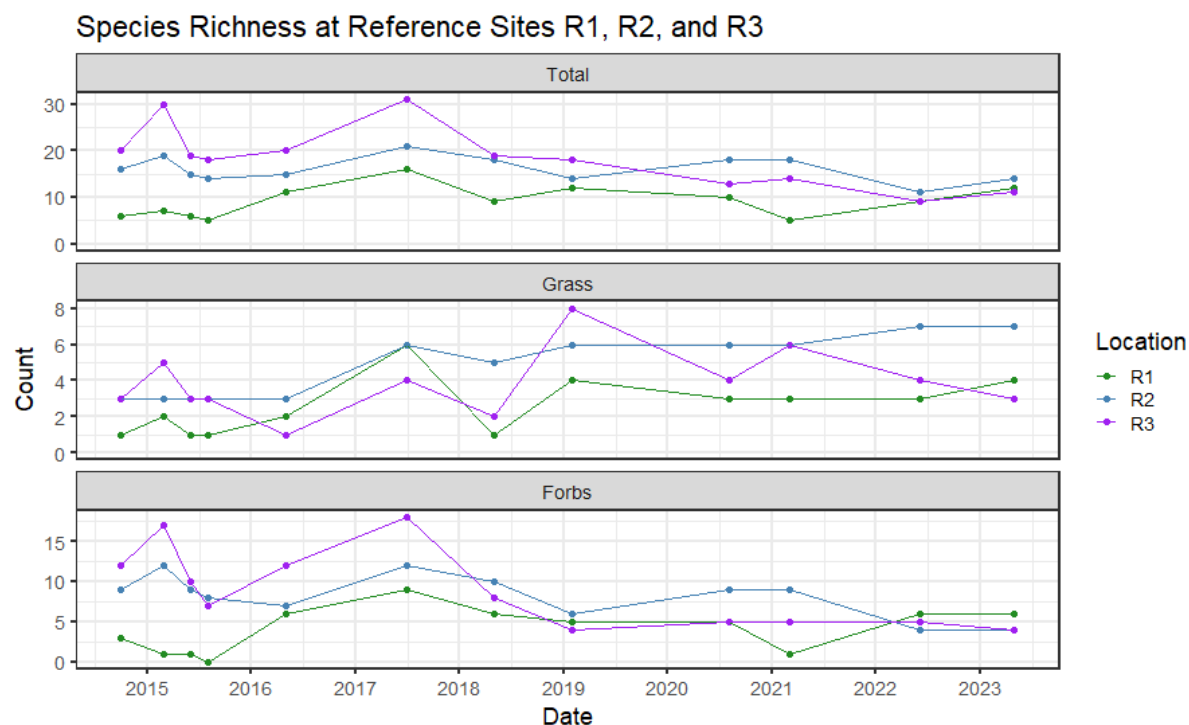


Figure 4-3: Species richness across Reference sites

4.1.2 Restricted invasive plant species

Restricted invasive species recorded at the reference sites during the 2023 RMP event included *Parthenium hysterophorus* (Parthenium Weed). Low levels of Parthenium weed were limited to the reference sites and it was consistently recorded in R2 and R3 (Table 4.1).

Table 4.1: Restricted invasive weed species present reference sites

Scientific name	Common name	Weed classification	Site	Monitoring event				
				2019	2020	2021	2022	2023
<i>Parthenium hysterophorus</i>	Parthenium Weed	Category 3 Restricted Invasive Plant	R1		X			
			R2	X	X	X	X	X
			R3	X	X	X	X	X

X – indicates presence of species

4.1.3 Woody stem density

Woody stem density averaged 0 stems/ha at the reference sites during the 2023 RMP event. Woody stem density at the reference sites has remained at negligible levels after a progressive decline in the species that commenced around 2015 (Figure 4-4).

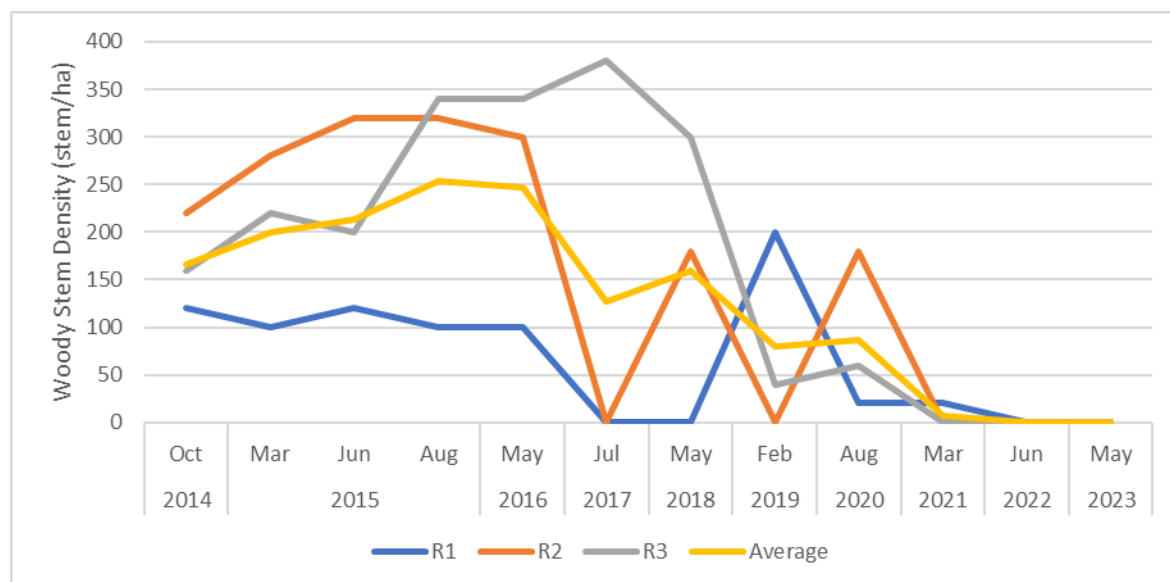


Figure 4-4: Mean woody stem density at reference sites

4.1.4 Canopy cover

Canopy cover (tree canopy cover over a 50 m transect) at the reference sites was again absent (i.e. 0%) during the 2023 RMP. Canopy cover at the reference sites has remained negligible since 2017 (Figure 4-5).

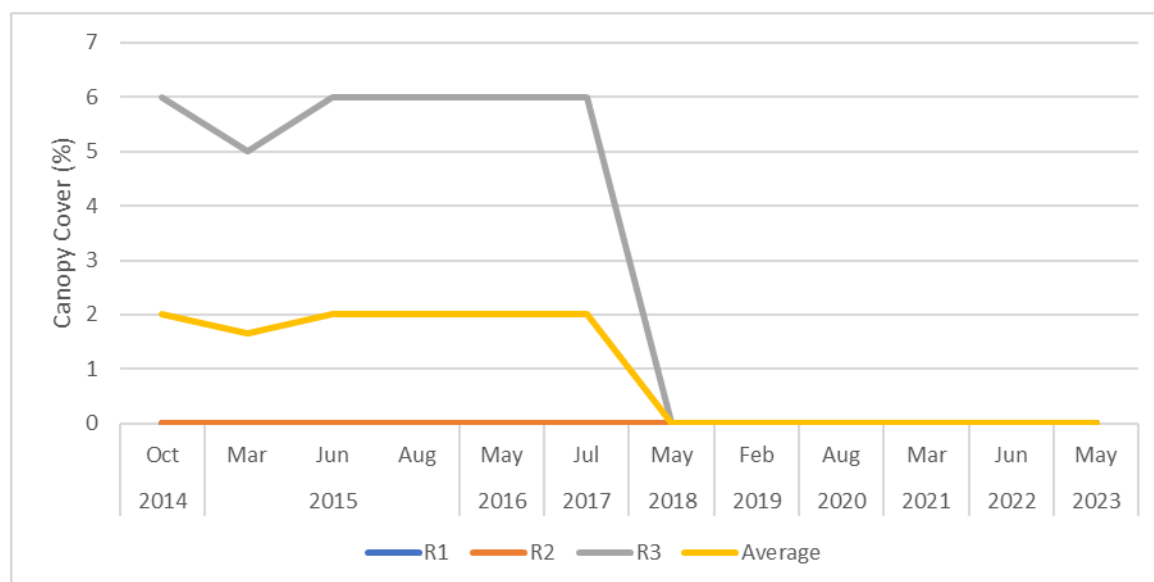


Figure 4-5: Canopy cover at reference sites

4.1.5 Erosion monitoring

Erosion was recorded at minor levels at the reference sites during the 2023 RMP event, consistent with previous monitoring events (Table 4.2).

Table 4.2: Erosion monitoring at Reference sites

Site	R1			R2			R3		
Date	Number	Depth	Class	Number	Depth	Class	Number	Depth	Class
Oct-14	<15	<10	minor	<15	<10	minor	<15	<10	minor
Mar-15	<15	<10	minor	<15	<10	minor	<15	<10	minor
Jun-15	<15	<10	minor	<15	<10	minor	<15	<10	minor
Aug-15	<15	<10	minor	<15	<10	minor	<15	<10	minor
May-16	<15	<10	minor	<15	<10	minor	<15	<10	minor
Jul-17	<15	<10	minor	<15	<10	minor	<15	<10	minor
May-18	<15	<10	minor	<15	<10	minor	<15	<10	minor
Feb-19	<15	<10	minor	<15	<10	minor	<15	<10	minor
Aug-20	<15	<10	minor	<15	<10	minor	<15	<10	minor
Mar-21	<15	<10	minor	<15	<10	minor	<15	<10	minor
Jun-22	<15	<10	minor	<15	<10	minor	<15	<10	minor
Apr-23	<15	<10	minor	<15	<10	minor	<15	<10	minor

4.2 Progressive rehabilitation sites

Progressive rehabilitation at Yandan has been completed at South Pit, the ROM Pad, the village infrastructure area, the infrastructure area, and Cell A of the TSF.

Results from the 2023 RMP for these areas is provided in the following subsections, with results compared to the reference sites to determine if the relevant rehabilitation objectives and completion criteria have been met (refer to Table 2.2).

Results from previous RMP events have been reviewed, to identify any trends occurring in the progressive rehabilitation sites and the overall trajectory of the rehabilitation.

4.2.1 Rehabilitated South Pit

4.2.1.1 Ground cover

Live ground cover coverage at the South Pit sites generally exceeded the range at the reference sites, demonstrating successful rehabilitation for this criteria.

Bare ground and rock cover showed a consistent decreasing trend across the three South Pit sites, similar to the reference sites (Figure 4-6). All South Pit sites recorded bare ground and rock cover in the lower value of the reference range (10.5 -17.2%) in 2023 (3 - 62.4%) (Figure 4-6).

Live ground cover at South Pit was generally around the mean score of the reference sites since monitoring commenced (Figure 4-6). Since woody vegetation is not a substantial component of live cover, it will vary with rainfall in the 3 - 12 months preceding the monitoring event (Guerschman *et al.* 2020). Values for total organic cover, which includes litter, were maintained around the mean reference site range for each of the monitoring years (Figure 4-6).

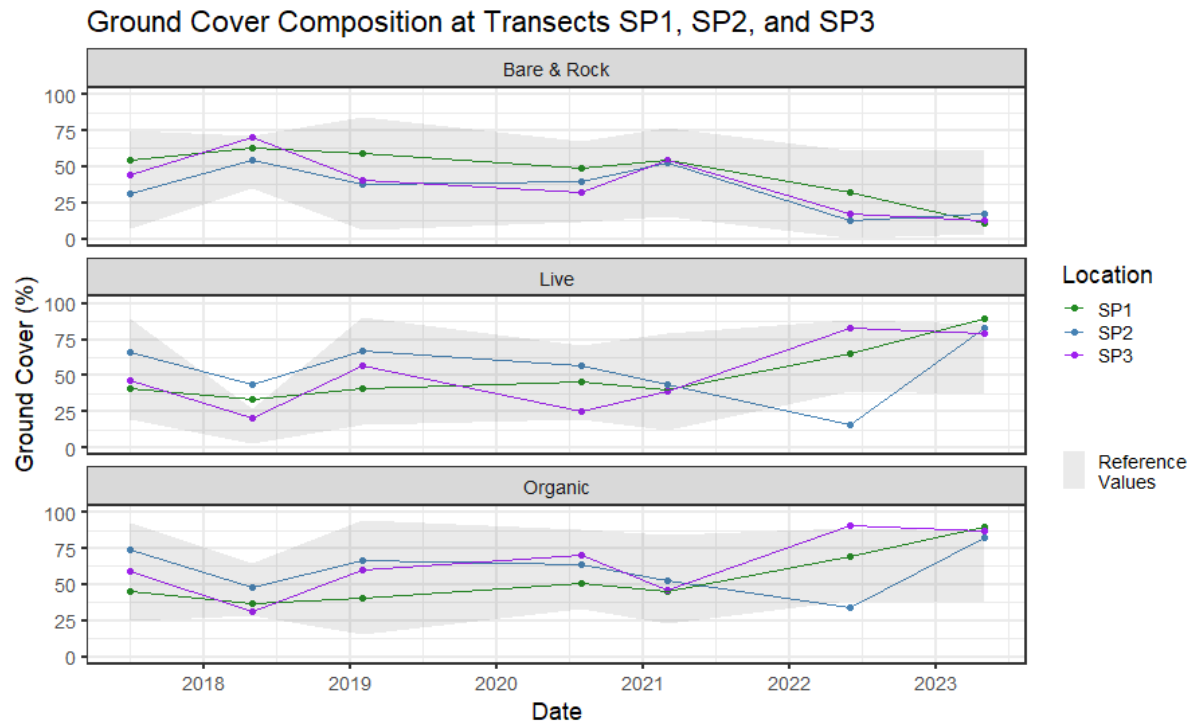


Figure 4-6: Proportion of mean reference ground cover for South Pit rehabilitation.

4.2.1.2 Species richness

Total species richness at the South Pit sites continued to meet the benchmark provided by the reference sites, demonstrating successful rehabilitation against this criteria.

Total species richness was again tightly clustered (17-19 species) during the 2023 RMP event. All three monitoring sites continued to exceed minimum reference site values (Figure 4-7 top), with all exceeding the maximum reference site value during the 2023 RMP event.

Grass species richness for all three monitoring sites continued to be consistent with the reference site range. Grass species richness has never been less than the reference site range. Grass species richness continued to indicate stable species richness of approximately 4 species (Figure 4-7 middle graph). Grass species richness was equivalent or better than the reference sites for the last six years.

Forb species richness continued to exceed maximum reference site abundance (Figure 4-7 bottom). Since 2017, forb species richness has exceeded the reference site maximum on all, but four occasions (2017 SP1 and SP2, 2020 SP1, 2021 SP1). Forb species richness was equivalent to, or higher, than the reference sites for the past five years of monitoring.

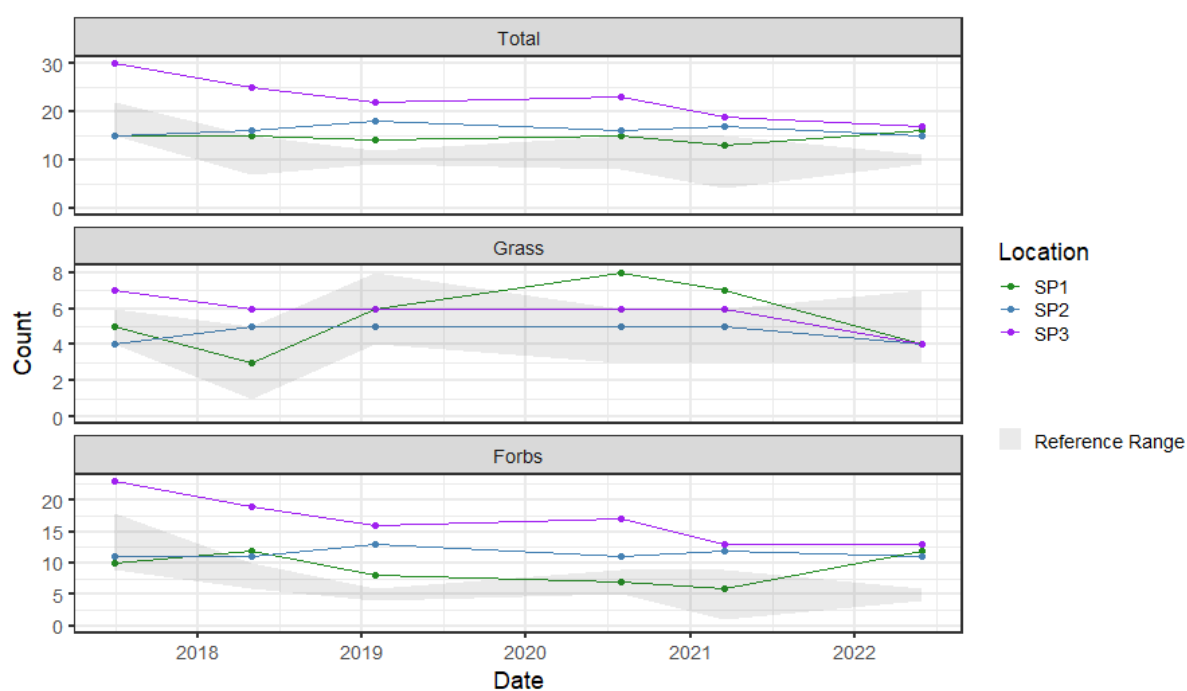


Figure 4-7: Species richness at South Pit monitoring sites

4.2.1.3 Restricted invasive plant species

The results from the South Pit sites indicate that the progressive rehabilitation area has met the criteria for restricted invasive plant species (Table 4.3).

No restricted invasive plant species were recorded at the South Pit sites during the 2023 RMP event (Table 4.3). This result is consistent with the 2022 and 2021 RMP event. Parthenium was now last observed in 2020.

Table 4.3: Restricted invasive plants at South Pit

Scientific name	Common name	Weed classification	Site	Monitoring event				
				2019	2020	2021	2022	2023
<i>Parthenium hysterophorus</i>	Parthenium	Category 3 Restricted Invasive Plant	SP1					
			SP2	X	X			
			SP3	X	X			
<i>Vachellia farnesiana</i>	Mimosa	Invasive biosecurity matter	SP1					
			SP2					
			SP3					

X – indicates presence of species

4.2.1.4 Woody stem density

Woody stem density at the South Pit sites has continued to exceed the benchmark set at the reference sites. Noting however, that woody vegetation has declined significantly at the reference sites since 2016 -2017.

Woody stem density at the South Pit sites during the 2023 RMP averaged 293.3 stems/ha. An uplift in woody stem density has been seen since the 2020 RMP, which has also been observed at the reference sites to a lesser degree (Figure 4-8).

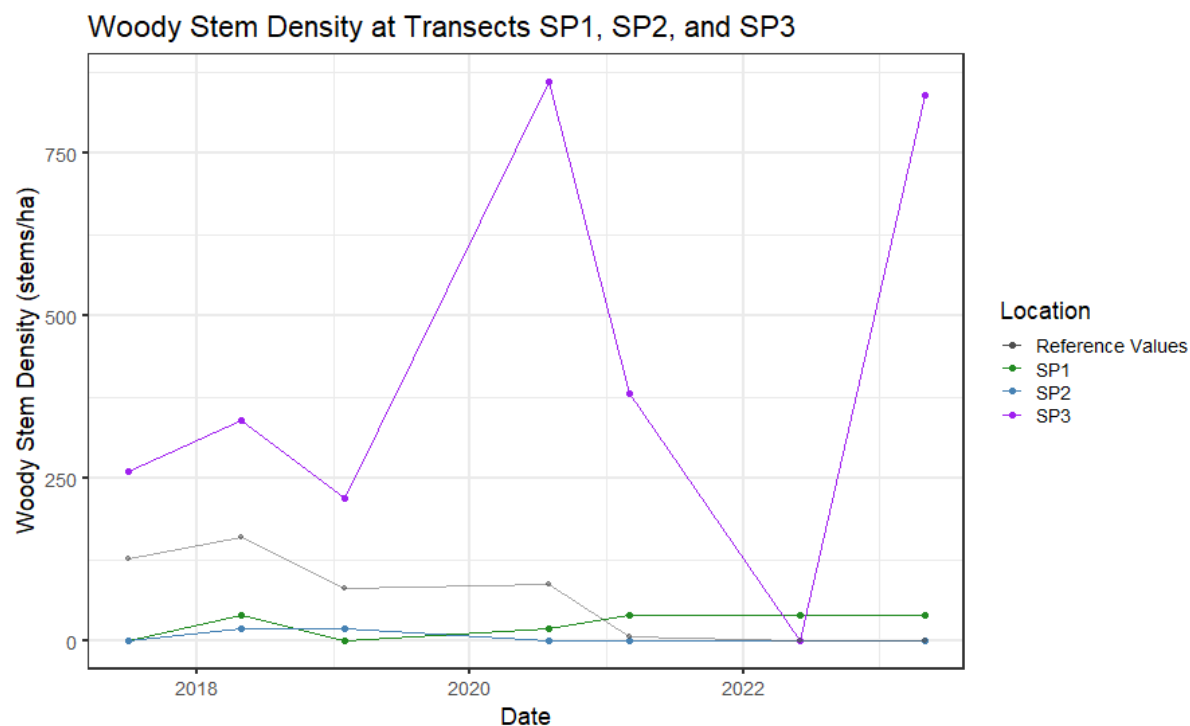


Figure 4-8: Mean woody stem density at South Pit

4.2.1.5 Canopy cover

Canopy cover at the South Pit sites remained low and consistent with reference values, indicating that this rehabilitation criteria has been met. Noting again, that woody stemmed vegetation (which canopy cover is a factor of) remains very sparse at the reference sites. (Figure 4-9).

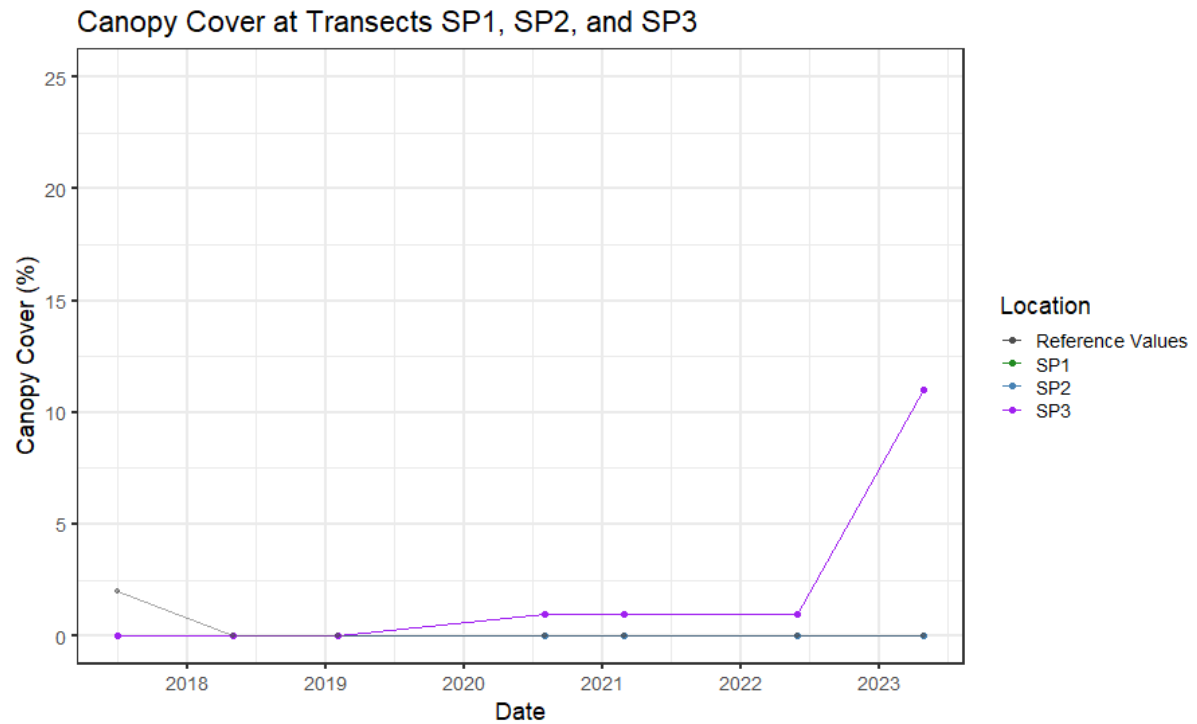


Figure 4-9: Mean canopy cover at South Pit

4.2.1.6 Erosion monitoring

Erosion levels at the South Pit sites remained minor, indicating the benchmark set by the reference sites have been met.

Erosion levels have remained stable at the South Pit sites since 2017, as summarised in Figure 4-10.

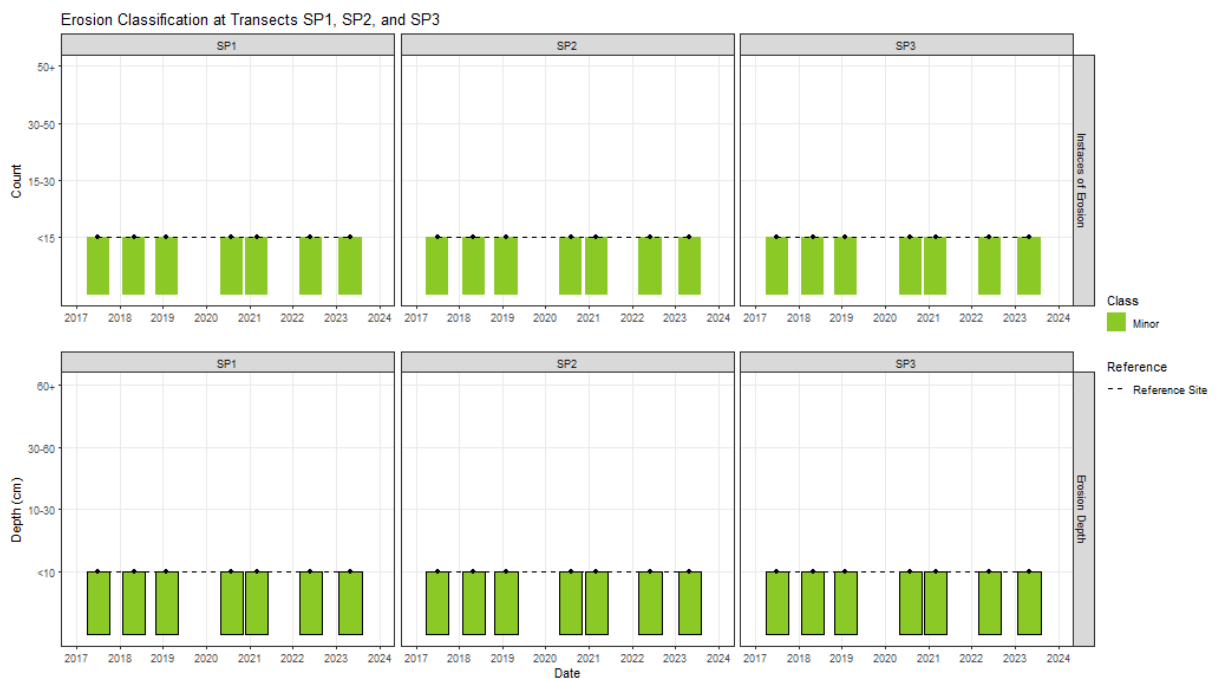


Figure 4-10: Erosion categories for South Pit sites

4.2.2 Rehabilitated ROM Pad

4.2.2.1 Ground cover

Live ground cover coverage at the ROM Pad sites continued to be within the reference site range, demonstrating successful rehabilitation against this criteria.

For the ROM Pad, live ground cover had been increasing over time. However, during the 2023 RMP, there was a slight reduction in live ground cover, at least for ROM1 and ROM3. The live ground cover remained within reference site ranges for the 2023 event. In 2023, there was a small increase in bare ground and rock cover at ROM1 and ROM3, however they remained below reference site levels (Figure 4-11 top graph).

The functional organic cover fraction at the South Pit sites continues to trend relatively higher than reference sites (Figure 4-11 *bottom*). ROM1 has consistently had the lowest proportional organic cover compared to reference site but remains within the reference range.

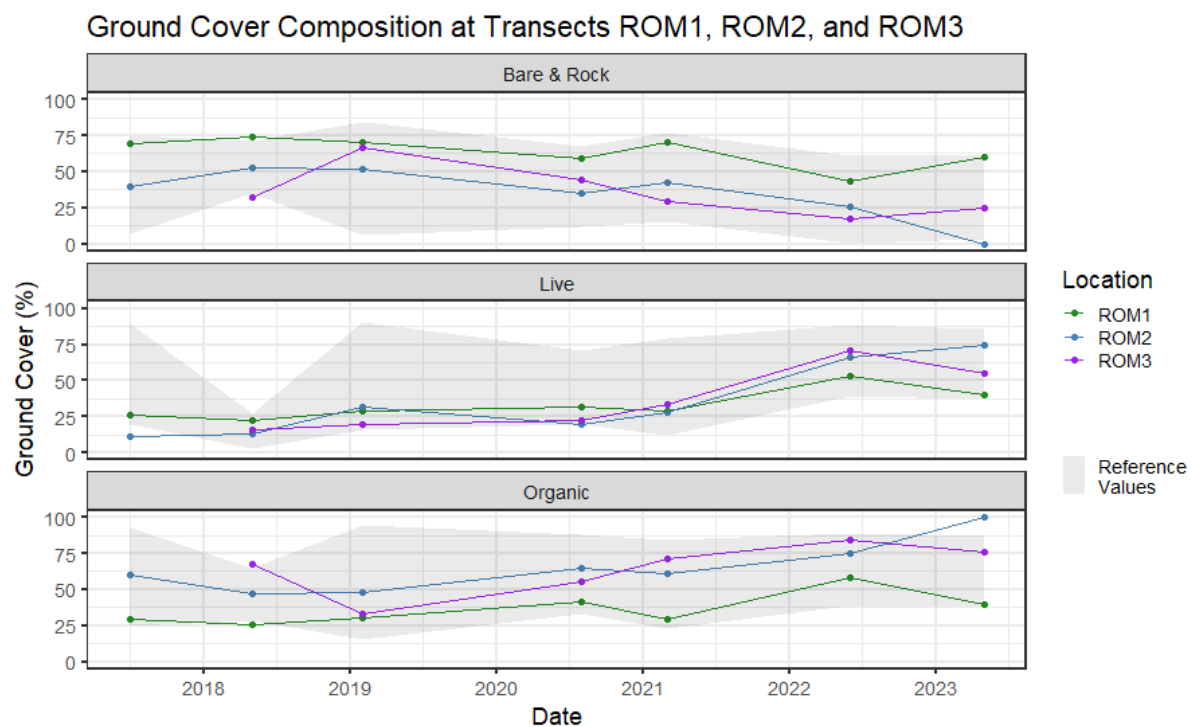


Figure 4-11: ROM rehabilitation area cover performance against reference site mean

4.2.2.2 Species richness

Total species richness at the ROM Pad continues to well exceed the benchmark provided by the reference sites, demonstrating successful rehabilitation against this criteria.

The ROM Pad monitoring sites are consistently more diverse than reference sites. During the 2023 RMP, an average of 24 species were recorded at the ROM Pad, well above the average of 14.5 species at the reference sites.

In terms of functional species richness, forbs were the main contributor to total richness, with grasses comprising the remaining vegetation composition. ROM3 had the highest total species richness in 2022 (28 species) with 16 forbs and non-grass species, four exotic pasture species, two native pasture species, one non-

pasture grass species, and five tree and shrub species. ROM1 had the lowest total species richness (17 species) with 10 forbs and non-grass species, four exotic pasture species, one native pasture species, two tree and shrub species.

Overall, total species richness is higher at the ROM Pad sites for all years compared to the minimum species richness of the reference sites, and has been higher than the maximum species richness since 2019. (Figure 4-12 top).

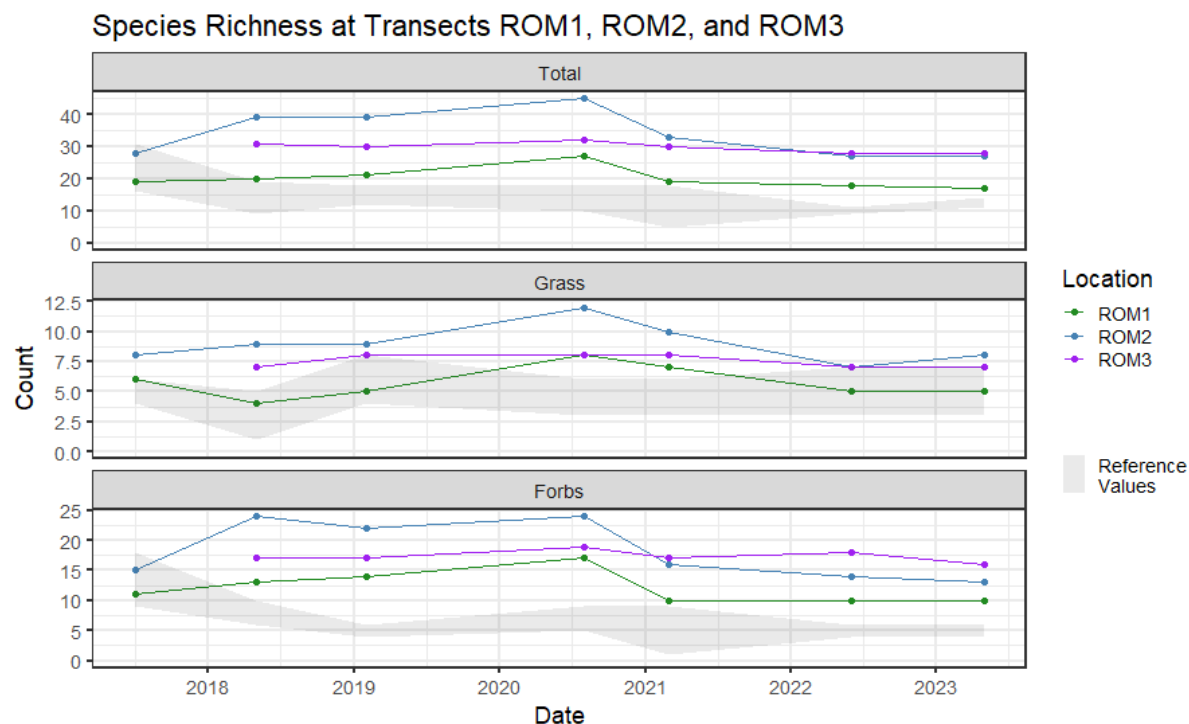


Figure 4-12: Species richness at ROM Pad monitoring sites

4.2.2.3 Restricted invasive plant species

Restricted invasive plant species were again identified at the ROM Pad sites during the 2023 RMP. This is currently preventing the ROM Pad from demonstrating successful weed management. During 2023, three restricted invasive species were recorded: Parthenium, Mimosa and Harissa cactus. Harissia cactus appears to have only recently established at the ROM Pad sites, whilst Parthenium and Mimosa are well established and have been recorded since 2019.

Whilst Parthenium is also established at reference sites, as the rehabilitation objective for the site targets light grazing the persistent presence of Parthenium is a priority management issue that needs to be addressed before considering progress to certification. Further management of Mimosa and Harrisia cactus is also required.

Table 4.4: Restricted invasive species at ROM Pad

Scientific name	Common name	Weed classification	Site	Monitoring event				
				2019	2020	2021	2022	2023
<i>Parthenium hysterophorus</i>	Parthenium	Category 3 Restricted Invasive Plant	ROM1					
			ROM2	X	X	X	X	X
			ROM3		X	X	X	X
<i>Vachellia farnesiana</i>	Mimosa	Invasive biosecurity matter	ROM1		X			
			ROM2	X	X	X	X	X
			ROM3					
<i>Harissia martinii</i>	Harrisia cactus	Category 3 Restricted Invasive Plant	ROM1					
			ROM2					
			ROM3				X	X

X – indicates presence of species

4.2.2.4 Woody stem density

Woody stem density at the ROM Pad sites continues to exceed the benchmark set at the reference sites. Noting however, that woody vegetation has declined significantly at the reference sites since 2016 -2017.

Woody stem density at the ROM sites increased during the 2023 RMP event (mean woody stem density of 173.3 stems/ha) (Figure 4-13). This is the lowest woody stem count for the ROM sites across all monitoring events. However, the ROM sites are still exceeding the reference sites in woody stem count.

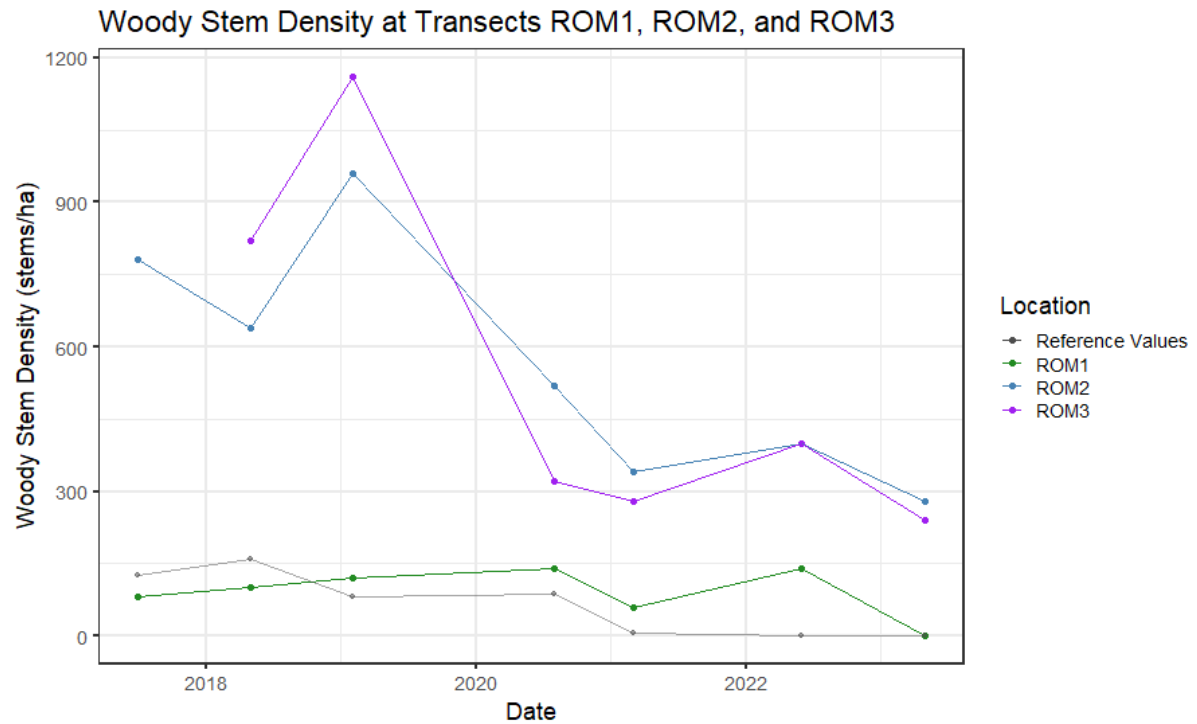


Figure 4-13: Mean woody stem density at ROM Pad

4.2.2.5 Canopy cover

Canopy cover at the ROM Pad sites remains considerably higher than reference sites, meeting this rehabilitation criteria.

During the 2023 RMP event, canopy cover averaged 9.3%. Canopy cover at the ROM Pad sites has remained relatively stable since 2020, and has consistently remained higher than the reference sites for the last five monitoring events (Figure 4-14). The reference sites have not recorded canopy cover since the 2017 RMP.

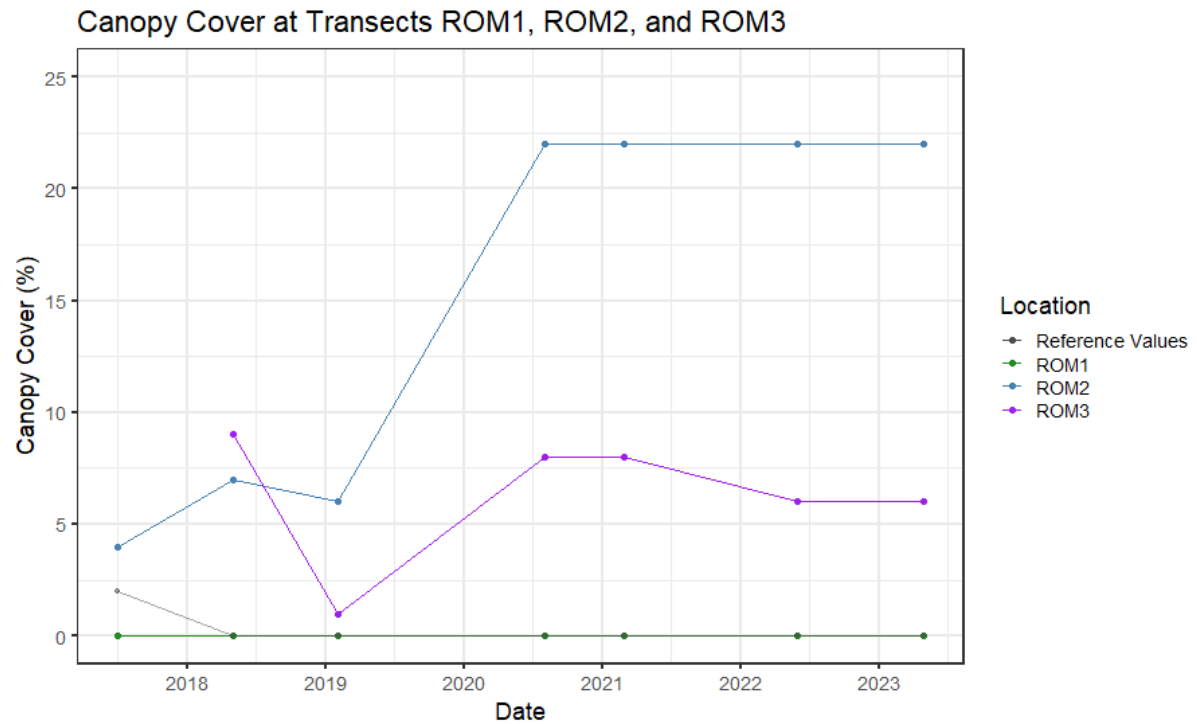


Figure 4-14: Mean canopy cover at ROM

4.2.2.6 Erosion monitoring

Erosion levels at the ROM Pad sites remain minor, meeting the benchmark set by the reference sites.

Erosion levels have remained stable at the ROM Pad sites since 2017, as summarised in Figure 4-15.



Figure 4-15: Erosion characteristics at ROM sites

4.2.3 Rehabilitated village infrastructure area

4.2.3.1 Ground cover

Live ground cover at the village infrastructure area continues to fall slightly below the range established by the reference sites, and therefore further improvement is required to achieve ground coverage commensurate with reference conditions.

The village infrastructure rehabilitation area has retained a consistently higher proportion of bare ground and rock since monitoring commenced. The proportion of bare ground and rock cover in monitoring sites exceeded mean reference cover in 2023 (VI1 76%, VI2 70.1%, Reference 41%) (Figure 4-16: top graph). Increased bare ground and rock cover fraction coincided with slight decreases in live cover and total organic cover fractions (Figure 4-16: middle graph). Live cover and total organic fraction appear stable at approximately 50% of the reference site mean since 2017.

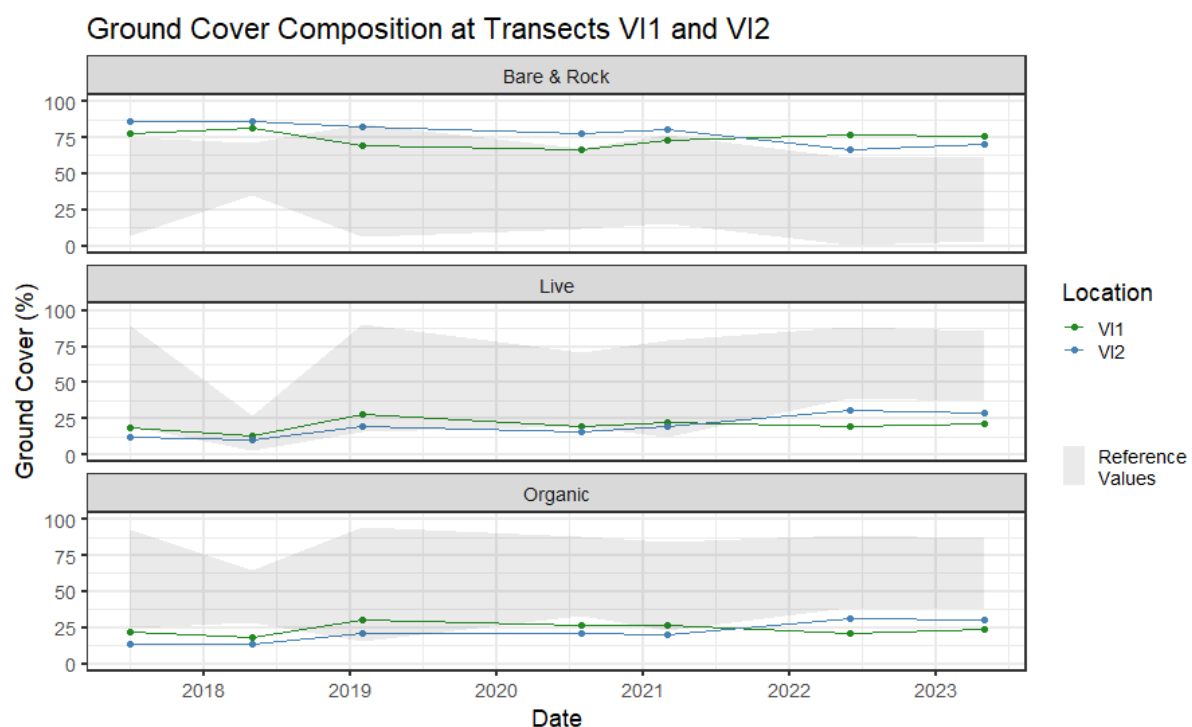


Figure 4-16: Ground cover proportional to reference site mean for village infrastructure sites

4.2.3.2 Species richness

Total species richness at the village infrastructure sites also fell below the reference range during the 2023 RMP (Figure 4-17), and similarly demonstrates further improvement is needed to achieve this criteria.

The poorer species richness results observed during the 2023 RMP follow a long-term trend of declining species richness at the village infrastructure area. There is also a general pattern of reduced species richness at the reference sites, although with this trend appearing slightly stronger at the village infrastructure sites.

In terms of functional composition, the village infrastructure sites contain a relatively diverse forb assemblage, generally exceeding the forb richness seen at reference sites. During the 2023 RMP, an average of 6 forbs and non-grasses were observed at the village infrastructure sites. Grasses were much less speciose, with only two exotic pasture grasses (2 species – VI1 and VI2), and one non-pasture grasses (one species – VI2) observed. Only one tree and shrub species was recorded.

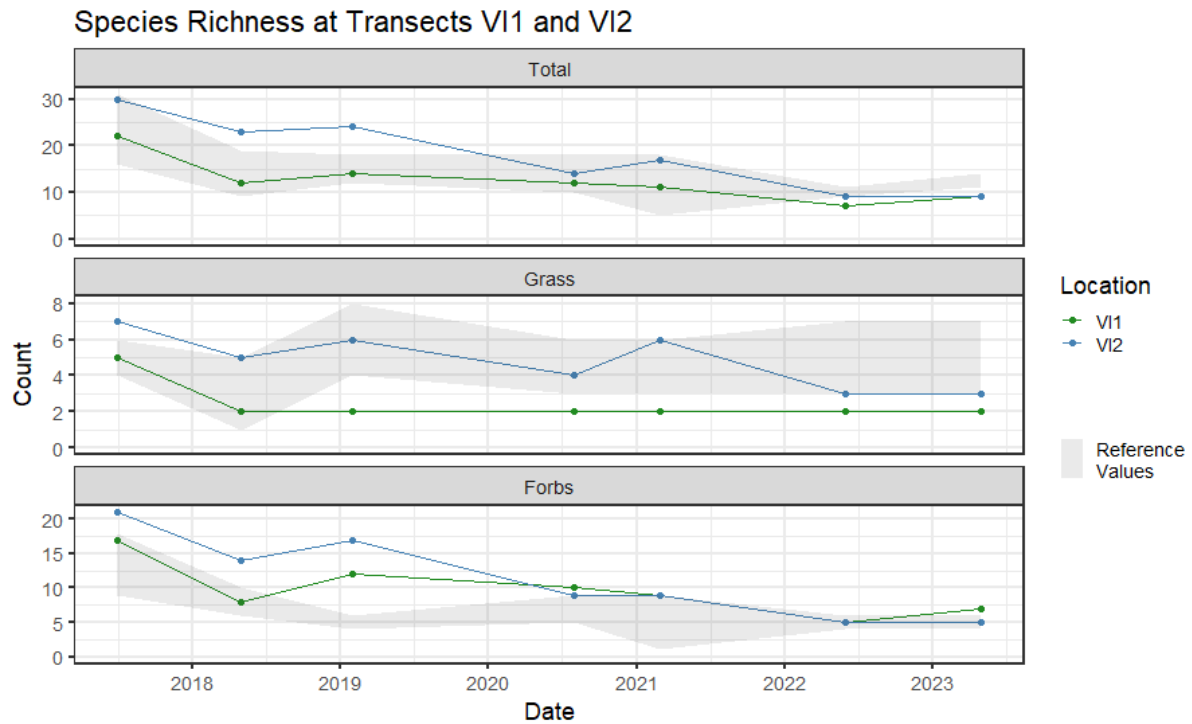


Figure 4-17: Species richness at village infrastructure monitoring sites

4.2.3.3 Restricted invasive plant species

No restricted invasive plant species were recorded at the village infrastructure sites, therefore meeting the criteria for weed management.

4.2.3.4 Woody stem density

Woody stemmed plants at the village infrastructure sites were limited to one transect (VI2), which is exceeding values at the reference sites.

Woody stem density at the village infrastructure sites during the 2023 RMP averaged 20 stems/ha, remaining thereabouts consistent with the trend observed since 2020 (Figure 4-18).

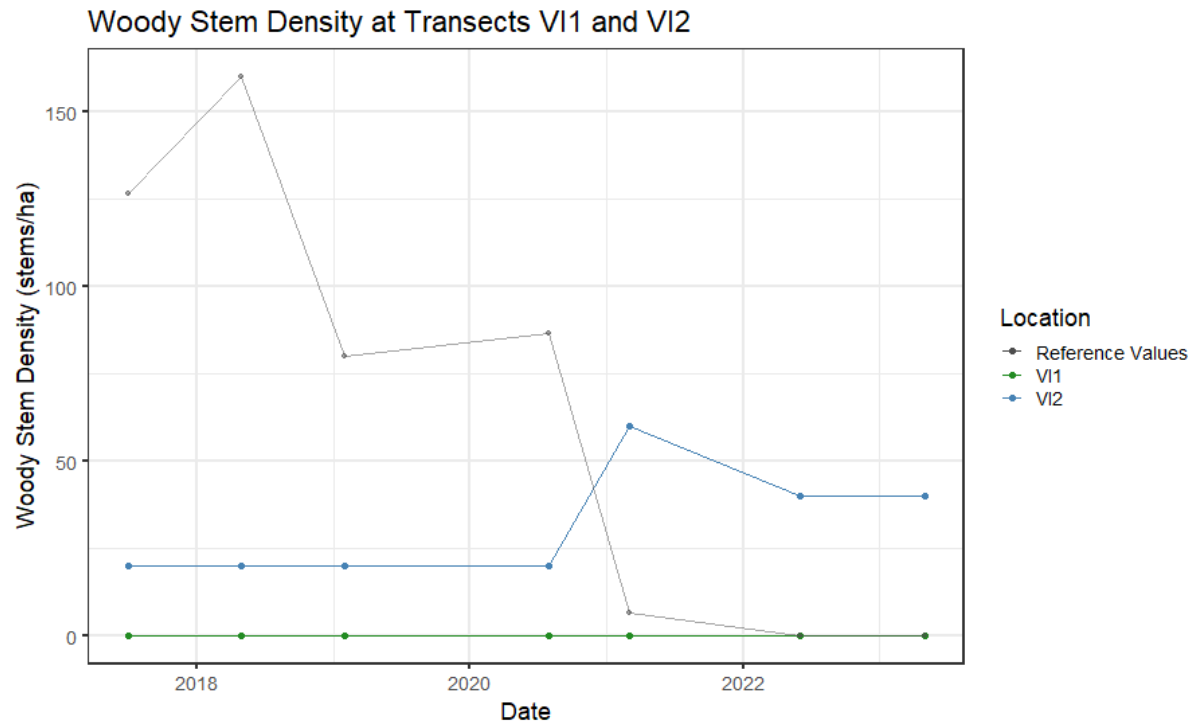


Figure 4-18: Mean woody stem density at village infrastructure monitoring sites

4.2.3.5 Canopy cover

Canopy cover at the village infrastructure sites remains negligible, and consistent with reference site values (

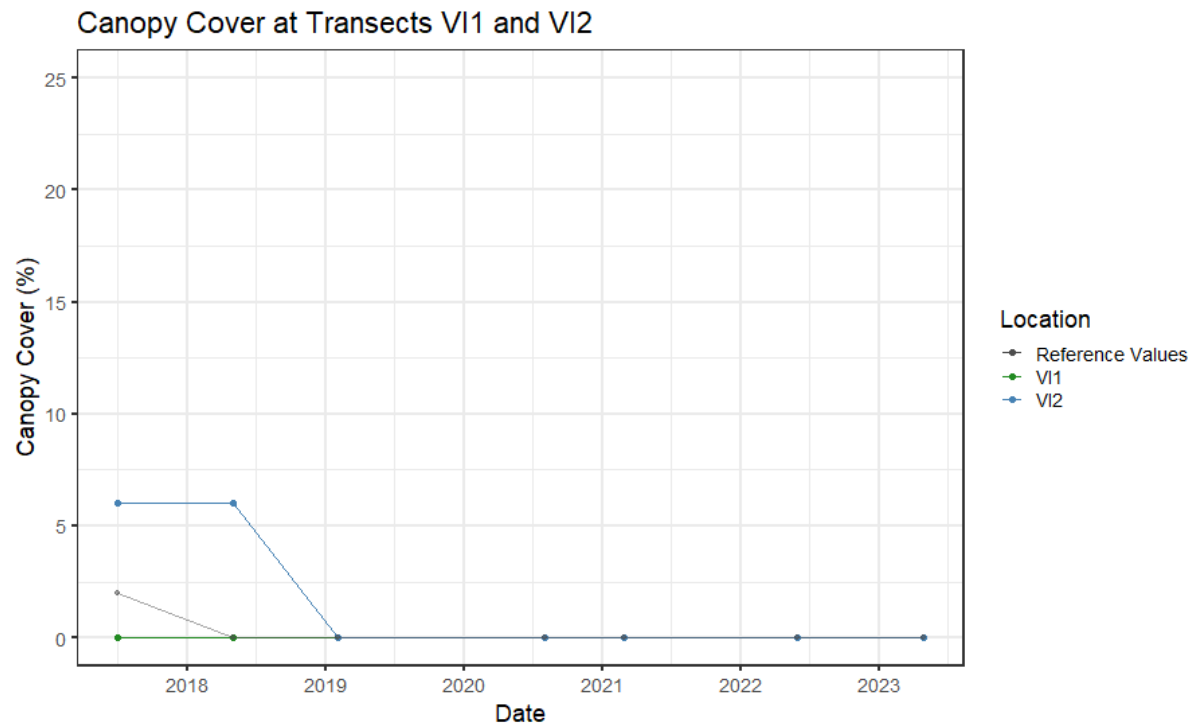


Figure 4-19).

Canopy cover has remained absent from the village infrastructure sites since the 2019 RMP, following the pattern also seen at the reference sites.

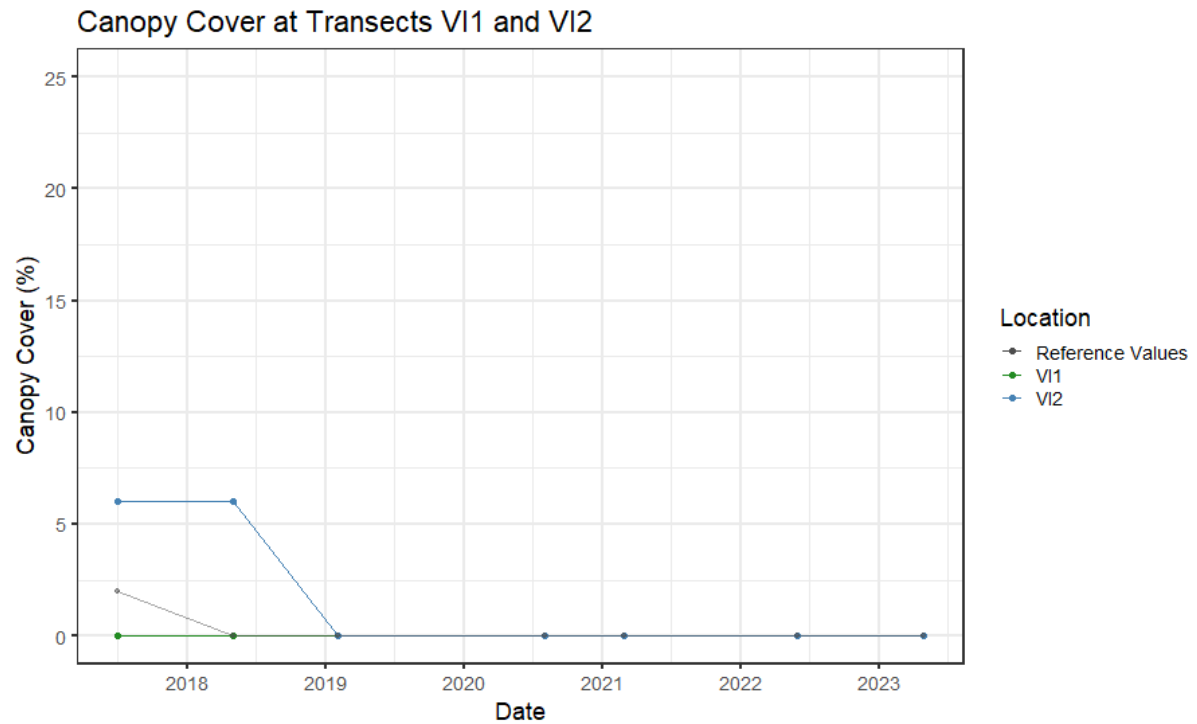


Figure 4-19: Mean canopy cover at village infrastructure monitoring sites

4.2.3.6 Erosion monitoring

Erosion levels at the village infrastructure area remain minor, meeting the benchmark set by the reference sites. (Figure 4-20).

These results are consistent with previous monitoring events, with no deterioration in erosion recorded since the 2017 survey. The minor erosion recorded at the VI sites is comparable with the minor erosion recorded at the reference sites.



Figure 4-20: Erosion characteristics for VI sites

4.2.4 Rehabilitated infrastructure area

4.2.4.1 Ground cover

Live ground cover at the rehabilitated infrastructure areas remains relatively low compared to reference site values and is currently falling short of the benchmark set by reference sites.

During the 2023 RMP, live ground cover was considerably lower at the rehabilitated infrastructure sites (25.4%) than the reference sites (54.7%) (Figure 4-21). This trend is consistent with long term monitoring data, with live groundcover generally being marginal with the minimum reference site value, or just below the reference range.

Rock cover has apparently reduced from 65% of the total ground cover in 2017, with similar values till 2019 when this reduced from 42% to 2% by 2022. This was significantly higher than the rock cover at the reference sites, with the highest cover being recorded in 2017 (11.63%), and less than 2% cover recorded between 2018 - 2022. The reductions in bare ground and rock cover correspond to an increase in live and organic coverage.

The lower percentage of live cover at the rehabilitated infrastructure area sites indicates an opportunity for improvement.

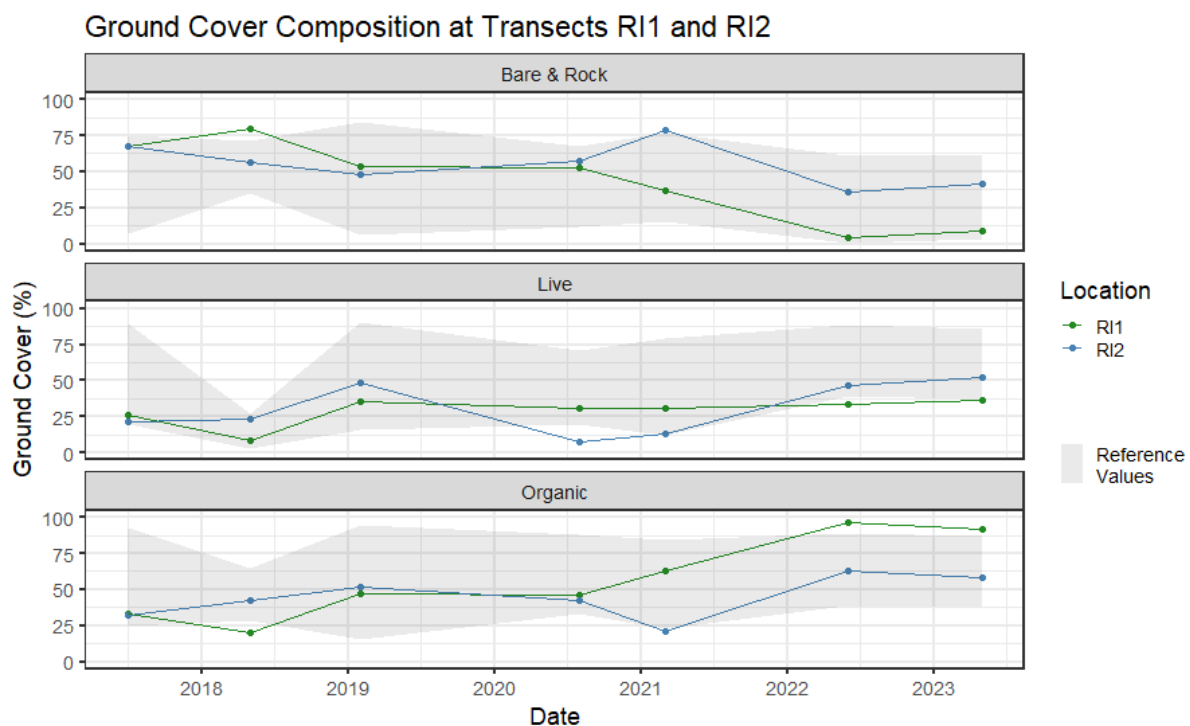


Figure 4-21: Ground cover proportional to reference site mean for RI monitoring sites

4.2.4.2 Species richness

Total species richness at the rehabilitated infrastructure sites continues to exceed the benchmark provided by the reference sites, demonstrating successful rehabilitation against this criteria.

The rehabilitated infrastructure area continues to record a much richer vegetation community, with an average of 21.5 species recorded between the two monitoring transects during the 2023 RMP, compared to a long-term average of 14.5 species at the reference sites (Figure 4-22).

Vegetation composition at the rehabilitated infrastructure areas was dominated by forbs, exceeding the diversity seen at the reference sites (Figure 4-22-*bottom*). Grass species richness similarly tends to be higher at the rehabilitated sites, although this trend softened at both the transects during the 2023 RMP.

Grass species richness was comprised of exotic pasture species (maximum of 5 species), and equal numbers of native pasture grasses and non-pasture grasses.

Overall, total species richness and forbs species richness at both sites outperformed the maximum value of the reference sites, with grass species richness falling within the reference site range. Total species richness has remained stable across the monitoring period (2017-2022) with minor decreases over the period corresponding with similar decreases in reference site species richness.

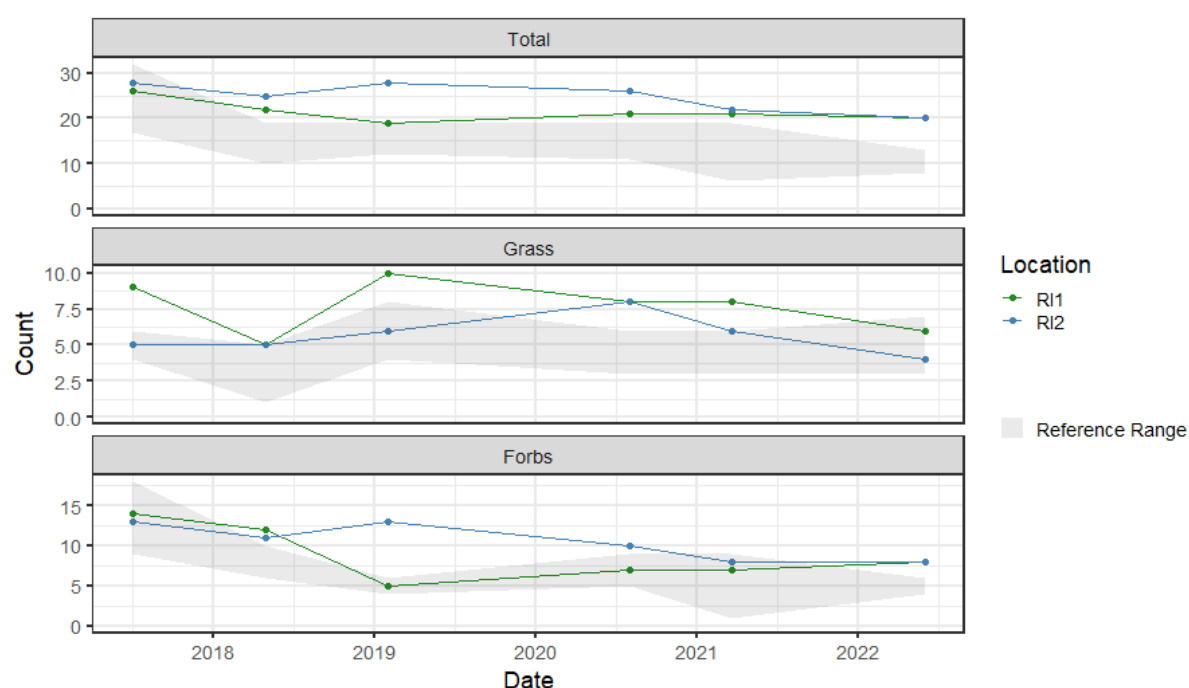


Figure 4-22: Mean species richness at rehabilitated infrastructure area

4.2.4.3 Restricted invasive plant species

Restricted invasive plant species were again identified at the rehabilitated infrastructure area sites during the 2023 RMP. This is currently preventing this domain from demonstrating successful weed management.

The restricted invasive species, Mimosa, was recorded at the rehabilitated infrastructure area. Mimosa has been recorded for each monitoring event over the last five years (Table 4.5).

It is the second consecutive year that Parthenium has not been recorded from this area, indicating that the weed has been eradicated from this area.

Table 4.5: Restricted invasive species at Rehabilitation Infrastructure

Scientific name	Common name	Weed classification	Site	Monitoring event				
				2019	2020	2021	2022	2023
			RI1		X	X		

Scientific name	Common name	Weed classification	Site	Monitoring event				
				2019	2020	2021	2022	2023
<i>Parthenium hysterophorus</i>	Parthenium Weed	Category 3 Restricted Invasive Plant	RI2					
<i>Vachellia farnesiana</i>	Mimosa Bush	Invasive biosecurity matter	RI1	X	X	X	X	X
			RI2	X			X	X

X – indicates presence of species

4.2.4.4 Woody stem density

Woody stem density at the rehabilitated infrastructure area continues to exceed the benchmark set at the reference sites. Noting however, that woody vegetation has declined significantly at the reference sites since 2016 -2017.

Woody stem density at the rehabilitated infrastructure sites averaged 210 stems/ha during the 2023 RMP event. Woody stem density remained stable at the RI1 transect during the 2023 RMP event, however a reduction was observed at the RI2 transect (Figure 4-23).

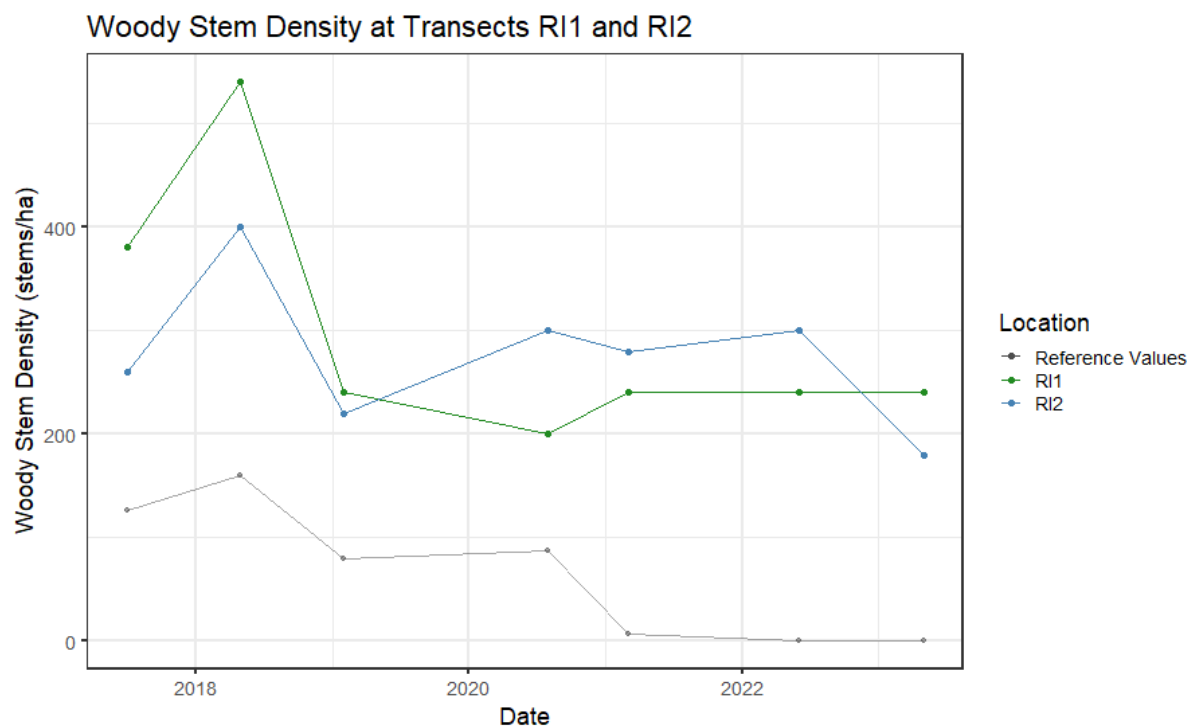


Figure 4-23: Mean woody stem density at Rehabilitated Infrastructure

4.2.4.5 Canopy cover

Canopy cover at the RI sites averaged 3.5% during the 2023 RMP (Figure 4-24).

It continues to fluctuate year-on-year, while remaining higher than the reference sites for all monitoring events.

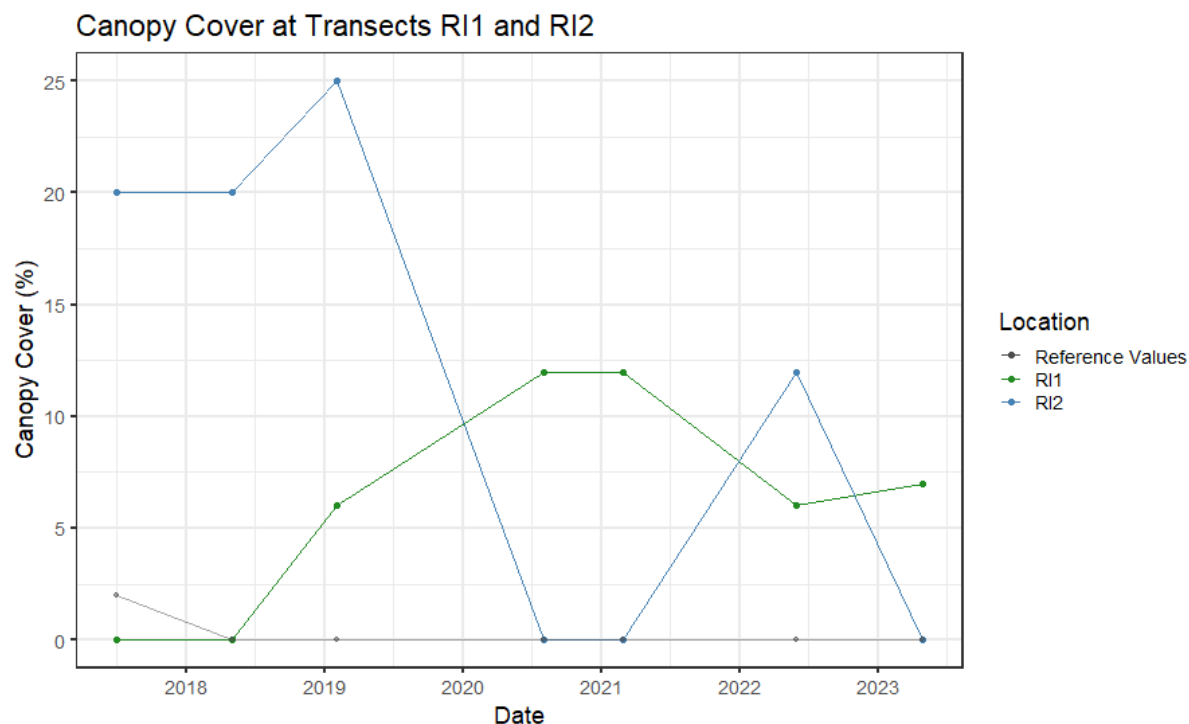


Figure 4-24: Mean canopy cover at Rehabilitated Infrastructure

4.2.4.6 Erosion monitoring

Erosion levels at the rehabilitated infrastructure area has remained at minor levels, meeting the benchmark set by the reference sites (Figure 4-25).

These results are consistent with previous monitoring events, with no further deterioration in erosion recorded since the 2019 survey. The minor erosion recorded at the monitoring sites is comparable with the minor erosion recorded at the reference sites. Both sites consistently observed 0 – 15 cm rills with low levels of erosion in for form of small rills and short depths.



Figure 4-25: Erosion characteristics at RI sites

4.2.5 Cell A rehabilitation

4.2.5.1 Ground cover

The rehabilitated surface of TSF Cell A continues to record live groundcover within the reference site range, demonstrating successful rehabilitation of the landform.

During the 2023 RMP, total live cover at Cell A sites (76.5% and 81%) significantly exceeded the reference range (37.6-85.9%) (Figure 4-26 middle graph). Similarly, organic matter (litter) cover on TSF Cell A fell within the upper portion of the reference range (Figure 4-26, *bottom*). Litter contributed a considerable proportion of total cover in the Cell A Sites when compared to reference sites.

Corresponding with the higher live and dead organic matter coverage results, was a lower bare ground and rock cover at the TSF Cell A sites. During the 2023 RMP, the two monitoring transects recorded bare ground (23.5% and 9.5% respectively) within the lower portion of the reference range (3-62.4%) (Figure 4-26 top graph).

The TSF Cell A monitoring sites are closely correlated in performance over time but vary strongly against the reference mean. A positive trend for live cover may be confirmed with continued monitoring.

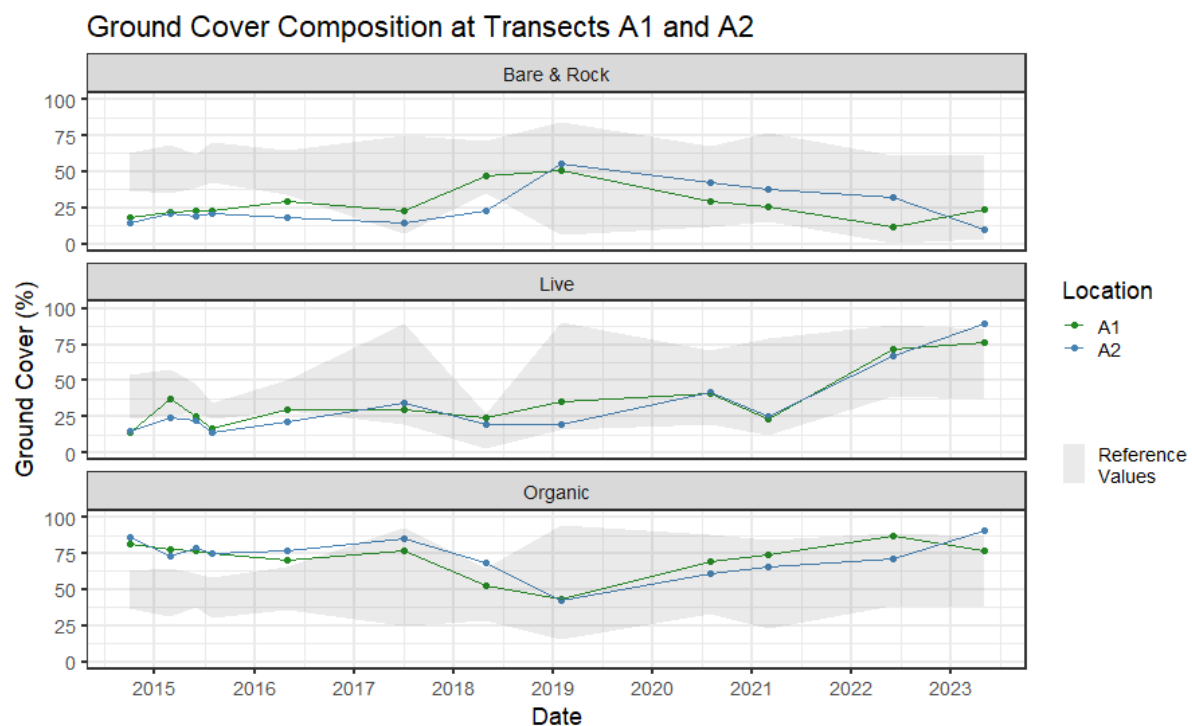


Figure 4-26: TSF Cell A bare ground (top), live vegetation cover (middle) and total organic cover (bottom)

4.2.5.2 Species richness

Total species richness at the TSF Cell A sites continues to meet and exceed the benchmark provided by the reference sites, demonstrating successful rehabilitation against this criteria.

Whilst total species richness subtly fluctuates at the monitoring sites over the long term, the transects frequently outperform the reference sites, and have maintained relatively stable values compared to the reduction in species richness observed at the reference sites.

Total species richness at the TSF Cell A sites is comprised of similar compositions of grasses and forbs, and the 2023 results indicate that TSF Cell A is maintaining a diverse assemblage of grasses. Long term monitoring data indicates that grasses have generally become more speciose on TSF Cell A over time, and appear to have recently stabilised (Figure 4-27- *middle*).

Forb species richness has been highly variable over time. Forb species richness has been consistently higher than the reference site maximum at both TSF Cell A monitoring sites; although generally (with the exception of the 2022 RMP) forb species richness falls within (or above) the reference site range.

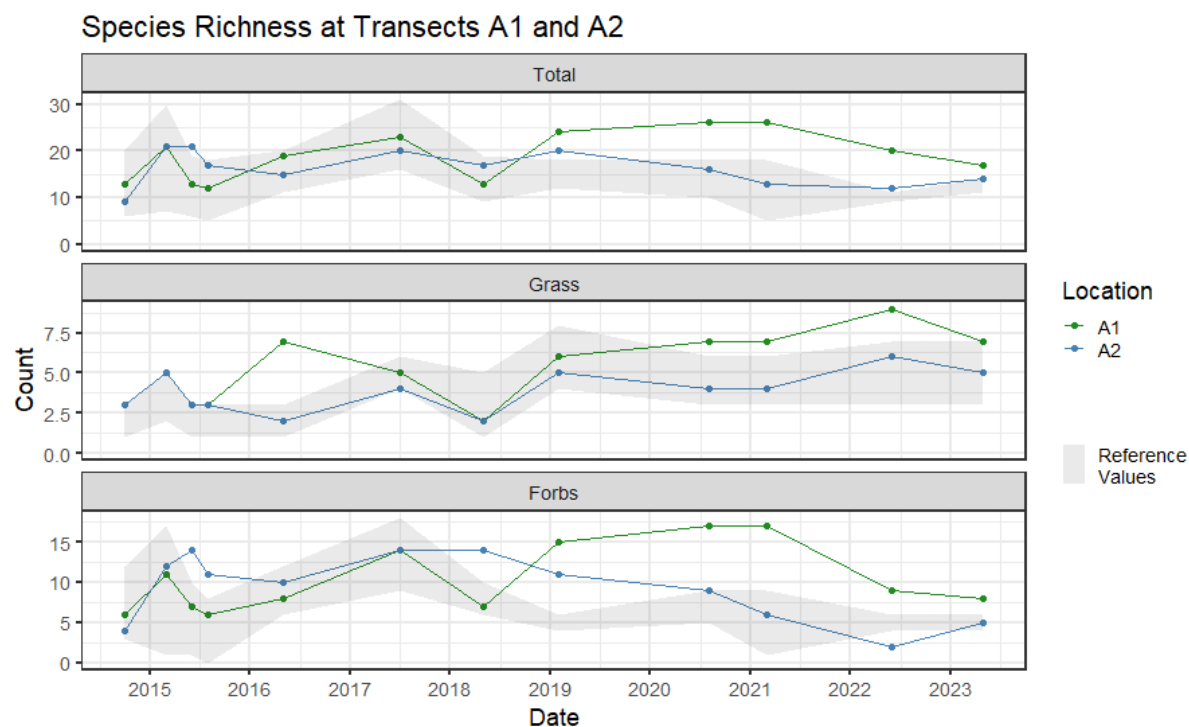


Figure 4-27: Mean species richness at Cell A

4.2.5.3 Restricted invasive plant species

Restricted invasive plant species were identified at the TSF Cell A sites during the 2023 RMP. This is currently preventing the domain from demonstrating successful weed management and achieving against this criteria.

Parthenium has been recorded at one of the rehabilitation monitoring sites for the last four monitoring events (Table 4.6). It is currently concentrated to one particularly dense section along the transect. Mimosa appears to be established at the second monitoring site.

Whilst Parthenium is also established at reference sites, the rehabilitation objective for the site is light grazing, the persistent presence of Parthenium is a management issue that should be addressed before considering applying to progressively certify the domain. Further management of Mimosa is also required.

Table 4.6: Restricted invasive plant species at Cell A

Scientific name	Common name	Weed classification	Site	Monitoring event				
				2019	2020	2021	2022	2023
<i>Parthenium hysterophorus</i>	Parthenium	Category 3 Restricted Invasive Plant	A1					
			A2	X	X	X	X	X
<i>Vachellia farnesiana</i>	Mimosa	Invasive biosecurity matter	A1	X		X	X	X
			A2					

X – indicates presence of species

4.2.5.4 Woody stem density

The woody stem density at the Cell A sites continues to significantly exceed the reference range.

During the 2023 RMP, woody stem density at the Cell A sites averaged 1080 stems/ha. Woody stem density has fluctuated at the Cell A sites over the years, however a seemingly significant decline was noted at the A1 transect during the 2023 RMP (Figure 4-28). Continued monitoring is required to understand the nature of this decline.

Long term monitoring of woody vegetation at the TSF Cell A sites has consistently recorded significantly denser woody vegetation than the reference sites. Over recent years (2021 -2023), the significantly higher density of woody vegetation on the rehabilitated TSF Cell A has contrasted with near non-existent woody vegetation at the reference sites, following the decline of woody vegetation at the reference sites from around 2016-2017. The higher density of woody vegetation is expected given the rehabilitation methodology of directly planting a variety of woody species into the surface of the facility during rehabilitation, approximately 23 years ago.

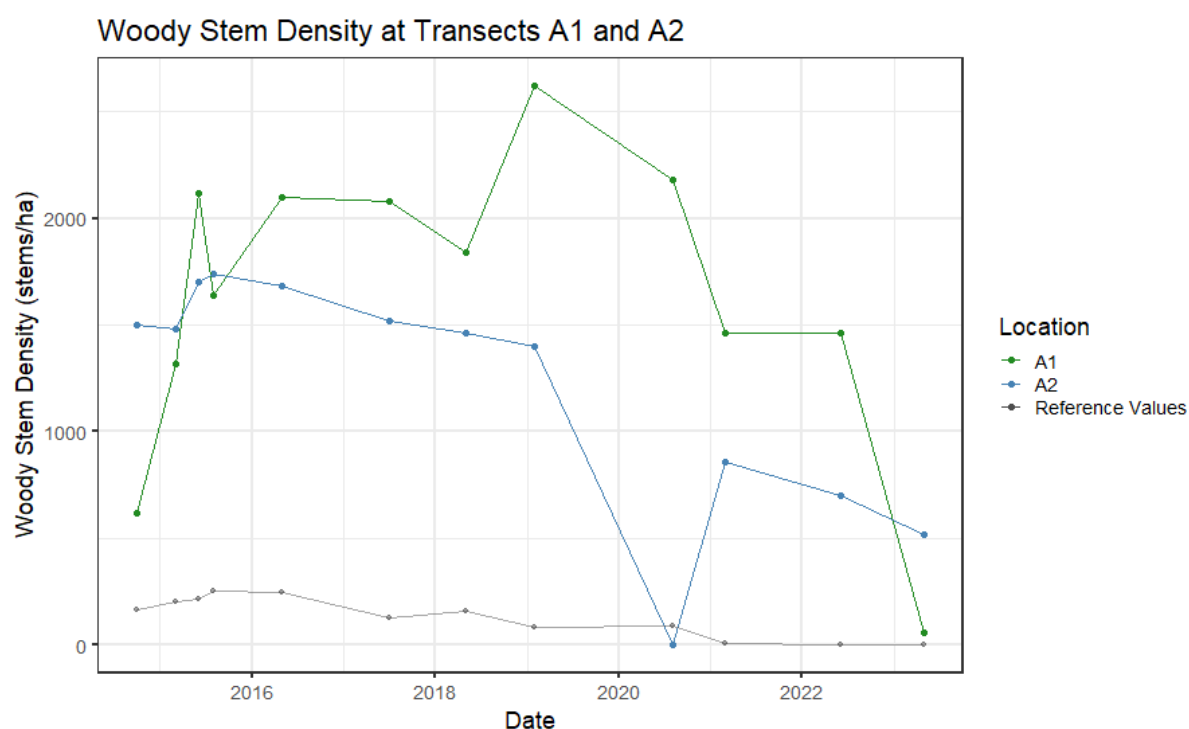


Figure 4-28: Mean woody stem density at Cell A monitoring sites

4.2.5.5 Canopy cover

Canopy cover at the Cell A sites averaged 4% during the 2023 RMP. Canopy cover at the Cell A sites continues to fluctuate year-on-year, with an apparent 4% reduction since the previous monitoring event (Figure 4-29).

Canopy cover at the TSF Cell A sites remains well above reference site values due to the significantly higher density of woody vegetation on TSF Cell A.

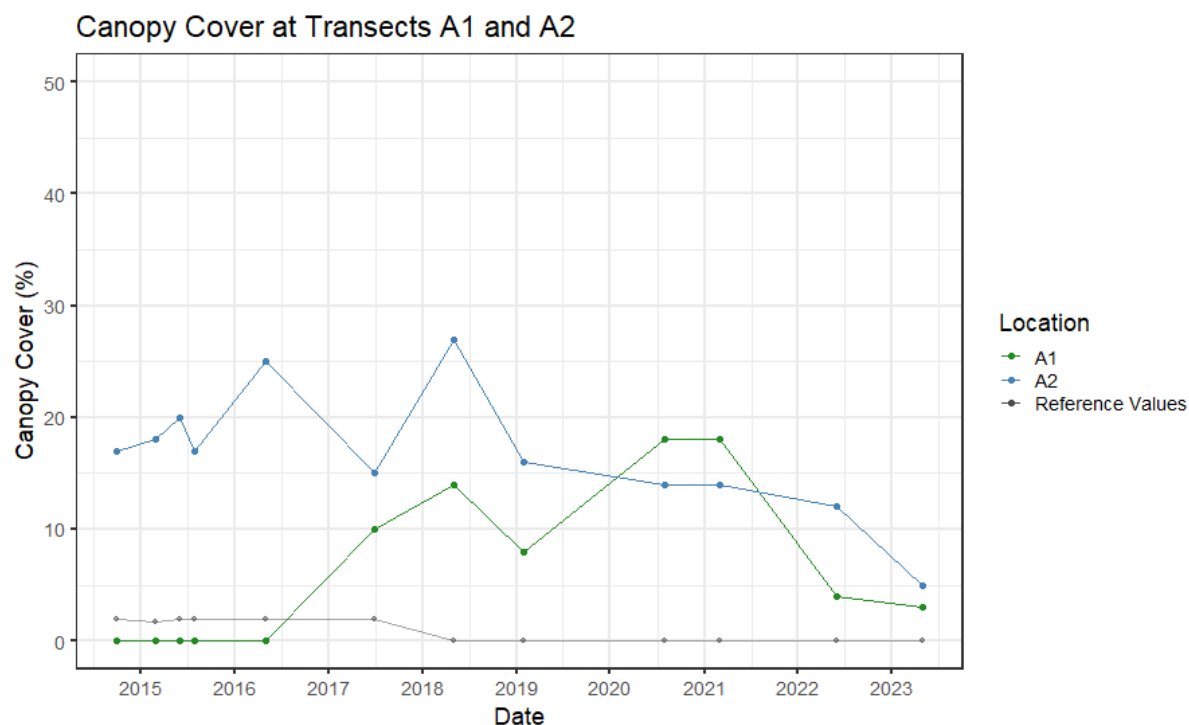


Figure 4-29: Mean canopy cover at Cell A

4.2.5.6 Erosion monitoring

Moderate erosion levels continue to be recorded in one of the TSF Cell A monitoring sites, preventing this domain from meeting the benchmark set by the reference sites (i.e. 'minor' erosion).

Site A2 has recorded moderate erosion for most of the monitoring events since monitoring commenced in 2014. During the 2019 and 2020 RMP, erosion levels appeared to reduce to minor levels, before again returning to moderate levels in 2020. This potentially suggests that there is some ongoing minor erosion occurring within the A2 site that has occurred from a disturbance event between 2017 and 2018 (Figure 4-30 right). Notwithstanding this, erosion levels do appear relatively stable, noting that erosion levels have not continued to escalate.

Erosion at site A1 has remained minor over the course of monitoring (Figure 4-30 left).

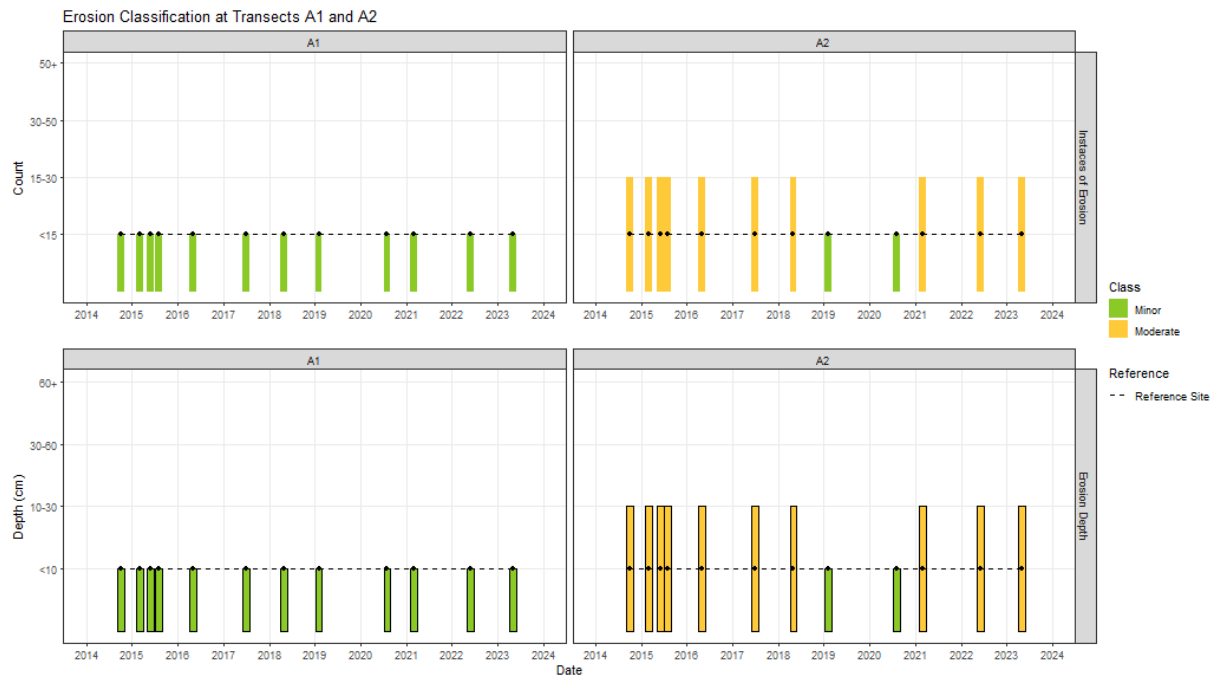


Figure 4-30: Erosion class for depth and number of rills in TSF Cell A

4.3 Cell B cover trials

To inform the rehabilitation strategy for Cell B of the TSF, three cover systems have been established on the surface of Cell B. This includes a 300 mm topsoil cover (thin cover) (results discussed in Section 4.3.1), a 450 mm topsoil cover (thick cover) (Section **Error! Reference source not found.**); and a gravelly topsoil cover with a depth of 0 – 600 mm and 400 – 600 mm (Section 4.3.3).

The performance of these cover trials was monitored through the annual RMP, comparing the results from the respective cover trial sites to the reference site results to determine if the rehabilitation objectives and rehabilitation criteria have been met.

4.3.1 Thin Topsoil (trials B1 and B2)

4.3.1.1 Ground cover

Live ground cover coverage (44.7- 64.4 %) on the thin topsoil trials fell within the reference range (37.6-85.9%) (Figure 4-31 middle graph) in 2023. Over the long-term however, live ground cover has generally been lower at the trial sites, suggesting this cover system design may be unsuitable for final rehabilitation of the facility.

Bare ground and rock cover tend to be elevated against the reference range sites most years, although both sites recorded a decrease in bare ground and rock during the 2023 RMP and were within the reference range (Figure 4-31 – top graph). Litter also increased with total organic fraction falling in the reference range (Figure 4-31 bottom graph).

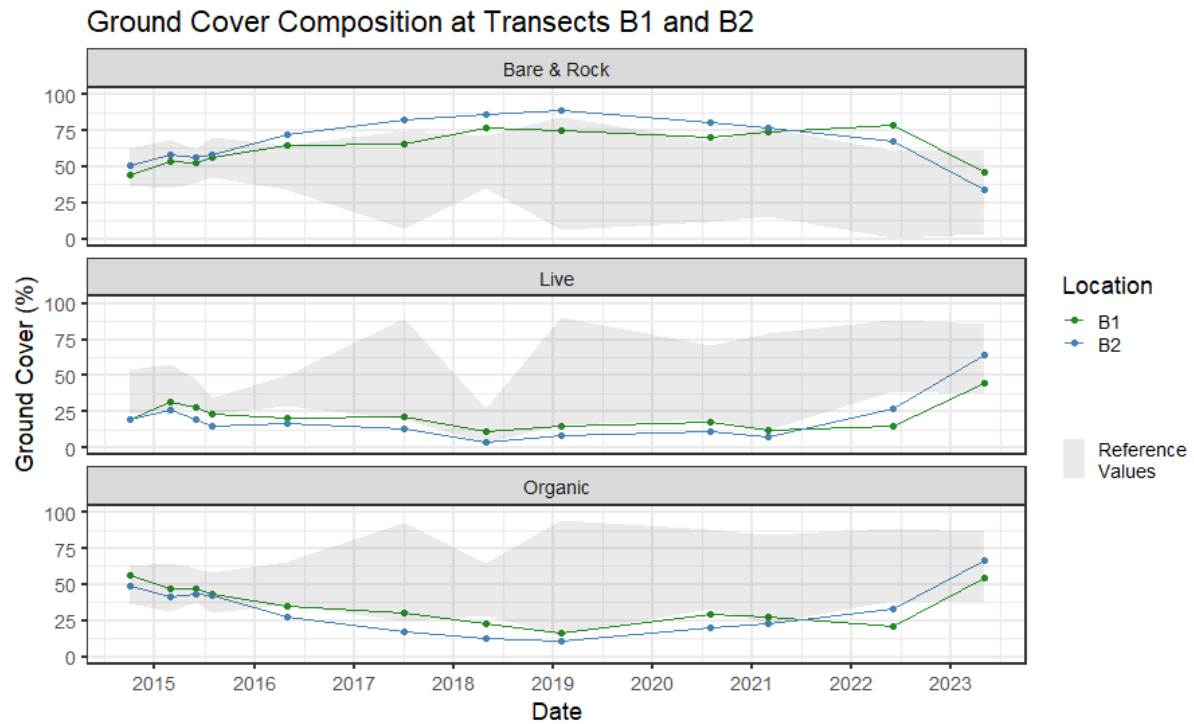


Figure 4-31: Proportional ground cover for thin topsoil capping trial (B1 and B2)

4.3.1.2 Species richness

Total species richness at the thin topsoil trial sites continues to meet the benchmark provided by the reference sites, demonstrating the cover adequately supports a diverse range of vegetation. For most years (including the 2023 RMP), the trial sites tend to record more species than reference sites, including during the 2023 RMP.

The trial sites support diverse assemblages of both grasses and forbs, with richness for both these functional groups recorded in excess of the reference site maximum (Figure 4-32 – middle and bottom graphs).

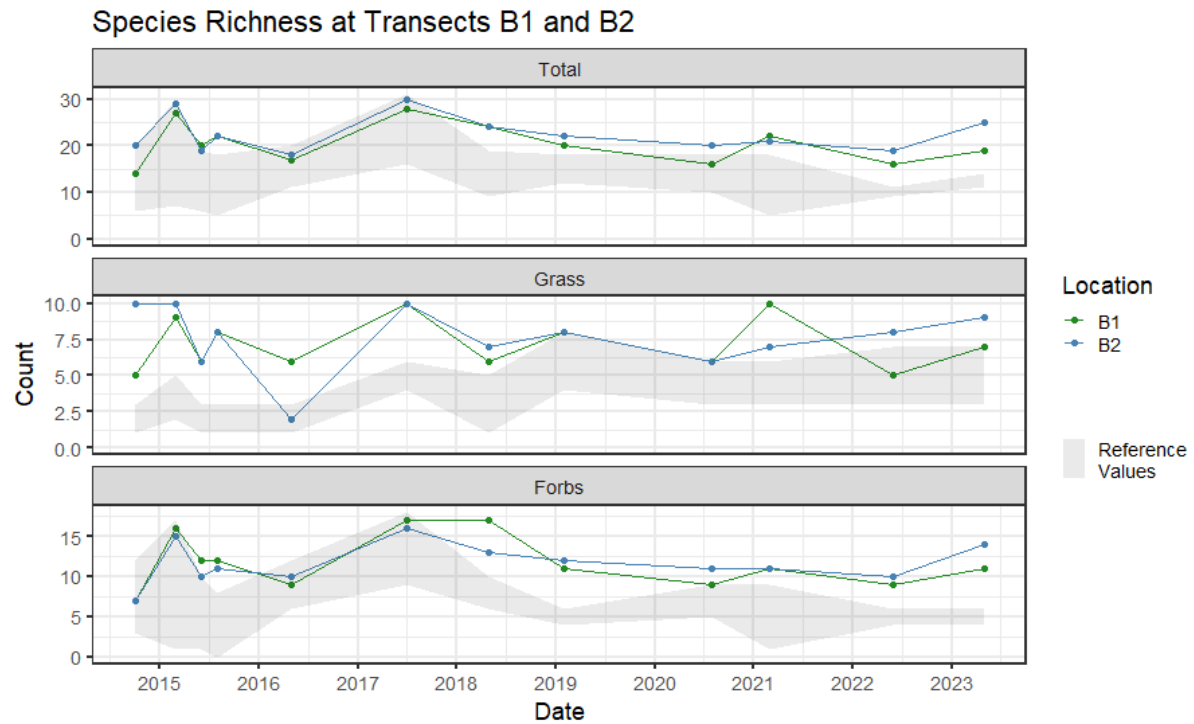


Figure 4-32: Species richness at Cells B1 and B2

4.3.1.3 Restricted invasive plant species

No restricted invasive plant species have been recorded at the thin cover trial sites during any of the monitoring events.

4.3.1.4 Woody stem density

Woody stem density at the thin cover trial sites is comparable with reference conditions, being negligible at both during the 2023 RMP event (Figure 4-38).

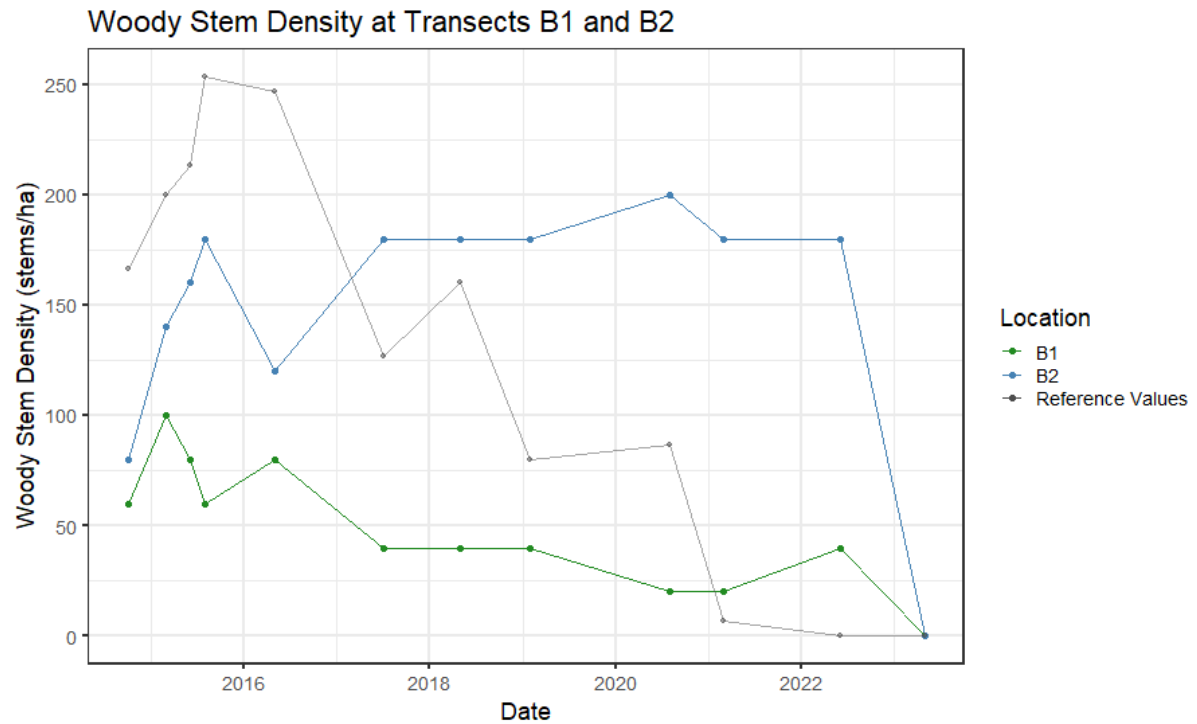


Figure 4-33: Mean woody stem density at Cell B thin cover trial sites

4.3.1.5 Canopy cover

Canopy cover at the thin cover trial sites was all but absent during the 2023 RMP, consistent with reference values. This result is consistent with all previous monitoring events (Figure 4-34). This result is comparable to the reference sites, which have recorded nil canopy cover since the 2018 RMP.

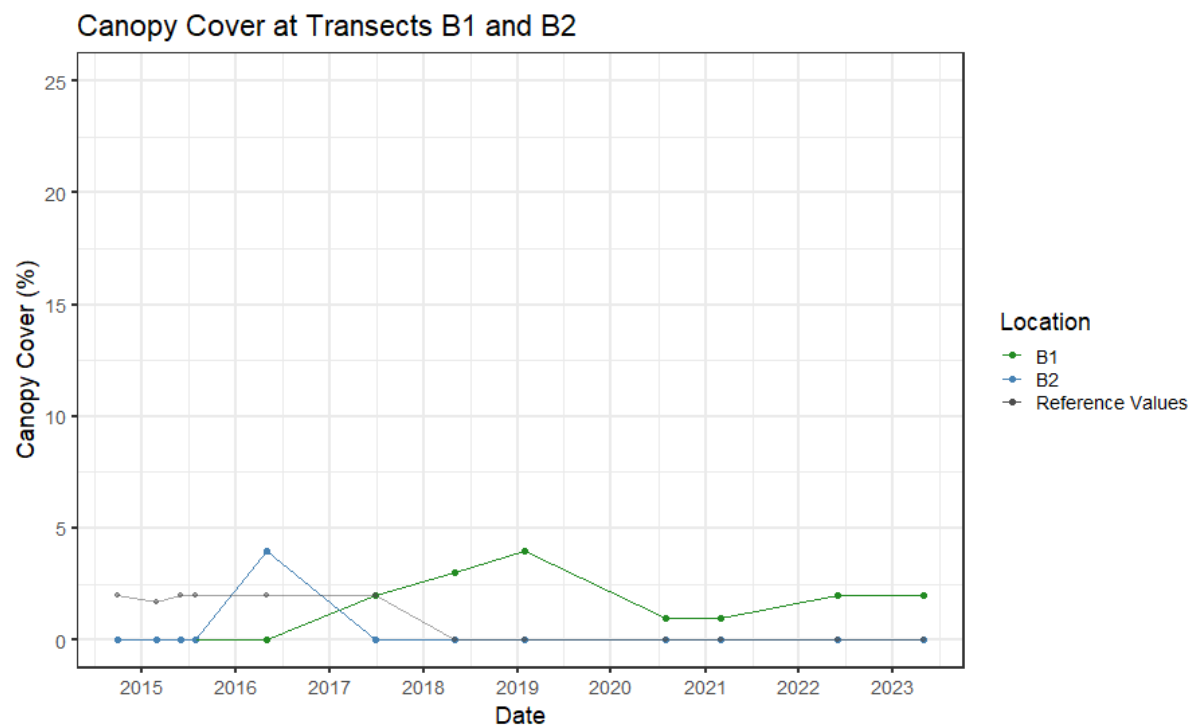


Figure 4-34: Mean canopy cover at Cell B thin cover trial sites

4.3.1.6 Erosion monitoring

The thin topsoil cap continues to remain in the minor erosion category (Category 1) (Figure 4-35). No change in erosion has been recorded in this location since 2015, indicating that the landform is stable and comparable to the reference sites.

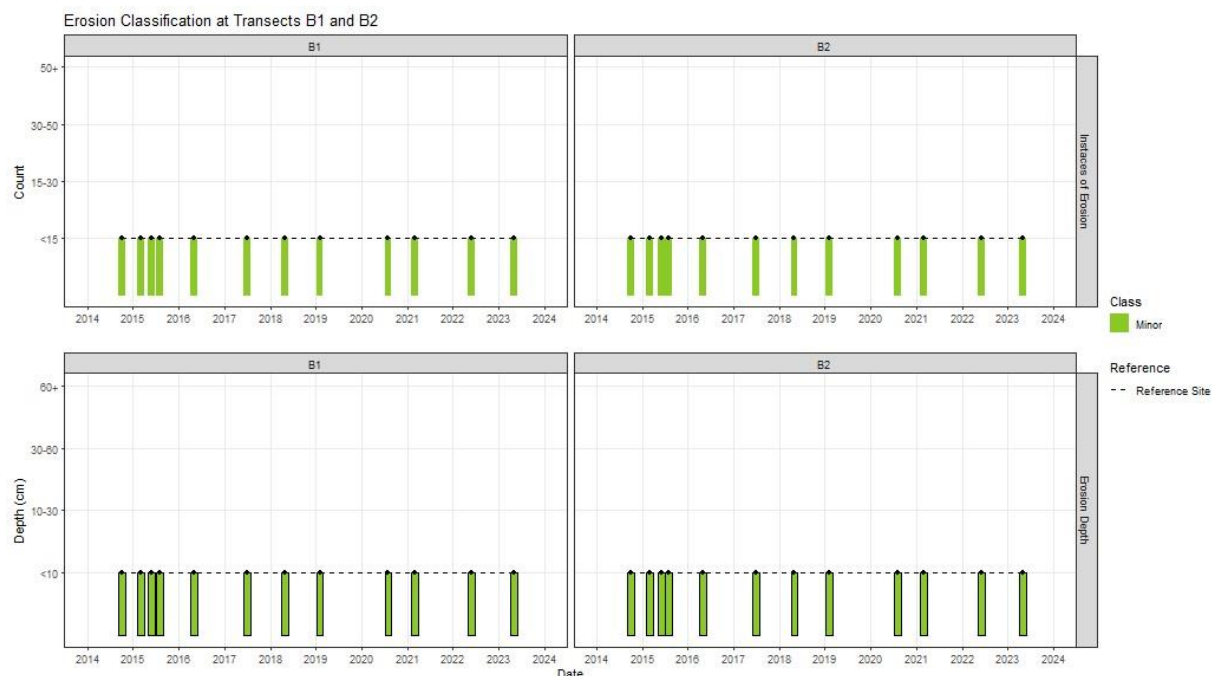


Figure 4-35: Erosion categories for TSF Cell B thick topsoil cover trial (B1 and B2)

4.3.2 Thick topsoil (trials B3 and B4)

4.3.2.1 Ground cover

Live ground cover at the thick topsoil cover trials (being 150 mm thicker than the 'thin topsoil' trials) demonstrate relatively higher proportions of live groundcover, tending to be within lower values of the reference range. During the 2023 RMP, live cover increased from a mean of 30.5% in 2022 to 65% in 2023 and fell within the reference range (Figure 4-36 middle).

Subsequently, bare ground and rock cover tend to be relatively higher within these trial plots, although these fell in the reference ranges during the 2023 RMP (Figure 4-36 top graph). Total organic fractional cover has tended to be below reference site values, however the 2023 results were in the median reference values (Figure 4-36 bottom graph).

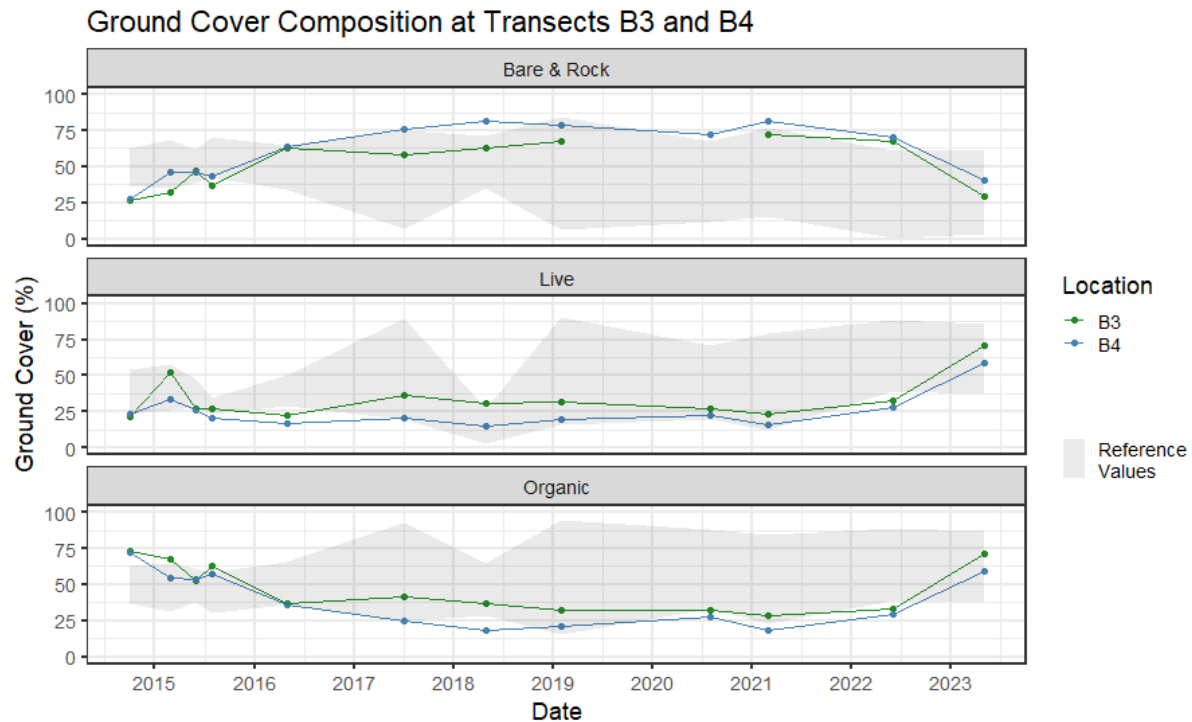


Figure 4-36: Thick topsoil fractional cover (B3 and B4)

4.3.2.2 Species Richness

Total species richness at the thick topsoil trials continued to meet the benchmark provided by the reference sites, indicating this cover design adequately supports a range of flora.

Overall, total species richness has seen a gradual decline since 2018, however both sites have remained above the reference site mean during this time. During the 2023 RMP, sites B3 and B4 recorded a total species richness mean of 16 species (Figure 4-37 top).

Grass species richness at the trial sites has been variable since monitoring commenced. Grass species richness initially exceeded the reference site mean (2014), however, monitoring site B3 fell below reference site mean for the fifth time in 2023 (Figure 4-37 middle graph). Monitoring site B4 is now within the reference range, but has trended lower within this range for the last three monitoring events.

Forb species richness has generally remained above the reference range since 2018 at the thick topsoil trials (Figure 4-37 bottom graph). Consistent with growth habit and life span, forb species richness tends to be variable, although sites B3 and B4 are correlated over time (Figure 4-37).

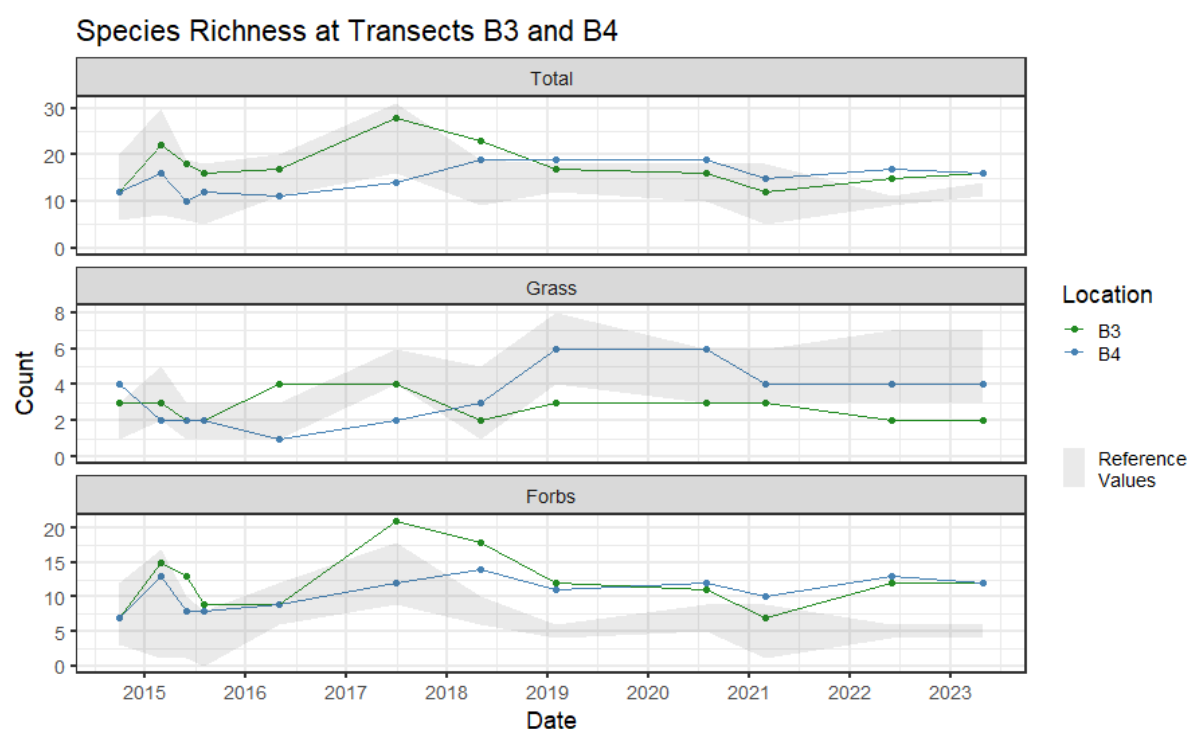


Figure 4-37: Species richness values at plots B3 and B4

4.3.2.3 Restricted invasive plant species

No restricted invasive plant species were recorded at the thick cover trial sites in 2023 (Table 4.7).

Previously, *Parthenium* has been recorded at the thick cover trial sites, however it has not been observed since the 2020 RMP.

Table 4.7: Restricted invasive species at Cell B (Thick Cover)

Scientific name	Common name	Weed classification	Site	Monitoring event				
				2019	2020	2021	2022	2023
<i>Parthenium hysterophorus</i>	Parthenium	Category 3 Restricted Invasive Plant	B3	X	X			
			B4	X	X			

4.3.2.4 Woody stem density

Woody stem density at the thick cover trial sites continues to be variable and in excess of the benchmark set at the reference sites. Noting however, that woody vegetation has declined significantly at the reference sites since 2016.

During the 2023 RMP, the thick cover trial sites averaged 60 stems/ha. Woody stem density has been variable over the last six RMP monitoring events, increasing in the 2020 RMP and returning to pre-2017 levels during the current monitoring event (Figure 4-38).

Woody stem density at the thick cover trial sites has exceeded the reference sites since the 2018 RMP.

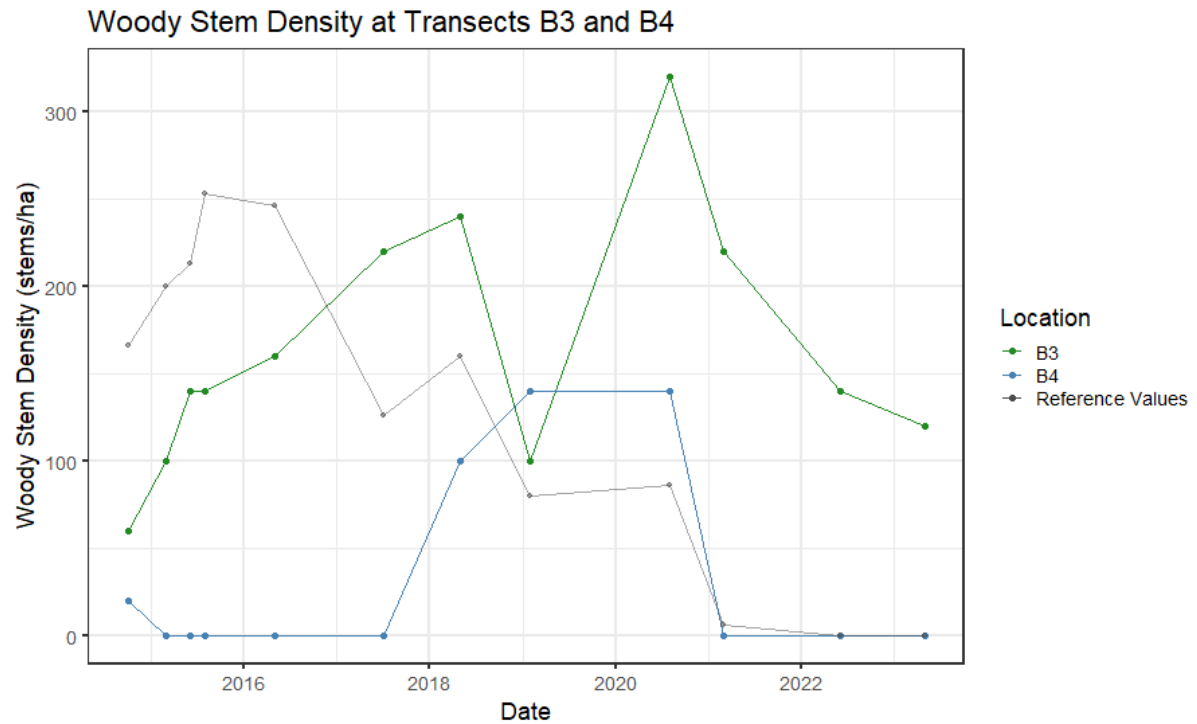


Figure 4-38: Mean woody stem density at Cell B thick cover trial sites

4.3.2.5 Canopy cover

Canopy cover at the thick cover trial sites was absent during the 2023 RMP. This result is consistent with all previous monitoring events (Figure 4-39).

This result is comparable to the reference sites, which have recorded nil canopy cover since the 2018 RMP.

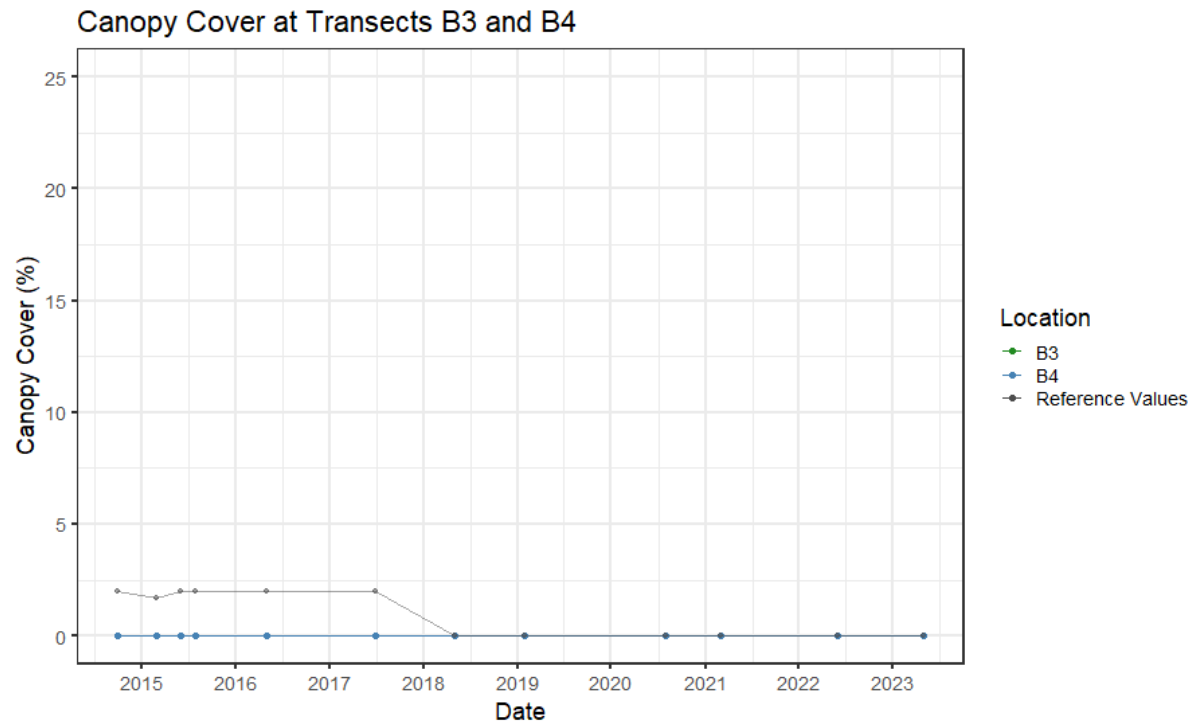


Figure 4-39: Mean canopy cover at Cell B thick cover trial sites

4.3.2.6 Erosion monitoring

Erosion levels at the thick topsoil cover trials remains minor, meeting the benchmark set by the reference sites. (Figure 4-40). No change in erosion has been recorded in this location since 2015, consistent with reference sites.



Figure 4-40: Erosion categories for TSF Cell B thick topsoil cover trial (B3 and B4)

4.3.3 Gravelly topsoil (trials B5 and B6)

Two large-scale gravelly topsoil cover designs have been established in Cell B of the tailings storage facility to plan for rehabilitation and closure.

Monitoring Site B5 is located within a thinner and more variable gravelly topsoil cover ranging in thickness from 0 - 0.6 m. Monitoring Site B5 is located in the southern trial area, which is an area of almost 6 ha.

Site B6 is located in an area with consistently thicker cover (0.4 - 0.6 m) capping layer. Monitoring Site B6 is located in the northern corner and is an area of 3.5 ha.

4.3.3.1 Ground cover

Live ground cover coverage at the gravelly topsoil cover trials continues to meet the benchmark set by the reference sites, with plot B6 particularly successful for this criteria.

As live groundcover has grown over the last three monitoring periods, bare ground and rock cover have accordingly fallen at the trials plots (Figure 4-41 top graph). Increasing the gravelly topsoil thickness (B6 0.4-0.6 m) creates an offset to higher proportional live cover that generally achieves or exceeds the reference site mean, including in 2023 (Figure 4-41 middle graph). A more variable and thinner cover of gravelly topsoil (B5 0-0.6m) exceeded rehabilitation targets in 2018, while other monitoring dates ranged between 40% and 80% of reference site mean (Figure 4-41 middle graph). Total functional organic cover displays an increasing trend over time for gravelly topsoil capping regardless of thickness (Figure 4-41 bottom graph). An offset between thicker and thinner cover is visible across all monitoring dates, indicating the thicker gravelly topsoil cover provides improved conditions for vegetation that facilitates higher live ground coverage.

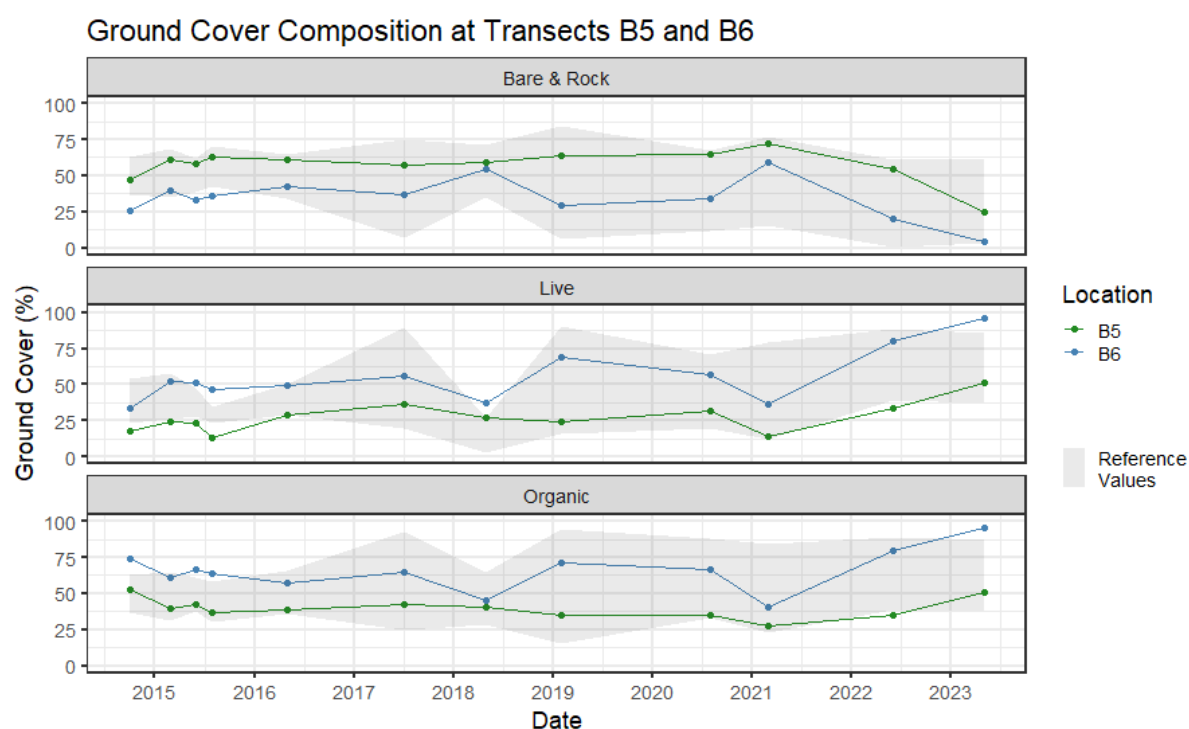


Figure 4-41: Performance of cover for broad area gravelly topsoil trials (B5 and B6) relative to reference site mean

4.3.3.2 Species richness

Total species richness indices at both the gravelly topsoil cover trials continue to exceed reference conditions, particularly for the thicker cover (B6: 0.4 – 0.6 m), indicating both cover designs can adequately support a variety of flora.

Overall, B5 and B6 have seen consistent total species richness values from 2014-2023, performing at or above the reference site mean. Species richness has remained above rehabilitation site mean since 2015 (nine years) for both grasses and forbs (Figure 4-42). Capping depth has not consistently affected species richness for grasses or forbs (Figure 4-42).

Grass species richness has remained at or above the reference site maximum, and continued to increase at both sites (Figure 4-42). Forb species richness appears to still be declining slightly, however B5 has seen a significant increase in 2023 and both sites have remained at, or above the reference site maximum (Figure 4-42).

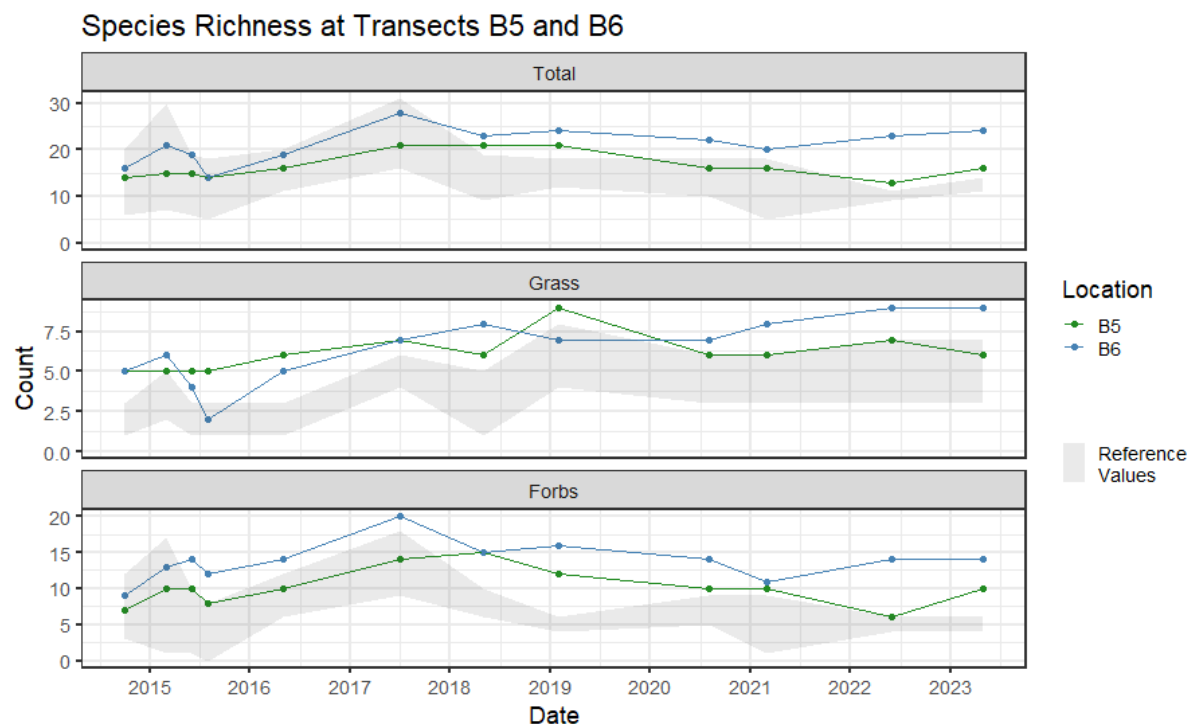


Figure 4-42: Species richness values at Cells B5 and B6

4.3.3.3 Restricted invasive plant species

No restricted invasive weed species have been recorded in the gravelly topsoil cover trial sites since 2017.

4.3.3.4 Woody stem density

Woody stems density appeared to increase significantly during the 2023 RMP, and are now exceeding the benchmark set at the reference sites. However, woody vegetation has declined significantly at the reference sites since 2016.

Woody stem density at the gravelly topsoil cover trials averaged 130 stems/ha in 2023 (Figure 4-43). Woody stemmed flora has not previously been observed at site B6, although some small scattered shrubs were observed during the 2023 RMP.

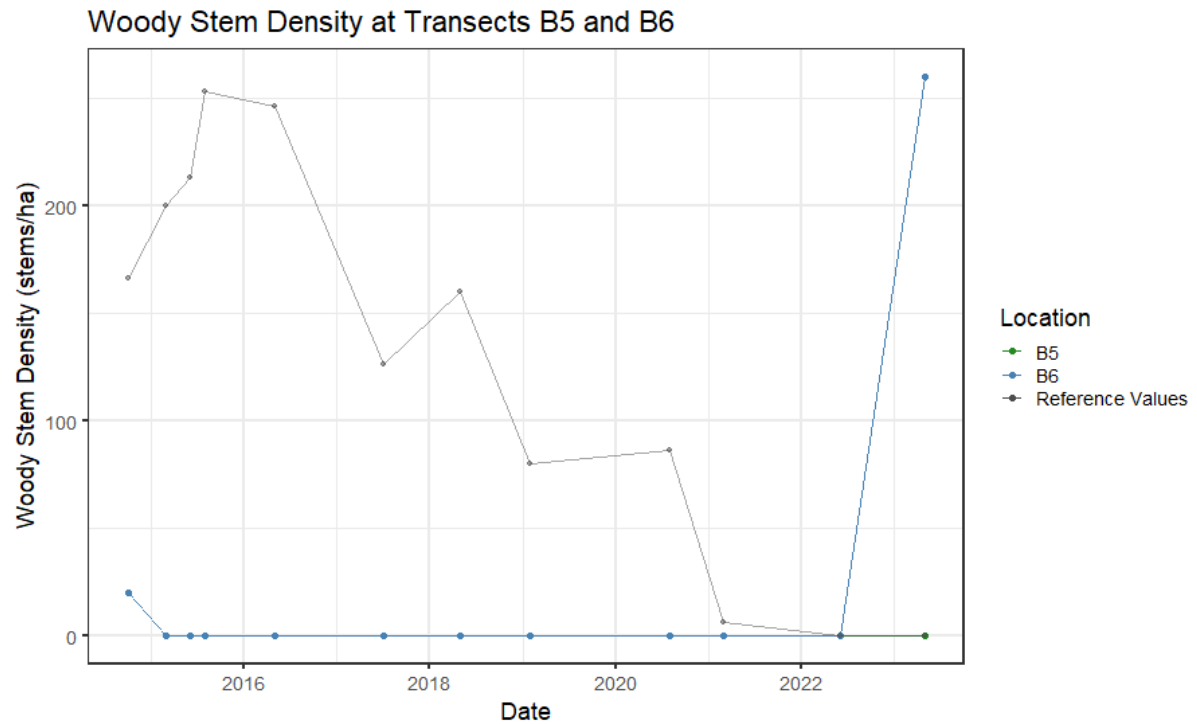


Figure 4-43: Mean woody stem density at the gravelly topsoil plots (B5 and B6)

4.3.3.5 Canopy cover

Canopy cover at the Cell B site during the 2023 RMP monitoring event was 0% and has remained at 0% for all RMP monitoring events (Figure 4-44). This is comparable to the reference site, which has recorded a canopy cover of 0% since 2018.

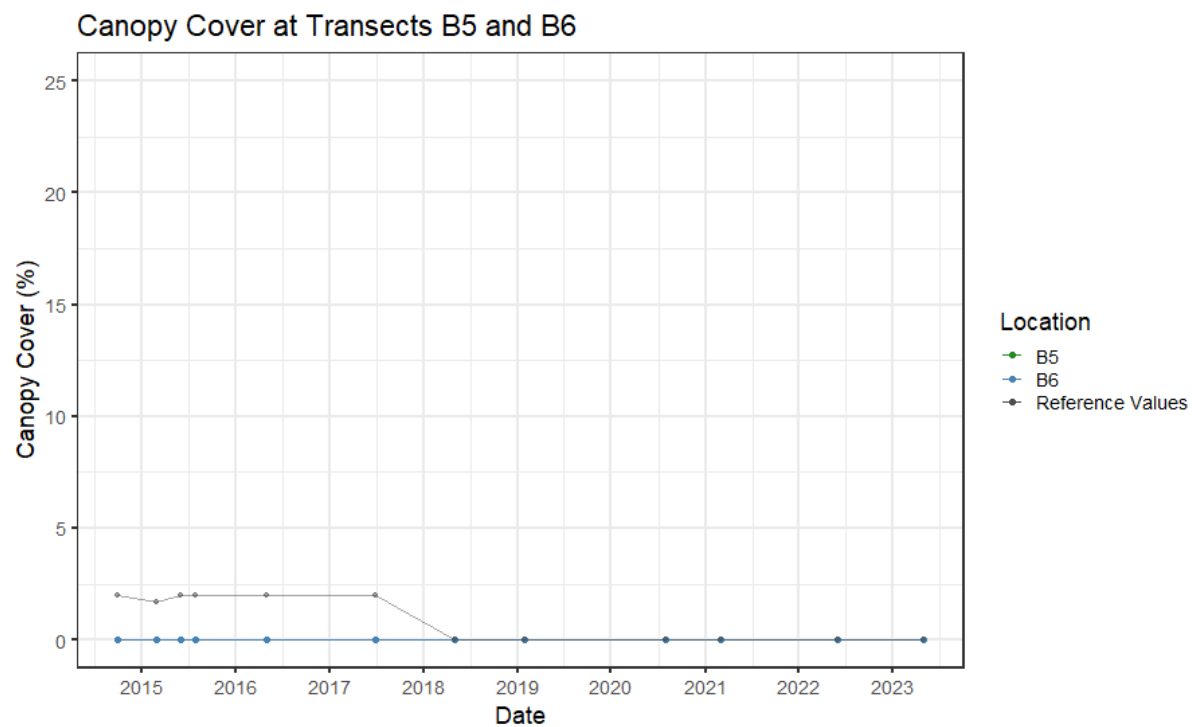


Figure 4-44: Mean canopy cover at Cell B (Gravel Topsoil)

4.3.3.6 Erosion monitoring

Erosion levels at the thick gravelly topsoil sites remains minor, meeting the benchmark set by the reference sites. (Figure 4-45).



Figure 4-45: Erosion within Cell B thin (B5) and thick (B6) gravelly topsoil capping trial

5 Discussion

5.1 Reference sites

5.1.1 Woody stem and canopy cover

Vegetation monitoring at the three reference sites continue to indicate woody vegetation management to maintain grazing capacity. This includes mature tree pushing/chaining (R3) and blade ploughing (R1 and R2). Woody vegetation at these sites remains negligible. Whilst the vegetation structure of these sites has been modified since rehabilitation monitoring began, it is acknowledged that the post-mining land use for the site is light intensity pasture grazing, so these sites remain good benchmarks for rehabilitation success. The suitability of completion criteria such as woody density and canopy cover should be considered during the PRCP transitioning process.

5.2 Progressive rehabilitation sites

Monitoring results from the progressive rehabilitation sites have been reviewed against the relevant completion criteria to determine the success of this rehabilitation, with the results of this review summarised below in Table 5.1.

Table 5.1: Rehabilitation objectives and completion criteria for rehabilitation sites in 2023

Objectives and completion criteria	Sites compared to reference site				
	South Pit	ROM Pad	Village Infra	Rehab. Infra	Cell A
<u>Rehabilitation objective: Adequate vegetation cover to minimise erosion</u>					
<u>Completion criteria: evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites</u>					
Ground cover	✓	✓			✓
Species richness	✓	✓		✓	✓
Restricted invasive plant species	✓		✓	✓	
Woody stem density	✓	✓	✓	✓	✓
Canopy cover	✓	✓	✓	✓	✓
Erosion	✓	✓	✓	✓	
<u>Rehabilitation objective: Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.</u>					
<u>Completion criteria: (below)</u>					
Key species are present	✓	✓	✓	✓	✓
Suitable diversity has been achieved and cover/density is adequate	✓	✓		/	✓
Evidence that weed management has been successful	✓		✓		

/ - indicates completion criteria partially achieved, ✓ – indicates completion criteria has been achieved

Results from the 2023 RMP event indicate that:

- The rehabilitated South Pit area is the most successfully rehabilitated domain, generally achieving all the relevant completion criteria. This includes total live cover, which the 2023 RMP confirmed has returned to meet the reference benchmark following temporary exploration disturbance and a minor reduction in groundcover during the 2022 monitoring period.
- Rehabilitation of the ROM Pad is proving successful in meeting the rehabilitation criteria, meeting all relevant completion criteria apart from the occurrence of restricted invasive species. Three restricted invasive species, *Parthenium*, *Mimosa* and *Harrisia Cactus*, were observed during the 2023 RMP. Overall, restricted invasive species tend to be similar in density or cover or slightly higher at the ROM Pad sites than reference sites, indicating an opportunity for further management. Otherwise, vegetation on the ROM Pad is well established and self-sustaining. Erosion monitoring indicates that the landform is stable.
- The rehabilitated village infrastructure area continues to record groundcover and species richness below the reference range. Long term monitoring indicates that the rehabilitated village infrastructure area consistently records lower live ground cover than reference sites, indicating opportunity for improved management. It is acknowledged that evidence of cattle disturbance was observed within the rehabilitated area, in addition to some remnant building material.
- The rehabilitated infrastructure area continues to meet most rehabilitation criteria, although the area recorded a low percentage for live ground cover relative to reference sites. One restricted invasive species, *Mimosa Bush*, was recorded during the 2023 RMP, however generally the presence of restricted invasive species is comparable or less than the reference sites. For other criteria, the rehabilitated infrastructure area has recorded higher species richness than the reference sites for all monitoring events; meeting this completion criteria and indicating that vegetation is well established and self-sustaining.
- Rehabilitation of Cell A continues to be very successful, with the area meeting most completion criteria during the 2023 RMP. Completion criteria not achieved during the 2023 RMP related only to the presence of restricted invasive species. Long term monitoring has demonstrated that the abundance of invasive species at Cell A sites has generally remained low and comparable to the reference sites; and that this completion criteria has been previously met. Nonetheless, the completion criteria strictly requires zero presence of restricted invasive species.

During the 2023 RMP, live ground cover and species richness at the Cell A sites recorded very highly against the reference site average. Overall, vegetation on Cell A appears to be well established and self-sustaining, with Cell A consistently meeting or exceeding completion criteria for most vegetation metrics (excluding restricted invasive species). The higher woody stem density and canopy cover at Cell A reflects the rehabilitation methodology for this area that included planting a number of woody species (e.g. *Eucalyptus argophloia*, *Eucalyptus camaldulensis*) in addition to pasture species. Woody species recorded a decline at Cell A, similar to the reference sites, likely due to grazing pressures and landholder activities.

Some evidence of elevated erosion levels at one Cell A sites has been observed through multiple monitoring events. Whilst this appears to be stable, with no further deterioration in severity, this erosion currently prevents Cell A from meeting the relevant completion criteria for erosion.

Overall, the majority of the rehabilitated domains are considered to have well-established vegetation that is generally consistent with reference sites, demonstrating considerable progress towards the rehabilitation objectives. Opportunities for improvement are available, with recommendations provided in Section 6.

5.3 TSF Cell B cover trials

Monitoring results from the Cell B cover system trials were reviewed against the relevant completion criteria to determine the performance of these trials and their suitability for use in final rehabilitation activities. The results of this review are summarised below in Table 5.2.

Table 5.2: Objectives and completion criteria for TSF sites in 2022

Objectives and completion criteria	Sites compared to reference site			
	Cell B (Thin Cover) (B1, B2)	Cell B (Thick Cover) (B3, B4)	Cell B (Gravel 0-600mm) (B5)	Cell B (Gravel 400-600mm) (B6)
<u>Rehabilitation objective: Adequate vegetation cover to minimise erosion</u>				
<u>Completion criteria: evidence in the rehabilitation report that the revegetation meets the limits set by the analogue sites</u>				
Ground cover	✓	✓	✓	✓
Species richness	✓	✓	✓	✓
Restricted invasive plant species	✓	✓	✓	✓
Woody stem density	✓	✓	✓	✓
Canopy cover	✓	✓	✓	✓
Erosion monitoring	✓	✓	✓	✓
<u>Rehabilitation objective: Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.</u>				
<u>Completion criteria: (below)</u>				
Certification within the rehabilitation report that key species are present.	✓	✓	✓	✓
Suitable diversity has been achieved and cover/density is adequate.	✓	✓	✓	✓
Evidence that weed management has been successful.	✓	✓	✓	✓

/ - indicates completion criteria partially achieved, ✓ – indicates completion criteria has been achieved

Monitoring of the Cell B cover system trials has found:

- The thin topsoil cover system trials (300 mm) tends to record considerably lower live groundcover than reference sites, although meeting the benchmark established by the reference sites during the 2023 RMP. Long term monitoring indicates this cover design is unlikely to be suitable for sustaining sufficient vegetation cover.
- The thick topsoil cover system trials (450 mm) indicates that a slightly thicker cover design enhances outcomes for vegetation, with improved live groundcover on these trial plots compared to the thin topsoil cover trials. Nonetheless, live groundcover continues to be in the lower values of the reference range, with some occasional monitoring periods recording below the reference range. This cover design supports a variety of flora, although tends to record less grass species than reference sites.
- The variable thickness gravelly topsoil cover system trial (0 – 600 mm) is achieving all completion criteria. Live groundcover results however tend to be in the lower range of reference values, and occasionally are below this range.
- The consistently thicker gravelly topsoil cover system trial (400 – 600 mm) consistently demonstrates successful results for all metrics. This includes live groundcover, and when compared to the variable thickness gravelly topsoil trial, is consistently above the reference mean.

Overall, the Cell B cover trials have achieved success in all of the completion criteria in 2023. The capping trials have resisted erosion and maintained high species richness, and indicate the cover is able to sustain vegetation

cover. Further monitoring should be undertaken, especially for the thick gravelly topsoil cover trial (B6), to monitor any further progress.

6 Conclusion and recommendations

To continue progressing towards the rehabilitation objectives for the site, the following management strategies, are recommended.

6.1 Live groundcover and species richness

It is recommended that a pasture seed mix based on the key target species be incorporated into the management plan for the village and rehabilitated infrastructure areas to enhance live groundcover and species diversity at these sites.

6.2 Weed management

The Category 3 Restricted Invasive Plant, such as Parthenium should be managed on an ongoing basis. It is recommended that monitoring continue at Cell A, ROM Pad and the rehabilitated infrastructure areas with weed management incorporated. Three restricted invasive species were identified during the 2023 RMP - Parthenium, Harrisia Cactus, and Mimosa. Successful rehabilitation requires restricted invasive species to be absent.

The Department of Agriculture and Fisheries (DAF) outlines a range of appropriate management strategies relevant to each species.

Information and advice on the management of Parthenium can be found here:

https://www.daf.qld.gov.au/_data/assets/pdf_file/0004/68602/IPA-Parthenium-PP2.pdf

Information and advice on the management of Harrisia Cactus can be found here:

https://www.daf.qld.gov.au/_data/assets/pdf_file/0003/49179/harrisia-cactus.pdf

Information and advice on the management of Mimosa Bush can be found here:

https://www.daf.qld.gov.au/_data/assets/pdf_file/0007/74167/mimosa-bush.pdf

The control measures considered for Parthenium are physical control, herbicide control and biological control:

- **Physical control:** Physical controls (hand-pulling plants) are not recommended because of the health hazard from allergic reactions and the risk of spreading the infestation by dropping mature seeds.
- **Herbicide control:** Due to the size of the Project and the vegetation characteristics (non-crop area), the recommended control method for Parthenium is herbicide control. Herbicides should be sprayed early on infestations before it the plant sets seed, and monitored for at least two years (DAF 2016).
- **Biological control:** In Queensland, the combined effects of biological control agents have been shown to reduce the density and vigour of Parthenium and increase grass production. There are currently several insect species and two rust pathogens that have been introduced to control Parthenium such as *Epiblema strenuana* (Stem Galling Moth), a moth introduced from Mexico established in all Parthenium areas; and *Zygogramma bicolorata* (Parthenium beetle) a defoliating beetle from Mexico which is highly effective at controlling Parthenium where present (DAF 2016). It is recommended to consult local government weeds inspector or the Department of Natural Resources, Mines and Energy before implementing biological control methods.

Each local government must have a biosecurity plan that covers invasive plants and animals in its area. This plan may include actions to be taken on certain species. Some of these actions may be required under local laws. It is advised to contact your local government for more information.

6.3 Site management

The presence of inorganic material was evident in one progressive rehabilitation site. Building material, rubble and other inorganic matter were observed within the Village Infrastructure site 'VI2'. This material will need to be removed to meet rehabilitation completion criteria.

6.4 Erosion

In accordance with the EA rehabilitation conditions and in line the success criteria (outlined in section 2.2.4) the final landform design should achieve appropriate erosion rates as well as adequate vegetation cover to minimise erosion. The Cell A sites 'A2' continues to present moderate erosion characteristics with all other sites recording minor erosion, in line with reference site conditions.

Erosion repair work is recommended in the areas experiencing erosion at the A2 monitoring site to achieve the relevant completion criterion.

6.5 Future rehabilitation monitoring

Rehabilitation monitoring should continue to be undertaken, to observe and confirm the performance of rehabilitated domains and the cover system trials on Cell B of the TSF.

Rehabilitation monitoring should be undertaken in May 2024, after the wet season. By undertaking monitoring during this time, conditions are more favourable for plant growth, which should result in higher species richness and diversity.

7 References

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Appendix A. Ground cover database

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
R1	Non-Pasture Species	0	0	0	0	0	0	0	0	0	0	0	0
R1	Exotic Pasture Species	29.2	26.1	28.3	28.8	21.5	53	3.2	10.2	19	12.1	59	40.5
R1	Native Pasture Species	0	0	0	0	0	1	0	0.4	0.4	0	12	0
R1	Shrubs	0	0	0	0	0	0	0	0.4	0	0	0	0
R1	Forbs	0.2	0.1	0	0	7	12.3	0.1	4.7	0.5	0	1	0
R1	Invasive Weed Species	0	0	0	0	0	2.2	0	0	0	0	0	0
R1	Bare Ground	50.2	67.3	57.8	55.1	63	25.6	55.7	83.8	34	55.9	28	57.5
R1	Organic Litter	18.5	5.5	9.9	12.3	7.1	4.1	30.7	0	43.3	32	1	2
R1	Rock	1.9	1	4	3.8	1.4	1.8	0.4	0.1	2.8	0	0	0
R2	Non-Pasture Species	0	0	0	0	0	0	0	0	2	0	1	0
R2	Exotic Pasture Species	19.3	22.3	20.9	17.6	17.5	12.1	7.1	17.7	15.7	17	27	18.4
R2	Native Pasture Species	0.4	0	0	0	0	0.1	0	12.5	0.6	1	4	0
R2	Shrubs	2.4	6.5	8.5	4.7	4	0.1	12.7	0	0	0	0	0
R2	Forbs	0.9	3	1.3	0.6	9	7.7	3.5	10.4	6.1	2.2	7	19.2
R2	Invasive Weed Species	0	0	0	0	0	0	0	0	0	0	0	0
R2	Bare Ground	61.9	51.5	58.7	69	60.5	43.2	71.2	59.7	64.6	76.7	61	62.4

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
R2	Organic Litter	14.1	7.9	9.3	7.1	8	5.1	5.3	0	8.5	3	0	0
R2	Rock	1	8.8	1.3	1	1	31.5	0.2	0	2.8	0	0	0
R3	Non-Pasture Species	0.1	0.5	0	0	0	0	0	0	0	0	0	0
R3	Exotic Pasture Species	38.6	49.6	47	34.3	43.5	85.1	26.9	86.9	69.6	75.9	87.8	84.3
R3	Native Pasture Species	10.7	0	0	0	0	0	0	1.7	0	0	0	0
R3	Shrubs	1	0	0	0	0	0	0	0	0.1	0	0	0
R3	Forbs	2.7	3.9	0.4	0.5	6	2.7	0.2	1.9	0.5	1.1	0.5	1.6
R3	Invasive Weed Species	1.3	4	0	0	1	1.2	0	0.2	0.4	2	0.2	0
R3	Bare Ground	37.2	33.1	37.8	41.7	33	5.3	34.9	6.6	11.8	15.5	1	3
R3	Organic Litter	8.4	6.6	13.7	23.2	15.5	4.1	37.5	3.8	17.6	5.4	0.3	1.5
R3	Rock	0	2.3	0.9	0.3	1	1.6	0	0	0.1	0	0	0
SP1	Non-Pasture Species						0	0	0.5	0.1	0	0	27.4
SP1	Exotic Pasture Species						38	30.9	39	44.2	38.5	61	55.6
SP1	Native Pasture Species						0	0	0	0	0	0	0
SP1	Shrubs						0	0	0	0	0	0	0
SP1	Forbs						3.1	2.7	1.2	1.5	2	4	6.5

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
SP1	Invasive Weed Species						0	0	0	0	0	0	0
SP1	Bare Ground						1.8	0.5	2	1	9.5	28	8.9
SP1	Organic Litter						4.3	3.3	0.3	4.9	4.6	4	0
SP1	Rock						52.8	62.6	56.9	48.3	45.4	4	1.6
SP2	Non-Pasture Species						0	2	1.1	0.2	0	0	0
SP2	Exotic Pasture Species						56.6	37	55.5	50.7	35.5	0	76
SP2	Native Pasture Species						0	0	0	0	0	0	0
SP2	Shrubs						0	0	0	0	0	0	1.3
SP2	Forbs						4.4	1.8	5.6	3.4	3	9	5.2
SP2	Invasive Weed Species						5.37	3.13	4.73	2.97	5.03	6.67	0
SP2	Bare Ground						0.5	0.8	0	0.9	14.9	9	16.5
SP2	Organic Litter						8	4.3	0	6.5	8.9	18	0.3
SP2	Rock						30.5	54.2	37.8	38.3	37.7	4	0.7
SP3	Non-Pasture Species						2	2	0.7	0.7	0	0	0
SP3	Exotic Pasture Species						31	12.9	47.8	16.8	26.3	48	64.3
SP3	Native Pasture Species						0.8	0	0	0.3	0	19	1.1

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
SP3	Shrubs						0	0	0.3	0.3	0	2	0
SP3	Forbs						8.6	4.9	7.4	4	10.1	7	13.7
SP3	Invasive Weed Species						4.6	0.9	1.1	3.2	2.8	7	0
SP3	Bare Ground						1.8	1	1	2	20.4	16	11.7
SP3	Organic Litter						12.6	11	3	45.4	7	8	8.3
SP3	Rock						42.5	69.2	39.8	30.5	33.7	1	0.9
ROM1	Non-Pasture Species						0	0	0	0	0	0	0
ROM1	Exotic Pasture Species						21.2	21.8	25.9	28.5	26.5	46	24
ROM1	Native Pasture Species						0	0	0	0	0	0	9.8
ROM1	Shrubs						0	0	2	0	0	0	0
ROM1	Forbs						4.6	0.9	1.1	3.2	2.8	7	6.2
ROM1	Invasive Weed Species						0	0	0	0	0	0	0
ROM1	Bare Ground						11.8	30.6	23.5	30.1	56.7	40	47.5
ROM1	Organic Litter						4	2.8	1	9.4	0	5	0
ROM1	Rock						58	43.9	46.5	28.8	14	3	12.5
ROM2	Non-Pasture Species						0.1	0	0.5	0.7	0	0	0

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
ROM2	Exotic Pasture Species						0.9	2.2	3.2	6.7	8	44	36
ROM2	Native Pasture Species						0	0	0	1.5	1	6	17
ROM2	Shrubs						0	1.7	7.2	0	1	0	0
ROM2	Forbs						8	5	15.1	7.4	13.6	15	20.5
ROM2	Invasive Weed Species						2.3	3.8	5.7	3.6	4.5	1	1
ROM2	Bare Ground						1.5	0.9	0	3	10.5	26	0
ROM2	Organic Litter						49	34.4	16.1	44.7	32.8	9	25.5
ROM2	Rock						38.1	52	52.2	32.1	31.8	0	0
ROM3	Non-Pasture Species							0.1	0	0.1	1.5	0	0
ROM3	Exotic Pasture Species							12.9	11.9	15.6	24.7	48	43
ROM3	Native Pasture Species							0	0.6	0.9	1	2	1
ROM3	Shrubs							1	0.5	0.5	0	1	0.5
ROM3	Forbs							1.6	6.2	3.9	6.7	18	10.8
ROM3	Invasive Weed Species							0.5	0	1.8	0	2	0
ROM3	Bare Ground							3.3	2	2.3	11	17	24.4
ROM3	Organic Litter							51.7	14.1	32.9	37.1	13	20.3

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
ROM3	Rock							28.9	64.9	42	18	0	0
RI1	Non-Pasture Species						0	0	0	0	0.5	0	0
RI1	Exotic Pasture Species						17.6	6.8	31.6	29	28.3	29	28.1
RI1	Native Pasture Species						0.5	0.1	1.5	0.3	0	2	4
RI1	Shrubs						1	1	1.2	0	0	0	0
RI1	Forbs						5.2	0.4	0.7	1.4	1.7	2	4.1
RI1	Invasive Weed Species						1.4	0.1	0	0	0	1	0.1
RI1	Bare Ground						1.8	10.8	3	8.7	31	0	0.5
RI1	Organic Litter						7.1	11.9	11.7	15.4	32.8	62	55.2
RI1	Rock						65.4	68.9	50.2	44.2	5.7	4	8
RI2	Non-Pasture Species						0.2	0	0	1	0	0	0
RI2	Exotic Pasture Species						18.6	23	47.6	4.5	11.2	0	36.2
RI2	Native Pasture Species						0	0	0	0.6	0	41	8.5
RI2	Shrubs						0	0	0	0	0	0	1.7
RI2	Forbs						2.3	0.3	0.6	0.9	1.5	6	5.5
RI2	Invasive Weed Species						0	0	0	0.1	0	0	0

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
RI2	Bare Ground						1.9	3.2	12.7	12.9	75.6	36	41.7
RI2	Organic Litter						10.9	19.2	3.5	35.4	8.5	16	6.4
RI2	Rock						66	53.3	35.4	44.6	3.2	0	0
VI1	Non-Pasture Species						0	0	0	0	0	0	0
VI1	Exotic Pasture Species						16.1	12.8	24.3	15.8	20.5	0	8.6
VI1	Native Pasture Species						0	0	0.2	0.2	0	17	0
VI1	Shrubs						0	0.3	0	0	0	0	0
VI1	Forbs						2.2	0	3.4	4.1	2.3	3	13
VI1	Invasive Weed Species						0	0	0	0	0	0	0
VI1	Bare Ground						4.3	8.5	14.9	58	67.6	77	75.5
VI1	Organic Litter						4	5.2	2.3	6.2	3.5	1	2.4
VI1	Rock						73.4	73.1	54.9	8.6	5.2	0	0.5
VI2	Non-Pasture Species						0	0	0	0	0.5	1	0
VI2	Exotic Pasture Species						9.3	8.7	16.4	14.4	18.5	0	25.6
VI2	Native Pasture Species						0.2	0	0.1	1.3	0	29	0
VI2	Shrubs						0	0	0	0	0	0	0

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
VI2	Forbs						2.3	1.2	2.9	0.3	0.2	1	3.6
VI2	Invasive Weed Species						0	0	0	0	0	0	0
VI2	Bare Ground						1.3	3.6	2.1	16.4	62.3	66	69.6
VI2	Organic Litter						2	4	1.4	5.4	0.6	0	0.7
VI2	Rock						84.9	82.5	79.9	61.8	17.9	1	0.5
A1	Non-Pasture Species	0	0	0	0	0	0	0	0	0	0	0	0
A1	Exotic Pasture Species	10.1	29.9	20.2	15.6	22.8	18.1	5.6	20	32.8	16.8	65	73
A1	Native Pasture Species	0	0	0	0	0	0	0	7	0	0	0	0
A1	Shrubs	0	1.5	4	0	2.5	2.7	1.5	0.2	0	0.5	0	0
A1	Forbs	4.3	6.2	1.4	0.8	4.7	9.1	17.6	8.6	8.6	6	7	3.5
A1	Invasive Weed Species	0	0	0	0	0	0	0	0	0	0	0	0
A1	Bare Ground	17.6	22.1	22.8	22.5	29.5	23	42.8	45.9	28.8	26.1	12	23.5
A1	Organic Litter	66.7	40.3	51.6	58.7	40.5	47.1	28.2	7.4	28.5	50.6	15	0
A1	Rock	0.3	0	0	0.1	0	0	4.3	4.6	0.6	0	0	0
A2	Non-Pasture Species	0	0	0	0	0	0	0	0	0	0	0	0
A2	Exotic Pasture Species	13.9	21.6	19	12.8	17.3	29.9	15.9	14.3	35.5	20.7	64	81

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
A2	Native Pasture Species	0	0	0	0	0	0	0	0	0	0	0	0
A2	Shrubs	0.5	0	0	0	0.5	0.1	0	0	0	0	0	0
A2	Forbs	1	3.1	3.3	1.1	3.1	4.3	3.3	4.5	6.8	4.4	3	0
A2	Invasive Weed Species	0	0	0	0	0.2	0	0	0.5	0.1	0	0	8
A2	Bare Ground	14.2	21.2	19.6	21.2	18.7	14.5	22.7	55.1	41.7	37.9	32	9.5
A2	Organic Litter	71	48.5	56.1	61	55.7	50.8	49	23.6	18.8	40.9	4	1.5
A2	Rock	0	0	0	0	0	0	0	0	0.7	0	0	0
B1	Non-Pasture Species	0.5	0.5	0	0	0	0	0	0	0	0.5	0	0
B1	Exotic Pasture Species	15.5	26.4	24.8	21	18.3	18.4	9.5	13.2	13.3	7.4	14	39
B1	Native Pasture Species	0	0.7	0	0	0	0.3	0	0.1	0.5	0.9	0	0
B1	Shrubs	3	2.5	1.5	1.5	0.2	0	0	0	0	0	0	0
B1	Forbs	0.6	1.9	1.5	0.8	2	2.9	1.9	1.3	3.7	3.3	1	5.7
B1	Invasive Weed Species	0	0	0.2	0	0	0	0	0	0	0	0	0
B1	Bare Ground	34	44.9	41.3	45.3	51	26.2	69.9	57.9	32.9	70.2	79	45.8
B1	Organic Litter	36.5	14.9	19.2	20.5	14.5	8.7	11.2	2.1	11.8	15	6	9.5
B1	Rock	9.9	8.7	11.5	10.9	14	39.9	7.2	17.4	37.8	4.2	0	0

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
B2	Non-Pasture Species	0	0	0	0	0	0	0	0	0	0.6	0	0
B2	Exotic Pasture Species	17.1	23.3	15.7	13.5	12.9	7.7	0.6	3.4	4.4	2.5	24	39.6
B2	Native Pasture Species	0.9	0	0.2	0.5	0	0.6	0	0.9	0.4	0	0	7
B2	Shrubs	0.5	0	0	0	0.5	0.1	0	0	0	0	0	0
B2	Forbs	1	3.1	3.3	1.1	3.1	4.3	3.3	4.5	6.8	4.4	3	17.8
B2	Invasive Weed Species	0	0	0	0	0	0	0	0	0	0	0	0
B2	Bare Ground	24.5	31.2	36.9	39.8	49.5	39.8	58.1	67.7	47.9	69.3	68	33.6
B2	Organic Litter	29.3	15.2	24.2	27.1	10.9	4.4	8.8	2.3	8.2	15.7	6	2
B2	Rock	26.7	27.2	19.7	18	23.1	43.1	27.9	21.2	32.3	7.5	0	0
B3	Non-Pasture Species	0	0	0	0	0	0	0	0	0	0	0	0
B3	Exotic Pasture Species	20.8	45.9	24.2	26	19.7	31.3	30.3	28.9	25.4	21.7	30	60.9
B3	Native Pasture Species	0	0	0	0	0.5	0	0	1.3	0	0	0	0
B3	Shrubs	0	0	0	0	0	0	0.3	0	0	0	0	0
B3	Forbs	1	6.5	2.5	1.2	2.5	5.3	0.6	1.7	2.1	1.9	3	10.1
B3	Invasive Weed Species	0	0	0	0	0	0	0	0	0	0	0	0
B3	Bare Ground	12.8	16.5	23.8	14.9	24.4	4.2	2.6	5	60.6	56	58	29

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
B3	Organic Litter	51.3	15	25.8	36	14.5	5.2	5.8	0.7	5.1	4.5	0	0
B3	Rock	14.1	16.1	23.7	21.9	38.4	54	60.4	62.4	60.6	15.9	10	0
B4	Non-Pasture Species	0.6	0	0	0	0	0	0	0	0	0	0	0
B4	Exotic Pasture Species	21.9	31.1	25.4	20	16.5	15.1	14.5	19.2	18.3	12.9	20	44.8
B4	Native Pasture Species	0	0	0	0	0	0	0	0.2	0.2	0	0	0
B4	Shrubs	0	0	0	0	0	0	0	0	0	0	0	0
B4	Forbs	0.5	2.3	1.1	0.4	0.6	5.1	0.4	0.4	4.3	3	8	14.2
B4	Invasive Weed Species	0	0	0	0	0	0	0	0	0	0	0	0
B4	Bare Ground	6.5	11.5	13.1	10.2	24.5	3.1	1	6.4	2.5	53.7	70	41
B4	Organic Litter	49.6	20.8	27.3	36.6	19.1	4.2	3.3	1.2	4.7	2.4	1	0
B4	Rock	20.9	34.3	33.1	32.8	39.3	72.5	80.8	72.6	70	28	0	0
B5	Non-Pasture Species	0	0	0	0	0	0	0	0	0	0	0	0
B5	Exotic Pasture Species	13.5	17.7	15.1	8.6	15.5	20.2	17	16.3	18	7	30	45
B5	Native Pasture Species	0.7	0	0	0.1	1	0.8	0	3.3	0.2	1	3	2
B5	Shrubs	1.5	0	0	0	0	0	0	0	0	0	0	0
B5	Forbs	2.1	6.8	7.9	4.2	12.5	15.3	10.4	4.4	13.1	6.5	1	4

Site	Type	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
B5	Invasive Weed Species	0	0	0	0	0	0	0	0	0	0	0	0
B5	Bare Ground	37.5	37.2	41.2	50.3	52.5	29.6	46.8	57.1	59.1	70.1	55	25
B5	Organic Litter	35.1	14.7	19.1	24.4	9.5	6.6	13.5	11.1	3.6	13.4	1	0
B5	Rock	9.6	23.6	16.7	12.4	9	27.5	12.3	7.1	6	2	0	0
B6	Non-Pasture Species	0	0	0	0	0	0	0	0	0	0	0	0
B6	Exotic Pasture Species	33.4	48.9	46.7	43.7	46.4	49.2	33.7	66.3	46.7	23.3	68.7	89.5
B6	Native Pasture Species	0	0	0.2	0	0	1	0	0	1.3	2.3	0	0
B6	Shrubs	0.2	0	0	0	0	0	0	0	0	1.5	0	0
B6	Forbs	0.3	2.9	4.1	3.3	2.7	6	3.4	2.8	9.1	9	11.4	6
B6	Invasive Weed Species	0	0	0	0	0	0	0	0	0	0	0	0
B6	Bare Ground	19.3	33	21.9	27.8	37.9	26.2	47.9	26.4	25.1	55.5	20	4.5
B6	Organic Litter	40.3	8.9	15.6	16.8	8	8.6	8.3	2.2	9.2	4.5	0	0
B6	Rock	6.6	6.3	11.5	8.4	5	11	6.7	3.1	8.6	3.9	0	0

Appendix B. Species richness database

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
R1	nonpg	0	0	0	0	0	0	0	0	0	0	0	0
R1	epg	1	2	1	1	1	3	1	1	1	3	1	2
R1	natpg	0	0	0	0	1	3	0	3	2	0	2	2
R1	forbs	3	1	1	0	6	9	6	5	5	1	6	6
R1	stems	2	4	4	4	3	1	2	3	2	1	0	2
R1	weeds	0	1	0	0	0	1	1	0	1	1	0	0
R1	total	6	7	6	5	11	16	9	12	10	5	9	12
R2	nonpg	0	0	0	0	0	0	0	0	1	1	1	1
R2	epg	1	3	2	2	1	3	2	2	2	2	3	3
R2	natpg	2	0	1	1	2	3	3	4	3	3	3	3
R2	forbs	9	12	9	8	7	12	10	6	9	9	4	4
R2	stems	4	4	3	3	5	3	3	2	3	3	0	3
R2	weeds	0	0	0	0	0	0	0	1	1	1	1	1
R2	total	16	19	15	14	15	21	18	14	18	18	11	14
R3	nonpg	1	1	1	0	0	0	0	0	0	0	0	0
R3	epg	1	3	2	3	1	3	2	5	3	3	3	3

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
R3	natpg	1	1	0	0	0	1	0	3	1	3	1	0
R3	forbs	12	17	10	7	12	18	8	4	5	5	5	4
R3	stems	5	8	6	8	7	9	9	6	4	3	0	4
R3	weeds	1	1	1	0	1	1	0	1	1	1	1	1
R3	total	20	30	19	18	20	31	19	18	13	14	9	11
SP1	nonpg						2	1	2	2	2	2	2
SP1	epg						2	2	2	2	2	2	2
SP1	natpg						1	0	2	4	3	0	0
SP1	forbs						10	12	8	7	6	12	13
SP1	stems						1	1	1	2	2	2	2
SP1	weeds						0	0	0	0	0	0	0
SP1	total						16	16	15	17	15	18	19
SP2	nonpg						2	2	1	1	1	0	1
SP2	epg						2	3	4	4	4	3	3
SP2	natpg						0	0	0	0	0	1	1
SP2	forbs						11	11	13	11	12	11	10

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
SP2	stems						0	1	1	0	1	0	2
SP2	weeds						1	1	1	1	0	0	0
SP2	total						15	17	19	16	18	15	17
SP3	nonpg						2	2	2	1	1	0	0
SP3	epg						3	2	2	2	2	3	3
SP3	natpg						2	2	2	3	3	1	1
SP3	forbs						23	19	16	17	13	13	13
SP3	stems						2	1	2	1	1	1	1
SP3	weeds						1	1	1	1	0	0	0
SP3	total						32	26	24	24	20	18	18
ROM1	nonpg						1	0	0	3	2	0	0
ROM1	epg						4	4	4	4	4	4	4
ROM1	natpg						1	0	1	1	1	1	1
ROM1	forbs						11	13	14	17	10	10	10
ROM1	stems						2	3	2	2	2	3	2
ROM1	weeds						1	0	0	1	0	0	0

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
ROM1	total						19	20	21	27	19	18	17
ROM2	nonpg						2	2	2	2	2	0	1
ROM2	epg						4	4	4	6	5	5	5
ROM2	natpg						2	3	3	4	3	2	2
ROM2	forbs						15	24	22	24	16	14	13
ROM2	stems						5	6	8	9	7	6	6
ROM2	weeds						1	1	1	2	2	2	2
ROM2	total						28	39	39	45	33	27	27
ROM3	nonpg							2	2	2	2	1	1
ROM3	epg							3	3	3	3	4	4
ROM3	natpg							2	3	3	3	2	2
ROM3	forbs							17	17	19	17	18	16
ROM3	stems							7	5	5	5	3	5
ROM3	weeds							1	0	1	1	2	2
ROM3	total							31	30	32	30	28	28
RI1	nonpg						1	0	1	1	1	0	1

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
RI1	epg						4	2	5	4	4	5	5
RI1	natpg						4	3	4	3	3	1	1
RI1	forbs						14	12	5	7	7	8	9
RI1	stems						2	4	4	6	6	4	5
RI1	weeds						1	1	0	0	0	1	1
RI1	total						25	21	19	21	21	18	21
RI2	nonpg						1	1	1	4	2	1	1
RI2	epg						2	4	2	3	3	2	3
RI2	natpg						2	0	3	1	1	1	1
RI2	forbs						13	11	13	10	8	8	8
RI2	stems						8	9	9	6	7	4	9
RI2	weeds						2	0	0	2	1	1	1
RI2	total						26	25	28	24	21	16	22
VI1	nonpg						0	0	0	0	0	0	0
VI1	epg						3	2	1	1	1	2	2
VI1	natpg						2	0	1	1	1	0	0

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
VI1	forbs						17	8	12	10	9	5	7
VI1	stems						0	2	0	0	0	0	0
VI1	weeds						0	0	0	0	0	0	0
VI1	total						22	12	14	12	11	7	9
VI2	nonpg						1	2	3	1	1	1	1
VI2	epg						3	2	2	1	2	2	2
VI2	natpg						3	1	1	2	3	0	0
VI2	forbs						21	14	17	9	9	5	5
VI2	stems						2	4	1	1	2	1	1
VI2	weeds						0	0	0	0	0	0	0
VI2	total						30	23	24	14	17	9	9
A1	nonpg	0	0	0	0	0	0	0	0	0	0	0	0
A1	epg	3	4	3	3	3	4	2	3	3	3	5	5
A1	natpg	0	1	0	0	4	1	0	3	4	4	4	2
A1	forbs	6	11	7	6	8	14	7	15	17	17	9	8
A1	stems	4	5	3	3	4	4	4	3	2	2	2	2

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
A1	weeds	0	1	0	0	1	2	1	1	1	1	1	1
A1	total	13	21	13	12	19	23	13	24	26	26	20	17
A2	nonpg	0	0	0	0	0	0	0	1	0	0	0	1
A2	epg	3	5	3	3	2	4	2	3	3	3	5	4
A2	natpg	0	0	0	0	0	0	0	1	1	1	1	0
A2	forbs	4	12	14	11	10	14	14	11	9	6	2	5
A2	stems	2	4	4	3	3	2	1	4	3	3	4	4
A2	weeds	0	1	1	0	1	1	0	1	1	1	1	1
A2	total	9	21	21	17	15	20	17	20	16	13	12	14
B1	nonpg	1	1	0	0	0	0	0	0	0	2	0	0
B1	epg	4	6	4	5	4	5	5	5	4	5	5	5
B1	natpg	0	2	2	3	2	5	1	3	2	3	0	2
B1	forbs	7	16	12	12	9	17	17	11	9	11	9	11
B1	stems	2	2	2	2	2	1	1	1	1	1	2	1
B1	weeds	0	1	1	0	0	0	0	0	0	0	0	0
B1	total	14	27	20	22	17	28	24	20	16	22	16	19

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
B2	nonpg	0	0	0	0	0	1	0	0	0	1	0	0
B2	epg	6	7	4	6	2	6	5	4	5	5	8	8
B2	natpg	4	3	2	2	0	3	2	4	1	1	0	1
B2	forbs	7	15	10	11	10	16	13	12	11	11	10	14
B2	stems	3	4	3	3	6	4	4	2	3	3	1	2
B2	weeds	0	0	0	0	0	0	0	0	0	0	0	0
B2	total	20	29	19	22	18	30	24	22	20	21	19	25
B3	nonpg	0	0	0	0	0	0	0	0	0	0	0	0
B3	epg	3	3	2	2	3	4	2	2	3	3	2	2
B3	natpg	0	0	0	0	1	0	0	1	0	0	0	0
B3	forbs	7	15	13	9	9	21	18	12	11	7	12	12
B3	stems	2	4	3	5	4	3	3	2	2	2	1	2
B3	weeds	0	0	0	0	0	1	1	1	1	0	0	0
B3	total	12	22	18	16	17	28	23	17	16	12	15	16
B4	nonpg	1	0	0	0	0	0	0	1	0	0	0	0
B4	epg	3	2	2	2	1	2	3	4	4	4	4	4

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
B4	natpg	0	0	0	0	0	0	0	1	2	0	0	0
B4	forbs	7	13	8	8	9	12	14	11	12	10	13	12
B4	stems	1	1	0	2	1	0	2	2	1	1	0	0
B4	weeds	0	0	0	0	0	1	1	1	1	0	0	0
B4	total	12	16	10	12	11	14	19	19	19	15	17	16
B5	nonpg	0	0	0	0	0	0	0	1	0	0	0	0
B5	epg	4	4	4	4	3	3	5	5	4	4	3	3
B5	natpg	1	1	1	1	3	4	1	3	2	2	4	3
B5	forbs	7	10	10	8	10	14	15	12	10	10	6	10
B5	stems	2	0	0	1	0	0	0	0	0	0	0	0
B5	weeds	0	0	0	0	1	1	0	0	0	0	0	0
B5	total	14	15	15	14	16	21	21	21	16	16	13	16
B6	nonpg	0	0	0	0	0	0	0	0	0	0	0	0
B6	epg	4	4	3	2	4	5	4	4	5	6	9	9
B6	natpg	1	2	1	0	1	2	4	3	2	2	0	0
B6	forbs	9	13	14	12	14	20	15	16	14	11	14	14

Site	Class	Oct-14	Mar-15	Jun-15	Aug-15	May-16	Jul-17	May-18	Feb-19	Aug-20	Mar-21	Jun-22	Apr-23
B6	stems	2	2	1	0	0	1	0	1	1	1	0	1
B6	weeds	0	0	0	0	0	1	0	0	0	0	0	0
B6	total	16	21	19	14	19	28	23	24	22	20	23	24

Appendix C. 2023 Rehabilitation monitoring database

Site name: R1				Site context: Pasture		Aspect: S		Stratum heights (m):		T1	T2	T3	S1	S2	G
Location: Southern part of lease, near entrance				Slope: 0		Erosion: none present, heavily grazed, alot of bare ground									0.3
Start: 501535 / 7644550				End: 501554 / 7644502		Altitude: 203		Soil description: Red clay/loam with minor small gravel							
DRY		Date:		Photo Start:		End:		Canopy cover (m):					0	0%	
Erosion		# of rills (<15, 15-30, >30) and depth): Nill													
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	0	Mean
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
			Bare ground	40	80	20	75	40	45	60	35	85	95		57.5
			Litter		5					10			5		2.0
			Rock												0.0
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	60	15	80	24	60	55	30	65	15			40.4
	Native Pasture	Sporobolis australis	Australian Dropseed												0.0
	Native Pasture	Dactyloctenium radulans	Button Grass												0.0
	Exotic Pasture	Urochloa mosambicensis	sabi				1								0.1
	Shrub	Capparis mitchellii	Buumb Tree												0.0
	Shrub	Salsola australis	roly poly												0.0
	Forb	Achyranthes aspera	chaff												0.0
	Forb	Chenopodium album	White goosefoot												0.0
	Forb	Enchylaena tomentosa	Ruby Saltbush												0.0
	Forb	Sclerolaena anisacanthoides	Yellow Copperburr												0.0
	Forb	Portulaca oleracea	Pigweed												0.0
	Forb	Trianthema triquetra	Red Spinach												0.0
Total Stems		Species diversity: 12		60	15	80	25	60	55	30	65	15	0	40.5	
0	Stem density: 0		Mean groundcover (%): 40.5				Notes:								

Site name: R2				Site context: Pasture			Aspect: W		Stratum heights (m):		T1	T2	T3	S1	S2	G
Location: Central-southern area of lease				Slope: 0			Erosion: None present									
Start: 500604 / 7644744				End: 500558 / 7644748			Altitude: 203		Soil description: Brown clay/loam with very small surface gravel							
DRY		Date:		Photo Start: 20210316_		End 20210316_140125		Canopy cover (m):		0		0%				
Erosion		# of rills (<15, 15-30, >30) and depth): Null														
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	0	Mean	
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
			Bare ground	50	95	75	65	20	70	65	80	60	44	62.4		
			Litter											0.0		
			Rock											0.0		
	Weed	Parthenium hysterophorus	Parthenium											0.0		
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	50			25	65	25	5			2	17.2		
	Native Pasture	Dactyloctenium radulans	Button Grass											0.0		
	Native Grass	Bothriochloa pertusa	Indian Bluegrass											0.0		
	Native Pasture	Sporobolis australis	Australian Dropseed											0.0		
	Native Pasture	Chloris divaricata	Slender Chloris											0.0		
	Exotic Pasture	Chloris inflata	Purpletop Chloris											0.0		
	Exotic Pasture	Urochloa mosambicensis	Sabi Grass				5	5	2					1.2		
	Forb	Portulaca oleracea	Pigweed											0.0		
	Forb	Salsola australis	Soft Roly-poly		5	15	5				10	30	50	11.5		
	Forb	Sclerolaena bicornis	Goathead burr			10		10	3	30	10	10	4	7.7		
	Forb	Enchylaena tomentosa	Ruby Saltbush											0.0		
	Shrub	Brunoniella australis	Bumble Tree											0.0		
	Tree	Acacia salicina	sally wattle											0.0		
	Shrub	Carrissa spinarum	Currant Bush											0.0		
Total Stems		Species diversity:		15	50	5	25	35	80	30	35	20	40	56	37.6	
0		Stem density:		0	Mean groundcover (%):			37.6	Notes:							

Site name: R3				Site context: Pasture/regrowth h open woodland		Aspect: W		Stratum heights (m):		T1	T2	T3	S1	S2	G
Location: Central portion of lease, south of road				Slope: 5		Erosion: None present		Altitude: 200		0	0	0	1	0	0
Start: 499024 / 7645607				End: 498976 / 7645623		Soil description: Red clay loam, small areas of minor gravel									
DRY				Date: 01.05.2023	Photo Start:		End:		Canopy cover (m):				0	0%	
Erosion				# of rills (<15, 15-30, >30) and depth): Nil											
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean	
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
			Bare ground	30											3.0
			Litter									10		5	1.5
			Rock												0.0
x	Weed	Parthenium hysterophorus	Parthenium				1								0.1
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass										90	95	9.0
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	70		90						80	10		25.0
x	Exotic Pasture	Urochloa mosambicensis	Sabi Grass		100	4	99	100	100	100					50.3
x	Forb	Chamaecrista rotundifolia	Round-leaf cassia												0.0
x	Shrub	Grewia latifolia	Dog's Balls												0.0
x	Forb	Sida hackettiana	Spiked Sida			1									0.1
x	Forb	Stylosanthes viscosa	Sticky stylo												0.0
x	forb	Stylosanthes scabra	Shrubby Stylo			5						10			1.5
x	Shrub	Carissa spinarum	Currant Bush												0.0
x	Tree	Acacia salicina	Sally Wattle												0.0
x	Tree	Ficus opposita	Sandpaper Fig												0.0
Total Stems		Species diversity	13	70	100	100	100	100	100	100	90	100	95	95.5	
0		Stem density:	0	Mean groundcover (%): 95.5				Notes:							

Site name:		A1		Site context: Rehab on tailings, direct seeding		Aspect: E		Stratum heights (m):		T1	T2	T3	S1	S2	G
Location:		South-west portion Cell A		Slope: 0		Erosion: None present		8		3		1		0.3	
Start:		499743 / 7646928		End: 499795 / 7646925		Altitude: 208		Soil description: Tailings (oxidised). Yellow sand with a patchy thin humic layer							
DRY		Date:	01.05.2023	Photo Start:		End:		Canopy cover (m):		1.6		3%			
Erosion		# of rills (<15, 15-30, >30) and depth): Null													
No. Stems	Classification	Scientific name	Common Name	0 Q1	0 Q2	0 Q3	0 Q4	0 Q5	0 Q6	0 Q7	0 Q8	0 Q9	0 Q10	Mean	
			Bare ground			5		25	75	25	50	5	50	23.5	
			Litter											0.0	
			Rock											0.0	
x	Weed	Vachellia farnesiana	Mimosa Bush											0.0	
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass							25		5		3.0	
	Native Pasture	Aristida calycina	Dark Wiregrass											0.0	
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	90	100	95	40		25	50	50	90	30	57.0	
x	Exotic Pasture	Chloris inflata	Purpletop Chloris					70						7.0	
x	Exotic Pasture	Cynodon dactylon	Green Couch				60							6.0	
	Forb	Pterocaulon sphacelatum	Fruit-salad Plant											0.0	
x	Exotic Pasture	Urochloa mosambicensis												0.0	
x	Native Pasture	Sporobolus australasicus	Australian Dropseed											0.0	
	Forb	Achyranthes aspera	Chaff Flower	1										0.1	
	Forb	Enchylaena tomentosa	Ruby Saltbush											0.0	
x	Forb	Salsola australis	Soft Roly-poly					5					20	2.5	
x	Forb	Sclerolaena bicornis	Goathead burr											0.0	
x	Forb	Sclerolaena tricuspis	Giant Redburr											0.0	
	Forb	Sida hackettiana	Spiked Sida	9										0.9	
	Forb	Trianthema triquetra	Red Spinach											0.0	
	Shrub	Grewia latifolia	Dog's Balls											0.0	
3	Tree	Acacia salicina	Sally Wattle											0.0	
Total Stems		Species diversity (inc weeds): 17		100	100	95	100	75	25	75	50	95	50	76.5	
3		Stem density: 60		Mean groundcover (%): 76.5				Notes:							

Site name:		A2	Site context:	Rehab on oxide tailings - direct seeding	Aspect:	SE	Stratum heights (m):	T1	T2	T3	S1	S2	G	
Location:		North-western part of Cell A	Slope:	0	Erosion:	present in the form of melon holes forming, some cracks present								
Start:		499637 / 7647361	End:	499683 / 76	Altitude:	200	Soil description:	Tailings. Yellow sand with a few shallow patches of humic material						
DRY		Date:	15.4.23	Photo Start:	End:	Canopy cover (m):	2.5	5%						
Erosion		(# of rills (<15, 15-30, >30) and depth): Up to 1m wide and 20cm deep max. Shows signs of inundation												
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	Mean	
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9		Q10
			Bare ground		30		20	10	20	5	5	5	0.0	
			Litter							5	5	5	0.0	
			Rock										0.0	
	Weed	Parthenium hysterophorus	Parthenium				80						0.0	
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	100	70	100		90	75	90	90	90	100	0.0
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass											0.0
	Exotic Pasture	Chloris inflata	Purpletop Chloris						5					0.0
	Exotic Pasture	Cynodon dactylon	Green Couch											0.0
	Forb	Achyranthes aspera	chaff flower											0.0
	Sedge	Cyperus rigidellus	Flat sedge											0.0
	Forb	Phyllanthus virgatus	Creeping Pissweed											0.0
	Forb	Pterocaulon sphacelatum	Fruit-salad Plant											0.0
x	Forb	Salsola australis	Soft Roly-poly											0.0
x	Forb	Trianthema triquetra	Red Spinach											0.0
	Tree		corymbia??											0.0
20	Tree	Acacia salicina	Sally Wattle											0.0
4	Tree	Eucalyptus camaldulensis	River Red Gum											0.0
2	Tree	Atalaya hemiglauca	Whitewood											0.0
Total Stems		Species diversity:	15	100	70	100	80	90	80	90	90	90	100	89.0
26		Stem density:	520	Mean groundcover (%): 89		Notes:								

Site name: B1		Site context: Rehab trial on thin cover and topsoil		Aspect: Runs west		Stratum heights (m):		T1	T2	T3	S1	S2	G	
Location: Northern trial in cell B. Southern patch.		Slope: 0		Erosion: None present		9						0.5		
Start: 500589 / 7647566		End: 500541 / 7647565		Altitude: 199		Soil description: Yellowish clay/loam with gravel patches								
DRY		Date:	01.06.2022	Photo Start:		End:		Canopy cover (m):		1		2%		
Erosion		# of rills (<15, 15-30, >30) and depth): Nil												
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
			Bare ground	35	20	95	40	98	85		55		30	45.8
			Litter	45					5		45			9.5
			Rock											0.0
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass				15					15		3.0
	Exotic Pasture	Chloris inflata	Purpletop Chloris											0.0
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass									15		1.5
	Exotic Pasture	Melinis repens	Red Natal Grass	10	60		45		10	100		15		24.0
	Exotic Pasture	Urochloa mosambicensis	Sabi Grass	10								55	40	10.5
	Native Pasture	Eragrostis sororia	Woodland Lovegrass											0.0
	Native Pasture	Enteropogon acicularis	Curly windmill grass											0.0
	Forb	Cleome viscosa	Tickweed											0.0
	Forb	Enchylaena tomentosa	Ruby Saltbush											0.0
	Forb	Gomphrena celosioides	Gomphrena Weed											0.0
	Forb	Salsola australis	Soft Roly-poly										30	3.0
	Forb	Sida hackettiana	Spiked Sida											0.0
	Forb	Stylosanthes scabra	Shrubby Stylo											0.0
	Forb	Sclerolaena bicornis	Goathead burr		20	5								2.5
	Forb	Trianthema triquetra	Red Spinach					2						0.2
	Forb	Maireana microphylla	Small-leaved Cottonbush											0.0
1	Tree	Eucalyptus sideoxylon	Red ironbark											0.0
1	Tree	Eucalyptus coolabah	Coolibah											0.0
Total Stems		Species diversity	18	20	80	5	60	2	10	100	0	100	70	44.7
2		Stem density:	40					Mean groundcover (%): 44.7		Notes:				

Site name: B2				Site context: Rehab trial on thin cover and topsoil				Aspect: Runs west		Stratum heights (m):		T1	T2	T3	S1	S2	G
Location: Northern trial in cell B. Southern patch.				Slope: 0				Erosion: None present				5	3			0.5	
Start: 500592 / 7647541				End: 500540 / 7647544				Altitude: 199		Soil description: Yellow/brown clay/loam with gravel							
DRY		Date:		Photo Start: 69				End: 74		Canopy cover (m):				0		0%	
Erosion		# of rills (<15, 15-30, >30) and depth): Nill															
No. Stems	Classification	Scientific name	Common Name	0 Q1	0 Q2	0 Q3	0 Q4	0 Q5	0 Q6	0 Q7	0 Q8	0 Q9	0 Q10	Mean			
			Bare ground		74	40	70	99	18	10	15	10		33.6			
			Litter								10	10		2.0			
			Rock											0.0			
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass											0.0			
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	75	1	10	15		60	50	8		50	26.9			
	Exotic Pasture	Chloris inflata	Purpletop Chloris								7			0.7			
	Exotic Pasture	Melinis repens	Red Natal Grass						5					0.5			
	Exotic Pasture	Urochloa mosambicensis	Sabi Grass						15	40		10	50	11.5			
	Exotic Pasture	Eragrostis sororia	Woodland Lovegrass											0.0			
	Exotic Pasture	Chloris divaricata	Slender Chloris											0.0			
	Native Pasture	Enteropogon acicularis	Curly windmill									70		7.0			
	Exotic Pasture	Sporobolus caroli	fairly grass											0.0			
	Forb	Enchylaena tomentosa	Ruby Saltbush											0.0			
	Forb	Malvastrum americanum	Malvastrum											0.0			
	Forb	Salsola australis	Soft Roly-poly			20					60			8.0			
	Forb	Stylosanthes scabra	Shrubby Stylo											0.0			
	Forb	Sida rohlenae	Shrub Sida											0.0			
	Forb	Cleome viscosa	Tickweed											0.0			
	Forb	Trianthema triquetra	Red Spinach					1						0.1			
	Forb	Maireana microphylla	Small-leaved Cottonbush											0.0			
	Forb	Gossypium sturtianum	Sturt's Desert Rose											0.0			
	Forb	Enchylaena tomentosa	Ruby Saltbush				5							0.5			
	Forb	Sclerolaena anisacanthoides	Yellow Copperburr	25	25	30	10		2					9.2			
	Forb	Sesbania cannabia	Sesbania Pea											0.0			
	Forb	Cyperus rigidellus	Flat sedge											0.0			
	Forb	Carrissa spinarum	Currant Bush											0.0			
	Shrub	Unidentified spp	Sample Succ											0.0			
8	Tree	Acacia salicina	Sally Wattle											0.0			
Total Stems		Species diversity		25	100	26	60	30	1	82	90	75	80	100	64.4		
0		Stem density:		0:an groundcover (%): 64.4				Notes:									

Site name: B3		Site context: Rehab trial on thick cover and topsoil		Aspect: Runs west		Stratum heights (m):		T1	T2	T3	S1	S2	G	
Location: Northern trial in cell B. Northern patch.		Slope: 0		Erosion: None present				9				1	0.2	
Start: 500588 / 76476:		Co-ordinates: 500542 / 7647613		Altitude: 199		Soil description: Reddish gravel/sandy loam								
DRY		Date:	01.05.2023	Photo Start:	End:		Canopy cover (m):		0		0%			
Erosion	# of rills (<15, 15-30, >30) and depth): Nil													
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
			Bare ground	50	40	60	70	5		65				29.0
			Litter											0.0
			Rock											0.0
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass					20	75				50	14.5
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	10	60	40	25	75	24	15	95	70	50	46.4
x	Forb	Gossypium sturtianum	Sturt's Desert Rose											0.0
x	Forb	Sida hackettiana	Spiked Sida											0.0
x	Forb	Vigna lanceolata												0.0
x	Forb	Gomphrena celosioides	Gomphrena Weed											0.0
x	Forb	Sida cordifolia	Flannel Weed											0.0
x	Forb	Glycine tabacina	Soybean											0.0
x	Forb	Sclerolaena anisacanthoides	Yellow Copperburr											0.0
x	Forb	Indigofera linnaei	Birdsville Indigo											0.0
x	Forb	Evolvulus alsinoides	Tropical Speedwell											0.0
x	Forb	Enchylaena tomentosa	Ruby Saltbush	40			5			20	5	30		10.0
x	Forb	Sida rohlenae	Shrub Sida						1					0.1
x	Forb	Stylosanthes scabra	Shrubby Stylo											0.0
x	Shrub	Unidentified spp.	Shrub sample											0.0
6	Tree	Acacia salicina	Sally Wattle											0.0
Total Stems		Species diversity	15	50	60	40	30	95	100	35	100	100	100	71.0
6		Stem density:	120	Mean groundcover (%): 71		Notes:								

Site name: B4		Site context: Rehab trial on thick cover and topsoil		Aspect: Runs west		Stratum heights (m):		T1	T2	T3	S1	S2	G	
Location: Northern trial in cell B. Northern patch.		Slope: 0		Erosion: None present		6								0.2
Start: 500588 / 7647592		End: 500540 / 7647599		Altitude: 174		Soil description: Very rocky yellow sandy loam								
DRY		Date:	15.4.23	Photo Start:		End:		Canopy cover (m):		0		0%		
Erosion		# of rills (<15, 15-30, >30) and depth): Nil												
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
			Bare ground	10	45		35	95	100	5	35	75	10	41.0
			Litter											0.0
			Rock											0.0
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass			10							10	2.0
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	68	30	90	55			90	15		80	42.8
x	Exotic Pasture	Chloris inflata	Purpletop Chloris											0.0
x	Exotic Pasture	Cynodon dactylon	Green Couch											0.0
x	Forb	Enchylaena tomentosa	Ruby Saltbush	10										1.0
x	Forb	Malvastrum americanum	Malvastrum											0.0
x	Forb	Phyllanthus maderaspatensis	-											0.0
x	Forb	Portulaca oleracea	Pigweed											0.0
x	Forb	Salsola australis	Soft Roly-poly		20					5	50	25		10.0
x	Forb	Sclerolaena bicornis	Goathead Burr		5		10	5						2.0
x	Forb	Sesbania cannabia	Sesbania Pea											0.0
x	Forb	Rhynchosia minima	Rhyncho											0.0
x	Forb	Gossypium sturtianum	Sturt's Desert Rose											0.0
x	Forb	Sida corrugata	Corrugated sida											0.0
x	Forb	Sida hackettiana	Spiked sida	2										0.2
x	Forb	Stylosanthes scabra	Shrubby Stylo	10										1.0
Total Stems		Species diversity	16	90	55	100	65	5	0	95	65	25	90	59.0
0		Stem density:	0	Mean groundcover (%): 59			Notes:							

Site Name: B5	Site context: Rehab trial on topsoil			Aspect: Runs east		tum heights (m):		T1	T2	T3	S1	S2	G	
Location: South-eastern trial	Slope: 0			Erosion: None present								0.5	0.4	
Start: 500650 / 7647056	End: 500690 / 7647019			Altitude: 202		Soil description: Sandy loam with patches of large rocks								
DRY		Date:	15.4.23	Photo Start:		End:		Canopy cover (m):			0			0%
Erosion		# of rills (<15, 15-30, >30) and depth): Nil												
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	1	0	0	0	Mean
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
			Bare ground	40	98			15	10	31	40		15	24.9
			Litter											0.0
			Rock											0.0
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass				45							4.5
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass			5	45	5	70				40	16.5
x	Exotic Pasture	Chloris inflata	Purpletop Chloris			60				50		90	40	24.0
x	Forb	Vigna lanceolata	Vigna lanceolata			30								3.0
x	Native Pasture	Sporobolus australasicus	Australian Dropseed						20					2.0
x	Native Pasture	Aristida calycina	Dark Wiregrass											0.0
	Native Pasture	Urochloa mosambicensis	Sabi Grass									10		0.0
	Forb	Cleome viscosa	Tickweed											0.0
	Forb	Sida hackettiana	Spiked Sida											0.0
	Forb	Portulaca oleracea	Pigweed							3	30		5	0.5
	Forb	Sclerolaena anisacanthoides	Yellow Copperburr	60	2		10	80		15	30			0.0
	Forb	Trianthema triquetra	Red Spinach											0.0
	Forb	Malvastrum americanum	Malvastrum											0.0
	Forb	Enchylaena tomentosa	Ruby Saltbush											0.0
	Forb	Salsola australis	Soft Roly-poly			5								0.5
	Forb	Stylosanthes scabra	Shrubby Stylo											0.0
Total Stems		Species diversity	16	60	2	100	100	85	90	68	60	100	85	75.0
0		Stem density:	0	Mean groundcover (%): 75		Notes:								

Site name: B6 Location: Northern edge of cell B				Site context: Rehab on topsoil over tails Slope: 0				Aspect: Runs north Erosion: clear sown rows, likely from soil ripping, has resulted in slight erosion				T1	T2	T3	S1 0.5	S2	G 0.2
Start: 500573 / 7647783				End: 500568 / 7647837				Altitude: 202		Soil description: Red brown sandy loam with patches of medium to large rocks							
DRY				Date:	01.05.2023	Photo Start: 45		End: 50		Canopy cover (m):			0		0%		
Erosion				(# of rills (<15, 15-30, >30) and depth): Minor <15													
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean			
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10				
			Bare ground			20	10			5	10				4.5		
			Litter												0.0		
			Rock												0.0		
x	Exotic Pasture	<i>Bothriochloa pertusa</i>	Indian Bluegrass	90	90	20		50	80	40	10	95	100		57.5		
x	Exotic Pasture	<i>Cenchrus ciliaris</i>	Buffel Grass			20	85	50	15						17.0		
x	Exotic Pasture	<i>Chloris inflata</i>	Purpletop Chloris												0.0		
	Exotic Pasture	<i>Melinis repens</i>	Red Natal Grass												0.0		
	Exotic Pasture	<i>Echinochloa colona</i>	Awnless Barnyard Grass								90				9.0		
x	Exotic Pasture	<i>Urochloa mosambicensis</i>	Sabi Grass							50					5.0		
x	Exotic Pasture	<i>Sporobolus australasicus</i>	Australian Dropseed												0.0		
x	Exotic Pasture	<i>Cynodon dactylon</i>	Green Couch			10									1.0		
	Exotic Pasture	<i>Eriochloa pseudoacrotricha</i>	Early spring grass												0.0		
x	Forb	<i>Trianthema triquetra</i>	Red Spinach												0.0		
12	Forb	<i>Sesbania cannabia</i>	Sesbania Pea												0.0		
x	Forb	<i>Cyperus rigidellus</i>	Flat sedge												0.0		
x	Forb	<i>Atriplex muelleri</i>	Annual Saltbush												0.0		
	Forb	<i>Phyllanthus virgatus</i>	Creeping Pissweed												0.0		
x	Forb	<i>Portulaca oleracea</i>	Pigweed												0.0		
	Forb	<i>Alternanthera denticulata</i>	Lesser Joyweed												0.0		
	Forb	<i>Achyranthes aspera</i>	Chaff Flower												0.0		
x	Forb	<i>Gomphrena celosioides</i>	Soft khaki weed												0.0		
x	Forb	<i>Salsola australis</i>	Soft Roly-poly			30									3.0		
x	Forb	<i>Sclerolaena tricuspis</i>	Giant Redburr				5								0.5		
x	Forb	<i>Sida corrugata</i>	Corrugated sida		10							5			1.5		
x	Forb	<i>Sida hackettiana</i>	Spiked sida												0.0		
x	Forb	<i>Stylosanthes scabra</i>	Shrubby Stylo	10											1.0		
1	Shrub	<i>Grewia latifolia</i>	Dog's Balls												0.0		
Total Stems		Species diversity 24		100	100	80	90	100	95	90	100	100	100		95.5		
13		Stem density: 260		Mean groundcover (%): 95.5				Notes:									

Site name: SP1			Site context: Back filled pit, rehab grassland			Aspect: W			Stratum heights (m):			T1	T2	T3	S1	S2	G
Location: Top of hill. North area of pit.			Slope: 1			Erosion: minor present on eastern slope										0.5	0.3
Start: 497367 / 7644773			End: 497316 / 7644776			Altitude: 88			Soil description: Large rocks. White, brown, orange.								
DRY			Date:	14.4.23	Photo Start: 1			End: 007			Canopy cover (m):			0	0%		
Erosion		# of rills (<15, 15-30, >30) and depth): Minor <15			one stake												
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean			
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10				
			Bare ground				15	25			20	9	20	8.9			
			Litter											0.0			
			Rock	10		2			4					1.6			
	Native Grass	Eriachne obtusa	Northern Wanderrie Grass						88	93	73			25.4			
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass	85	99	96	69	47				80	40	51.6			
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass										40	4.0			
	Native Grass	Heteropogon contortus	Black Spear grass				15					5		2.0			
	Forb	Urochloa mosambicensis	Sabi Grass					3						0.3			
	Forb	Evolvulus alsinoides	Tropical Speedwell									5		0.5			
	Forb	Rhynchosia minima	Rhyncho											0.0			
	Forb	Neptunia gracilis	Low Sensitive Plant		1						5			0.6			
	Forb	Vigna lanceolata	Vigna lanceolata				1		3	5		1		1.0			
	Forb	Trianthema triquetra	Red Spinach											0.0			
	Forb	Rostellularia adscendens												0.0			
	Forb	Sclerolaena anisacanthoides	Yellow Copperburr											0.0			
	Forb	Rhynchosia minima	Rhyncho											0.0			
	Forb	Salsola australis	Soft Roly-poly											0.0			
	Forb	Sida corrugata	Corrugated Sida											0.0			
	Forb	Sida hackettiana	Spiked Sida						5	2				0.7			
	Forb	Stylosanthes scabra	Shrubby Stylo	5		2		25			2			3.4			
1	Shrub	Erythroxylum australe	Cocaine Bush											0.0			
1	Shrub	Grewia latifolia	Dog's Balls											0.0			
Total Stems		Species diversity		18	90	100	98	85	75	8	7	7	91	80	64.1		
2	Stem density:		40	Mean groundcover (%): 64.1				Notes:									

Site name: SP2		Site context: Back filled pit, rehab grassland		Aspect: NW		Stratum heights (m):		T1	T2	T3	S1	S2	G	
Location: Centre of south pit		Slope: 5		Erosion: None present		0.6								
Start: 497379 / 7644712		End: 497335 / 7644738		Altitude: 88		Soil description: Large rocks. White, brown, orange.								
DRY		Date:	14.4.23	Photo Start:		End:		Canopy cover (m):			0	0%		
Erosion		# of rills (<15, 15-30, >30) and depth): Nil		no stakes										
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	Mean	
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9		Q10
			Bare ground		3		3			50	60	45	4	16.5
			Litter						3					0.3
			Rock		2		1		2				2	0.7
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass	97	88	87	82	93	91	48	40	40	92	75.8
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass											0.0
x	Exotic Pasture	Urochloa mosambicensis	Sabi Grass							1			1	0.2
x	Native Pasture	Aristida calycina	Dark Wiregrass											0.0
x	Forb	Vigna lanceolata		3		10	3							1.6
	Sedge	Cyperus rigidellus	Flat sedge											0.0
	Forb	Macroptilium lathyroides	bean plant					2	2					0.4
	Forb	Trianthema triquetra	Red Spinach											0.0
x	Forb	Sesbania cannabia	Sesbania Pea											0.0
	Forb	Gossypium sturtianum	Sturt's Desert Rose											0.0
x	Forb	Zornia muriculata			2									0.2
x	Forb	Neptunia gracilis	Low Sensitive Plant											0.0
	Forb	Evolvulus alsinoides	Tropical Speedwell											0.0
x	Forb	Rhynchosia minima	Rhyncho			3	3	5					1	1.2
x	Forb	Sida hackettiana	Spiked Sida						2	1		15		1.8
	Tree	Acacia holosericea	Silver wattle											0.0
x	Shrub	Stylosanthes scabra	Shrubby Stylo		5		8							1.3
Total Stems		Species diversity	15	100	95	100	96	100	95	50	40	55	94	82.5
0		Stem density:	0	Mean groundcover (%): 82.5		Notes:								

Site name: SP3		Site context: Back filled pit, rehab grassland		Aspect: W		Stratum heights (m):									
						T1	T2	T3	S1	S2	G				
Location: South portion of south pit		Slope: 0		Erosion: None present											
Start: 497373 / 7644677		End: 497322 / 7644670		Altitude: 85		Soil description: Large rocks. White, brown, orange.									
DRY		Date:	14.4.23	Photo Start:		End:		Canopy cover (m):				5.3	11%		
Erosion		# of rills (<15, 15-30, >30) and depth): Null													
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean	
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
			Bare ground		10	10	87		5			5		11.7	
			Litter				1	5	20	2	50	5		8.3	
			Rock		2	5	2							0.9	
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass	99	84	79		94	75	95	45			57.1	
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass		2								70	7.2	
	Exotic Pasture	Melinis repens	Red Natal Grass											0.0	
	Native Pasture	Aristida calycina	Dark Wiregrass				6				5			1.1	
	Forb	Neptunia gracilis	Low Sensitive Plant											0.0	
	Forb	Achyranthes aspera	Chaff Flower											0.0	
	Forb	Macroptilium lathyroides	bean plant				2							0.2	
	Forb	Jasminum didymum	Native Jasmine											0.0	
	Forb	Evolvulus alsinoides	Tropical Speedwell											0.0	
	Forb	Macroptilium atropurpureum	Siratro											0.0	
	Forb	Ipomoea plebeia	Bell Vine											0.0	
	Forb	Pterocaulon sphacelatum	Fruit-salad Plant											0.0	
	Forb	Unidentified spp.	sample									89		8.9	
	Forb	Rhynchosia minima	Rhyncho											0.0	
	Forb	Sida hackettiana	Spiked Sida			3	2							0.5	
	Forb	Stylosanthes scabra	Shrubby Stylo		2	2								0.4	
	Forb	Vigna lanceolata	-	1		1		1		3		1	30	3.7	
42	Shrub	Acacia holosericea	Soap Bush											0.0	
Total Stems		Species diversity	18	100	88	85	10	95	75	98	50	90	100	79.1	
42		Stem density:	840	Mean groundcover (%): 79.1				Notes:							

ROM1			Site context: rehab low slope			Aspect: SW		Stratum heights (m):		T1	T2	T3	S1	S2	G		
Location: Eastern ROM			Slope: 3			Erosion: minimal to none present		2					1		0.4		
Start: 497938 / 7645565			End: 497902 / 7645533			Altitude: 67		Soil description: rocky gravel orange grey brown									
DRY			Date: 01.05.2023			Photo Start: 32		End: 37		Canopy cover (m):			0			0%	
Erosion			# of rills (<15, 15-30, >30) and dept <15 minor														
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean			
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10				
			Bare ground	40		50	5	10	80	80	75	70	65	47.5			
			Litter											0.0			
			Rock				5	75				20	25	12.5			
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass			40	90	15	20	10	5	10		19.0			
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass							10				1.0			
	Exotic Pasture	Choris inflata	Purpletop Chloris			10								1.0			
	Native Pasture	Sporobolus australasicus	Australian Dropseed		98									9.8			
	Exotic Pasture	Urochloa mosambicensis	Sabi Grass								20		10	3.0			
	Forb	Abutilon oxycarpum	Desert Lantern											0.0			
	Forb	Vigna lanceolata	Vigna lanceolata											0.0			
	Forb	Rhynchosia minima	Rhyncho											0.0			
	Forb	Sclerolaena anisacanthoides	Yellow Copperburr											0.0			
	Forb	Achyranthes aspera	Chaff Flower											0.0			
	Forb	Sida cordifolia	Flannel Weed											0.0			
	Forb	Portulaca oleracea	Pigweed											0.0			
	Forb	Salsola australis	Soft Roly-poly	60										6.0			
	Forb	Stylosanthes scabra	Shrubby Stylo		2									0.2			
	Forb	Trianthema triquetra	Red Spinach											0.0			
	Shrub	Acacia holosericea	Soap Bush											0.0			
	Shrub	Carissa spinarum	Currant Bush											0.0			
	Tree	Acacia salicina	Sally Wattle											0.0			
Total Stems		Species diversity	17	60	100	50	90	15	20	20	25	10	10	40.0			
0		Stem density:	0	Mean groundcover (%): 40				Notes:									

Site name: ROM2			Site context: rehab slope			Aspect: SW			Stratum heights (m):			T1	T2	T3	S1	S2	G	
Location: ROM central west			Slope: 12			ion: Minor			4			2	0	1	0	0.5		
Start: 497795 / 7645464			End: 497751 / 7645443			Altitude: 65			Soil description: large rocks and gravel, orange red white brown									
DRY			Date:	01.05.2023			Photo Start:			End:			Canopy cover (m):			11	22%	
Erosion			# of rills (<15, 15-30, >30) and depth): Minor (<15 rills and <10m)															
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	0	Mean			
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10					
			Bare ground														0.0	
			Litter					70	70	20	95						25.5	
			Rock														0.0	
	Weed	Parthenium hysterophorus	Parthenium														0.0	
x	Weed	Vachellia farnesiana	Mimosa Bush		10												1.0	
	Native Pasture	Aristida calycina	Dark Wiregrass														0.0	
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass														0.0	
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass		75		98				2						17.5	
	Exotic Pasture	Cynodon dactylon	Green Couch														0.0	
x	Exotic Pasture	Melinis repens	Red Natal Grass							10	40		95	40			18.5	
x	Native Pasture	Sporobolus australasicus	Australian Dropseed	75		95											17.0	
	Exotic Pasture	Urochloa mosambicensis	Sabi Grass														0.0	
x	Forb	Achyranthes aspera	Chaff Flower														0.0	
	Forb	Cleome viscosa	Tickweed									2					0.2	
x	Forb	Macroptilium atropurpureum	Siratro	15	15	5	2	30	20	20							10.7	
x	Forb	Malvastrum americanum	Malvastrum														0.0	
	Forb	Rhynchosia minima	Rhyncho														0.0	
x	Forb	Sida hackettiana	Spiked Sida														0.0	
x	Forb	Sida rohlenae	Shrub Sida														0.0	
x	Forb	Stylosanthes scabra	Shrubby Stylo										5	60			6.5	
x	Tree	Bauhinia hookeri	White-flowered Bauhinia														0.0	
	Forb	Evolvulus alsinoides	Tropical Speedwell	10													1.0	
	Forb	Hibiscus sturtii	Sturt's Hibiscus														0.0	
	Forb	Ipomoea plebeia	Bell Vine														0.0	
x	Forb	Passiflora foetida	Stinking Passion Flower							20	1						2.1	
	Forb	Pterocaulon sphacelatum	Fruit-salad Plant														0.0	
	Sedge	Cyperus difformis	Dirty Dora														0.0	
6	Shrub	Acacia holosericea	Soap Bush														0.0	
2	Shrub	Ehretia membranifolia	Peach Bush														0.0	
1	Shrub	Myoporum acuminatum	Waterbush														0.0	
3	Tree	Acacia salicina	Sally Wattle														0.0	
2	Tree	Atalaya hemiglauca	Whitewood														0.0	
Total Stems		Species diversity	29	100	100	100	100	30	30	80	5	100	100				74.5	
14		Stem density:	280lean groundcover (%): 74.5												Notes:			

Site name: ROM3				Site context: Rehab Flat				Aspect: E		Stratum heights (m):		T1	T2	T3	S1	S2	G
Location: ROM Pad Central (East of Road)				Slope:				Erosion: None present				6			2	1	0.4
Start: 497800 / 7645437				End: 497848 / 7645444				Altitude: 73		Soil description: rocky gravel orange, grey brown							
DRY		Date:		01.05.2023		Photo Start:		End:		Canopy cover (m):		3.2		6%			
Erosion				# of rills (<15, 15-30, >30) and depth): Nil													
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	0	Mean		
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10				
			Bare ground			65	80	99								24.4	
			Litter						5	88	50	50	10			20.3	
			Rock													0.0	
	Weed	Parthenium hysterophorus	Parthenium													0.0	
	Weed	Harissia martinii	Harrisia Cactus													0.0	
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass				15						20			3.5	
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass	95	95	20	5		80				20	80		39.5	
	Exotic Pasture	Chloris inflata	Purpletop Chloris													0.0	
	Native Pasture	Sporobolus australasicus	Australian Dropseed	5	5											1.0	
	Exotic Pasture	Melinis repens	Red Natal Grass													0.0	
	Native Pasture	Aristida calycina	Dark Wiregrass													0.0	
	Native Grass	Eriachne obtusa	Northern Wanderrie Grass													0.0	
	Forb	Achyranthes aspera	Chaff Flower								2	5				0.7	
	Forb	Chenopodium album	Fat Hen													0.0	
	Forb	Cleome viscosa	Tickweed						5							0.5	
	Forb	Euphorbia drummondii	Caustic Weed													0.0	
	Forb	Malvastrum americanum	Malvastrum													0.0	
	Forb	Macroptilium atropurpureum	Siratro					1	10	5			10	10		3.6	
	Forb	Salsola australis	Soft Roly-poly			15										1.5	
	Forb	Sida hackettiana	Spiked Sida										20			2.0	
	Forb	Stylosanthes scabra	Shrubby Stylo										20			2.0	
	Forb	Trianthema triquetra	Red Spinach													0.0	
	Forb	Tridax procumbens	Tridax daisy													0.0	
	Forb	Passiflora foetida	Stinking Passion Flower								5					0.5	
	Forb	Physalis minima	Wild Gooseberry													0.0	
	Forb	Phyllanthus virgatus	Creeping Pissweed													0.0	
	Forb	Pterocaulon sphacelatum	Fruit-salad Plant													0.0	
	Forb	Glycine tabacina	purpleflo2ervine													0.0	
9	Shrub	Acacia holosericea	Soap Bush													0.0	
	Shrub	Capparis mitchellii	Bumble Tree													0.0	
	Shrub	Grewia rutisifolia	-													0.0	
1	Tree	Acacia salicina	Sally Wattle										5			0.5	
2	Tree	Atalaya hemiglauca	Whitewood													0.0	
Total Stems		Species diversity		30	100	100	35	20	1	95	12	50	50	90		55.3	
12		Stem density:		240	Mean groundcover (%): 55.3				Notes:								

Site name: R11			Site context: Rehab		Aspect: NE		Stratum heights (m):		T1	T2	T3	S1	S2	G	
Location: RI north			Slope: 0		Erosion: Minor				10	1.5	0	1	0	0.2	
Start: 498036 / 7645587			End: 498067 / 7645628		Altitude: 55		Soil description: Rocky gravel, orange white								
DRY			Date:	14.4.23	Photo Start:		End:		Canopy cover (m):			3.5	7%		
Erosion			(# of rills (<15, 15-30, >30) and depth): Minor (<15 rills and <10m)												
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	5	Mean	
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
			Inorganics										5	0.5	
			Bare ground	70	83	80	69	80	100	10	20	40		55.2	
			Litter	30	2	7	1					20	20	8.0	
			Rock											0.0	
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass							85	78	10	75	24.8	
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass			3						30		3.3	
	Exotic Pasture	Chloris inflata	Purpletop Chloris											0.0	
	Native Pasture	Sporobolus australasicus	Australian Dropseed				30	10						4.0	
	Exotic Pasture	Urochloa mosambicensis	Sabi Grass											0.0	
	Exotic Pasture	Sporobolus actinocladus	Katoora											0.0	
	Native Grass	Heteropogon contortus	Black Spear grass											0.0	
	Forb	Evolvulus alsinoides	Tropical Speedwell											0.0	
	Forb	Sclerolaena anisacanthoides	Yellow Copperburr											0.0	
6	Weed	Vachellia farnesiana	Mimosa Bush									1		0.1	
	Forb	Pterocaulon sphacelatum	Fruit-salad Plant											0.0	
	Forb	Phyllanthus virgatus	Creeping Pissweed											0.0	
	Forb	Sida cordifolia	Flannel Weed											0.0	
	Forb	Salsola australis	Soft Roly-poly		15	10		10		5				4.0	
	Forb	Sida hackettiana	Spiked Sida											0.0	
	Forb	Stylosanthes scabra	Shrubby Stylo								1			0.1	
	Forb	Trianthema triquetra	Red Spinach											0.0	
3	Shrub	Capparis mitchellii	Bumble Tree											0.0	
3	Tree	Acacia excelsa	Ironwood											0.0	
2	Tree	Atalaya hemiglauca	Whitewood											0.0	
6	Tree	Eucalyptus camaldulensis	River Red-gum											0.0	
1	Tree	Flindersia maculosa	Leopardwood											0.0	
Total Stems		Species diversity		22	0	15	13	30	20	0	90	80	40	75	36.3
12		Stem density:		240	Mean groundcover (%): 36.3			Notes:							

Site name: RI2		Site context: Rehab		Aspect: SW		Stratum heights (m):		T1	T2	T3	S1	S2	G	
Location: RI South		Slope: 2		Erosion: None present				12	0	0	2	0	0.4	
Start: 498141 / 7645484		End: 498100 / 7645460		Altitude:62		Soil description: Rocky gravel, red orange brown								
DRY		Date:	01.05.2023	Photo Start:		End:		Canopy cover (m):						0%
Erosion		# of rills (<15, 15-30, >30) and depth): Null												
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
			Bare ground	50	70	30	13	66	75	68		45		41.7
			Litter				2	2	5	15	15	15	10	6.4
			Rock											0.0
	Weed	Vachellia farnesiana	Mimosa Bush											0.0
	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass		30	62	85		20	10		40	80	32.7
	Exotic Pasture	Cenchrus ciliaris	Buffel Grass					30		2				3.2
	Native Pasture	Sporobolus australasicus	Australian Dropseed								85			8.5
	Native Grass	Heteropogon contortus	Black Spear grass											0.0
	Exotic Pasture	Urochloa mosambicensis	Sabi Grass										3	0.3
	Forb	Rhynchosia minima	Rhyncho											0.0
	Forb	Vigna lanceolata	Vigna lanceolata											0.0
	Shrub	Stylosanthes scabra	Shrubby Stylo			5				5			7	1.7
x	Forb	Salsola australis	Soft Roly-poly	50		3		2						5.5
	Forb	Sclerolaena bicornis	Flannel Burr											0.0
	Forb	Sida rohlenae	Shrub Sida											0.0
	Forb	Enchylaena tomentosa	Ruby Saltbush											0.0
	Forb	Evolvulus alsinoides	Tropical Speedwell											0.0
	Forb	Sesbania cannabia	Sesbania Pea											0.0
	Shrub	Grewia latifolia	Dog's Balls											0.0
x	Shrub	Carissa spinarum	Currant Bush											0.0
	Shrub	Erythoxylum australe	Cocaine Bush											0.0
1	Tree	Acacia holosericea	Silver wattle											0.0
3	Tree	Eucalyptus camaldulensis	River Red Gum											0.0
3	Tree	Acacia salicina	Sally Wattle											0.0
	Tree	Corymbia clarksoniana	Clarksons' Bloodwood											0.0
2	Tree	Atalaya hemiglauca	Whitewood											0.0
Total Stems		Species diversity	23	50	30	70	85	32	20	17	85	40	90	51.9
9		Stem density:	180	Mean groundcover (%): 51.9			Notes:							

Site name: V1				Site context: Rehabilitated infrastructure				Aspect: WNW		Stratum heights (m):		T1	T2	T3	S1	S2	G		
Location: North west sector of village, north if road				Slope: 0				: None present											
Start: 500913 / 7646442				End: 500872 / 7646470				Altitude: 93		Soil description: Rocky gravel, burnt red brown									
DRY				Date: 01.05.2023				Photo Start:		End:		Canopy cover (m):				0		0%	
Erosion				# of rills (<15, 15-30, >30) and depth): Null															
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	0	Mean				
				Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10						
			Bare ground	100	81	15	85	80	85	100	77	72	60	75.5					
			Litter		5	5	3	5			3	3		2.4					
			Inorganics											0.0					
			Rock						5					0.5					
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass		2		2		7		10	25	40	8.6					
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass											0.0					
	Forb	Salsola australis	Soft Roly-poly							10				1.0					
	Forb	Trianthema triquetra	Red Spinach											0.0					
x	Forb	Gomphrena celosioides	Gomphrena Weed											0.0					
x	Forb	Sclerolaena anisacanthoides	Yellow Copperburr											0.0					
x	Forb	Maireana microphylla	Small-leaved Cottonbush		10		10	15	3					3.8					
x	Forb	Sida hackettiana	Spiked sida		2									0.2					
x	Forb	Stylosanthes scabra	Shrubby Stylo			80								8.0					
Total Stems		Species diversity	9	0	14	80	12	15	10	0	20	25	40	21.6					
0		Stem density:	0	Mean groundcover (%): 21.6				Notes:	high present of metal and rubbish, requires clean up and removal										

Site name: V2		Site context: Rehabilitated infrastructure		Aspect: ESE		Stratum heights (m):								
Location: SW sector of village, south of road		Slope: 0		Erosion: None present		T1	T2	T3	S1	S2	G			
Start: 500883 / 7646405		End: 500927 / 7646384		Altitude: 105		Soil description: Rocky gravel, burnt red brown								
DRY		Date: 02.06.2022		Photo Start:		End:		Canopy cover (m):		0		0%		
Erosion		# of rills (<15, 15-30, >30) and depth		Nil		NO STAKES								
No. Stems	Classification	Scientific name	Common Name	0	0	0	0	0	0	0	0	0	0	Mean
			Bare ground	75	49	52	75	80	70	50	85	70	90	69.6
			Inorganics										5	0.5
			Litter	3		3				1				0.7
			Rock											0.0
x	Exotic Pasture	Cenchrus ciliaris	Buffel Grass			45	20	20	30	49	15		5	18.4
x	Exotic Pasture	Bothriochloa pertusa	Indian Bluegrass	22	50									7.2
x	Native Grass	Dactyloctenium radulans	Button Grass											0.0
x	Forb	Stylosanthes scabra	Shrubby Stylo		1									0.1
x	Forb	Phyllanthus maderaspatensis	-											0.0
x	Forb	Sida hackettiana	Spiked Sida											0.0
x	Forb	Portulaca oleracea	Pigweed											0.0
x	Forb	Salsola australis	Soft Roly-poly				5					30		3.5
2	Tree	Eucalyptus persistens	-											0.0
Total Stems		Species diversity	9	22	51	45	25	20	30	49	15	30	5	29.2
2		Stem density:	40	Mean groundcover (%): 29.2				Notes:						

Appendix D. Photo monitoring

Transect R1

Date **Start of Transect (0 m)**

501535 / 7644550

End of Transect (50 m)

501554 / 764502

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



April 2023



Aerial Photos from Drone Transect R1

501537 / 7644547



501543 / 7644527



501546 / 7644506



Transect R2

Date

Start of Transect (0 m)

End of Transect (50 m)

500604 / 7644744

500558 / 7644748

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect R2

500600 / 7644742



500585 / 7644744



500556 / 7644747



Transect R3

Date

Start of Transect (0 m)

End of Transect (50 m)

499024 / 7645607

498976 / 7645623

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Transect A1

Date

Start of Transect (0 m)

End of Transect (50 m)

499743 / 7646928

499795 / 7646925

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023

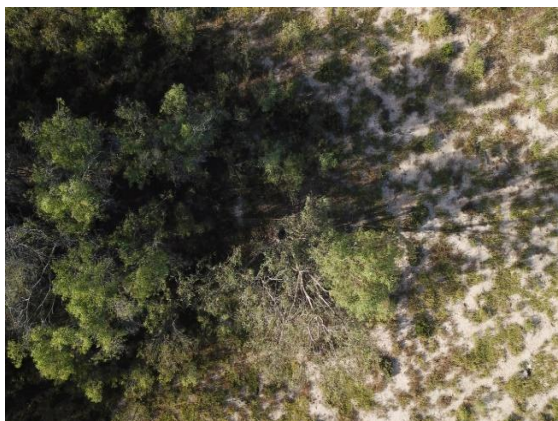


Aerial Photos from Drone Transect A1

4999745 / 7646931

499762 / 7646932

Feb 2019



499793 / 7646926



Transect A2

Date	Start of Transect (0 m)	End of Transect (50 m)
	499637 / 7647361	499683 / 7647343

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect A2

Feb 2019

499656 / 7647360

499676 / 7647351



499636 / 7647366



Transect B1

Date

Start of Transect (0 m)

End of Transect (50 m)

500589 / 7647566

500541 / 7647565

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect B1

Feb 2019

500589 / 7647565

500564 / 7647565



500549 / 7647568



Transect B2

Date

Start of Transect (0 m)

End of Transect (50 m)

500592 / 7647541

500540 / 7647544

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect B2

Feb 2019

500584 / 7647548 22

500569 / 7646544 20



Transect B3

Date

Start of Transect (0 m)

End of Transect (50 m)

500588 / 7647612

500542 / 7647613

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



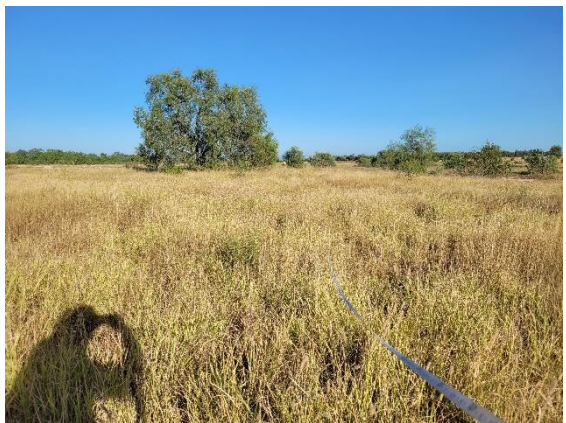
March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect B3

	500585 / 7647606	500561 / 7647617
Feb 2019		
	500537 / 7647614	
		

Transect B4

Date	Start of Transect (0 m)	End of Transect (50 m)
	500588 / 7647592	500540 / 7647599
Oct 2014		

Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect B4

Feb 2019

500589 / 7647596



500566 / 7647594



500545 / 7647599



Transect B5

Date

Start of Transect (0 m)

End of Transect (50 m)

500690 / 7647056

500690 / 7647019

Oct 2014



Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect B5

Feb 2019	500654 / 7647063	500669 / 7647046
		
	500692 / 7647019	
		

Transect B6

Date	Start of Transect (0 m)	End of Transect (50 m)
	500573 / 7647783	500568 / 7647837
Oct 2014		

Mar 2015



Jun 2015



Aug 2015



May 2016



Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect B6

Feb 2019

500570 / 7646809



500573 / 7647793



Transect SP1

Date

Start of Transect (0 m)

End of Transect (50 m)

497367 / 7644773

497316 / 7644776

Jul 2017



May 2018



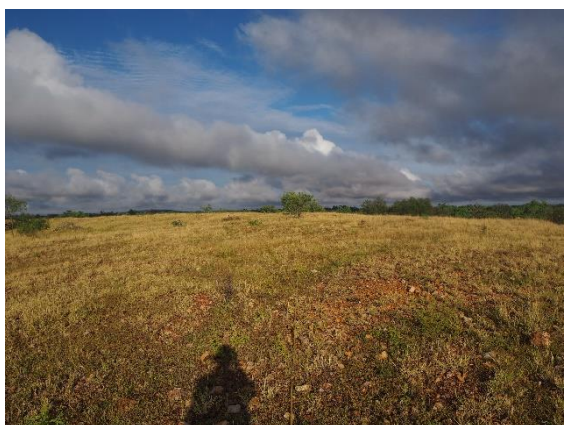
Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Transect SP2

Date

Start of Transect (0 m)
497379 / 7644712

End of Transect (50 m)
497335 / 7644738

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Aerial Photos from Drone Transect SP2

Feb 2019

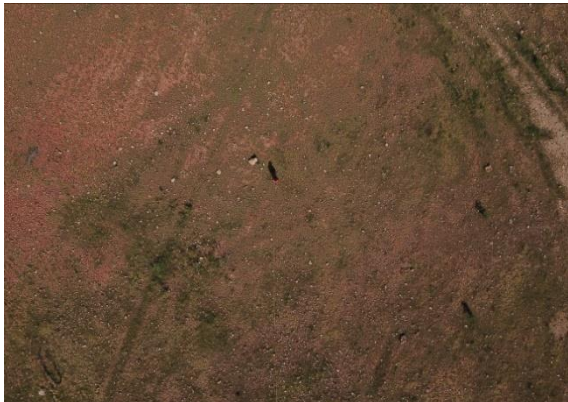
497375 / 7644711



4973566 / 7644723



497339 / 7644733



Transect SP3

Date

Start of Transect (0 m)

End of Transect (50 m)

497373 / 7644677

497322 / 7644670

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022

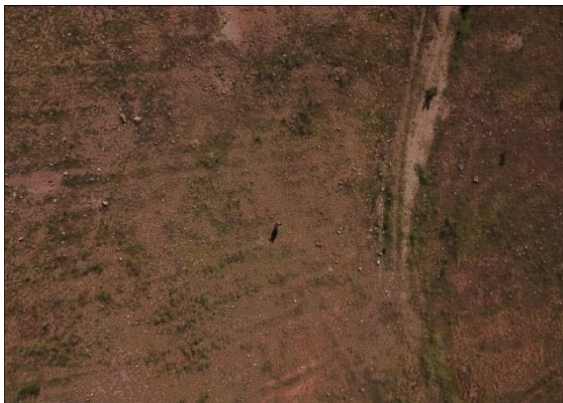


Apr 2023



Aerial Photos from Drone Transect SP3

Feb 2019



497318 / 7644675



ROM1

Date

Start of Transect (0 m)

End of Transect (50 m)

497938 / 7645565

497902 / 7645533

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Transect ROM2

Date

Start of Transect (0 m)

End of Transect (50 m)

497795 / 7645464

497751 / 7645443

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect ROM2

Date 497788 / 7645466

Feb 2019



497770 / 7645452



497760 / 7645442



Transect ROM3

Date **Start of Transect (0 m)**

497800 / 7645437

May 2018



End of Transect (50 m)

497848 / 7645444



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect ROM3

Feb 2019

497807 / 7645441



497822 / 7645451



497852 / 7645455



Transect RI1

Date

Start of Transect (0 m)

End of Transect (50 m)

498036 / 7645587

498067 / 7645628

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect RI1

Feb 2019

498034 / 7645591



498054 / 7645604



498071 / 7645617



Transect RI2

Date

Start of Transect (0 m)

End of Transect (50 m)

498141 / 7645484

498100 / 7646460

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023



Aerial Photos from Drone Transect RI2

Date 498133 / 7645481

Feb 2019



498122 / 7645471



498104 / 7645461



Transect V1

Date **Start of Transect (0 m)**

498141 / 7645484

End of Transect (50 m)

498100 / 7645460

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023

No photos

Aerial Photos from Drone Transect V1

Date

500902 / 7646395

500916 / 7646390

Feb 2019



500885 / 7646403



Transect VI2

Date

Start of Transect (0 m)

End of Transect (50 m)

500883 / 7646405

500927 / 7646384

Jul 2017



May 2018



Feb 2019



Aug 2020



March 2021



June 2022



Apr 2023





Yandan Gold Project

Erosion Stability Assessment

PREPARED FOR
Straits Gold Pty Ltd

MARCH 2024

Document Control

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Project Manager:	Rod Hailstone

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List of Abbreviations

AARC	AARC Environmental Solutions Pty Ltd
EA	Environmental authority
ML	Mining lease
PMLUP	Post mine land use plan
PRCP	Progressive rehabilitation and closure plan
RMP	Rehabilitation monitoring program
RUSLE	Revised Universal Soil Loss Equation
TSF	Tailings storage facility

1 Introduction

AARC Environmental Solutions Pty Ltd (AARC) has been commissioned by Straits Gold Pty Ltd (Straits Gold) to complete an erosion stability assessment for the Yandan Gold Project (the Project, Yandan).

This assessment has been prepared to satisfy information requirements of the *Guideline — Progressive rehabilitation and closure plans* (PRCP Guideline, DES 2021). Specifically, this plan has been prepared to satisfy the completion of erosion modelling to predict the long term stability of final landforms at the Project.

Erosion modelling for this assessment uses the Revised Universal Soil Loss Equation (RUSLE) to predict long term stability outcomes for final landforms (both existing and proposed) on site. The RUSLE analysis predicts long term average annual soil loss values based on factors such as rainfall erosivity, slope steepness and length, soil properties, groundcover, and land management factors.

This modelling was used to assess the erosional stability of specific rehabilitation areas of the Project that have a high-risk of erosion, being the tailings storage facility (TSF) embankments and the Heap Leach Pad. This modelling also assessed the erosional stability of the existing rehabilitated South Pit area.

1.1 Scope

The following scope of works has been completed for the erosion stability assessment:

- review of landform design for the rehabilitated South Pit area, the TSF embankment and the Heap Leach Pad;
- review of rehabilitation monitoring data associated with the rehabilitated South Pit area;
- collection of soils data from the three areas of interest for input into the erosion model;
- erosion modelling (RUSLE analysis) for slopes in the final landform;
- provide recommendations of suitable landform design criteria and vegetation cover criteria for inclusion in the PRCP; and
- provide recommendations of other management actions and measurable objectives to ensure long term stability of rehabilitated slopes.

This assessment incorporates modelling and analysis of theoretical surface erosion risk for structures. The assessment does not address geotechnical stability of the constructed landforms or the associated risk of mass failure.

2 Background

2.1 Rehabilitation areas potentially subject to erosion

The assessment identified key areas considered to be at risk of long term surface erosion based on:

- characteristics of the final landform design;
- existing erosion / rehabilitation monitoring data;
- site specific environmental factors; and
- an understanding of material properties available for use in rehabilitation on the site.

Rehabilitation of existing mine disturbance was partially complete across the site at the time of this report. Three rehabilitation areas were identified for further analysis including:

- the backfilled and rehabilitated South Pit area;
- the TSF main embankment (yet to be rehabilitated); and
- the Heap Leach Pad (yet to be rehabilitated).

Although the recommendations of this assessment apply directly to these three structures. It is reasonable to assume that equivalent measures could be adopted for other similar landforms at the Yandan site.

2.2 EA Landform design requirements

Post mining land use descriptions for land disturbed by mining activities are established in the Project's Post Mine Land Use Plan (PMLUP) (identified as an applicable land outcome document for PRC Plan purposes) (AARC 2018), as detailed in Table 1. Post mining land use descriptions established in the PMLUP are consistent with Condition F2-1, Schedule F – Table 1 of the Environmental Authority (EA) for the Project (EPML00771913).

Landform design criteria (e.g. slope angle, maximum slope length) for final landforms are not defined in the Project EA.

Table 1 : Post Mine Land Description (after Table 1 from AARC 2018)

Tenure ID	Disturbance type	Associated infrastructure ¹	Maximum surface area (ha)	Post-mine land description	Post mine land classification
ML1095	Backfilled pit	South Pit	4	Open pasture	VII
	Tailings dam	Cell A Cell B TWRD Spillway	39	Open pasture	VII
	Stockpile area	Topsoil Stockpile	8.3	Open pasture	VII
	Run-off dam	Mine Water Dam	16.6	Water storage	VII
	ROM pad	ROM Pad	3.8	Low hill	VII
	Processing Plant	Hardstand Area	1.8	Open pasture	VII
	Open pit	Main Pit East Hill Pit	18.8	Lake	Void

Tenure ID	Disturbance type	Associated infrastructure ¹	Maximum surface area (ha)	Post-mine land description	Post mine land classification
	Infrastructure	Tailings Water Return Dam Water Storage Dam ¹ Water Harvest Trench Roads Airstrip	79.8	Open pasture	VII
	Heap Leach	Heap Leach Pad (HLP) HLP Stormwater Pond Pregnant Pond Barren Pond	21	Low hill	VII
	Borrow pit	Borrow pit	8	Open pasture	VII
	Exploration	Exploration areas	4.5	Open pasture	VII
ML 1096	Village infrastructure	Village infrastructure	15	Open pasture	VII
	Tailings Dam	Cell A Cell B	75	Open pasture	VII

¹ Water Storage Dam to be retained in final landform under landholder agreement

It is acknowledged that some of the LOD PMLUs (Table 1) provide limited descriptions of the target rehabilitation that is to be achieved. This is particularly so for the 'low hill' PMLU, which more describes the intended resulting landform topography rather than the actual land use to be achieved.

In an effort to improve rehabilitation outcomes for the Project, the LOD PMLUs have been reviewed as part of the development of the PRCP and better defined (Table 2), where appropriate, to provide greater clarity of the PMLU intent for the Project; including the landform and vegetation type to be achieved.

Table 2: Nominated PMLU in the Project PRCP

Tenure ID	Disturbance type	Associated infrastructure	Post-mine land description	Post mine land classification
ML1095	Backfilled pit	South Pit	Open pasture – low intensity grazing	VII
	Tailings dam	- Cell A - Cell B - TSF Spillway - TSF Embankment	Open pasture – low intensity grazing	VII
	Stockpile area	Topsoil Stockpile	Open pasture – low intensity grazing	VII
	Runoff dam	Mine Water Dam	Retained water storage	VII
	ROM pad	ROM Pad	Low hill – low intensity pasture grazing	VII

Tenure ID	Disturbance type	Associated infrastructure	Post-mine land description	Post mine land classification
	Main Pit bund	- Northern bund - Western bund	Flood protection landform	N/A
	Open pit	- Main Pit - East Hill Pit	Void (None Use Management Area)	Void (Non Use Management Area)
	Infrastructure	- Tailings Water Return Dam - Water Storage Dam² - Water Harvest Trench - Infrastructure Area (including processing plant) - Laydown - Landfill Area - Roads and tracks¹ - Airstrip - Core Yard - Miscellaneous footprint (cleared areas)	Open pasture – low intensity grazing ²	VII
	Heap Leach	- Heap Leach Pad - HLP Stormwater Pond - Pregnant Pond - Barren Pond	Low hill – low intensity grazing	VII
	Borrow pit	Borrow pit	Open pasture – low intensity grazing	VII
	Exploration	Exploration areas	Open pasture – low intensity grazing	VII
ML 1096	Village infrastructure	Village infrastructure	Open pasture – low intensity grazing	VII
	Tailings Dam	- Cell A - Cell B	Open pasture – grazing	VII

2.3 Additional landform design considerations

The final landform design for key infrastructure is provided below.

TSF Embankment

Yandan Tailings Dam is comprised of two cells: being Cell A (containing exclusively oxide tailings) and Cell B (containing predominantly oxide tailings, overlaying sulphide tailings). Cell A of the facility has been fully rehabilitated (circa 1999–2000), while Cell B has remained unrehabilitated since closure pending use for future mining operations.

It is understood that the embankment of the TSF was constructed with a central clay core, with this material borrowed from around the perimeter of the TSF (Greater Boulder Holdings Ltd 1988). Clay cores are effective in restricting seepage from reporting to the receiving environment, and in this instance, it is also understood to have

the dual purpose of preventing upstream waters from infiltrating the facility and wetting the tailings. Given the TSF was constructed across a minor drainage channel, some ponding occurs against the upstream wall which is located within the top of the catchment. The inclusion of a clay core in the embankment walls was therefore an important consideration for the long term stability and function of the facility.

A slope analysis was conducted over the current (unrehabilitated) embankment of the TSF, principally on the Main Wall (downstream face of the TSF). Several cross sections were analysed on the Main Wall showing a slope length of 35 m and a slope gradient of 33%. To minimise the potential of surface / soil erosion as a consequence of steep slopes an alternate design is proposed. Backfilling on the downstream face of the wall is proposed to achieve 30% grade slopes with 20 m horizontal length and a single, intermediate flat bench of 5 m (Figure 1). This proposed final landform design forms the basis of further erosion assessment in this report.

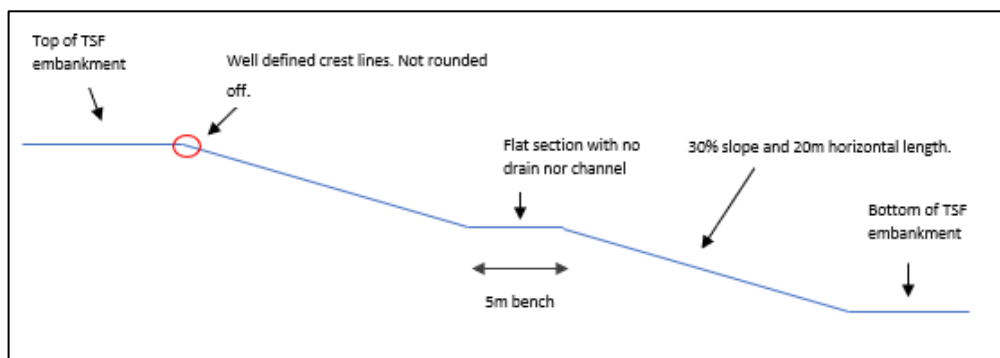


Figure 1: Final landform design of TSF Cell A Main Wall

Heap Leach Pad

The existing Heap Leach Pad is approximately 550 m (L) x 450 m (W) x 26 m (H), covering an area of approximately 16.9 ha. The coarse rock material has been end-dumped and dozed in two ten m lifts, and one six m lift, at or below the natural angle of repose.

The final landform design proposes a downward push of material from the top of the Heap Leach Pad, to regrade the existing landform to a slope of grade of 25% with 5 m benches every 30 m (Figure 2). Benches are used to break continuous slopes and special care should be taken when constructing the benches, to ensure they do not concentrate water and potentially cause erosion. The top of the facility will also be graded from centre to edge to achieve a water shedding design.

Following re-shaping works, the facility is to be capped using a minimum of 0.5 m of top rock and a minimum of 0.15 m of topsoil, with the final landform to be seeded with pasture species. The erosional stability of the Heap Leach Pad has been done considering the proposed design. This proposed final landform design forms the basis of further erosion assessment in this report.

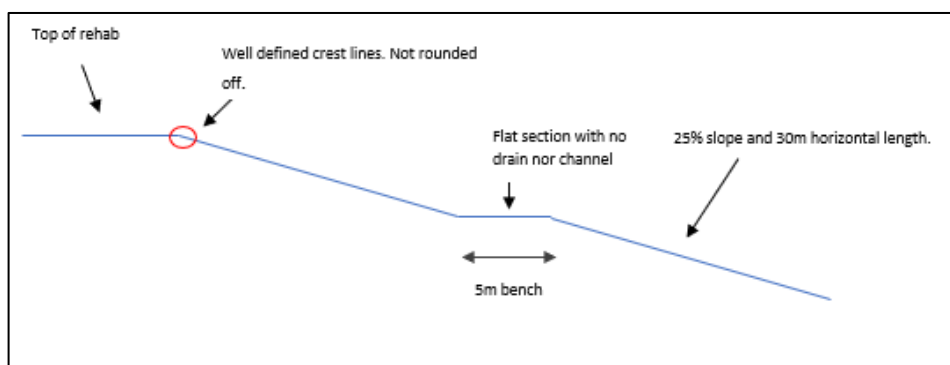


Figure 2: Final landform design of the Heap Leach Pad

Main Pit bund

The existing Main Pit bund runs around the perimeter of Main Pit void and is broken into two sections by the North and South Spillways.

The bund that runs along the northern catchment of the pit (a relatively clean catchment) diverts flow around Main Pit, to the Suttor River, without interaction with pit waters. This bund therefore ensures pit water levels do not increase dramatically due to inflows from the localised pit catchment. Diverted waters also work to provide increased flow to the Suttor River, to support the mixing potential as pit outflows occur.

The second portion of the bund, that runs along the western extent (between the pit and the Suttor River) is designed to hold a short head of water within the pit and manage pit outflows through constructed spillways.

The bunds were constructed as earth fill embankments, utilising clay material sourced on-site from a nearby borrow pit, with a clay core and rock facing on the embankment face.

A slope analysis was undertaken at a representative cross-section of the bund, showing a slope length of 7 m on the outer face and 10 m on in the inner face and height of 3.5 m. Monitoring of the bund shows signs of erosion and will require reparation prior to the placement of groundcover. Nevertheless, this proposed design forms the basis of the erosion assessment within this report.

3 Rehabilitation monitoring

The Yandan Rehabilitation Monitoring Program (RMP) was established in 2014, providing annual monitoring of the progress of rehabilitated domains towards successful rehabilitation. The RMP assesses the ecological condition of rehabilitated sites, using metrics related to vegetation cover and structure, vegetation composition, and erosion stability. The ecological data collected from rehabilitated sites was compared to reference site data, with a view to measuring the long term success of rehabilitated areas.

The rehabilitated South Pit area is a fully rehabilitated domain at Yandan, with results of the RMP suggesting that the site is on trajectory to achieving completion criteria. The rehabilitated South Pit area is proposed as a site specific benchmark for successful rehabilitation at the Yandan site, and as such forms the focus of this section.

3.1 Monitoring locations

The RMP provides for monitoring over a total of 21 sites, with these located across progressive rehabilitation sites, cover trial sites on Cell B of the TSF, and reference sites. Three of these sites are located within the rehabilitated South Pit area, as shown in Table 3 and Figure 3.

Table 3: Rehabilitation monitoring sites in the rehabilitated South Pit area

Site Name	Start MGA (GDA 94)		End MGA (GDA 94)	
	Easting	Northing	Easting	Northing
SP1	497367	7644773	497316	7644776
SP2	497379	7644712	497335	7644738
SP3	497373	7644677	497322	7644670

3.2 Rehabilitation monitoring methodology

The RMP methodology includes the following components:

- vegetation monitoring at established monitoring transects using standard methods adapted from the Queensland Herbarium survey technique titled *Methodology for Surveying and Mapping of Regional Ecosystems and Vegetation Communities in Queensland* (Version 5.1) (Neldner *et al.* 2020), and the *Method for the Establishment and Survey of Reference Sites for BioCondition* (Eyre *et al.* 2017);
- photographic monitoring from permanent photo points within the rehabilitated areas; and
- erosion monitoring including feature type, rill number and depths.

Monitoring data for the rehabilitated South Pit area was available for the 2017–2021 period.



Figure 3: Monitoring transects in the rehabilitated South Pit area

3.3 Monitoring results

3.3.1 Groundcover

Rehabilitation monitoring indicates total live cover was similar between the 2020 and 2021 monitoring events, with the rehabilitated South Pit area found to have slightly decreased in vegetation cover over the monitoring period. This finding was consistent with the reference sites and is considered reflective of local rainfall patterns and grazing activity within the rehabilitated areas and reference sites. Since 2021, total live cover has increased significantly with live cover reported between 79-89%. Generally, total live cover provided a dominant portion of ground cover at the South Pit. Furthermore, average for the 2017–2023 period yields an average of 42%, with SP2 having the highest value at 51% (Table 4).

Table 4: Total live cover at rehabilitated South Pit area sites

Site	Monitoring Survey	Total Live Cover (%)	Average for site (%)
SP1	Jul-17	41	51
	May-18	34	
	Feb-19	41	
	Aug-20	46	
	Mar-21	41	
	Jun-22	65	
	Apr-23	89	
SP2	Jul-17	61	59
	May-18	41	
	Feb-19	62	
	Aug-20	54	
	Mar-21	39	
	Jun-22	70	
	Apr-23	83	
SP3	Jul-17	43	47
	May-18	20	
	Feb-19	56	
	Aug-20	22	
	Mar-21	36	
	Jun-22	76	
	Apr-23	79	
TOTAL			42

The composition of total live cover at the rehabilitated South Pit area was predominantly from exotic pasture species followed by forbs. Non pasture species have had a marginal contribution during the five monitoring periods while native pasture species, shrubs and invasive weed species have had no contribution (Table 5).

Table 5: Live cover composition at rehabilitated South Pit area monitoring sites

Site	Monitoring Survey	Non-Pasture Species (%)	Exotic Pasture Species (%)	Native Pasture Species (%)	Shrubs (%)	Forbs (%)	Invasive Weed Species (%)	Total Live Cover (%)
South Pit	Jul-17	1	42	0	0	5	0	48
	May-18	1	27	0	0	3	0	31
	Feb-19	1	47	0	0	7	0	56
	Aug-20	0	37	0	0	3	0	41
	Mar-21	0	33	0	0	5	0	38
	Jun-22	0	36	6	1	7	0	70
	Apr-23	9	40	1	1	12	0	84

3.3.2 Species richness

The mean total species richness across reference and the rehabilitated South Pit area sites was lower in the 2021 monitoring period when compared to the 2020 monitoring period. Total species richness across the rehabilitated South Pit area appears to have reduced slightly in comparison with the four preceding monitoring events (2017–2020), with an average of 21 species recorded during 2017–2020, and an average of 18 species during the current monitoring event. Nevertheless, in comparison with the reference sites, the rehabilitated South Pit area species richness has consistently been higher for the last three monitoring periods (2019–2021) (Figure 4).

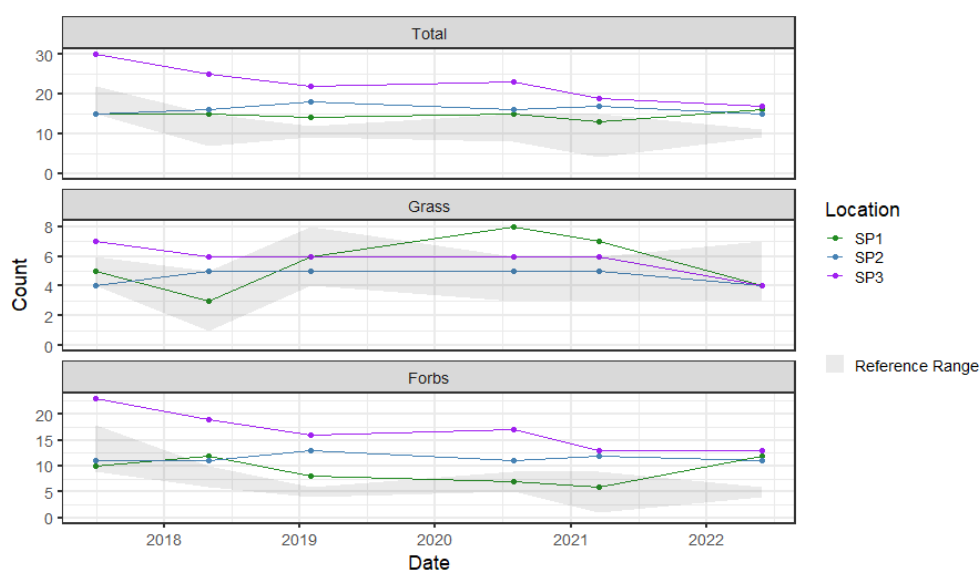


Figure 4: Mean species richness at reference and the South Pit sites

3.3.3 Erosion characteristics

A summary of erosion monitoring from 2017 to 2021 surveys is provided in Table 6. Erosion conditions at the reference and rehabilitated South Pit area sites have been recorded as minor over the past five monitoring years. All sites consistently observed 0 to 15 cm rills. Low levels of erosion in the form of small rills and short depths have remained constant at most rehabilitation transects with no further deterioration since the 2017 survey.

3.3.4 Monitoring conclusions

Overall, the rehabilitated South Pit area supports a well-established pasture community that is generally consistent with reference sites. The data demonstrates sustainable ecosystem function over at least 4 years, including periods of variable rainfall and livestock grazing pressures. Erosion monitoring indicates surface soils are stable and non-erosive. Monitoring data indicates that rehabilitation objectives are generally met for the rehabilitated South Pit area. Erosion modelling of the rehabilitated South Pit area in the following sections provides a performance benchmark for comparison with future rehabilitation areas.

Table 6: Extent of erosion at reference and South Pit sites

Monitoring Sites		R1	R2	R3	SP1	SP2	SP3
Jul-17	Number of rills	<15	<15	<15	<15	<15	<15
	Average depth of rills (cm)	<10	<10	<10	<10	<10	<10
	Erosion classification	minor	minor	minor	minor	minor	minor
May-18	Number of rills	<15	<15	<15	<15	<15	<15
	Average depth of rills (cm)	<10	<10	<10	<10	<10	<10
	Erosion classification	minor	minor	minor	minor	minor	minor
Feb-19	Number of rills	<15	<15	<15	<15	<15	<15
	Average depth of rills (cm)	<10	<10	<10	<10	<10	<10
	Erosion classification	minor	minor	minor	minor	minor	minor
Aug 20	Number of rills	<15	<15	<15	<15	<15	<15
	Average depth of rills (cm)	<10	<10	<10	<10	<10	<10
	Erosion classification	minor	minor	minor	minor	minor	minor
Mar-21	Number of rills	<15	<15	<15	<15	<15	<15
	Average depth of rills (cm)	<10	<10	<10	<10	<10	<10

Monitoring Sites		R1	R2	R3	SP1	SP2	SP3
	Erosion classification	minor	minor	minor	minor	minor	minor
Jun-22	Number of rills	<15	<15	<15	<15	<15	<15
	Average depth of rills (cm)	<10	<10	<10	<10	<10	<10
	Erosion classification	minor	minor	minor	minor	minor	minor
Apr-23	Number of rills	<15	<15	<15	<15	<15	<15
	Average depth of rills (cm)	<10	<10	<10	<10	<10	<10
	Erosion classification	minor	minor	minor	minor	minor	minor

4 RUSLE analysis

The RUSLE analysis was developed to predict long term average annual soil loss based on factors that include rainfall erosivity, slope steepness and length, soil properties, groundcover and management factors (Loch and Roswell 1992). The equation was originally developed by US Department of Agriculture in the late 1950s for plot scale soil conservation purposes, although it later gained acceptance in broad scale applications. As noted by Lu et al. 2001, erosion is considered unacceptable when soil loss is more than 10 t/ha/yr; this value has been used as the threshold for comparison of assessed values for the Project

RUSLE analysis was applied to the rehabilitated South Pit area, TSF embankments and the Heap Leach Pad to assess existing and proposed landform design criteria and assist in identifying suitable completion criteria for inclusion in the PRCP.

Methodology and calculation for each RUSLE parameter is described in section 4.1 and the results are presented in section 5.

4.1 Methodology

The RUSLE calculation for mean annual soil loss (t/ha/yr) as used for the Project is a product of five variables.

$$A = R K L S C P$$

Where:

A = Average annual soil loss (t/ha/yr)

R = Rainfall erosivity factor

K = Soil erodibility factor

LS = slope length/gradient factor

C = ground cover and management factor

P = Supporting practice factor

The following considerations are taken for each of the RUSLE variables:

- the rainfall erosivity factor (R) and the supporting practice factor (P) are the same for all three areas of study (section 4.1.1 and section 4.1.5).
- the soil erodibility factor (k) and the slope length/gradient factor (LS) are specific for each of the three areas of study (section 4.1.2 and section 4.1.3).
- the cover and management factor (C) has been empirically calculated for the South Pit only, as that area has established and well-sustained ground cover. Assumed cover values were adopted for the two areas of future rehabilitation. Adopted values considered the slope risk and expected achievable revegetation outcomes.

4.1.1 Rainfall erosivity factor (R)

This factor is a measure of the ability of rainfall to cause erosion. It was calculated utilising the dataset available from the Queensland Spatial Catalogue and then overlaying the Project mining leases. Individual pixel values of rainfall erosivity were then obtained within the ML boundaries. The total range of R values for the different Project locations are shown in Table 7. The average of all values was selected for the analysis.

Table 7: Rainfall Erosivity Factors

R - value	
R ₁	2191.7
R ₂	2207.6
R ₃	2192.2
Average	2197.17

4.1.2 Soil erodibility factor (K)

Soil erodibility factor (*K*) is a measure of the susceptibility of the soil to erosion. For this Project the calculation of the *K*-factor was done using the following equation elaborated for Australian soils (Lu *et al.* 2001):

$$K = 2.77 (100 P_{125})^{1.14} (10^{-7}) (12 - 2 O_c) + 3.29 (10^{-3})(Pr - 3)$$

Where:

*P*₁₂₅ = Percentage of particles with diameter less than 0.125mm

*O*_c = Percentage of organic carbon

Pr = Soil permeability rating

In December 2021, 22 soil samples from across the Project were collected and sent for laboratory analysis. The results were used to calculate the *K*-factor for the soils within the areas of interest (being the rehabilitated South Pit area, Heap Leach Pad and TSF embankment). The *P*₁₂₅ and *O*_c values were directly obtained from the lab results. The soil permeability rating was estimated from the soil management units and according to the following scale (Rosewell 1993):

6 = very slow (<1 mm per hour)

5 = slow (1 to 5 mm per hour)

4 = slow to moderate (5 to 20 mm per hour)

3 = moderate (20 to 60 mm per hour)

2 = moderate to rapid (60 to 130 mm per hour)

1 = rapid (> 130 mm per hour)

Typically, Queensland soil *K* factors range between <0.01 (very low) to >0.06 (very high). Table 8 provides typical *K* factors for different soil groups in Queensland.

Table 8: Soil erodibility classes (Hazelton & Murphy 2016)

Rating	<i>K</i> value	Expected soil erodibility of soil groups
Very low	0.00-0.01	Red Chromosol
Low	0.01-0.02	Dermosol
Moderate	0.02-0.04	Red Chromosol, Red Ferrosol, Red Dermosol
High	0.04-0.06	Vertosols, Dermosols, Red Chromosol

Rating	K value	Expected soil erodibility of soil groups
Very High	>0.06	Exposed sodic soils

4.1.2.1 Rehabilitated South Pit area

The outcomes of the soil analysis for the rehabilitated South Pit area are shown in Table 9. Results show that soils have low erodibility.

Table 9: K values for the South Pit

Location	Sample	P ₁₂₅ (%)	O _c (%)	Permeability Rating	K value
South Pit	South Pit 0-10	38.64	0.93	1	0.028

4.1.2.2 TSF embankment

The outcomes of the soil analysis for the TSF embankment are shown in Table 10. Results show that local soils / growth mediums range from moderate to high erodibility class. This is due to a combination of low organic carbon content and high content of sand in the soil which results in poor soil structure.

Where alternate topsoil sources are not otherwise available, amelioration measures are proposed for soils placed on the final TSF main embankment slope to reduce its erodibility. Organic matter (such as hay mulch) and gypsum application is recommended to improve soil structure by creating a binding effect and it will increase organic carbon levels. Gypsum (calcium carbonate) will increase the structural stability of sandy soils by allowing clay particles to form stable aggregates. Soil aeration and water infiltration rates may also be improved, minimising runoff and formation of rill erosion. In consideration of the proposed amelioration actions, a K-factor similar to that recorded at the rehabilitated South Pit area ($K = 0.028$) was applied in the RUSLE analysis.

Table 10: K values for the TSF embankment

Location	Sample	P ₁₂₅ (%)	O _c (%)	Permeability Rating	K value
TSF Embankment	Cell A – Main Wall #1	46.64	0.93	1	0.036
	Cell A – Main Wall #2	53.42	1.28	1	0.039
	Cell A – northern perimeter embankment	72.75	0.47	1	0.071

4.1.2.3 Heap Leach Pad

The outcomes of the soil analysis for the Heap Leach Pad are shown in Table 11. Like the results of the TSF embankment, the Heap Leach Pad results show that soils range from moderate to high erodibility class as a consequence of low organic carbon content and a high content of sand.

Where alternate topsoil sources are not otherwise available, amelioration measures are proposed for soils placed on the final heap leach slopes to reduce its erodibility. Organic matter (such as hay mulch) and gypsum application is recommended to improve soil structure by creating a binding effect and it will increase organic carbon levels. Gypsum (calcium carbonate) will increase the structural stability of sandy soils by allowing clay particles to form stable aggregates. Soil aeration and water infiltration rates may also be improved, minimising runoff and

formation of rill erosion. In consideration of the proposed amelioration actions, a K-factor similar to that recorded at South Pit ($K = 0.028$) was applied in the RUSLE analysis.

Table 11: *K values for the Heap Leach Pad*

Location	Sample	P ₁₂₅ (%)	O _c (%)	Permeability Rating	K value
Heap Leach Pad	Heap Leach Pad	36.89	0.29	1	0.030
	Heap topsoil stockpile #1	75.82	0.87	1	0.069
	Heap topsoil stockpile #2	49.57	0.47	1	0.043

4.1.2.4 Main Pit bund

The outcomes of the soil analysis for clayey soils likely used for construction of the Main Pit bund are shown in Table 12.

Results show that soils are slowly permeable (5-50 mm/day) and moderately dispersive, this is due to the poor soil structure demonstrated by the low Emerson class number (2) and low Ca:Mg ratio (2.1). However, moderate organic matter content (2.1%) may provide stability to the surface horizon. While soils are planned to be ameliorated, a worst-case scenario assessment was undertaken applying a k -factor of 0.048545 to the analysis.

Table 12: *K values Main Pit bund*

Location	Sample	P ₁₂₅ (%)	O _c (%)	Permeability Rating	K value
Main Pit bund	YP-01	51	0.8	3	0.048545
	YP-01	51	0.8	3	0.048545

4.1.3 Slope length/gradient factor (LS)

The slope length/gradient factor (LS) describes the combined effect of slope length and slope gradient on soil loss. A digital elevation model of the site was utilised to calculate the LS -factor from representative cross sections at the Project. The Heap Leach Pad and TSF embankment are currently at the angle of repose, as such LS for the Heap Leach Pad was calculated from the proposed final landform.

Once the gradient and length were calculated for each section, Figure 5 was used to obtain the actual LS value for each slope. If the Project values did not match exactly with the table values, simple interpolation was done to obtain the final LS value. Results are shown in Table 13.

Slope ratio	Slope gradient (%)	Slope length (m)															
		5	10	20	30	40	50	60	70	80	90	100	150	200	250	300	
100:1	1	0.09	0.11	0.13	0.15	0.16	0.17	0.18	0.19	0.19	0.20	0.20	0.23	0.24	0.26	0.27	
50:1	2	0.14	0.18	0.24	0.28	0.31	0.34	0.36	0.39	0.41	0.43	0.44	0.52	0.58	0.64	0.69	
33.3:1	3	0.17	0.24	0.34	0.41	0.47	0.52	0.57	0.61	0.65	0.69	0.72	0.87	1.00	1.11	1.22	
25:1	4	0.21	0.30	0.44	0.54	0.63	0.71	0.78	0.85	0.91	0.97	1.03	1.26	1.47	1.65	1.82	
20:1	5	0.24	0.36	0.54	0.68	0.80	0.91	1.01	1.10	1.19	1.27	1.35	1.70	2.00	2.28	2.53	
16.6:1	6	0.28	0.42	0.64	0.81	0.97	1.11	1.24	1.36	1.47	1.58	1.68	2.14	2.54	2.91	3.25	
12.5:1	8	0.34	0.53	0.83	1.08	1.31	1.51	1.70	1.88	2.05	2.21	2.37	3.07	3.70	4.28	4.82	
10:1	10	0.42	0.68	1.09	1.44	1.75	2.04	2.31	2.56	2.81	3.04	3.27	4.06	4.94	5.75	6.52	
8.3:1	12	0.52	0.85	1.39	1.85	2.27	2.66	3.02	3.37	3.70	4.02	4.33	5.77	7.07	8.28	9.42	
7.1:1	14	0.62	1.02	1.69	2.26	2.79	3.28	3.74	4.18	4.61	5.02	5.42	7.27	8.95	10.52	12.01	
6.3:1	16	0.71	1.19	1.98	2.67	3.31	3.90	4.46	5.00	5.52	6.02	6.51	8.78	10.86	12.81	14.65	
5.5:1	18	0.80	1.35	2.27	3.07	3.82	4.51	5.17	5.81	6.42	7.02	7.59	10.30	12.78			
5:1	20	0.89	1.50	2.55	3.47	4.32	5.12	5.88	6.61	7.32	8.01	8.68	11.92	14.84			
4:1	25	1.09	1.88	3.23	4.43	5.54	6.59	7.60	8.57	9.51	10.43	11.32					
3.3:1	30	1.28	2.23	3.86	5.32	6.69	7.99	9.23	10.43	11.60	12.74	13.85					
2.5:1	40	1.61	2.83	4.98	6.92	8.74	10.48	12.15	13.77								
2:1	50	1.88	3.33	5.89	8.22	10.42	12.52	14.55									

Figure 5: LS factors (Rosewell 1993)

4.1.3.1 Rehabilitated South Pit area

A digital elevation model of the site was utilised to calculate the *LS*-factor from representative cross sections at the South Pit as shown in Figure 6 to Figure 8. *LS* factor for South Pit is between 1.44 – 1.85, pending slope design (Table 13).

Table 13: LS factors for the rehabilitated South Pit area

Cross Section	LS-Factor
A-A	1.44 ^a
B-B	1.85 ^b

^aSlope gradient 10%. Slope length 30 m. ^bSlope gradient 12%. Slope length 30 m.

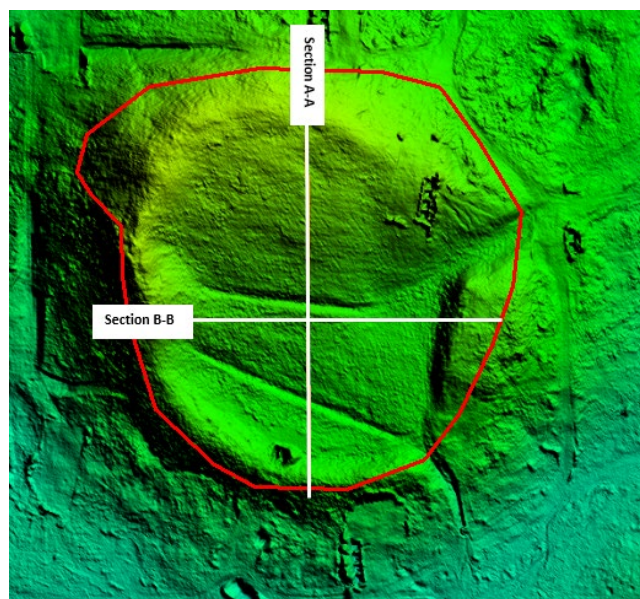


Figure 6: Cross Sections from the rehabilitated South Pit area

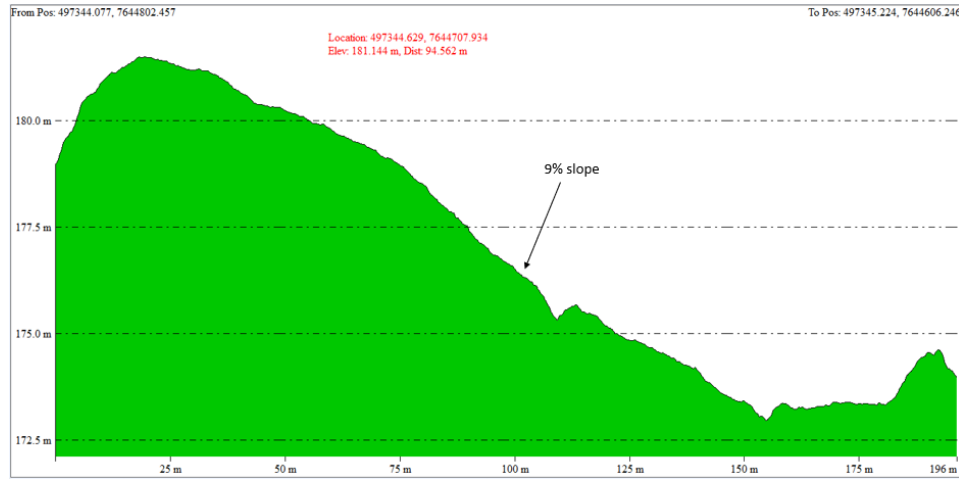


Figure 7: Cross section A-A at the rehabilitated South Pit area

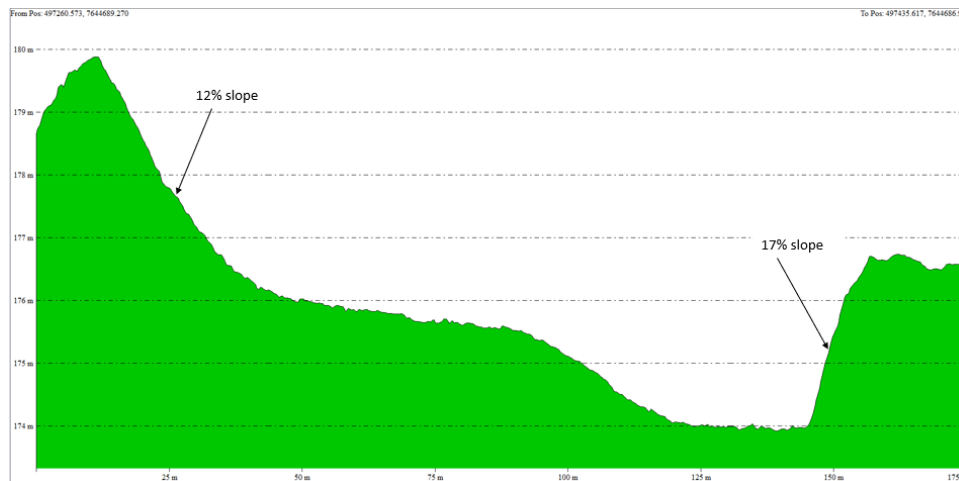


Figure 8: Cross section B-B at the rehabilitated South Pit area

4.1.3.2 TSF embankment

Existing TSF embankment cross sections are shown in Figure 9 to Figure 10. The TSF embankment Main Wall will be reprofiled to a final landform with slope length of 20 m and a slope gradient of 30% as specified in section 2.3. *LS*-factors are shown below for all TSF sections. *LS*-factors at the TSF embankment are between 0.8 – 3.86 (Table 14).

Table 14: *LS*-factors for the TSF embankment

Cross Section	LS-Factor
A-A	1.09
B-B	0.8
Main Wall	3.86

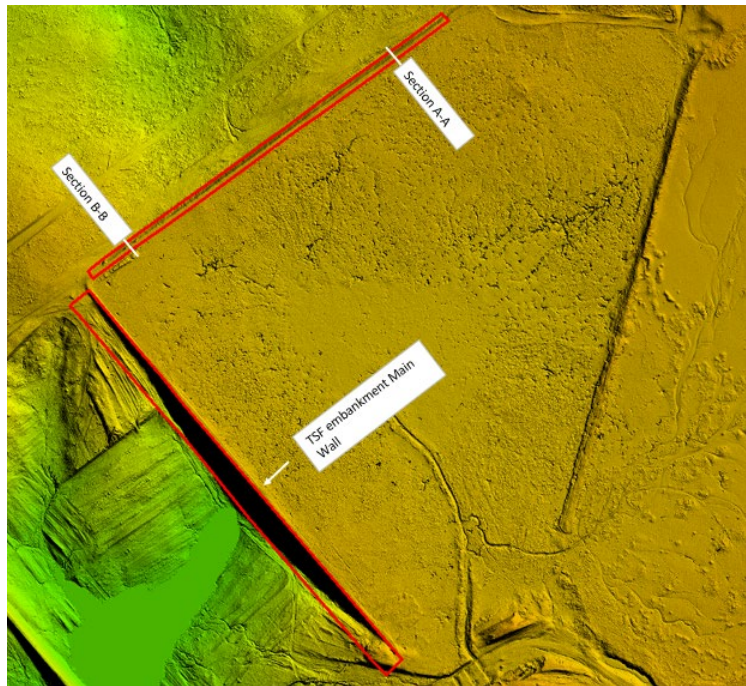


Figure 9: LS analysis areas for the TSF embankment



Figure 10: Cross sections A-A and B-B at TSF embankment

4.1.3.3 Heap Leach Pad

The proposed final landform design for the Heap Leach Pad includes slope lengths of 30 m and a slope gradient of 25% with intermediate flat benches of 5 m every 30 m (refer Section 2.3). This single design will be applied along the whole perimeter of the Heap Leach Pad and therefore, a single LS-factor of 4.43 was calculated for this area.

4.1.3.4 Main Pit bund

A digital elevation model of the site was utilised to calculate the LS-factor from a representative cross section at Main Pit bund, as shown on Figure 11 and Figure 12. The LS-factor estimated at Main Pit bund is 2.22.

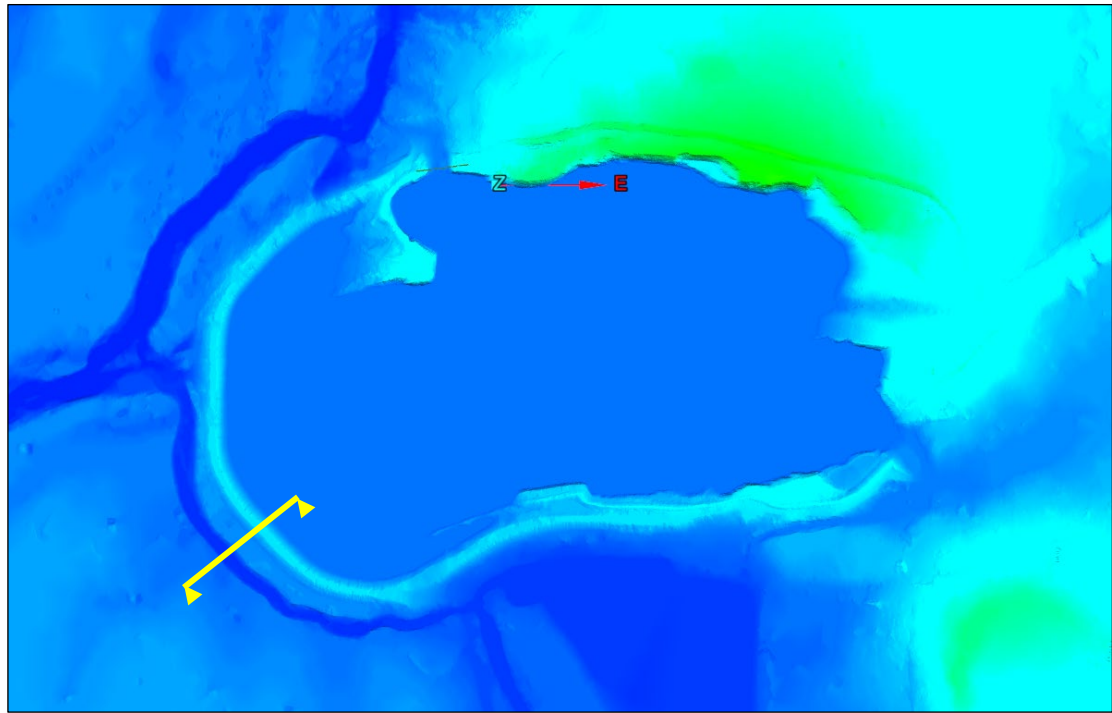


Figure 11: Cross section at Main Pit bund (after Black Rock Mining 2024)

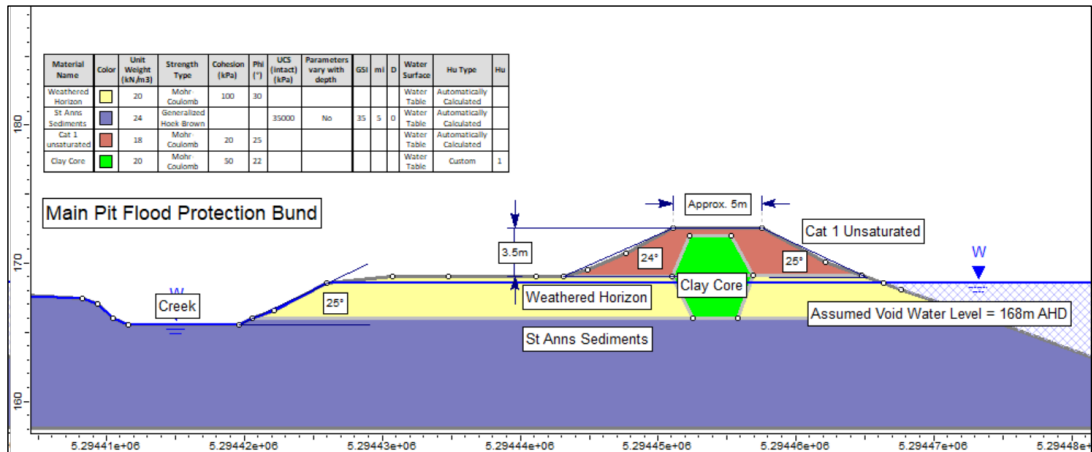


Figure 12: Cross section profile at Main Pit bund (after Black Rock Mining 2024)

4.1.4 Cover and management factor (C)

The cover and management factor (C) is a value that ranges from 0 to 1 as it represents the ratio of soil loss from land under specified cover conditions to the corresponding loss from continuously bare soil. Hence, as higher the groundcover, the lower the C-factor is going to be, as shown in Figure 13. Furthermore, as stated by Lu et. al (2003) cover and management factors results can be improved by combining surface rock cover and the estimated vegetation cover. Rosewell (1993) further states that any rock protection on the surface should be treated as surface cover and allowed for in the C-factor.

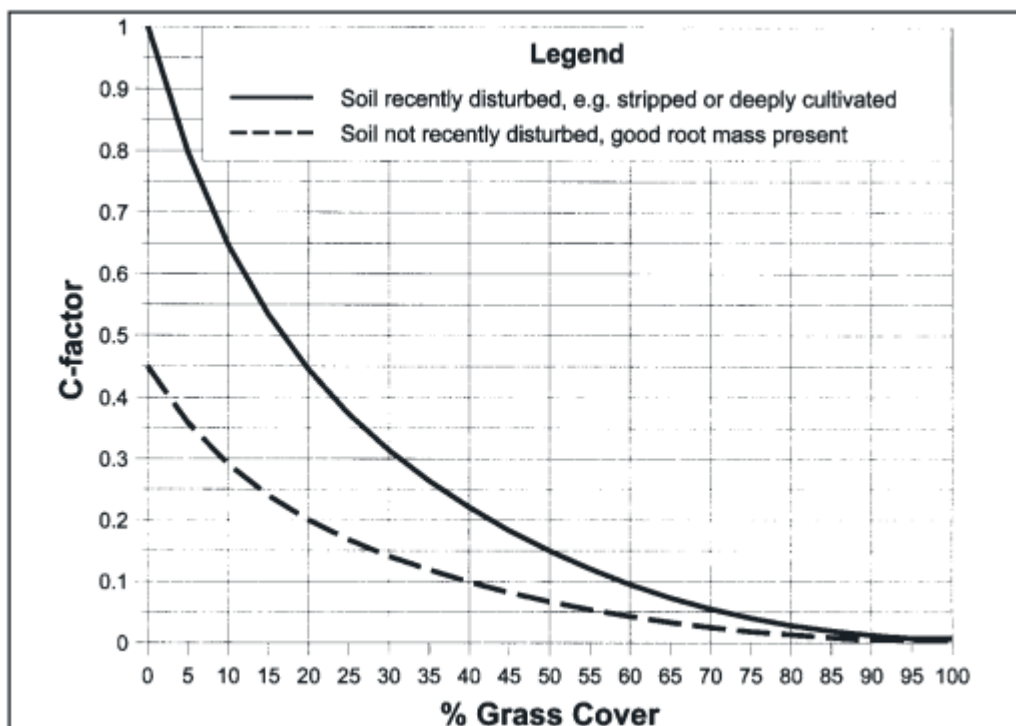


Figure 13: C factors (Rosewell 1993)

As the scenarios being evaluated are landforms assumed to be at a mature rehabilitation stage (more than 12 months since establishment), the values obtained correspond to soils not recently disturbed (the dashed line in Figure 12). Furthermore, given it is hard to get exact C-factor values from the curve, an equation for the line was developed to calculate the C-factor more accurately.

The formula is the following:

$$Y = 0.4459e^{-0.039x}$$

4.1.4.1 Rehabilitated South Pit area

To obtain the specific groundcover of the rehabilitated South Pit area, rehabilitation monitoring data from the last five monitoring periods (2017–2021) was used to estimate total live groundcover. As shown in Table 15, the total live groundcover averages for the rehabilitated South Pit area are consistent with reference sites (42% vs 40%). Groundcover for the rehabilitated South Pit area was used in the C – factor formula to obtain a value of 0.08667.

Table 15: Live groundcover distribution in the South Pit and reference sites

Site	Transect ID	Monitoring Period	Average live groundcover (%)	Total average for site (%)
South Pit	SP1	2017-2021	41	42
	SP2	2017-2021	51	
	SP3	2017-2021	35	
Reference Site	R1	2017-2021	24	40
	R2	2017-2021	23	
	R3	2017-2021	74	

4.1.4.2 TSF embankment

The proposed final landform for the TSF main embankment represents a relatively steep slope, in comparison to landform of the backfilled South Pit. As such, a higher groundcover is anticipated to be required to achieve surface erosion stability in the rehabilitated landform. A rock mulch groundcover (cross-rippled with topsoil) may be applied on the embankment to provide additional cover and stability while reducing surface water runoff and potential erosion. This is consistent with RUSLE literature (Rosewell 1993, Lu *et al.* 2003) where it is stipulated that rock cover should be used in combination with vegetation cover to estimate the total groundcover for the C-factor. Total groundcover (rock and/or vegetation) proposed for the final landform is 65%, resulting in a C-factor value of 0.035 adopted into the model. Further analysis was undertaken to determine the impact of increased vegetation cover of 70% total groundcover (rock and/or vegetation), with a C-factor of 0.02908.

4.1.4.3 Heap Leach Pad

The proposed final landform for the Heap Leach Pad represents a relatively steep slope, in comparison to landform of the backfilled South Pit. As such, a higher groundcover is anticipated to be required to achieve surface erosion stability in the rehabilitated landform. A rock mulch groundcover (cross-rippled with topsoil) may be applied on the embankment to provide additional cover and stability while reducing surface water runoff and potential erosion. This is consistent with RUSLE literature (Rosewell 1993, Lu *et al.* 2003) where it is stipulated that rock cover should be used in combination with vegetation cover to estimate the total groundcover for the C-factor. Total groundcover (rock and/or vegetation) proposed for the final landform is 65%, resulting in a C-factor value of 0.035 adopted into the model. Further analysis was undertaken to determine the impact of increased vegetation cover of 70% total groundcover (rock and/or vegetation), with a C-factor of 0.02908.

4.1.4.4 Main Pit bund

The proposed final landform for the Main Pit bund represents a relatively steep slope, in comparison to landform of the backfilled South Pit. As such, a higher groundcover is anticipated to be required to achieve surface erosion stability in the rehabilitated landform. A rock mulch groundcover (cross-rippled with topsoil) may be applied on the bund slopes to provide additional cover and stability while reducing surface water runoff and potential erosion. This is consistent with RUSLE literature (Rosewell 1993, Lu *et al.* 2003) where it is stipulated that rock cover should be used in combination with vegetation cover to estimate the total groundcover for the C-factor. Total groundcover (rock and/or vegetation) proposed for the final landform is 70%, resulting in a C-factor value of 0.035 adopted into the model. Further analysis was undertaken to determine the impact of increased vegetation cover of 70% total groundcover (rock and/or vegetation), with a C-factor of 0.02908.

4.1.5 Supporting practice factor (*P*)

Supporting practice factor (*P*) is defined as the ratio of soil loss with a specific supporting practice as compared to soil loss in regular conditions. It is reduced by practices that reduce both the velocity of runoff and the tendency of runoff to flow directly downhill. Due to lack of reliable data, it is assumed that for all modelled cases, the value

is equal to 1. Thus, it reflects the potential for soil loss under current conditions with no soil conservation support practices.

5 Results

5.1 Rehabilitated South Pit area

The current landform design and rehabilitation status of the rehabilitated South Pit area present soil erosion values within acceptable limits as shown in Table 16. No management measures are needed for any of the RUSLE variables in this area.

Table 16: RUSLE results for the rehabilitated South Pit area

Location	Cross Section	R-factor	K-factor	LS-factor	C-factor	P-factor	RUSLE value t/ha/year
South Pit	A-A	2197.17	0.028	1.44	0.08667	1.00	7.65
	B-B	2197.17	0.028	1.85	0.08667	1.00	9.83

5.2 TSF embankment

In consideration of the proposed landform design, soil characteristics and cover characteristics detailed in section 4.1, RUSLE values for the TSF embankment are within acceptable limits. Surface erosion of these structures is predicted to be manageable under these conditions (refer Table 17).

Table 17: RUSLE results for the TSF embankment

Location	Cross Section	R-factor	K-factor	LS-factor	C-factor	P-factor	RUSLE value t/ha/year
TSF embankment	A-A	2197.17	0.028	1.09	0.035	1.00	2.36
					0.02908		1.64
	B-B	2197.17	0.028	0.8	0.035	1.00	1.73
					0.02908		1.20
	Main Wall	2197.17	0.028	3.86	0.035	1.00	8.37
					0.02908		5.81

5.3 Heap Leach Pad

In consideration of the proposed landform design, soil characteristics and cover characteristics detailed in section 4.1, RUSLE values for the Heap Leach Pad are within acceptable limits. Surface erosion of these structures is predicted to be manageable under these conditions (refer Table 18).

Table 18: *RUSLE values for the Heap Leach Pad*

Location	Cross Section	R-factor	K-factor	LS-factor	C-factor	P-factor	RUSLE value t/ha/year
Heap Leach Pad	-	2197.17	0.028	4.43	0.035	1.00	9.60
					0.02908		6.67

5.4 Main Pit bund

In consideration of the proposed landform design, soil characteristics and cover characteristics detailed in section 4.1, RUSLE values for the Main Pit bund are within acceptable limits. Surface erosion of these structures is predicted to be manageable under these conditions.

Table 19: *RUSLE values for the Main Pit bund*

Location	Cross Section	R-factor	K-factor	LS-factor	C-factor	P-factor	RUSLE value t/ha/year
Main Pit bund	1	2197.17	0.04854	4.43	0.03534	1.00	8.36
					0.02908		6.88

6 Discussion and conclusions

Rehabilitation monitoring data shows that the rehabilitated South Pit area has maintained a high self-sustaining groundcover since 2017 and is comparable to groundcover in reference sites, with no evidence of ongoing active erosion recorded. When analysed using RUSLE, the rehabilitated South Pit area presents erosion levels that are within acceptable limits (<10 t/ha/yr) for all cross sections analysed. As such, the South Pit is considered to be meeting rehabilitation objectives.

The proposed final landform of the TSF embankment, the Heap Leach Pad and Main Pit bund present steeper landform conditions and more erodible soils than the rehabilitated South Pit area. However, it was found that an increase in total groundcover from 65% to 70%, provides a significant reduction in soil loss per annum, particularly in areas which report a higher LS factor. Management actions are therefore recommended to achieve acceptable erosion levels, including soil amelioration and rock mulching in combination with vegetation cover to enhance the total groundcover. Considering these management actions for the RUSLE calculation, values fall below 10 t/ha/yr and are therefore considered acceptable.

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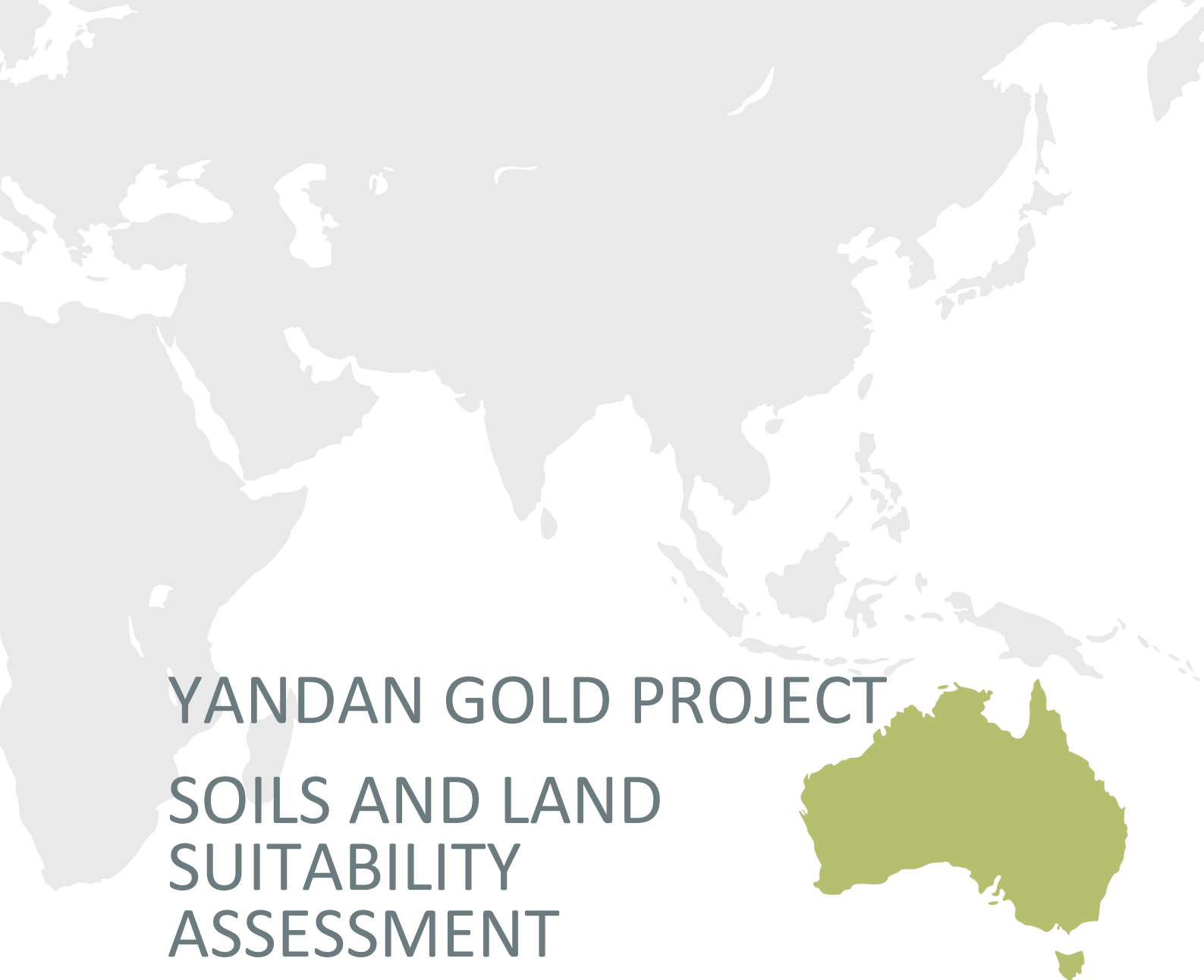
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YANDAN GOLD PROJECT SOILS AND LAND SUITABILITY ASSESSMENT

PREPARED FOR
STRAITS GOLD PTY LTD

25 MARCH 2024



Yandan Gold Project

Progressive Rehabilitation & Closure Planning (PRCP) Geotechnical Assessment Report

March 2024

BMS-P24003C-AAR-YAN-R-1-V2.0



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DOCUMENT CONTROL SHEET

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EXECUTIVE SUMMARY

A geotechnical assessment was carried out by Blackrock Mining Solutions (Blackrock) for the Yandan Gold Project ('Project') to inform the development of a Progressive Rehabilitation and Closure Plan (PRCP) in accordance with the Department of Environment and Sciences' Guideline – Progressive Rehabilitation and Closure Plans (2019) and Environmental Authority (EA) for the Project.

The purpose of the assessment was to identify areas of concern related to long-term geotechnical stability of the final landform, and to provide recommendations for the long-term stability of slopes to meet the final landform design objectives.

Geotechnical analyses were carried out for pit slopes from the residual voids of both the Main and East Hill Pit. The remaining structures (HLF, TSF, and numerous water storage dams and Main Pit spillway and flood protection bund) were sectioned using client provided high resolution point cloud data. Analyses were carried out using industry-standard 2D limit equilibrium methods in Slide2 (V9.023) developed by Rocscience.

The generally accepted Factor of Safety (FoS) criterion for geotechnical stability of long-term slopes or residual voids is ≥ 1.5 . The FoS is generally a measure of driving forces versus resisting forces in a system, where a FoS of 1 equates to a 50% probability that failure will occur. FoS values >1 generally indicate that a system is likely to be geotechnically stable. All models were analysed static conditions only (i.e., no earthquake loading).

The PRCP Guideline generally specifies that the residual void and surrounding landforms must be geotechnically and geochemically stable and consider the effects of long-term erosion and weathering of the slopes (Department of Environment and Science [DES], 2019).

For all slope stability cases, except for the submerged in-pit dumped materials in the Main Pit, the results of the limit equilibrium analyses indicate long-term stable slopes within the current landform, based on the assumptions.

Detailed rock mass defect information for the pit slopes was not available at the time of modelling, the influence of which could change the outcome of the analysis if kinematic failure mechanisms are identified. Further assessment of rock mass structure and pit slope defects should be carried out where possible prior to closure.

It can be concluded for the Main Pit, East Hill Pit, TSF and various water storage dams the geotechnical assessment and analyses that:

- The proposed final landform exceeds the minimum FoS of 1.5 for long-term stability, based on the assumptions, and is therefore acceptable from a geotechnical perspective;
- The final pit slopes were assessed to be geotechnically stable against large-scale failure, based on the assumptions, and scenarios examined. Localised instability can occur where geological structures daylight on the pit face and form geometries that are kinematically unstable. This has not been evaluated as part of this assessment; however, these failures may occur as the pit slopes erode; and
- The downstream slope of the TSF, TRWD, RWD and MWD embankments were assessed to be geotechnically stable, based on the assumptions, and scenarios examined.

It can also be concluded that the HLF from the geotechnical assessment and analyses that:

- At the current angle of repose, the slopes failed to meet the minimum FoS of ≥ 1.5 which is reflective of the current slope geometry and of remnant of operations;
- The slopes were generally maintaining a short term FoS of 1.2, consistent with observations of minor failure observed in aerial photographs and digital terrain models; and
- Reprofilng of the HLF slopes to the required 14° (25%) as nominated for closure criteria results in a FoS < 1.5 .

Based on the outcomes of the analyses and assessment presented herein, the following recommendations are proposed:

- Regrade the HLF to 14° (25%), allowing water to shed without facilitating erosion;
- Regrading of the thin Quaternary layer around the pit rim where applicable could be considered to prevent small scale circular failures into the pit void and establish sufficient drainage around the crest area in order to prevent deep gully erosion; and
- Bunds should be designed to accommodate the discharge of surface water during rainfall events to prevent overtopping. In this case, cut-throughs leading to rubble-lined discharge spillways should be installed at regular intervals along the bund;
- To assess the potential for kinematic mechanisms on the pit slopes, carry out opportunistic geological/geotechnical mapping of the pit walls (mainly in East Pit), if practicable; and
- Carry out inspection at closure to confirm final landforms remain geotechnically stable.

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ACRONYMS & ABBREVIATIONS

Term	Description
AHD	Australian Height Datum
BHWE	Base of Weathering
BMS	Blackrock Mining Solutions
DTM	Digital Terrain Model
FoS	GLE, Morgenstern-Price Factor of Safety
GLE	General Limit Equilibrium Method
GSI	Geological Strength Index
GSQ	Geological Survey of Queensland
HLF	Heap Leach Facility
MWD	Mine Water Dam
NAF	Non Acid Forming waste rock
WRD	Waste Rock Dump
RWD	Raw Water Dam
TRWD	Tailings Return Water Dam
mbgl	Metres Below Ground Level
PAF	Potentially Acid Forming waste rock
RL	Reduced Level
SWL	Standing Water Level
TSF	Tailings Storage Facility

DISCLAIMER

Subject to the professional standard of care expected of a professional service provider, Blackrock Mining Solutions (Blackrock) has formulated recommendations for review and approval by AARC Pty Ltd (AARC) and GBM Resources Ltd (GBM). The recommendations formulated by Blackrock have been made based on the information provided by and assumptions described. Blackrock assumes no responsibility for undisclosed variations in the geotechnical conditions from those assumed.

The assumptions used by Blackrock to formulate recommendations are subject to approval by GBM and AARC, and that GBM and AARC accept full responsibility if these assumptions prove different to what is found at the site due to undisclosed variations in ground conditions beyond those assumed.

We expect that should Project personnel disagree with any of these assumptions, or become aware of any additional relevant information, GBM and AARC will promptly notify Blackrock, to enable the conclusions and recommendations to be revised accordingly.

1 INTRODUCTION

At the request of AARC Environmental Solutions Pty Ltd (AARC), a geotechnical assessment was carried out by Blackrock Mining Solutions (Blackrock) for the Yandan Gold Project ('Project') to inform the development of a Progressive Rehabilitation and Closure Plan (PRCP) in accordance with the Department of Environment and Sciences' Guideline – Progressive Rehabilitation and Closure Plans (2019) and Environmental Authority (EA) for the Project.

The assessment was carried out to determine the geotechnical stability of the final landform which includes two final voids - Main Pit and East Hill Pit, Main Pit spillway, heap leach facility (HLF), tailings storage facility (TSF), tailings return water dam (TRWD), raw water dam (RWD) and mine water dam (MWD).

The purpose of the assessment is to identify areas of concern related to long-term geotechnical stability of the final landform, and to provide recommendations for the long-term stability of slopes to meet the final landform design objectives.

A detailed assessment of the Project final landform and residual voids should be completed by a suitably qualified person prior to closure to assess the condition of slopes (i.e. exposed pit slopes, HLF and engineered embankments) and to provide further recommendations on bunding requirements and slope remedial measures, if required, to achieve a long-term, geotechnically stable and non-eroding final landform for the Project.

1.1 Limitations

It should be noted that the geotechnical assessment does not consider future erosional or geomorphological processes that may affect geotechnical stability. An assessment of erosion stability is provided in the Erosion Stability Assessment report prepared by AARC (2024). We would recommend further assessment be carried out if any significant change to the final landform occurs in the future.

2 SCOPE OF WORK

The following scope of work was completed to achieve project outcomes:

- Review of existing geological and groundwater datasets for the Project area, reports, and regional geology;
- Development of two-dimensional slope stability models through the open pit voids, HLF, TSF and various water storage embankments with the application of appropriate shear strength parameters and groundwater assumptions;
- Slope stability modelling of final landforms to examine failure modes, to identify areas of potential geotechnical risk, and to develop appropriate slope design criteria for long-term geotechnical stability, based on the assumed/derived parameters; and
- Provision of recommendations for long-term, geotechnically stable and non-eroding final landforms as required by the Project EIS Terms of Reference and the *Guideline - Progressive Rehabilitation and Closure Plans (PRC Plans)*.

3 SITE DESCRIPTION

The Yandan Gold Project located approximately 155 km south of Charters Towers, Queensland (approximate co-ordinates in GDA94 Z55). The Project has multiple mine related structures over an area approximately 5 km long by 2 km wide. The mine site occupies an area east of the confluence of the Suttor River and Yandan Creek.

The mine site is approximately 20 m higher than the surrounding undulating terrain (known as the Anakie High), with flatter floodplains along the Suttor River at approximately 165 m AHD and higher relief terrain to the east up to 200 m AHD.

The Project consists of multiple mine related structures which include the Main Pit void, East Hill Pit void, Tailings Storage Facility (Cell A and B), and various water storage reservoirs with engineered embankments Figure 3-1.

The following sub-sections refer to Figure 3-1.

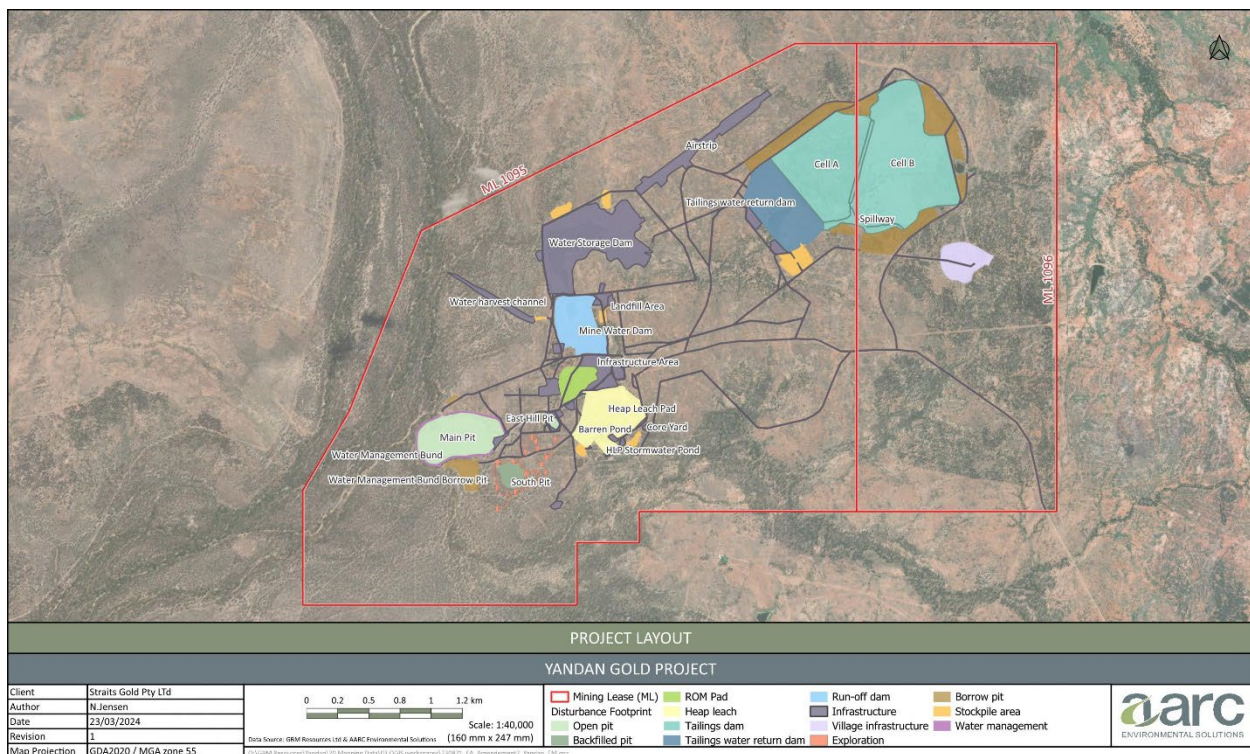


Figure 3-1: Yandan Gold Project - Relevant Landforms

3.1 Main Pit Void

The Main Pit void is approximately 720 m long x 350 m wide and 60 mbgl, as determined by the model data supplied.

In Quaternary and weathered horizons which are 1 – 4 m thick, batter slopes are approximately 30°. Below the Quaternary, cut slopes were assumed to be between approximately 50° and 80°, the majority of which are currently below the current standing water level in the pit, therefore are not

able to be observed. This assumption was based on historical photos from the reports completed by SRK 1999 and PSM 2021.

The pit walls generally comprise St Anns Formation metasedimentary units of varying physical and chemical characteristics, such as weathering, oxidation, and fault controlled/epithermal alteration halo zones of clay, silica, carbonate and sulphide combinations, as indicated from the pit geological maps.

Most rehabilitation works for Main Pit were completed following the decommissioning of the pit in 1999. Prior to flooding the pit, sulphide material in the pit was dozed flat, treated with lime at a rate of 1 kg/m² and capped with compacted oxide material (Ross Mining 2000) at a minimum depth of 0.3 m (SRK Consulting 1999). A water layer was established during the 1999/2000 wet season (Ross Mining 2000). Based on the recent digital elevation model (DEM), the Main Pit appears to be currently inundated close to crest level, with the Main Pit Level logger recording a depth of 162.21 m AHD on the 13/02/2024.

3.2 Main Pit Spillway (s) and Flood Protection Bund

The Suttor River flows northward adjacent to the western boundary of the Main Pit and regularly inundates the Main Pit void. Two spillways located on the north and southeast embankments control the outflow of flood water from the void both spilling at approximately 169.05m AHD.

A flood protection embankment (3 – 4 m high) surrounds the southern and western portions of the Main Pit, originally constructed as a temporary measure for protection during mining, was relied upon to slow the release of contaminated floodwater to the Suttor River after flooding. An assessment by See Built Earth (SBE) in 2022 indicated that this bund could be removed.

3.3 East Hill Pit Void

The Yandan East Hill Pit void is approximately 100 m long, 60 m wide and 26 mbgl with the model data provided (Figure 3-1). The pit walls comprise predominantly andesite volcanics, fault-contacted with St Anns formation sediments that have fault-controlled epithermal alteration halo zones of clay, silica, and sulphide combinations.

Cut slopes in the St Anns Formation and in the andesite are estimated from the geological model to be approximately 70° in both fresh andesite and 60° in St Anns Formation.

The current pit shape was triangulated from LiDAR point cloud data, the East Pit water level logger recorded a standing water depth on the pit floor at 163.64 m AHD (13/02/2024). Although the void below the water surface could not be modelled from data, based on the narrow void width, that the floor would be just below the water surface. No catch benches were evident from the pit shell in the upper 26 m of the pit.

3.4 Heap Leach Facility (HLF)

The HLF is located 1.2 km west of the Main Pit and has an approximate footprint area 550 m by 450 m and is approximately 36 m high. The HLF appears built in three lifts approximately: 14 m for the bottom lift, 13 m for the section lift and 23 m for the upper lift for a total height of approximately 36 m. In some locations, the first and second lift form a single batter slope with a height of 27 m. The final slope angles for the HLF are between 31° and 38°, which is approximately angle of repose. The HLF geometry was triangulated from LiDAR point cloud data set.

3.5 Tailings Storage Facility (TSF)

The TSF is located approximately 3.5 km NE of the Main Pit void and is made up of cells A and B. Cell A has a triangular surface area approximately 900 m long by 700 m wide and appears in an advanced state of revegetation. However, it is noted that Cell A will undergo reparation activities as outlined in the Project PRCP.

Cell A is bounded by two significant embankments, the main SW embankment is approximately 12 m high and 530 m long and closes out a small valley between two ridges in the natural landform. The NW embankment is approximately 3 m high and 575 m long and appears to be built along (and raising the height of) one of the natural ridge lines.

Cell B built contiguous with Cell A, is also triangular shaped and has an approximate coverage of 1200 m x 800 m. A single embankment raise, approximately 4.5 m high, retains tailings on the southwest boundary and multiple smaller embankments generally less than 3 m high confine the remainder of the compartment. Significantly less vegetative regrowth is observed from aerial photos when compared to Cell A.

It is not known if the tailings are currently saturated at depth.

3.6 Tailings Return Water Dam (TRWD)

The TRWD is located 340 m due west and downstream of the TSF southwestern embankment. The dam is approximately 500 m long and 8 m high, bridging the valley between two natural ridges in the landform. A spillway is located on the southern wall section with spill height of approximately 183 m AHD.

3.7 Raw Water Dam

A raw water dam operates approximately 2 km west and downstream of the Main (Cell A) tailings embankment and 1.7 km west and downstream of the TRWD. The raw water dam trends north to south and blockades the valley formed between two natural landform ridges. The dam embankment is approximately 7.5 m high maximum by 560 m long (including a 30 to 35 m long plastic lined spillway on its southern section). The spillway is designed to spill at 174 m RL.

3.8 Mine Water Dam

The mine water dam located approximately 800 m north of both the Heap Leach and East Hill Pit is made up of a single elbow bent 600 m length of embankment, up to 8.7 m high. The structure encompasses a slight valley in the landscape enclosing an area approximately 250 m².

4 GEOLOGY

Regional scale geology of the Yandan deposit is shown in Figure 4-1 (GBM 2022).

The Yandan deposit is hosted in a downfaulted block of Lower St. Anns Formation sediments, bounded by ENE and NNW-striking faults. The sediments comprise regular thick limestone interbedded with arenaceous and tuffaceous units, some of which have been subject to low grade metamorphism. The sediments contain an abundance of carbonaceous and siliceous material (Doherty 1997a, b).

Within the sedimentary block, the geological structure is dominated by a series of closely spaced E-W to ENE subvertical faults. The two most significant structures, the Yandan Feeder Zone and the Stage 3 Feeder Zone, are believed to be the main controls on mineralization. Breccias are associated with the two feeder zones but whether these are tectonic or sedimentary in origin is unclear.

A review of the Main Pit geology indicated that the wall rocks could be categorised according to alteration into six major groups (Straits 2013). The alteration types and extent within the Main Pit are shown in Figure 4-3, and are summarised below.

Yandan Main Pit geology is comprised of:

1. Weathered horizon;
2. Siliceous oxide;
3. Siliceous sulphide (moderate to strong);
4. Siliceous carbonate;
5. St Anns sedimentary units;
6. Moderate to strong siliceous and sulphide; and
7. Altered oxide/clay.

Additional to the 6 lithotypes, in pit dumps of sulphide waste and oxide waste were also noted. The weathered horizon is assumed to extend up to approximately 30 m thick.

The East Hill Pit is constrained to the northeast by the Yandan East Fault, which strikes approximately north-south. It should be noted that there was no digital geological data recorded for the East Hill Pit. In this case, only hard copy mapping information was used to develop assumptions about geological structure and geological domains.

Based on the mapping information supplied, the East Hill Pit geology varies to that of the Main Pit, in that andesite volcanics dominate the southern wall faces and is fault-contacted with St Anns Formation sediments in the northern wall.

A sinter replacement alteration appears to halo the sub vertical fault contact. The mineralisation/alteration zonation dips at approximately 70° toward the south and is thought to approximate the steeply dipping alteration and sulphide mineralisation mapped in the wall rocks of the Main Pit (Figure 4-3).

The weathered horizon is estimated to extend up to approximately 2 - 4 m thick.

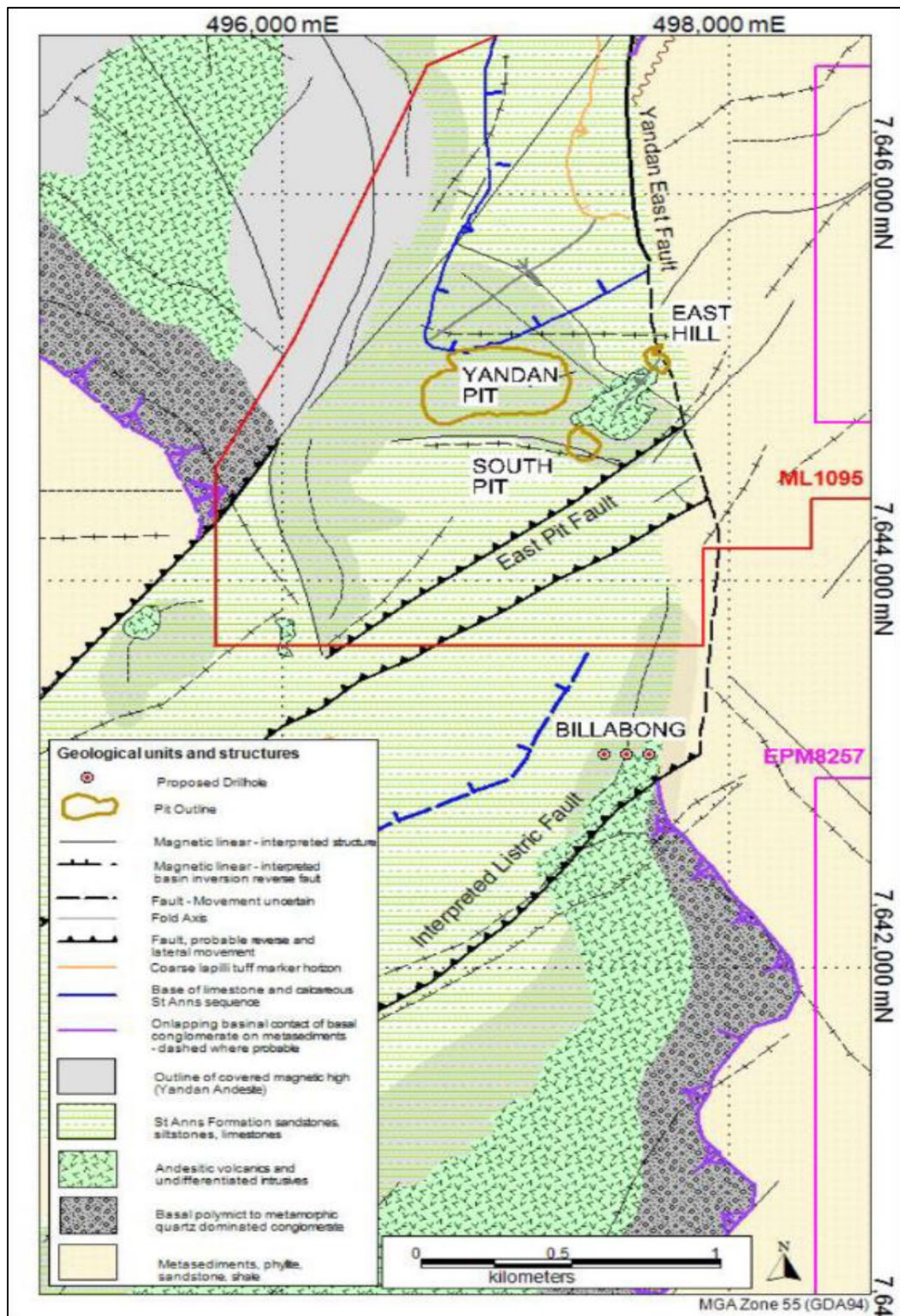


Figure 4-1: Yandan Regional Geology (after GBM 2022)

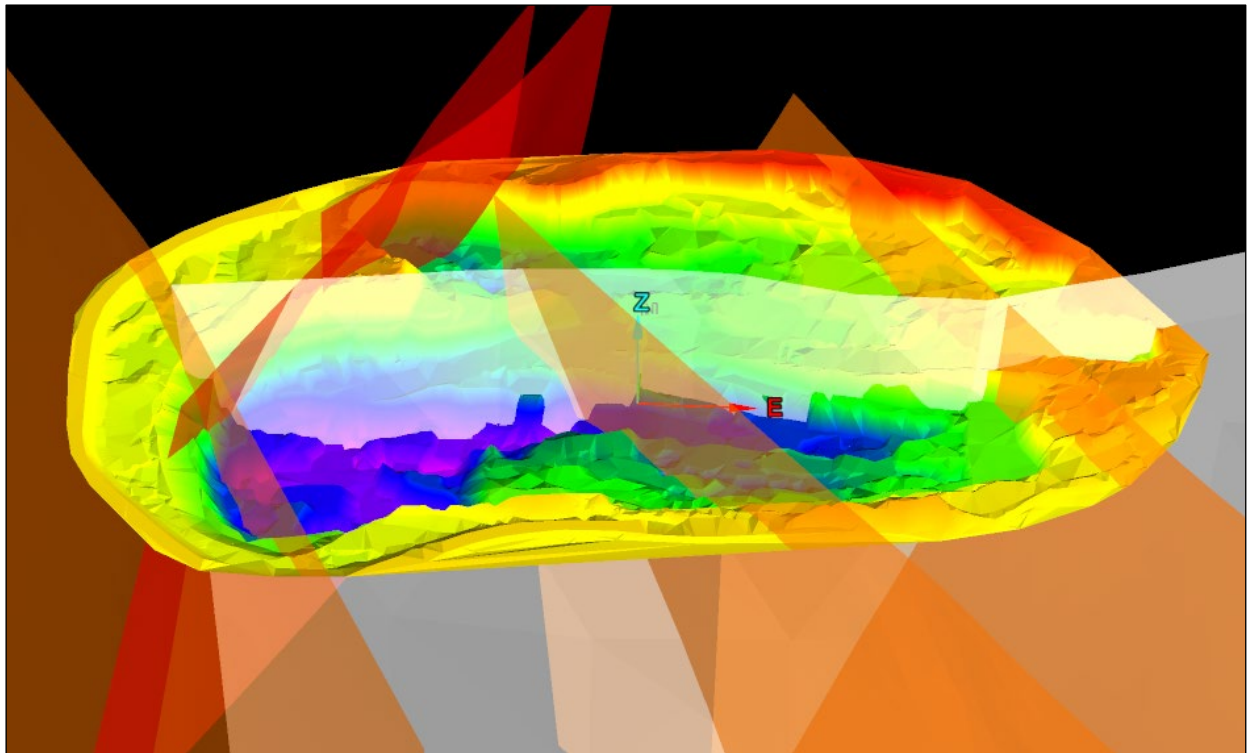


Figure 4-2: Generalised Structural Layout – Main Pit

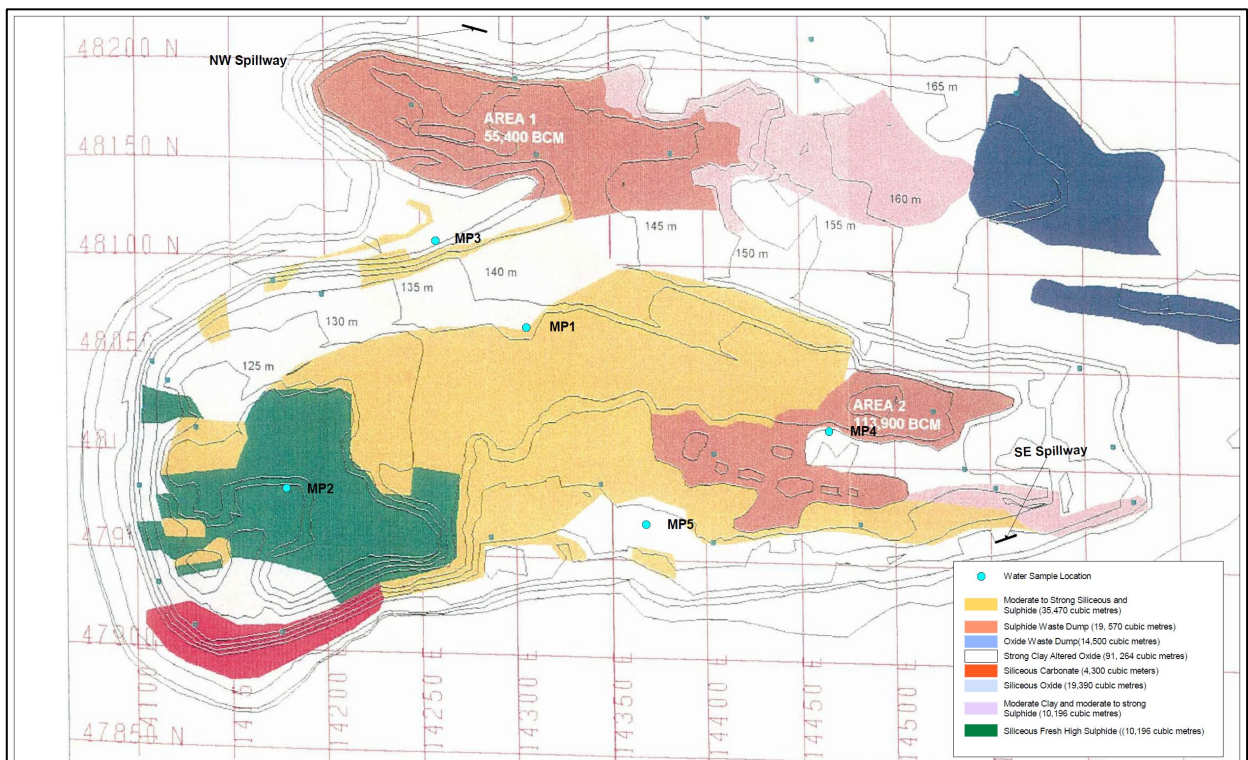


Figure 4-3: Main Pit - Mapped Wall Rock & Waste Rock Dump Location (Straits 2013)

5 OPERATIONAL SLOPE DESIGN

The general slope design criteria for in pit slopes in weathered and unweathered materials are summarised below:

- Berms are designed to specific RL depending on material types of weathering horizon. In this case, a nominal 5 m berm would suffice to accommodate materials from the weathered horizon;
- Batter angles in the weathered horizon typically are generally up to 50°, depending on the geotechnical characteristics;
- Rock batters in fresh would generally be up to 70° (maximum) but cuts have been observed to be as steep as approximately 80°; and
- Bench heights in fresh rock up to 30m (maximum) and in weathered rock up to 20 m (maximum).

To achieve the specified pit slope design, blasting and/or excavator ripping would have been the likely methods to form the pit slopes.

6 LONG TERM GEOTECHNICAL STABILITY – FINAL VOIDS AND LANDFORM

6.1 Progressive Rehabilitation and Closure Plan (PRCP) Compliance – Geotechnical Stability

The PRCP Guideline generally specifies that the residual void and surrounding landforms must be geotechnically and geochemically stable and consider the effects of long-term erosion and weathering of the slopes (Department of Environment and Science [DES], 2019).

Although the requirements for final slopes are not specific in terms of geotechnical design parameters, pit slope designs typical of those used in open cut mining are normally suitable for closure purposes, with remedial modifications sometimes required to achieve long-term stable slopes, particularly in the weathered horizon.

Remedial modifications often involve re-grading the slope to a shallower angle, where practicable, and the establishment of surface water management to reduce the impacts of erosion and water infiltration to the surrounding rock mass.

External dumps (not engineered structures) such as the HLF, are generally constructed in lifts/benches at angle of repose to a maximum lift height of up to 25 m between berms, which is a common industry design for rockfill dumps on flat or gently dipping ground, that would meet typical PRCP requirement for geotechnical stability.

A summary of final landform requirements for geotechnical stability is presented in Table 6-1.

Table 6-1: Proposed Closure Specifications – Open Pit Slopes

Disturbance Type	Proposed Design Criteria
Unweathered Pit Slopes (Competent Rock)	$\leq 70^\circ$ slopes
Weathered Pit Slopes (Incompetent Rock)	$\leq 50^\circ$ slopes
External Dumps/HLF/TSF downstream slopes	$\leq 25\%$ (14°) outer slopes HLF (AARC 2024) $\leq 30\%$ (17°) outer slopes TSF and water storage embankments (AARC 2024)

6.2 Geotechnical Stability – Pit Walls and Spillway(s)

Geotechnical stability in rock slopes is generally controlled by geological structure, as rock material is generally too strong to permit shear failure. Permit shear failure is unlikely for the current Project design for the following reasons:

- Given the thin covering of Quaternary and potential friability of the weathered material across the site, which can extend up to approximately 30 m (combined thickness), these units are unlikely to cause geotechnical instability over the long-term; and
- Rock mass strength failures are unlikely to occur at slope heights below 300 m under normal conditions (Simmons, 1995). Given maximum slope heights are typically > 60 m for both pits, the residual void slopes are likely to be inherently stable from mass failures in the absence of adverse geological structures (i.e., faults or shears) that could interact with the pit slopes.

However, rock mass strength is typically scale-dependent, and if the block size produced by the discontinuities is small enough compared to the slope height, steep slip pathways could be generated in the batter faces through the intersection of fractures or discontinuities in the rock mass – referred to as kinematic availability. This type of instability is possible on the batter slopes of both the Main Pit and East Hill Pit.

Given Main Pit is a legacy pit, with a water cover capping design for the management of ARD and AMD, assessment of potential kinematic failure mechanisms on the pit slopes cannot be undertaken at this stage. However, it would be possible to investigate the likelihood of these failure mechanisms, as part of periodic inspections of the East Hill Pit slopes to acquire structural geology information and apply a similar likelihood to Main Pit.

6.3 Geotechnical Stability – HLF and Engineered Embankments

6.3.1 Tailings Storage Facility

This impoundment is a homogenous earth fill dam (AGC Woodward-Clyde 1991), constructed using a combination of embankments, and natural features (Ross Mining 1993). In the absence of TSF as constructed records, weathered sedimentary rock spoil within the vicinity of the dam is generally sandy with some clay component.

Without adequate erosion control measures, ageing TSF embankment dump surfaces are likely to be susceptible to erosion from surface run-off with the possibility of loss of fines. Were this to

occur at the Project, this would apply mainly to the downstream face of the TSF embankment. In this instance fines would report to the tailings return water dam catchment and is unlikely to have a significant effect on geotechnical stability. Further, the erosion stability analysis undertaken for the Project indicates that sustainable erosion rates can be achieved with adequate vegetative cover (AARC 2024).

It should be noted that except for the main 12 m high TSF embankment, the remaining embankments heights are very low and are unlikely to present a significant risk from a geotechnical stability perspective.

6.3.2 Heap Leach Facility

The Heap Leach Facility was constructed from low grade oxide materials, interbedded with limestone to lift pH to liberate gold through cyanide leaching (SBE 2022). In the absence of HLF construction records, heap leach material is assumed to be generally granular from mechanical crushing with moderate clay and fines components from time dependent degradation.

Without adequate vegetation cover, ageing HLF surfaces are likely to be susceptible to erosion from surface run-off with a possibility of loss of fines. In this case, fines would report to the bunded catchment surrounding the base of the HLF. Larger slumps and rills are possible through the materials, where sufficient height and slope steepness would allow such failure. In this case, material could spill beyond the HLF catchment bund.

6.3.3 Main Pit Flood Protection Bund

The flood protection bund around the Mian Pit was constructed from earthen material from local borrow sources, including the clay core, and rock armour on the embankment face (AECOM 2015).

Instability of the outer face was noted during the 2021 inspection by PSM; however, this was more likely to be related to erosion than geotechnically related.

6.3.4 Environmental Stability – Weathering and Erosion

Quaternary and weathered rock materials will continue to degrade over time via dispersive mechanisms if exposed for extended periods, and eventually form flatter slope angles. This process typically results in the weathered sediments being highly friable and susceptible to erosion due to the alteration of minerals to clay. Surface water drainage is likely to be a key contributor for erosion, particularly in the upper weathered portion of exposed lithologies.

It is generally difficult to ascribe a timeframe for weathering, however, studies carried out at mine sites within the Bowen Basin of Queensland (of similar geology to Yandan) show a possible estimated degradation rate of approximately 40 to 50 millimetres per year (mm/year) on the exposed pit walls, which is equivalent to approximately 1 m every 20 years (Ward, 2016). Overall, these weathering and erosional processes should not prejudice the geotechnical stability of the entire slope.

7 SLOPE STABILITY ASSESSMENT

7.1 Methodology and Assumptions

Geotechnical analyses were carried out for pit slopes from the residual voids of both the Main and East Hill Pit. The remaining structures (HLF, TSF, and numerous water storage dams and Main Pit spillway and flood protection bund) were sectioned using client provided high resolution point cloud data. The point cloud was first contoured into half meter vertical intervals, then triangulated

into a surface and sectioned using Maptek Eureka v2022.2.

Where available, embankment design records were scaled to fit the as embankment profile sections to provide a model of the internal structure for clay core constructed embankments. Embankments/dams greater than 3 m in height were assumed to have been built with a clay core. Embankments/dams below 3 m in height were assumed to be built using a homogenous compacted fill only.

Analyses were carried out using industry-standard 2D limit equilibrium methods in Slide2 (V9.023) developed by Rocscience.

The generally accepted Factor of Safety (FoS) criterion for geotechnical stability of long-term slopes or residual voids is ≥ 1.5 . The FoS is generally a measure of driving forces versus resisting forces in a system, where a FoS of 1 equates to a 50% probability that failure will occur. FoS values >1 generally indicate that a system is likely to be geotechnically stable.

All models were analysed static conditions only (i.e., no earthquake loading).

These were then tested using circular and non-circular failure methods and reported as the Morgenstern – Price General Limit of Equilibrium Factor of Safety (GLE FoS).

7.1.1 Main Pit, Main Pit Spillway and Flood Protection Bund Assumptions

The client provided Main Pit final shell triangulation (yanpittfinal 1298) along with pit wall mapping (Figure 4-3 and Figure 4-4, Section 4) which was used to model and create representative vertical sections of pit slopes in two dimensions.

Whilst wall rock exposure maps were reasonably detailed (refer Figure 4-3, Section 4), assumptions were required as to the structural orientation of alteration halos and mineral zones (assumed similarly replicated to that of the East Hill pit, Figure 4-5). Fault location and geometry were determined from the large-scale structural map (Figure 4-2) additional to client provided fault surface models.

The majority of faults were steeply dipping with no daylighting faces toward the void suggesting these would have little to no impact on overall slope stability. Pit void shape was interpreted to presumably follow encountered geological and geotechnical constraints observed in the regional scale mapping.

Rock mass structural defect data was not available to determine the precise location, orientation, or extent of defects within the pit. It is not known whether structural defects could control slope failure beyond the assumed parameters for intact rock mass strength estimated in this report.

7.1.2 East Hill Pit Assumptions

The client provided large scale cross section showing generalised geology and ore grade in relation to the East Hill Pit (Figure 4-5) was relied upon to determine the location of lithologies and structures within the pit shell. No detailed wall rock mapping or drill hole data was available to accurately ascertain the distribution of rock types within the pit.

No rock mass structural defect data was available to determine whether structural defects could control slope failure beyond the assumed parameters for intact rock mass strength estimated in this report. In-situ intact rock strength parameters were estimated using Generalised Hoek Brown parameters estimated from review of historic wall rock photographs (Figure B 7 to Figure B 12) in conjunction with lithological description. An in-pit water level of 169 m AHD was assumed providing approximately 1m of floor cover that appeared consistent with historic photographs.

7.1.3 Heap Leach Facility Assumptions

The heap leach was assumed constructed on top of altered oxide clay no greater than 12 m thick, with andesite as the underlying bedrock. The siltstones underlying the HLF have a low hydraulic conductivity (SBE 2022).

The sectioned point cloud indicated a slight gentle slope toward the west that could provide a non-circular failure surface which was included in modelling. The stacked material was assumed originally granular from rock crushing of the ore and having a moderate clay alteration because of heap leaching.

7.1.4 Tailings Storage Facility (TSF) Assumptions

For dams and embankments 3 m or higher, cross-sectional profiles were assumed to include a clay core. Embankments below 3 m were constructed with compacted homogeneous engineered fill (Ross Mining 1993). All embankments were assumed keyed into the Quaternary cover. For the purpose of the assessment material contained within the tailing's facility was assumed to be fine grained sandy silt with Cat 1 spoil mass shear strength parameters which is considered consistent with the properties within the Tailings Storage Facility.

7.1.5 Water Storage Dams Assumptions

The water storages were assumed constructed similarly to that of the tailing's embankments using similar fill and construction materials (Ross Mining 1993). As all water storage structures were over 3m tall, they have been modelled with the inclusion of a clay core. Any sediments impounded by the water storages were assumed to have the same material properties as tailings.

7.2 Material Properties

Laboratory or field derived material properties were not available for all final landforms. In this case, these material properties were estimated using a combination of industry standard values assigned to similar material types.

For pit void geological lithotypes, material properties were estimated using two methods:

1. Assigning typical values for similar geological structures from other projects such as weak planes (faults and shears); Table 7-2.
2. Using photographs of documented lithotypes provided in historical reports to estimate the Geological Strength Index (GSI) and subsequent Generalised Hoek Brown parameters. This included estimating:
 - Unconfined compressive strength of intact rock based on provided lithological description;
 - GSI from photographs included in the historical reports;
 - Intact rock material constant 'mi' based on known material types; and
 - Blast disturbance factor for the rock mass on the slope faces.

For weak rock or weathered horizons, HLF dumped materials and materials used for embankment construction, estimated Mohr Coulomb strength values were used, based on experience with similar materials.

Table 7-1 and Table 7-2 summarises the material properties used for the slope stability assessment.

Material Name	Color	Unit Weight (kN/m ³)	Strength Type	Cohesion (kPa)	Phi (°)	UCS (intact) (kPa)	GSI	mi	D	Water Surface	Hu Type
Weathered Horizon		20	Mohr-Coulomb	100	30					Water Table	Automatically Calculated
Andesite Volcanics		24	Generalized Hoek-Brown			175000	55	25	0	Water Table	Automatically Calculated
Altered Oxide/Clay		19	Generalized Hoek-Brown			16000	45	5	0	Water Table	Automatically Calculated
Siliceous Sulphide		21	Generalized Hoek-Brown			35000	30	4	0	Water Table	Automatically Calculated
St Anns Sediments		24	Generalized Hoek-Brown			35000	35	5	0	Water Table	Automatically Calculated
Shears		20	Mohr-Coulomb	0	21					Water Table	Automatically Calculated
Sulphide Waste		23	Mohr-Coulomb	5	25					Water Table	Automatically Calculated

Table 7-1: Assumed Material Properties – Pit Slopes

Material Name	Color	Unit Weight (kN/m ³)	Strength Type	Cohesion (kPa)	Phi (°)	UCS (intact) (kPa)	Parameters vary with depth	GSI	mi	D	Water Surface	Hu Type	Hu
Strong Clay Altered Ox		19	Generalized Hoek-Brown			16000	No	45	5	0	Water Table	Automatically Calculated	
Compacted fill		19	Mohr-Coulomb	100	30						Water Table	Automatically Calculated	
Quaternary		20	Mohr-Coulomb	1	35						Water Table	Custom	1
Clay Core		17	Mohr-Coulomb	50	22						Water Table	Automatically Calculated	
Accumulated fines (Same parameter as Cat 1 Spoil)		20	Mohr-Coulomb	0	18						Water Table	Automatically Calculated	

Table 7-2: Assumed Material Properties – Dams and Embankments

7.3 Analysis Scenarios

Where applicable, single or multiple representative sections of each final landform were examined to assess long term slope stability and potential failure for each of the residual voids and mine site structures.

7.3.1 Main Pit, Main Pit Spillway and Main Pit Flood Protection Bund

The following representative sections were generated through the Main Pit void, spillway and flood protection bund, as shown in Figure 7-1 and Figure 7-2.

- Section 1 – North-south section of the deepest portion of the Main Pit void looking west (Figure 7-3);

- Section 2 – North-south section through the middle of the Main Pit void looking west (Figure 7-4);
- Section 3 – West to east section through the Main Pit void western and deepest wall, looking north (Figure 7-5);
- Section 4 (Spillway) – West to east section through the northern spillway, looking north (Figure 7-6); and
- Section 5 (Main Pit flood protection bund) – Northeast – southwest section through flood protection bund (.

Pit slope stability analyses were carried out for the following scenarios:

- In pit void completely inundated to spillway height;
- Assumed weathered horizon tested for circular failure where applicable; and
- Global slope failure (crest to toe) using non-circular methods.

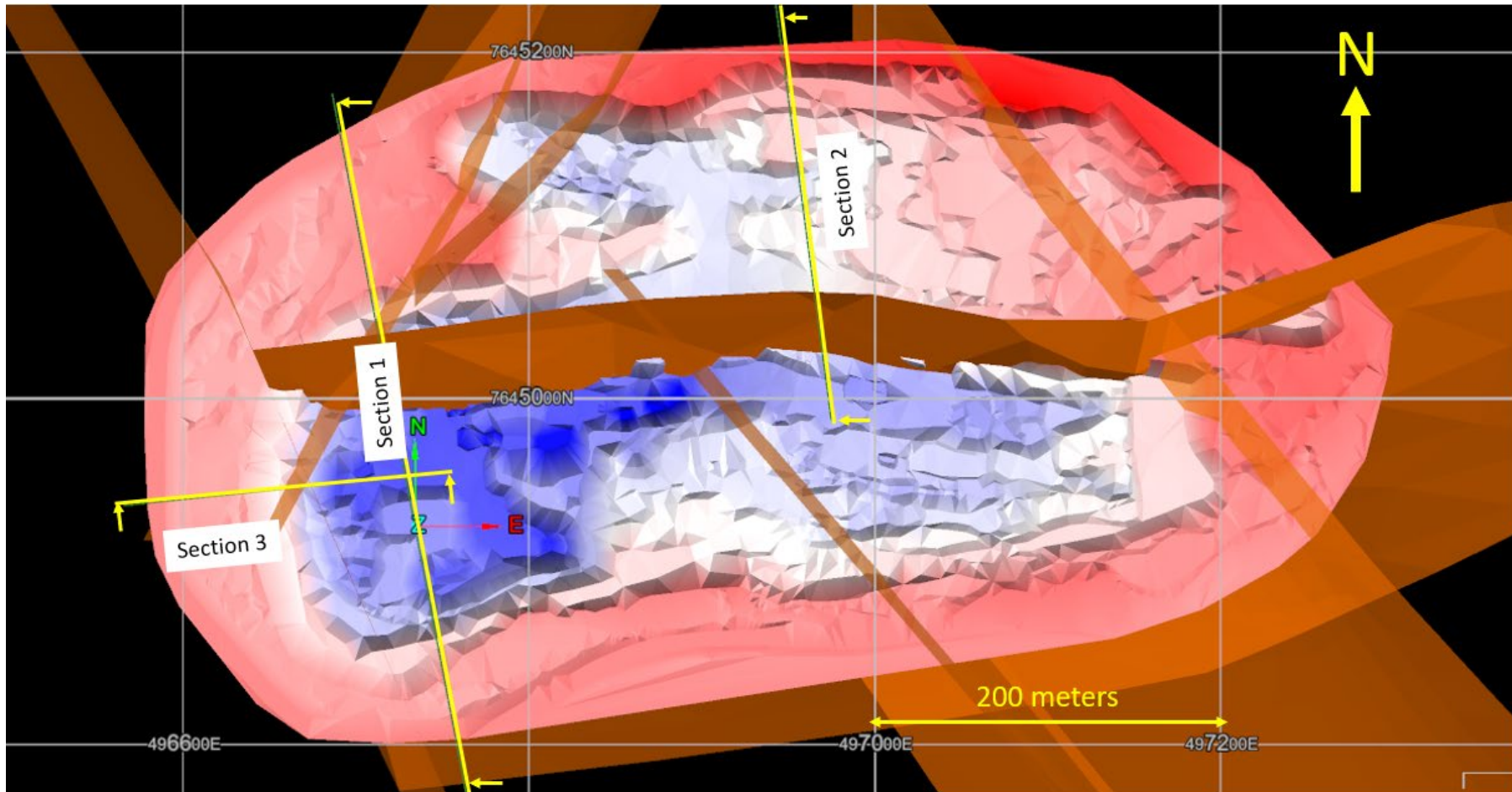


Figure 7-1: Yandan Main Pit – Representative Sections

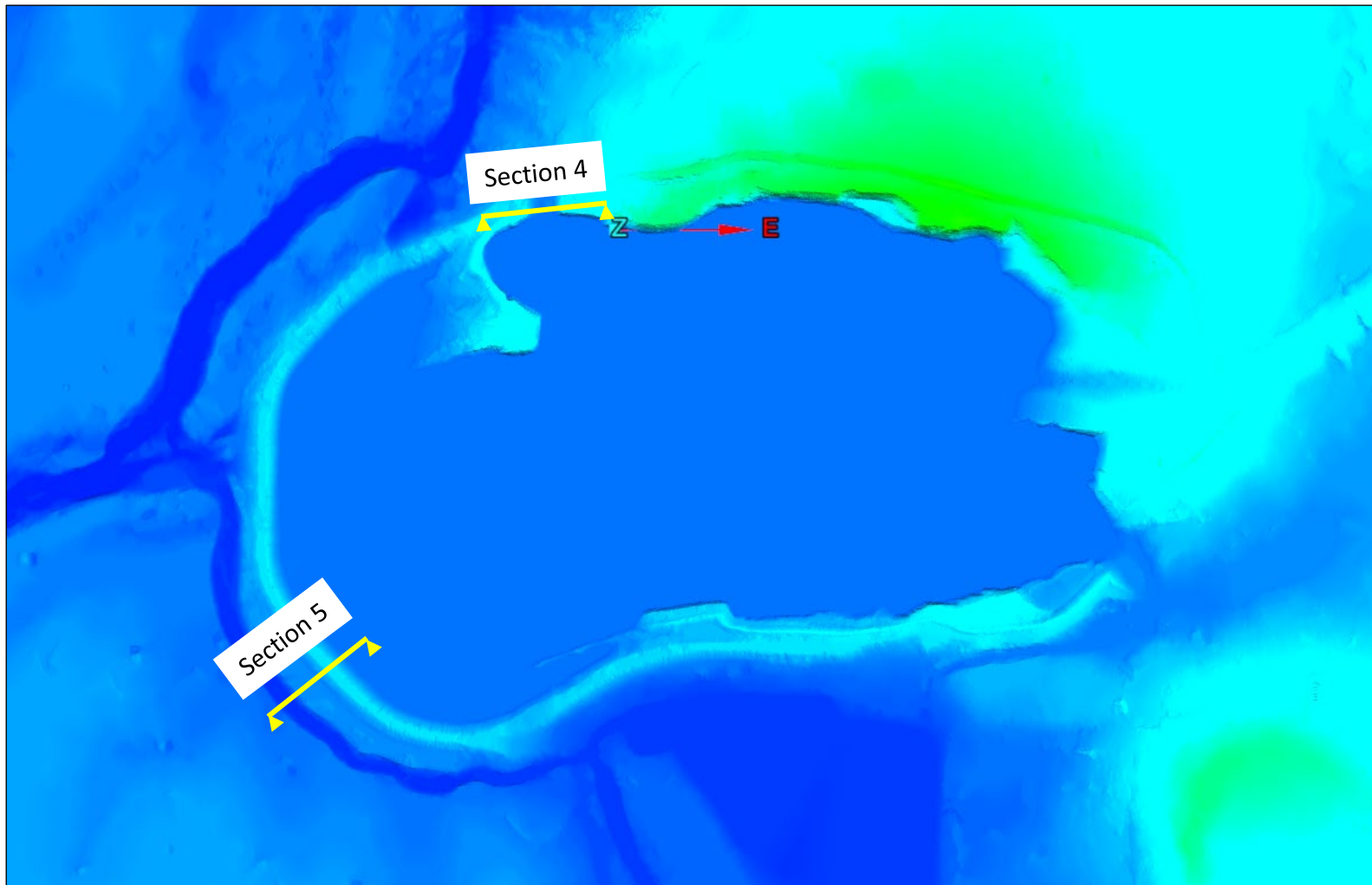


Figure 7-2: Yandan Main Pit Spillway and Flood Protection Bund – Representative Section Locations

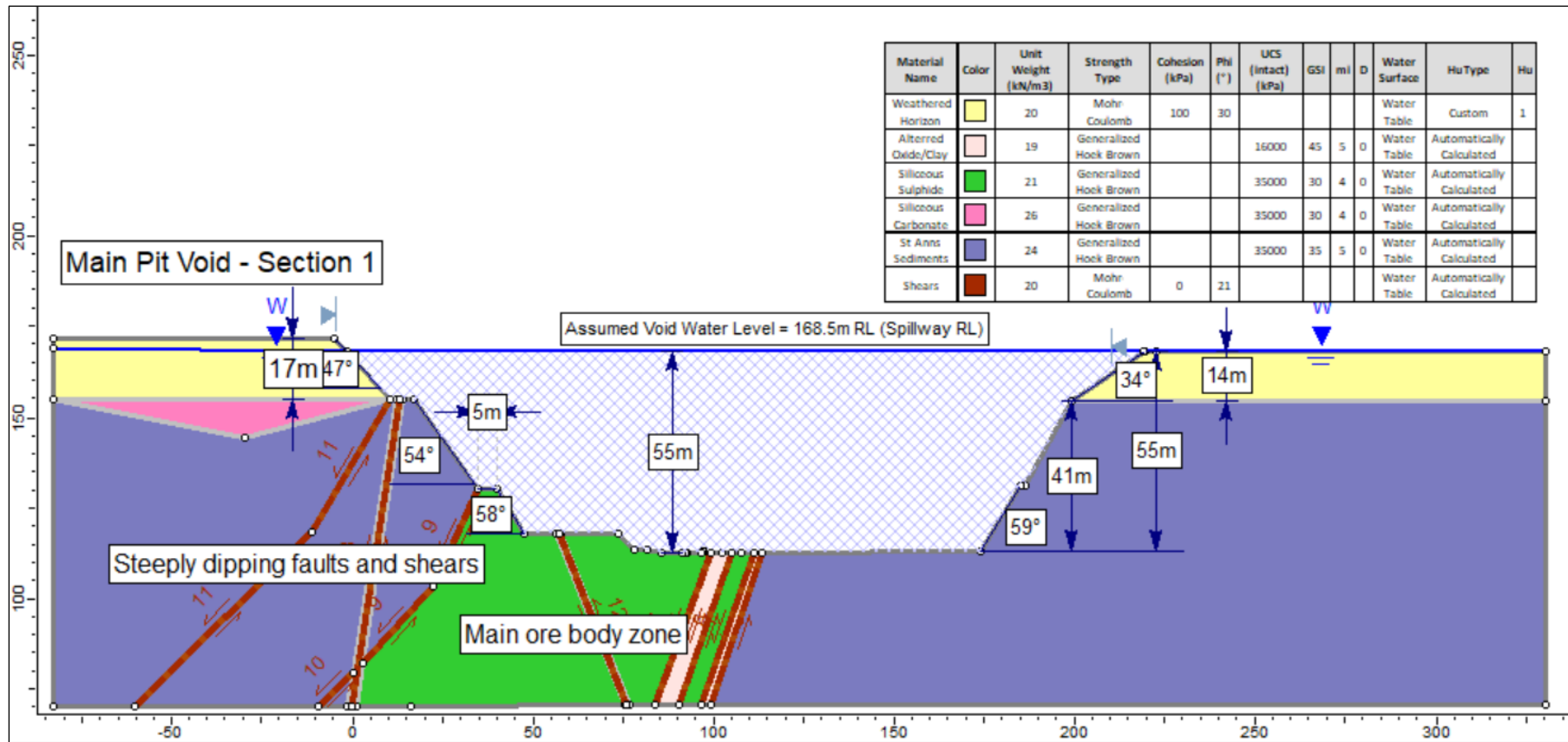


Figure 7-3: Main Pit Void – Section 1 (East Facing)

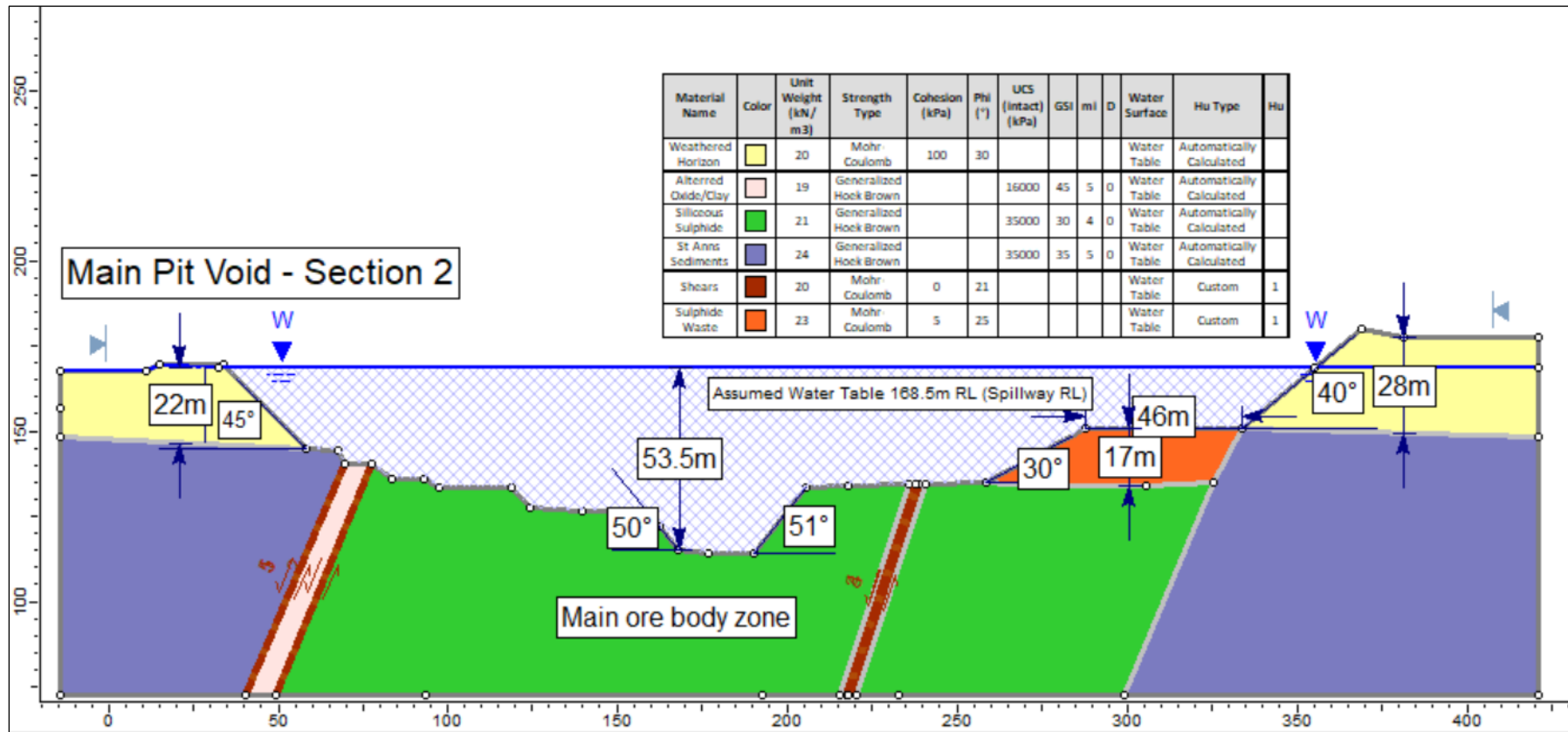


Figure 7-4: Main Pit Void – Section 2 (West Facing)

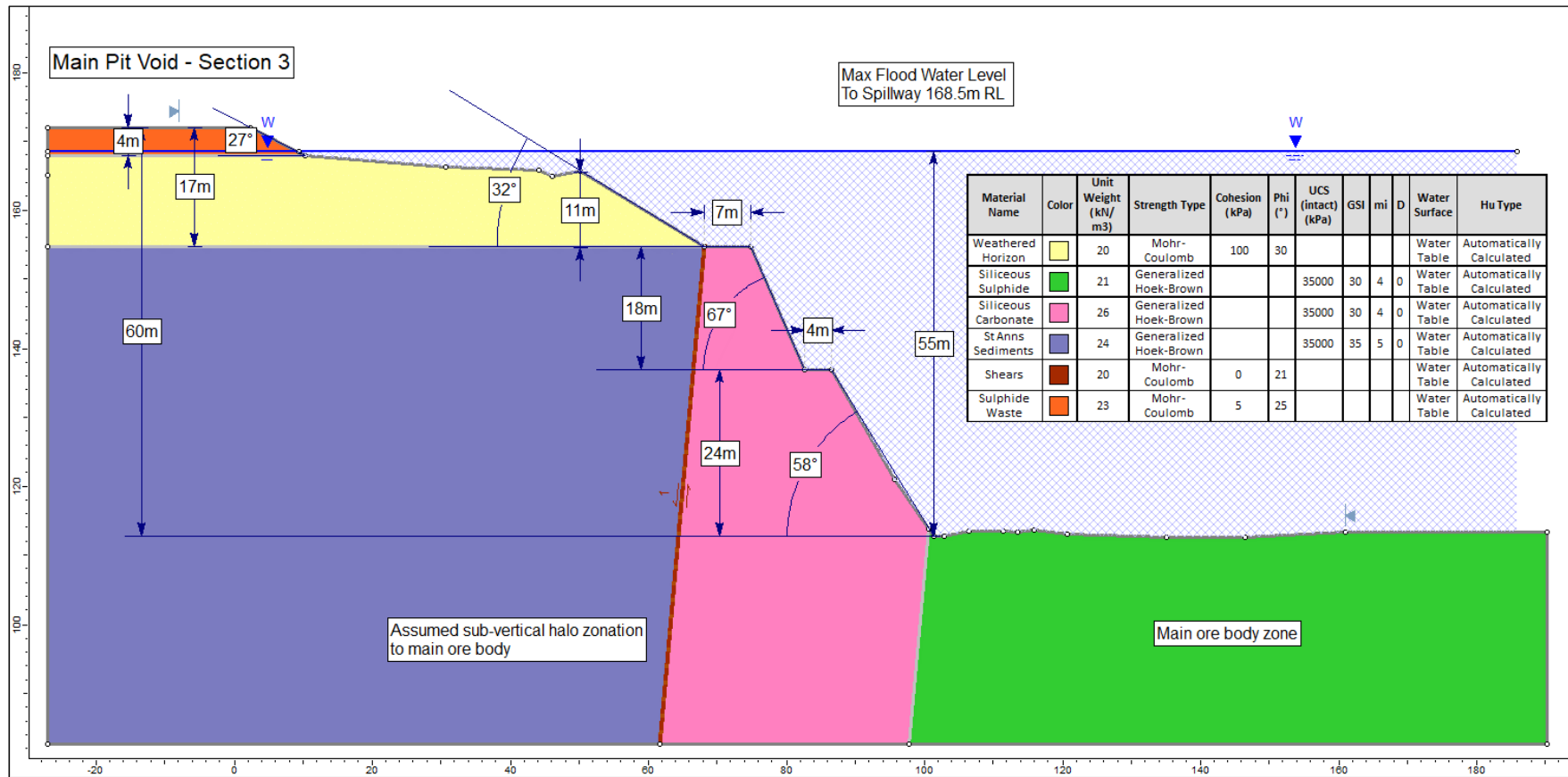


Figure 7-5: Main Pit Void – Section 3 (North Facing)

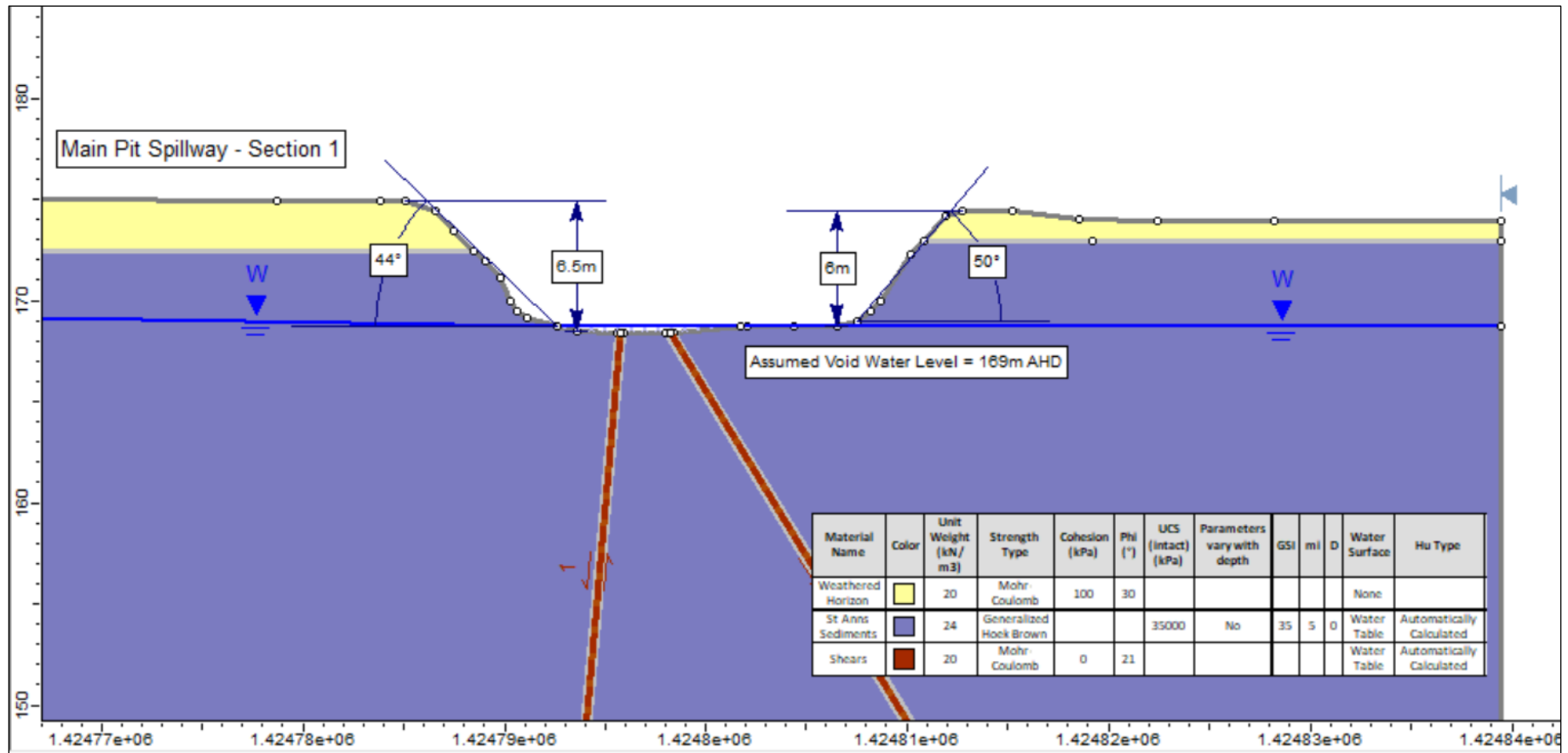


Figure 7-6: Main Pit Spillway – Section 1 (Looking North)

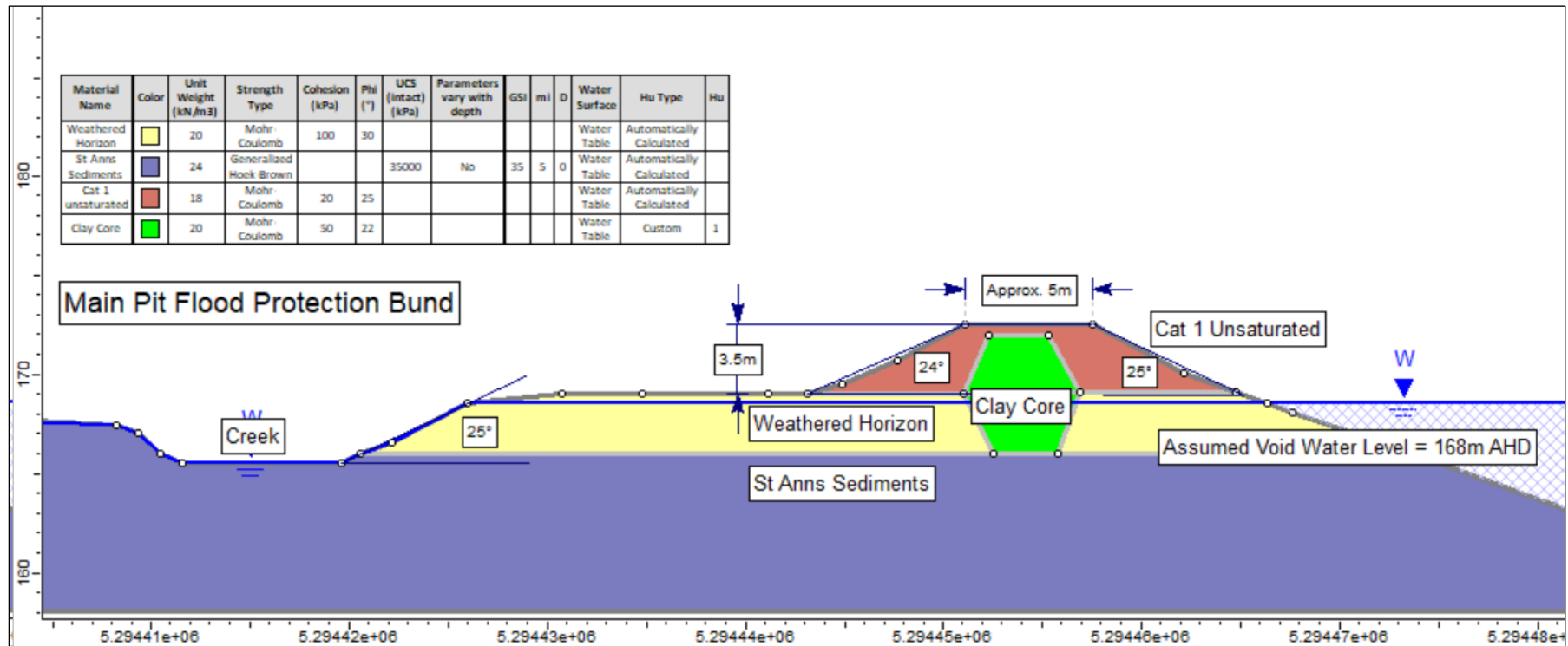


Figure 7-7: Main Pit Bund (Looking Northwest)

7.3.2 East Hill Pit

The following representative sections were generated through the East Hill Pit void, as shown in Figure 7-8.

- Section 1 – Southwest to northeast section through the central region of the Main Pit void looking northwest, as shown in Figure 7-9; and
- Section 2 – South to north section of the steep northern wall, looking west, as shown in Figure 7-10.

Pit slope stability analyses were carried out for the following scenarios:

- Weathered horizon Circular failure; and
- Global non-circular slope failure (crest to toe).

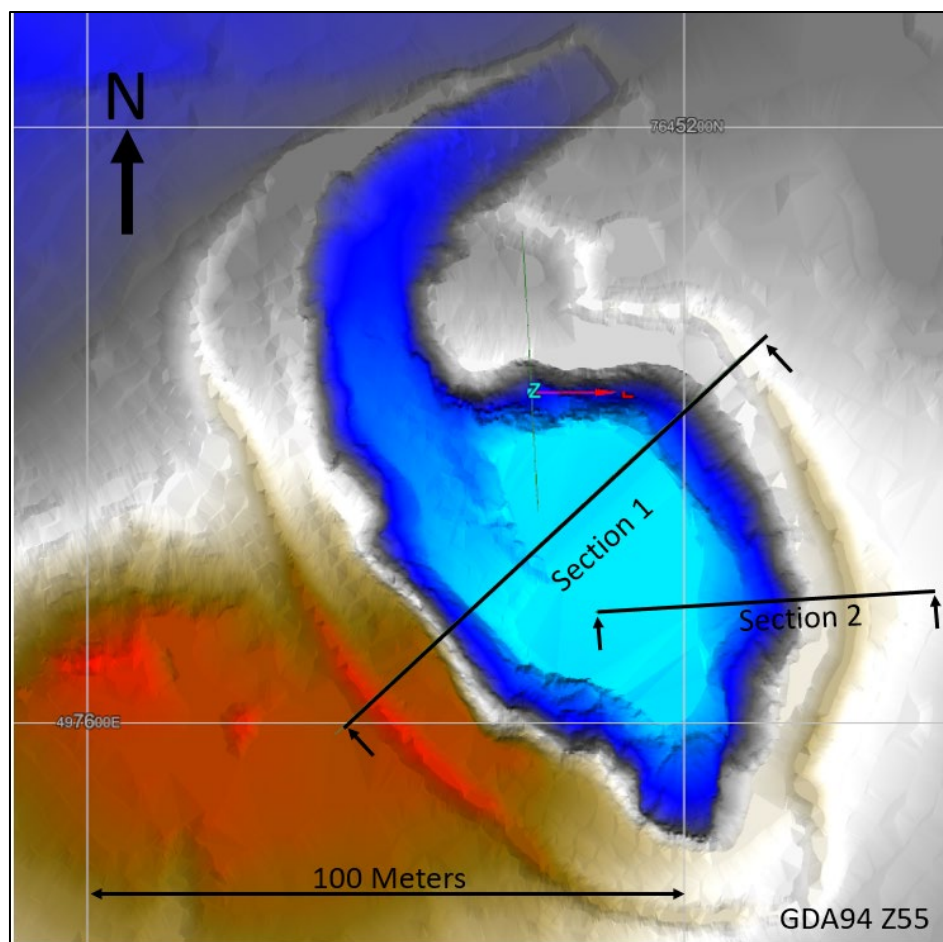


Figure 7-8: East Hill Pit – Representative Sections

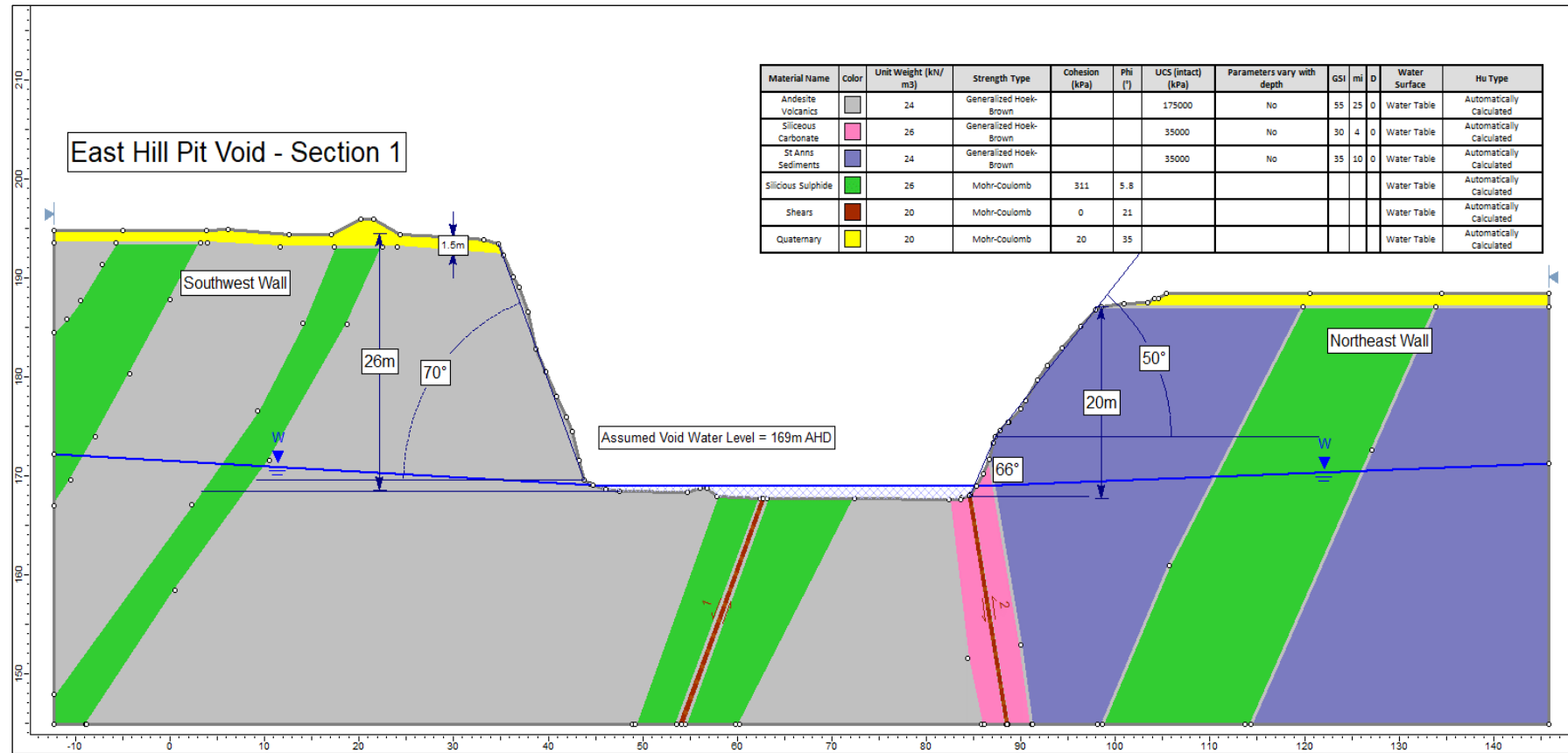


Figure 7-9: East Hill Pit Void – Section 1 (South Facing)

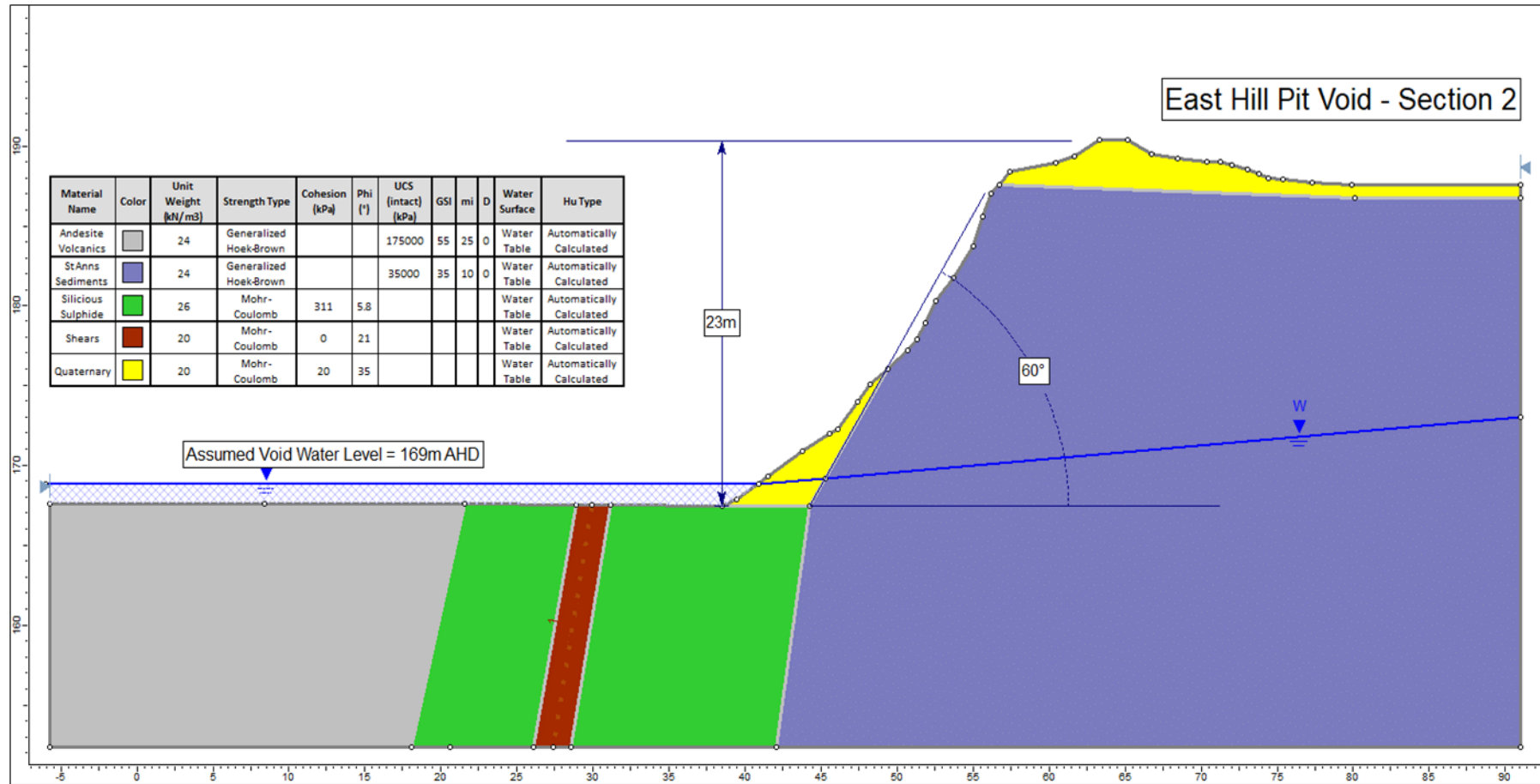


Figure 7-10: East Hill Pit Void – Section 1 (North Facing)

7.3.3 Heap Leach Facility (HLF)

The following representative sections were generated through the HLF as shown in Figure 7-11.

- Section 1 – South to north section through the central region of the HLF looking west, as shown in Figure 7-12, providing both a southern and northern slope profile for slope stability assessment; and
- Section 2 – Southwest to northeast section modelling the steep north-eastern face paralleling an adjacent erosional rill, view looking northwest, as shown in Figure 7-13.

Slope stability analyses were carried out for the following scenarios:

- Global slope failure (crest to toe).
 - Circular Auto Refine
 - Non-Circular Block search for down dipping sloping ground.

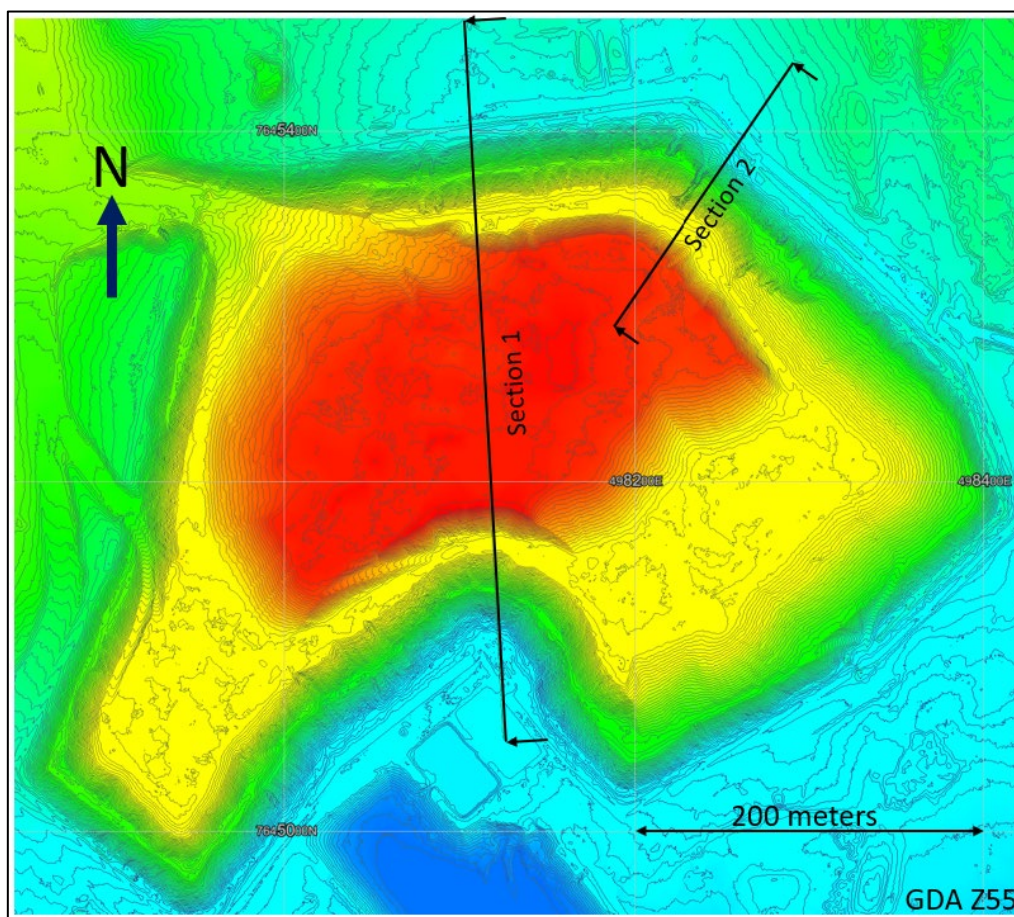


Figure 7-11: HLF Representative Section Locations

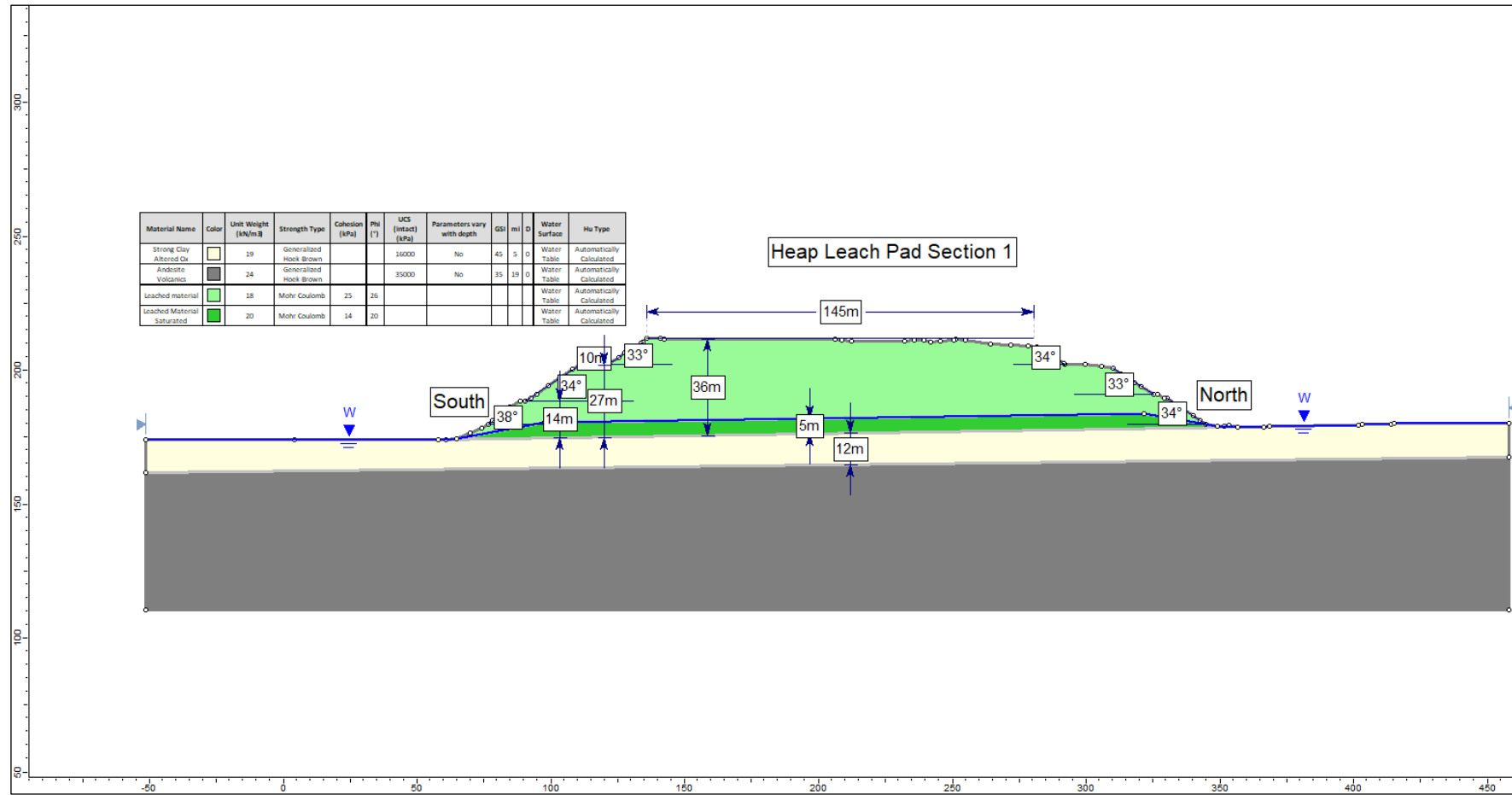


Figure 7-12: Heap Leach Facility – Section 1 (West Facing)

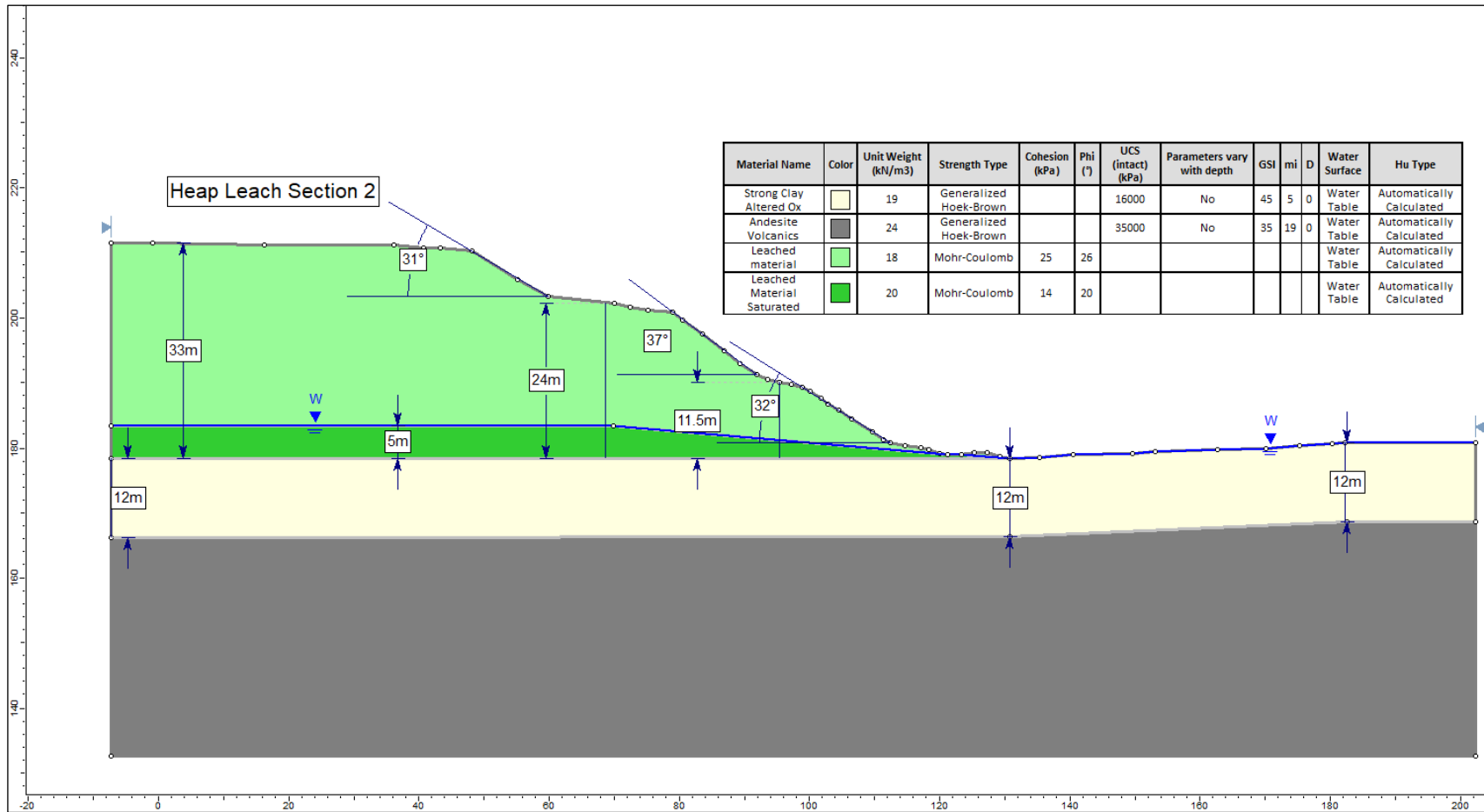


Figure 7-13: Heap Leach Facility – Section 2 (Southwest Facing)

7.3.4 Tailings Storage Facility (TSF)

The following representative sections were generated through the Tailings Storage Facility (TSF), as shown in Figure 7-14. Detail for the upstream portion of the embankments was taken from design supplied by other. The downstream part of the embankment:

- Cell A Section 1 – A south-west to north-east representative section of the main embankment looking north-west, as shown in Figure 7-15;
- Cell A Section 2 – A north-west to south-east representative section of the north-western embankment, viewed looking north-east, as shown in Figure 7-16; and
- Cell B Section 3 – A west to east section through eastern wall, where the embankment has been raised to increase capacity. The lift design was used as template to model the internal structure of the embankment, as shown in Figure 7-17.

Embankment slope stability analyses were carried out for the following scenarios:

- Global slope failure (crest to toe); and
- Ground water raised near surface.

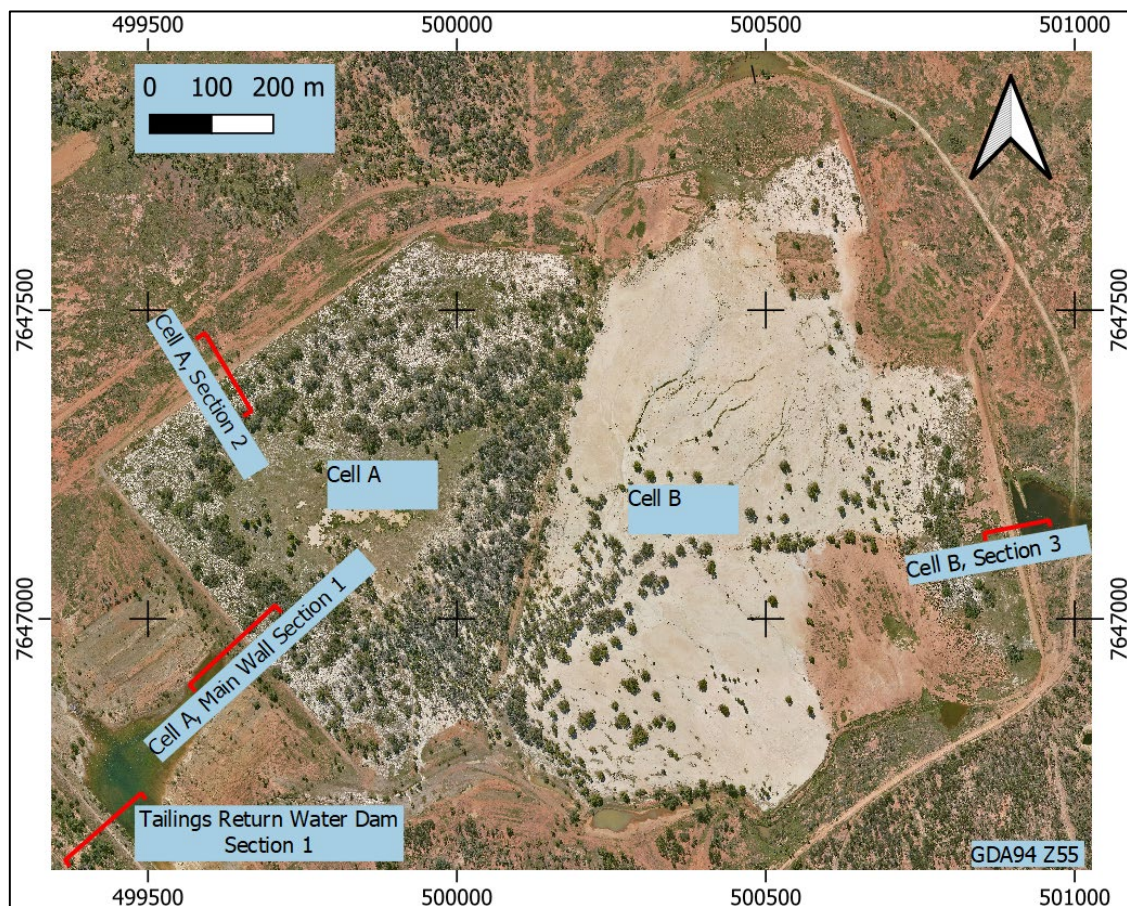


Figure 7-14: Tailings Storage Facility Sections Plan

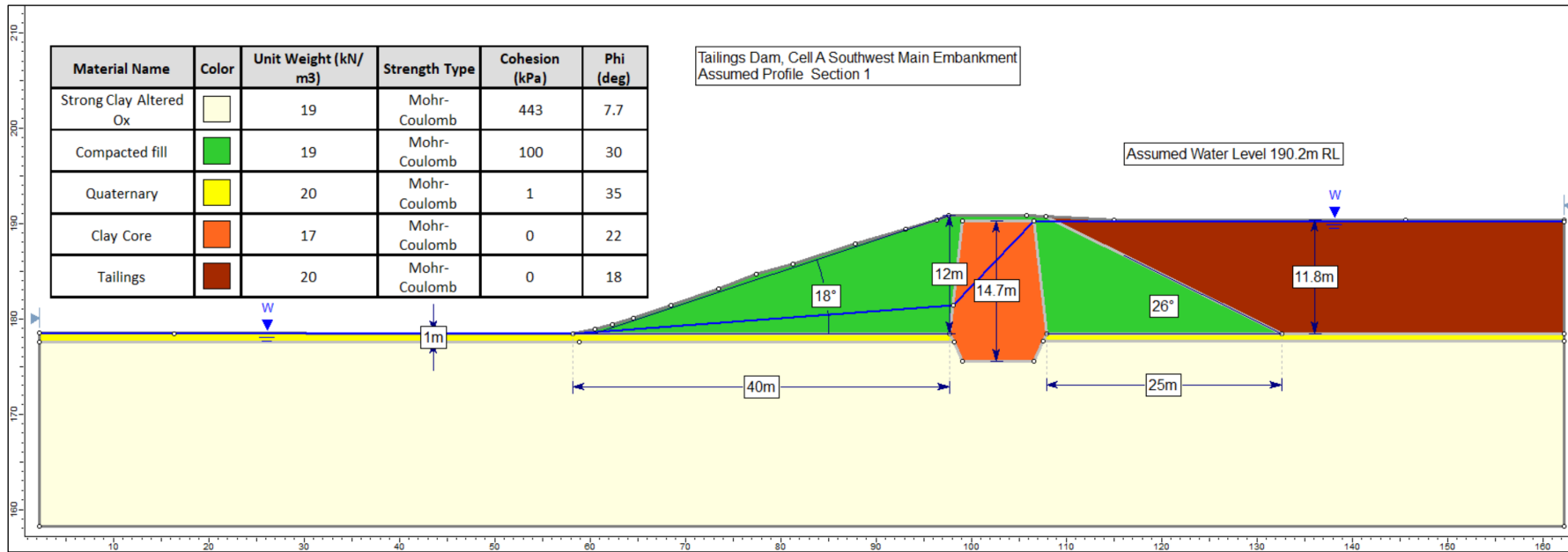


Figure 7-15: Tailings Dam Cell A - Section 1 (Southwest Facing)

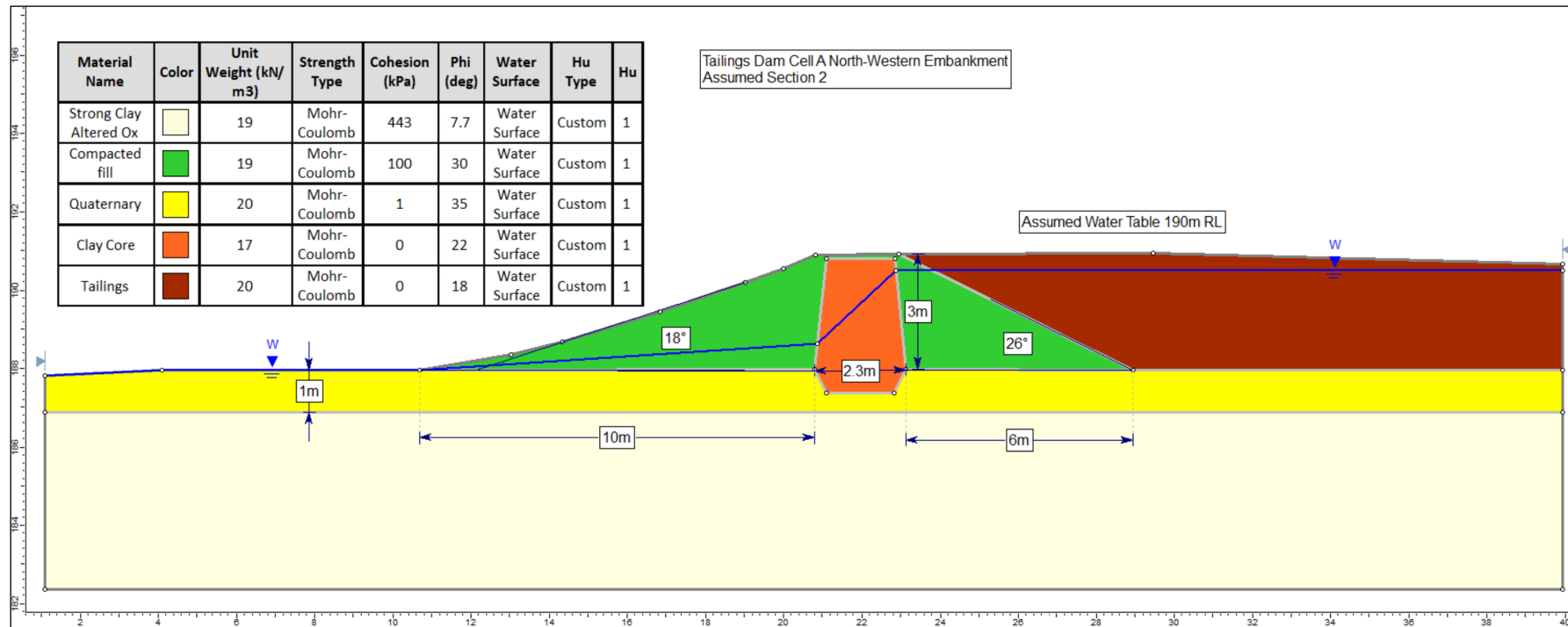


Figure 7-16: Tailings Dam Cell A - Section 2 (Northwest Facing)

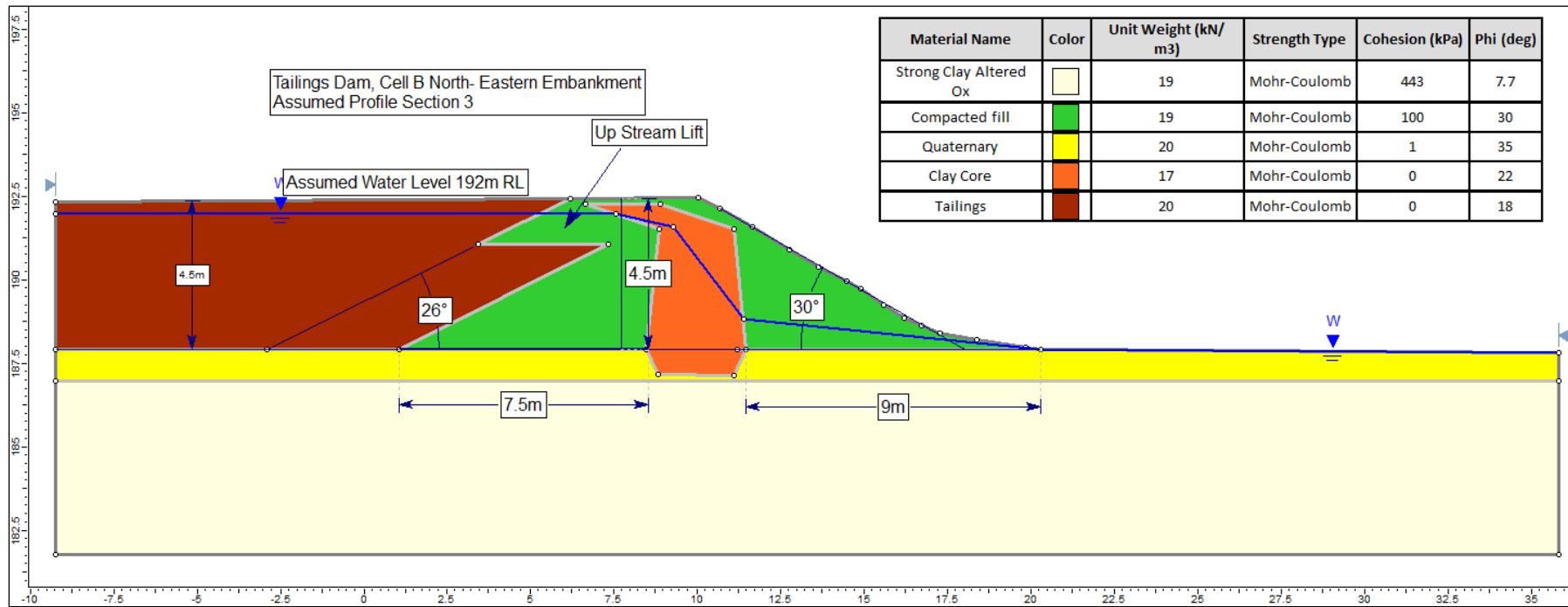


Figure 7-17: Tailings Dam Cell B - Section 3 (Southeast Facing)

7.3.5 Water Storage Representative Limit Equilibrium Sections

The following representative sections were generated through the various Yandan water storage facilities, as located in Figure 7-18.

- A single representative Tailings Return Water Dam section. A south-west to north-east section of the main embankment looking north-west (Figure 7-19);
- A single representative Raw Water Dam section. A west to east section, view looking north (Figure 7-20); and
- A single representative Mine Water Dam section. A west to east section view looking north, through the western limb of embankment. (Figure 7-21).

Embankment slope stability analyses were carried out for the following worst case scenario:

- Impoundment filled to capacity with defining limit being spillway height for the particular structure;
- Impoundment partially filled with sediment where apparent in the digital terrain model; and
- Global slope failure (crest to toe) using circular and non-circular methods.

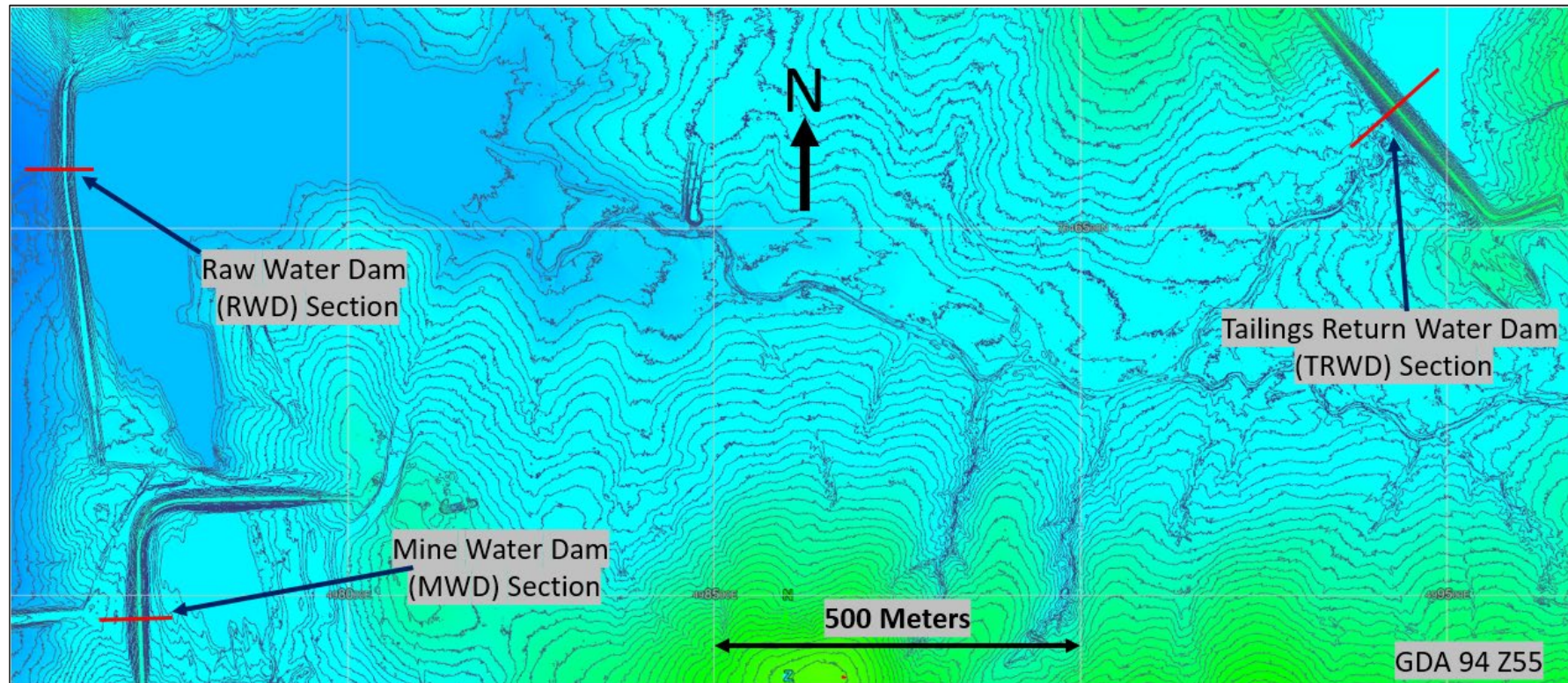


Figure 7-18: Multiple Water Storage Facility Section Locations Plan

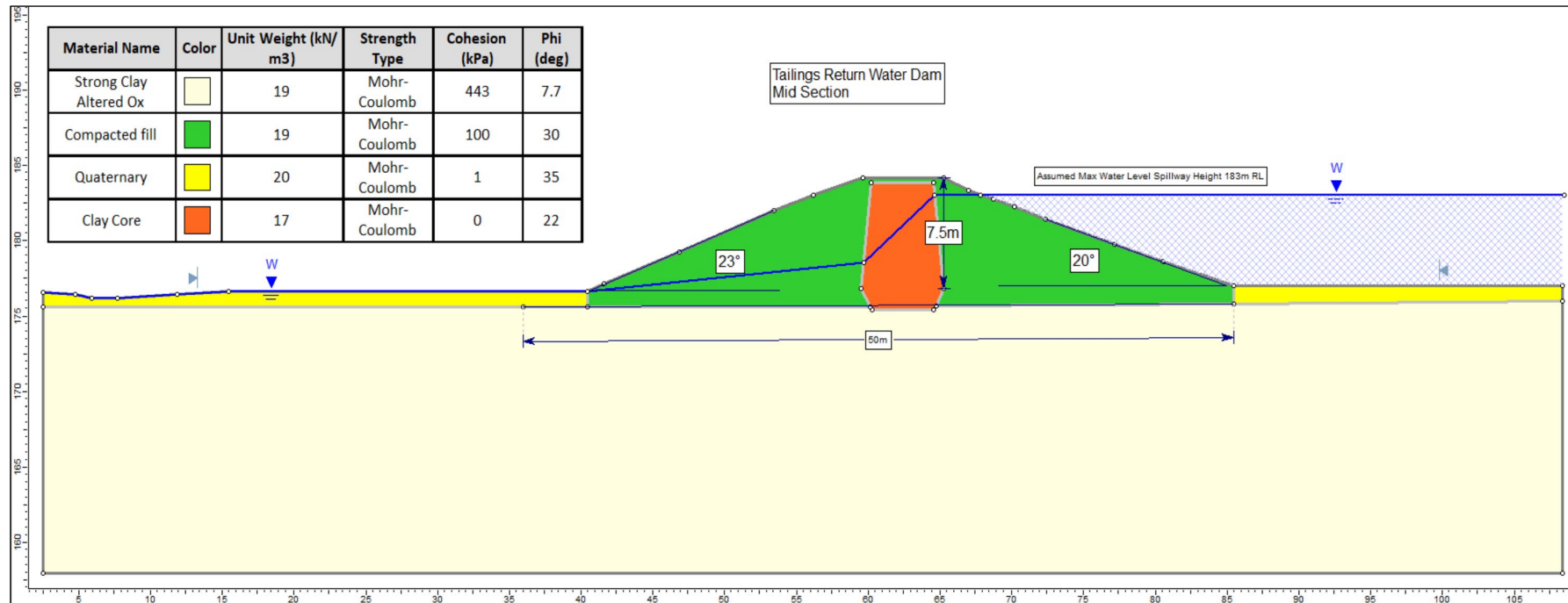


Figure 7-19: Tailings Return Water Dam (TRWD) Section

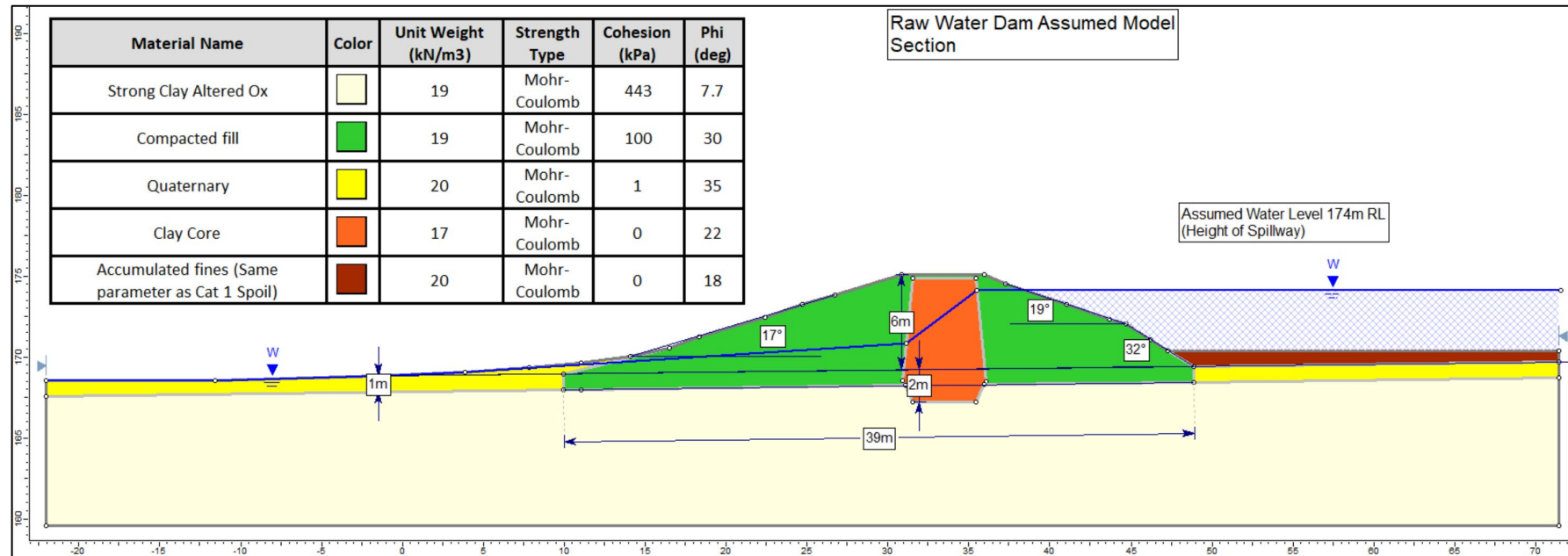


Figure 7-20: Raw Water Dam (RWD) Section

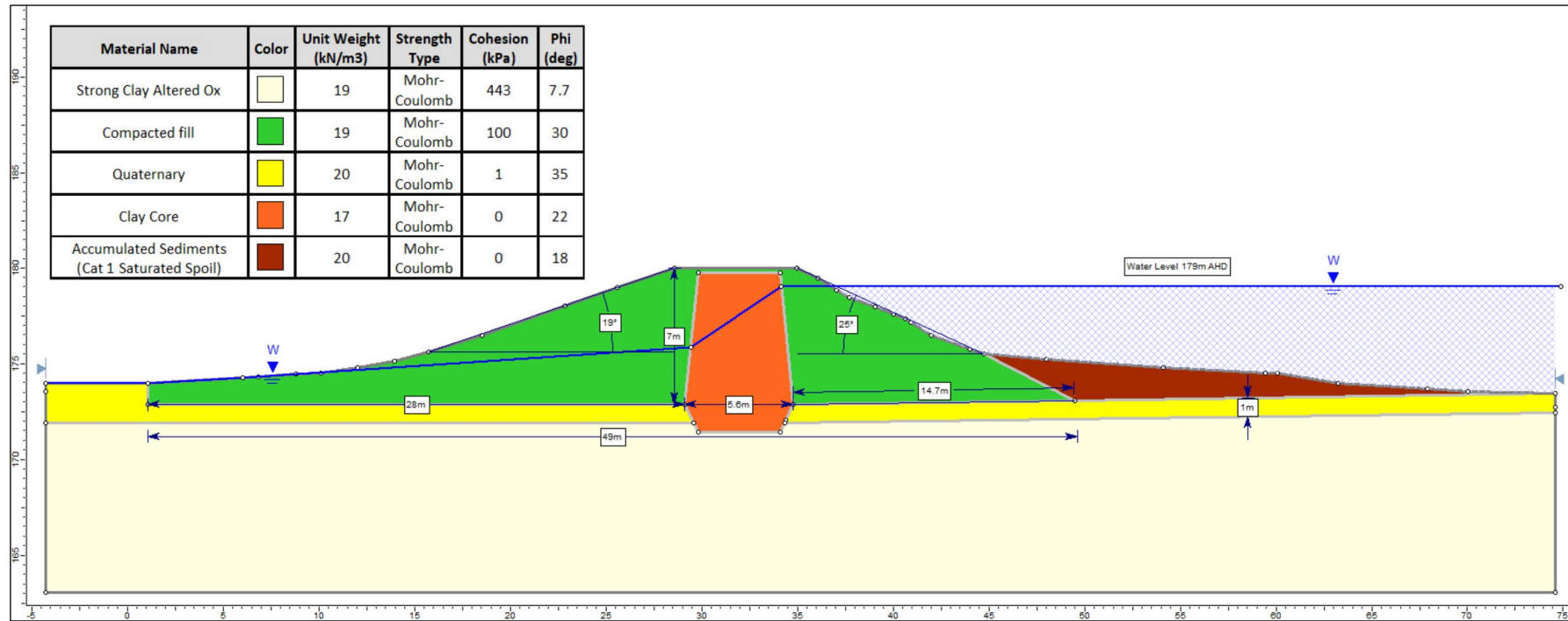


Figure 7-21: Mine Water Dam (MWD) Section

8 2D LE Analysis Results and Discussion

8.1 Main Pit Void Results and Discussion

The results of the Main Pit void slope stability analyses are summarised in Table 8-1. Individual slope stability analyses outputs referenced in the table are presented in Appendix A.

Most slope stability scenarios analysed exceeded the minimum required FoS value for long-term geotechnical stability of 1.5. The scenario that did not meet the requirement was:

1. Failure of the in-pit sulphide backfill in Section 2 which reported a minimum critical FoS of 1.26.

Any failures from this submerged in-pit dump which does not form part of the pit slope would report to the void and do not pose any risk to the overall long term wall stability of the pit. Therefore, the Main Pit void is unlikely to pose a significant long-term slope stability risk, based on the assumptions and analysis methods used.

Table 8-1: Main Pit Limit Equilibrium Analyses Results

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 1	North Slope	Non-Circular - AutoRef	2.64
	South Slope	Non-Circular - AutoRef	2.86
Section 2	North Slope	Non-Circular - AutoRef	3.34
		Non-Circular - Cuckoo	3.35
	South Slope	Non-Circular - AutoRef	1.26
		Non-Circular - Cuckoo	1.26
Section 3	West	Non-Circular - AutoRef	2.32
		Non-Circular - Cuckoo	2.34

8.2 Main Pit Spillway Results and Discussion

The results of the Main Pit spillway slope stability analyses are summarised in Table 8-2. Individual slope stability analyses outputs referenced in the table are presented in Appendix A.

All slope stability scenarios analysed exceeded the minimum required FoS value for long-term geotechnical stability of 1.5, based on the assumptions and analysis methods used.

Table 8-2: Main Pit Spillway Limit Equilibrium Analyses Results

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 4	East Slope	Non-Circular - AutoRef	8.01
	West Slope	Non-Circular - AutoRef	9.23

8.3 Main Pit Flood Protection Bund

The results of the Main Pit flood protection bund slope stability analyses are summarised in Table 8-3. Individual slope stability analyses outputs referenced in the table are presented in Appendix A.

All slope stability scenarios analysed exceeded the minimum required FoS value for long-term geotechnical stability of 1.5, based on the assumptions and analysis methods used.

Table 8-3: Main Pit Floor Protection Bund Limit Equilibrium Analyses Results

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 5	East Slope	Non-Circular - AutoRef	13.72
	West Slope	Non-Circular - AutoRef	10.26

8.4 East Pit Void Results and Discussion

The results of the East Hill Pit void slope stability analyses are summarised in Table 8-4. Individual slope stability analyses outputs referenced in the table are presented in Appendix A.

All slope stability scenarios analysed exceeded the minimum required FoS value for long-term geotechnical stability of 1.5, based on the assumptions and analysis methods used.

Table 8-4: East Hill Pit Limit Equilibrium Analyses Results

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 1	Northeast Slope	Non-Circular - AutoRef	3.35
		Non-Circular - Cuckoo	3.49
	Southwest Slope	Non-Circular - AutoRef	11.43
		Non-Circular - Cuckoo	11.86

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 2	Northeast Slope	Non-Circular - AutoRef	2.80
		Non-Circular - Cuckoo	3.05

8.5 HLF Results and Discussion

The results of the HLF slope stability analyses are summarised in Table 8-5. Individual slope stability analyses outputs referenced in the table are presented in Appendix A.

For the current slope geometries, the analyses indicated that the Section 1 north and south slope scenarios were below the long-term FoS of 1.5. Similarly, the Section 2 northeast slope was below the minimum FoS of 1.5 when using the circular auto refine method.

To achieve the nominated FoS criterion, the heap leach slopes were re-profiled to approximately 14°, based on the slope angles nominated in the PRCP for final landforms. This involved re-grading the HLF batters to a shallower overall slope angle.

Table 8-5: HLF Limit Equilibrium Analyses Results – Current Profile

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 1	North Slope	Circular – AutoRef	1.26
	South Slope	Circular – AutoRef	1.14
		Non-Circular – Block	1.28
Section 2	Northeast Slope	Circular – AutoRef	1.40
		Non-Circular – Block	2.49

Analyses were carried out for the re-profiled slopes in accordance with nominated slopes in the PRCP. This required the HLF slopes to be flattened to approximately 14° (25%), as shown in Figure 8-1.

As expected, the results of the analyses for the flattened slopes reported minimum critical FoS values of > 2 for all sections, based on the assumptions and analysis methods, as summarised in Table 8-6.

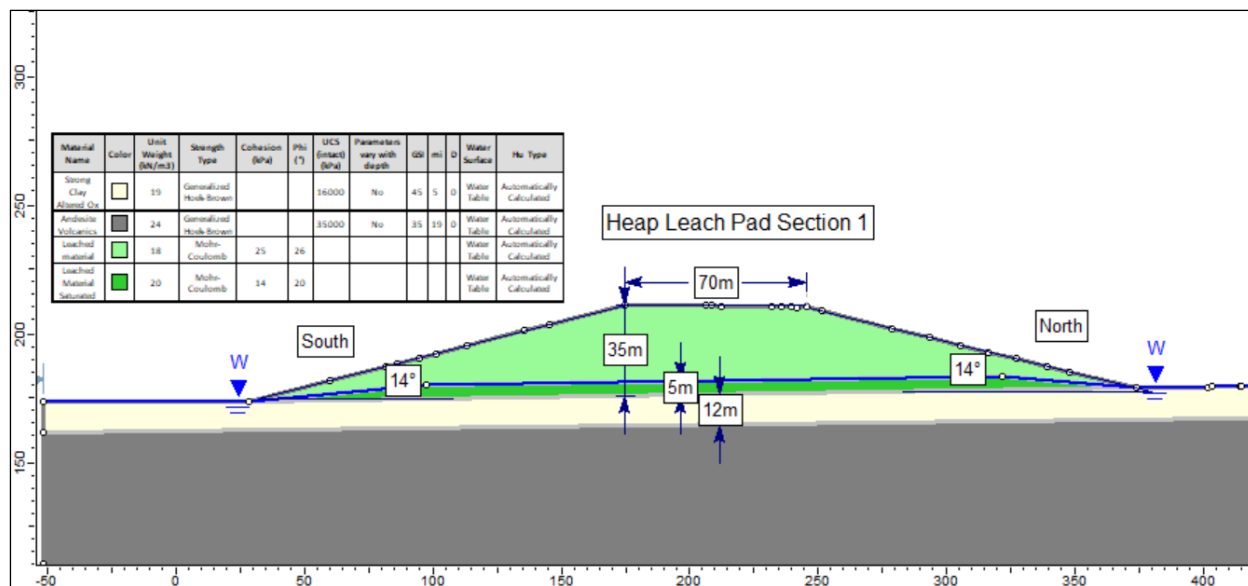


Figure 8-1: Re-Profiled HLF Slope Geometry

Table 8-6: HLF Limit Equilibrium Analyses Results – Re-Profiled Slopes

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 1	North Slope	Circular - AutoRef	2.27
	South Slope	Circular - AutoRef	2.11
		Non-Circular - Block	2.13
Section 2	Northeast Slope	Circular - AutoRef	2.09
		Non-Circular - Block	2.18

8.6 Tailings Storage Facility Results and Discussion

The results of the TSF slope stability analyses are summarised in Table 8-7. Individual slope stability analyses outputs referenced in the table are presented in Appendix A.

All slope stability scenarios analysed exceeded the minimum required FoS value for long-term geotechnical stability of 1.5. Therefore, the TSF slopes are unlikely to pose a significant long-term slope stability risk, based on the defined scenarios and assumptions.

Review of TSF aerial imagery indicated some minor rilling of gentle sloping surfaces may be occurring (especially for Cell B). This is likely due to a loss / movement of fines during heavy rain and is not expected to pose a long-term stability risk to the structure. It is noted that this structure is yet to be full rehabilitated, with planned rehabilitation to include reshaping, capping, topsoiling and seeding. This will likely rectify as the surface undergoes rehabilitation.

Table 8-7: Tailings Storage Facility Limit Equilibrium Results

Section	Scenario	Failure Surface	GLE/M-P FoS
Section 1	Downstream Face – Cell A	Circular - Grid	4.48
		Non-circular - Block	3.25
Section 2	Downstream Face – Cell A	Circular - Grid	4.15
		Non-circular - Block	3.14
Section 3	Downstream Face – Cell B	Circular - Grid	4.00
		Non-circular - Block	2.04

8.7 Water Storage Results and Discussion

The results of the various water storage dams modelled are summarised in Table 8-8. Individual slope stability analyses outputs referenced in the table are presented in Appendix A.

All slope stability scenarios analysed exceeded the minimum critical FoS of 1.5. Therefore, all the water storage embankments are unlikely to pose a significant long-term slope stability risk, based assumptions and analysis methods.

Table 8-8: Water Storage Facilities Limit Equilibrium Results

Dam	Scenario	Failure Surface	GLE/M-P FoS
Mine Water	Downstream Face	Circular - Grid	4.73
		Non-circular - Block	9.74
Tailings Raw Water	Downstream Face	Circular - AutoRef	6.36
		Circular - Grid	6.39
Tailings Return Water	Downstream Face	Circular - AutoRef	6.15
		Non-circular - Block	6.34

8.8 General Results Discussion

For all slope stability cases, with the exception of submerged in-pit dumped materials in the Main Pit, the results of the limit equilibrium analyses indicate long-term stable slopes within the current landform, based on the assumption that the material properties, lithological boundaries, current slope geometries and groundwater reasonably represent actual site conditions.

Based on a review of available site photos, rock mass structural conditions suggest that kinematic failure mechanisms would be possible; however, any failures of this type would report directly to the void and are unlikely to present a significant geotechnical risk post closure.

Detailed rock mass defect information for the pit slopes were not available at the time of modelling, the influence of which could change the outcome of the analysis. Further assessment of rock mass structure and pit slope defects should be carried out where possible prior to closure.

9 SURFACE WATER MANAGEMENT

Run-off over the pit crest should have no impact on the stability of the rock benches, and there were no areas of potential mass instability identified from the assessment, based on the available data; however, concentrated run-off will continue to erode and gully the Heap Leach Facility potentially erode fines from the surface of the Tailings Storage Facility without sufficient vegetative cover. This is likely a result of surface erosion processes and is unlikely to result in global failure of pit slope.

Prominent erosional features are evident from aerial photos and from the terrain models provided. As part of closure planning, these surface areas should be re-graded to encourage the flow of surface water away from crest areas. Where earthen bunds are placed, there will be a need to minimise the catchment area between the pit crest and bund to prevent water ponding on the surface.

10 CREST BUNDING

In general, it is not practicable to treat all slopes to eliminate geotechnical stability hazards. The usual approach is to mitigate the likelihood of such hazards that present a significant risk, and then restrict access to the void. This is achieved by bunding-off the access ramps and placing exclusion bunds along perimeter of the pit void.

The perimeter exclusion bund should be located at an adequate distance from the pit crest to avoid damage from erosion or time dependent degradation. Whilst there are no official guidelines in Queensland pertaining to the appropriate location of exclusion bunds, generic guidelines were developed by Ward (2016), based on unpublished, comprehensive studies of open-cut voids in the Bowen Basin.

Bunding, for the purpose of restricting access, should have a minimum height of 2 m and should be constructed of non-dispersive material, or alternatively by placing hard barriers which would prevent access, without constricting run-off, if water is being directed into the void.

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

It can be concluded for the Main Pit, East Hill Pit, TSF and various water storage dams the geotechnical assessment and analyses that:

- The proposed final landform exceeds the minimum FoS of 1.5 for long-term stability, based on the assumptions, and is therefore acceptable from a geotechnical perspective;
- The final pit slopes were assessed to be geotechnically stable against large-scale failure, based on the assumptions, and scenarios examined. Localised instability can occur where geological structures daylight on the pit face and form geometries that are kinematically

unstable. This has not been evaluated as part of this assessment; however, these failures may occur as the pit slopes erode; and

- The downstream slope of the TSF, TRWD, RWD and MWD embankments were assessed to be geotechnically stable, based on the assumptions, and scenarios examined.

It can also be concluded that the HLF from the geotechnical assessment and analyses that:

- At the current angle of repose, the slopes failed to meet the minimum FoS of ≥ 1.5 which is reflective of the current slope geometry and of remnant of operations;
- The slopes were generally maintaining a short term FoS of 1.2, consistent with observations of minor failure observed in aerial photographs and digital terrain models; and
- Reprofilng of the HLF slopes to the required 14° (25%) as nominated for closure criteria results in a FoS < 1.5 .

11.2 Recommendations

Based on the outcomes of the analyses and assessment presented herein, the following recommendations are proposed:

- Regrade the HLF to 14° (25%), allowing water to shed without facilitating erosion;
- Regrading of the thin Quaternary layer around the pit rim where applicable could be considered to prevent small scale circular failures into the pit void and establish sufficient drainage around the crest area in order to prevent deep gully erosion; and
- Bunds should be designed to accommodate the discharge of surface water during rainfall events to prevent overtopping. In this case, cut-throughs leading to rubble-lined discharge spillways should be installed at regular intervals along the bund;
- To assess the potential for kinematic mechanisms on the pit slopes, carry out opportunistic geological/geotechnical mapping of the pit walls (mainly in East Pit), if practicable; and
- Carry out inspection at closure to confirm final landforms remain geotechnically stable.

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APPENDIX A: GENERAL LIMIT EQUILIBRIUM MODEL OUTPUTS

Main Pit Limit Equilibrium Model Outputs

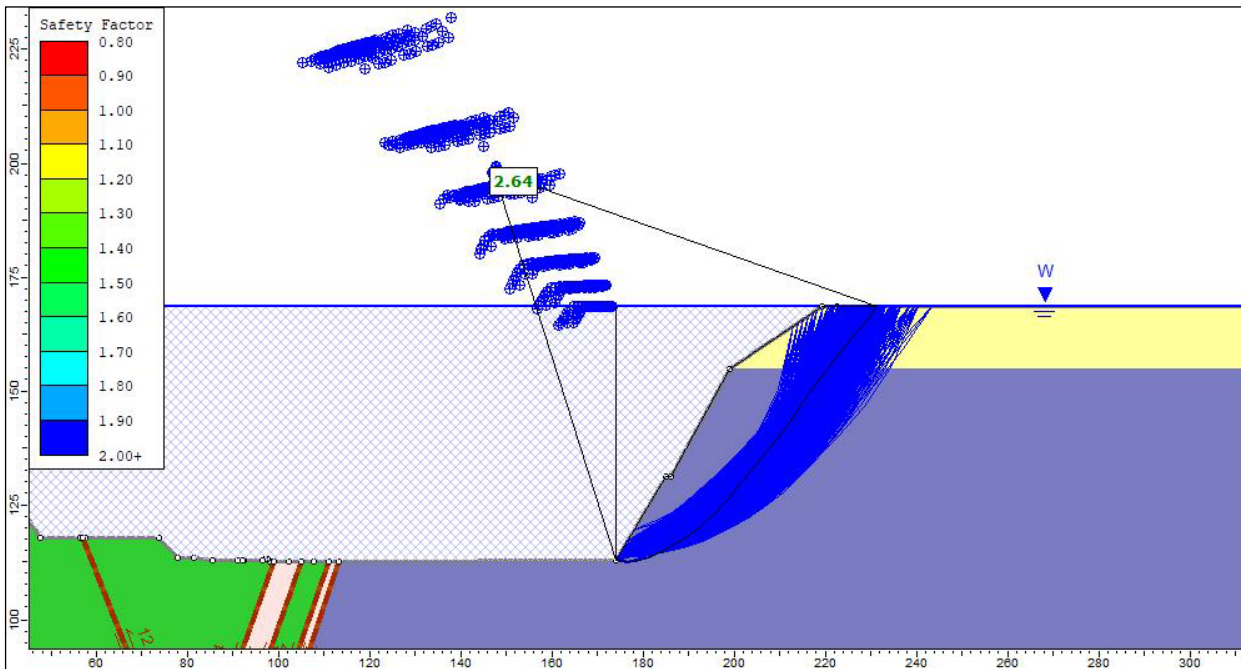


Figure A 1: Main Pit - Section 1 - North Wall – Auto Refine Search - FoS = 2.64

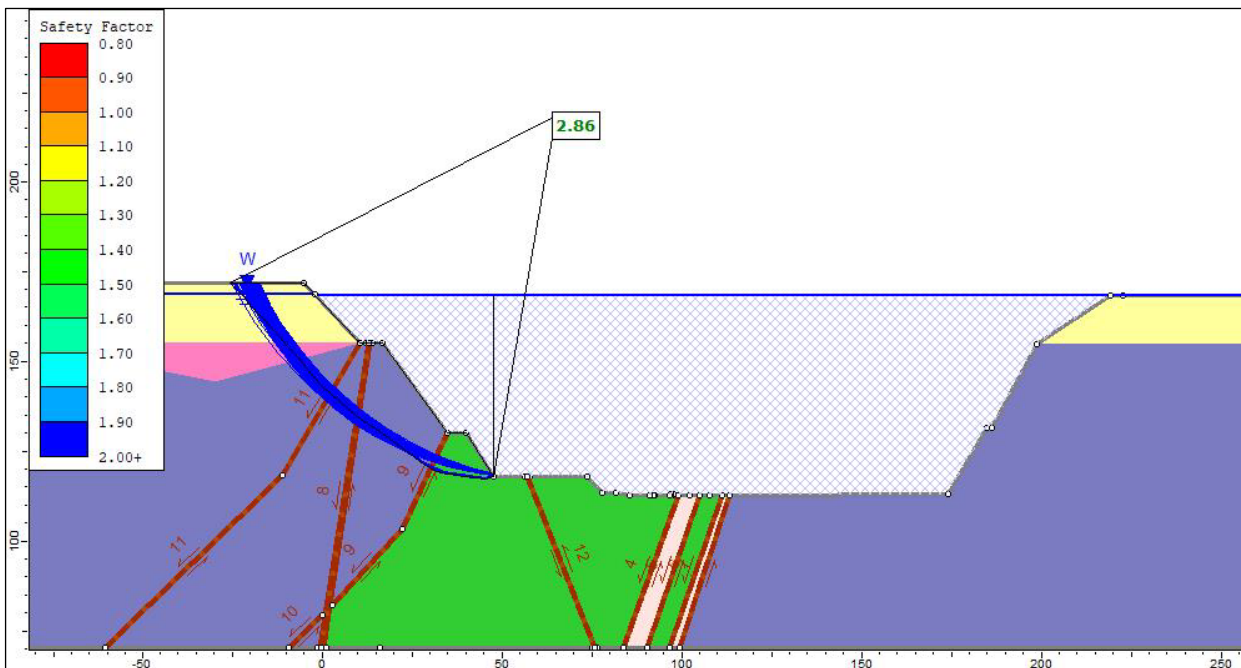


Figure A 2: Main Pit - Section 1 - South Wall – Auto Refine Search - FoS = 2.86

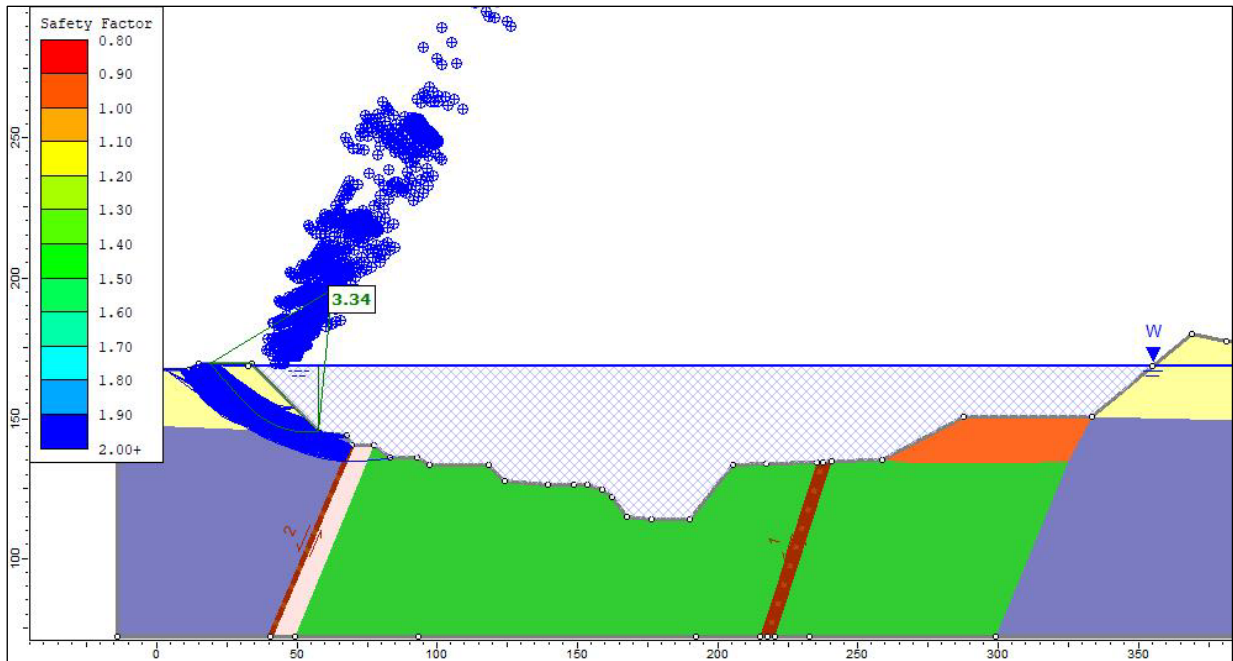


Figure A 3: Main Pit - Section 2 - North Wall – Auto Refine Search - FoS = 3.34

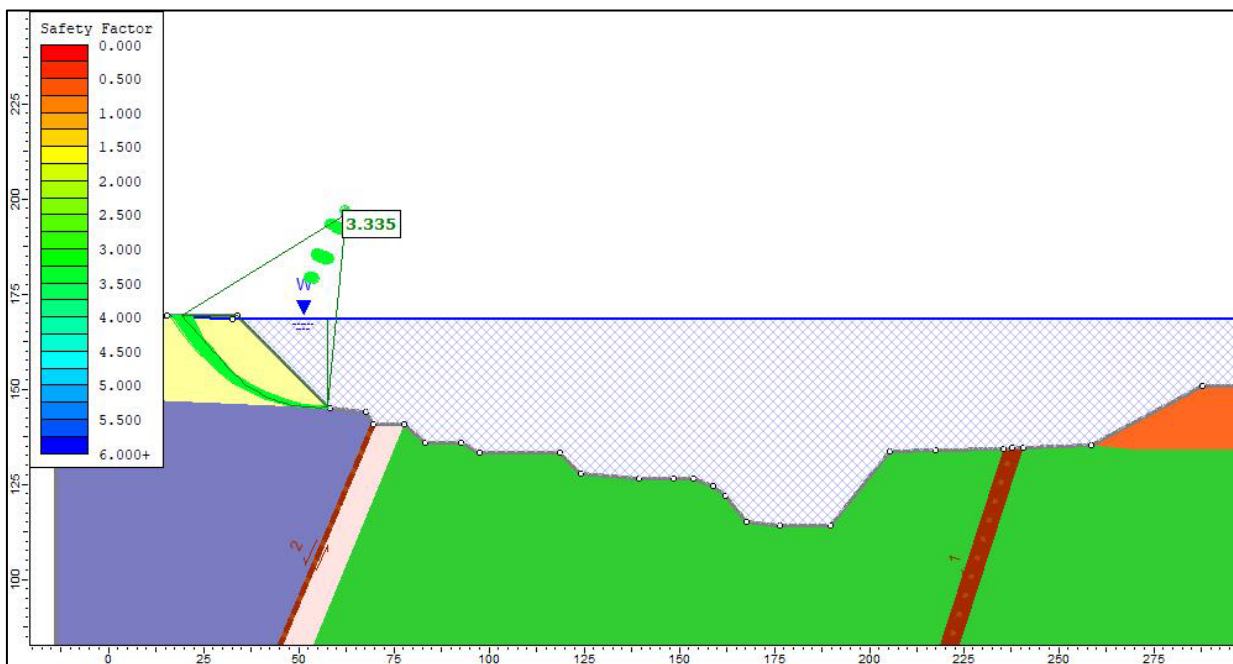


Figure A 4: Main Pit - Section 2 - North Wall – Cuckoo Search - FoS = 3.34

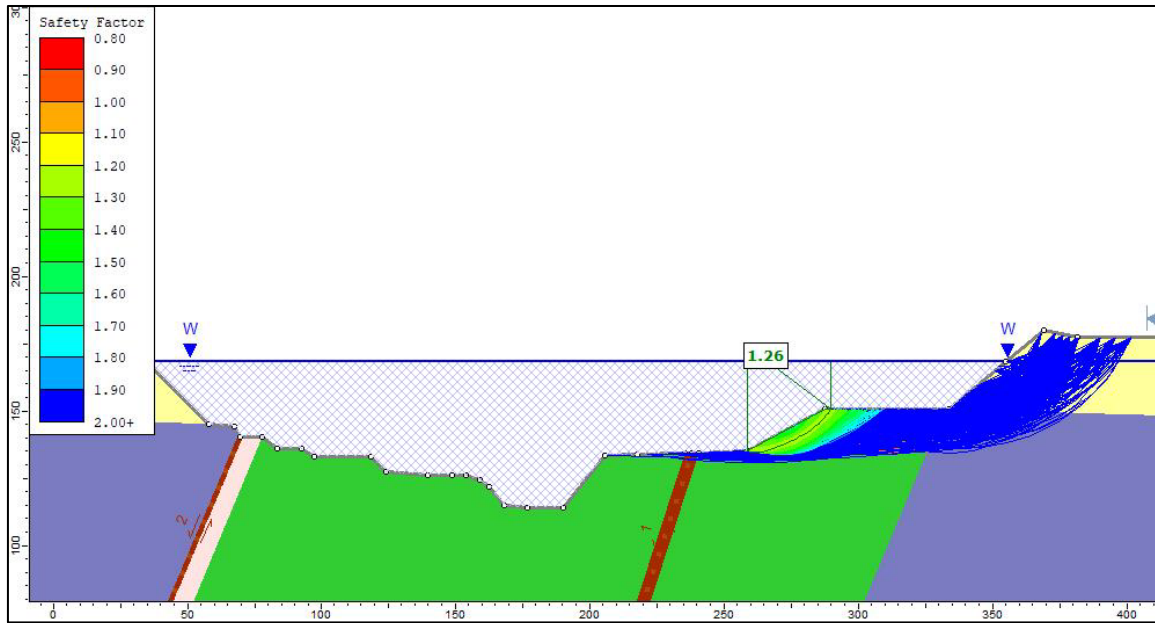


Figure A 5: Main Pit - Section 2 - South Wall - Auto Refine Search - FoS = 1.26

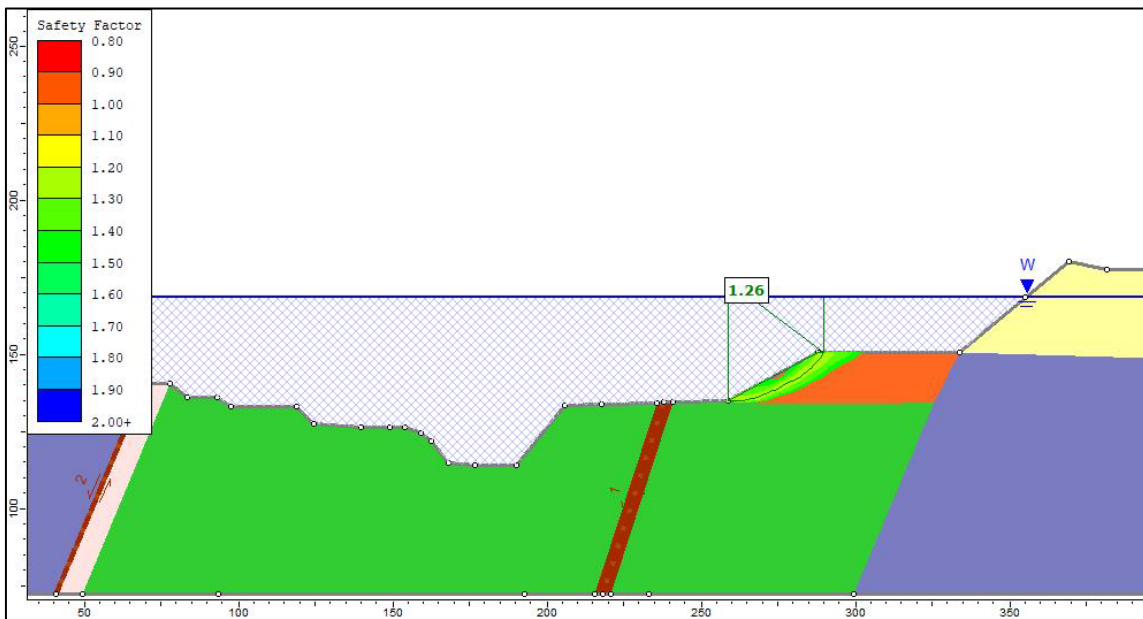


Figure A 6: Main Pit - Section 2 - South Wall - Cuckoo Search - FoS = 1.26

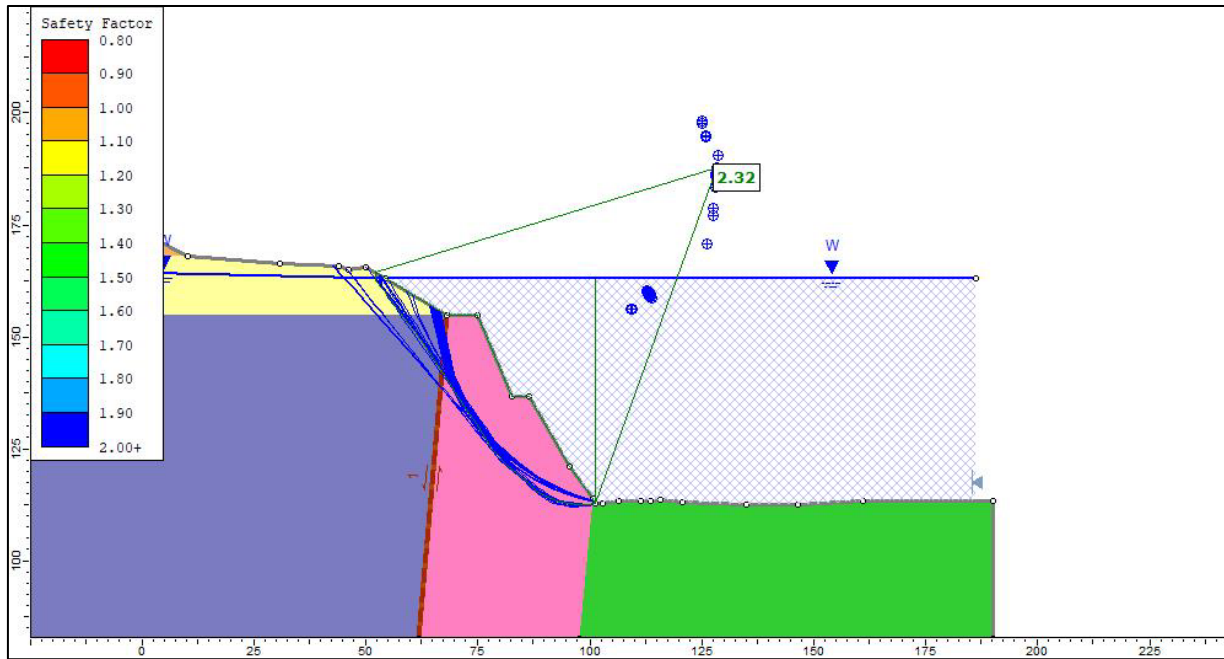


Figure A 7: Main Pit - Section 3 - West Wall - Auto Refine Search - FoS = 2.32

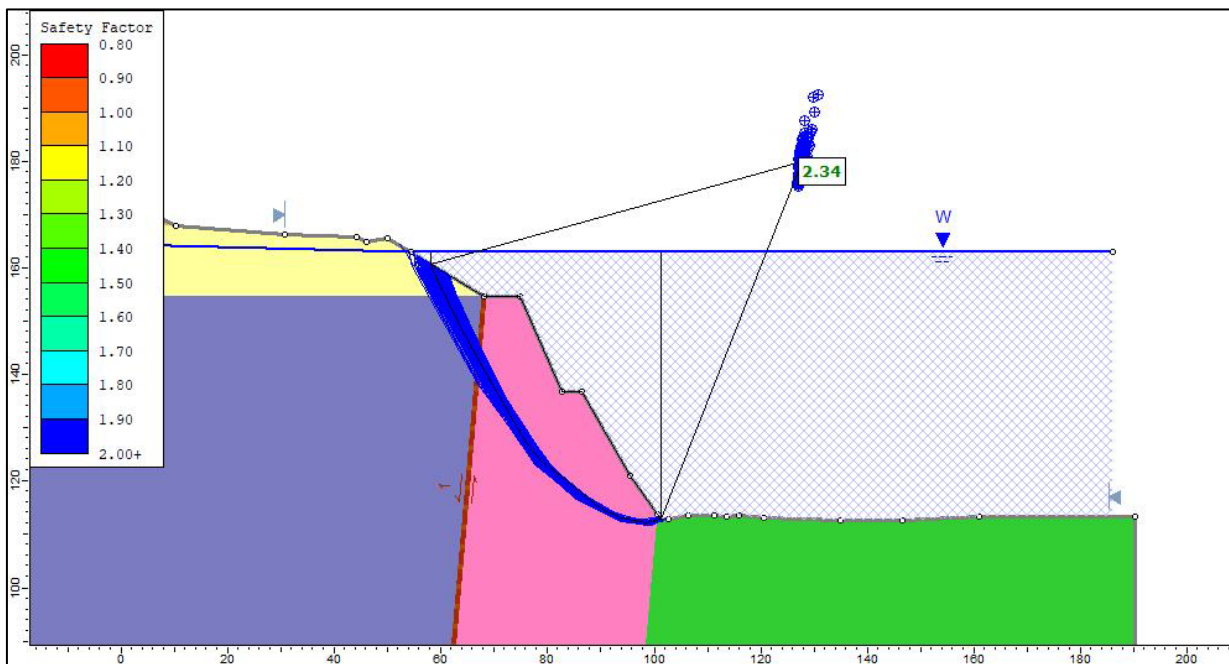


Figure A 8: Main Pit - Section 3 - West Wall - Cuckoo Search - FoS = 2.34

Main Pit Spillway Limit Equilibrium Model Outputs

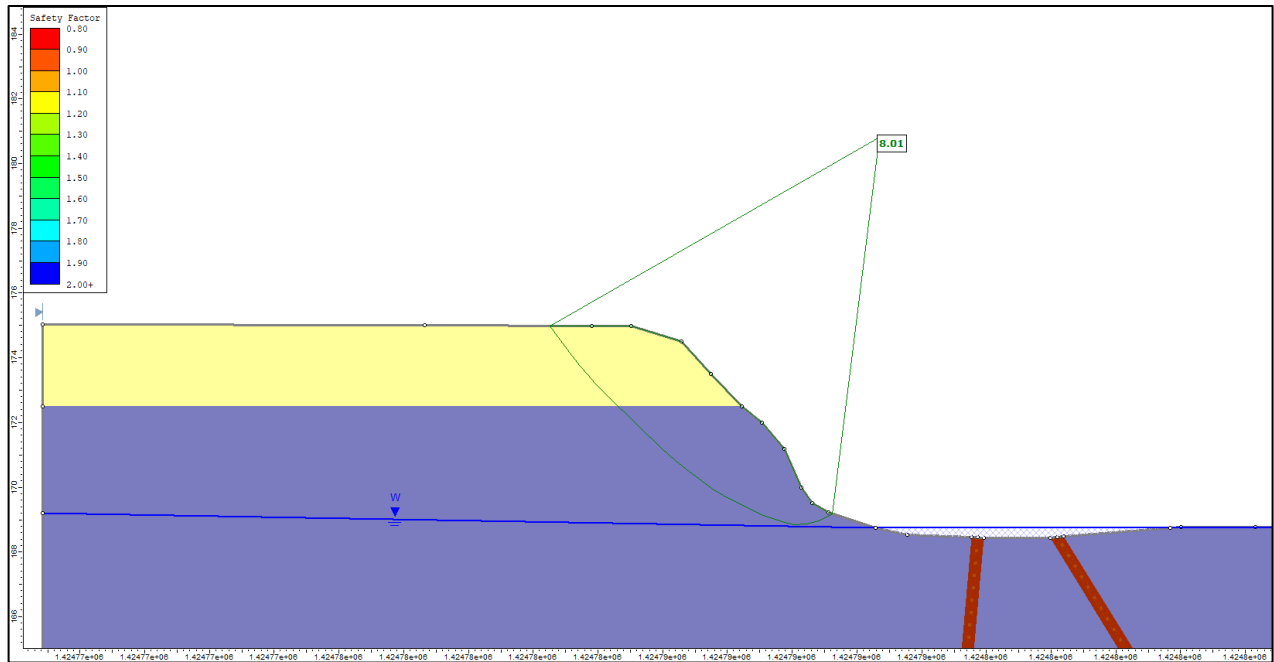


Figure A 9: Main Pit Spillway - Section 1 – Northern Slope – Auto Refine Search – FoS = 8.01

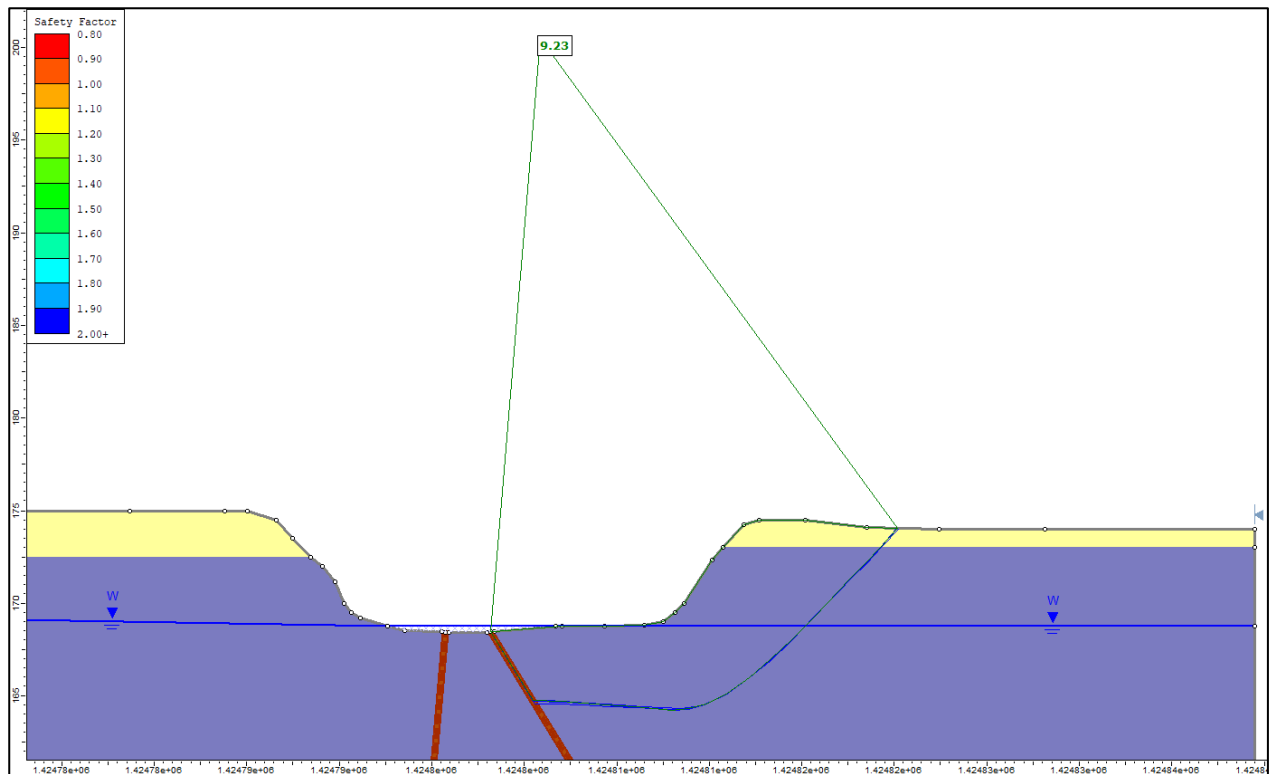


Figure A 10: Main Pit Spillway - Section 1 – Southern Slope – Auto Refine Search – FoS = 9.23

Main Pit Flood Protection Bund Limit Equilibrium Output Models

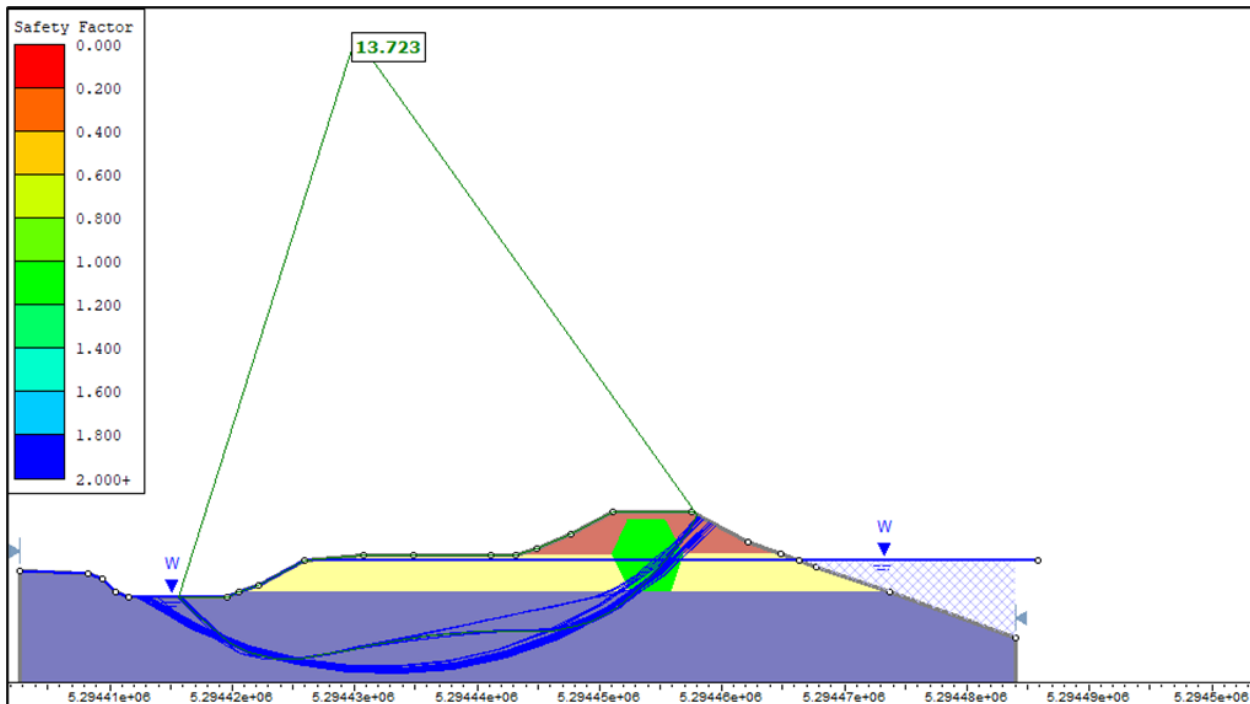


Figure A 11: Main Pit Bund – Right to Left – Auto Refine Search – FoS = 13.72

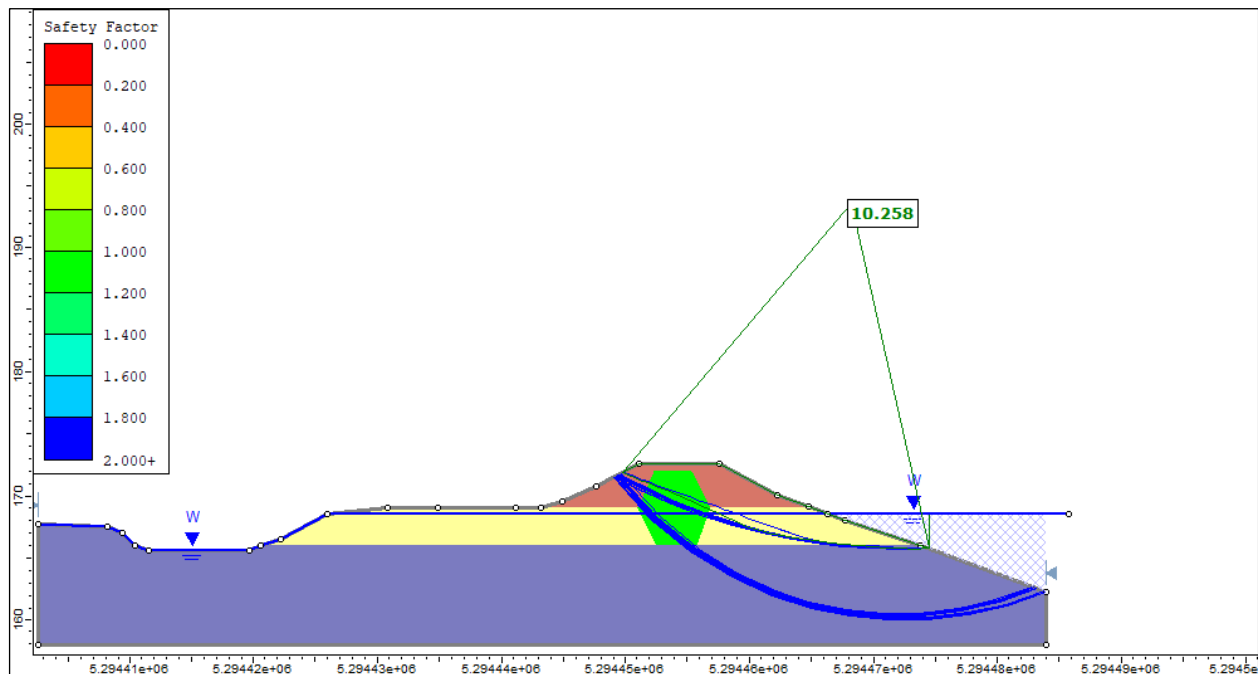


Figure A 12: Main Pit Bund – Left to Right – Auto Refine Search – FoS = 10.26

East Hill Pit Limit Equilibrium Model Outputs

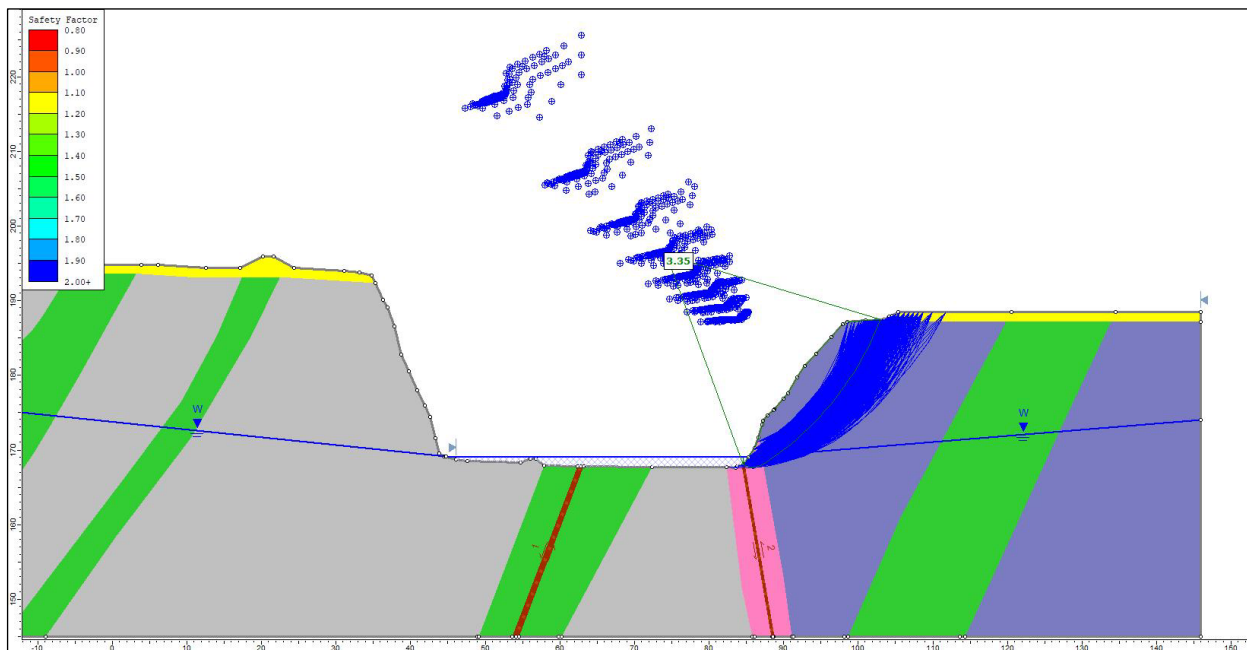


Figure A 13: East Hill Pit - Section 1 – Northeast Slope – Auto Refine Search - FoS = 3.35

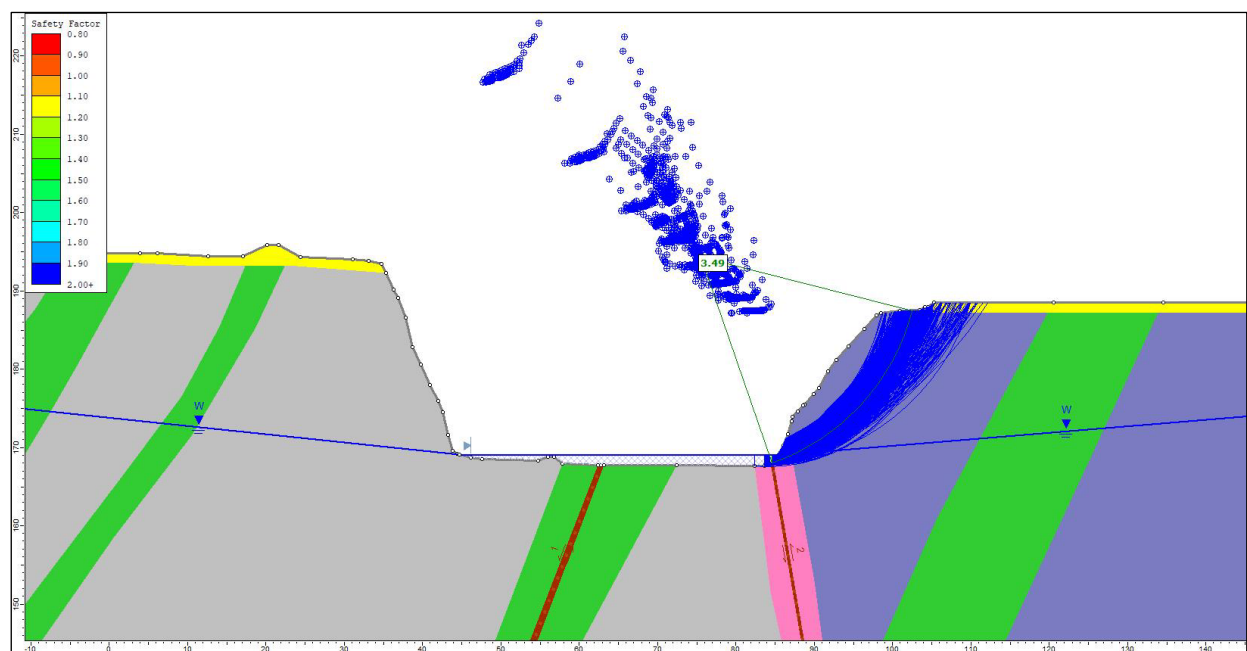


Figure A 14: East Hill Pit - Section 1 – Northeast Slope – Cuckoo Search - FoS = 3.49

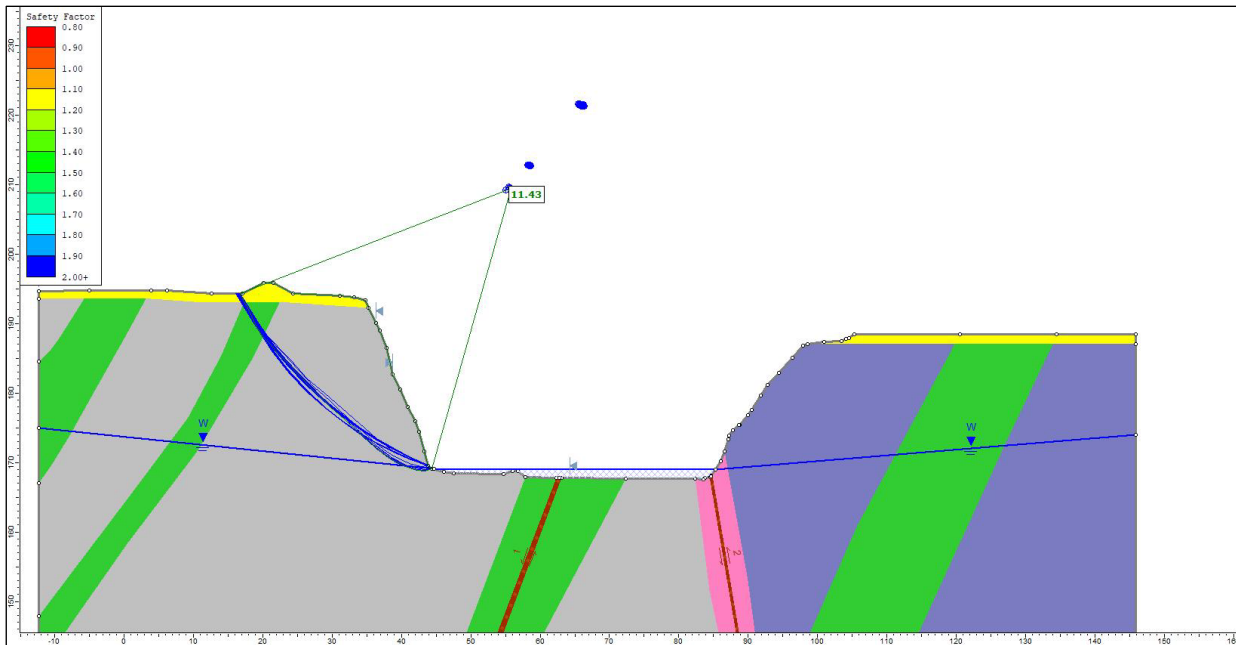


Figure A 15: East Hill Pit - Section 1 – Southwest Slope – Auto Refine Search - FoS = 11.43

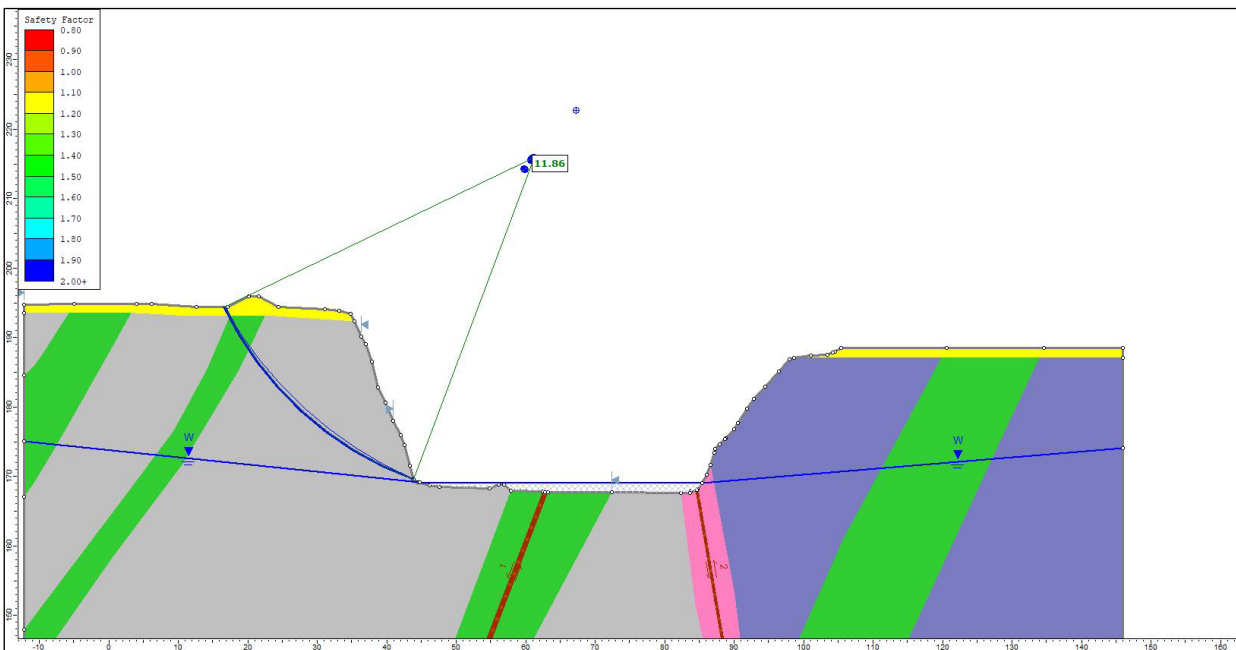


Figure A 16: East Hill Pit - Section 1 – Southwest Slope – Cuckoo Search - FoS = 11.86

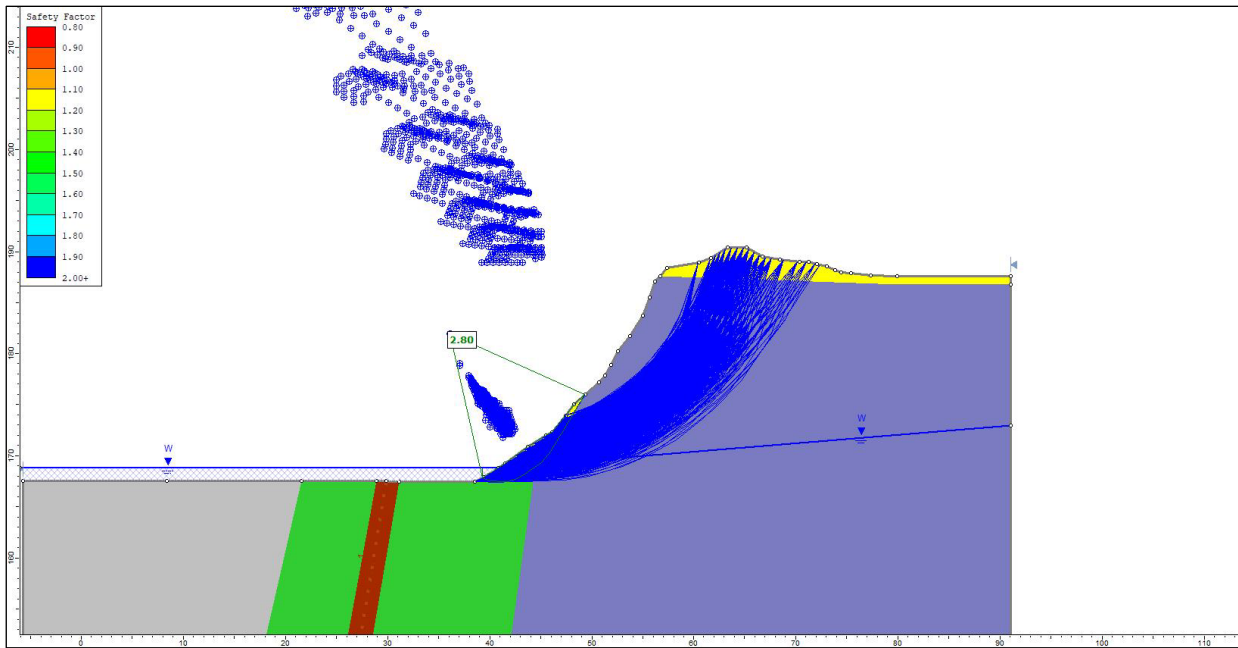


Figure A 17: East Hill Pit - Section 2 – Northeast Slope – Auto Refine Search - FoS = 2.80

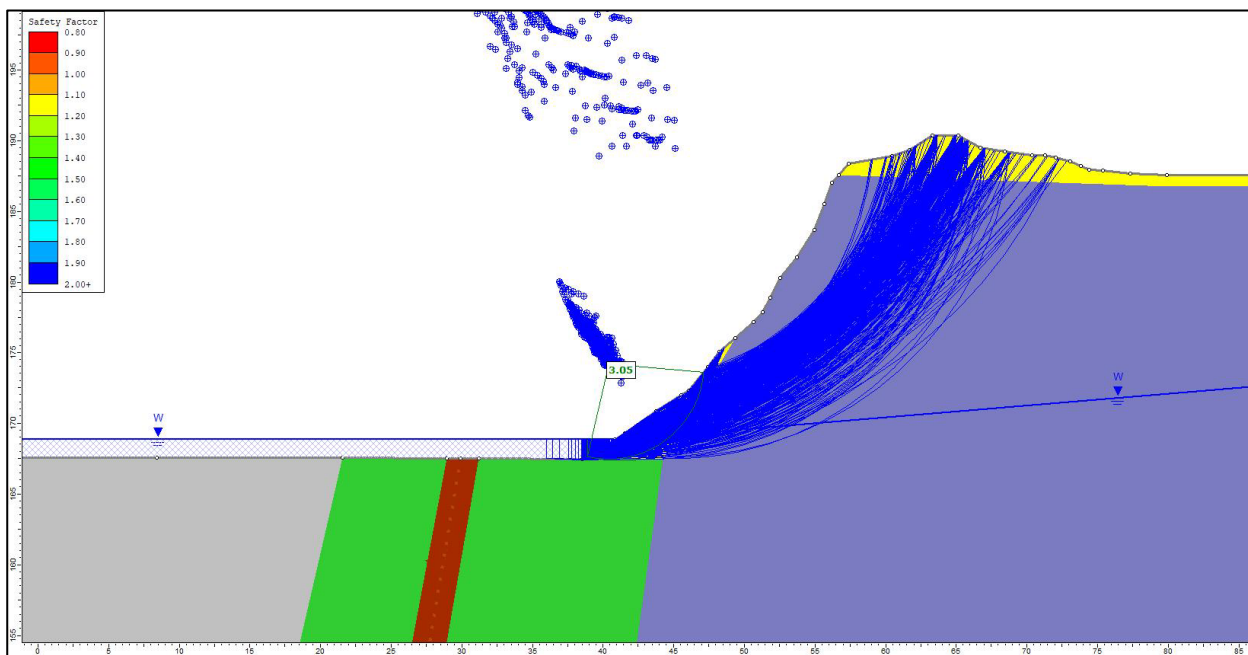


Figure A 18: East Hill Pit - Section 2 – Northeast Slope – Cuckoo Search - FoS = 3.05

Heap Leach Facility (HLF) Limit Equilibrium Model Outputs

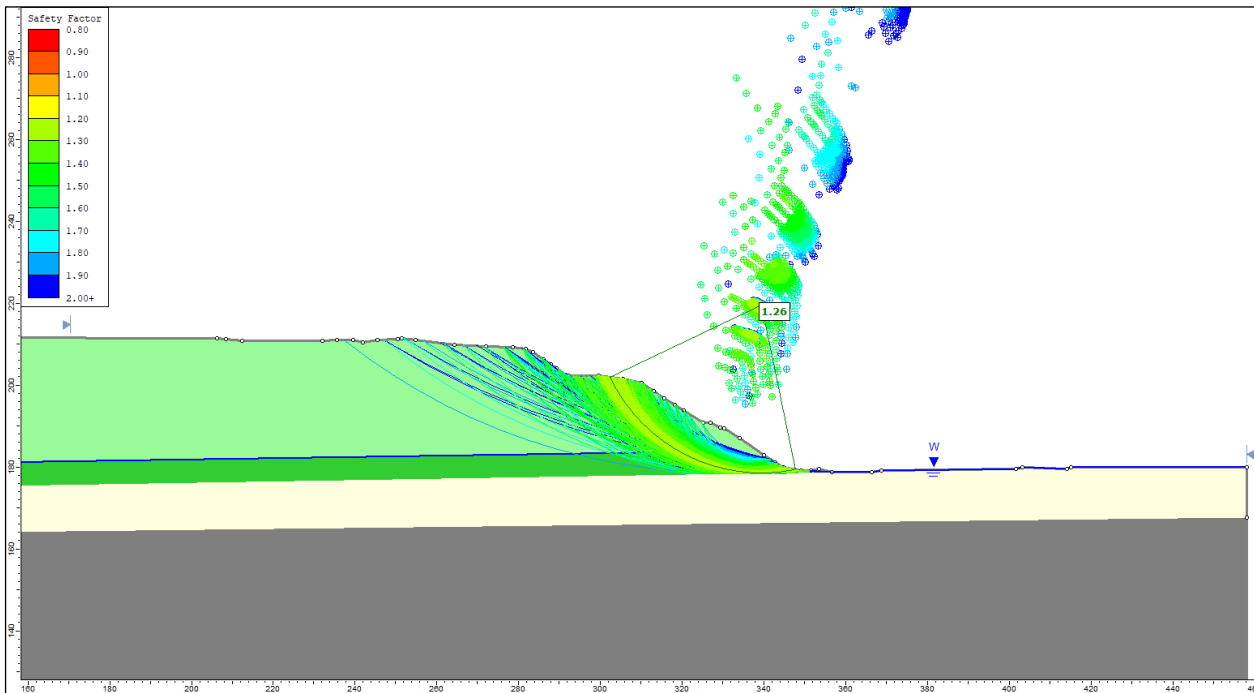


Figure A 19: HLF - Section 1 - North Face - Auto Refine Search - FoS = 1.26

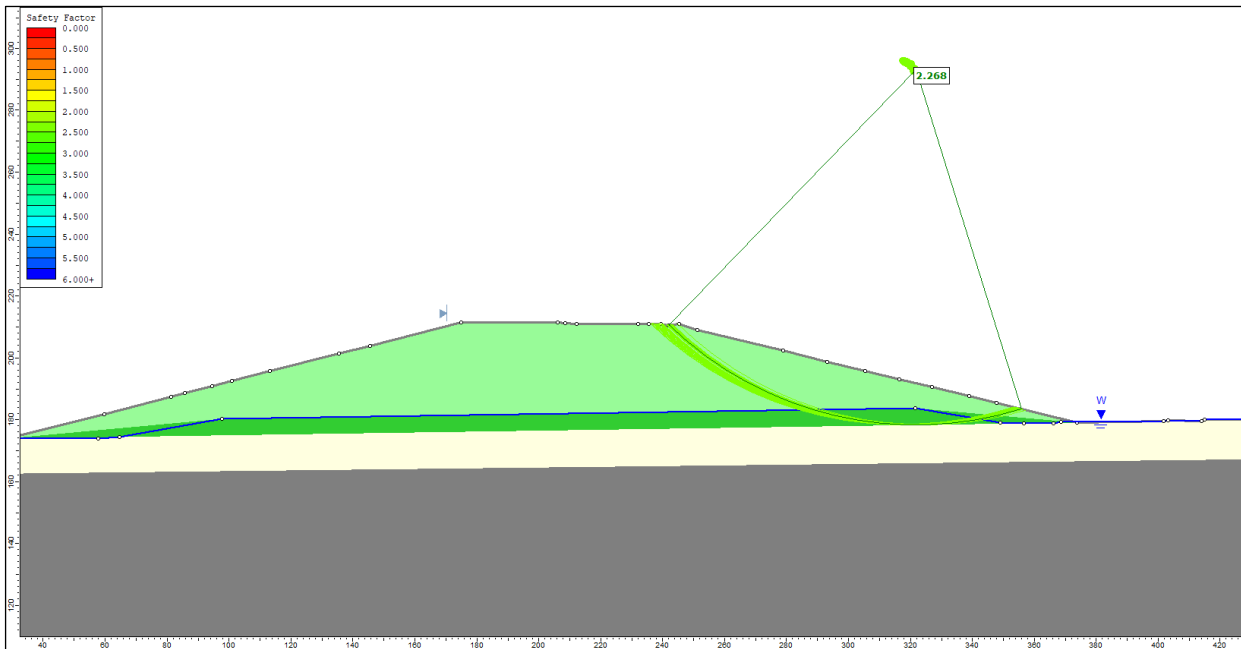


Figure A 20: HLF - Section 1 - North Face Re-Profiled - Auto Refine Search - FoS = 2.27

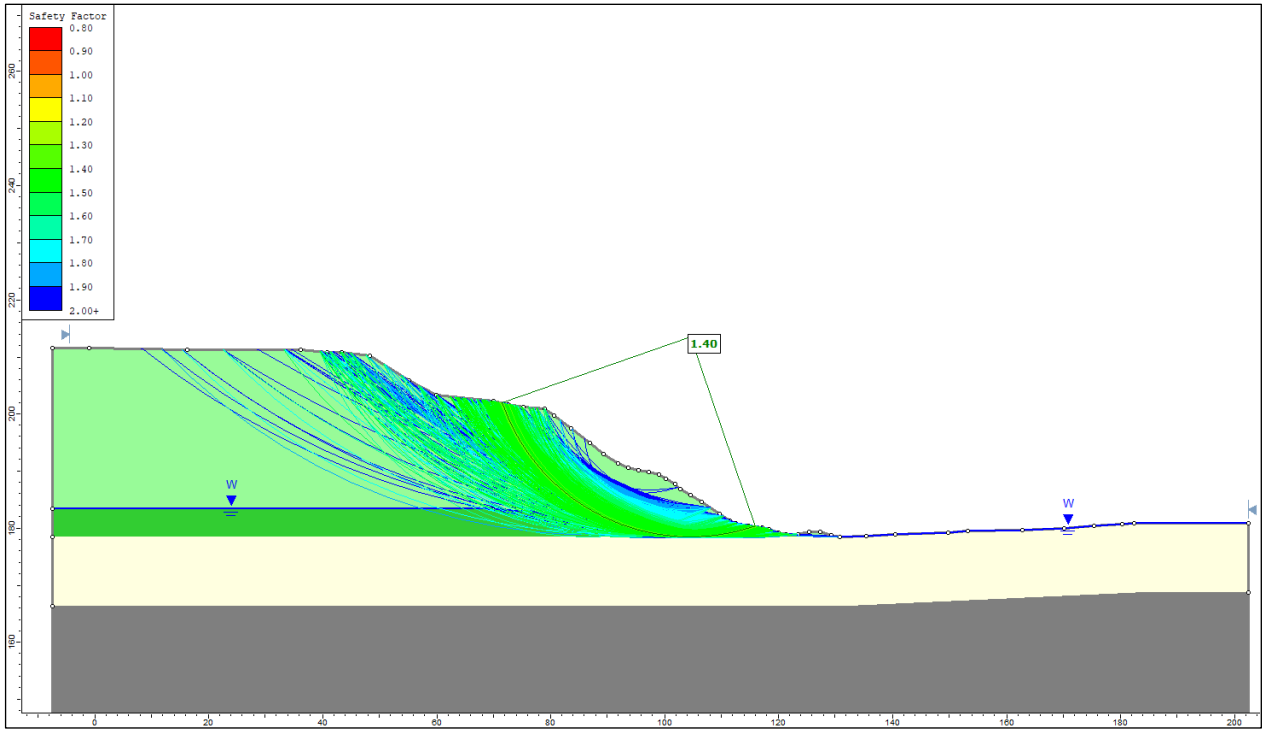


Figure A 21: HLF - Section 1 - North Face - Grid Search - FoS = 1.40

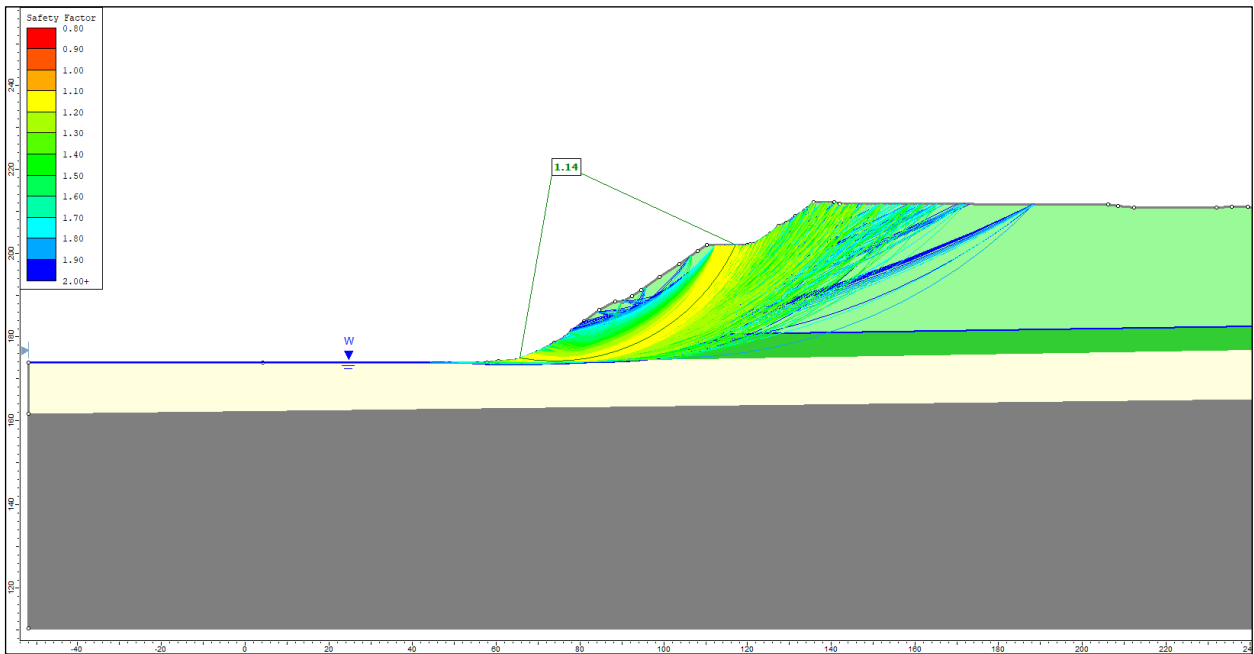


Figure A 22: HLF - Section 1 - South Face - Auto Refine Search - FoS = 1.14

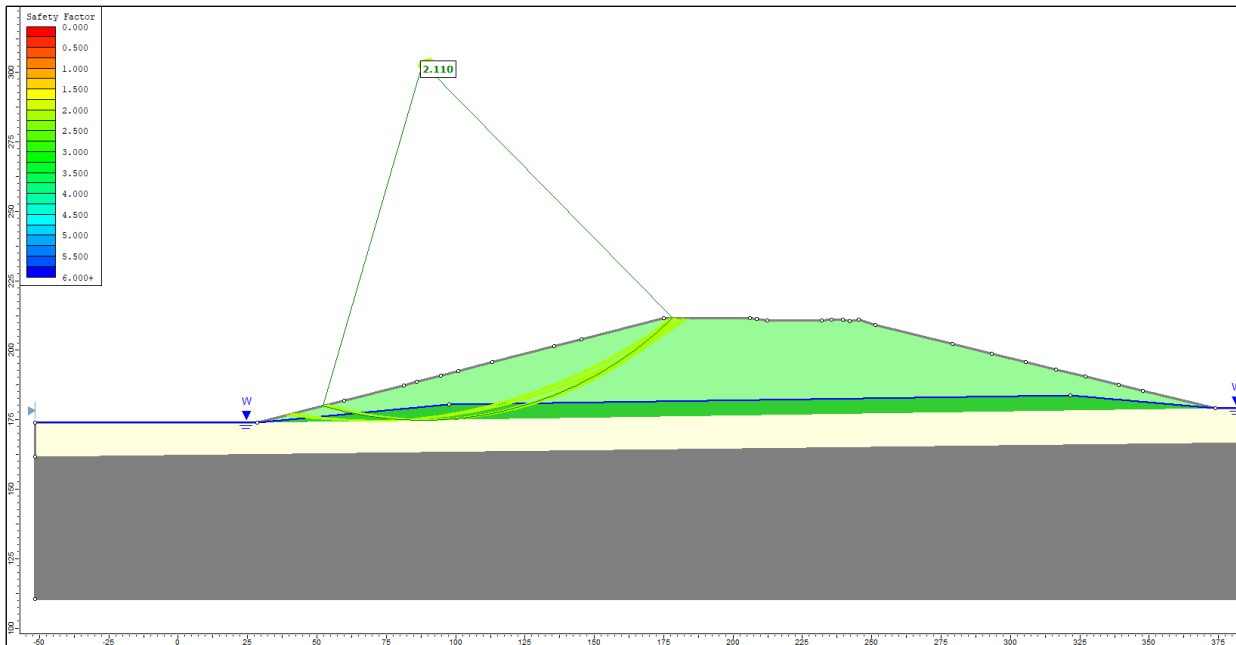


Figure A 23: HLF - Section 1 – South Face (Re-Profiled) – Auto Refine Search - FoS = 2.11

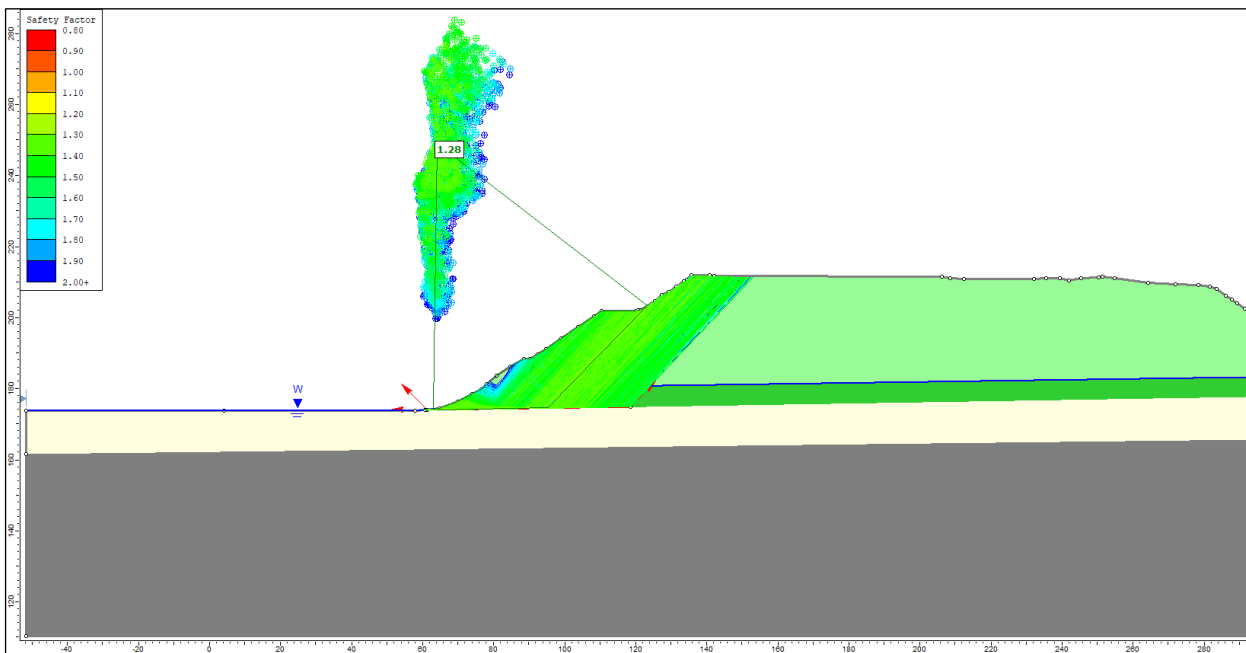


Figure A 24: HLF - Section 1 South Face – Block Search - FoS = 1.28

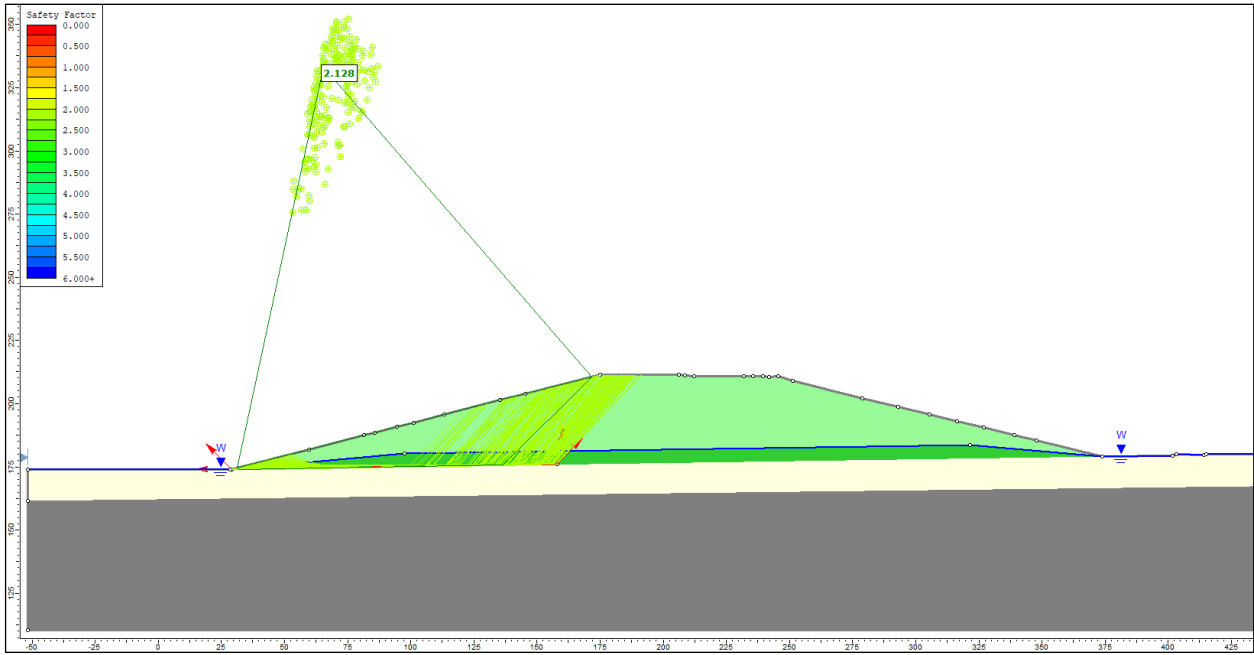


Figure A 95: HLF - Section 1 South Face Re-Profiled - Block Search - FoS = 2.13

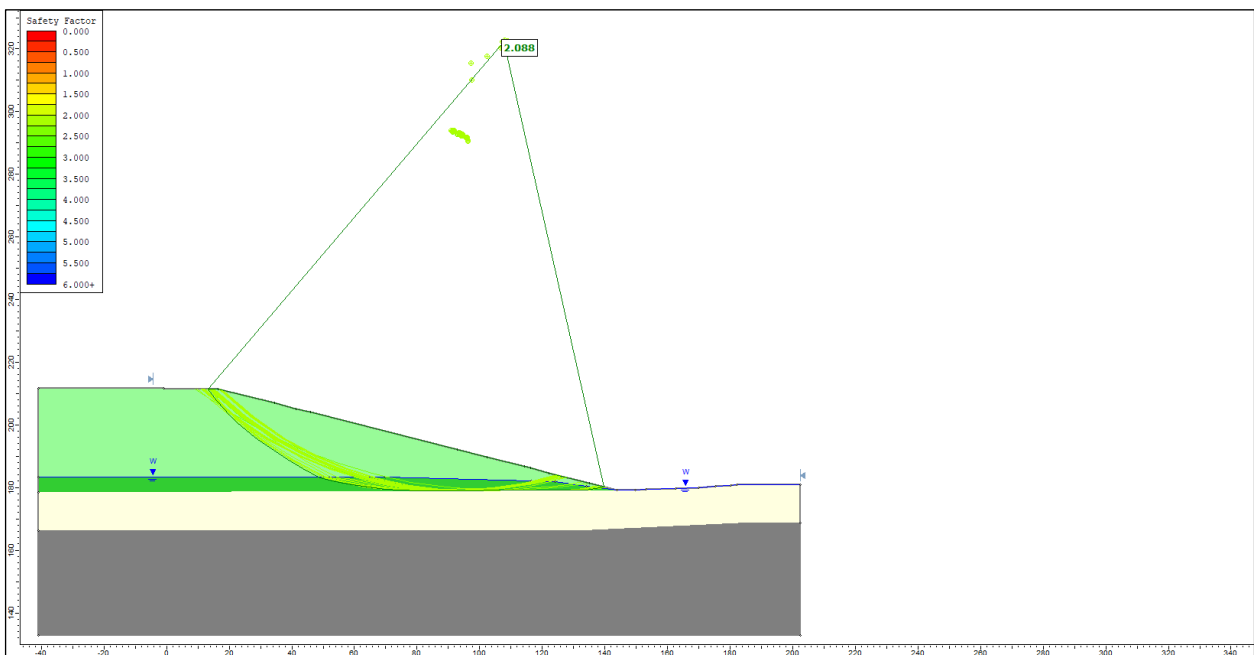


Figure A 106: HLF - Section 2, Northeast Face Re-Profiled – Auto Refine Search - FoS = 2.09

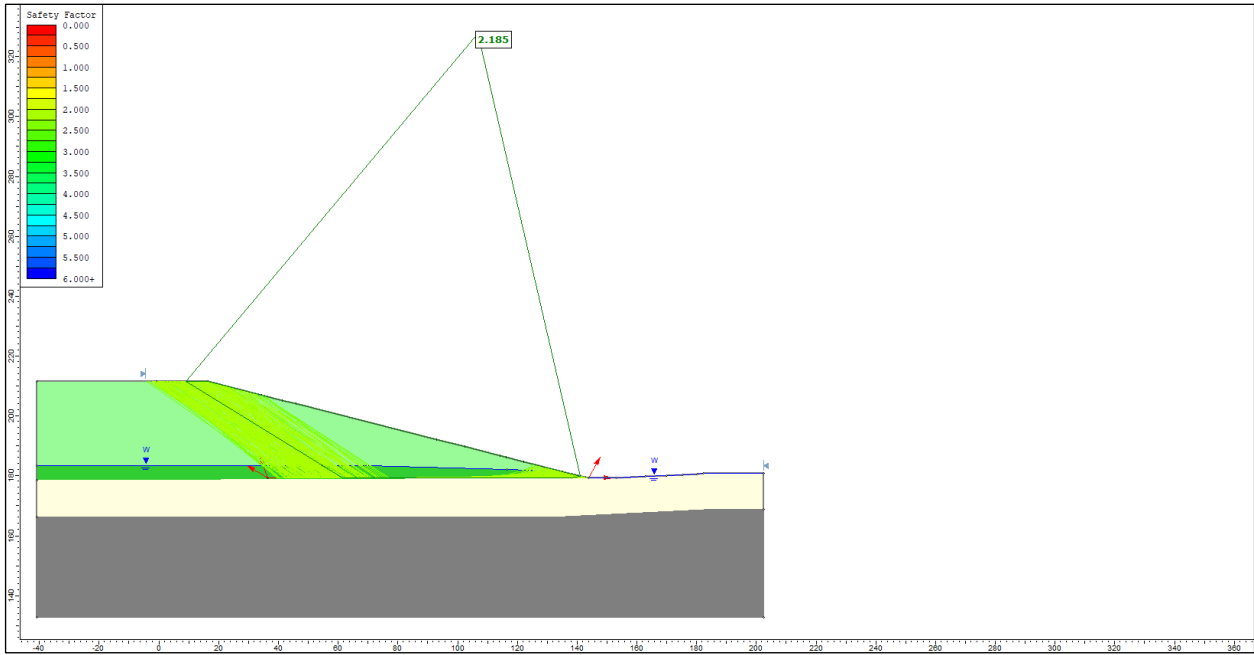


Figure A 117: HLF - Section 2 Northeast Face Re-Profiled - Block Search - FoS = 2.19

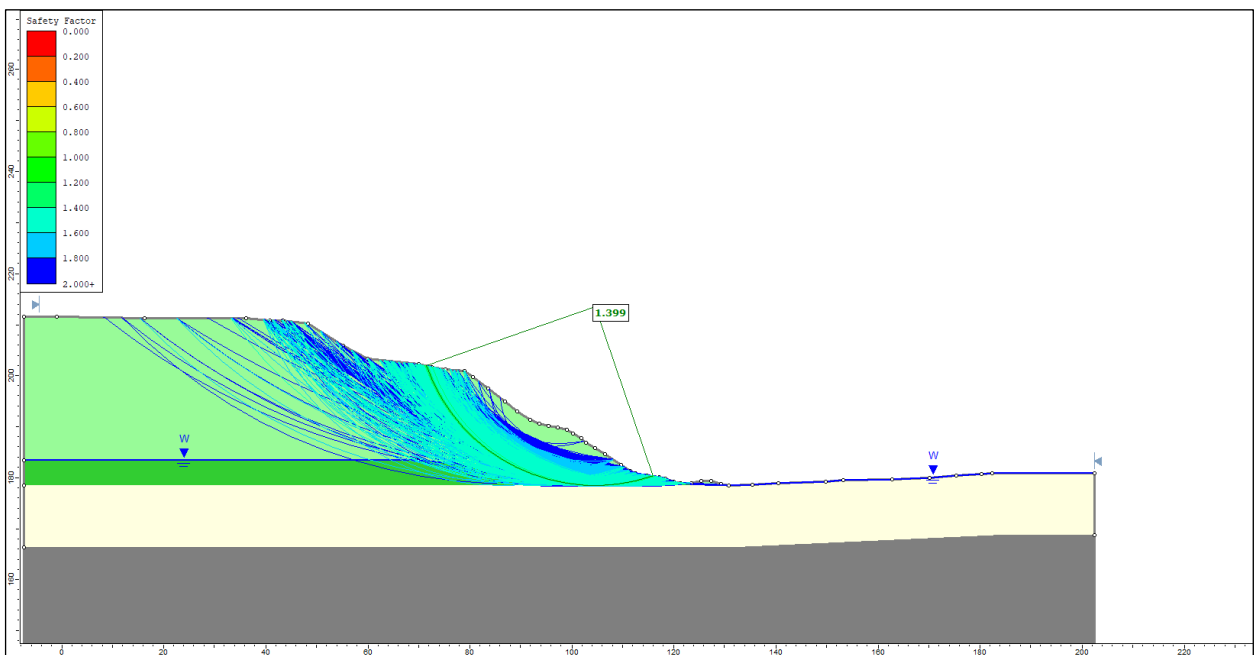


Figure A 129: HLF - Section 2 Northeast Face - Auto Refine Search - FoS = 1.40

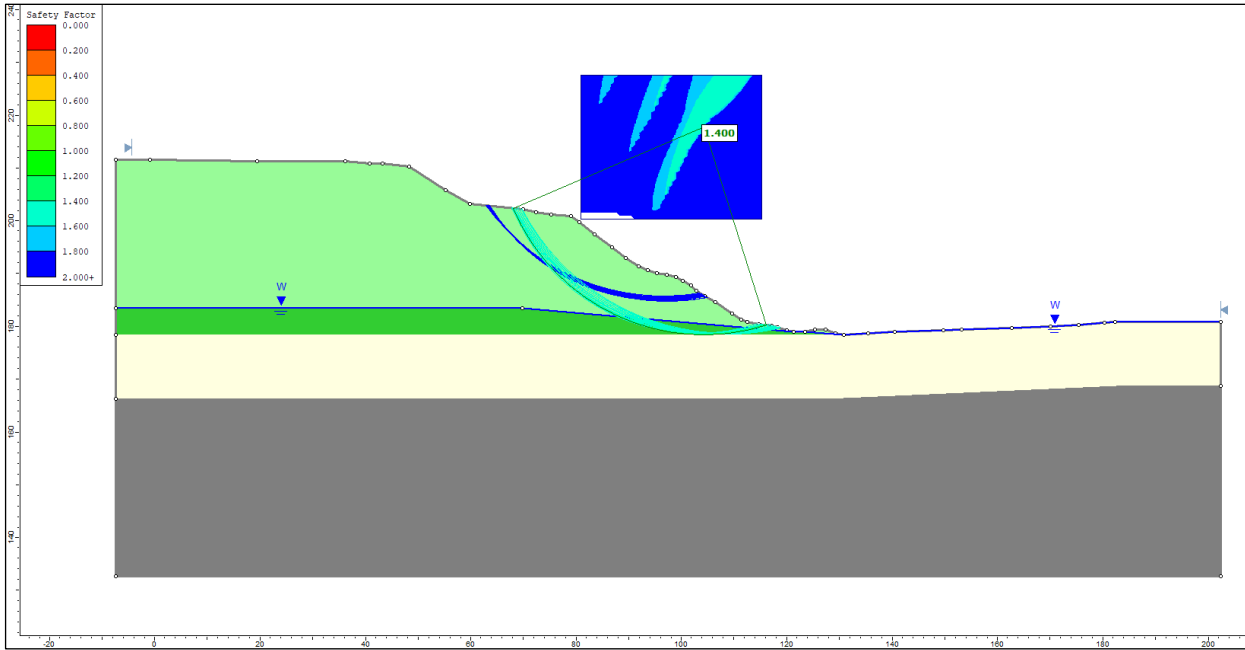


Figure A 139: HLF - Section 2 Northeast Face - Grid Search - FoS = 1.40

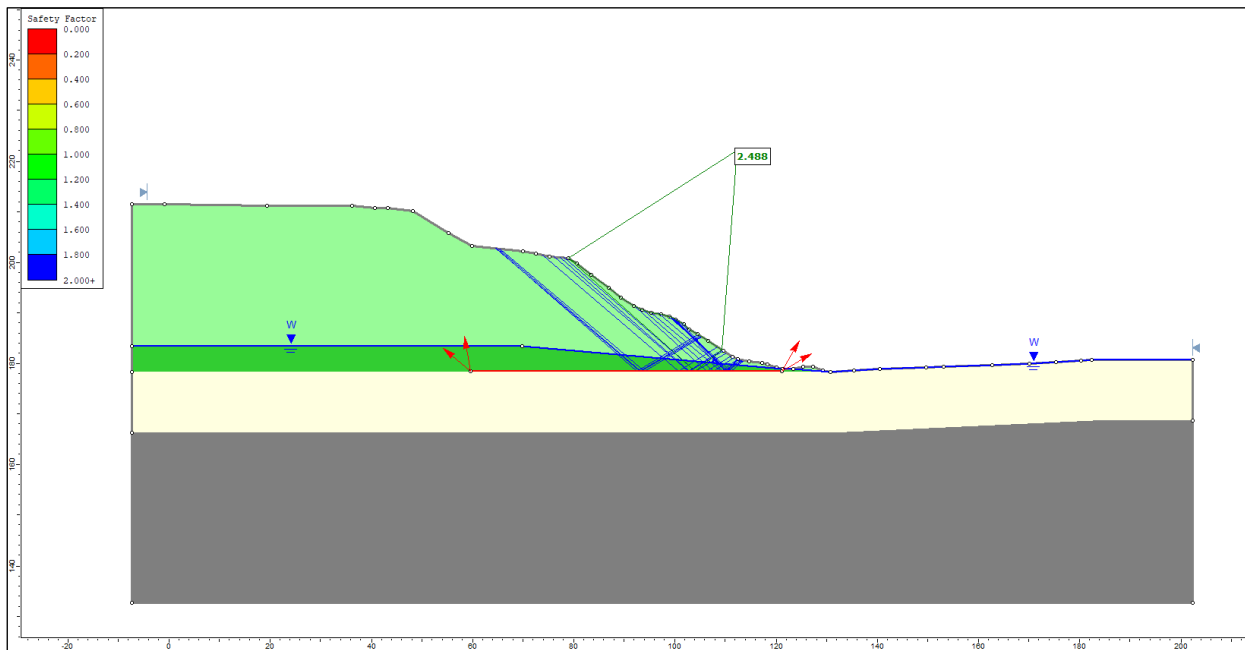


Figure A 30: HLF - Section 2 Northeast Face - Block Search - FoS = 2.49

Tailings Storage Facility Limit Equilibrium Outputs

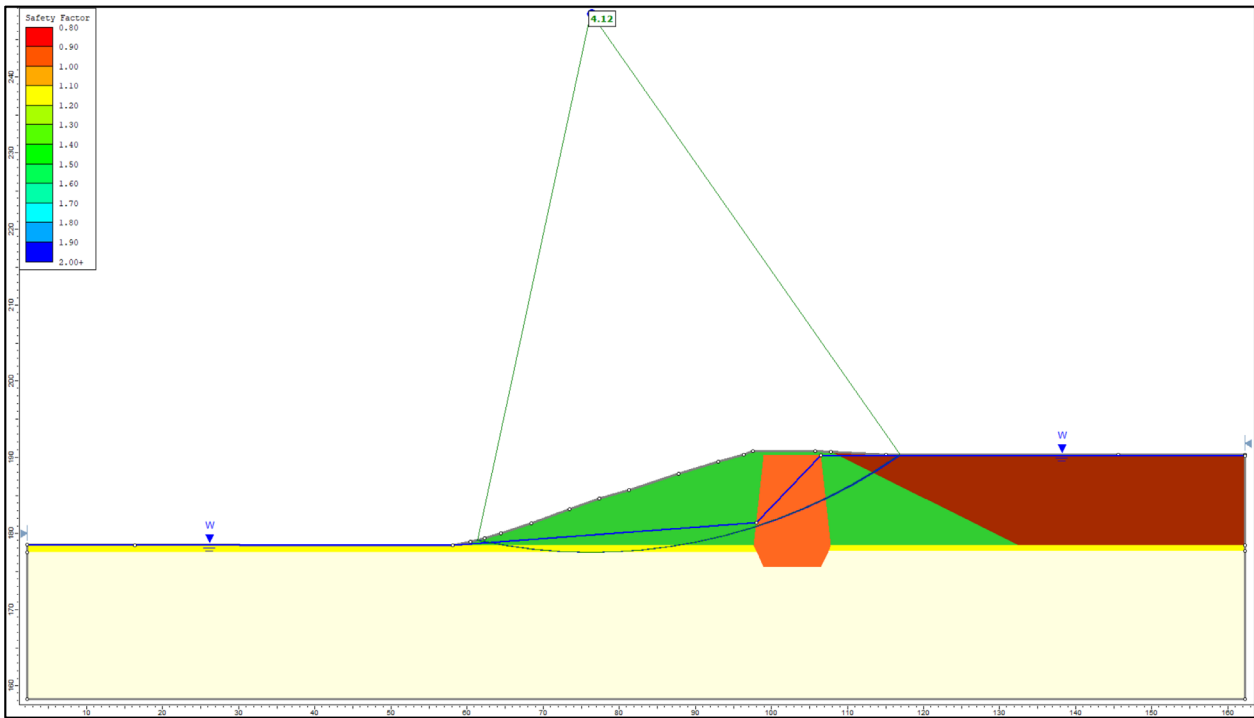


Figure A 31: Tailings Dam Cell A - Section 1 - Auto Refine Search - FoS = 4.12

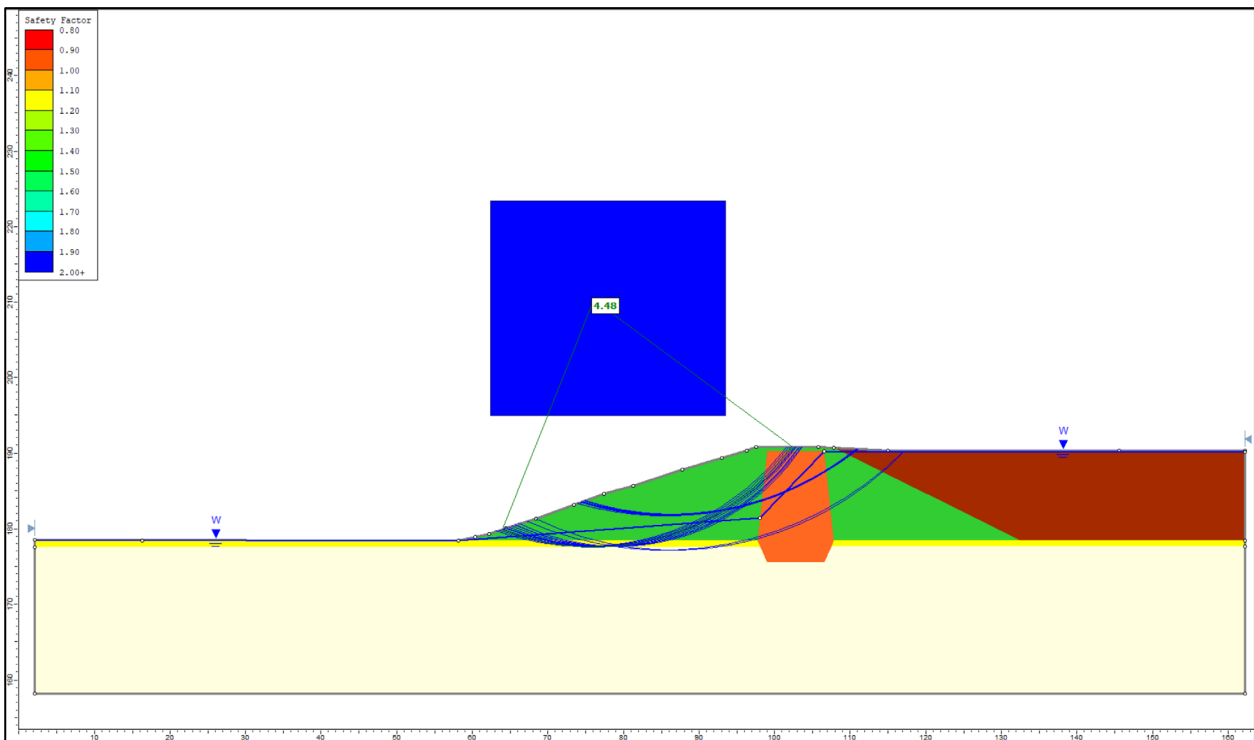


Figure A 32, Tailings Dam Cell A - Section 1 – Grid Search - FoS = 4.48

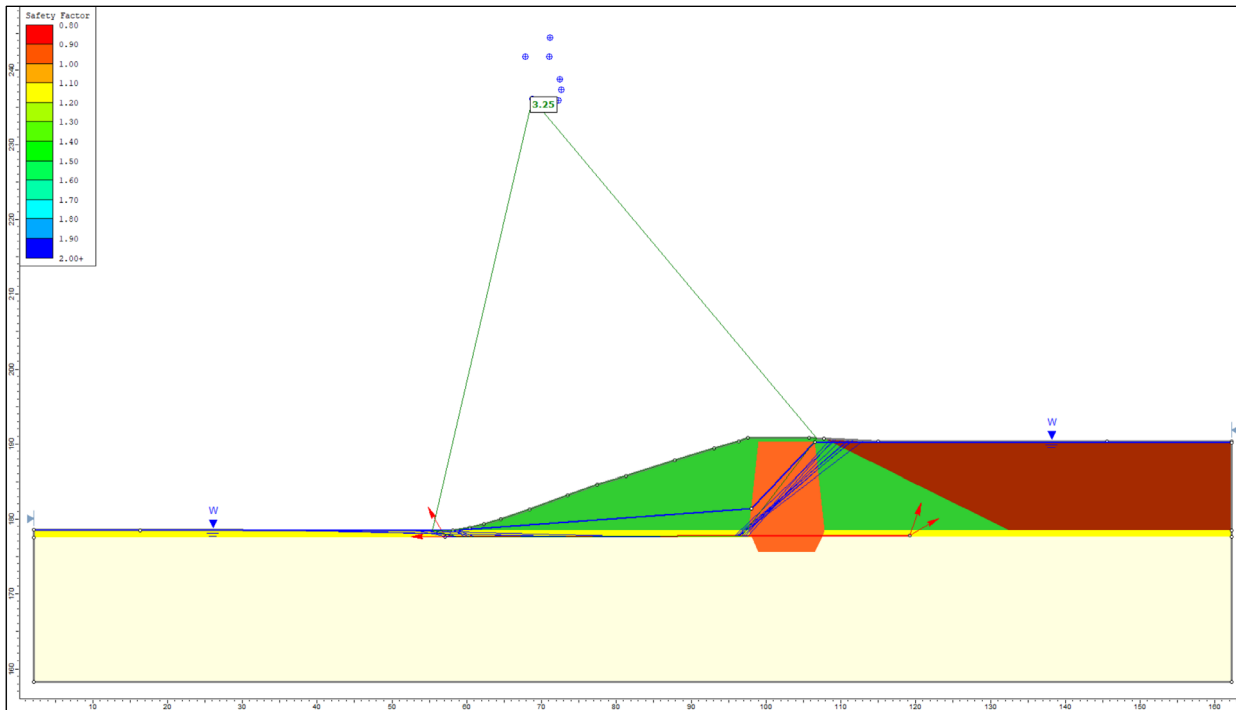


Figure A 33: Tailings Dam Cell A - Section 1 – Block Search - FoS = 3.25

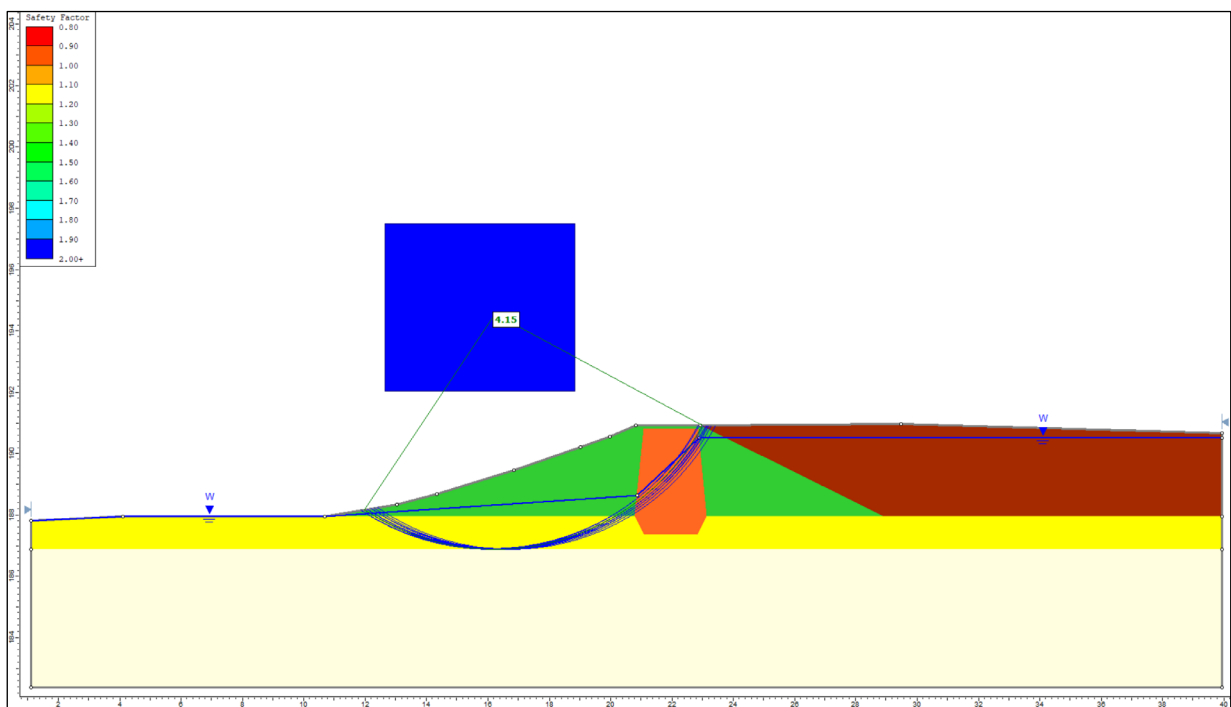


Figure A 34: Tailings Dam Cell A - Section 2 – Grid Search - FoS = 4.15

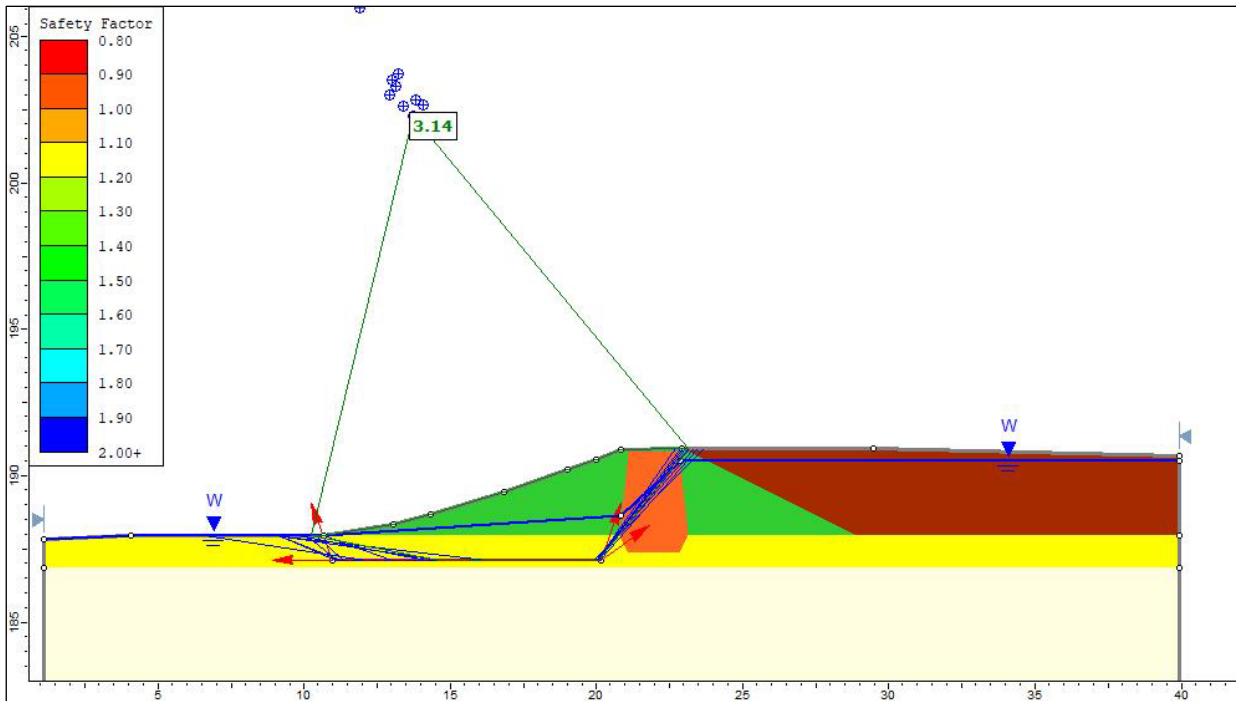


Figure A 35: Tailings Dam Cell A - Section 2 – Block Search - FoS = 3.04

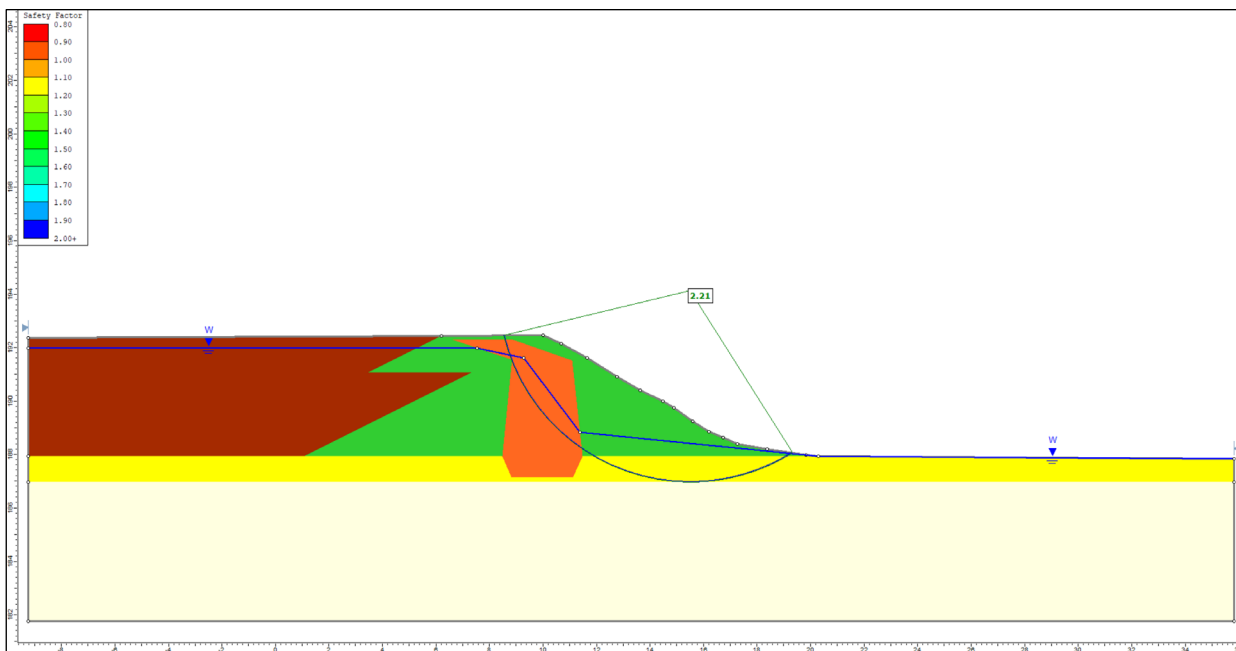


Figure A 36: Tailings Dam Cell B - Section 3 – Auto Refine Search - FoS = 2.21.

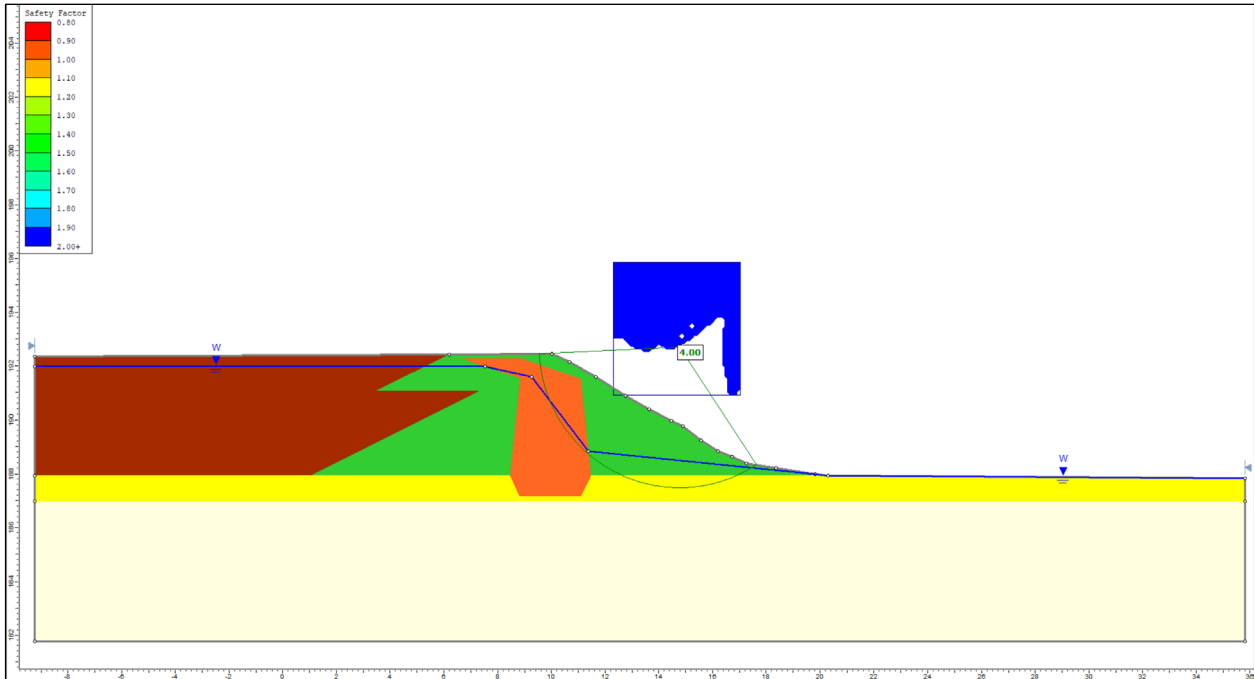


Figure A 37: Tailings Dam Cell B - Section 3 – Grid Search - FoS = 4.00

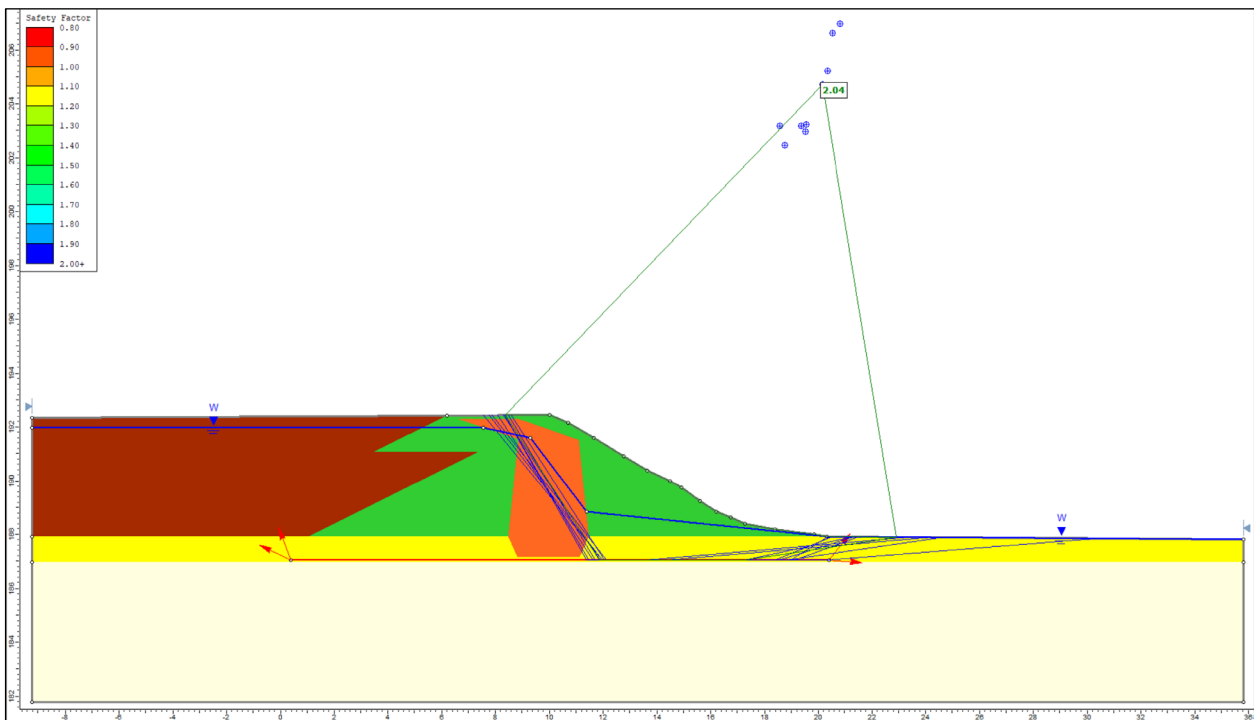


Figure A 38: Tailings Dam Cell B - Section 3 – Block Search - FoS = 2.04

Water Storage General Limit Equilibrium Outputs

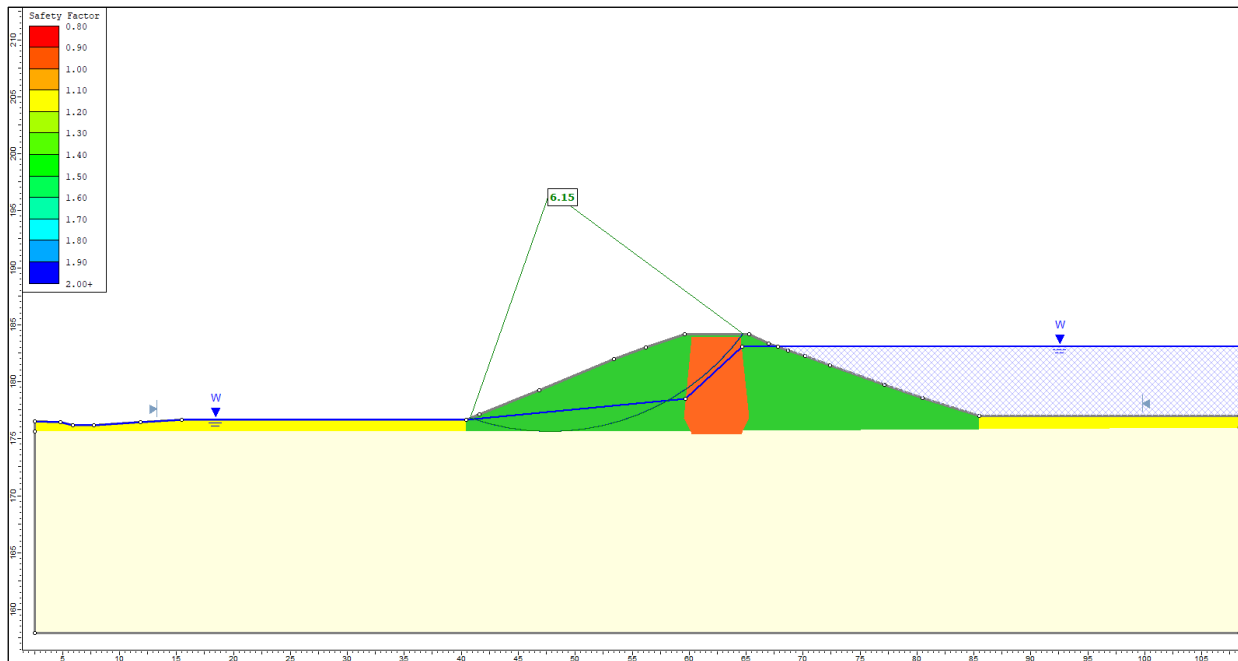


Figure A 39: Tailings Return Water Dam – Auto Refine Search - FoS = 6.15

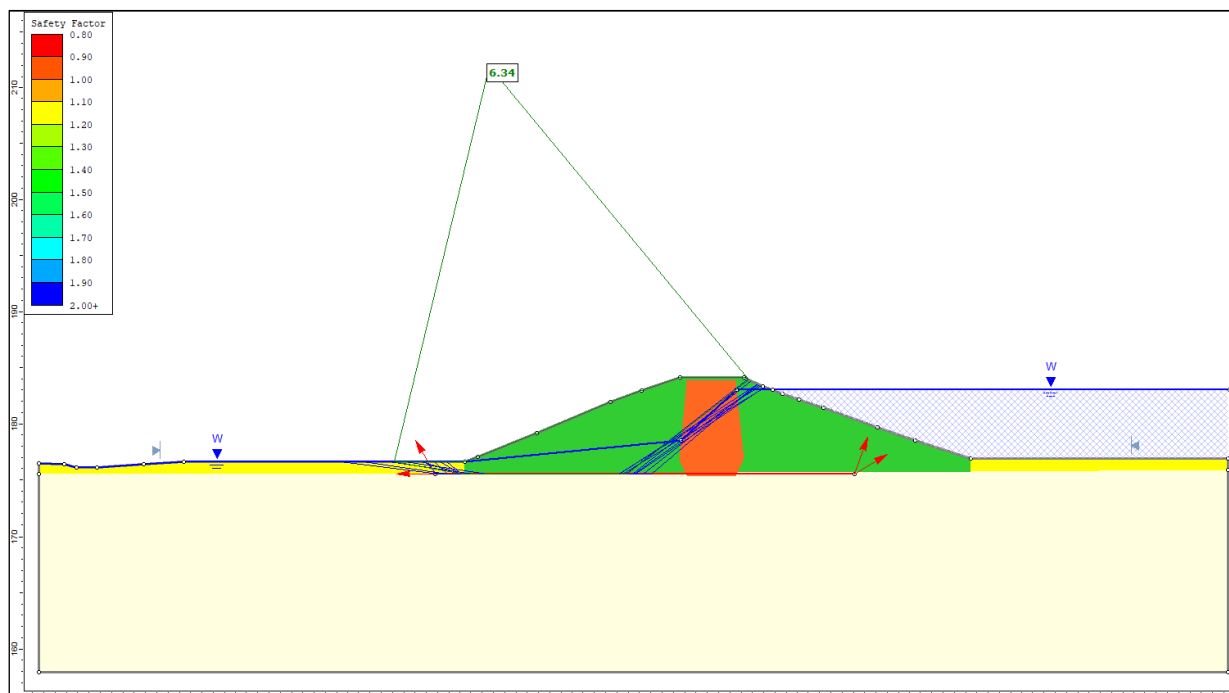


Figure A 40: Tailings Return Water Dam – Block Search - FoS = 6.34

Raw Water Dam General Limit Equilibrium Outputs.

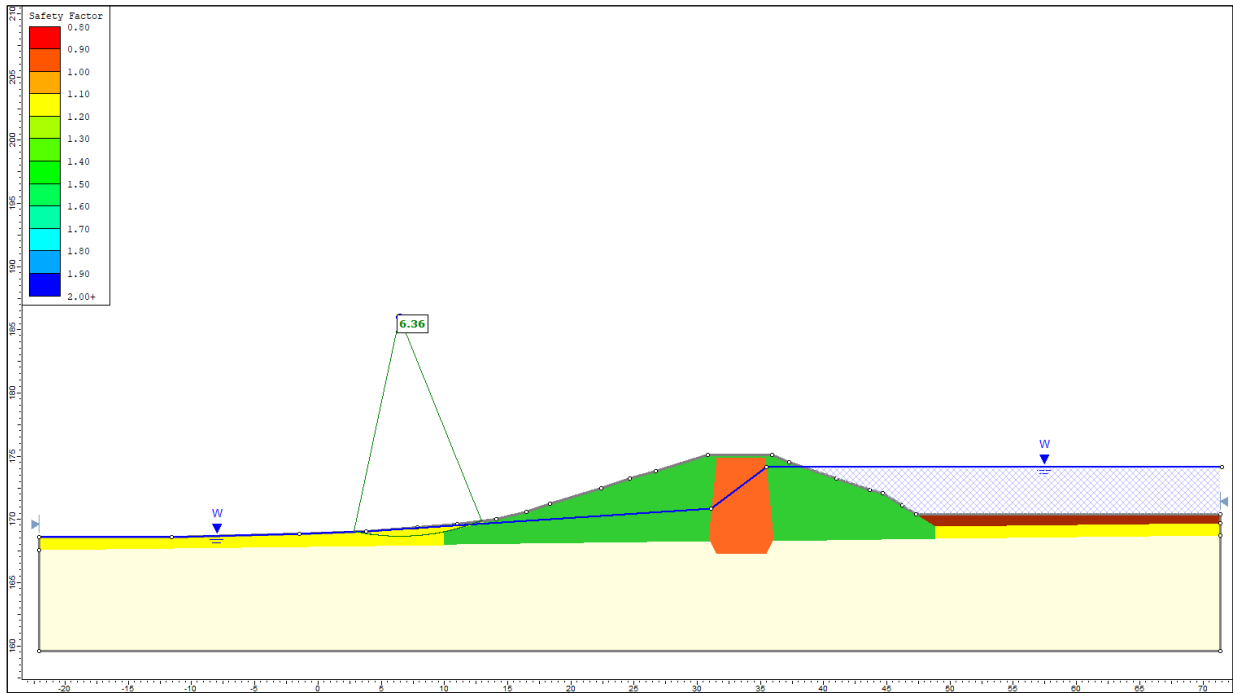


Figure A 41: Raw Water Dam - Auto Refine Search - FoS = 6.36

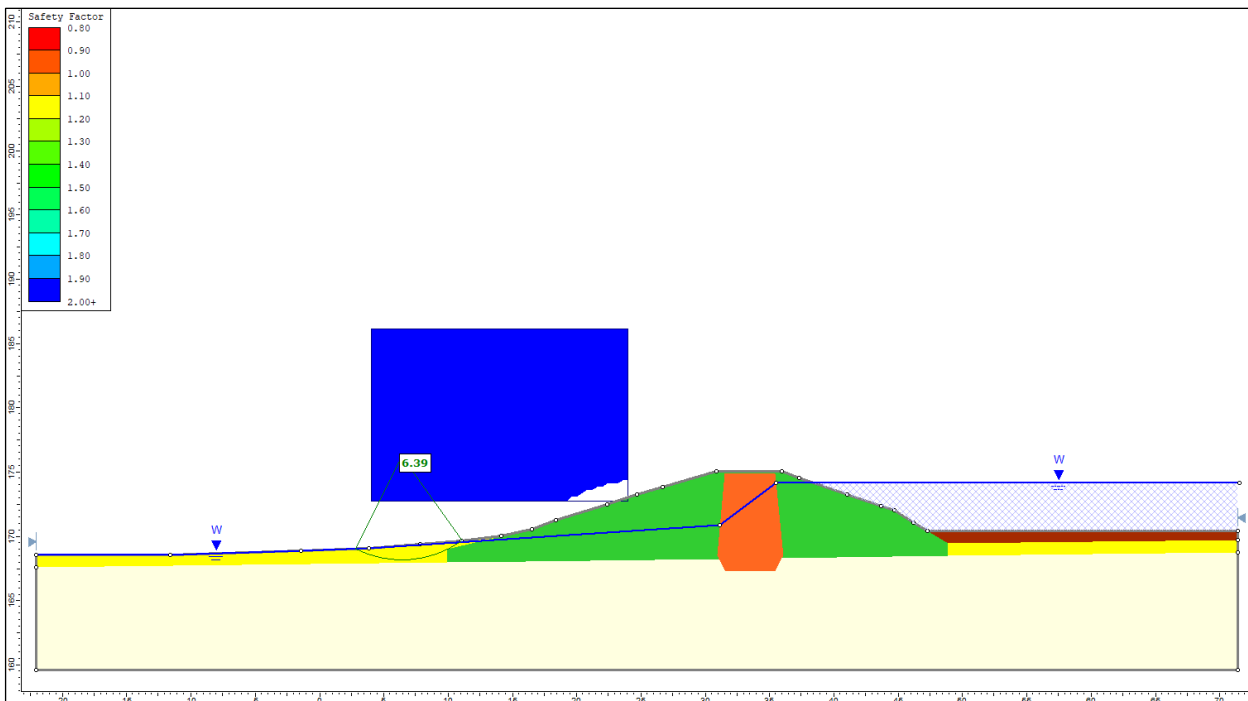


Figure A 42: Raw Water Dam - Grid Search - FoS = 6.39

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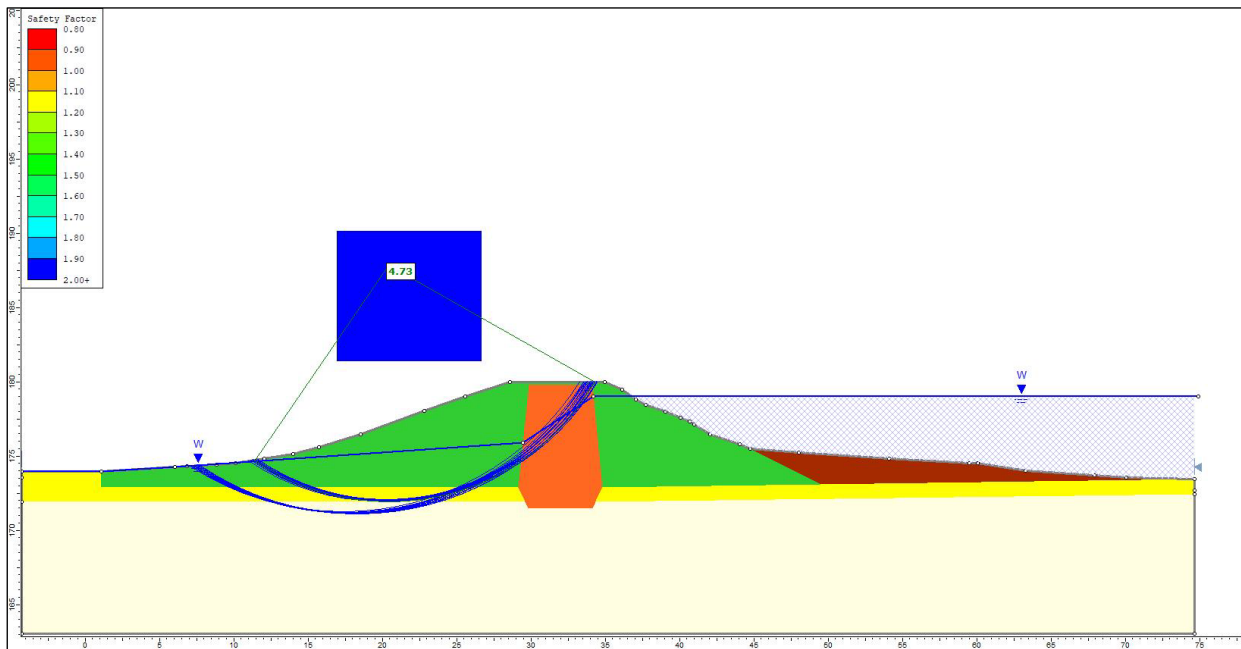


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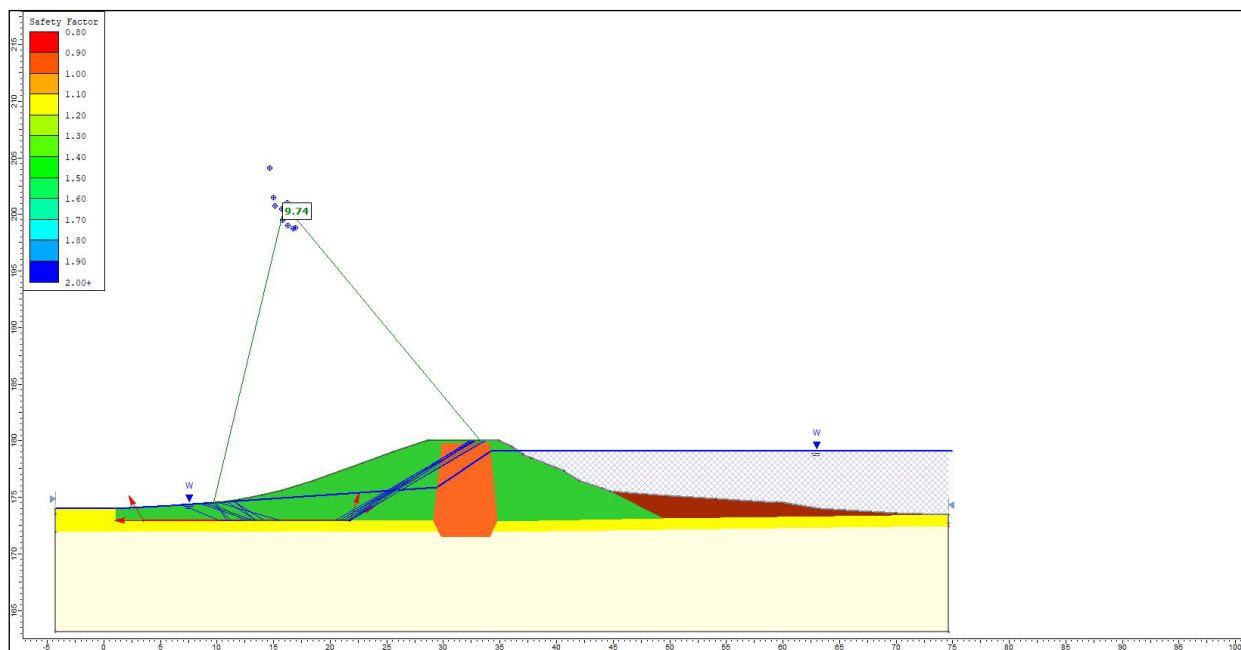


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Document Control

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Table of Abbreviations

AARC	AARC Environmental Solutions Pty Ltd
ASC	Australian soil classification
BoM	Bureau of Meteorology
CEC	Cation exchange capacity
DIWA	Directory of Important Wetlands in Australia
EA	Environmental authority
EC	Electrical conductivity
ESP	Exchangeable sodium percentage
HLP	Heap leach pad
ML	Mining lease
PAWC	Plant available water capacity
PMLU	Post mining land use
SLSA	Soil and Land Suitability Assessment
SMU	Soil management units
TSF	Tailings storage facility

1 Introduction

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Straits Gold Pty Ltd (Straits Gold) to conduct a Soil and Land Suitability Assessment (SLSA) on the Yandan Gold Project (the Project). The Project is authorised by Environmental Authority (EA) EPML00771913. The EA encompasses mining lease (ML) 1095 and ML 1096.

This SLSA documents the nature and distribution of major soil types in the study area and assesses their suitability for the land use of cattle grazing. This assessment establishes reference environmental characteristics and values relating to land use and suitability and provides recommendations for the management of soil resources within the Project area.

1.1 Objectives

This report provides an assessment of the soils and land suitability of the study area and includes the following objectives:

- Describe and map soil management units (SMUs) within the Project area, focusing on the area mapped as 'Oc27' (hard pedal red duplex soils), according to the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain 2009), *Guidelines for Surveying Soil and Land Resources* (McKenzie et. al. 2008) and *Australian Soil Classification* (Isbell and National Committee on Soil and Terrain 2021). This area contains the majority of the Project's infrastructure and has been indicated as relevant to future development.
- Describe and map land suitability classes of the survey area in accordance with *The Technical Guidelines for Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (State of Queensland 1995), *The Guidelines for Agricultural Land Evaluation in Queensland – Second Edition* (DSITI and DNRM 2015) and *The Regional Land Suitability Frameworks for Queensland* (State of Queensland 2013).
- Identify soils that require specialised management due to soil characteristics (e.g. erosivity and salinity), and soils that have a predisposition to land stability issues.
- Review the potential requirement for soil ameliorants and fertilisers, based on the results of the soil laboratory analyses and existing reporting.
- Review the suitability of soil sources for the post mining land use (PMLU) and rehabilitation methodology.
- Develop a material balance for the site, to identify:
 - the quality of available resources for rehabilitation use; and
 - the location and accessibility of cover materials for rehabilitation use.

2 Project background

The Project is situated in the Drummond Basin, central Queensland, located approximately 50 km to the west of the township of Mount Coolon and approximately 150 km southeast of Charters Towers (Figure 1). The Project falls on the boundary of the Whitsunday Regional Council and Charters Tower Regional Council local government areas.

The Impact Assessment Study for approval of the Project was submitted in December 1988, with ML1095 and ML1096 granted in June 1991. In July 1992, and in addition to the Wirralie Gold Mine, Ross Mining N.L. acquired the Project, a controlling interest in the Mount Coolon joint venture and exploration tenements associated with the three assets.

Ross Mining N.L. operated the Project between 1993–2002, producing over 350,000 ounces of gold from heap leach operations and a carbon in leach process plant. Mining operations ceased in 1998, with the heap leach pad remaining operational until September 2002. The site was placed into care and maintenance in April 1999, pending final closure works. The gold processing plant was later removed in 2006/2007, prior to the acquisition of the Project by Straits Gold, at the time a wholly owned subsidiary of Aeris Resources Ltd. The Project has remained in care and maintenance since closure in 1999.

GBM Resources acquired the Project and the Straits Gold entity on 13 January 2020 and have since taken significant steps towards restoring operations. This has included the 2021 drilling program, which focused on the identification of potential open pit targets in the area between the existing Main Pit and East Hill deposits.

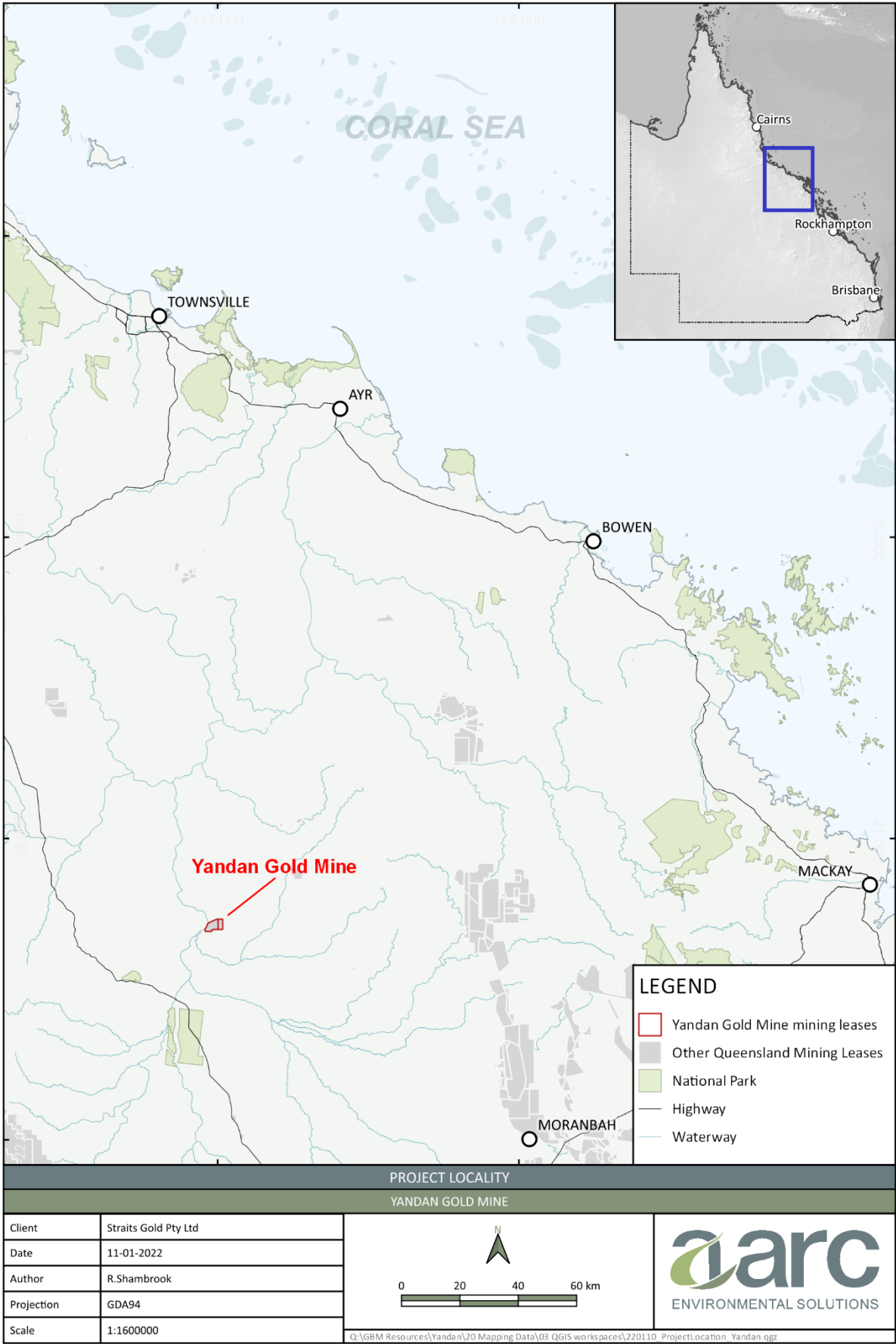


Figure 1: Project locality

2.1 Local topography and waterways

The Yandan Gold Project is situated within the Burdekin Drainage Basin and the Suttor River drainage sub-basin. The Suttor River is located on the western boundary of the Project within ML 1095, with a number of minor ephemeral tributaries running across the Project site (Figure 1). The relief at the Project site is about 30 m above sea level, elsewhere locally the undulating terrain has much less relief – approximately 5-10 m. The land rises gently away from the Suttor River towards the east. The highest elevation in the area is 212 m approximately 2 km north of the site.

The Suttor River is a braided stream occupying a broad depression. The Suttor River drainage sub-basin spans an area of approximately 74,000 km². The Suttor River flows south to north into two nationally important wetlands, as identified in the *Directory of Important Wetlands in Australia* (DIWA) (DAWE 2019). These DIWA wetlands include Lake Dalrymple and the Scartwater Aggregate. Lake Dalrymple was historically formed from the damming of the Burdekin River, which is located further upstream (HLA - Envirosciences 2000).

Stream flow in the rivers and tributaries of the Suttor River Sub-basin are dependent on the frequency and intensity of rainfall events within the catchment. Periods of flow are directly related to large rainfall events in the catchment, which is typical of ephemeral systems.

A number of ephemeral drainage lines intersect the Project area, being associated with Sandy Creek in the north, and Yandan Creek in the south (Figure 2). Both waterways drain to the Suttor River.

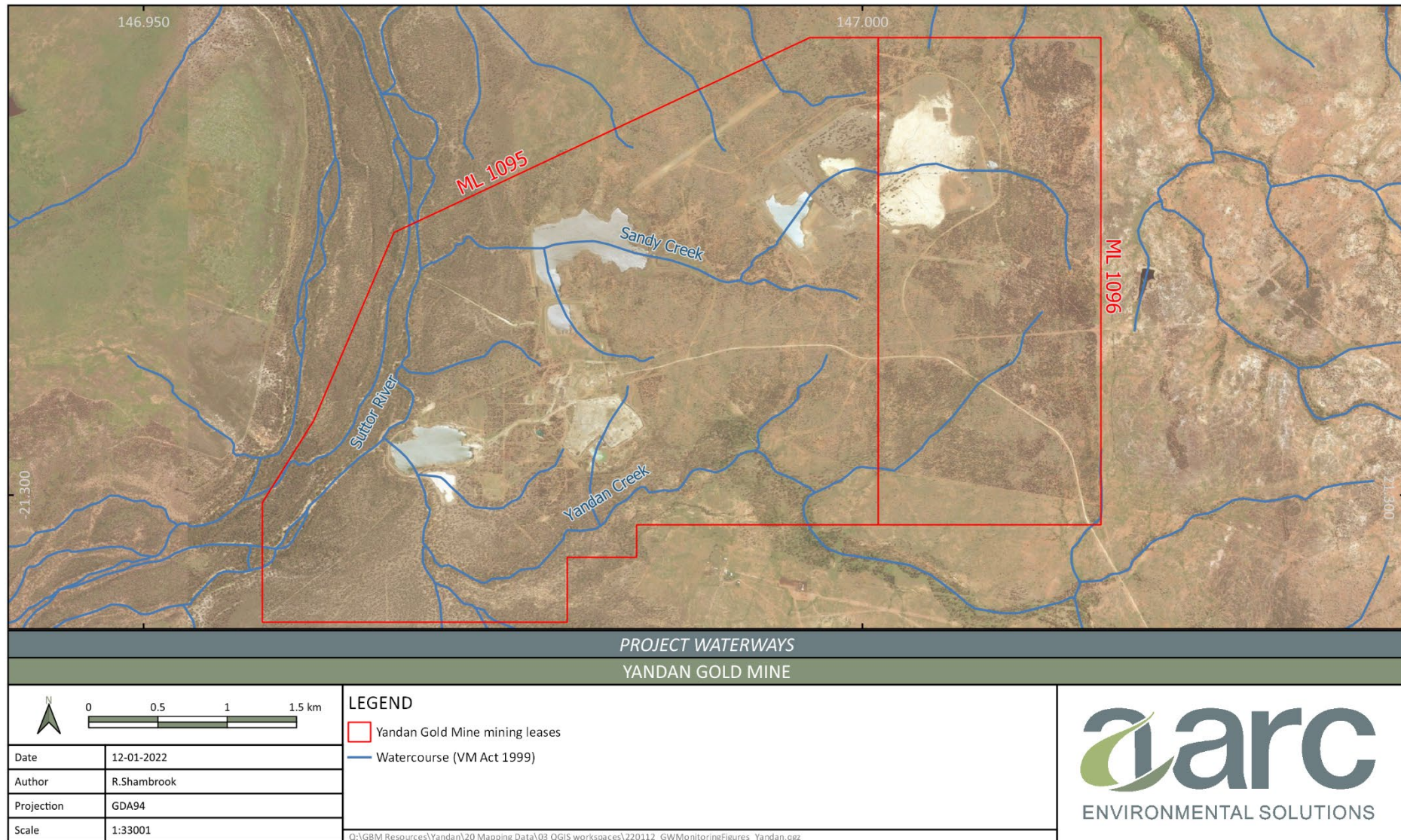


Figure 2: Yandan surface drainage system

2.2 Regional geology

The Yandan Gold Project is located on the eastern margin of the western arm of the Drummond Basin, a geological basin comprised of Middle Devonian to Early Carboniferous sedimentary and volcanic rocks (Straits n.d.). The Project area is proximal to the Anakie Inlier, a north-trending basement block of greenschist facies metavolcanic and metasedimentary rocks of Lower Cambrian age (de Caritat & Braun 1992).

The host geology underlying the Project is comprised of basement Anakie Inlier Les Jumelles metasediments, unconformably overlain by Middle Devonian Ukalunda Beds, which in turn are unconformably overlain by the St Anne's Formation of the Middle Devonian to Early Carboniferous Drummond Basin Sequence (Straits n.d.). On the western side of the tenement, parts of the Project have been unconformably overlain by fluvial deposits of the Scartwater Formation and Mount Hall Formation (Straits n.d.). The general composition of the three main geological units is summarised as follows.

Basement geology

The basement Les Jumelles metasediments are metamorphosed quartz-muscovite sandstones and siltstones (Townend 2005, within Straits n.d) and chloritic black shale. Also, within the basement geology, the Ukalunda Formation sediments are various interbedded massive and bedded lithologies containing quartzose, calcareous and carbonaceous sandstones, siltstones and mudstones (Straits n.d.).

Lower St Anne's Formation

The Lower St Anne's Formation generally consists of three lithologies: andesite flows, andesite clastics and polyolithic volcanic breccia (Straits n.d.). Overlying this are primarily feldspar-lithic sandstone and siltstone (Yandan Host), formed through weathering and erosion of the Yandan Andesite. Calcareous sandstone and Yandan Limestone is the youngest unit in the local stratigraphy, overlying parts of the Yandan Host in Main Pit (Straits n.d.).

Gold mineralisation on the Project has been substantially mined out, with the East Hill area containing the most encouraging remaining mineralisation (Straits n.d.). Three phases of gold mineralised silica have been identified within the East Hill area, including crustiform banded veining which commonly suggests high-grade gold mineralisation (Straits n.d.).

Surface geology

Tertiary and Quaternary sediments cover much of the Project area. In the south and east, the surface geology is predominantly Tertiary Suttor Formation comprised of lateralised sandstone, mudstone, claystone, oil shale, diatomite and carbonaceous claystone (Hutton *et al.* 1991). Channels incise the Suttor Formation and contain Quaternary alluvial channels that drain to flood plains (Straits n.d.). Quaternary alluvium covers much of the underlying Drummond Basin Sequence on the Project, with the depth of this stratum increasing towards major drainage lines (i.e. Suttor River, Rosetta Creek, Belyando River) (Straits n.d.).

Geological units and structures on the Project are shown through Figure 3.

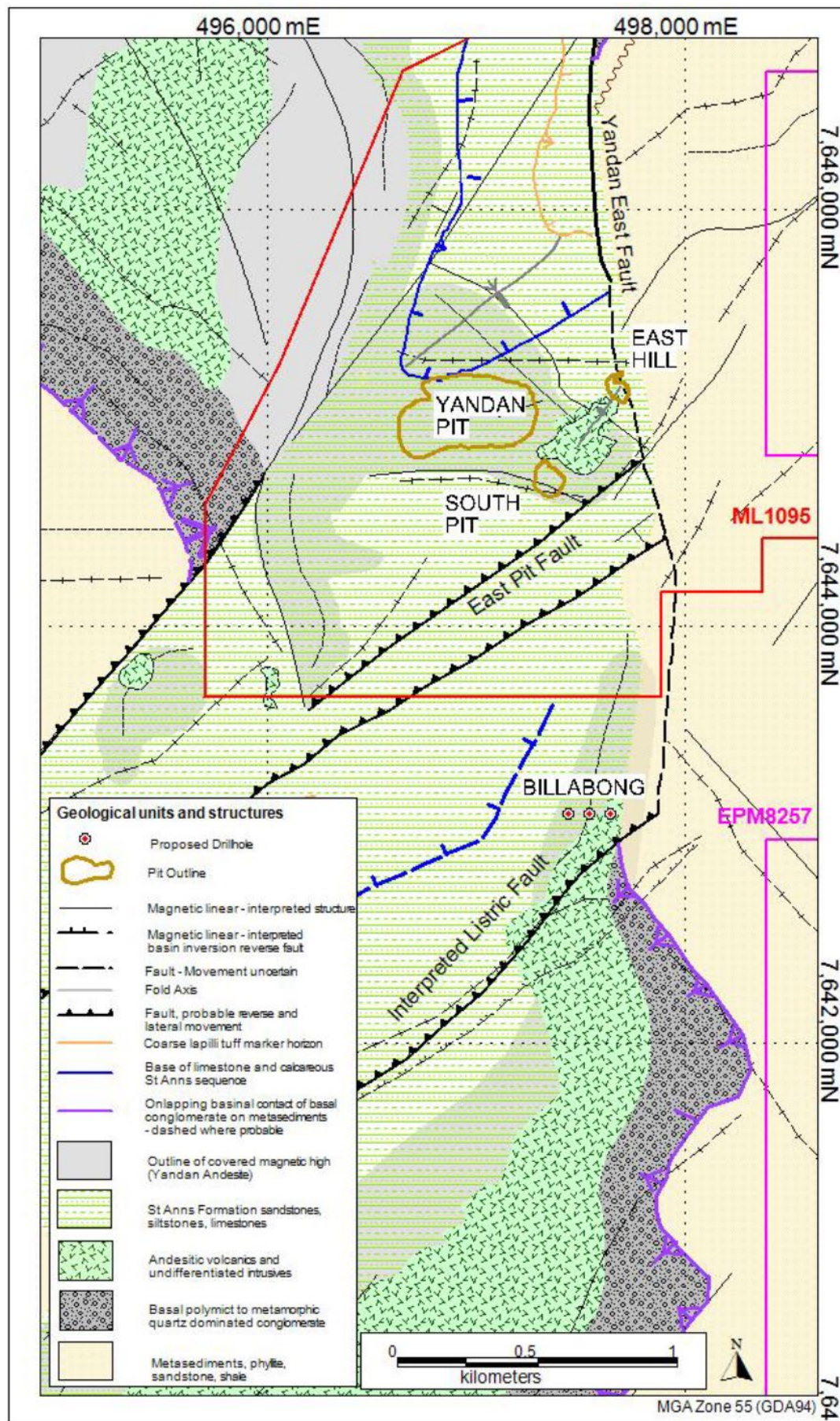


Figure 3: Geology of Yandan (Source: Straits n.d.)

2.3 Regional climate

The Yandan Gold Project is located within a region identified as having a sub-tropical climate with moderately dry winters and hot summers (BoM 2001). Most of the rainfall for this region occurs during the November to March wet season, with limited rainfall recorded throughout the rest of the year. Rainfall records (for the 1899 – 2020 period) for the surrounding region are available from the nearby Mount McConnell Bureau of Meteorology weather station (located approximately 66 km north-east of the Project site) and represented in Figure 3.

Rainfall records (1899 – 2020) indicate annual rainfall totals are within the range of 190–1,480 mm/year, with a median annual total of 597 mm/year. The majority of rainfall occurs during rainfall events in the wet season, with dry conditions persisting for the majority of the year (on average 321 days per year).

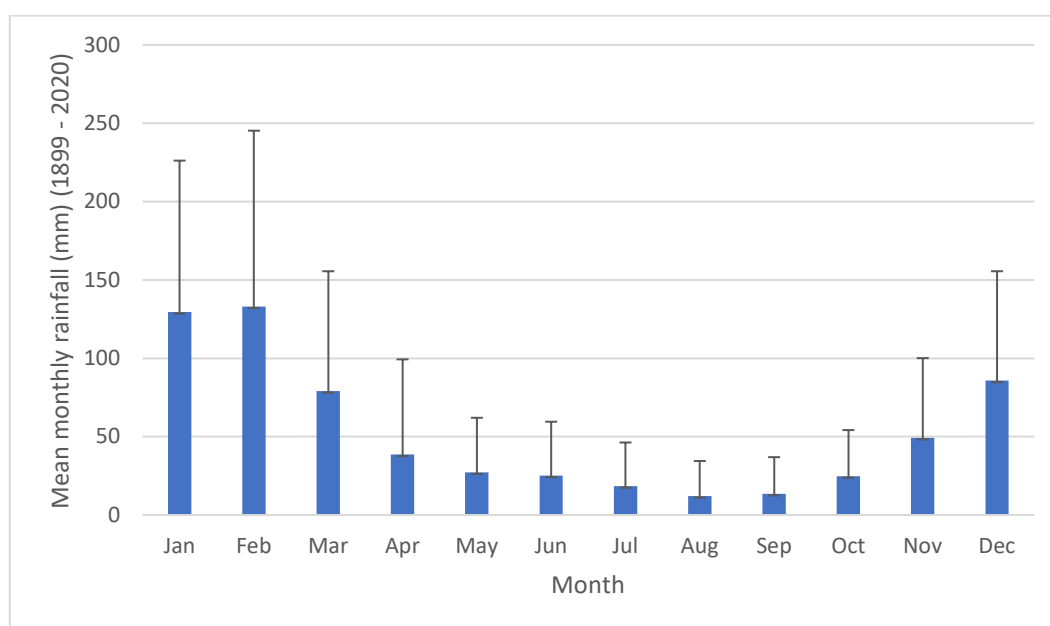


Figure 4: Mean monthly rainfall within the surrounding Project region (Mount McConnell BoM station)

2.4 Current land use

Low intensity beef cattle grazing is the primary land use for the region, with much of the naturally occurring open forest and woodlands cleared for this purpose. Limitations of the soil, together with low rainfall and high rainfall variability render the stock carrying capacity relatively low. Information obtained from the then Department of Primary Industries indicated that the carrying capacity of the land is approximately one beast per 15 ha (GHD 2008).

The pre-mining land use for the Project area was low intensity livestock grazing, which is consistent with the surrounding land use.

2.5 Strategic cropping land

The Project is not located in a Priority Agricultural Area or a Strategic Cropping Area, as defined by the *Regional Planning Interests Act 2014*.

2.6 Land systems

The report *Lands of The Nogoa-Belyando area, Queensland* (Gunn *et al.* 1967) (mapped at a scale of 1:500,000) notes the study area as containing the land system units described in the following sub-sections.

2.6.1 Disney Land System

The Disney Land System is characterised by small lateritic mesas with ironbark and red or yellow earths on Tertiary sandstone. The surrounding lowlands are texture contrast soils on weathered Drummond Basin sediments, occupied with Box *Eucalyptus spp.* and *Acacia harpophylla* (Brigalow).

The potential use of the Disney Land System is limited cultivation and/or pasture improvement due to limitations including moderate erosion, shallow soils, salinity, alkalinity and/or microrelief (gilgai soils).

2.6.2 Peak Vale Land System

The Peak Vale Land System comprises undulating terrain on granite with texture contrast soils under Silver-Leaved Ironbark woodland and eastern mid-height pasture. The rolling country consists of moderately deep soils but diversified by occasional rocky tors up to 15 m high and basalt plugs up to 150 m. The limitations found in the Disney Land Systems also occurs in this landscape, including moderate erosion, shallow soils, salinity, alkalinity and/or microrelief (gilgai soils).

2.6.3 Blackwater Land System

The Blackwater Land System is mostly found within the Belyando catchment, where the tertiary land surface and weathered zone have been partially removed. It is a depositional land system described as Brigalow plains with cracking clay soils on acid clay exposed within the Tertiary weathered zone. Gravel is common in this material and gilgai microrelief occurs in the lower sites. The landscape may be limited by moderate erosion, salinity, alkalinity, unreliable rainfall, and microrelief.

2.6.4 Banchory Land System

The Banchory Land System is within a post tertiary alluvial system, within the lower alluvial plains. It is characterised by alluvial plains with gidgee and cracking clay soils. The landscape is susceptible to flooding, hence, very frequent overflow from streams/drainage lines limits the potential land use to intensive grazing.

2.6.5 Humboldt Land System

The Humboldt Land System consists of *Eucalyptus cambageana* (Dawson Gum) woodland, which usually forms scrubs with Brigalow. These woodlands are on texture contrast soils formed on acid clay exposed within the Tertiary weathered zone. Relief is generally gently undulating but both plains and hills are present, the land system is stony in places.

3 Soil survey methodology

3.1 Desktop analysis

A desktop analysis was conducted prior to field sampling. This analysis was comprised of background research and evaluation of available information for the study area. Resources used included:

- The *Digital Atlas of Australian Soils* (Bureau of Rural Science 1991). Australian soils were mapped at a scale of 1:2,000,000. Although this scale is broad, it provided a good foundation for understanding the soils that may be present in the study area.
- Government maps featuring regional topography, geology, contour data and watercourse locations were used to help refine mapping boundaries, particularly where soil types are a function of gradient.
- Reference information for land systems: *Land Systems of the Nogoa-Belyando Area, Queensland* (Gunn *et al.* 1967)
- Reference information for grazing land management: *Land types of Queensland* (FutureBeef 2011)
- High resolution imagery and digital elevation data for the Project area was captured in late 2022 and provided by GBM Resources.

3.2 Survey design

Methodologies employed throughout this study followed procedures detailed in the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain 2009) and the *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al.* 2008).

The conventional form of soil survey is commonly referred to as free survey (Steuer 1961). It is suited to detailed-scale survey and has been utilised in this study with the intention to map soil boundaries. Soil profile and observation sites were selected to best represent all soil types present in the study area.

Mapping scales for the study area were selected in order to satisfy the requirements of a Progressive Rehabilitation and Closure Plan, taking into consideration available resources, land access and soil complexity.

For the study area, a scale between 1:25,000 to 1:100,000 was deemed most appropriate based on McKenzie *et al.* (2008). The final mapping scale of 1:30,000 for the study area fell within the specified range.

To achieve a mapping scale of 1:25,000 to 1:100,000, McKenzie *et al.* (2008) suggest a minimum sampling density of one site per 100 ha with data collection comprising detailed soil profile descriptions (15 to 35% of sites), representative profile sampling for lab analysis (1 to 5%) and mapping observations sites (55 to 83%).

The lower range of recommended ground observations was selected (a total of 39 observations), which exceeded the minimum requirements of a conventional qualitative land resource survey (Table 1). The number of laboratory analysis samples also exceeded the upper recommended range to improve the accuracy of soil descriptions and mapping.

Table 1: Chosen survey observation quantities

Survey site	Scale	Objectives	Detailed soil profiles	Representative profiles for analysis	Mapping observations	Total
Study area (,1971 ha)	1:50,000	- General suitability for various forms of land use - Planning for low intensity land uses	7	4	28	39

3.3 Field investigations

AARC completed field sampling for the SLSA during 11–12 December 2021, with this consisting of primary sampling sites (profiles) and secondary visual assessments (observations).

Sampling site locations were determined based on the desktop analysis, land management units, landform and vehicle access. Visual assessments were conducted continually while traversing the landscape to confirm major soil types and boundaries between soil units. The GPS coordinates of each location were recorded.

Detailed soil profiles were undertaken at seven (7) sites within the Project boundaries. A soil auger was used to excavate cores to a maximum depth of 80 cm. Soil samples were collected from profiles at standard depths of 0–10 cm, 20–30 cm, 50–60 cm and 70–80 cm, where possible. Samples were sealed in clean, plastic zip-lock bags and labelled with the site number, date and depth of sampling.

Parameters recorded included micro relief, permeability, drainage, substrate, site disturbance, landform (slope, relief, elevation, morphological type, landform element and landform pattern), runoff, erosion, surface coarse fragments, rock outcrops, surface condition and dominant vegetation type. Soil profile morphology was described in the field in terms of horizon type, horizon depth, boundary, colour, mottles, texture, coarse fragments, structure, segregations, consistency and field pH.

Field pH was measured using a Manutec soil pH test kit. To test the pH, few drops of the pH dye indicator liquid is placed on a small soil sample. Barium sulphate powder was dusted over the sample and the colour change was observed. The pH value was determined comparing the colour of the sample with the colour chart provided in the kit. The sampling equipment was washed thoroughly between samples to avoid contamination.

The field assessment also involved refinement of the existing material balance for the site. Potential rehabilitation materials identified during the desktop assessment were verified in the field, with this involving the verification of the location and extent, and soil sampling to confirm suitability for use. Confirmed footprints of material sources were later analysed in a three-dimensional model of the site, with the material resources within these footprints then calculated.

3.4 Laboratory analysis

Samples from a total of four (4) sites were chosen for analysis through Australian Laboratory Services for NATA approved physical and chemical analyses. Samples from all standard depths at the chosen sites were analysed to:

- confirm the classification of the described soil profile;
- assist in the description of soil physical and chemical characteristics;
- assist in the determination of land suitability classes; and
- assist in the identification of soils that would require specialised management.

Physical and chemical parameters analysed for all samples included:

- pH;
- electrical conductivity (EC);
- moisture content;
- chloride (soluble);
- exchangeable cations (Ca, Mg, Na, K);
- cation exchange capacity (CEC); and
- exchangeable sodium percentage (ESP).

Additional physical and chemical parameters analysed for topsoil samples included:

- organic matter (%);
- particle size analysis (PSA);
- extractable trace elements/metals (Fe, Cu, Zn, Mn);
- boron (CaCl₂ extractable);
- nitrogen as nitrate;
- sulphate (water-soluble S as sulphate);
- phosphorus and potassium (Colwell); and
- Emerson class.

3.5 Characterisation of soil management units

Soil classification was undertaken using the methodologies specified in *The Australian Soil Classification* (Isbell and the National Committee on Soil and Terrain 2021). SMUs were then defined based on grouping soils of like soil morphology, parent material, and land attributes in accordance with the (McKenzie *et al.* 2008). Each SMU has been described in terms of its soil profile class with the attributes and limitations of the soil interpreted using the *Guidelines for Agricultural Land Evaluation in Queensland – Second Edition* (DSITI and DNRM 2015) to determine their suitability for cattle grazing. SMUs were mapped at a scale of 1:30,000 across the study area.

3.6 Interpretation of chemical data

The characteristics and chemical data for each SMU have been described in section 4. The following guidelines were used to assist in interpretation of the SMU physical and chemical properties and to determine ratings and categories of the assessed soil parameters:

- *Interpreting Soil Test Results* (Hazelton and Murphy 2016);
- *Soil Chemical Methods of Australasia* (Rayment GE and Lyons D 2011); and
- *Standard Soil Test Methods and Guidelines for Interpretation of Soil Results* (Government of South Australia 2013).

Broad descriptions for each soil parameter have been provided below and where applicable, a summary of the rating system used.

3.6.1 pH

Soil pH influences the availability of plant available nutrients and toxic elements by controlling the solubility of these elements. At extreme pH, the availability of essential plant nutrients can be severely reduced while toxic elements can become mobile within the soil solution in acidic environments. The soil pH ratings used

are shown in Table 2. In general, a suitable soil pH ranges from 5.5–9.0 as at this pH all essential nutrients are available to some degree.

Table 2: Interpretation of pH measured in water (1:5 soil/water ratio) (Hazelton and Murphy 2016)

pH _{water}	Rating	Soil chemistry indications
<4.0	Very strongly acid	Typical of disturbed acid sulphate soils
4.0 to <5.0	Strongly acid	Acidified soils
5.0 to <6.0	Moderately acid	Range most suitable for plant growth
6.0 to <7.0	Slightly acid	
7.0	Neutral	
>7.0 to <8.0	Slightly alkaline	
8.0 to <9.0	Moderately alkaline	Some nutrients becoming unavailable, indication of sodicity
9.0 to 10.0	Strongly alkaline	
>10.0	Very strongly alkaline	Extreme pH, high sodicity and carbonates

3.6.2 Electrical conductivity

Soil salinity is determined by measuring the electrical conductivity of soil:water suspensions in soil. This provides an indication of the presence of water-soluble salts, including sodium, calcium and magnesium, which can be chlorides, sulphates or carbonates, in the soil profile.

Electrical conductivity is determined by converting the EC_(1:5) (soil:water suspension) to saturated extract (EC_{SAT}) (dS/m), which is based on the estimated water holding capacity of the soil based on soil texture. To convert EC_(1:5) to EC_{SAT}, the following formula is used:

$$EC_{SAT} \text{ (dS/m)} = EC_{(1:5)} \text{ (dS/m)} \times \text{multiplier factor (Hazelton and Murphy 2016)}$$

High soil salinity can increase soil erosion, severely effecting plant growth and land use. Highly saline conditions compromise the ability of a plant to take up water as needed, resulting in water stress regardless of the water content in the soil. The texture of soil needs to be considered when interpreting EC as the clay content determines the amount of salt present that will affect plant growth. Table 3 provides the multiplier factors to be applied to the formula for converting EC_(1:5) (dS/m) to EC_{SAT} (dS/m), as described in Hazelton and Murphy (2016).

Table 3: Soil salinity ratings (based on EC values in dS/m)

Soil texture	Multiplier factors
Sand, loamy sand, clayey sand	23
Sandy loam, fine sandy loam, light sandy clay loam	14
Loam, fine sandy loam, silty loam, sandy clay loam	9.5

Soil texture	Multiplier factors
Clay loam, silty clay loam, fine sandy clay loam, sandy clay, silty clay, light clay	8.6
Light medium clay	8.6
Medium clay	7.5
Heavy clay	5.8

Saline soils are defined as having an $EC_{SAT} > 4$ dS/m (Table 4).

Table 4: Salinity ratings for soil based on EC_{SAT}

Rating	EC dS/m	Effect on plants
Non-saline	<2	Salinity effects are mostly negligible
Slightly saline	2 – 4	Yields of sensitive crops are affected
Moderately saline	4 – 8	Yields of many crops are affected
Highly saline	8 – 16	Only tolerant crops yield satisfactorily
Extremely saline	>16	Only very tolerant crops yield satisfactorily

3.6.3 Chloride

Chloride is associated with EC as soluble salts contain chloride, thus the presence of soluble salts in soils is directly proportional to chloride in soil. A high chloride concentration can induce chloride toxicity and interfere with the osmotic capacity of plants. Table 5 below provides chloride ratings (Rayment and Bruce 1984).

Table 5: Chloride concentration ratings

Chloride rating	Cl concentration (mg/kg)
Very Low	< 100
Low	100 – 300
Medium	300 – 600
High	600 – 2,000
Very High	> 2,000

3.6.4 Cation exchange capacity and exchangeable cations

Cation Exchange Capacity (CEC) is an indication of the capacity of a soil to adsorb cationic nutrients to the surface of soil particles. This process of adsorption prevents nutrients leaching from the soil and buffers the concentration of plant available nutrients in the soil solution. A high CEC of the soil contributes to larger quantities of exchangeable cations (Ca, K, Mg, Na) available. The ratio of cations on the exchange is also an important consideration as cations that dominate the exchange can interfere with the availability of other

cations. Table 6 and Table 7 provide ratings for soil CEC and extractable cations sourced from Hazelton and Murphy (2016).

Table 6: Soil CEC ratings

CEC rating	CEC (cmol(+)/kg)
Very Low	< 6
Low	6–12
Medium	12–25
High	25–40
Very High	> 40

Table 7: Extractable cations (cmol(+)/kg) ratings

Cation	Very Low	Low	Moderate	High	Very High	Ideal range (% of CEC)
Ca	0–2	2–5	5–10	10–20	> 20	65–80
K	0–0.2	0.2–0.3	0.3–0.7	0.7–2	> 2	1–5
Mg	0–0.3	0.3–1	1–3	3–8	> 8	10–15
Na	0–0.1	0.1–0.3	0.3–0.7	0.7–2	> 2	< 1

3.6.5 Exchangeable sodium percentage

Exchangeable sodium percentage (ESP) is defined as the amount of exchangeable sodium as a percentage of the total CEC of the soil. It provides a measure of how much of the CEC of the soil is dominated by sodium. Due to the chemical characteristics of sodium ions, an increasing ESP indicates increasing sodicity thus increasing the risk of dispersion. Table 8 provides ESP ratings sourced from Hazelton and Murphy (2016).

Table 8: Soil ESP ratings

ESP (%)	ESP rating
< 6	Non-sodic
6–15	Sodic
> 15	Strongly sodic

3.6.6 Organic matter

Organic matter is an essential constituent of soil. It is an important component of microbial processes and nutrient cycling. Furthermore, it contributes to the ability of a soil to buffer changes to pH and nutrient

content and supports the aggregation of soils thereby improving the structural stability of the soil. Table 9 provides soil organic matter ratings sourced from Hazelton and Murphy (2016).

Table 9: Soil organic matter ratings

Organic matter rating	Organic matter content (g/100 g)
Extremely low	< 0.7
Very low	0.7–1
Low	1–1.7
Moderate	1.7–3
High	3–5.15
Very High	> 5.15

3.6.7 Particle size analysis

Particle size analysis determines the percentage composition of sand, silt and clay sized particles which controls the soil texture. Soil texture influences the structural stability and water holding characteristics of a soil as the particle size distribution influences the porosity and permeability of soil.

3.6.8 Extractable trace elements/metals

Trace elements such as copper, iron, manganese, zinc and boron are essential nutrients required for plant growth, although needed in much smaller quantities than exchangeable cations. Table 10 provides trace element/metal ratings sourced from Government of South Australia (2013).

Health investigation levels (HILs) are generic assessment criteria outlined in *Schedule B1 – Investigation Levels for Soils and Groundwater* (National Environmental Protection Measure, 2011), designed to be used in the first stage of an assessment of potential risks to human health from chronic exposure to contaminants. The HILs for soil contaminants of standard residential with accessible soils are provided in Table 11.

Table 10: Ideal concentration ranges for trace elements/metals

Trace element/metal	Rating	Concentration (mg/kg)
Boron	Low	< 0.5
	High	> 15
Copper	Low	< 0.3
	High	> 1
Iron	Low	< 10
	High	> 70
Manganese	Low	< 1

Trace element/metal	Rating	Concentration (mg/kg)
	High	> 10
Zinc	Low	< 0.5
	High	> 1

Table 11: Health investigation levels for soil contaminants (Residential A)

Trace element/ metal	Health-based Investigation Levels (mg/kg) Residential A
Boron	5,000
Copper	7,000
Manganese	3,000
Zinc	8,000

3.6.9 Nitrate

Nitrate is a plant available form of nitrogen. It is an essential nutrient and is often the most limiting to plant growth. It is also susceptible to nitrification and leaching which reduces nitrate concentration in soil. Table 12 provides soil nitrate ratings sourced from Hazelton and Murphy (2016).

Table 12: Soil nitrate ratings

Rating	Nitrate concentration (mg/kg)
Very low	0–6
Low	7–15
Moderate	16–22
High	23–30
Very High	> 30

3.6.10 Sulphate

Sulphate is another essential plant nutrient and has a similar behaviour to nitrate in that it is susceptible to leaching and is important in microbial processes. Table 13 provides soil sulphate ratings sourced from Government of South Australia (2013).

Table 13: Soil sulphate ratings

Rating	Sulphate concentration (mg/kg)
Low	< 5

Rating	Sulphate concentration (mg/kg)
Marginal	5–10
High	> 10

3.6.11 Phosphorous and potassium

Both phosphorous and potassium are the next most essential nutrients after nitrogen and sulphate. Phosphorous and potassium are involved in several chemically- and microbially-driven processes within the soil with most forms of these nutrients being unavailable for plant uptake. Table 14 and

Table 15 provide ratings for soil phosphorous and potassium levels sourced from Hazelton and Murphy (2016).

Table 14: Soil phosphorus ratings

Rating	Phosphorous concentration (mg/kg)
Very low	< 5
Low	5–10
Moderate	10–17
High	17–25
Very High	> 25

Table 15: Soil potassium ratings

Soil Texture	Potassium critical concentration (mg/kg)*
Sand	126
Sandy loam	129
Sandy clay loam	143
Clay loam	161

* Critical concentration is that concentration where 95% of maximum yield is achieved

3.6.12 Emerson class

Emerson class is a class assigned to soil that is determined on the stability of dry aggregates in water. The Emerson class number of a soil is assigned as an indication of the dispersion and slaking ability of a soil. Table 16 below describes the Emerson Dispersion Class (Emerson 1967).

Table 16: Emerson class numbers

Emerson dispersion class	Level of dispersion
1	Slaking and complete dispersion

Emerson dispersion class	Level of dispersion
2	Slaking and some dispersion
3	Slaking and no dispersion
4	CaCO ₃ /CaSO ₄ present. No dispersion at field capacity
5	No CaCO ₃ /CaSO ₄ present. No dispersion at field capacity, however, dispersion in an aggregate-water suspension
6	No CaCO ₃ /CaSO ₄ present. No dispersion at field capacity, however, flocculation in an aggregate-water suspension
7	No slaking and swelling
8	No slaking and no swelling

3.7 Land suitability assessment

Land suitability refers to the adequacy of land for a defined use. Land suitability assessment considers environmental factors including climate, soils, geology, geomorphology, erosion, topography and the effects of past land uses. The classification does not always represent the current land use. Rather, it indicates the potential of the land to be used for specific agricultural activities. The aim of this land suitability assessment is to evaluate the suitability of the Project area for agricultural land uses, specifically cattle grazing, prior to further development of the mine.

The assessment for land suitability (cattle grazing) has been carried out in accordance with the methodologies described in:

- *Guidelines for Agricultural Land Evaluation in Queensland* (2nd edition) (DSITI and DNRM 2015).
- *Regional Land Suitability Frameworks for Queensland* (State of Queensland 2013)

The five land suitability classes used for assessing land are defined in Table 17. Land is considered less suitable as the severity of limitations for a land use increase. The land suitability class reflects the score of the most limiting attribute for a given SMU. An increase in limitations may reflect either:

- reduced potential for production;
- increased inputs to achieve an acceptable level of production;
- increased inputs to prepare the land for successful production; and/or
- increased inputs required to prevent land degradation.

Table 17: Land suitability class description

Class	Agricultural description	Conservation description
Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.	Areas well suited for conservation uses must possess significant conservation benefits in the pre-mining environment and be capable of being returned to that use post-mining.

Class	Agricultural description	Conservation description
Class 2	Suitable land with minor limitations which either reduce production or require more than the simple management practices of class 1 land to maintain economic production.	Areas suited to conservation use in that a significant component of the pre-mining conservation values can be restored post-mining. There will however, be some loss in conservation values where soil terrain or hydrological post-mining conditions may inhibit the full replication of the pre-mining values.
Class 3	Suitable land with moderate limitations which either further lower production or require more than those management practices of class 2 land to maintain economic production.	These lands contain significant conservation values pre-mining, however, restoration of all of these values may not be feasible. These areas could, however, be restored to a form of conservation use which provides alternative conservation benefits.
Class 4	Marginal land , which is presently considered unsuitable due to severe limitations. The long-term significance of these limitations on the proposed land use is unknown or not quantified. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production.	These lands contain limited conservation value pre-mining and/ or are incapable of being effectively restored post-mining to any alternative conservation use which provides similar benefits. The area could however, be restored to provide a stable form of use which does not impact on surrounding conservation values.
Class 5	Unsuitable land with extreme limitations that preclude its use.	These lands contain no significant conservation values.

A list of limitations has been compiled for districts throughout Queensland in the *Regional Land Suitability Frameworks for Queensland* (State of Queensland 2013). The Project area is located within the Inland Fitzroy and southern Burdekin area. The limitations outlined for the assessment of land suitability for land uses are:

- Water erosion;
- Erosion hazard, subsoil erodibility;
- Soil water availability;
- Narrow moisture range;
- Surface condition;
- Rockiness;
- Microrelief; and
- Wetness

A land use is a combination of a crop and its management options (e.g. dryland pastures, rain-fed sorghum etc.). The regional frameworks outline limitation criteria for various dryland cropping land uses. However, the suitability for dryland native pastures was not described for the Project district. It is inferred that the suitability of dryland agricultural crops can be applied to native dryland pastures due to the development of similar tolerance traits.

Native grasses are mostly perennials and persist well in the Australian environment. They are well adapted to the harsh and varying climate (e.g. severe droughts and low rainfall) and highly-weathered soils. Hence, many native species tolerate low fertility, acid soils and water stress, as well as being more resistant to disease (Victoria State Government 2021).

Where land uses have been grouped due to differing limitation rankings, the most lenient criteria for dryland conditions were applied as pastures generally have lower requirements, as previously discussed.

The following sections discuss the definitions, attribute assessment and subclass determination of each limitation.

3.7.1 Water erosion (E)

The water erosion limitation considers the potential impact of accelerated erosion of the land surface caused by various human activities. Most agricultural land uses (including pasture) increase the potential for soil loss from water erosion due to an increased volume of runoff, increased velocity of water flow, and decreased protection of the soil surface when devoid of surface cover. The rate of soil loss will increase above natural levels in many localities where surface water is concentrated, such as at water outlets and cross drains, particularly where these are located in flood-prone areas.

Subclasses are based on the added management operations required to control erosion (Table 18). Subclasses may then be described in terms of the slope ranges permitted for each land use and soil type.

Table 18: Water erosion limitation description and suitability subclass

Water erosion description	Suitability subclass
Slopes of 0-0.5% with non-dispersive moderate to strongly coherent soil in the surface 200mm	1
Slopes of 0-0.5% with non-dispersive weakly coherent soil in the surface 200mm	1
Slopes of 0-0.5% with dispersive soil in the surface 200mm	3
Slopes of 0.5-1% with non-dispersive moderate to strongly coherent soil in the surface 200mm	1
Slopes of 0.5-1% with non-dispersive weakly coherent soil in the surface 200mm	2
Slopes of 0.5-1% with dispersive soil in the surface 200mm	4
Slopes of 1-3% with non-dispersive moderate to strongly coherent soil in the surface 200mm	2
Slopes of 1-3% with non-dispersive weakly coherent soil in the surface 200mm	3
Slopes of 1-3% with dispersive soil in the surface 200mm	5
Slopes of 3-5% with non-dispersive moderate to strongly coherent soil in the surface 200mm	3
Slopes of 3-5% with non-dispersive weakly coherent soil in the surface 200mm	4
Slopes of 3-5% with dispersive soil in the surface 200mm	5
Slopes of 5-8% with non-dispersive moderate to strongly coherent soil in the surface 200mm	3
Slopes of 5-8% with non-dispersive weakly coherent soil in the surface 200mm	4
Slopes of 5-8% with dispersive soil in the surface 200mm	5
Slopes greater than 8% with non-dispersive moderate to strongly coherent soil in the surface 200mm	5
Slopes greater than 8% with non-dispersive weakly coherent soil in the surface 200mm	5
Slopes greater than 8% with dispersive soil in the surface 200mm	5

3.7.2 Erosion hazard, subsoil erodibility (Es)

Some soils have a low surface erodibility, but high subsoil erodibility – for example Sodosols with hard setting surfaces. Therefore, it is recommended that subsoil erodibility be considered as a separate limitation or included as a distinct diagnostic attribute within the water erosion limitation. Although a potential for subsoil erosion does not necessarily correlate with increased erosion risk at the soil surface.

The major soil profile properties assessed for this limitation are the dispersibility of the subsoil and the depth at which dispersible subsoil occurs. Subclasses are typically based on soil data and slope classes (Table 19). Soil types, or some Australian Soil Classification (ASC) soil classes, were referred for the allocation of subclasses.

Table 19: Subsoil erodibility limitation description and suitability subclass

Subsoil erodibility description	Suitability subclass
Slopes of 0–0.5% with no subsoil (200–1,000mm) dispersion	1
Slopes of 0–0.5% with low to moderate dispersive subsoil (200–1,000mm) and clay content greater than 20%	1
Slopes of 0–0.5% with strongly dispersive subsoil (200–1,000mm) on 2 or more tests and clay content greater than 20%	2
Slopes of 0.5–1% with no subsoil (200–1,000mm) dispersion	1
Slopes of 0.5–1% with low to moderate dispersive subsoil (200–1,000mm) and clay content greater than 20%	2
Slopes of 0.5–1% with strongly dispersive subsoil (200–1,000mm) on 2 or more tests and clay content greater than 20%	3
Slopes of 1–3% with no subsoil (200–1,000mm) dispersion	1
Slopes of 1–3% with low to moderate dispersive subsoil (200–1,000mm) and clay content greater than 20%	3
Slopes of 1–3% with strongly dispersive subsoil (200–1,000mm) on 2 or more tests and clay content greater than 20%	4
Slopes of 3–5% with no subsoil (200–1,000mm) dispersion	3
Slopes of 3–5% with low to moderate dispersive subsoil (200–1,000mm) and clay content greater than 20%	3
Slopes of 3–5% with strongly dispersive subsoil (200–1,000mm) on 2 or more tests and clay content greater than 20%	5
Slopes of 5–8% with no subsoil (200–1,000mm) dispersion	3
Slopes of 5–8% with low to moderate dispersive subsoil (200–1,000mm) and clay content greater than 20%	4
Slopes of 5–8% with strongly dispersive subsoil (200–1,000mm) on 2 or more tests and clay content greater than 20%	5
Slopes >8% with no subsoil (200–1,000mm) dispersion	5
Slopes greater than 8% with low to moderate dispersive subsoil (200–1,000mm) and clay content greater than 20%	5
Slopes >8% with strongly dispersive subsoil (200–1,000mm) on 2 or more tests and clay content greater than 20%	5

3.7.3 Soil water availability (M)

All plants require adequate moisture to achieve optimum production. Soil water availability is assessed in terms of the capacity of the soil to retain and supply water for plant use, while recognising that different

species will differ in their ability to extract soil water. Plant available water capacity (PAWC) provides the best estimate of a soil's moisture storage capacity.

The criteria of Group B were applied to determine the suitability subclass of soil water availability for dryland native pastures. Native grasses are well adapted to severe drought and low rainfall conditions and developed a variety of mechanisms for drought avoidance. These include prolonged dormancy, deep root systems or through having a below-ground crown which is capable of surviving drought and grazing (Wang and Bughara 2008, McWilliam 1968). Hence, it is understood that native pastures will be more tolerant in conditions of low PAWC.

Group B consists of criteria for crops with greater capacity to extract water from soil in dryland conditions, e.g. severe limitations (subclass 4) as opposed to extreme limitations (subclass 5) in some areas of low PAWC.

Table 20: Soil water availability limitation description and suitability subclass

	Soil water availability description	Suitability subclass		
		Group A	Group B	Group C
1	PAWC greater than 150mm/100cms	1	2	2
2	PAWC 125-150mm/100cms	2	2	3
3	PAWC 100-125mm/100cms	3	3	4
4	PAWC 75-100mm/100cms	3	4	5
5	PAWC 50-75mm/100cms	4	5	5
6	PAWC less than 50mm/100cms	5	5	5

3.7.4 Soil physical factors – narrow moisture range (Pm)

The moisture content of a soil can be an important factor in determining its capacity to be cultivated efficiently to achieve the desired result within the constraints of available machinery. Some soils may be cultivated at virtually any moisture content, while others can only be cultivated efficiently over a very narrow moisture range. Soils with moisture contents above that range will be too wet to cultivate; and cultivation of the soil at moisture contents below that range gives a coarse seedbed.

Table 21: Narrow moisture range limitation description and suitability subclass

	Narrow moisture range descriptions	Suitability subclass
1	Wide moisture range for cultivation – moderately well drained to rapidly drained; not hard setting when dry and not 'spewy' (i.e. boggy) when wet. Deep sands and thick sandy surfaced texture contrast soils	1
2	Moderate moisture range for cultivation – moderately well drained to rapidly drained; not hard setting when dry and not 'spewy' when wet. Moderately to strongly self-mulching clays	1
3	Moderate moisture range for cultivation – moderately well drained to rapidly drained; predominantly hard setting when dry and not 'spewy' when wet. Well drained earths and moderately well drained hard setting loamy surfaced soils	2

	Narrow moisture range descriptions	Suitability subclass
4	Moderate moisture range for cultivation (but less than Pm3) – imperfectly drained to moderately well drained; not hard setting (or only weakly) when dry and ‘spewy’ when wet. Sandy surfaced (less than 0.4m), sodic texture contrast soils	3
5	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting, firm or weakly self-mulching when dry and not ‘spewy’ when wet. Hard setting, firm or weakly self-mulching, pedal clays	3
6	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting when dry and ‘spewy’ when wet. Loamy surfaced (less than 0.4 m), sodic texture contrast soils or dermosols	3
7	Very narrow moisture range for cultivation – imperfectly drained to moderately well drained; very hard setting when dry and ‘spewy’ when wet. Very hard setting, sodic clays	4

3.7.5 Surface conditions (Ps)

Seedling emergence and establishment are affected by adverse physical conditions of the surface soil including hard setting, crusting, coarse self-mulching, hydrophobic or tough clay conditions. This limitation is used to downgrade suitability where poor surface conditions affect production, or where increased management inputs are required to manage those soils.

Table 22: Surface conditions limitation description and suitability subclass

	Surface conditions description	Suitability subclass
1	Soils with soft or loose sandy to sandy loam surface horizons	1
2	Very fine self-mulching clays (peds less than 2mm)	1
3	Soils with soft, firm or only weakly hard setting, sandy to loamy surface horizons	2
4	Fine self-mulching clays (peds greater than 2-5mm)	2
5	Coarse self-mulching clays (peds greater than 5-10mm); poor seed-soil contact due to separation of large peds with drying	3
6	Clay soils with hard setting, firm pedal or weakly self-mulching surface horizons	3
7	Very coarse self-mulching clays (peds greater than 10mm)	4
8	Loamy, fine sand, silty or clayey surface soils that are extremely hard setting, massive or crusting	4

3.7.6 Rockiness (R)

Rockiness refers to rock outcrop and coarse fragments at the soil surface. Assessment of rockiness is based on the size, abundance and distribution of coarse fragments and stone on the surface and/or in the surface soil and on the abundance of rock outcrop using the categories outlined in McDonald *et al.* (2009), as outlined in Table 23. Subclasses for grazing are based on the decreased productivity associated with large amounts of surface stones and rock outcrop and possibly the potential impacts on mustering and other operations.

The criteria of Group A were applied to determine the suitability subclass of rockiness for dryland native pasture. Native grasses may be found in areas with harsh surface conditions, among rocky outcrops, sandy surface soils or shallow stony soils (Government of South Australia 2017, State of Queensland 2013). It is understood that native pasture species will be better adapted to establishing on rocky surface conditions, with greater productivity than most agricultural crops.

Group A consists of criteria for crops with greater productivity on rocky areas, e.g. moderate limitations (subclass 3) as opposed to severe limitations (subclass 4) in some areas with greater size, abundance and distribution of coarse fragments.

Table 23: Rockiness limitation and suitability subclass

Rockiness description	Suitability subclass	
	Group A	Group B
Cobbles 60 to 200mm and abundance less than 10%	3	3
Cobbles 60 to 200mm and abundance 10-20%	3	4
Cobbles 60 to 200mm and abundance 20-50%	4	4
Cobbles 60 to 200mm and abundance greater than 50%	4	4
Gravel less than 20mm and abundance less than 10%	1	1
Gravel less than 20mm and abundance 10-20%	2	2
Gravel less than 20mm and abundance 20-50%	2	3
Gravel less than 20mm and abundance greater than 50%	3	3
Pebbles 20 to 60mm and abundance less than 10%	2	2
Pebbles 20 to 60mm and abundance 10-20%	2	2
Pebbles 20 to 60mm and abundance 20-50%	3	4
Pebbles 20 to 60mm and abundance greater than 50%	4	4
Stones greater than 200mm and abundance less than 10%	3	3
Stones greater than 200mm and abundance 10-20%	3	4
Stones greater than 200mm and abundance 20-50%	5	5
Stones greater than 200mm and abundance greater than 50%	5	5

3.7.7 Microrelief (Tm)

This limitation includes the overall slope of the land surface as well as an uneven land surface due to microrelief. Suitability subclasses are based on the amount of earthworks required to level the land or create a required slope to an extent sufficient for grazing (Table 24).

Table 24: *Microrelief limitation description and suitability subclass*

Microrelief description	Suitability subclass
No microrelief across the majority (greater than 70%) of the land surface	1
Very weakly developed microrelief (VI less than 0.1m) that occurs across much (30-70%) of the land surface	2
Normal, lattice or linear gilgai (VI 0.1–0.3m) that occurs across less than 30% of the land surface	2
Normal, lattice or linear gilgai (VI 0.1–0.3m) that occurs across much (30–70%) of the land surface	2
Normal, lattice or linear gilgai (VI 0.1–0.3m) across majority (greater than 70%) of the land surface	2
Shallow, melonhole gilgai (VI 0.3–0.6m) that occurs across less than 30% of the land surface	2
Shallow, melonhole gilgai (VI 0.3–0.6m) that occurs across much (30–70%) of the land surface	3
Shallow, melonhole gilgai (VI 0.3–0.6m) across the majority (greater than 70%) of the land surface	4
Strongly developed, deep, melonhole gilgai (VI 0.6–1.5m) that occurs across less than 30% of the land surface	4
Strongly developed, deep, melonhole gilgai (VI 0.6–1.5m) that occurs across much (30–70%) of the land surface	5
Strongly developed, deep, melonhole gilgai (VI 0.6–1.5m) across the majority (greater than 70%) of the land surface	5

3.7.8 Wetness (W)

The wetness limitation is an assessment of site drainage; determined by considering both internal (soil profile permeability) and external (landscape) factors (Table 25).

Soil permeability is the potential of the soil to transmit water internally. It is controlled by the saturated hydraulic conductivity of the least permeable layer in the soil. This can be inferred from soil attributes such as structure, the presence of hardpans, colour, texture and cracking. The supply and removal of water from the site is a function of slope, topographic position and depth to the water table.

Subclasses are established by relating site drainage attribute levels to yield reduction caused by poor aeration.

The criteria of Group A were applied to determine the suitability subclass of wetness for dryland native pasture. Forage grass species can develop flood tolerant roots, hence, better adapted to unfavourable drainage or permeability conditions (Baruch and Merida 1995).

Group A consists of criteria for crops with greater tolerance to imperfectly drained conditions, e.g. minor limitations (subclass 2) as opposed to moderate limitations (subclass 3) in imperfectly drained and highly permeable areas.

Table 25: Wetness limitation description and suitability subclass

Wetness description	Suitability subclass		
	Group A	Group B	Group C
Very poorly to poorly drained	5	5	5
Imperfectly drained and highly permeable	2	3	3
Imperfectly drained and moderately permeable	3	3	3
Imperfectly drained and slowly permeable	4	4	4
Moderately well drained and highly permeable	1	1	2
Moderately well drained and moderately permeable	1	1	2
Moderately well drained and slowly permeable	2	2	2
Well drained	1	1	1
Rapidly drained	1	1	1

4 Soil survey results

Five SMUs have been described within the study area. Table 26 details the SMUs present, with the spatial distribution of the mapped SMUs (mapped at a scale of 1:30,000) shown in Figure 5. The coordinates for each sampling site are provided in Appendix B.

Table 26: Soil management units identified within the survey area

Soil management unit	Surface area (ha)	Per cent of study area
Clayey	541	27.4
Sandy	800	40.6
Shallow*	153	7.4
Silty*	99	5
Alluvial**	105	5.3
Mine disturbance	280	14.3
Total area	1,971	100

*SMUs were grouped without laboratory analysis. Assessments were conducted based on soil profile descriptions, field observations and available desktop resources.

**SMU was mapped based on Bureau of Rural Science (1991) mapped unit 'CC35'.

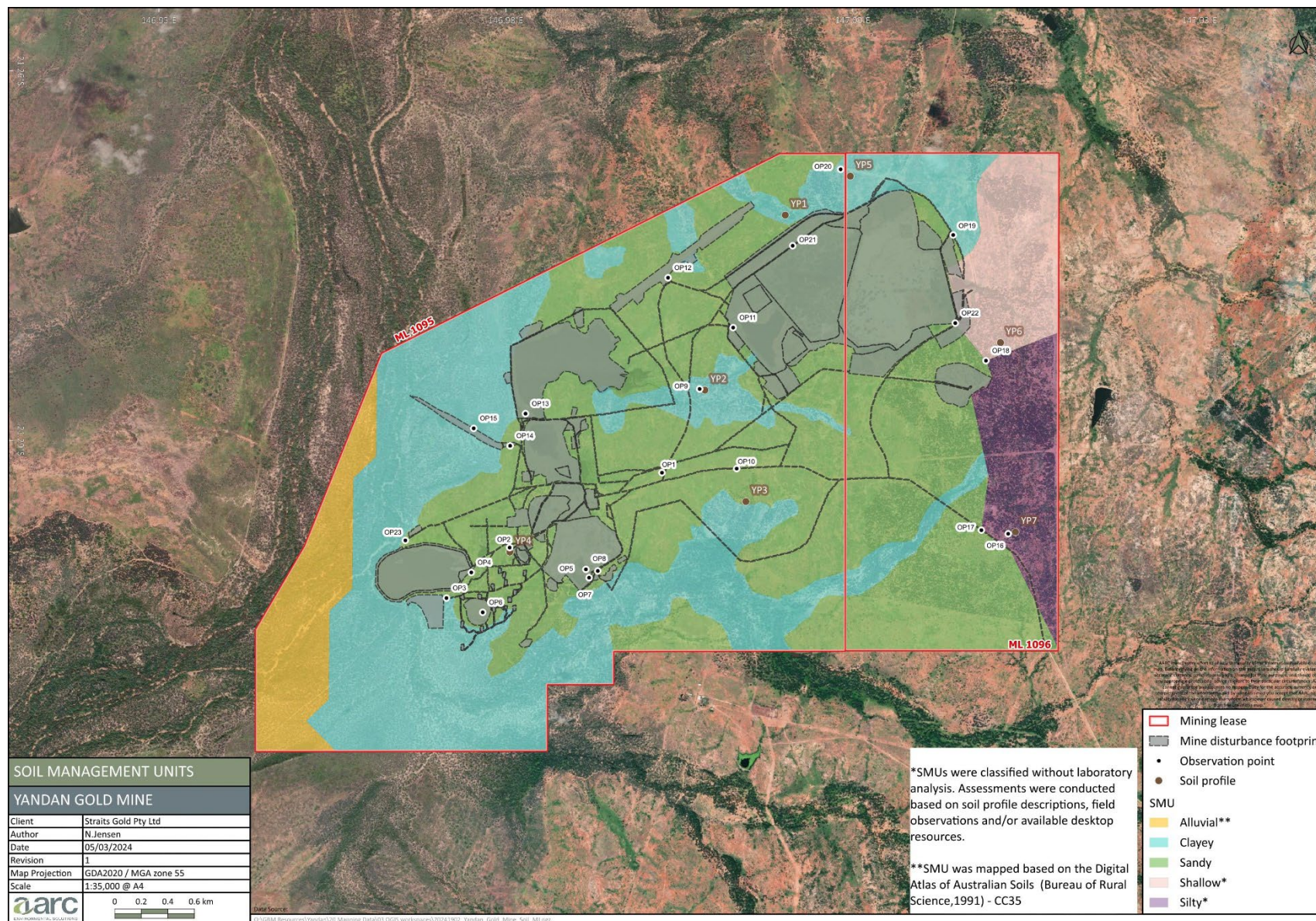


Figure 5: Distribution of soil management units (1:30,000)

4.1 Clayey soil management unit

4.1.1 Soil unit description

Greyish brown earths occurring on gently inclined or level landforms, distributed on the northern half of the study area. Soil textures grade from light clay to light medium clay at the surface to medium clays with depth. Vegetation associated with this unit is predominantly Brigalow.



Photo Plate 1: Clayey SMU Vegetation

Table 27: Key Clayey SMU Parameters

Parameter	Soil unit description
Profile Site Numbers	YP1, YP2
Observation Site Numbers	OP9, OP15, OP20, OP23
Landform	Plains
Australian Soil Classification	Brown Chromosol
Land System	Disney
Slope	0%
Geology	Saint Anns Formation
Vegetation	Brigalow (<i>Acacia harpophylla</i>), Narrow-Leafed Ironbark (<i>Eucalyptus creba</i>), False sandalwood (<i>Eremophila mitchelli</i>)
Runoff	Very slow
Permeability	Slowly permeable (5–50 mm/day)
Drainage	Imperfectly drained

4.1.2 Profile description

The soil profile was described up to 0.8 m depth, as detailed in Table 28. Surface conditions were defined as firm with 90% ground cover. Field pH ranged from slightly acid to slightly alkaline with depth. The profile consists of a very thin A1 horizon observed to be slightly darker in colour than underlying horizons, containing humified organic matter. Soil structure is generally weak, single grain, grading from angular blocky to sub angular blocky, size of peds increase with depth.

Moisture was noted in the lower 0.4 m of the profile. Mottling was observed within the moderately moist horizons, described as many (20–50%), medium (5–15 mm) and clear, orange ferruginous segregations.

Table 28: Soil profile characteristics of Clayey SMU

Depth (m)	Horizon	Field pH	Field Colour	Field Texture	Structure	Soil profile
0–0.05	A1	6	2.5Y 3/2 Very Dark Greyish Brown	Clay Loam	< 0.2 mm, Single grain, Weak, Angular blocky	
0.05–0.2	B21	6.5	2.5Y 4/2 Dark Greyish Brown	Silty Clay Loam	< 0.2 mm, Single grain, Weak, Angular blocky	
0.2–0.4	B22	6.5	2.5Y 4/2 Dark Greyish Brown	Light Clay	< 0.2 mm, Single grain, Weak, Subangular blocky	
0.4–0.6	B23	7	10YR 4/2 Dark Greyish Brown	Silty Loam	5–10 mm, Single grain, Weak, Subangular blocky	
0.6–0.8	B24	7.5	10YR 4/2 Dark Greyish Brown	Medium Clay	2–5 mm, Single grain, Weak, Subangular blocky	

4.1.3 Chemical and physical analysis

The Clayey SMU gradually increases from slightly acid (pH 6.6) to very slightly alkaline (pH 7.2) at depth, and is non saline and non-sodic (Table 29). The pH throughout the soil profile is within a suitable range for plant growth; it is not expected to limit the availability of essential nutrients. EC_{SAT} values are very low, ranging

between 0.00052 dS/m to 0.00135 dS/m. Chloride concentration remains below 10 mg/kg. This SMU is not affected by issues associated with salinity and toxic chloride concentrations (Rayment and Lyons 2011).

CEC levels for this SMU are considered low throughout the profile (6.9–10.9 milliequivalents (meq)/100g), CEC decreases with depth before an increase in the lower horizon due to an increase in clay content. The increase in CEC results in increased concentrations of exchangeable cations in the lower 10 m of the profile. The generally low CEC contributes to poor availability of nutrients in subsoil, with calcium (Ca), potassium (K) and sodium (Na) below levels ideal for plant growth. The soil profile contains moderate to high magnesium (Mg) levels. The distribution of nutrients in the topsoil shows Na concentrations are within the ideal range of the exchange. Mg and K occupy a relatively larger proportion of the CEC, while Ca concentrations are below the ideal range.

The calcium to magnesium ratio (Ca/Mg) indicates that relative to Mg, soil Ca is considered low to deficient. Soil ESP levels suggest non-sodic conditions due to the extremely low Na content in the soil profile. However, low Ca concentrations are an indication of dispersive soils, demonstrated by the low Emerson class number of 2–3. Aggregates were prone to breaking into microaggregates with some dispersion in the top 60 cm of the profile. The lower 10 cm of the profile is prone to slaking with no dispersion.

Table 29: Chemical properties of the Clayey SMU - representative site YP1

Depth (m)	pH	ECSAT (dS/m)	Cl (mg/kg)	ESP (%)	Moisture (%)
0–10	6.6	0.00077	<10	1.0	19.9
20–30	6.7	0.00052	<10	1.0	14.3
50–60	6.8	0.00067	<10	1.4	14.8
70–80	7.2	0.00135	<10	1.9	22.7

Depth (m)	CEC (meq / 100g)	Exchangeable cations (meq/100g)				Ca/Mg Ratio	Emerson class no.
		Ca	Mg	K	Na		
0–10	8.6	5.2	2.5	0.8	<0.1	2.1	2
20–30	7.2	4.3	2.4	0.4	<0.1	1.8	2
50–60	6.9	3.6	3.0	0.2	<0.1	1.2	2
70–80	10.9	4.8	5.6	0.2	0.2	0.8	3
Nutrient distribution in topsoil (%)		60.5	29.1	9.3	1.1	-	-

The topsoil is dominated by sand (37%) and silt (36%), with 16% clay and 11% gravel, contributing to a loose and incoherent structure when dry (Table 30). Poor structure is also demonstrated by the low Emerson class number (2) and low Ca:Mg ratio (2.1), indicating a risk of dispersion upon disturbance. However, moderate organic matter content (2.1%) may provide average stability to the surface horizon.

Extractable nutrients are considered poorly balanced with both phosphorus (<5 mg/kg) and nitrate (0.5 mg/kg) concentration well below appropriate levels for plant growth (Hazelton and Murphy 2016). Sulphate (<10 mg/kg) presence in the topsoil is considered marginal and only potassium (1,190 mg/kg) content is well above suitable concentrations. Extractable metals were mostly highly concentrated within the topsoil, which may induce toxic conditions to plant growth (Government of South Australia 2013). However, boron was detected below suitable concentrations (<0.2 mg/kg) and iron was present at a suitable

concentration (35.5 mg/kg) for plant growth. Extractable metal concentrations are significantly under HILs and do not pose a risk to human health (National Environment Protection Measure 2011).

Table 30: Surface soil (0-10 cm) properties of the Clayey SMU

Particle Size Analysis %				Soil Particle Density (g/cm3)	Organic Matter (%)			
Clay	Silt	Sand	Gravel					
16	36	37	11	2.68	2.1			
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
<5	1190	<10	0.5	<0.2	1.38	35.5	22.7	12.9

4.2 Sandy soil management unit

4.2.1 Soil unit description

Shallow sandy soil unit occupying the southern region of the study area, with extremely low relief (<3%). The profile only consists of a B horizon with clay loam to sandy clay loam textures. Vegetation associated with this unit includes Narrow-Leafed Ironbark (*Eucalyptus crebra*).



Photo Plate 2: Sandy SMU Vegetation

Table 31: Key Sandy SMU Parameters

Parameter	Soil unit description
Profile Site Numbers	YP3, YP4
Observation Site Numbers	OP1, OP2, OP3, OP4, OP5, OP6, OP7, OP8, OP10, OP11, OP12, OP13, OP14, OP17, OP18, OP19, OP21, OP22
Landform	Plains
Australian Soil Classification	Yellow Arenosols
Land System	Disney
Slope	2%
Geology	Wondoola beds
Vegetation	Narrow-Leafed Ironbark (<i>Eucalyptus crebra</i>), Whitewood (<i>Atalaya hemiglauc</i>), Sally wattle (<i>Acacia salicina</i>), Currant Bush (<i>Carissa ovata</i>)
Runoff	Slow
Permeability	Highly permeable (>500 mm/day)
Drainage	Rapidly drained

4.2.2 Profile description

The soil profile was described up to 0.65 m depth, as detailed in Table 32. Surface conditions were defined as loose with 30% ground cover. Field pH is slightly acidic throughout the solum. The profile consists of only a reddish yellow B2 horizon of clay loam texture. Soil structure is described as weak and granular.

No mottling was observed in the dry soil profile.

Table 32: Soil profile characteristics of Sandy SMU

Depth (m)	Horizons	Field pH	Field Colour	Field Texture	Structure	Soil profile
0–0.65	B2	6.5	7.5YR 6/6 Reddish Yellow	Clay Loam	<2 mm Single Grain, Weak, Granular	

4.2.3 Chemical and physical analysis

The pH of the Sandy SMU is moderately acidic throughout the profile with pH values increasing with depth; but remaining within a suitable range for plant growth. The profile is non-saline and non-sodic, indicated by low EC_{SAT} and ESP values. Chloride values are also very low and not expected to impact the osmotic capacity of plants.

CEC is low throughout the solum (7.5–7.7 meq/100g), influenced by the sandy soil texture. Mg cations were detected with moderate to high levels on the soil exchange. Other extractable cations (Ca, K and Na) were present at low concentrations; below the ideal range present on the soil exchange. The nutrient distribution in the topsoil is not favourable as there is an imbalanced proportion of Ca and Mg cations, where Mg concentrations are well above the ideal range. K and Na are present within a suitable percentage.

The Ca/Mg ratio of the profile indicates soil Ca cations are low to deficient, compared to Mg concentration. The solum has a risk of dispersion, supported by the low Emerson class number of 2, where aggregates break down and disperses slightly. Although ESP values suggests non-sodic conditions, it is likely contributed by the extremely low Na concentrations.

Table 33: Chemical properties of the Sandy SMU – representative site YP3/4

Depth (m)	pH	EC _{SAT} (dS/m)	Cl (mg/kg)	ESP (%)	Moisture (%)		
0–10	5.6	0.0219	20	1.9	4.6		
20–30	5.8	0.0260	20	1.7	3.9		
50–60	5.8	0.0223	30	3.3	4.3		
Depth (m)	CEC (meq / 100g)	Exchangeable cations (meq/100g)				Ca/Mg Ratio	Emerson class no.
		Ca	Mg	K	Na		
0–10	7.5	4.4	2.6	0.3	0.1	1.7	2
20–30	7.4	3.9	3.1	0.2	0.1	1.2	2
50–60	7.7	1.8	5.4	0.1	0.2	0.3	2
Nutrient distribution in topsoil (%)		59.5	35.1	4.2	1.2	-	-

The topsoil is dominated by sand (48%), followed by gravel (15%), silt (18%) and clay (13%), described in Table 34. The sandy profile contributes to loose and weak granular structure. This, in conjunction with the low organic matter content (1.3%) suggests poor structural stability of topsoil layer. The topsoil is prone to erosive conditions.

Apart from phosphorus, extractable nutrients were present in the topsoil at concentration suitable for plant life (Hazelton and Murphy 2016). Extractable metals were mostly highly concentrated within the topsoil, potentially inducing toxic conditions for plant growth (Government of South Australia 2013). With the exception of boron, detected below suitable concentrations (<0.2 mg/kg), only iron was present at a suitable concentration (26.9 mg/kg) for plant growth. HILs were not exceeded, and do not pose risks to human health (National Environment Protection Measure 2011).

Table 34: Surface soil (0 -10 cm) properties of the Sandy SMU

Particle Size Analysis %				Soil Particle Density (g/cm³)	Organic Matter (%)			
Clay	Silt	Sand	Gravel					
13	18	48	15	2.61	1.3			
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
10	536	30	46.7	<0.2	1.18	26.9	53.2	1.95

4.3 Shallow soil management unit

Reddish brown earths containing calcareous segregations, occupy the northeast region of the study area which displays low topographical relief (<3%). The soil profile is made up of a B horizon that grades from loam to light clay. Vegetation associated with this unit includes Brigalow.



Photo Plate 3: Shallow SMU Vegetation

4.3.1 Soil unit description

Table 35: Key Shallow SMU Parameters

Parameter	Soil unit description
Profile Site Numbers	YP5, YP6
Observation Site Numbers	OP18, OP22
Landform	Plains
Australian Soil Classification	Red Calcarosol
Land System	Disney
Slope	0%
Geology	Anakie Metamorphic
Vegetation	Brigalow (<i>Acacia harpophylla</i>), Sally wattle (<i>Acacia salicina</i>), Currant bush (<i>Carissa ovata</i>)
Runoff	Slow
Permeability	Moderately permeable (50–500 mm/day)
Drainage	Imperfectly drained

4.3.2 Profile description

The relatively shallow soil profile was described up to 0.55 m depth (representative site defined as 'YP6', see Appendix B), as detailed in Table 36.

Surface conditions were described as firm with 40% ground cover. Field pH ranged from slightly to moderately alkaline. The profile consists of a relatively shallow B2 horizon, before reaching unconsolidated purplish material defined as the C horizon at 0.3 m depth.

The majority of the profile was noted to be dry except the B22 horizon, which was moist with mottling observed. Segregations were described as common (10–20%) and fine (<2 mm), calcareous and ferruginous. The presence of calcium carbonate segregations contributed to greater pH levels as observed in the field pH tests.

Table 36: Soil profile characteristics of Shallow SMU

Depth (m)	Horizons	Field pH	Field Colour	Field Texture	Structure	Soil profile
0–0.2	B21	7	5YR 5/4 Reddish Brown	Loam	< 2mm, Single Grain, Weak, Granular	
0.2–0.3	B22	8 ½	5YR 4/6 Yellowish Red	Light Clay	5–10 mm, Massive, Moderate, Subangular Blocky	
0.3–0.55	C	9	5YR 6/3 Light Reddish Brown	Light Clay	< 2 mm, Single Grain, Weak, Granular	

4.3.3 Chemical and physical analysis

Laboratory analysis was not conducted for this SMU.

4.4 Silty soil management unit

Yellowish brown soils occurring on level landforms; mapped on the southeast corner of the study area. Soil texture is generally silty, grading from clay loam to silty loam. Vegetation associated with this unit is predominantly *Acacia cambagei* (Gidgee).



Photo Plate 4: Silty SMU Vegetation

4.4.1 Soil unit description

Table 37: Key Silty SMU Parameters

Parameter	Soil unit description
Profile Site Numbers	YP7
Observation Site Numbers	OP16, OP17, OP18
Landform	Plains
Australian Soil Classification	Brown Tenosol
Land System	Disney
Slope	0%
Geology	Anakie Metamorphic
Vegetation	Gidgee (<i>Acacia cambagei</i>), Brigalow (<i>Acacia harpophylla</i>), Sally wattle (<i>Acacia salicina</i>), Currant bush (<i>Carissa ovata</i>), False sandalwood (<i>Eremophila mitchellii</i>)
Runoff	Slow
Permeability	Moderately permeable (50–500 mm/day)
Drainage	Imperfectly drained

4.4.2 Profile description

The soil profile was described up to 0.7 m depth, with the representative site labelled as 'YP7' (Appendix A2). Surface conditions were described as firm with 30% ground cover. Field pH was noted as slightly acidic to slightly alkaline with depth. The profile consists of yellowish brown B2 horizons of loamy texture.

Moisture was noted in the B22 horizon, mottling was noted as common (10 – 20%), fine (<5 mm), distinct, orange and clear ferruginous segregations. The lower profile consisted of weathered bedrock, observed with a gravelly soil texture.

Table 38: Soil profile characteristics of Silty SMU

Depth (m)	Horizons	Field pH	Field Colour	Field Texture	Structure	Soil profile
0–0.2	B21	6.5	10YR 5/8 Yellowish Brown	Clay Loam	< 2mm, Single Grain, Weak, Granular	
0.2–0.4	B22	7	10YR 3/4 Dark Yellowish Brown	Silty Clay Loam	5–10 mm, Massive, Moderate, Polyhedral	
0.4–0.7	B23	7.5	10YR 5/6 Yellowish Brown	Silty Loam	< 2mm, Single Grain, Weak, Granular	

4.4.3 Chemical and physical analysis

Laboratory analysis was not conducted for this SMU.

4.5 Alluvial soil management unit

No soil profile descriptions or field observations were made on the western edge of the study area due to safety and land access constraints. The Alluvial SMU was mapped based on the Digital Atlas of Australian Soils (Bureau of Rural Science 1991), mapped unit 'CC35'. The unit is described as alluvial plains associated with major streams subject to irregular flooding. Soils are grey fine cracking clays with smooth faced peds, underlain by mottled clay.

Field observations noted a section of brown cracking clays (approximately 30 m) among red soil at the flooded water channel (OP15). The presence of cracking clays was likely contributed by flooded conditions detaching and moving soil particles downstream from the Alluvial SMU.

5 Land suitability assessment outcomes

Land suitability assessments were only conducted on SMUs where chemical and physical analyses were available. The land suitability outcomes for the Clayey SMU and Sandy SMU are described in the following sub-sections.

5.1 Water erosion

Table 39 provides the outcomes of the land suitability class assessment on the basis of water erosion. Water erosion is ranked based on slope and soil dispersive characteristics. Soil with steep slopes and strong dispersive characteristics negatively impacts land suitability for agriculture as it can remove valuable topsoil resource, reduce the ability of soil to store water and nutrients, expose subsoil with poor physical and chemical properties, as well as cause deposition in low-lying areas.

Table 39: Suitability subclass on the basis of water erosion

Soil management unit	Limiting features	Suitability subclass
Clayey	Slopes of 0–0.5 % with dispersive soil in the surface 200 mm	1
Sandy	Slopes of 1–3% with dispersive soil in the surface 200 mm	5

5.2 Erosion hazard, subsoil erodibility

Table 40 provides the subclass determination of SMUs identified in the survey area on the basis of erosion hazard and subsoil erodibility. Exposure of subsoil with poor physical and chemical properties may result in hazards such as gully, tunnel or stream bank erosion. Erosion hazards can reduce the available land for agriculture, increase turbidity and nutrient loads in streams, and cause land access issues due to safety concerns.

Table 40: Suitability subclass on the basis of subsoil erodibility

Soil management unit	Limiting features	Suitability subclass
Clayey	Slopes of 0–0.5% with low to moderate dispersive subsoil (200–1,000 mm)	1
Sandy	Slopes of 1–3 % with low to moderate dispersive subsoil (200–1,000 mm)	3

5.3 Soil water availability

Soil water availability may restrict dryland pastures because of the effect on productivity. The PAWC of soil is difficult to measure in the field, so surrogate soil properties are used instead to allocate soils into a subclass as outlined in the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland* (1995). The surrogate field properties associated with PAWC, and for the subclass determination of SMUs are provided in Table 41.

Table 41: Suitability subclass on the basis of soil water availability

Soil management unit	Limiting features	Suitability subclass
Clayey	Gradational earths, 75–125 cm depth to weathered or hard rock PAWC 100–125 mm	3
Sandy	Clay loams, 50–75 cm depth to weathered or hard rock PAWC 75–100 mm	4

5.4 Narrow moisture range

Narrow moisture range may be considered a limitation for any land uses where cultivation is required. The workability of soils affects the capacity of the soil to support machinery during management practices such as tillage. Table 42 provides the assessment of soil physical properties to infer the narrow moisture range and associated subclass.

Table 42: Suitability subclass on the basis of narrow moisture range

Soil management unit	Limiting features	Suitability subclass
Clayey	Narrow moisture range for cultivation – imperfectly drained to moderately well drained; hard setting, firm or weakly self-mulching when dry and not ‘spewy’ when wet. Hard setting, firm or weakly self-mulching, pedal clays	3
Sandy	Wide moisture range for cultivation – moderately well drained to rapidly drained; not hard setting when dry and not ‘spewy’ (i.e. boggy) when wet. Deep sands and thick sandy surfaced texture contrast soils	1

5.5 Surface conditions

Soil surface conditions for each SMU identified have been assessed with suitability outcomes presented in Table 43. Conditions of surface soil when dry play a direct role in seed germination and establishment. Adverse conditions such as hard setting or crusting of surface soils creates a barrier, reducing seed-soil contact, subsequently impacting plant establishment.

Table 43: Suitability subclass on the basis of surface conditions

Soil management unit	Limiting features	Suitability subclass
Clayey	Soils with soft, firm or only weakly hard setting, sandy to loamy surface horizons	2
Sandy	Soils with soft or loose sandy to sandy loam surface horizons	1

5.6 Rockiness

Table 44 provides the subclass determination of SMUs identified in the survey area on the basis of rockiness. The presence of high stone content in soils may influence soil properties such as increasing infiltration rates

while decreasing soil erosion, susceptibility to compaction, soil water storage and the surface area available for plant establishment.

Table 44: Suitability subclass on the basis of rockiness

Soil management unit	Limiting features	Suitability subclass
Clayey	Gravel less than 20 mm and abundance 10–20%	2
Sandy	Gravel less than 20 mm and abundance 10–20%	2

5.7 Microrelief

The microrelief for each SMU identified has been assessed, with subclass presented in Table 45. Microrelief refers to local relief (up to several metres) around the plane of the land (National Committee on Soil and Terrain 2009). Impacts of microrelief on the suitability of land for agriculture are only experienced when soil is severely melonholed. Ponding of water in the depressions can compromise growing conditions directly impacting on productivity.

Table 45: Suitability subclass on the basis of microrelief

Soil management unit	Limiting features	Suitability subclass
Clayey	No microrelief across the majority (greater than 70%) of the land surface	1
Sandy	No microrelief across the majority (greater than 70%) of the land surface	1

5.8 Wetness

The wetness limitation refers to any excess water both in and on the soil profile. The adverse effects of excess water include reducing plant growth, impeding oxygen supply to plant roots (possibly leading to denitrification) and increased risk of plant disease. Table 46 provides the assessment of site drainage and subclass determination.

Table 46: Suitability subclass on the basis of wetness

Soil management unit	Limiting features	Suitability subclass
Clayey	Imperfectly drained and slowly permeable	4
Sandy	Rapidly drained	1

5.9 Summary of land suitability for cattle grazing

Table 47 provides a summary of the assessed land suitability limitation for beef cattle grazing land use.

In the study area, the suitability of land for cattle grazing is most limited by wetness in the Clayey SMU and water erosion in the Sandy SMU.

The Clayey SMU is restricted by soil properties causing imperfectly drained and low permeability profiles. This is demonstrated by mottling observed within the moderately moist horizons of the soil profile, indicating the risk of waterlogged soils with heavy rainfall. Livestock production may be impacted by a reduction in pasture growth.

The overall land suitability class for the Clayey SMU is Class 4; defined as marginal land, and comprising 588 ha of the study area. Additional studies are required to determine whether soil ameliorants (see section 7.3.1) can reduce the limitations of this soil to achieve sustained economic production.

The Sandy SMU was observed on slightly inclined slopes of 2%, with dispersive qualities, causing increased risk of erosion and soil loss. Erosive conditions are evident through field observations, with active rill erosion present within the SMU. Livestock production on this SMU may be impacted through topsoil loss and plant establishment failure.

The overall land suitability class of the Sandy SMU is Class 5; defined as unsuitable land, and occupying 800 ha of the study area. The SMU has extreme limitations that preclude its use for agricultural activities. Some areas within this SMU were previously disturbed by mining activities. Erosive properties contribute to safety hazards within this SMU.

It is noted that the land suitability framework provides guidance in determining land suitability outcomes, however, this determination should also provide consideration to historical and existing land uses. In this instance, it is acknowledged that the pre-mining land use for the Project area was low intensity cattle grazing, as is the current use for the surrounding region. It is therefore inferred that native pastures are adapted to the adverse soil characteristics. On this basis, it is considered that the Project area is suitable for low intensity cattle grazing, carefully managed with the implementation of intensive management regimes to support this land use (see section 6 and section 7).

Figure 6 shows the distribution of land suitability classes for cattle grazing across the study area.

Table 47: Summary of land suitability assessment

Limitation	Clayey SMU	Sandy SMU
Water erosion	1	5
Erosion hazard, subsoil erodibility	1	3
Soil water availability	3	4
Narrow moisture range	3	1
Surface condition	2	1
Rockiness	2	2
Microrelief	1	1
Wetness	4	1
Overall suitability rating	4	5

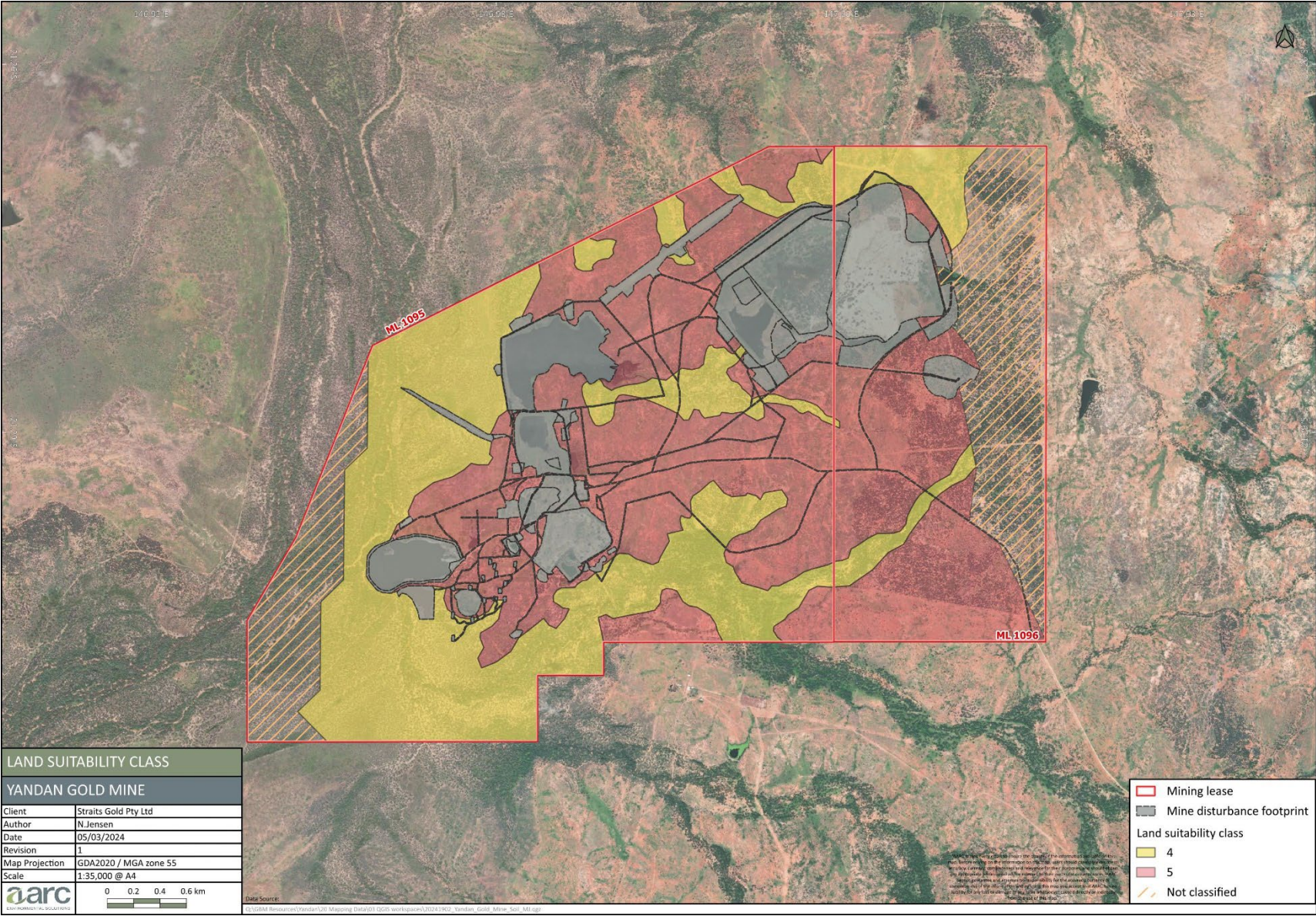


Figure 6: Land suitability classes for grazing pastures

6 Potential impacts and management

Further development on the Project is anticipated in the near-future, subject to resource development and mine planning. Future development is likely to cause additional disturbance within the Project area, and may potentially impact the existing land suitability of the area. To mitigate potential impacts to land suitability a number of measures have been proposed, as detailed within this section.

The existing land suitability classes are detailed in section 5 and summarised in Table 48.

Table 48: Summary of land suitability classes and area of SMUs in the study area

SMU	Land Suitability Class (Grazing)	Area (ha)
Clayey	4*	588
Sandy	5*	800

Note: Green = suitable; red = unsuitable. Items displayed with an asterisk (*) are considered suitable based on current land use of low intensity grazing.

The outcomes of the land suitability assessment indicate the Project area is capable of supporting the land use of cattle grazing, as per the pre-mining land use of the Project area and the surrounding land use.

The economic viability of using rehabilitated land for grazing will be considered based on post-mine land suitability, as well as the total area available for cattle grazing. If developed, improved pastures will likely incorporate 3P (perennial, persistent and palatable) species such as Buffel grass (*Cenchrus ciliaris*) and other exotic grasses to reflect reference conditions. Legume species such as Seca (*Seca stylo*) may also be incorporated in the seed mix for long-term improvements in soil fertility and self-sustaining vegetation.

Mining activities, including stripping, stockpiling and handling of soil, have the potential to impact the physical, chemical and biological properties of soil. Therefore, the land suitability outcome for cattle grazing can be reduced for rehabilitated landforms. The impact of mining activities on soils can be mitigated through:

- good topsoil management practices (see section 7);
- the addition of fertilisers and soil ameliorants (see section 7.3.1);
- grading and shaping (see section 7.4.1);
- timely seeding with suitable species; and
- post-establishment management of rehabilitated areas.

Where final landforms represent a relatively flat landscape (e.g. slopes less than 5%) it is envisaged that the post-mining land suitability for cattle grazing will reflect that of the pre-mining landscape.

6.1 Topsoil and subsoil stripping impacts and mitigation

Topsoil and/or subsoil stripping is required where land is planned to be disturbed by mining activities to recover soil resources for rehabilitation purposes. The soil is commonly stockpiled until land is available for rehabilitation, or preferably, is stripped and applied directly.

Stripping activities may lead to negative impacts on the chemical and physical attributes of soil, and subsequently the land suitability classification. Impacts associated with topsoil stripping include the following:

- Exposure of dispersive subsoil during soil stripping;

- Loss of soil physical structure due to excavation and handling;
- Loss of soil seedbank; and
- Impacts on soil fertility due to mixing of inviable subsoils and resulting changes in soil chemistry.

Mitigation measures recommended to monitor topsoil stripping procedures include development of a Topsoil Management Plan with the following management aspects:

- Minimising the handling of topsoil.
- Supervision of stripping to determine recovery depth and identify suitable soils.
- Delineation of areas to be stripped and date of stripping.
- Delineation of suitable stockpile areas (as required).
- Ensuring stockpiles are generally less than 2 m high and contours encourage water drainage.
- If topsoil resources are to be stockpiled for a period in excess of six months, testing of soil properties prior to use in rehabilitation should be carried out. The proponent could consider conducting soil physiochemical analysis of stockpiled topsoil resources to assess for changes in topsoil quality (changes to soil chemistry and biological activity as a result of being stockpiled). Key parameters that should be considered during this additional testing, if undertaken, include pH, ESP, CEC (major cations), organic matter content and other essential nutrients such as nitrate, phosphorous and sulphate.
- Delineation of planned areas for direct return of topsoil (as required).
- The application of fertilisers, soil ameliorants and an appropriate seed mix as to increase the likelihood of rehabilitation success (See section 7.3).

6.2 Erosion impacts and mitigation

Disturbance of vegetation and the topsoil layer can lead to the mobilisation of soil through the process of erosion, particularly water erosion from heavy rainfall or overland flow. The risk of erosion at the Project will be increased by the following activities:

- clearing of vegetation;
- topsoil stripping and stockpiling;
- construction of infrastructure; and
- exposure of slopes.

Management recommendations to be considered, as appropriate, to reduce the risk and impacts of erosion include:

- limiting land clearing to the minimum amount of land required for the safe operation of the Project;
- diversion of overland flow/runoff around disturbed areas;
- amelioration of dispersive soils through the addition of gypsum, if used in rehabilitation (see section 7.3.2);
- hay mulching using non-feed quality hay/stubble at a rate of 8 t/ha, to be applied immediately after sowing/deep ripping and should be maintained until >50% groundcover is achieved;
- progressive rehabilitation of landforms and direct placement of topsoil to help preserve the seed bank and reduce erosion;
- seeding of topsoil as soon as possible after placement onto rehabilitated areas, to ensure root masses assist in mitigating erosion;
- placing of topsoil stockpiles away from drainage areas, roads, machinery, transport corridors, and stock grazing areas;

- as required, seeding or covering topsoil stockpiles with a water-shedding lining to prevent unnecessary erosion of soil; and
- the use of sediment control structures such as retention ponds, to minimise the release of water and suspended sediments into the receiving environment.

7 Soil handling recommendations

The following subsections discuss soil management recommendations for identified SMUs within the study area. Recommendations are provided based on the characteristics of SMUs described in section 4.1 (Clayey SMU) and section 4.2 (Sandy SMU).

7.1 Topsoil suitability and stripping

Topsoil stripping is required in planned mining disturbance areas to recover valuable topsoil resource for rehabilitation purposes. The identification and stripping of suitable topsoil is necessary to ensure removal of the maximum volume of viable topsoil and reduce wastage. Subsequent maintenance of topsoil viability must be supervised through employing best practices in soil stripping, stockpiling and spreading activities.

Generally, soil fertility decreases with depth in response to the variation within a number of factors including soil texture, pH, organic matter content etc. Chemical and physical analysis of the SMUs identified in the study area indicates usable soil resources are mainly confined to the surface horizons, which contain seedstock, micro-organisms and nutrients necessary for plant growth.

Where practicable, stripping should be timed to avoid periods of excessive rain or prolonged dry periods. Topsoil should be directly placed in prepared rehabilitation areas and used immediately rather than stockpiled for later use. Where topsoils have been identified as requiring amelioration and where practicable, the areas where they have been re-spread and/or the stockpiles where they have been stored should be delineated and recorded to ensure the appropriate treatment subsequently occurs.

Table 49 summarises the maximum stripping depth recommended for each SMU; a detailed discussion of the recommended topsoil resource depth follows.

Table 49: Recommended topsoil stripping depth for Clayey and Sandy soil management units

SMU	Topsoil stripping depth (m)
Clayey	0.1
Sandy	0.1

Clayey soil management unit (stripping depth 0.1 m)

The Clayey SMU contains low CEC, contributing to limited capacity to retain nutrients on pedal surfaces throughout the profile. Although the solum does not indicate sodicity concerns, it presents dispersive characteristics. However, moderate organic matter content in the top 10 cm of the profile may provide additional stability to the surface horizon along with further nutrients upon decomposition.

A stripping depth of 0.1 m is recommended for the Clayey SMU. The application of this topsoil resource for rehabilitation purposes would benefit from further amelioration to improve productivity of cattle grazing as a PMLU.

Sandy soil management unit (stripping depth 0.1 m)

The top 0.1 m of the Sandy SMU is suitable for most rehabilitation uses, as it contains most nutrients, seedstock and organic matter. The nutrient composition and distribution of this SMU is generally low and unfavourable, therefore would benefit from additional fertiliser application.

The topsoil of this SMU is predominantly composed of sand (48%) and should not be placed on slopes exceeding 3% without consideration of appropriate measures to manage stability. Organic matter content is low, contributing to poor structural stability of topsoil. The profile is non-sodic, however, presents dispersive

characteristics and is susceptible to erosive conditions. Amelioration is recommended to improve structural stability of topsoil through the addition of organic matter and/or gypsum (refer section 7.3.1).

7.2 Topsoil stockpiling

Stockpiling of topsoil for extended periods can lead to physiochemical and biological deterioration in the soil and affect the viability of the soil seed bank. Where possible, topsoil should be directly placed in prepared rehabilitation areas rather than stockpiled to assist in maintaining a viable seedbank and promote timely revegetation.

Where stockpiling of topsoil is required, the following recommendations for soil management will reduce the risk of soil degradation and improve the chances of rehabilitation success:

- Stockpiles should generally be less than 2 m high and be constructed and positioned in a manner that encourages water drainage and discourages erosion; and with appropriate erosion and sediment controls in place.
- If there is a risk of a grass cover not establishing voluntarily, stockpiles will need to be ripped and seeded with a quick establishment pasture. Topsoil should ideally be stockpiled for the minimum time. Studies in the Hunter Valley have shown that most deterioration occurs within the first year (Keipert *et al.* 2005).
- Stockpiles should be monitored for erosion and weeds and control measures implemented as appropriate.
- Where soil has been stockpiled for extended periods, soil testing is recommended before use for rehabilitation purposes. If required, fertilisers and soil ameliorants should be applied.

Table 50 shows the estimated volumes of topsoil resource per SMU within the study area, given the stripping depths outlined in Section 7.1.

Table 50: Estimated topsoil resource volumes – study area

SMU	Topsoil stripping depth (m)	SMU area (m ²)	Potential soil volume (m ³)
Clayey*	0.1	5,880,000	588,000
Sandy*	0.1	8,000,000	800,000
Total Topsoil = 1,388,000 m ³			

Notes: SMUs with an asterisk (*) indicate soils where amelioration measures (e.g. liming agents, fertiliser), or actions (e.g. mixing) are considered beneficial to achieve a grazing land use outcome.

7.3 Topsoil placement

The estimated topsoil volumes suggests that the topsoil resource will be sourced predominantly from the Sandy SMU. The Sandy SMU is characterised as having low organic matter content and relatively high sand content, therefore at a greater risk of erosion-induced movement (section 0). For this SMU, establishing a sufficient vegetative cover to mitigate erosion risk is important, particularly as rehabilitated slopes increase. To create a favourable environment for vegetation growth, topsoil from the Sandy SMU will require application of one or more of the amelioration measures outlined in the following sub-sections.

Where possible, placement of topsoil at a minimum thickness of 0.2 m is recommended for rehabilitation areas to create a growth medium of sufficient depth to hold water and support revegetation. For all rehabilitated areas, deep ripping to a depth of 90 cm of the landform after topsoil placement should be undertaken to key the topsoil and subsoil layers together, and to improve seed germination conditions.

7.3.1 Topsoil amelioration

7.3.1.1 Organic matter application

Sandy soils, represented by the Sandy SMU, are characterised by poor soil structure, low moisture retention and low available nutrient concentrations. The addition of organic matter to such soils improves soil structure by creating a binding effect. Humus molecules bind soil particles into aggregates which are more resistant to physical breakdown. The humus molecules increase soil moisture retention, minimise erosion, and provide an important source of nitrogen, phosphorus and sulphur. Where possible, topsoil should be stripped with its existing ground cover vegetation and, if subject to stockpiling, relocated with its cover crop vegetation.

Depending on availability, additional organic matter (such as mulches, manures, or compost), could be incorporated into the topsoil. Organic materials incorporated into the topsoil will increase organic carbon levels, providing more exchange sites for necessary cations, increase water holding capacity, and ensure less organic matter is oxidised into carbon dioxide and nitrous oxide or reduced into methane (Smith *et al.* 2018). Application rates will vary depending on mulch type. Straw mulch should be applied at a rate of 8 t/ha. Note that fresh mulch should not be used in acidic soils. Manure should be incorporated at rates of 5–30 t/ha (depending on the type of manure) (MLA n.d.). If available, compost can be applied at 70–150 t/ha (Kelly 2006).

7.3.1.2 Fertiliser application

The low concentration and imbalanced distribution of nutrients in soils can be ameliorated through fertiliser application. It is noted that some ameliorants (such as ammonium-based fertilisers) can contribute to an acidifying effect, hence, care must be taken when selecting fertiliser types to be applied on acidic soils. The Sandy SMU is moderately acidic (pH of 5.6), requiring lime (calcium carbonate) application to neutralise the acidifying effects of certain fertilisers upon application.

Urea (47% N) is widely applied as it is the most economical nitrogen fertiliser. This fertiliser must be applied in combination with lime as it contributes to acidifying effects. A rate of 150 kg/ha of urea is recommended for soils in low rainfall areas where soil nitrate content is below 3 mg/kg. For best results, nitrogen fertiliser should be incorporated into the ground, either through rainfall soon after broadcasting on the surface or by burying into the soil.

The suggested rate of calcium carbonate is approximately 1 t/ha of lime. It is expected that 1 t/ha of lime (incorporated in the top 10 cm of soil) can increase the pH of sandy soils by 0.57 units (Department of Primary Industries n.d.). A follow up pH test is necessary to evaluate the need for additional lime applications. Lime should be applied initially in small doses, gradually increasing application rates as necessary.

Alternatively, calcium nitrate-based fertilisers such as calcium ammonium nitrate (15 to 27% N) may be selected for their near neutral effect on soil pH, providing both nitrogen and calcium cations. An application rate of 25–50 kg N/ha should be sufficient for successful vegetation establishment (CRDC 2020). Sulphate of potash (41% K) may be applied in conjunction with calcium ammonium nitrate to increase potassium and sulphate levels in soils. The fertiliser is drilled with seeds before spreading onto the soil surface (unlike other potassium fertilisers such as muriate of potash which can have negative effects on seed germination). Typical application rates of potassium for pastures in light soils are 20 kg K/ha (Department of Primary Industries n.d.).

The natural Australian landscape is low in available phosphorus, causing native species to be adapted to low soil phosphorus concentrations. Phosphorus application rates should be considered carefully. Application rates of 10–20 kg P/ha have been suggested for grazing pastures (Victoria Government 2013) and mine restoration (Daws *et al.* 2013). Single superphosphate (8.8% P) may be applied, which satisfies the phosphorus requirements as well as supplying sulphate. It should be noted that this fertiliser should not be blended with urea.

Upon application of soil ameliorants, it is important to incorporate fertilisers into the soil, preferably to a depth of approximately 0.3 m (using a scarifier or ripper tynes). This is to prevent loss of nutrients through wind erosion (blown away) or water erosion (carried/washed away by rainfall). Following vegetation establishment (6 to 12 months after sowing), it is recommended to analyse the chemical and physical properties of topsoil to determine the requirement for any further ameliorants.

Natural methods of increasing soil nitrogen levels may be applied through the incorporation of native leguminous forbs such as *Rhynchosia minima* (Rhynchosia) and *Glycine tabacina* (Variable Glycine) to the seed mix. The legume species are capable of fixing nitrogen, as well as establishing a natural nitrogen cycle within the topsoil resulting in long-term improvements in soil fertility and self-sustaining vegetation.

7.3.2 Gypsum application

The poor structural stability of the Sandy SMU is not aided by the low organic matter content and soil texture. Structural stability issues may be enhanced through addition of gypsum (calcium sulphate), allowing clay particles to form stable aggregates. Soil aeration and water infiltration rates should be improved, minimising runoff and formation of rill erosion. The recommended gypsum application rate (based on the light textured soils of the Sandy SMU) is 2.5–5t/ha of fine grade gypsum to be broadcasted every few years, assuming water application rate of up to 10 mm/h (equivalent to moderately intense rain) (Abbott and McKenzie 1996).

7.3.3 Cover crops

Topsoil loss to erosive processes may be minimised through the establishment of ground cover vegetation. A fast-establishing sterile annual cover crop is recommended to be included in the seed mix. This approach will also suppress weeds and assist in reviving biological processes in the soil, creating a favourable micro-environment for the germination and emergence of the native seeds. Considering the sandy nature of the Sandy SMU topsoil resource, it is recommended that a cover crop is sown at a high seed density, of approximately 30 kg/ha. This should provide a rapid ground cover and assist in achieving soil stabilisation. *Echinochloa esculenta* (Japanese Millet) could be used for summer applications and *Lolium sp.* (Rye Grass) for winter applications. In the transition between cold and warm seasons, a combination of both species should be used.

7.3.4 Hydromulching

The use of hydromulching as an alternative to direct seeding is a further option that can be considered in zones at higher risk of erosion. Hydromulch consists of a semi-liquid water-based mixture composed of seed, water, mulch and other components (such as fertiliser, coir and tackifiers) which can be added depending on the amelioration requirements. The seed mix is included in the hydromulch slurry, which is sprayed onto the revegetation site as a thin layer (approximately 10 mm) to the soil surface, usually at a rate of approximately 50 m³/ha for topsoil applications. The aim of using hydromulch is to cover and protect the soil, together with providing a suitable germination environment for seeds. The use of hydromulch can be effective at controlling erosion and stabilising the soil, by providing an erosion resistant layer for the period of time it takes for vegetation to become established.

7.4 Subsoil management

The study area consists of low ESP soil, with a high risk of dispersion due to low Ca:Mg ratios. Use of subsoil as a resource is not recommended as dispersive soils contribute to low porosity, low air movement and subsequent low oxygen availability for plants.

Dispersive subsoils left exposed after soil stripping presents an erosion and potential downstream sedimentation risk. Appropriate erosion and sediment control methods must be implemented in conjunction with topsoil stripping plans throughout the study area.

7.4.1 Grading and shaping

The Sandy SMU is most prone to water erosion due to its dispersive topsoil qualities with risk increasing as slopes increase. Grading and shaping can improve final appearance, stability, enhance vegetation establishment and reduce overall erosion risk. It is recommended that slopes are graded to as low as possible to improve the chance of achieving a suitable land outcome. Flat terrain minimises runoff and sediment yield, subsequently improving effectiveness of amelioration (e.g. fertiliser and gypsum) and vegetation establishment.

However, in situations where gentle slopes are not achievable, gypsum application (section 7.3.2) and cover crops (section 7.3.3) are recommended as a minimum to manage dispersive characteristics.

8 Material suitability for rehabilitation

Materials suitable for rehabilitation include stripped and stockpiled soil resources, accumulated in various locations throughout the Project area (refer to Section 9).

A number of material characterisation programs have assessed the suitability of these materials for rehabilitation, including sampling conducted by O’Kane Consultants in 2019 (with the suitability of capping materials being the focus of this program). Additional sampling was completed during the 2022 SLSA, with sampling completed for topsoil stockpiles adjacent to the heap leach pad and for the soils contained in the Main Pit levee.

Results from the material characterisation assessments completed by AARC for the 2022 SLSA and previously, by O’Kane Consultants (2019), are summarised in the following sub-sections.

8.1 Available resources and fertility results

Soil fertility of soil resources are assessed as it relates to the chemical properties of the soils and their influence on vegetation growth and establishment. Soil fertility results were assessed against criteria described by Hazelton and Murphy (2016), provided below in Table 51.

Parameters important for soil fertility include pH, electrical conductivity (relates to salinity), nitrogen, phosphorus, potassium and sulphur. Plant growth and establishment may be significantly inhibited by unfavourable concentrations of these parameters, such as high alkalinity (e.g. excess of OH⁻ ions) or high sodicity (e.g. excess sodium ions). Assessing the fertility of topsoil sources to be used for rehabilitation is therefore an important step towards ensuring the establishment of vegetation and ultimately achieving successful rehabilitation.

The suitability of soil sources for rehabilitation are summarised as follows:

- Topsoil sources adjacent to heap leach pad: soil analysis results show topsoil sources have suitable pH for plant growth, are non-saline and non-sodic. Soil fertility is considered adequate with high levels of plant available nitrogen (nitrate) and adequate levels of potassium and sulphur. The topsoil resource may benefit from phosphorus addition to improve soil fertility before application.
- Main Pit levee: soil resources were measured with low pH values, presenting the risk of aluminium toxicity to plant growth. Lime addition would benefit to raise pH into plant growth suitable range. EC and ESP values were low, indicating non-saline and non-sodic soils. Soil potassium and sulphur levels are considered adequate. Soil phosphorus concentrations are relatively high, with potential to cause toxic conditions to plant growth. However, nitrate levels are extremely low therefore requiring fertiliser addition to improve soil fertility before application.
- Various topsoil sources (previously assessed by O’Kane Consulting 2019): soil fertility testing confirmed acceptable fertility characteristics and grading of soils on-site. Some topsoil sources exhibited dispersive qualities and limited water holding capacities. However, it is considered that these materials may still be suitable for use as topsoil.

Table 51: Rehabilitation material fertility results.

		O’Kane Consulting 2019			Yandan SLSA 2022			
Test	Units	Offsite Dam Topsoil (YAN-001)	Tailings Embankment Topsoil (YAN-018)	Tailings Embankment Gravel and Topsoil (YAN-021)	HLP topsoil stockpile #1	HLP topsoil stockpile #2	Main Pit levee	Comments
pH	-	5.7	8.3	6.5	6.2	6.0	4.4	Ranging between strongly acidic to moderately alkaline. Most are within suitable range for plant growth except Main Pit levee, presenting potential for aluminium toxicity to plants.
Electric Conductivity	dS/cm	0.00067	0.00562	0.00637	0.00052	0.00388	0.0327	All considered non-saline, with negligible effects.
Exchangeable Sodium Percentage	%	2.6	9.7	3.7	1.6	<0.1	3.4	ESP values above 6 is considered sodic. YAN-018 is sodic but still within acceptable range (O’Kane Consulting 2019).
Sulphur	%	0.01	0.02	0.02	-	-	-	Negligible impact.
Sulphur	mg/kg	-	-	-	<10	20	400	Negligible impact.
Nitrate	mg/kg	-	-	-	25.6	131	1.8	HLP stockpiles contain high nitrate levels. Main Pit levee has very low concentrations, fertiliser addition would benefit.
Total Nitrogen	mg/kg	690	450	800	600	820	400	Negligible impact.
Total Kjeldahl Nitrogen	mg/kg	660	450	780	580	600	400	Negligible impact.
Extractable Phosphorus	mg/kg	-	-	-	14	<5	34	HLP Stockpile #2 contains low phosphorus levels and would benefit from fertiliser application. High phosphorus concentrations in Main Pit levee may present potential for toxic conditions to plants.

		O’Kane Consulting 2019			Yandan SLISA 2022			
Organic Matter	%	1.4	0.5	1.2	1.5	0.8	0.6	Negligible impact.
Total Organic Carbon	%	0.8	<0.5	0.7	-	-	-	Negligible impact.
Exchangeable Aluminium	meq/100g	<0.1	-	-	-	<0.1	0.2	Within desired range.
Exchangeable Calcium	meq/100g	2.9	12	3.3	5.7	2.6	6.1	YAN-001, YAN-021 and HLP stockpile #2 are lower than desired.
Exchangeable Magnesium	meq/100g	1.1	1.9	2.7	3.1	4.6	7.9	YAN-001 is lower than desired.
Exchangeable Potassium	meq/100g	0.2	<0.2	0.2	0.5	0.8	0.3	YAN-001, YAN-018 and YAN-021 are lower than desired.
Exchangeable Sodium	meq/100g	0.10	1.5	0.2	0.2	<0.1	0.5	YAN-018 is higher than desired.
Cation Exchange Capacity	meq/100g	4.3	15.6	6.6	9.4	8.0	15.5	YAN-001 below desired range.
Calcium/Magnesium Ratio	-	2.6	6.3	1.2	1.8	0.6	0.8	1 – 4 is low in Calcium. 6 – 10 is low in Magnesium.
Magnesium/Potassium Ratio	-	6.4	-	10.9	6.4	5.6	29.5	Within desirable range.

8.2 Material suitability Summary

The results of the material characterisation program are summarised as follows (O’Kane Consultants 2019):

- Potential clay sources: materials from the embankment of the Heap Leach Pond embankment core, upstream of Mine Water Dam and upstream of the Water Storage Dam were found to have good consistency for constructing a barrier layer.
- Potential topsoil sources: soil fertility testing confirmed acceptable fertility characteristics and grading of soils on-site. Some topsoil sources exhibited dispersive qualities and limited water holding capacities. However, it is considered that these materials may still be suitable for use as topsoil.
- Potential growth medium sources: the particle size of material located immediately north of Cell A confirms the suitability of this material as growth medium. Other suitable material adjacent to the tailings storage facility (TSF) has been identified with positive permeability and fertility characteristics. One potential growth medium source displayed slight dispersive characteristics, however, given that growth medium will be located under a topsoil layer this property is not considered a concern.
- Potential coarse rock sources: material sources adjacent to Cell B and the heap leach pad were found to be coarse, well-graded material suitable for use as a capillary break layer.

8.2.1 Amelioration requirements

The results indicate the materials sampled are generally suitable to support vegetation and could be used for as a topsoil and/or growth medium layer of a cover system.

Resources would benefit from amelioration to improve plant establishment and rehabilitation success, as described in section 7.3.1. The SMUs identified in this SLISA describes non-sodic soil profiles with dispersive qualities, soil resources are likely susceptible to erosion. Appropriate erosion and sediment control methods must be implemented throughout the study area.

Based on soil fertility results, amelioration requirements may include:

- lime application to neutralise acidic soil resources;
- gypsum application to improve structural stability; and
- various fertiliser applications to improve nutrient availability in soil.

According to pre-mining and current land use, as well as outcomes of this SLISA, it is anticipated that rehabilitated landforms may be able to support a post-mining land use of cattle grazing. Additional studies are required to determine whether the effect of the limitations can be reduced to achieve sustained economic production.

9 Material balance

Estimates of available rehabilitation materials (including topsoil, growth medium and clay) are available from material volume assessments completed as part of this 2022 SLSA soil survey, and as part of the material characterisation work completed by O’Kane Consultants (2019) for the Cell B cover system design assessment. The Project requires an estimated 319,369 m³ of topsoil resources and an estimated 851,790 m³ of growth medium (coarse rock materials) to complete rehabilitation. The Project material balance indicates that there are sufficient resources available, with an estimated 469,560 m³ of topsoil resources available; and an estimated 3,542,352 m³ of growth medium resources available.

Estimated volumes of rehabilitation materials are detailed in Table 52 with locations shown in Figure 7.

Table 52: Estimated rehabilitation materials available and required

Material type	Source	Estimated maximum volume (m ³) of material available	Estimated volume (m ³) of material required
Clay	HL Pond Embankment (clay core) ¹	2,430	If required
	Upstream of MWD (clay borrow)	8,000	If required
	Upstream of Water Storage Dam (clay borrow)	380,000	If required
Topsoil	Topsoil (borrows north and south of the TWRD)	80,000	80,000
	HLP topsoil stockpile #1	22,000	27,345
	HLP topsoil stockpile #2	9,400	
	Floodplain Borrow Pit	11,150	If required
	North WSD topsoil stockpile	12,000	12,000
	Gravelly topsoil (around the TSF and TWRD) borrow pits	60,000	60,000
	Borrow pits ³	65,043	65,043
	TWRD topsoil stockpile	17,800	17,800
	MWD topsoil stockpile	1,550	If required
	WSD topsoil stockpile	19,700	10,764
	WHD topsoil stockpile	2,000	If required
Growth medium (including coarse rock)	Gravel / coarse rock (around the TSF and TWRD)	510,000	510,000
	Coarse rock from Heap Leach Pad ²	3,032,352	341,790
Dam embankment material (combined)	Mine Water Dam embankment	83,200	Not proposed for use in rehabilitation
	Water Storage Dam embankment	28,200	Not proposed for use in rehabilitation
	Water Harvest Trench embankments	58,500	17,000

Material type	Source	Estimated maximum volume (m ³) of material available	Estimated volume (m ³) of material required
	Tailings Water Return Dam embankment	104,500	103,500
	HL Pond embankment ¹	1,800	1,800
	TSF Spillway	4,117	4,117

1 HL Pond Embankment was constructed using two materials which has been taken into account for the volume calculation. The HL Pond embankment consists of a 3 m width and 3 m high clay core (for the entire length of the embankment) in addition to being capped with dam embankment material (combined).

2 Physical properties of the heap leach pad material indicate the material is suitable for use as coarse rock capillary break layers. Prior to any potential use, a QC/QA and testing program would need to be developed to confirm use of the material. Additional material from the heap leach pad may be suitable for rehabilitation purposes, if required.

3. Topsoil material to be stripped from the borrow pits and placed adjacent the pit. Topsoil to be placed back over pit of origin for rehabilitation purposes.

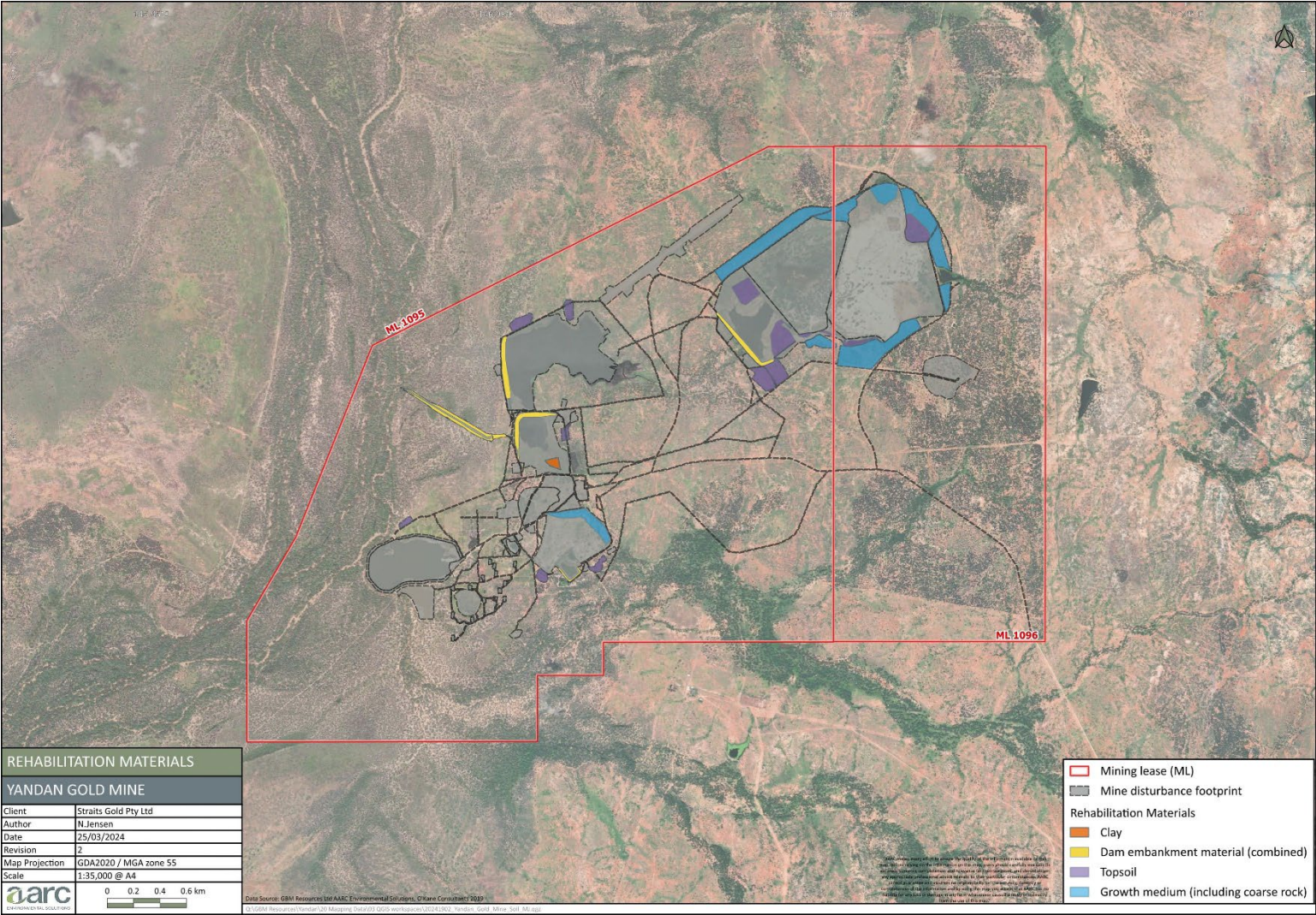


Figure 7: Available rehabilitation material on the Project

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Appendix A. Laboratory Results

Appendix B. Soil Profile Field Data

Site Description

Date:	12/12/21		Site:	YP1	
Location:	North of Cell A		Coordinates:	E 146.9967	N -21.2724
Landform Pattern:	PLA		Micro Relief:	-	
Landform Element:	PLA		Rock Outcrops:	-	
Morphological Type:	F		S C Fragments:	-	
Site Disturbance:	1		Substrate:	-	
Erosion:	0		Surface Condition:	F	
Landform	Elevation:	192m	Permeability:	2	
	Slope (%):	0	Drainage:	3	
	Relief:	0	Run-off:	1	

- dark grayish brown
- mottling in lower profile, making it appear orange (many, fine/medium sized, prominent, clear boundaries)
- Clay loam to silty material to medium clay
- Iron segregations: common occurrence, concretion, very coarse
- slightly acid to neutral pH
- subplastic in last 20cm
- GLM: BD05?

Soil Description

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH
A1	0 – 5		2.5 Y 3/2	NA	CL	-	GW2AB	-	D00N1	6
B11	5 – 20	G	2.5 Y 4/2	NA	ZCL	-	GW1AB	-	D01N1	6.5
B12	20 – 35	A	2.5 Y 4/2	NA	LC	-	GW1SB	-	D01N2	6.5
B13	35 – 60	S	10 YR 4/2	M41POC	ZL	-	GW3SB	3FC32M	T22N1	7
B14	60 – 80	S	10 YR 4/2	M42POC	MC	-	GW2SB	3FC32M	T22U3	7.5

Vegetation: predominantly Brigalow/Gidgee; White Gum. Notes: Very vegetated with grass

Site Description

Date:	11/12/21		Site:	YP2	
Location:	Southwest of Tailings Dam		Coordinates:	E 146.9908	N -21.2843
Landform Pattern:	PLA		Micro Relief:	-	
Landform Element:	PLA		Rock Outcrops:	ME	
Morphological Type:	F		S C Fragments:	-	
Site Disturbance:	1		Substrate:	-	
Erosion:	0		Surface Condition:	F	
Landform	Elevation:	221m	Permeability:	2	
	Slope (%):	0	Drainage:	3	
	Relief:	0	Run-off:	1	

- dark grayish brown
- mottling in lower profile, making it appear orange (many, fine/medium sized, prominent, clear boundaries)
- Clay loam to silty material to medium clay
- Iron segregations: common occurrence, concretion, very coarse
- slightly acid to neutral pH
- subplastic in last 20cm
- GLM: BD05?

Soil Description

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH
O	0 – 2	-	-	-	-	-	-	-	-	6
A2e	2 – 10	-	10 YR 5/4	-	CL	-	GW3SB	-	D01N2	6
B21	10 – 30	A	10 YR 5/6	-	MC	-	GW3PO	-	D01N3	6
B22	30 – 45	A	10 YR 5/4	-	MC	-	GW3PO	-	D01N3	7
B23	45 – 80	G	10 YR 4/4	-	MHC	-	GW2PO	-	D01U3	7 ½

Vegetation: Brigalow/gidgee, wattles. Notes: undisturbed area, sedimentary material, dry creek nearby

Site Description

Date:	11/12/21		Site:	YP3	
Location:	MID of ML		Coordinates:	E 146.9938	N -21.2919
Landform Pattern:	PLA		Micro Relief:	-	
Landform Element:	PLA		Rock Outcrops:	SA/ME/Schist	
Morphological Type:	F		S C Fragments:	-	
Site Disturbance:	8		Substrate:	-	
Erosion:	A R3		Surface Condition:	L	
Landform	Elevation:	196m	Permeability:	4	
	Slope (%):	2	Drainage:	6	
	Relief:	0 – 9m	Run-off:	2	

- dark grayish brown
- mottling in lower profile, making it appear orange (many, fine/medium sized, prominent, clear boundaries)
- Clay loam to silty material to medium clay
- Iron segregations: common occurrence, concretion, very coarse
- slightly acid to neutral pH
- subplastic in last 20cm
- GLM: BD05?

Soil Description

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH
B2	0 – 65	-	7.5 YR 6/6	-	CL	-	GW1GR	-	D0000	6 ½

Vegetation: wattle, bauhinia, ironbark? Notes: visible erosion, 20% ground cover, slight incline, rocky outcrop east of hole (15m)

Site Description

Date:	11/12/21		Site:	YP4	
Location:	between HLP and MainPit		Coordinates:	E 146.9767	N -21.2954
Landform Pattern:	RIS		Micro Relief:	-	
Landform Element:	HSL		Rock Outcrops:	5SA	
Morphological Type:	S		S C Fragments:	-	
Site Disturbance:	8		Substrate:	-	
Erosion:			Surface Condition:	F	
Landform	Elevation:	188m	Permeability:	4	
	Slope (%):	3	Drainage:	6	
	Relief:	9 – 30m	Run-off:	2	

- dark grayish brown
- mottling in lower profile, making it appear orange (many, fine/medium sized, prominent, clear boundaries)
- Clay loam to silty material to medium clay
- Iron segregations: common occurrence, concretion, very coarse
- slightly acid to neutral pH
- subplastic in last 20cm
- GLM: BD05?

Soil Description

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH
B2	0 – 30	-	5YR 4/4	-	L	-	GW1GR	-	M0000	6

Vegetation: wattle, bauhinia, ironbark? Notes: very rocky outcrop, surface 5cm dry moist underneath with roots, rock refusal

Site Description

Date:	12/12/21		Site:	YP5	
Location:	Northwest of ML1096		Coordinates:	E 147.0014	N -21.2698
Landform Pattern:	PLA		Micro Relief:	-	
Landform Element:	PLA		Rock Outcrops:	3ME	
Morphological Type:	S		S C Fragments:	-	
Site Disturbance:	5		Substrate:	-	
Erosion:	0		Surface Condition:	F	
Landform	Elevation:	202m	Permeability:	2	
	Slope (%):	2	Drainage:	3	
	Relief:	0 – 9m	Run-off:	1	

- dark grayish brown
- mottling in lower profile, making it appear orange (many, fine/medium sized, prominent, clear boundaries)
- Clay loam to silty material to medium clay
- Iron segregations: common occurrence, concretion, very coarse
- slightly acid to neutral pH
- subplastic in last 20cm
- GLM: BD05?

Soil Description

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH
B21	0 – 10	-	5 YR 4/4	-	L	-	GW1GR	-	D0000	6 ½
B22	10 – 40	S	5 YR 4/6	M1FRD	MC	-	VM3AB	1KFS1	T21U3	7
B23	40 – 60	A	5 YR 4/6	M1FRD	MHC	-	GW2SB	1KFS1	D21U3	8 ½
B24	60 – 70	G	5 YR 3/4	M1FRD	LMC	-	GW2SB	1KFS1	D01U3	8 ½
B25	70 – 80	S	5 YR 3/4	-	LC	-	GW1GR	-	D03N2	9

Site Description

Date:	12/12/21		Site:	YP6	
Location:	East edge of ML1096		Coordinates:	E 147.0123	N -21.2811
Landform Pattern:	PLA		Micro Relief:	-	
Landform Element:	PLA		Rock Outcrops:	-	
Morphological Type:	F		S C Fragments:	-	
Site Disturbance:	1		Substrate:	-	
Erosion:	A R1		Surface Condition:	F	
Landform	Elevation:	209m	Permeability:	2	
	Slope (%):	0	Drainage:	3	
	Relief:	0 – 9m	Run-off:	3	

- dark grayish brown
- mottling in lower profile, making it appear orange (many, fine/medium sized, prominent, clear boundaries)
- Clay loam to silty material to medium clay
- Iron segregations: common occurrence, concretion, very coarse
- slightly acid to neutral pH
- subplastic in last 20cm
- GLM: BD05?

Soil Description

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH
B21	0 – 20		5 YR 5/4	-	L	-	GW1GR	-	D0000	7
B22	20 – 30	G	5 YR 4/6	-	LC	-	VM3SB	3KFS1	M11N2	8 ½
C	30 – 55	A	5 YR 6/3	-	LC	-	GW1GR	-	D11N2	9

Vegetation: gidgee, gum tree. Notes: hit bedrock (purple material); sedimentary

Site Description

Date:	12/12/21		Site:	YP7	
Location:	Southeast edge of ML 1096		Coordinates:	E 147.0134	N -21.2940
Landform Pattern:	PLA		Micro Relief:	-	
Landform Element:	PLA		Rock Outcrops:	-	
Morphological Type:	F		S C Fragments:	-	
Site Disturbance:	0		Substrate:	-	
Erosion:	A G3 (40cm gully)		Surface Condition:	F	
Landform	Elevation:	191m	Permeability:	3	
	Slope (%):	0	Drainage:	4	
	Relief:	0 – 9m	Run-off:	3	

- dark grayish brown
- mottling in lower profile, making it appear orange (many, fine/medium sized, prominent, clear boundaries)
- Clay loam to silty material to medium clay
- Iron segregations: common occurrence, concretion, very coarse
- slightly acid to neutral pH
- subplastic in last 20cm
- GLM: BD05?

Soil Description

Horizon	Depth (cm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH
B21	0 – 20		10 YR 5/8	-	CL	-	GW1GR	-	T01-0	6.5
B22	20 – 40	C	10 YR 3/4	M31DOC	ZCL	-	VM3PO	3FS2	M21N1	7
B23	40 – 70	A	10 YR 5/6	-	ZL	52STRVS (?)	GW1GR	-	D02-0	7.5
						B23 (weathered stuff structure) >> GW4AB				

Vegetation: Brigalow melaleuca, wattle, gidgee. Notes: lower profile consists of weathered bedrock, gravelly; visible erosion

Appendix C. Soil Field Observation Data

Obs	Date	Site ID	Vegetation	Soil description/unit	Notes
1	11/12/21	Centre of ML	Cleared, juvenile ironbark, sparse Sally wattles	Red soil, loose	More densely covered grassland
2	11/12/21	Next to YP4	Ironbark, sally wattle, whitewood	Red soil, very rocky outcrop	Plains in the north and steep slope in the south where the HLP is
3	11/12/21	Close to main pit	Brigalows?	Looks lighter red	Flooded pond, dense vegetation
4	11/12/21	Main pit levee	Brigalows?	Rocky, very red	High elevation of levee, pronounce erosion (40cm depth)
5	11/12/21	HLP	Brigalows?	Brownish red, boulders around, rocky	-
6	11/12/21	South of pit	Cleared, with vegetation further south	Brownish red, rocky	No sign of active erosion, large channel/ depression from previous erosion?
7	11/12/21	HLP 2	Brigalows?	Brownish red, boulders around, rocky	-
8	11/12/21	HLP 2	Brigalows?	Brownish red, boulders around, rocky	Erosion observed
9	11/12/21	Close to Sandy Creek	Ironbark	Clayey soils, reddish/yellowish brown	
10	11/12/21	Centre of ML	Cleared juvenile ironbark, sparse	Sandy, red	On road
11	11/12/21	Tailings return water dam	Gidgee?	Red soils, sandstone	On stockpile
12	11/12/21	Near airstrip Water dam	Gidgees/ Brigalow	Red soils	Looking east

Obs	Date	Site ID	Vegetation	Soil description/unit	Notes
13	11/12/21	Water storage dam	Gidgees/Brigalow to west	Lighter red soil	-
14	11/12/21	Water channel	Brigalow, sally wattle	Rocky reddish brown	-
15	11/12/21	Mid water channel	Brigalow	Cracking clay, brown, only 30m of it	Washed up from creek when flooded
16	12/12/21	Edge of ML	Mostly Brigalow and gidgee	Brownish red, silty stuff	A lot of erosion
17	12/12/21	Soil boundary edge ML	Gidgee more abundant in the east	Lighter red	erosion
18	12/12/21	Soil boundary NW ML edge	Brigalow/gidgee in east, ironbark NW		Between S19 and Qa14?
19	12/12/21	NE ML Edge	Brigalow/gidgee in east, west cleared	Redder soil to west	-
20	12/12/21	North ML edge	Brigalow/gidgee	Qa14? red duplex?	Next to cleared area
21	12/12/21	Cell A embankment	Brigalow/gidgee to east	Red, rocky surface soil, loose	Mine disturbed
22	12/12/21	Boundary between soil Atlas types	Brigalow/gidgee in east Ironbark in west	-	-
23	12/12/21	Main pit overflow	Brigalow/gidgee	Brown reddish	

**REHABILITATION OF YANDAN TAILINGS FACILITY AND RETURN
WATER DAM
WATERWORKS LICENCES G-55021 AND G-55022**

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APPENDICES

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EXECUTIVE SUMMARY

1. Compartment A of the Yandan Gold Mine tailings facility comprises oxide tailings
2. Compartment B of the Yandan Gold Mine tailings facility comprises a layer of sulphide tailings almost entirely enveloped on top and bottom by oxide tailings
3. Permanent drainage works are to be constructed to prevent water ponding on the tailings surface.
4. The proposed decommissioning strategy for Compartment A is to plant vegetation directly onto the tailing surface
5. The proposed decommissioning strategy for Compartment B is to cap exposed areas of sulphidic tailings with 300mm of topsoil and plant vegetation directly onto the capped sulphide and uncapped oxide tailings surface.

1 INTRODUCTION

This report discusses the tailing characterisation, revegetation trials, and rehabilitation methods and objectives for the Yandan Gold Mine tailings facility. The operation of this dam is described in detail in Appendix III of the Yandan Gold Mine 1993 Plan of Operations. Waterworks licences G-55021 and G-55022 for the facility are presented in Appendix A.

The dam has a central causeway that separates two compartments, known as Compartment A and Compartment B. Selective placement of tailings into these compartments was undertaken during processing. Oxide tailings were deposited in Compartment A. A sequence of oxide, sulphide, then oxide tails were deposited into Compartment B. The facility therefore has one compartment of pure oxide tailings and one compartment of oxide tailings encompassing or partially encompassing sulphide tailings.

The tailings facility was operational for nearly six years. During this time a total of 7.5 million tonnes of tailings was deposited.

Sampling was undertaken of *in situ* tailings to enable chemical and physical characterisation of the material. The characterisation of tailings is necessary to determine the long term behaviour of the tailings which in itself gives an indication of appropriate rehabilitation techniques.

Revegetation trials were established to determine the species most suited for revegetation of the tailings surface. Pasture grasses growing directly into tailings material were analysed to determine their suitability for the final landuse, low intensity grazing.

Ground and surface water monitoring analysis results taken over a period of three years are reviewed and discussed.

2 FIELD ASSESSMENT

2.1 Compartment A

2.1.1 *Geochemical*

A total of nineteen representative sampling locations (A1 to A19) were chosen (Figure 1) for geochemical characterisation of the tailings. One kilogram samples were collected from each of the sites. The samples were a composite of the top 300 mm of tailings. Samples were collected with a shovel and placed into individual plastic sample bags.

Groundwater and surface water samples underwent a full analysis for metals and major cations and anions. The samples were taken from water monitoring locations shown in Figure 1.

Composite samples of Buffel and Rhodes grasses were sampled from the tailings surface. The grass samples were analysed for metals commonly found in the tailings material.

2.1.2 *Physical*

Sampling was undertaken at several depths (0cm, 15cm, 30cm, 60cm), at sites (A1-A19) to characterise the physical properties and salt profile of the tailings. Core samples were collected using PVC tubing. The analysis of these samples was undertaken on-site.

2.1.3 *Nutritional*

Selected samples of tailings and regional soil were analysed for their nutritional status.

2.1.4 *Revegetation Trials*

Three revegetation trials (A1, A2, Pot Trials) have been undertaken on Compartment A tailings material. Trial A1 commenced in January 1998, Figure 2. The trial was undertaken to determine the most effective, in terms of vegetative re-establishment, substrate material.

Trial A2 commenced in mid-1998, Figure 3. The trial was used to determine the fertilisation rate(s) and species selection needed to achieve a sustainable vegetative cover. The objective was to determine the rates of establishment and survival of native and introduced trees, shrubs and grasses when different fertilisation rates were applied.

Pot trials (P1 and P2) were undertaken in unamended tailings material to determine potential as a growth medium for vegetation. Trial P1 was undertaken in November 1998. Tailings samples were taken from five sites in Compartment A of the Yandan tailings dam, Figure 1. Three samples were taken from each of the five sites. Each sample was a composite of the top 300 mm of tailings material.

Trial P2 was undertaken over a four month period in 1998 by Ms. Leanne Thompson of Gatton University. The aim of the study was to determine the tailings suitability as a rooting medium for a number of tree species. A copy of Ms. Thompson's report has been made available for review to minimise unnecessary replication. Significant findings of the report have been included, with discussion, where appropriate.

2.2 Compartment B

2.2.1 *Geochemical*

The compartment was surveyed to determine areas of exposed sulphidic tailings. A total of twenty eight representative sampling locations (B1 to B28) were chosen, Figure 1, for the tailings characterisations. Samples included oxide and sulphide tailings material. One kilogram samples were collected from each of the sites. The samples were a composite of the top 500 mm of tailings. Samples were collected with a shovel and placed into individual plastic sample bags.

Composite samples of Buffel and Rhodes grasses were sampled from the tailings surface. The grass samples were analysed for metals commonly found in the tailings material.

2.2.2 *Nutritional*

Selected samples of tailings and regional soil were analysed for their nutritional status.

REPLACE WITH FIGURE OF ALL LOCATIONS

A3 Size

3 LABORATORY ANALYSIS

3.1 Geochemical Properties

3.1.1 Tailings

3.1.1.1 Compartment A

Geochemical laboratory tests were conducted by Australian Laboratory Services (Brisbane). The nineteen representative samples were analysed for:

- Sulphur content (total);
- pH;
- Electrical Conductivity (EC);
- Metals – copper, lead, zinc, silver, arsenic, bismuth, cadmium, cobalt, manganese, molybdenum, nickel, antimony and chromium.

Total sulphur was chosen as a conservative indicator of the acid producing potential of the tailings material. Total sulphur analysis was undertaken according to the high temperature Leco furnace method.

pH and EC were calculated using a 1:5 mix of tailings to distilled water.

The metals selected for analysis were chosen on the basis of element concentrations common to the Yandan deposit. Metal analysis of the tailings was undertaken by ICP optical emission spectrometry on a mixed acid digest (total extraction).

Thirteen selected samples (A5-A6, A8, A10-A19) were tested for:-

- Maximum Potential Acidity (MPA) (ALS EA-009);
- Acid Neutralising Capacity (ANC) (ALS EA-009);
- Net Acid Producing Potential (NAPP) (ALS EA-009); and
- Net Acid Generation (NAG) (ALS EA-0011);.

Five samples (A15-A19) were tested (ALS EK-028A) for Weak Acid Dissociable (WAD) cyanide.

Twenty five sites (A1-A25) were tested, 1:5 tailings to distilled water, by the onsite laboratory for conductivity (μ S), salinity (ppm) and pH at depths of 0 cm, 30 cm, 60 cm, and 90 cms.

3.1.1.2 Compartment B

Sample descriptions are presented in Appendix B. Geochemical laboratory tests were conducted by Australian Laboratory Services (Brisbane). Methodologies as for Compartment A. The twenty eight representative samples were analysed for:-

- Sulphur content (total);
- pH;
- Electrical Conductivity;
- Metals – copper, lead, zinc, silver, arsenic, bismuth, cadmium, cobalt, manganese, molybdenum, nickel, antimony and chromium; and

Ten selected samples were tested for:-

- Maximum Potential Acidity (MPA);
- Acid Neutralising Capacity (ANC);
- Net Acid Producing Potential (NAPP); and
- Net Acid Generation (NAG).

Four samples were tested for Weak Acid Dissociable (WAD) cyanide.

3.1.2 Groundwater and Surface Waters

Groundwater monitoring bores and surface waters, from the return water pond and runoff dam, are sampled on a bi-annual basis. The normal analytical parameters were extended in sampling undertaken on the 28/09/1999 to comprise a full suite of metals and major cations and anions. Water analysis was undertaken by A.L.S Brisbane.

3.1.3 Vegetation

Vegetative samples of the two predominant grasses growing on tailings within Compartments A and B, namely Buffel Grass (*Cenchrus ciliaris*) and Rhodes Grass (*Chloris sp.*), were analysed (ALS EG-005T; EG-020T) for copper, lead, zinc, silver, arsenic, bismuth, cadmium, cobalt, manganese, molybdenum, nickel, antimony and chromium.

Representative samples of Buffel and Rhodes grasses were sampled from background areas and analysed for the above metals.

3.2 Physical Properties

3.2.1 Compartment A

Laboratory testing of physical properties were conducted by Ross Mining N.L in the Yandan mine laboratory. Testwork included:-

25 *in situ* Bulk Density tests, and

25 *in situ* Moisture Content tests

3.3 Nutritional Properties

3.3.1 *Compartment A*

Every second tailings sample (A1, A3 etc.), and representative local soil samples, were analysed by Agritech Laboratory Services Pty. Ltd for:-

- Acidity
- Major Elements (Nitrogen, Phosphorus, Potassium)
- Secondary Elements (Sulphur, Calcium, Magnesium)
- Trace Elements (Copper, Zinc, Manganese, Iron, Boron)
- Organic Matter
- Salinity (Conductivity, Sodium, Chloride)

Methods for analysis are listed in the Agritech laboratory report presented in Appendix C

Calculations were used to determine:-

- Cation Exchange
- Exchangeable Sodium, Potassium, Calcium and Magnesium
- Ca/Mg Ratio

3.3.2 *Compartment B*

Every second sample (B1, B3 etc.) were analysed by Australian Laboratory Services Pty. Ltd for:-

- Acidity
- Major Elements (Nitrogen, Phosphorus, Potassium)
- Secondary Elements (Sulphur, Calcium, Magnesium)
- Trace Elements (Copper, Zinc, Manganese, Iron, Boron)
- Organic Matter
- Salinity (Conductivity, Sodium, Chloride)

Methods for analysis are listed in the Agritech laboratory report presented in Appendix C

Calculations were used to determine:-

- Cation Exchange
- Exchangeable Sodium, Potassium, Calcium and Magnesium
- Ca/Mg Ratio

3.4 Revegetation Trials

3.4.1 Trial A1

A 70 metre by 5 metre section of tailings was divided into 5 metre by 5 metre individual plots, as shown in Figure 2. Seven treatments, with replication, were applied to the plots. The treatments included:-

1. Tailings surface
2. 10 cm oxide waste
3. 10 cm oxide waste + 10 cm soil
4. 10 cm soil
5. 25 cm oxide waste + 10 cm soil
6. 50 cm oxide waste + 10 cm soil
7. 50 cm oxide waste

All treatments were grass seeded (10 kg/ha) and fertilised (200 kg/ha Diammonium phosphate). Monitoring of the trial area was undertaken periodically. Percentage ground area, species composition and species dominance for each individual treatment is recorded.

A1, A2 and A3 sampling points have been used to characterise the tailing substrate of the trial area.

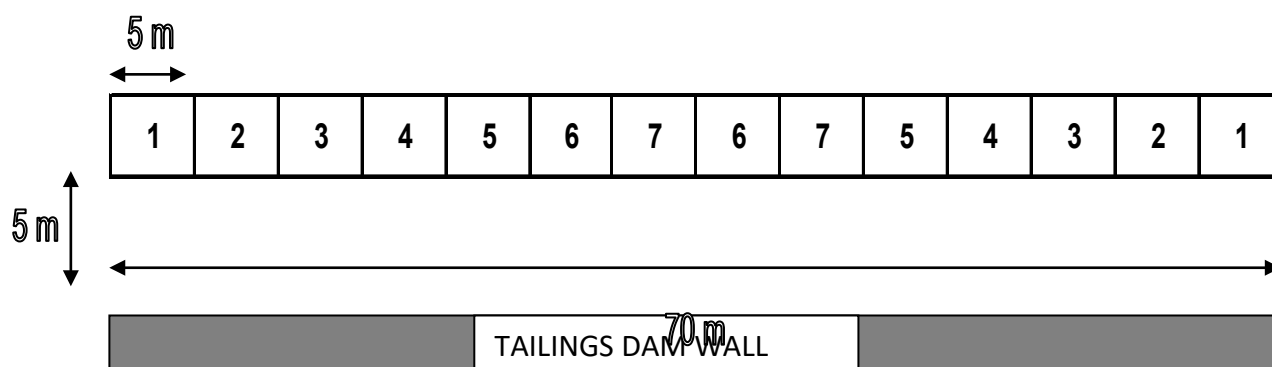


Figure 2 - Trial A1 Compartment A, Yandan Tailings Dam

3.4.2 Trial A2

A 10 cm layer of topsoil was spread over a 2500 m² area. The area was then subdivided into twenty five 10 m by 10 m plots, as shown in Figure 3. A specific treatment was applied to each individual plot. The treatments, each replicated three times, applied were:-

1. 10 kg/ha Pioneer Rhodes Mix + 100 kg/ha Diammonium Phosphate (P1)
2. 10 kg/ha Pioneer Rhodes Mix + 200 kg/ha Diammonium Phosphate (P2)

3. 4 kg/ha Tree Mix (*E.crebra*, *E.dichromophloia*, *E.papuana*) + 100 kg/ha Diammonium Phosphate (T1)
4. 4 kg/ha Tree Mix (*E.crebra*, *E.dichromophloia*, *E.papuana*) + 200 kg/ha Diammonium Phosphate (T2)
5. 4 kg/ha Katembora Rhodes + 100 kg/ha Diammonium Phosphate (K1)
5. 4 kg/ha Katembora Rhodes+ 200 kg/ha Diammonium Phosphate (NG2)
6. 4 kg/ha Saltbush (*Atriplex spp.*) + 100 kg/ha Diammonium Phosphate (S1)
7. 4 kg/ha Saltbush (*Atriplex spp.*) + 200 kg/ha Diammonium Phosphate (S2)
8. Control 100 kg/ha Diammonium Phosphate (C1)
9. Control 200 kg/ha Diammonium Phosphate (C2)

A7, A10, A12 and A13 samples were used to characterise tailing substrate of the trial area.

Monitoring of the trial area has been undertaken on an annual basis. Parameters recorded comprise percentage ground cover and species dominance. Percentage ground cover is a qualitative measure.

3.4.3 Pot Trials

3.4.3.1 Trial P1

The location of tailings sampling sites are shown in Figure 4. Tailings samples were placed in growing trays (15 cm x 34 cm). A specific treatment was applied to each individual tray. Replicates of treatments were either scarified or left undisturbed. The treatments applied were:

1. A native grass seed mix, applied at the equivalent of 10 kg/ha, The native grass seed mix comprised Queensland Bluegrass, Mitchell Grass, Kangaroo Grass and Black Speargrass.
2. Quinine tree seed applied at the equivalent of 10 kg/ha.
3. Crotalaria sp. seed applied at the equivalent of 10 kg/ha.
4. Wynn Cassia seed applied at the equivalent of 10 kg/ha.
5. Speedy Couch seed applied at the equivalent of 10 kg/ha.
6. Verano stylo seed applied at the equivalent of 10 kg/ha.
7. Chloris sp. seed applied at the equivalent of 10 kg/ha

A one off measurement of establishment was recorded three weeks after sowing of the seeds.

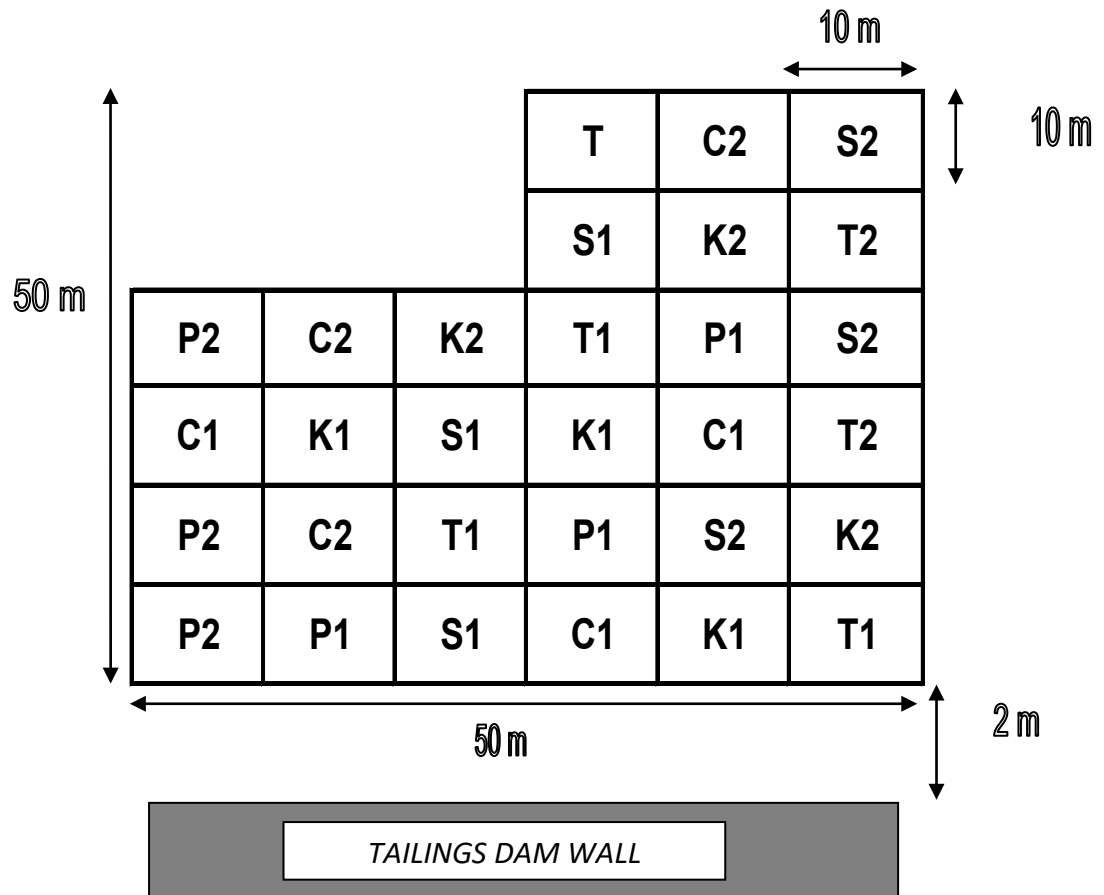


Figure 3 - Trial A2 Compartment A, Yandan Tailings dam.

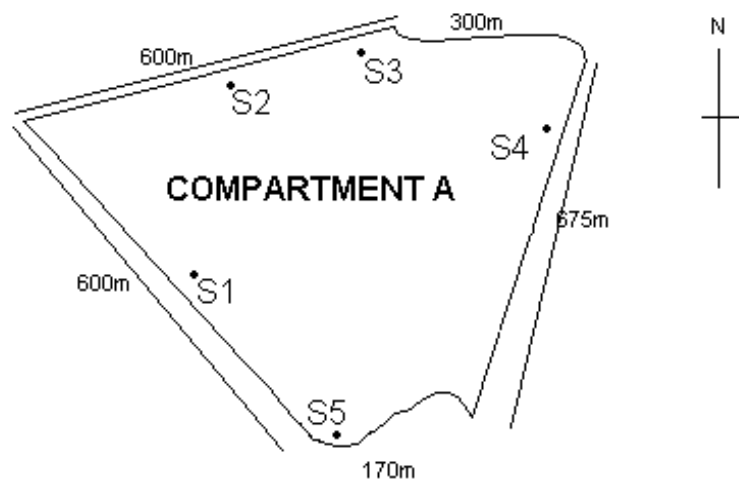


Figure 4 Trial P1 Sample Sites (S1-S5)

3.4.3.2 *Trial P2*

An extensive pot trial was undertaken in 1998 to determine the suitability of tailings material as rooting media for various tree species. The methodology and results of the trial are outlined in Thompson (1999). A discussion of the trials results is presented in Section 4.3.3.2

4 RESULTS AND DISCUSSION

Original laboratory reports, where available, are presented in Appendix C.

4.1 Geochemical Properties

4.1.1 Acid Base Accounting – Compartment A

The results of the acid base accounting testwork for ten selected Compartment A tailings samples are given in Table 1.

The total sulphur content of the tailings samples ranged from 0.15 to 0.51 % (average 0.23 %). Assuming all sulphur present is in the form of sulphides (pyritic sulphur), that could potentially produce acid if exposed to oxidising conditions, the corresponding maximum potential acidity (MPA) would range from 4.59 to 15.62 kg H₂SO₄/t (average 7.1 kg H₂SO₄/t).

The acid neutralising capacity (ANC) of the samples ranged from 1.6 to 5.3 kg H₂SO₄/t (average 2.51 kg/t).

The net acid producing potential (NAPP), which represents the balance between the MPA and ANC of the samples, ranged from –0.09 to 13.52 kg H₂SO₄/t (average 4.59 kg H₂SO₄/t).

Final NAG pH of the samples ranged from 3.9 to 7 (average 5.48). Based on the average pH value, the tailings in Compartment A will not release acid.

Net acid generation (NAG) of the samples ranged from <0.1 to 2.9 kg H₂SO₄/t (average 1.1 kg H₂SO₄/t).

The acid base accounting and NAG testwork indicates that tailings stored within Compartment A of the Yandan tailings facility have no potential to release acid. The tailings are in fact classified as acid consuming material (ACM) with average final NAG pH greater than 4.5, static NAG values near zero, and NAPP values less than 100 kg H₂SO₄/t.

4.1.2 Acid Base Accounting – Compartment B

The results of the acid base accounting testwork for ten selected Compartment B tailings samples are given in Table 2.

The total sulphur content of the tailings samples ranged from 0.10 to 0.8 % (average 0.32 %). Assuming all sulphur present was in the form of sulphides (pyritic sulphur), the corresponding maximum potential acidity (MPA) would range from 3.6 to 28.8 kg H₂SO₄/t (average 11.52 kg H₂SO₄/t).

The acid neutralising capacity (ANC) of the samples ranged from 0.5 to 5 kg/t (average 2.65 kg/t).

The net acid producing potential (NAPP), which represents the balance between the MPA and ANC of the samples, ranged from 0.5 to 23 kg H₂SO₄/t (average 10.6 kg H₂SO₄/t).

Final net acid generation (NAG) pH of the samples ranged from 2.7 to 6.6 (average 4.36).

Distinct differences in the potential to produce acid are evident in samples taken from the oxide capping of Compartment B, to those samples taken from sulphidic material lying beneath the oxide cap.

Oxide samples B11, B15, B17, B23 and B27 recorded NAG values averaging 0.9 kg H₂SO₄/t.

Sulphidic samples B1, B9 and B21 have NAG values averaging 11.7 kg H₂SO₄/t.

Overall, the NAG of the samples ranged from 0.2 to 15.7 kg H₂SO₄/t (average 4.57 kg H₂SO₄/t). Based on NAG results the tailings material can be classified as Potentially Acid Forming – Low Capacity (PAF-LC).

4.1.3 WAD Cyanide – Compartment A

WAD cyanide levels are below the DME (1995) acceptable surface soil remediation criteria (50 mg/kg) within the tailings material with an average of <0.7 mg/kg. The low levels of WAD cyanide present reflect the weak (generally 10-20 mg/L) cyanide concentration in decant liquor recorded throughout the operation of the tailings facility. The majority of cyanide present in the tailings stream either formed HCN or was returned within the decant liquor to the Dump Leach.

4.1.4 WAD Cyanide – Compartment B

WAD cyanide levels are below the DME (1995) acceptable surface soil remediation criteria (50 mg/kg) within the tailings material with an average of 13.25 mg/kg. The average WAD figure is greatly influenced by the analysis result of 41 mg/kg WAD recorded for B26. Excluding the B26 result the average WAD figure is reduced to 4 mg/kg. The anomalous WAD recording could possibly be the result of analysis error.

Table 1 – Acid Base Accounting, Compartment A Yandan Tailings Facility

SAMPLE LOCATION	DEPTH (mm)	ACID BASE ACCOUNTING						
		TOTAL S	MPA kg	ANC kg/t	NAPP	Final	NAG	WAD
SAMPLE LOCATION	DEPTH (mm)	ACID BASE ACCOUNTING						
		TOTAL S (%)	MPA kgH ₂ SO ₄ /t	ANC kg/t	NAPP kgH ₂ SO ₄ /t	Final pH	NAG kgH ₂ SO ₄ /t	WAD Cyanide (mg/kg)
B1	0-500	0.97	28.60	1.58	23.06	2.80	15.78	-
B10	0-500	0.18	5.61	2	3.61	4.6	1.6	-
B11	0-500	0.2	6.13	2.2	3.93	4.5	1.5	<1
B12	0-500	0.521	16.43	0.59	15.93	3.18	6.58	-
B13	0-500	0.19	5.95	2.59	6.59	6.28	1.98	-
B14	0-500	0.15	4.59	2.58	11.58	3.58	3.78	-
B15	0-500	0.15	4.59	3.5	1.09	6.5	0.1	7.08
B16	0-500	0.16	5.78	2.00	3.00	5.30	1.00	4.08
B17	0-500	0.35	12.60	4.00	8.00	4.40	1.40	0.5
B18	0-500	0.45	16.20	3.00	11.00	3.90	2.30	<0.5
B19	0-500	0.64	23.04	1.00	18.50	2.70	12.90	1.5
B23	0-500	0.45	16.20	4.50	9.50	6.60	0.20	-
B26	0-500	-	-	-	-	-	-	41.00
B27	0-500	0.35	12.60	5.00	5.50	5.00	0.90	-

Table 2 – Acid Base Accounting, Compartment B, Yandan Tailings Facility

1. MPA = Maximum Potential Acidity (% Total S x 30.6)
2. ANC = Acid Neutralising Capacity
3. NAPP = Net Acid Producing Potential
4. NAG = Net Acid Generation

4.1.5 Metal Analysis – Compartment A

Total metal concentrations of individual samples from Compartment A are shown in Table 3. Significant concentrations of three metals, arsenic, antimony and chromium, were recorded. Concentrations of these metals exceed the DME (1995) surface remediation criteria for the majority of samples tested.

Arsenic is present in the tailings at an average concentration of 111 mg/kg. This concentration is over five times the DME (1995) remediation criteria of 20 mg/kg.

Although arsenic concentrations are above the remediation criteria the risk of environmental or health impacts remain low. Soils have a high capacity to reduce the toxicity of applied dissolved arsenic through adsorption to clay and reaction with phosphorus (CCREM 1991 in ANZECC 1992). Tailings by their very nature have a high clay content that aids in arsenic adsorption. The moderate concentration of phosphorus in the tailings, see Section 4.1.10, helps detoxify the arsenic.

The edible parts of plants do not generally accumulate arsenic to levels dangerous to consumers (ANZECC, 1992). This is shown in the case of Buffel and Rhodes grasses growing on the tailings. Both grasses recorded <1 mg/kg of arsenic in their above ground matter, see Section 4.1.8.

Water monitoring results (Table 5) of bores positioned around the perimeter of the tailings facility (Figure 1) have shown little indication of arsenic availability within the local groundwater. The average concentration of arsenic in the groundwater is <0.1 mg/L compared with ANZECC 1992 criteria for aquatic ecosystems of 0.05 mg/L.

Antimony is present in the tailings at an average concentration of 24 mg/kg. This concentration is slightly above the DME (1995) remediation criteria level of 20 mg/kg.

Water monitoring results (Table 5) show no indications of antimony availability within the local groundwater. The average concentration of antimony in the groundwater is less than the detection limit of 0.01 mg/L. The concentration of antimony in the groundwater is below the 1992 ANZECC criteria for aquatic ecosystems of 0.03 mg/L.

Chromium is present in the tailings at an average concentration of 55 mg/kg. This concentration is slightly above the DME (1995) remediation criteria level of 50 mg/kg.

Water monitoring results (Table 5) show no indications of chromium availability within the local groundwater. The average concentration of chromium in the groundwater is <0.01 mg/L compared with ANZECC 1992 criteria for aquatic ecosystems of 0.01 mg/L.

Samples A1, A4 and A7 recorded levels of molybdenum above the DME (1995) remediation criteria level of 5 mg/kg. Overall molybdenum levels in the tailings fall within the guideline criteria.

Water monitoring results (Table 5) show no indications of molybdenum availability within the local groundwater. The average concentration of molybdenum in the groundwater is <0.01 mg/L compared with ANZECC 1992 criteria for aquatic ecosystems of 0.01 mg/L.

The analytical detection limit of 5 mg/kg used for cadmium within the tailings material does not allow the determination of compliance with the 1 mg/kg DME (1995) criteria value. It can be stated however that the levels of cadmium in the tailings are low with little potential for environmental impact.

Water monitoring results (Table 5) show the average concentration of cadmium in the groundwater is <0.002 mg/L compared with ANZECC 1992 criteria for aquatic ecosystems of 0.002 mg/L.

4.1.6 Metal Analysis – Compartment B

Total metal concentrations of individual samples from Compartment B are shown in Table 4. Significant concentrations of arsenic were recorded. Concentrations of arsenic exceed the DME (1995) surface remediation criteria for the majority of samples tested.

Arsenic is present in the tailings at an average concentration of 139 mg/kg. This concentration is over six times the DME (1995) remediation criteria of 20 mg/kg. Refer to Section 4.1.5 for discussion.

4.1.7 Ground and Surface Waters

Groundwater and surface water monitoring results for the period of 17/10/1997 to 15/06/2000 are shown in Table 5. Baseline groundwater quality results for the Yandan mining lease are shown in Table 6.

4.1.7.1 pH

pH levels within the monitoring bores have remained constant over the sampling period. The pH levels range from 6.66-8.45. The monitoring results possibly, assuming some level of seepage is occurring from the facility, indicate the effectiveness of the encapsulation of PAF sulphidic tailings within acid neutralising oxide tailings in Compartment B. The likely effect is that water moving 'vertically' through the tailings material has its pH raised by the oxide covering, possibly reduced by the underlying sulphidic material, and again raised by the lower oxide tailings layer. The end result is groundwater with near neutral pH.

4.1.7.2 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) levels recorded are generally in accordance with baseline groundwater quality (average TDS of 4698 mg/L), refer Table 6. It should be noted that the baseline water quality data used has been sourced from historical data from bores proposed for potable and or milling use ie bores that had been selected due to their relatively high quality of water.

An exception is the high (>21000 mg/L) levels of TDS recorded from the TD6 monitoring bore located adjacent to the eastern saddle dam. Assessments, 4/08/1997 and 28/08/1999, were undertaken to determine specific ion concentrations comprising the TDS levels. Both assessments found chloride and sodium to be the major ion constituents in the groundwater. The concentration of these ions has remained relatively constant over the

monitoring period. The respective levels of the ions taken from the 28/08/1999 sampling are 11,700 mg/L and 7,290 mg/L compared with 04/08/1997 levels of 13,400 mg/L and 8,710 mg/L.

The key causal factor in the elevation of TDS level in groundwater within the vicinity of the eastern saddle dam is the ponding of rainwater runoff adjacent to the foot of the dam wall. The tailings dam was built through the construction of two saddle dams across an existing creek channel. The eastern saddle dam causes some water to pond above it during times of high rainfall creating a small neo swamp area.

There would appear to be few options regarding the rehabilitation of the swamp area nor any necessity for it as the swamp has become a habitat in its own right. Previously a diversion drain was constructed in an attempt to divert water flow within the creek out of the tailings catchment. The drain had limited success due to the topographical limitations on its positioning. *Typha sp* has fully established the swamp area and provides protection for the soil during the dry season.

4.1.7.3 Metals

Copper concentrations within groundwater have remained consistent with baseline levels. The average concentration of copper within the monitoring bores is <0.1 mg/L. This level of copper is less than the ANZECC criteria value for livestock of 0.5 mg/L.

Iron concentrations ranged from 0.1 mg/L to 5.2 mg/L, the latter recorded in TD3 on the 03/07/1999. Latest sampling shows iron levels at below 0.1 mg/L. The iron levels are low and pose no potential impact to groundwater systems.

The most recent zinc recordings are consistent with baseline water quality data, see Table 6.

Arsenic levels within groundwater are below the guideline level (0.05 mg/L) for the protection of aquatic ecosystems. Surface waters of both the Runoff Dam (0.1 mg/L) and Return Water Pond (0.3 mg/L) recorded levels of arsenic above the guideline levels on the 28/08/1999. The arsenic concentrations are low however, and little impact would be expected.

The most recent lead recordings are consistent with baseline water quality data, see Table 6.

Aluminium concentrations recorded from groundwater samples do not exceed guideline water quality levels. ANZECC guideline levels for the protection of aquatic systems are <0.005 mg/L if pH ≤ 6.5, or 0.1 mg/L if pH > 6.5. The latter applies to the tailings groundwater and surface water.

An average of <0.05 mg/L aluminium was recorded in the most recent water monitoring. Surface water samples from the tailings return water pond and runoff dam have recorded aluminium concentrations <0.1 mg/L.

Cadmium concentrations in TD5 (0.003 mg/L) and TD6 (0.006 mg/L) slightly exceed ANZECC criteria (0.002 mg/L) for the protection of aquatic systems. However, cadmium concentrations in surface waters from the tailings are <0.005 mg/L. This would suggest that the source of any detectable cadmium is from natural ground.

Chromium concentrations within groundwater and surface waters of the tailings average <0.01 mg/L and are within guideline criteria (0.01 mg/L) for the protection of aquatic ecosystems.

Nickel concentrations within groundwater and surface waters of the tailings average <0.02 mg/L and are within guideline criteria (0.150 mg/L) for the protection of aquatic ecosystems.

Cobalt concentrations within groundwater range from less than 0.01 mg/L to 0.8 mg/L. Concentrations within surface water samples ranged from 0.2 mg/L in the runoff dam to 0.98 mg/L in the return water pond. The Canadian guideline level, taken from Sittig (n.d), for cobalt concentration in water for livestock is 1 mg/L. All surface and ground waters have cobalt concentrations within the recommended guideline value.

Manganese concentrations within groundwater range from 0.02 mg/L to 1.93 mg/L. Concentrations within surface waters are typically less than 0.1 mg/L. Sittig (n.d) lists the Canadian guideline value of 0.2 mg/L manganese for agricultural waters. As such monitoring indicates that water within TD3 does not meet the guideline value.

Vanadium concentrations of less than 0.01 mg/L were recorded for all ground and surface water samples. Sittig (n.d) lists the Canadian guideline value of 0.2 mg/L vanadium for fisheries water.

Barium concentrations, ranging from less than 0.1 mg/L to 0.2 mg/L, recorded for ground and surface water samples are within the Commonwealth of Independent States, listed in Sittig (n.d), guideline value of 0.2 mg/L for fisheries water.

Silicon concentrations ranged from 5.7 mg/L to 14.7 mg/L for ground and surface water samples. The author found no relevant criteria for silicon concentration in groundwater.

Strontium concentrations from 0.63 mg/L to 6.35 mg/L recorded for ground and surface water samples are within the Sittig (n.d) guideline value of 18 mg/L for domestic drinking water.

4.1.7.4 Cyanide

Free Cyanide (FCN), Total Cyanide (TCN), and Weak Acid Dissociable Cyanide (WADCN) are recorded in the bi-annual groundwater and surface water monitoring. FCN is the sum of molecular hydrogen cyanide (HCN) and the cyanide ion. TCN is the total mass of the cyanide ion contained within the solid or liquid being considered. WADCN is a measurement of complexes formed between cyanide and metal ions, excluding iron and copper, that are readily dissociated in water by weak acids eg the cadmium-cyanide complex $[\text{Cd}(\text{CN}_4)]^{2-}$. The difference between TCN and WADCN values is taken as being the concentration of the stable iron cyanide complex.

FCN within water monitoring boreholes is constantly recorded at <0.005 mg/L. One anomalous result, 0.01 mg/L, in TD5 was recorded on the 28/08/1999. Based on historical data, it is expected that the result was due to analysis or sampling error. In general the water monitoring results for FCN are within guideline levels.

Traces of TCN have been recorded in monitoring bores TD2 (0.033 mg/L) and TD5 (0.021 mg/L) during recent sampling. Historically these bores have recorded TCN levels <0.005 mg/L. In the case of TD2 it is expected that cyanide bearing (0.075 mg/L, 28/08/1999) water held within the tailings runoff dam, which TD2 is located downstream of, has resulted in an increase in TD2 TCN levels. The runoff dam had not previously held cyanide bearing water.

TCN levels in TD2 are expected to decline over time as the residual cyanide within the runoff dam water body is decayed by sunlight. The decay process is indicated by the decline in cyanide concentration in runoff dam water from 0.14 mg/L to 0.009 mg/L over the period from 03/07/1999 to 15/06/2000.

TD5 has historically recorded TCN levels ranging from <0.005 mg/L to 0.1 mg/L. Recent monitoring indicates a stable level of 0.021 mg/L TCN within the bore.

A one off sample, taken on the 3/07/1999, of seepage from Compartment A of the tailings facility recorded a TCN concentration of 0.035 mg/L. Further tests have not been possible as the seepage has abated. The TCN concentration exceeds guideline levels but is seen as a minor risk to the environment due to the small volume of seepage and the fact the seepage reports to the tailings runoff dam, and the water quality within this dam is in any case of acceptable quality.

All TCN concentrations recorded above ANZECC criteria are offset by very low WADCN concentrations ie the cyanide is present as the stable iron cyanide compound and poses little risk to the environment. Any toxicity of iron cyanide is related to the free cyanide formed through chemical or phytolytic dissociation and not the complex itself, Mudder (1997). Iron cyanide compounds are not readily dissociated under the ambient temperatures and near neutral pH of the groundwater monitored.

WADCN levels have declined rapidly at all sampling locations since the cessation of tailings operations. WADCN concentrations at all monitoring sites are currently <0.005 mg/L.

4.1.7.5 Major Cations and Anions

In general calcium, magnesium and chlorine concentrations recorded in groundwater are comparable with baseline water quality levels. An exception is TD6 which recorded highly elevated (11,700 mg/L) levels of chlorine.

Sodium and potassium levels recorded appear elevated when compared to the baseline water quality. Again it is TD6 that records the highest concentrations for these ions.

Sulphate concentrations (1370 mg/L) for the TD6 monitoring bore exceed the ANZECC criteria for livestock watering (1000 mg/L). The levels of sulphate recorded in TD6 however are not excessive and pose little threat to the health of livestock. The high level of sulphates (4,430 mg/L) recorded for the RWP are now inconsequential as the RWP has been backfilled and no longer ponds water.

Nitrate-N is below ANZECC criteria for livestock within the tailings groundwater, but above the criteria in the runoff dam and return water pond surface waters. The runoff dam and return water pond recorded nitrate-N levels of 56.3 mg/L and 88.1 mg/L respectively. This compares with the ANZECC criteria level for cattle of 40 mg/L. Surface waters will continue to be monitored for an expected decline in nitrate-N values.

4.1.8 Vegetation

Metal analysis results from vegetation growing on Compartments A and B, and natural soils are shown in Table 7.

The majority of metal concentrations are comparable between samples and species taken from the three areas. An exception is manganese which recorded higher concentrations in vegetation growing on the tailings than vegetation growing on natural soils. Buffel grass growing on Compartment A and Compartment B of the tailings contained 200 mg/kg and 133 mg/kg

manganese respectively. This compares with background levels of 46 mg/kg manganese recorded in buffel grass growing in natural soil.

Rhodes grass growing on Compartment A and Compartment B of the tailings contained 940 mg/kg and 431 mg/kg manganese respectively. This compares with background levels of 94 mg/kg manganese recorded in rhodes grass growing in natural soil.

Molybdenum concentrations in Compartment A buffel grass (1 mg/kg) and rhodes grass (2 mg/kg) have the potential to interact with copper, once ingested by livestock, and pull copper out of the livestock's system (DPI, pers. comm.). Theoretically this could potentially lead to cases of copper deficiency should the stock only feed on grass growing on Compartment A. In reality it is very unlikely that stock would solely graze on Compartment A grasses and the molybdenum levels within the feed as a whole would be within acceptable levels.

4.1.9 Depth pH/Conductivity/Salinity Properties

The depth pH, conductivity and salinity properties for samples collected from Compartment A are shown in Table 8, Table 9 and Table 10. The Compartment A properties, excluding pH for Compartment B sulphidic material, are assumed to be similar for material held within Compartment B of the tailings.

The pH of the tailings ranged from 6.6 to 9.14 remaining constant with depth. Based on this pH range the tailings can be termed very slightly acidic to strongly alkaline. The pH range has a number of effects on the ability of plant nutrients.

Iron, copper, zinc and aluminium are not readily available to plants in the 6.6 to 9.14 pH range. The availability of each of these metals decreases as the pH rises. Manganese, molybdenum and boron are readily available within the 6.6 to 9.14 pH range, explaining the high concentration of these metals found in the grasses growing on the tailings.

Calcium, sulphur, potassium and phosphorus are readily available in the 6.6 to 9.14 pH range. Nitrogen is available around a neutral pH and becomes less available as the pH increases.

Conductivity and salinity properties of the tailings indicate that the tailings are both saline, with EC greater than 2-4 dS/m, ESP less than 15 and pH less than 8.2, and sodic, with EC less than 2-4 dS/m, ESP greater than 15 and pH greater than 8.2. The major products under these conditions are sodium, chlorine, sulphate, carbonate and hydrocarbonate, see Section 4.1.10.

The major constraints that these conditions impose of plant growth are water deficiency, toxicity from sodium and chlorine, nutrient imbalances and adverse effects on soil structure, aeration and infiltration.

EC_e values for the tailings samples ranged from 1.4 dS/m to 11.2 dS/m (average 5.19 dS/m). These salinity values are below those at which plant establishment and growth are halted. Rhodes grass may show some signs of decline at EC_e values greater than 7, but will not cease growing until levels of 39 dS/m have been reached.

4.1.10 Nutrient Properties

The nutrient properties for the selected samples are shown in Table 10. In general, the nutrients are present in concentrations that will not significantly affect plant establishment and growth.

Nitrogen (nitrate) within the tailings samples has an average concentration of 157 mg/kg. The high concentration of nitrogen is due to the break down of the sodium cyanide compound present in the tailings stream. The level of nitrogen will increase the level of growth in vegetation growing on the tailings dam.

Zinc concentrations and percentage organic matter are low for plant establishment and growth. The application of additional zinc to the tailings material is not thought to be necessary.

The average recorded level of exchangeable sodium in the tailings samples was 9.17 meq/100g. It is recommended that soils with exchangeable sodium levels greater than 3 meq/100g be ameliorated with either gypsum or dolomite. If amelioration was to be undertaken dolomite application would be preferable as gypsum would only add to the high concentration of calcium ions in the tailings material.

Exchangeable potassium, calcium and magnesium levels in the tailings are within limits of plant tolerance.

Table 3 – Compartment A Characterisation: Metals (mg/kg) and Total Sulphur (%).

Element	Copper	Lead	Zinc	Silver	Arsenic	Bismuth	Cadmium	Cobalt	Manganese	Molybdenum	Nickel	Antimony	Chromium	Total Sulphur
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%
Sample No.														
DME (1995)	60	300	200	20	20	-	3	50	500	4	60	20	50	
A1	14	8	10	1	124	<5	<5	<5	50	15	<5	42	78	0.12
A2	21	10	9	<1	88	<5	<5	<5	34	<5	<5	21	56	0.08
A3	15	13	13	<1	105	<5	<5	<5	60	<5	7	23	53	0.06
A4	12	9	8	<1	99	<5	<5	<5	46	13	<5	38	52	0.07
A5	20	16	12	<1	167	<5	<5	<5	36	<5	6	26	53	0.25
A6	25	15	20	<1	125	<5	<5	<5	105	<5	7	22	36	0.51
A7	12	8	8	1	95	<5	<5	<5	45	12	<5	38	107	0.09
A8	12	24	15	<1	75	<5	<5	<5	75	<5	<5	18	33	0.17
A9	18	13	11	<1	128	<5	<5	<5	37	<5	6	23	44	0.12
A10	14	10	13	<1	76	<5	<5	<5	89	<5	<5	18	49	0.18
A11	17	12	15	<1	111	<5	<5	<5	142	<5	8	20	74	0.2
A12	14	9	15	<1	84	<5	<5	<5	114	<5	5	19	55	0.21
A13	17	12	16	<1	82	<5	<5	<5	88	<5	6	20	46	0.3
A14	13	15	15	<1	156	<5	<5	<5	38	<5	6	22	38	0.2
A15	17	17	18	<1	109	<5	<5	<5	88	<5	6	25	57	0.15
A16	15	15	15	<1	162	<5	<5	<5	41	<5	6	28	38	0.12
A17	19	10	11	<1	124	<5	<5	<5	30	<5	5	23	57	0.15
A18	18	18	19	<1	130	<5	<5	<5	68	<5	6	21	39	0.11
A19	24	15	8	<1	83	<5	<5	<5	33	<5	5	20	82	0.09

Table 4 – Compartment B Characterisation: Metals (mg/kg) and Total Sulphur (%).

Element Unit	Copper mg/kg	Lead mg/kg	Zinc mg/kg	Silver mg/kg	Arsenic mg/kg	Bismuth mg/kg	Cadmium mg/kg	Cobalt mg/kg	Manganese mg/kg	Molybdenum mg/kg	Nickel mg/kg	Antimony mg/kg	Chromium mg/kg	Total Sulphur %
Sample No.														
DME (1995)	50	300	200	20	20	-	3	50	500	4	60	20	50	
B1	13	10	36	<1	228	<1	<1	8	37	<1	10	<1	11	0.80
B2	9	6	8	<1	88	<1	<1	3	26	<1	4	<1	11	0.34
B3	7	6	5	<1	91	<1	<1	3	12	2	3	<1	10	0.29
B4	13	8	6	<1	88	<1	<1	4	18	2	5	<1	14	0.33
B5	13	6	7	<1	66	<1	<1	3	35	<1	5	<1	12	0.26
B6	9	10	12	<1	86	<1	<1	3	36	<1	5	<1	16	0.23
B7	12	7	8	<1	121	<1	<1	3	28	3	5	<1	11	0.27
B8	11	8	11	<1	158	<1	<1	3	31	4	7	<1	16	0.32
B9	13	8	22	<1	138	<1	<1	6	52	2	8	<1	13	0.52
B10	7	7	3	<1	56	<1	<1	2	14	<1	4	<1	12	0.22
B11	6	7	6	<1	59	<1	<1	2	22	<1	4	<1	12	0.10
B12	9	5	8	<1	154	<1	<1	4	25	2	5	<1	10	0.45
B13	10	6	9	<1	122	<1	<1	3	31	2	6	<1	22	0.21
B14	11	10	53	<1	133	<1	<1	2	44	<1	7	<1	20	0.20
B15	8	4	8	<1	107	<1	<1	2	24	<1	5	<1	15	0.16
B16	12	10	14	<1	191	<1	<1	4	32	2	8	<1	18	0.24
B17	12	7	13	<1	178	<1	<1	4	33	4	8	<1	19	0.39
B18	8	5	10	<1	147	<1	<1	6	23	2	6	<1	15	0.45
B19	10	8	9	<1	146	<1	<1	2	31	2	6	<1	17	0.18
B20	12	10	10	<1	172	<1	<1	3	36	2	7	<1	20	0.23
B21	7	16	19	<1	163	<1	<1	3	6	4	5	<1	5	0.64
B22	20	7	20	<1	207	<1	<1	5	48	2	9	<1	13	0.26
B23	24	9	14	<1	170	<1	<1	5	31	2	10	<1	17	0.45
B24	14	11	11	<1	182	<1	<1	6	33	3	8	<1	17	0.25
B25	10	6	17	<1	184	<1	<1	4	33	<1	7	<1	16	0.33
B26	8	6	7	<1	129	<1	<1	6	28	2	6	<1	15	0.24
B27	10	12	18	<1	166	<1	<1	5	31	6	7	<1	16	0.35
B28	10	7	12	<1	153	<1	<1	4	27	<1	6	<1	14	0.27

Table 5 - Water Monitoring Results 17/10/1997 – 05/12/1998, Yandan Tailings Facility

Date	ID	pH	Cond.	TDS	Cu	Fe	Zn	As	Pb	FCN	TCN	WADCN	SAR	Ca	Mg	Na	K	CaCO3	SO4	Cl	AL	B	Cd	Co	Cr	Mn	Mo	Ni	V	Be	Li	Se	U	Hg
10/17/97	TD3									<.005	<.005	<.005																						
9/30/97	TD1	7.39	1400	790	<.01	0.1	0.01	0.01	0.026	<.005	<.005																							
	TD2	7.64	2000	1110	<.01	0.1	0.01	0.01	0.016	<.005	<.005																							
	TD3	7.57	5970	3620	<.01	0.1	0.01	0.01	0.01	<.005	<.005																							
	TD4	7.48	25000	15600	<.1	0.1	0.1	0.01	0.14	<.005	<.005																							
	TD5	7.47	8680	5100	<.1	0.1	0.1	0.01	0.04	<.005	<.005																							
	TD6	7.72	40000	24200	<.1	0.1	0.1	0.01	0.02	<.005	<.005																							
	TD7	7.08	7630	4780	<.1	0.1	0.1	0.01	0.02	<.005	0.015																							
8/4/97	TD1	7.61		752	<.01	0.1	0.05	0.002	0.007	0.005	0.01		7.7	752	33	235	<.1	408	42	157	<.1	0.4	<.005	<.01	<.01	0.01	<.01	<.01	<.01	<.001	0.035	<.01	0.007	<.0005
	TD2	7.71		1140	<.01	0.1	0.04	0.002	0.08	<.005	<.005		10.3	1140	42	372	6	518	102	299	0.4	0.6	<.005	<.01	<.01	0.18	0.02	<.01	<.01	<.001	0.09	<.01	0.004	<.0005
	TD3	7.53		3670	<.01	0.1	0.05	0.009	0.008	<.005	<.005		18.6	3670	229	972	13	1090	354	1210	0.1	2	<.005	<.01	0.02	0.47	0.02	<.01	<.01	<.001	0.151	<.01	0.023	<.0005
	TD4	7.28		15200	<.01	0.1	0.1	0.002	0.161	<.005	<.005		31.3	15200	867	4350	30	700	901	8220	<.1	<.2	<.05	<.1	<.1	0.2	<.1	<.1	<.1	<.001	0.148	<.01	0.023	<.0005
	TD5	7.4		5230	<.01	0.7	0.3	0.001	0.021	<.005	<.005		24.4	5230	25	1660	37	1250	344	2100	2	<.2	<.05	<.1	<.1	0.2	<.1	<.1	<.1	<.001	0.149	<.01	0.081	<.0005
	TD6	7.14		25300	<.01	0.1	0.1	0.001	0.075	<.005	<.005		77.1	25300	59	8710	103	926	1410	13400	<.2	<.2	<.05	<.1	<.1	0.2	<.1	<.1	<.1	<.001	0.376	<.01	0.071	<.0005
7/3/97	TD1	8.09	1460	748	<.1	0.1	0.1	0.001	0.021	<.005	<.005																							
	TD2	7.9	2230	1120	<.1	0.1	0.1	0.001	0.069	<.005	<.005																							
	TD3	7.84	6260	3590	<.1	0.1	0.1	0.006	0.032	<.005	<.005																							
	TD4	7.38	28000	16100	<.1	0.1	0.1	0.003	0.369	<.005	<.005																							
	TD5	7.73	10200	6020	<.1	0.1	0.1	0.001	0.86	<.005	<.005																							
	TD6	7.41	44000	25600	<.1	0.1	0.1	0.001	0.247	<.005	<.005																							
3/20/98	TD2	8.31									.005																							
	TD3	8.11		3740							<.005																							
	TD5	7.76		4690							<.005																							
	TD6	7.92		22000							<.005																							
	TD7										5.58	3.80																						
5/12/98	TD2	7.69		1330							.005																							
	TD3	8.04	3680								<.005																							
	TD3	7.68		4790							.015																							
	TD6	7.59		23400							<.005																							
	TD7										10.4	5.62																						

Table 5(cont) - Water Monitoring Results 07/07/1998 – 28/08/99, Yandan Tailings Facility

Date	ID	pH	Cond.	TDS	Cu	Fe	Zn	As	Pb	FCN	TCN	WADCN	S	Ca	Mg	Na	K	CaCO3	SO4	Cl	N	AL	B	Cd	Co	Cr	Mn	Mo	Ni	V	Ba	Si	Se	Sr
7/7/98	TD2	7.93		1430							.005																							
	TD3	8.1		3760							<0.005																							
	TD5	8.25		5180							0.10																							
	TD6	7.67		22700							<0.005																							
	RWP										10.4	4.94																						
9/14/99	TD2	7.99		1440							<0.005																							
	TD3	8.43		3880							<0.005																							
	TD5	7.92		6470							<0.005																							
	TD6	7.75		23300							<0.005																							
	RWP										17.5	5.61																						
11/24/98	TD2	7.83		1740							<0.005																							
	TD3	8.3		4500							<0.005																							
	TD5	8.31		6680							0.01																							
	TD6	7.88		23000							<0.005																							
	RWP										42.06	7.05																						
2/17/99	TD2	7.72		1540							<0.005																							
	TD3	6.66		140							<0.005																							
	TD5	8.38	6760								0.005																							
	TD6	7.53		21800							<0.005																							
7/3/99	TD2	7.88		1580	.02	1.6		0.005	.05	<0.005	.01	<0.005							<200													.01		
	TD3	7.79		3800	.01	5.2		0.012	.039	<0.005	0.02	<0.005							<400													<0.01		
	TD5	8.21		6450	<.1	3		0.01	.3	<0.005	0.06	0.01							<800													<.1		
	TD6	7.77		21700	.2	8		0.02	.1	<0.005	0.005	<0.005							>1600													<.1		
	R/O Dam	7.99		3450	.04	0.1		0.013	<.001	<0.005	.14	.01							<1600													.07		
	RWP	7.93		5790	<.1	1		0.02	<.01	<0.005	.42	.025							>1600													.1		
	Seepage	7.13		3640	<0.01	0.4		0.02	<.01	<0.005	.035	.01							<200													.1		
8/28/99	TD2	8.33		1650	0.02	0.3	0.19	<0.1	0.07	<0.005	0.015	<0.005	53	54	79	414	4	427	158	563	1.18	0.1	0.3	<0.005	0.02	<0.01	0.02	0.01	<0.01	<0.01	<0.1	8.5		0.63
	TD3	8.29		4400	0.03	4.6	0.31	<0.1	0.02	<0.005	0.005	<0.005	155	61	248	1270	10	1020	459	1880	1.44	0.8	1.4	<0.005	<0.01	<0.01	1.93	<0.01	<0.01	<0.01	0.2	14.7		1.37
	TD5	8.45		6860	0.07	1.9	0.57	<0.1	0.34	0.01	0.05	0.01	190	22	290	2050	47	1130	555	2910	11.8	0.5	1	0.011	0.08	<0.01	0.12	<0.01	<0.01	<0.01	<0.1	9.5		1.33
	TD6	8.24		21400	0.11	0.8	1.55	<0.1	0.33	<0.005	0.01	<0.005	475	80	571	7290	115	918	1370	11700	0.8	0.2	1.7	0.018	<0.01	<0.01	0.08	<0.01	<0.01	<0.01	0.1	11		6.35
	R/O Dam	8.01		4640	0.03	<0.1	0.04	0.1	<0.01	<0.005	0.075	0.02	444	305	35	1210	128	84	1350	1470	56.3	<0.1	<0.2	<0.005	0.2	<0.01	0.04	0.17	0.04	<0.01	0.1	5.7		1.75
	RWP	7.96		13500	0.06	0.1	0.06	0.3	<0.01	<0.005	0.015	<0.005	1470	971	87	3260	368	134	4430	3670	88.1	0.1	0.4	<0.005	0.98	<0.01	0.1	0.55	0.04	<0.01	0.1	10		5.64

Table 5(cont) - Water Monitoring Results 29/11/99 – 16/01/00, Yandan Tailings Facility

Date	ID	pH	TDS	Cu	Fe	Zn	As	Pb	FCN	TCN	WADCN	Ca	Mg	Na	K	CaCO3	SO4	Cl	Al	B	Cd	Co	Cr	Mn	Mo	Ni	V	Ba	Si
11/29/99	TD2	8.05	1480	0.006	0.1	0.071	0.001	0.015	<0.005	0.02	0.005	53	80	404	4	<1	187	522	0.13	0.3	0.0014	0.03	<0.01	0.03	<0.01	<0.01	<0.01	<0.1	7.2
	TD3	8.15	4240	0.011	0.5	0.114	0.01	0.007	<0.005	<0.005	<0.005	59	280	1230	10	<1	480	1750	0.23	1.3	0.0016	<0.01	<0.01	0.34	<0.01	<0.01	<0.01	0.1	11.6
	TD5	8.25	6390	0.019	0.7	0.226	0.009	0.204	<0.005	0.04	0.015	21	285	1950	49	<1	595	2740	0.29	1	0.008	0.09	<0.01	0.12	<0.01	<0.01	<0.01	<0.1	7.3
	TD6	7.85	18.8g/L	0.015	0.3	0.208	0.001	0.061	<0.005	0.02	<0.005	68	495	6530	108	<1	1240	10.4g/L	0.16	1.3	0.0098	<0.01	<0.01	0.11	<0.01	<0.01	<0.01	<0.1	8
	RWP	8.23	5030	0.092	1.1	0.004	0.02	<0.001	0.47	1.7	0.575	413	25	1170	167	<1	1900	1330	0.11	<0.2	0.001	1.59	<0.01	0.02	0.3	0.05	<0.01	<0.1	0.8
	R/O Dam	7.96	3280	0.022	0.2	0.011	0.011	0.001	0.04	0.04	0.02	210	35	850	86	<1	1010	1050	0.23	<0.2	0.0006	0.05	<0.01	0.03	0.1	<0.01	<0.01	0.1	1.8
10/1/00	TD2	8.25	1700	0.004	<0.1	0.038	0.002	0.002	<0.005	0.02	<0.005	52	82	423	4	-	-	-	<0.01	0.3	0.0005	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	7.6
	TD3	7.8	4600	0.004	<0.1	0.055	0.011	<0.001	<0.005	<0.005	<0.005	57	271	1180	9	-	-	-	<0.01	1.3	<0.0002	<0.01	<0.01	0.24	<0.01	<0.01	<0.01	0.09	11.9
	TD5	8.3	6490	0.007	<0.1	0.047	0.009	0.035	<0.005	0.04	0.005	21	290	1940	47	-	-	-	<0.01	1	0.0037	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	7.8
	TD6	8.18	21 g/L	0.01	<0.1	0.054	0.017	0.002	<0.005	<0.005	<0.005	50	561	6820	110	-	-	-	<0.01	1.5	0.0036	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	9.4
	R/O Dam	7.5	2490	0.006	<0.1	0.007	0.005	<0.001	<0.005	0.14	0.05	163	23	571	62	-	-	-	0.03	<0.2	0.0005	0.26	<0.01	0.16	0.06	<0.01	<0.01	0.1	0.7
	RWP	4.6	2280	0.004	0.1	0.117	0.003	<0.001	<0.005	0.363	0.185	150	22	514	60	-	-	-	6.53	<0.2	0.0019	0.5	0.01	1.21	0.03	0.12	<0.01	0.05	1.6
06/15/00	TD2	8.56	2760	0.012	<0.01	0.007	0.002	<0.001	<0.005	0.033	<0.005	118	163	505	7	-	-	-	<0.05	0.3	0.002	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	9.1
	TD3	9.02	4280	0.016	<0.01	0.008	0.008	<0.001	<0.005	<0.005	<0.005	59	259	1120	12	-	-	-	<0.05	1.4	<0.001	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.1	13.6
	TD5	9.09	6510	0.013	0.02	0.014	0.004	0.035	<0.005	0.021	<0.005	22	297	1920	53	-	-	-	<0.05	1.1	0.003	0.09	0.03	<0.01	<0.01	<0.01	<0.01	<0.1	8.5
	TD6	8.87	21g/L	0.013	<0.01	0.027	0.001	0.001	<0.005	<0.005	<0.005	84	596	6860	134	-	-	-	<0.05	1.7	0.006	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	0.1	10.7
	R/O Dam	7.82	1560	0.005	<0.01	0.006	0.002	<0.001	<0.005	0.009	<0.005	124	18	346	39	-	-	-	<0.05	<0.2	<0.001	0.04	<0.01	<0.01	0.02	<0.01	<0.01	<0.1	0.4

Table 6 - Baseline Groundwater Quality – Yandan Gold Mine

Location	Date	pH Value	TDS (Est)	Copper (mg/L)	Iron (mg/L)	Zinc (mg/L)	Arsenic (mg/L)	Lead (mg/L)
Bore 1	01-Apr-88	7	4730	0.1	5	0.1	-	-
P22	01-Apr-88	6.9	6420	0.1	14	0.4	-	-
P24	01-Apr-88	6.9	4020	0.2	33	0.4	-	-
P146a	01-Apr-88	6.9	3920	0.1	23	0.8	<0.005	0.04
P146b	01-Apr-88	6.7	4400	0.1	13	0.1	<0.005	0.06
	Average	6.88	4698	0.12	17.6	0.36	0	0.02
Location	Date	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Sulphate (mg/L)	Chloride (mg/L)	Nitrate (mg/L)
Bore 1	01-Apr-88	160	420	870	21	480	2000	<0.1
P22	01-Apr-88	160	380	1300	22	350	3200	<0.1
P24	01-Apr-88	95	280	900	15	320	1900	0.3
P146a	01-Apr-88	340	320	1300	34	560	3000	<0.01
P146b	01-Apr-88	270	220	930	35	440	2200	<0.01
	Average	205	324	1060	25.4	430	2460	0.06

4.2 Physical Properties

4.2.1 *In situ* Densities and Moisture Contents – Compartment A

The *insitu* densities of individual samples and overall average of the samples are listed in Table 11. Moisture contents of the samples and an overall average of the samples are also listed. These parameters are assumed to be similar to those of tailings held within compartment B of the tailings facility.

The average *insitu* bulk density of the samples was 1.38 t/m³ with a standard deviation of 0.12 t/m³. The average *in situ* moisture content of all samples tested was 13.48 % with a standard deviation of 5.91 %.

The sampled material showed little correlation between moisture content and *in situ* density. Samples of higher moisture content recorded similar levels of *insitu* density to those with less moisture content.

4.2.2 *In situ* Permeabilities – Compartment B Oxide Capping

Permeability and compaction testing of Compartment B oxide capping was undertaken by Ullman and Nolan Geotechnical Engineers in August 1999. The complete report is presented in Appendix C. The findings of the report are summarised as follows:

- Capping thicknesses varied from 120mm to 520mm,
- Capping material has an *insitu* permeability in the range of 1.6×10^{-6} to 9.6×10^{-7} .
- The high moisture content of capping material (19.5% to 34%) can be expected to significantly reduce oxygen diffusion through the material,

- Shrinkage cracks in the capping layer adversely effect the capacity of the seal to reduce oxygen diffusion.

Although shrinkage cracks are evident in some areas of the capping the reworking of these areas is not thought to be warranted or practical. The establishment of a vegetative groundcover over the tailings surface will aid in the consolidation of the capping material.

Table 7 - Metal Analysis of Grass Species Growing on the Yandan Tailings Facility

Element	Copper	Lead	Zinc	Silver	Arsenic	Cadmium	Cobalt	Manganese	Molybdenum	Nickel	Antimony	Chromium
Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Sample No.												
Compartment A												
Buffel Grass	5	<1.0	82	<0.5	<1.0	<1.0	<1.0	200	1	3	2	6
Rhodes Grass	9	<1.0	51	<0.5	<1.0	<1.0	1	940	2	1	1	6
Compartment B												
Buffel Grass	3	2	26.25	<0.5	<0.5	<0.5	<0.5	133	<0.5	<0.5	<0.5	2.5
Rhodes Grass	5.5	<0.5	29	<0.5	9.5	<0.5	<0.5	431	<0.5	1	<0.5	5.5
Control												
Buffel Grass	2.5	3.5	19.5	<0.5	<0.5	<0.5	<0.5	46	<0.5	1	<0.5	4.5
Rhodes Grass	3.5	<0.5	48.5	<0.5	<0.5	<0.5	<0.5	94	<0.5	1	<0.5	3.5

Table 8 - Compartment A – Depth Conductivity/Salinity/pH Results

Sample	0 cm				30 cm				Misc Depths					Misc Depths				
	Conduc uS	Salinity ppm	pH	Temp °C	Conduc uS	Salinity ppm	pH	Temp °C		Conduc uS	Salinity ppm	pH	Temp °C		Conduc uS	Salinity ppm	pH	Temp °C
A1	7810	4140	8.82	22.3	705	337.00	8.76	22.7	60 cm	1068	518	8.31	22.7	74 cm	636.00	303	8.62	22.7
A2	10690	5750	8.4	25.5	493	231	9.14	25.5	60 cm	1673	829	8.19	26	79 cm	545.00	257	8.84	25.8
A3	11140	5980	8.76	29.6	577	273	8.76	28.7	60 cm	663	315	8.72	28.6	79 cm	694	331	8.16	28.6
A4	16010	8760	8.39	25.7	640	304	8.99	25.2	60 cm	418	195	8.75	25.5	70 cm	558	263	8.62	25.5
A5	10730	5730	7.38	24.3	508	236	7.87	24	60 cm	704	334	8.32	24.1	72 cm	604	285	8.24	24.3
A6	3400	1730	7.56	27.1	201	90.3	6.77	27.5	60 cm		152	8.59	27.5					
A7	2025	1005	7.17	33.6	494	231	8.42	32.6	60 cm	242.2	109.5	7.68	33	73 ccm	671	317	7.21	32.5
A8	6620	3460	7.61	32.6	1091	527	8.33	32.6	58 cm	802	382	8.11	32.7					
A9	5810	3020	8.07	25.6	725	344	8.1	25.7	51 cm	642	303	8	25.9					
A10	5980	3110	7.02	29.6	605	285	8.5	29.3	60 cm	647	305	8.4	29.4	81 cm	830	396	7.56	29.4
A10*	4400	2260	8.01	29.8	610	287	7.74	29.6	65 cm	657	310	8.44	29.5					
A11	5590	2900	6.16	30.2	738	351	8.03	30.2	59 cm	559	262	7.39	30.3					
A12	3560	1810	7.22	31.6	746	354	7.8	30.5	62 cm	319	146	6.6	30.3					
A13	10610	5660	7.04	26	1089	526	7.99	25.5	64 cm	770	367	7.92	25.5					
A15	12930	6950	7.23	24.1	657	307	8.19	24.3	60 cm	632	298	8.27	24.5	74 cm	361	166	7.16	24.7
A15*	5130		6.67	31.1	713	338	8.35	29.6	42 cm	471	219	7.09	29.6					
A16	8020	4230	6.98	29.7	596	281	8.59	29.6	50 cm	508	237	8.32	29.2					
A17	2960	1490	8.29	27.6	804	384	6.67	27.6	60 cm	475	222	8.25	27.6	70 cm	1417	695	8.04	27.7
A18	7890	4180	8.42	22.9	747	357	8.84	22.7	60 cm	241.4	109.9	8.97	23.1					
A19	8660	4590	8.17	30	564	265	7.39	29.9	65 cm	805	385	7.36	29.7					
A20	3000	1530	7.26	25.2	503	236	8.55	24.5	50 cm	517	244	8.36	24.6					
A21																		
A22	11680	6300	8.01	26	718	343	8.56	25.5	60 cm	560	264	8.22	25.4	82cm	825	396	8.02	25.5
A23	9600	5100	8.23	33	746	354	8.41	31.6	60 cm	708	336	8.86	31.6	82 cm	997	480	7.88	31.4
A24	2380	1198	8.33	30	358	167	8.67	28.9	60 cm	620	295	8.5	28.8					
A25	12050	6470	7.64	27.6	370	171	7.05	27.1	60 cm	296	136	7.71	26.9	78 cm	232.7	105.1	6.9	27.2
A26	5370	2780	7.79	32.3	557	261	8.48	31.6	60 cm	567	266	8.44	32.3	81 cm	806	384	8.32	32.3

Table 9 – EC_e Compartment A

Sample	EC _e					
	0 cm	30 cm	Misc		Misc	
A1	5.467	0.4935	60 cm	0.7476	74 cm	0.4452
A2	7.483	0.3451	60 cm	1.1711	79 cm	0.3815
A3	7.798	0.4039	60 cm	0.4641	79 cm	0.4858
A4	11.207	0.448	60 cm	0.2926	70 cm	0.3906
A5	7.511	0.3556	60 cm	0.4928	72 cm	0.4228
A6	2.38	0.1407	60 cm	0		
A7	1.4175	0.3458	60 cm	0.1695	73 ccm	0.4697
A8	4.634	0.7637	58 cm	0.5614		
A9	4.067	0.5075	51 cm	0.4494		
A10	4.186	0.4235	60 cm	0.4529	81 cm	0.581
A10*	3.08	0.427	65 cm	0.4599		
A11	3.913	0.5166	59 cm	0.3913		
A12	2.492	0.5222	62 cm	0.2233		
A13	7.427	0.7623	64 cm	0.539		
A15	9.051	0.4599	60 cm	0.4424	74 cm	0.2527
A15*	3.591	0.4991	42 cm	0.3297		
A16	5.614	0.4172	50 cm	0.3556		
A17	2.072	0.5628	60 cm	0.3325	70 cm	0.9919
A18	5.523	0.5229	60 cm	0.169		
A19	6.062	0.3948		0.5635		
A20	2.1	0.3521	50 cm	0.3619		
A21	0	0		0		0
A22	8.176	0.5026	60 cm	0.392	82cm	0.5775
A23	6.72	0.5222	60 cm	0.4956	82 cm	0.6979
A24	1.666	0.2506	60 cm	0.434		
A25	8.435	0.259	60 cm	0.2072	78 cm	0.1629
A26	3.759	0.3899	60 cm	0.3969	81 cm	0.5642

Table 10 – Yandan Tailings Characterisation, Nutrient Properties

Analysis	Unit	101	103	105	107	109	111	113	115	117	119	Average	Standard Deviation
pH	mg/kg	8.8	8.9	8.3	9	8.8	8.8	8.3	8.5	8.4	8.9	8.67	0.27
Nitrogen (nitrate)	mg/kg	240	2	180	250	190	90	220	110	65	230	157.70	85.40
Phosphorus	mg/kg	10	9	9	5	12	12	12	15	7	8	9.90	2.92
Potassium	mg/kg	400	130	420	400	470	210	420	380	220	520	357.00	126.23
Sulphur	mg/kg	600	57	1300	320	340	220	1000	600	510	500	544.70	368.60
Calcium	mg/kg	730	1400	2090	440	530	710	1700	1200	640	620	1006.00	562.06
Magnesium	mg/kg	45	100	40	20	20	50	85	50	20	15	44.50	28.81
Copper	mg/kg	0.5	0.4	1.9	0.3	1.1	0.6	1.2	1.6	2.2	3.4	1.32	0.98
Zinc	mg/kg	0.2	0.1	0.2	0.1	0.3	0.2	0.5	0.5	0.2	0.2	0.25	0.14
Manganese	mg/kg	2	0.6	1.2	1	0.5	1.2	1.4	8.1	2.4	0.6	1.90	2.26
Iron	mg/kg	11	4.8	15	5.9	14	8.5	16	44	17	10	14.62	11.13
Boron	mg/kg	0.2	0.2	0.4	0.1	0.3	0.2	0.5	0.3	0.2	0.2	0.26	0.12
Organic matter	%	1.2	1.2	1.2	0.9	0.5	0.4	0.5	0.9	0.8	1.2	0.88	0.32
Conductivity	dS/m	3.08	0.24	3.54	2.47	3.08	1.37	3.61	2.32	1.56	3.74	2.50	1.15
Sodium	mg/kg	2900	190	2500	2300	2800	1200	2800	2100	1100	3200	2109.00	971.10
Chloride	mg/kg	3100	120	3000	2500	4100	1300	3500	2400	1200	4700	2592.00	1403.56
Cation Exchange	meq/100g	17.7	9	22.3	13.4	16.2	9.7	22.5	16.5	9.7	18.5	15.55	4.99
Exchange sodium	meq/100g	12.6 (71.4%)	0.8 (9.2%)	10.9 (48.8%)	10 (74.7%)	12.2 (75.2%)	5.2 (53.7%)	12.2 (54.2%)	9.1 (53.3%)	4.8 (49.2%)	13.9 (75.3%)	9.17	-
Exchange potassium	meq/100g	1.0 (5.8%)	0.3 (3.7%)	1.1 (4.8%)	1.0 (7.7%)	1.2 (7.4%)	0.5 (5.5%)	1.1 (4.8%)	1.0 (5.9%)	0.6 (5.8%)	1.3 (7.2%)	0.91	-
Exchange calcium	meq/100g	3.7 (20.7%)	7.0 (77.8%)	10.0 (44.9%)	2.2 (16.4%)	2.7 (16.4%)	3.6 (36.5%)	8.5 (37.8%)	6.0 (36.3%)	4.2 (43.2%)	3.1 (16.8%)	5.1	-
Exchange magnesium	meq/100g	0.4 (2.1%)	0.8 (9.3%)	0.3 (1.5%)	0.2 (1.2%)	0.2 (1.0%)	0.4 (4.3%)	0.7 (3.2%)	0.4 (2.5%)	0.2 (1.7%)	0.1 (0.7%)	0.37	-
Ca/Mg ratio		9.7	8.4	30	13.2	15.9	8.5	12	14.4	25.2	24.8	16.21	7.73

Table 11 - Bulk Density and % Moisture Tailings Material

Sample Site	Weight before drying (g)	Weight after drying (g)	Volume (cm ³)	Bulk Density (g/cm ³)	% Moisture
A1	400.9	382.7	304.60	1.26	4.54
A2	194.6	172.0	116.80	1.47	11.61
A3	152.0	136.1	114.51	1.19	10.46
A4	364.0	324.5	229.02	1.42	10.85
A5	400.3	327.1	229.02	1.43	18.29
A6	317.4	292.0	229.02	1.27	8.00
A7	390.8	330.4	229.02	1.44	15.46
A8	386.5	304.9	229.02	1.33	21.11
A9	392.1	317.9	229.02	1.39	18.92
A10	391.1	322.0	229.02	1.41	17.67
A11	456.5	359.0	229.02	1.57	21.36
A12	245.4	238.5	190.09	1.25	2.81
A13	331.0	285.0	229.02	1.24	13.90
A14	407.5	338.2	229.02	1.48	17.01
A15	417.0	319.6	229.02	1.40	23.36
A16	374.4	296.9	229.02	1.30	20.70
A17	405.2	342.6	229.02	1.50	15.45
A18	455.1	363.7	229.02	1.59	20.08
A19	360.6	324.3	229.02	1.42	10.07
A20	323.2	284.6	229.02	1.24	11.94
A21	341.7	309.0	229.02	1.35	9.57
A22	411.0	374.7	229.02	1.64	8.83
A23	336.0	312.7	229.02	1.37	6.93
A24	355.4	304.1	229.02	1.33	14.43
A25	194.3	187.1	162.61	1.15	3.71
				AV = 1.38 SD=0.12	AV = 13.48 SD =5.91

4.3 Revegetation Trials

4.3.1 Trial A1

Tailings samples A1, A2 and A3 were used to characterise the substrate of the trial area. Analysis recorded elevated levels of arsenic, molybdenum, antimony and chromium in the samples. The average total sulphur percentage of the samples was 0.086%. pH of the samples averaged 8.66. The conductivity and salinity of the samples declined from surface to 300mm depth. Average surface conductivity recorded was 9880 μ S compared with an average conductivity of 1135 μ S at 600mm depth. Average surface salinity recorded was 2683 ppm compared with an average 233 ppm at 600 mm depth. Sample A3 recorded lower than average concentrations chloride, sodium, conductivity, iron potassium and nitrogen.

Revegetation monitoring results are shown in Table 12.

Table 12 - Revegetation Monitoring Results, Trial A1.

TREATMENT	DATE	REP	% COVER	SPECIES	DATE	REP	% COVER	SPECIES	DATE	REP	% COVER	SPECIES
	18/04/98				01/07/1998				31/10/99			
Tailings		1	0-2%	2		1	4%	2*,5		1	100%	1,2*
		2	4%	2		2	90%	1,2*,3,4		2	100%	2*
10cm Oxide		1	35%	3*,11		1	60%	1*,2,3,4,5,6,7,11		1	100%	1*,2,3,11, 14
		2	20%	3		2	60%	1,2,3*,5,6,7,8		2	100%	1*,2,3,8
10cm Oxide/10cm Soil		1	30%	3*,6		1	40%	1,2,3*,4,6		1	100%	1,3*,4
		2	25%	3		2	35%	1*,2,3*,4,6,7,8,9,10		2	100%	1*,2,3,4
10cm Soil		1	32%	3		1	45%	1,2,3*,4,6,7,8,9,11		1	90%	1,3*,4,14
		2	40%	2,3*,6		2	70%	1*,2,3,4,6,7		2	100%	1*,2,3,4
25cm Oxide/10cm Soil		1	30%	6		1	35%	1,3*,4,6,7,8,10,11		1	90%	1,3*,4,8
		2	25%	6		2	35%	1*,3*,4,6,7,8,9,10,11,12		2	100%	1*,3*,4,11
50cm Oxide/10cm Soil		1	5-8%	3*,6		1	10%	1,3*,6,7,9,10		1	80%	1,3*,8,11
		2	5-8%	3*,6		2	10%	1*,2,3*,4,5,6,8,9,10,11		2	100%	1,2,3*,4,9,10,11
50cm Oxide		1	70%	2,3*,11*		1	90%	1*,2,3,4,5,6,7,10,11,13		1	90%	1*,3,4,9,11
		2	45%	2,3*,6		2	60%	3*,4,6,7,9,10,11		2	80%	1,3*,4,7

SPECIES

COMMON NAME

No.

* Most Abundant

Pioneer Rhodes	1
Indian Couch	2
Buffel Grass	3
Panicum sp.	4
Eragrostis sp.	5
Paspalum sp.	6
Many Headed Wiregrass	7
Awnless Barnyard Grass	8
Potatoe Plant	9
Vine (purple)	10
Soft Rolly Polly	11
Vine (yellow)	12
Slender Chloris	13
Atriplex vesicaria	14

Percentage cover of vegetation has increased to 100% for the majority of treatments over the 18 months since the trial began. The exception is the 50cm oxide treatment that recorded an average of 85% cover at the end of 18 months.

Buffel, rhodes and couch grasses were the dominant species present in the treatments. Couch grass was particularly dominant on the straight tailings treatment where it established and formed a thick vegetative covering.

The findings of the trial suggest that in terms of the establishment of a groundcover on the tailings, there is no quantifiable advantage in the placement of oxide and soil layers onto the tailings, assuming similar properties to A1-A3 samples, prior to revegetating.

4.3.2 Trial A2

Tailings samples A7, A10, A12 and A13 were used to characterise the substrate of the trial area. Analysis recorded elevated levels of arsenic, molybdenum, and chromium in the samples. The average total sulphur percentage of the samples was 0.195%. pH of the samples averaged 7.36. The conductivity and salinity of the samples declined from surface to 600mm depth. Average surface conductivity recorded was 5148 uS compared with an average conductivity of 497 uS at 600mm depth. Average surface salinity recorded was 2683 ppm compared with an average 233 ppm at 600mm depth. Sample A3 recorded lower than average concentrations chloride, sodium, conductivity, iron potassium and nitrogen.

Revegetation monitoring results are shown in Table 13. Pioneer rhodes grass, at both fertilisation rates, has shown moderate establishment with around 50% ground cover. This species is well suited to growth in the tailings environment and as such is a proposed species for rehabilitation.

The establishment of trees through tree seeding has proved unsuccessful with no trees germinating after a period of one year. This result highlights the advantages of planting seedlings into the tailings. The direct planting of seedlings into tailings will be the method of tree establishment used for the tailings compartments.

Katembora rhodes grass showed excellent establishment with ground covers of greater than 90%. The level of ground cover appeared to be lessened by the higher rate of fertilisation, however the results to date are by no means conclusive. Katembora rhodes grass will be used in the revegetation of the tailings facility.

Saltbush establishment has, to date, been very low. Only two specimens of *Atriplex vesicaria* and *Atriplex nummularia* were recorded for the trial. The lack of establishment is most likely due to the inadequate pre treating of the saltbush seed prior to sowing. It is common to 'rinse' the seed prior to sowing to simulate heavy rainfall

Table 13 - Revegetation Monitoring Results, Trial A2.

Date Sampled	Treatment	Replication	% Ground Cover	Species
31/10/99	P1	1	60	1*
		2	50	1*
		3	100	1*
	P2	1	50	1*
		2	50	1*,3
		3	50	1*,3
	T1	1	10	1*,3,5
		2	<10	1,3*,5
		3	40	1*,5
	T2	1	10	3*,5
		2	40	1,3*,5
		3	10	1*,3,5
	K1	1	>90	2*
		2	60	2*
		3	80	2*
	K2	1	<10	2*,5,7
		2	10	2*,3
		3	40	2*,8
	S1	1	<10	5
		2	10	1,3*,7
		3	40	1*,3,7
	S2	1	60	1*,3,5
		2	<10	1*,3,6
		3	50	2*,5
	C1	1	90	2*,3
		2	40	1,3*,5, 7
		3	60	1*,9
	C2	1	20	3*,4,5
		2	70	2*,3,5
		3	50	1,3*

SPECIES**COMMON NAME****No.**

* Most Abundant

Pioneer Rhodes	1
Katembora Rhodes	2
Buffel Grass	3
Atriplex vesicaria	4
Soft Rolly Polly	5
Atriplex nummularia	6
Ruby Saltbush	7
Couch	8
Spear Grass	9

required for saltbush establishment. Any seed still present in the trial plots are unlikely to germinate until sufficient rainfall occurs. Limited amounts of saltbush may be incorporated in the revegetation of the dams due to their value as feed for cattle.

The control plots showed relatively high levels of ground cover due to the encroachment of rhodes and buffel grasses from neighbouring plots.

The trial has served as evidence that the establishment of grasses, namely rhodes grasses, is an appropriate revegetation method for the Yandan gold mine tailings dam.

4.3.3 Pot Trials

4.3.3.1 Trial P1

The results from trial P1 are presented in Table 14. The number of germinations per species generally rose when the tailings material was disturbed. The disturbance aided in reducing crusting allowing germinants to rise above the tailings surface.

The species that recorded the highest number of germinants were Wynn Cassia, Speedy Couch, Native Grass and Rhodes grass. These species are seen as being appropriate for the tailings dam revegetation.

Table 14 - Revegetation Monitoring Results, Trial P1.

SPECIES	NUMBER OF INDIVIDUALS	
	Germination	
	Scarified	Not Scarified
Quinine Tree	1	4
Crotolaria sp.	29	40
Wynn Cassia	200	100
Speedy Couch	200	100
Native Grass	130	70
Verano Stylo	80	60
Rhodes Grass	150	110
Control	0	4

4.3.3.2 Trial P2

The results of trial P2 are discussed fully in Thompson (1999). A summary of the findings is as follows:-

- Of the species tree species tested, *Eucalyptus argophloia*, *E. camaldulensis* and *E.ochrophloia* displayed the highest tolerance to the tailings material.
- *Eucalyptus argophloia* and *E. camaldulensis* performed the best in tailings of high conductivity, average bulk density and low moisture content. These species also grew well in tailings of lower conductivity, higher bulk density and high moisture content sites.
- *E.ochrophloia* showed only a moderate tolerance to conductivity.

Based on the findings of trial P2 it is suggested that *Eucalyptus argophloia* and *E. camaldulensis* be used as the primary species for tree revegetation. Local tree species, such as narrow and silver-leaved ironbarks, have shown not to be tolerant of the tailings.

5 REHABILITATION

5.1 Drainage

Compartment A currently has a depression (Figure 1) situated in the compartments north-west corner. The lowest point of the depression is 1.1 m below the level of the nearest retaining wall. A condition of the tailings waterworks licence is that the rehabilitated surface of the tailings must be free draining. To meet this condition it is proposed to excavate a drainage line from the lowest point in the depression to the southern corner of the compartment. Water flowing through the drain and away from the tailings dam would report to the tailings return water dam. The drain would have appropriate dimensions for the catchment, in general a wide shallow drain, approximately 200 m in length, with less than a 0.5:100 fall.

A 250m section of the wall separating the two tailings compartments has been flattened and revegetated for aesthetic reasons.

Compartment B had a depression near the decant point (Figure 1) on its southern perimeter. To prevent ponding the level of the wall encompassing the decant dam was lowered to near tailings surface level. The decant dam was backfilled with the wall material. Surface water now reports directly to the existing spillway feeding into the tailings return water dam.

The return water dam will be retained for use by the local landowner as a watering point for livestock.

The majority of exposed sulphidic areas on Compartment B have been capped. The remaining (approx 1 ha) areas will be capped within the next year.

5.2 Vegetation Establishment

Species selection for the revegetation of the tailings has been based on a number of revegetation trials. The trials focused on the establishment of grasses and trees in tailings material.

Grasses such as *Cenchrus* spp. and *Chloris* spp. will be sown, at 10kg/ha, directly into tailings material. Grass will be sown within the annual wet season to ensure early establishment of a vegetative groundcover that will reduce water and wind erosion. Both species are fast growing, of economic value to grazing and establish readily in the tailings environment. Coated and uncoated seed will be used for the revegetation.

Tree species such as the Western White Gum and River Red Gum, both with environmental and commercial value, have been planted on compartment A of the tailings dam. Trees were planted on a per hectare basis in accordance with the surrounding tree densities of undisturbed lands. Trees were planted in windrows running north-south. This places the treelines at a 90 degree angle to the prevailing easterly wind pattern, refer WMC (1988). Planting the trees in such a way gives the benefit of windbreaks over the tailings surface. The reduction in wind speed results in a lower potential for the erosion of

the surface of the tailings and a better environment for the establishment and maintenance of pasture between the windbreaks.

5.3 Revegetation Monitoring

Initially visual monitoring will be undertaken to determine if there is a need for follow up seed sowing and or tree planting.

Long term revegetation monitoring will be undertaken on an annual basis in accordance with the vegetation assessment methodology for sites under rehabilitation outlined in the 1999 Yandan Gold Mine Plan of Operations. The tailings surface will be deemed rehabilitated when the rehabilitation criteria set out in the Plan of Operations are met.

5.4 Water Monitoring

Water monitoring of parameters of interest will continue until application for relinquishment of waterworks licences is sought. Water monitoring will initially be conducted on a bi-annual basis.

5.5 Schedule of Rehabilitation

A proposed schedule of rehabilitation is presented in Table 15. The schedule shows all of the revegetation work being undertaken in the 2000/2001 wet season.

Table 15 - Rehabilitation Schedule

Activity	1999										2000												2001					
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
Revegetation trials																												
Compartment A																												
Tailings																												
characterisation (cont.)																												
Confirm rehabilitation																												
strategy																												
Submit for approval																												
Rehabilitate																												
compartments A,B																												
Rehabilitation																												
monitoring																												

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Thompson, L (1999). *Revegetation of Yandan Gold Mine Tailings Dam*.

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PLATES

APPENDIX A

WATERWORKS LICENCES

APPENDIX B

SAMPLE DESCRIPTIONS – COMPARTMENT B

Sample Number	Description	Comments
B1	Highly Sulphidic; Heavy Clay 0-50cm	-
B2	Highly Sulphidic; Heavy Clay 0-50cm	Band of oxide 30-33cm
B3	Sulphidic; Sandy 0-30cm; Heavy Clay 30-50cm	Yellow staining (Jarosite) on surface
B4	Sulphidic; Sandy 0-30cm; Heavy Clay 30-50cm	Red clay surface and banding down hole
B5	Sulphidic; Sandy-Clay 0-50cm	Red clay surface no banding down hole
B6	Sulphidic (grey); Sandy 0-30cm; Wet Clay 30-50cm	-
B7	Not Obviously Sulphidic; Sandy 0-50cm	Grey/Green/Yellow staining on surface of tailings
B8	Brown Light Clay 0-40cm; Sulphidic 40-50cm	Sulphides included in sample
B9	Sulphidic 0-5cm; Oxide 5-30cm; Sulphidic 30-50cm	Grey/Green/Yellow staining on surface of tailings
B10	Lightly Sulphidic 0-50cm	Dry to moist at depth
B11	Lightly Sulphidic 0-22cm; Oxide 22-50cm	Dry tailings
B12	Oxide 0-20cm; Sulphidic 20-50cm	-
B13	Oxide 0-40cm; Sulphidic 40-50cm	Sulphides included in sample
B14	Oxide 0-15cm; Sulphidic 15-50cm	Oxide sample; Sandy
B15	Oxide 0-23cm; Sulphidic 23-50cm	Oxide sample; Sandy
B16	Oxide 0-33cm; Sulphidic 33-50cm	Oxide sample; Sandy
B17	Oxide 0-25cm; Sulphidic 25-50cm	Oxide sample; Sandy
B18	Oxide 0-40cm; Sulphidic 40-50cm	Oxide sample; Sandy
B19	Oxide 0-20cm; Sulphidic 20-50cm	Copper staining on surface; Oxide sample
B20	Oxide 0-20cm; Sulphidic 20-50cm	Copper staining on surface; Oxide sample
B21	Oxide 0-20cm; Sulphidic 20-50cm	Only sulphides sampled
B22	Sulphidic 0-35cm; Oxide 35-50cm	Oxide and sulphide sample
B23	Oxide 0-12cm; Sulphidic 12-50cm	Oxide sample
B24	Oxide 0-30cm; Sulphidic 30-50cm	Oxide sample
B25	Oxide 0-12cm; Sulphidic 12-50cm; Heavy Clay	Oxide and sulphide sample
B26	Oxide 0-18cm; Sulphidic 18-50cm; Heavy Clay	Oxide sample
B27	Oxide 0-22cm; Sulphidic 22-50cm; Heavy Clay	Oxide sample
B28	Oxide 0-50cm; Heavy Clay 0-30cm; Sandy 30-50cm	Oxide sample
TS1	Earth 0-40cm	Light/Brown Earth
TS2	Earth 0-40cm	Light/Brown Earth
BUFFEL (TAILS)	South/Eastern corner	Mature growing plants
BUFFEL (BACKGROUND))	Eastern soil stockpile	Mature growing plants
RHODES (TAILS)	South/Eastern corner	Mature growing plants
RHODES (BACKGROUND))	Road to plant site from Compartment B	Mature growing plants

APPENDIX C

LABORATORY REPORTS

**Minerals Council of Australia
Environmental Workshop October 1999**

**Water Quality Prediction for the Flooding of the Open Pit
at the
Yandan Gold Mine**

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INTRODUCTION

Operations at the Yandan Gold Mine, commissioned in September of 1993, ceased in December of 1998. The mine, owned and operated by Ross Mining NL., is located approximately 180 km SSE of Charters Towers, central Queensland and ore was mined from an open pit. The pit is located on the eastern bank of the Suttor River, at the confluence with Yandan Creek and is separated from the Suttor River by a temporary earthen bund.

At the minesite, the Suttor River is ephemeral, and the flow is characterized by a high silt content and elevated total iron concentrations. The average rainfall is about 500 mm per annum and the average pan evaporation is about 2200 mm per annum at the minesite.

Increasing sulphide rich ore and waste was encountered as mining of the open pit progressed. Testing of the sulphidic waste rock showed it to be net acid generating. Since it was intended to flood the pit after operations, sulphide rich waste rock was deposited within restricted areas of the open pit (Figure 1). The objective for backfilling was to establish a water cover to provide protection against continued oxidation of the sulphidic waste rock.

MINE CLOSURE ISSUES

Placement of the sulphidic waste rock in the pit where it will be below the final pit lake level, represents "best environmental practice" for the disposal of potentially acid generating waste rock. Permanent underwater storage of potentially acid generating waste rock, to limit oxidation and acid generation, has been accepted as best practice in many parts of the world, including Canada (MEND program), the USA, Scandinavia and Europe. However, sulphidic waste rock and pit wall rocks oxidise when exposed to atmospheric conditions during the period between mining and flooding. This leads to the accumulation of soluble metal

sulphate salts and acidity in the waste and wall rock. These soluble salts and acidity are released when the waste and wall rocks are inundated following flooding of the pit, and may result in unacceptable pit lake and ground water quality.

At the Yandan pit the waste rock and wall rocks have been oxidising for several years, and field paste and conductivity measurements showed a significant accumulation of acidity and soluble sulphate salts which is expected to impact the pit lake. Therefore, mine closure issues related to the flooding of the Yandan open pit centred around the:

- i) short term water quality that may develop within the pit;
- ii) long term water balance and water quality;
- iii) potential for incorporating the pit lake as a backwater to the Suttor River; and,
- iv) potential impact on the water quality in the Suttor River.

Consequently, to assess the rehabilitation needs for the open pit it was necessary to develop a water quality prediction model to estimate the water quality that may develop in the pit lake, and to evaluate the performance of remediation alternatives if required.

The following section outlines the approach that was followed to complete the water quality prediction for the pit lake.

APPROACH

A simple four step approach was followed to estimate the water quality that may develop within the pit during flooding.

First, a geological map of the pit walls was developed to show the distribution of sulphide and carbonate altered wall rocks and as well as the sulphide waste rock backfill. The purpose of the map was to estimate the total exposed surface area of each type of wall rock, and total mass of waste rock that had been backfilled.

Second, a field program was undertaken to obtain representative samples from each category of wall rock. These representative samples were submitted for leach extraction testing to determine solute release rates.

Third, on the basis of the leach extraction test results for each rock type and the wall rock exposure, a dilution model was developed to calculate solute concentrations in the pit lake. The model also included calculation of the pit volume as a function of the flood elevation, and simplified short and long term water balances.

Finally, geochemical speciation modeling, using MINTEQA2, was undertaken to calculate saturation indices and estimate final solute concentrations from equilibrium conditions.

The principle of the approach was to compile an inventory of solutes (soluble metal sulphate salts and free acid generated from sulphide mineral oxidation) that may be released from the wall rocks and waste rock during flooding. Solute concentrations were then established through simple dilution calculations. Once the solute concentrations were established, geochemical equilibrium modelling was completed to estimate final water quality.

RESULTS

Geological Map

A review of the geology indicated that the wall rocks could be categorised according to alteration into six major groups. The alteration types are shown on Figure 1, and are summarised in Table 1, which also summarises the approximate wall rock exposure. The exposure is illustrated in Figure 1.

Based on the relative exposure and a field paste pH and conductivity survey, sample locations were selected as shown on Figure 1. The locations were selected as high up within each zone to ensure that the most oxidised material was sampled. For the backfilled waste rock, which was free dumped in the areas shown, composite samples were obtained to represent the entire backfill area. At all locations, only the less than 8 mm size fraction was sampled. Testing methods are discussed in the next section.

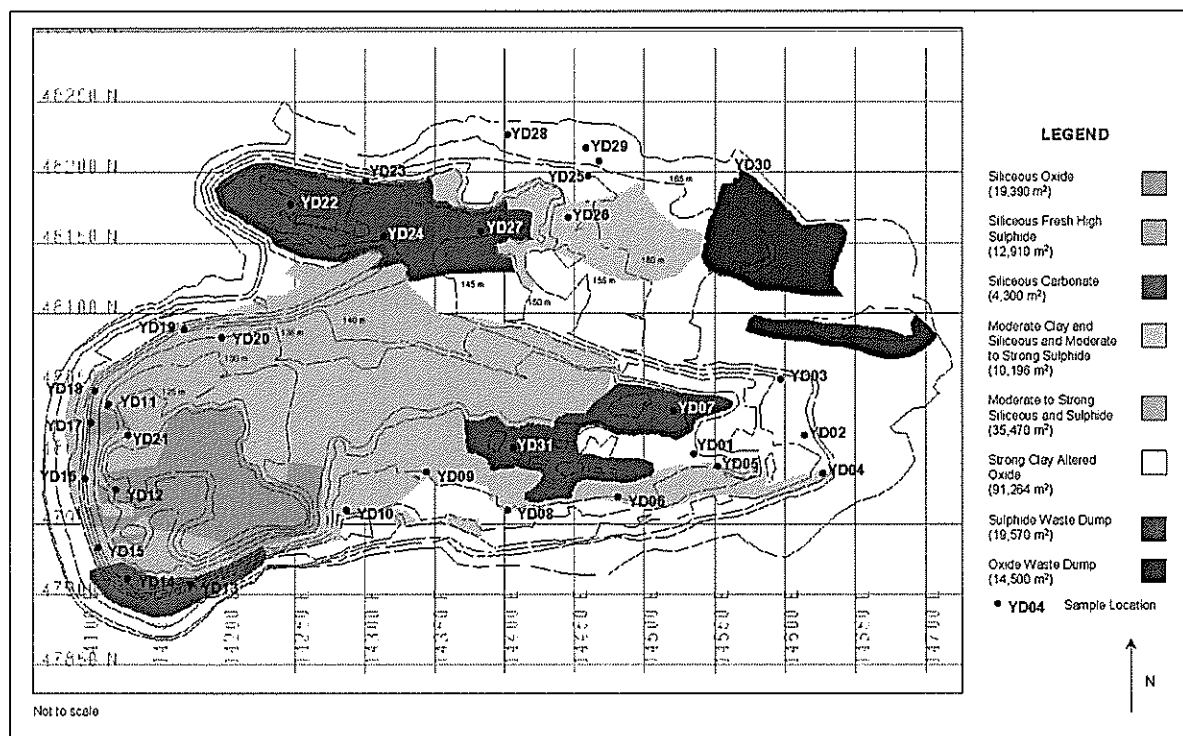


Figure 1. Yandan Pit Wallrock Alteration Exposure and Sample Locations

TABLE 1. Summary of Estimated Wall Rock Surface Exposure for Each Alteration Type

Elev. (RL) (m)	ROCK CLASSIFICATION (by alteration)					
	Siliceous Oxide (m ²)	Siliceous Fresh High Sulphide (m ²)	Siliceous Carbonate (m ²)	Mod. clay and Siliceous / Moderate to Strong Sulphide (m ²)	Moderate to Strong Siliceous / Sulphide (m ²)	Strong Clay Alt. Oxide (m ²)
110	0	0	0	0	0	0
115	0	1937	0	0	532	0
120	679	4467	0	0	1135	0
125	2676	8366	0	0	3370	0
130	6282	10677	0	0	5498	0
135	10141	12329	0	0	12556	2738
140	13011	12729	860	41	22346	6845
145	15260	12910	2150	459	30469	11225
150	16365	12910	3440	2936	33980	16884
155	18711	12910	3870	6169	35115	25280
160	19390	12910	4300	8687	35470	34224
165	19390	12910	4300	10196	35470	47457

Note: Expressed as cumulative actual surface.

Laboratory Testing

Leach extraction tests as well as size distributions were completed on all samples. In addition, sulphur, sulphate and carbonate analyses of the solids were completed for samples from areas that are anticipated remain above the final flood level.

Leach extraction tests were completed on representative sub-samples of 750 g. Each sample was placed in a 5 litre roll bottle, 1 500 mL distilled water was added, and the slurry was agitated on rollers for 24 hours. After completing the extraction and allowing the solids to settle, the clear decant was tested for pH and conductivity, and analysed for the total solute concentrations (including alkalinity/acidity, metals by ICP and select anions).

Calculation of Solute Release

Saturation indices were calculated for the solute concentrations observed in the leach extraction leachants using MINTEQA2. The results indicated that apart from gypsum for some tests, no other significant solubility controlling mineral phase limited the dissolution of solutes. However, it should be noted that kinetic constraints may have limited the dissolution of some phases, which cannot be accounted for by conventional equilibrium modelling calculations.

Specific solute release rates were then calculated on a surface area basis (from particle size distributions) for all the exposed alteration units. However, since the total mass of sulphide backfill was known, solute release was calculated on a weight basis. The results are summarised in Table 2.

To relate the surface area solute release rates to exposed wall rock surfaces it is necessary to establish the ratio of the exposed surface area to the total reactive surface area created during blasting and fracturing during mining. This ratio however is not that easily determined. A study carried out in three open pits measured ratios of reactive surface area to pit wall area ranging from 27:1 to 161:1 (Morin and Hutt, 1995). While the pit benches at

Yandan are relatively free of accumulated rubble and fines, the wall rocks generally are very fractured. Therefore, it was assumed that the ratio for Yandan would fall in the upper quartile of this range. For simplicity, a ratio of 130 was adopted for all of the alteration types.

Table 2. Summary of Solute Release Calculated from Leach Extraction Tests

Alteration Unit		PARAMETER							
		Acidity (mg/kg)	Alkalinity (mg/kg)	SO ₄ (mg/kg)	Fe (mg/kg)	As (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Sulphide Backfill	Average	2467		5707	944.80	4.59	11.65	9.19	96.99
	Maximum	3100		8412	1430.0 0	9.24	22.20	30.80	172.20
		(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)
Siliceous Oxide	Average	108	0.2	399	50	0.6	0.8	6.6	0.7
	Maximum	477	1	1106	237	2.9	3.1	21.2	2.5
Siliceous Fresh High Sulphide	Average	1411	Na	2310	670	20	0.7	0.7	6.1
	Maximum	1596	Na	2587	792	21	0.9	0.8	6.5
Siliceous Carbonate Alteration	Average	Na	27	148	0.2	0.01	0.001	0.3	0.02
	Maximum	Na	53	201	0.3	0.02	0.002	0.5	0.03
Soft. Moderate Siliceous Alteration and Moderate to Strong Sulphide	Average	657	Na	1714	334	9	4.3	2.5	9.6
	Maximum	849	Na	2040	389	12	9.2	6.2	19
Moderate to Strong Siliceous and Sulphide Alteration	Average	808	0.4	1517	336	10	2.1	1.0	3.7
	Maximum	1603	3	2505	669	27	6.6	3.4	10.9
Oxide	Average		12	37	0.05	0.01	0.003	0.02	0.02
	Maximum		22	101	0.2	0.01	0.006	0.05	0.06

Short Term Solute Release

The solute release calculations showed that in the absence of any remediation, the pit lake is likely to be acidic following flooding. Under these conditions, the estimated solute concentrations would adversely impact the water quality in the Suttor River. It was concluded that preventive measures were required to protect the receiving environment. Predicted pH and solute profiles are illustrated in Figures 2, 3 and 4.

An assessment of the primary sources of solute release indicated that in excess of 95 percent of the total solute loading that may enter the pit lake is likely to originate from the backfilled waste rock. The evaluation of remedial options therefore focused on controlling solute release from the waste rock. Options that were evaluated included surface compaction of the waste rock, placement of a soil cover, and placement of a chemically amended soil cover over the waste rock backfill areas.

To evaluate the efficiency of these selected options, solute release was modelled assuming a diffusional transport mechanism. The modelling results indicated that a simple, continuous soil cover, with a minimum thickness of about 0.3 m in thickness would effectively reduce the rate of solute release from the waste rock. Also, geochemical equilibrium modelling indicated that the efficiency of the cover might further be improved if the soil used in for construction of the cover were to be amended with a nominal amount of lime prior to placement. Projected solute concentrations after the placement of the soil covers over the oxidised sulphide waste are presented in Figures 5, 6 and 7.

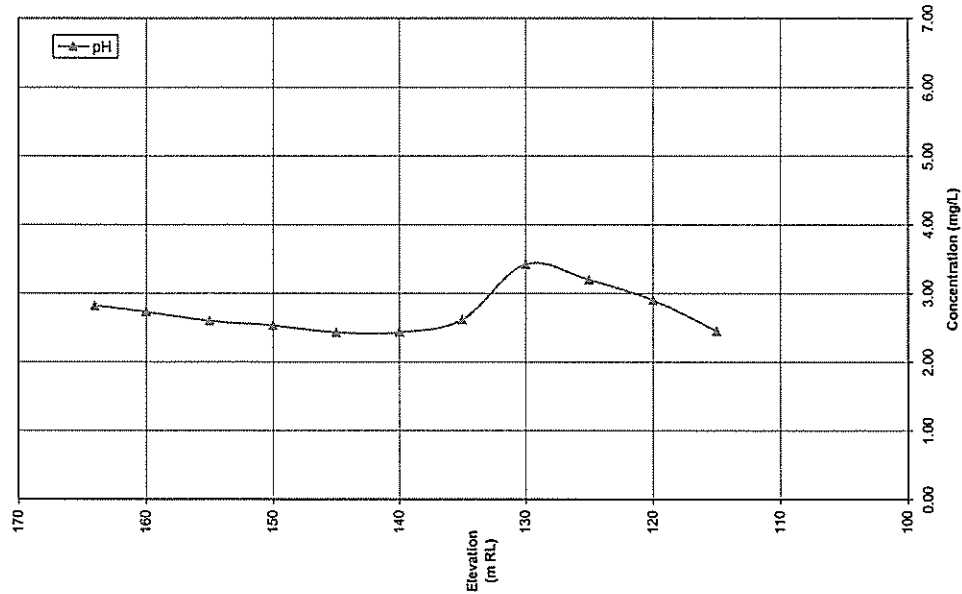


Figure 2 Estimated Pit Lake pH

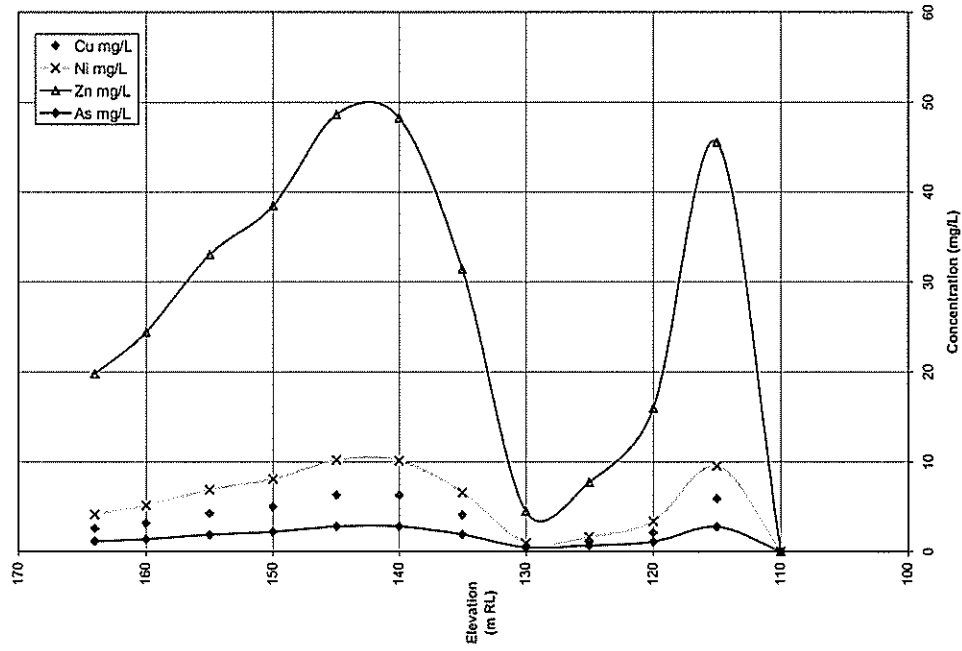


Figure 3. Estimated Trace Metal Concentrations

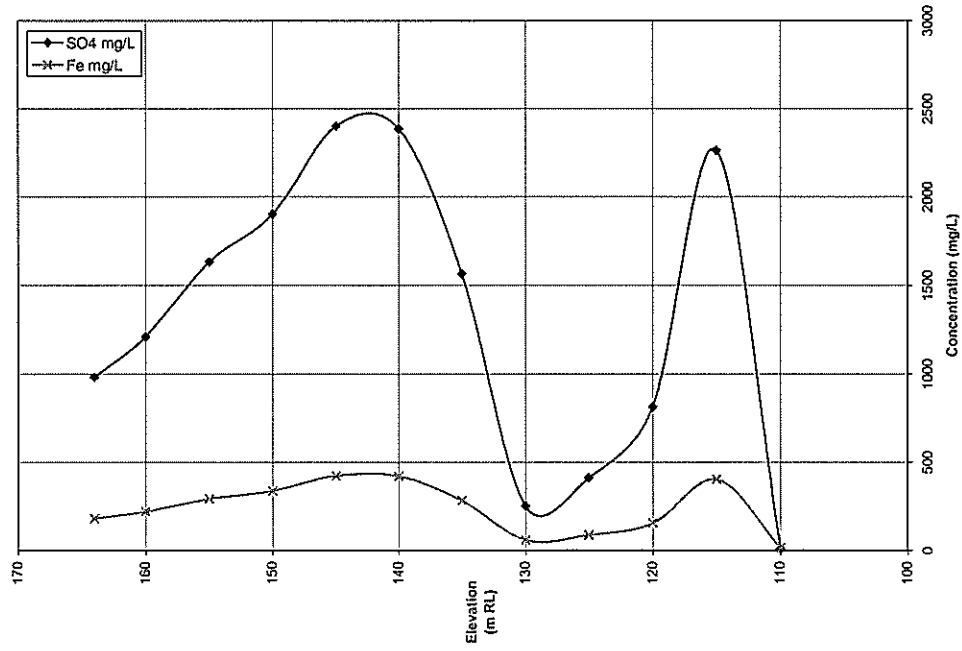


Figure 4 Estimated Sulphate and Iron Concentrations

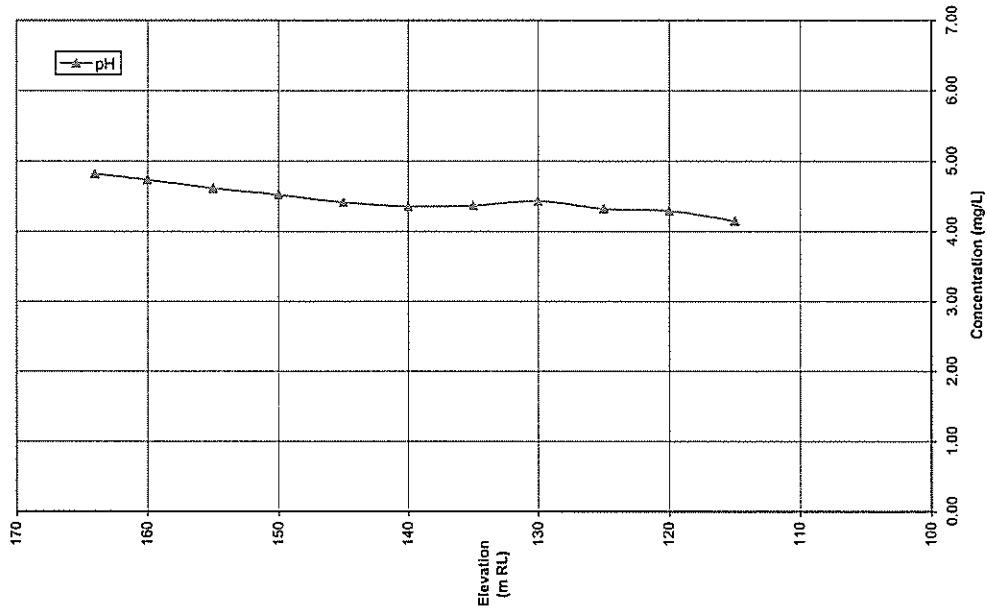


Figure 5. Estimated Pit Lake pH After Soil Cover Placement.

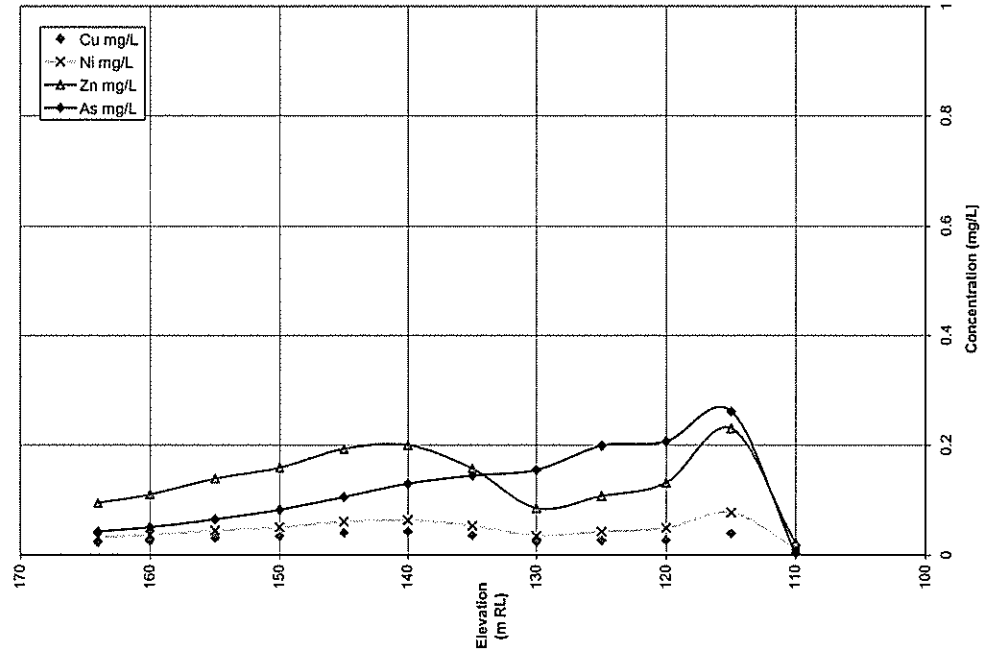


Figure 6. Estimated Trace Metal Concentrations After Cover Placement

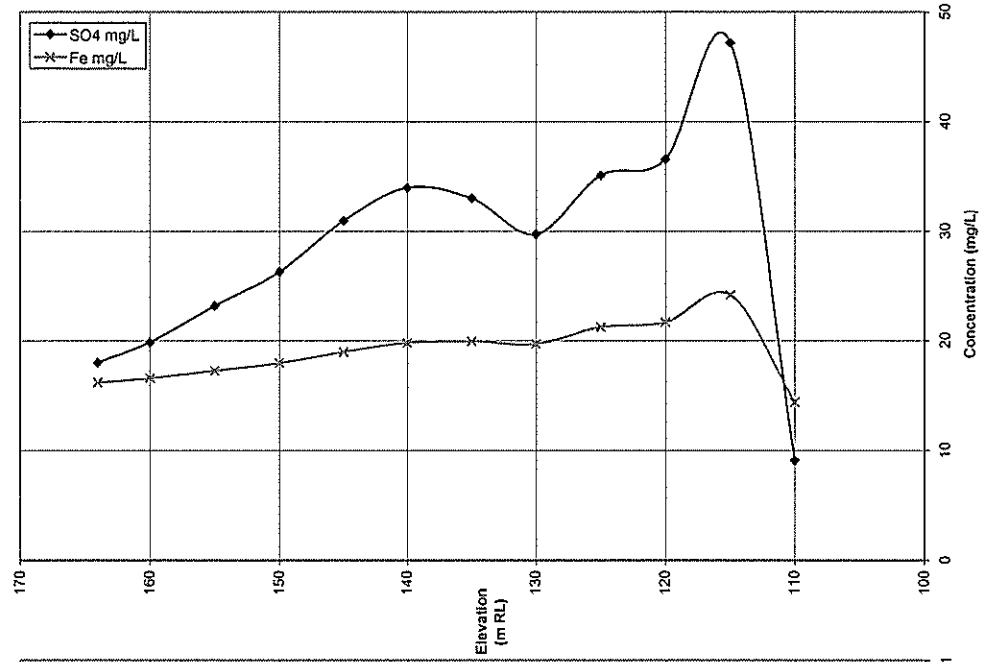


Figure 7. Estimated Iron and Sulphate Concentrations After Cover Placement

Long Term Solute Release

Water balance calculations suggested that on average the pit lake level is likely to be sustained within half a meter of the river bed elevation for average climatic conditions. At this flood elevation, the backfilled sulphidic waste rock will be about 5 m or more below the surface of the pit lake. Similarly, the net acid generating sulphide altered pit wall rocks are expected to remain below the water level. Under extreme drought conditions, the pit lake level may decrease, which may result in the exposure of a small proportion of the sulphide altered wall rocks. However, the potential for solute release from oxidation was found to be small, and the impact on the pit lake water quality, if incorporated as a backwater to the Suttor River, is expected to be insignificant.

STUDY CONCLUSIONS AND RECOMMENDATIONS

Study Conclusions

The results of the solute release calculations identified the oxidised sulphide waste rock backfill as the primary source for solute release and served to focus remediation activities on the backfill. Calculations further showed that limiting the interaction between the pit lake water and the pore water could control the release of solutes from the oxidised waste rock backfill. A soil cover in the order of about 0.3 m would effectively achieve this.

Study Recommendations

On the basis of the modelling it was recommended that a soil cover with a minimum thickness of 0.3 m, amended with 0.2 percent lime be placed over the sulphide backfill. Recommendations included erosion protection for all sideslopes, with additional protection for soil cover placed immediately below the point from which the river will flow into the pit.

Furthermore, to control water exchange between the pit lake and the river, it was recommended that the connecting channel between the river and the lake be established at about 0.6 m above the river bed. Thus, the pit lake will not discharge during low flow conditions, providing additional protection against potential impacts from the pit lake when available dilution in the river is at a minimum.

Anticipated Benefits

The direct benefit for restricting solute release from the backfilled sulphide waste rock is that initial pit lake water quality is expected to be similar to that observed in the Suttor River. This means that the pit lake could be incorporated as a backwater to the Suttor River. Thus the water level in the pit lake would be sustained at a maximum possible level, limiting oxidation and solute release from the sulphide altered wall rocks.

Benefits are also expected from the cyclical interaction between the pit lake and river water during the wet season. The pit lake would act as a settling basin for river water that may enter the lake during flood events. The contained silt would be deposited on the lake bottom and is expected to act as an additional cover, further restricting solute release from the backfilled waste rock. In addition, organic matter that may accumulate with the silt is expected to promote reducing conditions, which would provide an additional "barrier" against the release of solutes from the backfilled waste rock and the wall rocks. Biologically

catalysed reducing conditions would lead to the reduction of sulphate and subsequent precipitation of sulphide metal phases.

IMPLEMENTATION OF CONTROL MEASURES

Conservatively, Ross Mining has opted to increase the soil cover to double the recommended minimum thickness. However, soil properties (clayey soil) at site precluded effective lime mixing prior to placement. Therefore, lime was spread on the sulphidic waste rock backfill at an application rate of about 1 kg/m² prior to the placement of the soil cover. The cover was placed as two consecutive layers, each 0.3 m in thickness, placed on top of the lime layer.

Ross Mining however was unable to obtain a permit to breach the bund and achieve rapid filling of the pit lake by harvesting water directly from the Suttor River. Instead, once the soil covers were in place, flooding was initiated by pumping water from various sources, including an existing water harvesting channel from the Suttor River, a flooded borrow area and a water storage facility on site. This resulted in some delay in flooding of the pit. The following briefly describes the actual implementation of the proposed remediation alternatives, and the outcome.

Monitoring

The pit lake was monitored at six locations around the perimeter of the pit, approximately 5 m from the pit wall to minimise short range wall effects, as well as in the middle of the pit. Sampling was initially undertaken for every 10 m increase in pit lake elevation. Early results are summarised in Table 3.

TABLE 3. Summary of Early Monitoring Results

Lake Elevation (RL)	pH	EC at 25°C (uS)	Solute Concentrations (mg/L)						
			Ca	SO4	Cl	Al	Cu	Iron	Zn
120	5.2	312	18	92	28	1.57	0.02	4.73	0.39
130	6.3	272	na	na	na	na	na	na	Na
140	4.8	276	na	na	na	na	na	na	na

As shown in the table, during the early stages of flooding, water quality monitoring indicated that the pit lake was neutral and that dissolved solids were comparable with the Suttor River. The results compared favourably with the estimated concentrations. Part of the sulphide backfill was placed at the deepest location in the pit, and inundated early on. The results indicated that the soil cover was performing effectively.

Once flooding reached the 144 m rL elevation, the pH decreased to about 3.0 s.u., and iron concentrations increased and stabilised at around 20 to 30 mg/L. Reasons for the observed deviation from the estimated water lake properties are discussed below.

DISCUSSION

Based on the monitoring results, the modelling underestimated the total solute release to the pit lake. The approach that was followed represented a 'snap-shot' of the total inventory of solutes at the time of the investigation. This approach was deemed suitable because the

operations were about to cease, and it was anticipated that the closure activities could be completed soon after and flooding could be achieved in quick succession. However, a number of factors contributed to the differences between the estimated and observed pit lake water quality. The most significant factor is considered to be the delay that occurred between the completion of the study and flooding of the pit. This lead to the generation of additional soluble oxidation products from ongoing oxidation which was not be accounted for in the study. Other factors that may have contributed include windrows that were left in place and not consolidated under the soil cover and a block of subgrade ore, that was blasted but not mined, that was not accounted for in the calculations.

It is concluded that the modelling approach was valid for the intended purpose. However, should long time delays be anticipated before flooding occurs, the pit lake water quality prediction should also address subsequent accumulation of acidity from continued oxidation.

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- Morin, K.A. and Hutt, N.M., 1995. **A Technique for Predicting Water Chemistry in Open Pit and Underground Mines.** In: Sudbury '95 Mining and the Environment Conf. Proc.

WESTERN MINING CORPORATION LIMITED

YANDAN GOLD PROJECT

GROUNDWATER DEWATERING STUDY

C.F. Forbes
September, 1988

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1.0

PREAMBLE

Western Mining Corp. Ltd. is investigating the feasibility of establishing a gold mining operation at its Yandan prospect. As part of this study, they have instituted a study of groundwater conditions at the site to provide estimates of dewatering flows required to maintain access to a proposed open pit. It was also required to comment on the possibility of obtaining the projects water supply from this source.

The Yandan prospect is located approximately 200km south of Townsville in North Queensland, at the junction of the Yandan Creek and the Suttor River, see Fig. 1.

It is estimated that the daily water requirement will be between:

(a)	Process Water	2,900 m ³ /day
	Potable Water	270 m ³ /day

and

(b)	Process Water	3,600 m ³ /day
	Potable Water	270 m ³ /day

The general arrangement of the proposed pit, tailings dam area, Suttor River and Yandan Creek are shown at Figure 2.

Owing to the constraints of the wet season (1987/88) and the need to produce a preliminary report, this work has been carried out in two campaigns. The initial work comprised a site visit, study of available material and hydraulic testing of two specially constructed production bores YNDP 146 and 147. This work resulted in the April, 1988 report.

In order to test the conclusion of that report and to provide a supply of water for construction purposes, six additional bores were drilled, three production and three observation bores, these were YNDP 168, 169 and 170 and observation bores YNDC 156, 157 and 158.

These bores are shown located at Figure 4. In addition, geological work progressed on the deposit and the surrounding area which resulted in the more detailed geological map incorporated in Figure 4.

Pumping tests were conducted on bores YNDP 168, 169. The test on YNDP 169 running for 11,500 minutes.

In addition, a reconnaissance geophysical survey has been carried out in order to provide additional drilling sites across the flood channel of the Suttor River.

The work suggests that additional drilling sites beyond the area of this study will be unnecessary either for dewatering or process water supply purposes. Thus, the results of the survey are not discussed in this report.

2.0 ENVIROMENT

2.1 Climate

The area is in the Australian tropics, rainfall details are summarised in Table 1.

Table 1a
Approximate Rainfall Data - Yandan

Annual Rainfall	10 Percentile	50 Percentile	90 Percentile
mm	330	588	1,025

Table 1bMonthly Rainfall

Monthly Rainfall	J	F	M	A	M	J	J	A	S	O	N	D
50 percentile	95	110	65	17	10	20	4	1	2	15	27	62

Average annual evaporation for the area is given as approximately 1,950 mm.

2.2

Topography

The site occupies three small hills at the confluence of the Suttor River and Yandan Creek. The Suttor River is a braided stream occupying a fairly board depression. The relief at the project site is about 30 meters, elsewhere locally the undulating terrain has much less relief - approximately 5 - 10m.

The country rises gently away from the Suttor River towards the east. The highest hill in the area is approximately 2km north of the site. It reaches an elevation of about 212m.

2.3

Geology

Yandan prospect is situated on the Anakie High. Rocks forming the Anakie inlier are the oldest in the area and occur to the east of a north south fault located approximately one km from the junction of Yandan Creek and the Suttor River. The deposit has been formed in the St. Anne's Formation, a suite of rocks comprising acid and intermediate lavas with tuff, akosic and lithic sandstones, conglomerate and assorted mudstones which form the base beds in the Drummond trough. This outcrop of the St. Anne's formation abuts the alluvial channel of the Suttor and Yandan creeks. Within 10km of the

deposit the outcrop geology is quite complex including to the west an outcrop of an intrusive formation comprising granite, granite porphyry and minor rhyolite together with additional outcrops of Ukalunda beds and St. Anne's formation.

Outcrop geology is shown at Figure 3. This Figure also suggests that the stream courses may be structurally controlled.

Figure 4 gives structural and lithological details in the deposit and immediately adjacent areas. This work, which greatly assists interpretation of the hydraulic tests has been carried out by Mr. S. Hancock, Senior Supervising Geologist, Townsville.

2.4

Hydrogeology

Possible aquifer systems close to the deposit which could cause water inflow problems during mining and provide a water supply source were thought to be:-

- . fracture systems in the rocks comprising the deposit and adjacent country rock;
- . A deep alluvial channel underlying the adjacent stream which if it existed might be in hydraulic connection with the fractured rocks and provide a virtual constant head source. This could make dewatering considerably more difficult.

Data obtained during this investigation from mineral exploration drilling suggests that although up to 30m of alluvium exists in the flood plain of the Suttor River, it comprises mainly of clay and silt and further pumping tests do not reveal hydraulic connection to the fractured rock aquifers.

The hydrogeological model which has emerged from these works is that of a highly permeable zone bounded by a northern and southern Yandan fault zone. This zone is also bounded to the east and west by faulting, see Figure 4. Surrounding this highly permeable zone are less permeable fractured rocks in semi hydraulic connection. Measured transmissivities from the two zones are in the order of $1,000\text{m}^2/\text{day}$ and $50\text{m}^2/\text{day}$ respectively.

3.0 FIELD PROGRAMME

3.1 General

A programme of field investigations was planned to provide information about:-

- . The hydraulic parameters of aquifer transmissivity and storativity and secondly about aquifer hydraulic geometry and type;
- . groundwater quality distribution;
- . the phreatic surface; elevation of the groundwater, in relation to the streams and the direction of groundwater flow.

In order to obtain this information, it was necessary to carry out the following field programmes.

3.2 Drilling

Initial Programme

An initial programme was undertaken to provide two test production bores (YNDP 146 and 147, see Figure 4) and two additional observation bores, YNDC 104 and YNDC 105.

Production bores were drilled to a depth of 100m and cased with 150mm ID slotted steel casing.

Observation bores were drilled YNDC 105, 100m and YNDC 104, 82m and cased with 50mm UPVC pipe.

Final Programme

A final drilling programme was carried out to provide three additional observation bores in the area south of the deposit and three additional production bores to provide a source of supply of construction water and to enable a long term (>10,000 minute) pumping test to be carried out.

Location of production bores YND P168, 169 and 170 and observation bores YNDC 156, 157 and 158 are shown on Figure 4.

3.3 Hydraulic Testing

Pumping tests were carried out as follows:-

Initial Programme

Pumping tests were carried out on production bores:

. YNDP 147 - pumped at 2.5 litres per second for 7,700 minutes and then at 3.3 l/s to 9,900 minutes.

. YNDP 146 - pumped at 3.3 l/s for 8,800 minutes.

Final Programme

Pumping tests were carried out on bores:

. YNDP 169 - pumped at 12 l/s for 11,390 minutes.

. YNDP 168 - pumped at 3.3 l/s for 14,415 minutes.

3.4 Water Level Measurements

Water level measurements were taken in a representative number of bores, reduced to AHD and plotted, see Figure 4.

3.5 Bore Water Yield

Water yields during drilling from a limited number of holes is shown on Figure 4.

3.6 Water Quality

Samples were collected from bores P 146, 147, 168 and 169 during the pumping tests. From bores YNDC 105, 106, 108, 65, 132, 170 and 86 during drilling and by bailing from bores P 22, and "Bore No. 1".

All samples were analysed for the seven major constituents as well as some minor constituents and some metals.

Results of analyses are reported at Table 2 and Figures 5 to 8 inclusive.

4.0 RESULTS

4.1 Water Level Measurements

Figure 4 shows details of water level measurements and includes the 158 M AHD and 159 M AHD contours. These data indicate:-

- . A generally westerly drainage of groundwater.
- . The probability that permeability of the ukalunda beds/anakie metamorphics is very much lower than that of the St. Anne's formation west of the N.S. fault.
- . The existence of a zone of higher permeability within the St. Anne's formation (bounded approximately by the 159 M contours) which opens towards the south west.

Figure 4 shows considerable variability in water level over quite short distances which is symptomatic, of a fractured rock aquifer, the difficulty of obtaining data from inclined holes and the fact that RL of measuring points of some of the outlying holes were estimated from contour plans. Surveyed information is available for almost all the holes measured in the deposit area.

The water level data suggests that there are three permeability zones:

- . Area (1) occupied by the anakie metamorphics/ukalunda beds east of the eastern north south fault - a zone of very low - lowest permeability.
- . Area (2) occupied by the St. Anne's formation generally of low permeability but higher than area 1.

- . Area (3) also occupied by St. Anne's formation but of significantly higher permeability. This area largely coincides with the mineral deposit and is contained within the north and south Yandan fault zones.

Overall the groundwater appears to drain to the west, however, area (3) for which we have the greatest information, drains to the south west.

Almost certainly there would be hydraulic continuity across the boundaries of the three areas. However, these transitions would be marked by extremely high groundwater gradients, which would largely attenuate, the effect of drawdown due to pumping tests, across the boundaries.

4.2

Water Quality

Water samples for chemical analysis were obtained from fourteen bores. Samples being taken from:

- . Permeability Area (1) - Bore No. 1, P 22 and P 24
- . Permeability Area (2) - YNDC 108, 106 and 105
- . Permeability Area (3) - YNDP 146, 147, YNDC 65, 123, 86, YNDP 168, 169 and 170.

Results of chemical analysis are tabulated at Table 2. Selected analyses have been plotted, see Schoeller plots, Figure 5 to 8 inclusive.

Field conductivity was also obtained from bores YNDC 205 and YNDC 206 which are included below.

Hole No.	Depth	Conductivity u s/cm Micro Siemens/cm	pH
YND 205	76 - 77m	4,000	6.8
(3 samples)	83 - 84m	8,200	7.1
	83 - 84m	4,500	7.1
YND 206	101 - 102m	4,300	6.8

These results indicate a much lower salinity than for any other bores sampled. YND 205 and 206 are in the flood plain of the Suttor River and maybe under the influence of recharge from that source. This information strengthens the possibility of a competent north trending hydraulic barrier immediately west of YNDP 168 and 169.

Total dissolved solids results are also shown on Figure 4.

Total solids vary from a low of 4,020 mg/l to a high of 31,000 mg/l in an apparent random fashion.

It is interesting to note that samples with high salinity including YNDP 147, (12,170 mg/l), YND 132 (13,100 mg/l), YNDP 168 (14,900 mg/l) and YNDP 169 (13,900 mg/l) are located in the most permeable area which is unusual; unless better quality water from the more permeable sections of the formation are being contaminated with poorer quality water associated with saline stagnant waters trapped in lower sections of the sequence penetrated.

The other saline sample YND 108 (21,016 mg/l) is located in the St. Anne's formation north of the deposit, in permeability area No. 2. It's higher salinity may be caused by contamination from deeper sections of the sequence (containing highly saline water) only poorly connected with the upper circulating waters.

In general, groundwater in the area might be described as of poor quality stock water, unsuitable for either irrigation or domestic purposes.

Schoeller diagrams, Figures 5, 6, 7 and 8, show that the water samples can be grouped into five groups on the basis of ionic ratio.

These comprise:-

- . Group 1 Bore No. 1, P 22 and P 24 (all east of the north south fault)
- . Group 2 YNDP 146
- . Group 3 YNDP 147, YNDC 132 and 108
- . Group 4 YNDC 65, 86, 105 and 106
- . Group 5 YNDC 170, YNDP 168 and 169

Group 1 bores are all located in the ukalunda/anakie metamorphics and perhaps are displaying the signature of these rocks.

Group 3 comprises the three high salinity sample bores YNDP 147, YNDC 132 and 108.

Group 4 the largest group contains YNDC 65, 86, 105 and 106. These bores with average TDS 5,000 mg/l have water of intermediate composition between Group 2 (YNDP 146 - 440 mg/l) and Group 3 of average salinity about 15,000 mg/l.

Group 5, all these bores are located at the western end of the deposit. Their analyses are very similar to groups 2 and 3 except that Ca/Mg ratios are much closer to 1 as is their Na+K/Cl ratios.

Groups 2, 3, 4 and 5 comprise of samples all taken from the St. Anne's formation. It is probable that variations in their ionic ratios relate to the proportion of water drawn from circulating and stagnant water within the rock formation.

The ore body appears to have almost no effect on the percentage composition of the seven major constituents.,

4.3 Hydraulic Testing

Data from the pumping tests have been plotted and analysed. The tests are difficult to analyse although all tests have some similar characteristics.

4.3.1 Test of YNDP 146

Figure 9 is a semilog plot of drawdown versus time for the pumped bore YNDP 146 and the two observations wells YNDP 147 and YNDC 104.

Figure 10 is a log plot of the same data. The drawdown vs. time curve for P 146 is typical for an aquifer showing delayed yield. The initial slope of the curve, up to 7 minutes, represents the period when water is supplied from elastic storage. The flattened portion of the curve from 15 to 3,500 minutes represents the period in which the transition of supply from elastic storage to gravity drainage of the interstices takes place. Finally, the steep section of the curve beyond 4,000 minutes which has the same slope as the first portion of the curve represents the aquifers response during the gravity drainage portion of the test.

This curve does not display any barrier boundaries. However, since no drawdown was observed in bore YNDC 105 it is reasonable to assume that a barrier boundary exists between P 146 and YNDC 105 and the effect of that boundary was felt at the bore prior to the first reading of drawdown at one (1) minute.

This means that the transmissivity calculated from the first and the last slopes of the curve ($20 \text{ m}^2/\text{day}$) is too low by a factor of 2 and should be $40 \text{ m}^2/\text{day}$.

Results from the observation bores are as follows:-

YNDC 104

The flattest - first portion of the curve recorded, represents the transition from water being supplied from elastic storage to gravity drainage of the aquifer. The initial period was not recorded. The second slope represents the true aquifers response to pumping except that the derived value of transmissivity must be increased by a factor of 2 because of the effect of the boundary between P 146 and YNDC 105. The

third slope of this curve is due to a barrier boundary which affects the results in this bore at 3,500 minutes but hasn't affected the results of P 146 up to 9,000 minutes.

P 147

The remarks on YNDC 104 above apply here except that barrier boundary is not felt until 5,300 minutes.

4.3.2 **Test on P 147**

In this test the pumping rate was increased from 2.3 l/sec at 7,700 minutes to 3.3 l/s to the end of test at 10,000 minutes.

Figure 11 includes log log plots of drawdown versus time data for the pumped bore. Figure 12 is a semi log plot of the same data. Except for the increase in drawdown beyond $t = 7,700$ minutes these graphs are very similar to those of YNDP 146 in that they both display delayed yield characteristics and neither shows the effect of barrier boundaries.

From the test on YNDP 146 it is known that a barrier must exist between YNDP 146 and YNDC 105 and also that a second barrier must exist south of YNDC 104 and P 147.

Results from observation bores are as follows:-

Figure 11 includes log log plots of drawdown versus time for observation bores YNDC 104 and YNDP 146.

Figure 13 is a semi log plot of the same data although the data points are scattered the data can be interpreted as showing delayed yield changing to full gravity drainage of the aquifer at time 2,400 minutes for YNDC 104 and 2,600 minutes for YNDP 146 respectively.

The data shows the effect of increased discharge but does not show any evidence for barrier boundaries.

Values of transmissivity and storativity have been calculated and are shown tabulated at Table 3.

TABLE 3
AQUIFER HYDRAULIC PROPERTIES

Pumped Bore	Observed Bore	Apparent Transmissivity m^2/Day	Transmissivity M^2/day^*	Storativity	Remarks
YNDP 147	YNDP 147	8.4	25.0		Jacob
	YNDP 146	53	159	0.003	Theiss
		61	183		Jacob
	YNDP 104	53	159	0.003	Theiss
		61	183		Jacob
YNDP 146	YNDP 146	20.0	40		Jacob
	YNDP 147	67	134		Jacob
		64	128	3×10^{-4}	Theiss
	YNDC 104	89	178		Jacob
		63	126	0.004	Theiss
YNDP 168	YNDP 168	200			Jacob 1 - 10 min
		753			Jacob 10 - 470 min
		190			Jacob 470 - 5100 min
		60			Jacob 5100 - 14000 min
	YNDP 169	1054			Jacob 100 - 400 min
		210			Jacob 400 - 200 min
		124			Jacob 2000 - 7000 min
		54			Jacob 7000 - 14000 min
	YNDP 170	66			Jacob 8000 - 14000 min
	YNDC 104	1318			Jacob 70 - 450 min
		224			Jacob 450 - 2300 min
		66			Jacob 2300 - 6000 min
		43			Jacob 6000 - 14400 min
	YNDC 83	26		0.0001	Theiss
	YNDP 146	38		0.0013	Theiss
	YNDP 69	69		0.0004	Theiss
	YNDC 157	60		0.0013	Theiss
	YNDC 158	36		0.001	Theiss
	YNDP 169	340		0.002	Theiss
	YNDC 158	36		0.001	Theiss
	YNDP 169	340		0.002	Theiss
YNDP 169	YNDP 169	1580			Jacob 1 - 1000 min
		95			Jacob 1000 - 11500 min
	YNDP 168	520			Jacob 100 - 600 min
		57			Jacob 8000 - 11500 min
		46		0.0036	Theiss
	YNDP 170	133			Jacob 3000 - 11500 min
		97		0.0085	Theiss

Pumped Bore	Observed Bore	Apparent Transmissivity m ² /Day	Transmissivity M ² /day*	Storativity	Remarks
	YNDP 147	72			Jacob 8000 - 11500 min
		46		0.0004	Theiss
	YNDC 83	1178		0.0007	Theiss
	YNDC 104	46		0.0021	Theiss
		140			Jacob 1000 - 5000 min
		140			Jacob 1000 - 5000 min
		84			Jacob 5000 - 11500 min
	YNDC 107	109		0.0035	Theiss
		132			Jacob 5000 - 11500 min
	YNDC 157	127		0.0025	Theiss
		225			Jacob 1000 - 8000 min
		113			Jacob 8000 - 11500 min
	YNDC 36			0.0004	Theiss
		65			Jacob 8200 - 11500 min
YNDP 170	YNDP 170	7			Jacob 20 - 240 min
	Data from this test is unreliable and unsuitable for analysis				

The most important point to be observed from Table 3 is that the value of transmissivity measured for P 146 and P 147 when they are pumped bores is very much less than that measured when they are observation bores.

This result is thought to be due to incomplete hydraulic connection throughout the aquifer which limits drawdown in the observation bore and thus yields values of transmissivity greater than the correct one.

Correct values of transmissivity are obtained by analysing results from the pumped bores and adjusting the results for the effect of close boundaries.

Because of the influence of the early boundaries values for storativity have not been calculated. For design purposes a value of 0.002 has been adopted for storativity.

4.3.3. Test on YNDP 168

This bore was pumped at $285 \text{ m}^3/\text{day}$ (3.3 l/s). Water level measurements were read on a number of holes. Drawdown was measured in the following bores. YNDP 146, 147, 169 and 170 and YNDC 83, 104, 157 and 158. Figures 14 to 17 are semi log plots of drawdown vs. time. Figures 18 and 19 are log log plots of drawdown vs. time. Figures 20 to 22 are semi log plots of residual drawdown vs. t/t . Inspection of Figure 14 showing results for the pumped bore YNDP 168 suggests there are three hydraulic boundaries. The data up to 10 minutes suggest the aquifer has a local transmissivity of about $190 \text{ m}^2/\text{day}$. Between 10 and 500 minutes it appears that the drawdown cone is tranversing a more permeable section of the aquifer which gives the area sampled by the test a effective transmissivity of $700 \text{ m}^2/\text{day}$. At time 500 and again at time 7,000 the drawdown cone has intersected progressively less permeable zones with reduction in effective transmissivity to $117 \text{ m}^2/\text{day}$ and $60 \text{ m}^2/\text{day}$ respectively. Both YNDP 169 and YNDC 104 appear to have been constructed in the zones of higher permeability predicted by the results from YNDP 168. They further show the effects of intersecting zones of lower permeability. In both cases the final effective transmissivity is about $60 \text{ m}^2/\text{day}$.

4.3.4 Test on YNDP 169

This bore was pumped at 1,036 m³/day (12 l/s). Drawdown was measured in YNDP 147, 168, 170 and YNDC 83, 104, 157, 158. The pumping phase of the test lasted for 11,390 minutes. Subsequently, water level recovery measurements were made up to 45,600 minutes after pumping ceased.

Figures 23 to 27 are semi log plots of drawdown vs. time. Figures 28 to 31 are log log plots of drawdown vs. time and Figures 32 to 35 are semi log plots of residual drawdown vs. t/t' .

The results confirm results obtained from the test on YNDP 168 and will be discussed in detail below.

4.4 Observation Bores

During tests, water levels were measured in the bores tabulated below. This list also indicates the holes in which drawdown occurred – thus proving a considerable degree of hydraulic connection between the observed bore and the pumped bore.

Table 4
Observation Bores

Bore	Comment
YNDP 146	Drawdown measured – all tests
YNDP 147	Drawdown measured – all tests
YNDP 168	Drawdown measured – later tests (YNDP 168 & 169)
YNDP 169	Drawdown measured – later tests (YNDP 168 & 169)
YNDP 170	Drawdown measured – later tests (YNDP 168 & 169)
YNDC 74	Drawdown measured – later tests (YNDP 168 & 169)
YNDC 82	No drawdown – any test
YNDC 83	Drawdown occurred – later tests (YNDP 168 & 169)
YNDC 102	Possible drawdown at end of test YNDP 169 only
YNDC 103	Possible drawdown at end of test YNDP 169 only
YNDC 104	Drawdown measured – all tests
YNDC 105	No drawdown measured any tests

YNDC 106	No drawdown measured early tests
YNDC 107	Drawdown in later tests only
YNDC 108	No drawdown early tests - possibly later tests
YNDC 109	No drawdown early tests - possibly later tests
YNDC 156	New bore - no drawdown later tests
YNDC 157	New bore - drawdown in later tests
YNDC 158	New bore - drawdown in later tests

The meaning of these results will be considered below.

During the investigation some effort was made to determine which mineral investigation bores had intersected water. This information has been included in Figure 4. It must be realised that the information shown is very incomplete, suffice to say, significant flows were obtained in many holes even those which did not exhibit drawdown during any of the pumping tests. Some water was obtained in almost all holes.

4.5 Hydraulic Properties

The aquifer hydraulic properties determined from the above tests are presented at Table 3.

5.0 ANALYSIS

5.1 Aquifer Model

Completion of detailed geological mapping and the pumping tests on bores YNDP 168 and 169 has greatly increased knowledge of the geo hydrology of the area.

Analysis of all available data at the conclusion of the earlier pumping tests on bores YNDP 146 and 147 led to the postulation (1) that the area may be draining to a palaeo channel associated with the Suttor River and that the main aquifer comprised of a highly variable fracture system which was wedge shaped in plan opening to the west. Pumping tests on YNDP 146 and 147 did not reveal hydraulic connection to either a paleochannel or a zone of high permeability to the west. However, it was thought that because of the very low pumping rates the evidence was inconclusive.

The recent pumping tests prove conclusively that the Yandan deposit is not in hydraulic connection with any highly permeable systems to the west and that none exist in any other direction. The tests actually indicate that the bores have been completed in a highly permeable zone which is surrounded by a zone of much lower permeability such that the long term effective transmissivity of the combined high and low permeability zones is of the order of $60 \text{ m}^2/\text{day}$.

Drilling west of the deposit at holes YNDC 205, 206, 207, 209, 210 and 211 confirmed a thickness of alluvium under the Suttor River flood plain of from 17 to 30m comprising very low energy material. However, this drilling did not disprove the possibility of more permeable sections further west. The drilling did show that a geological discontinuity exists between holes YNDC 205, 206, 207, 210 and 211 and the ore deposit. It also confirmed the presence of water in significant amounts in the fracture systems in the rocks and in the case of holes YNDC 205 and 206, this water was of significantly better quality, see above.

Recent geotechnical drilling has shown the existence of thin sand and gravel layers in the Suttor River alluvium adjacent to the area where the proposed flood bund will be constructed. Permeability testing in these holes suggest values of permeability of $10^{-5} - 10^{-4} \text{ m/sec}$. This translates to values of transmissivity of less than $20 \text{ m}^2/\text{day}$ for the saturated alluvium which fits in with the results of the hydraulic testing which shows that no highly permeable material exists outside the area bounded by the easterly and northerly trending sets of faults. Almost certainly the saturated alluvium immediately adjacent to the proposed pit will be drained by the pit dewatering operation.

The earlier pumping tests only demonstrated hydraulic connection between three bores YNDP 146, 147 and YNDC 104. Tests on YNDP 168 and 169 proved hydraulic connection over a much wider area, see Figure 4 and Table 4. This exists beyond the block bounded by the eastern north south fault and the northern and southern Yandan fault zones.

The evidence still shows that the aquifers drain to the west, that probably the drainage line is associated with the Suttor River flood plains, probably in bedrock fractures, however this total westwards flow is very small.

The geological mapping, together with the pumping test results suggests that the shape of the zone of higher permeability is roughly rectangular, see Figure 4. Within this area there are fractures with very high permeability. (Transmissivities of more than 1,500 m^2/day). These highly permeable fractures bound blocks with very much lower permeability (measured transmissivities of the order of 40 m^2/day).

Pumping test and geological evidence also suggests that there probably exist within the highly permeable zone, hydraulic boundaries of short and longer length and that bulk permeability is greatest in an east west direction.

This considerable heterogeneity together with the small discharge rates of the two earlier tests would explain the fact that drawdowns were only measured in bores YNDP 146, 147 and 104.

This rectangular zone can be assumed to act as a uniform well of very low storativity, approximately 0.2%. As mentioned above, this zone is surrounded by less permeable rocks. The whole system behaving like a large well (of low storage potential) constructed in an aquifer with an effective transmissivity of approx 60 m^2/day .

Recharge to this system is quite small about 330 m^3 per sq. kilometre/annum, see (1) which explains the poor quality of the groundwater.

5.2

Dewatering

Figure 4 shows the location of the proposed mine superimposed on the detailed geology and hydraulic information. Figure 36 is a section showing the vertical profile of the proposed pit and the probable profile of the watertable if dewatering was carried out from a group of wells located along the western boundary of the pit.

Study of Figure 4 shows that suitable sites for dewatering wells would be adjacent to the existing bore YNDP 169 and near the point marked "A". Study of Figure 4 and 36 in conjunction, indicates that the better site from a purely dewatering point of view would be on the western end of the pit. However, if a site with similar hydraulic properties as the western site could be found near "A" it would have advantages from the points of view of ease of flood protection and pipe and power line costs.

5.2.1 Dewatering Requirement

Two dewatering schedules have been considered:

. To dewater the pit to 100m in two years.

. To dewater the pit to 100m in four years.

Present groundwater level is approximately 158m. Results of the pumping test on YNDP 169 will be used by extension to calculate dewatering flow to achieve these requirements.

5.2.2 Calculation

(a) 2 years = 1.05×10^6 minutes

(b) 4 years = 2.1×10^6 minutes

Figure 23 shows a semilog plot of drawdown vs. time from the test on YNDP 169.

In these calculations it is assumed that the drawdown at 1 minute is zero. This is a reasonable assumption on the basis of Figure 23 and should the 1 minute drawdown for greater discharges prove greater than zero the results are that much more conservative.

Aim to Calculate

Discharge to produce drawdown to 95m in 2 years

Try 5,000 m³/day

$$S_{1,000} = \frac{0.65 \times 5,000}{1,036} = 3.14M$$

$$S_{1,000 - 10^6} = \frac{4 \times 5,000}{1,036} \times 3 = 57.92M$$

$$\therefore S_{10^6} = 3.14 + 57.92 = 61M$$

$$\therefore \text{RL of Water Table} = 158 - 61 = 97M \quad \text{OK} < 100M$$

At the end of two years the deposit would be mined out and the stockpiled ore would be treated throughout the remaining 2 years of the project life. During this period, process water requirements has been estimated to be 3,600 m³/day. The effect of pumping at this rate on groundwater level may be estimated as follows:-

- (a) Calculation of drawdown at end of four years (2.1×10^6 minutes) due to pumping at 5,000 m³/day.

$$\begin{aligned}
 S_{2.1 \times 10^6} &= 10^6 + 5,000 \times \frac{27}{83} \\
 &= 61 + \frac{4 \times 5,000 \times 27}{1,036} \\
 &= 61 + 6.3\text{m} \\
 &= 67.3\text{m} \quad (1)
 \end{aligned}$$

- (b) Reduction in drawdown due to pumping at 3,600m³/day for two years.

This may be modelled by calculating the drawdown due to pumping at $5,000 - 3,600 = 1,400\text{m}^3/\text{day}$ for 2 years starting from end of year 2 as zero time and subtracting it from (1) above.

$$\begin{aligned}
 S_{1,000 \text{ (for } 1,400\text{m}^3/\text{day})} &= \frac{0.65 \times 1,400}{1,036} = 0.9\text{m} \\
 S_{1,000 - 2.1 \times 10^6} &= \frac{4 \times 1,400 \times 3}{1,036} \\
 &= 16.3\text{m}
 \end{aligned}$$

$$\therefore S_{2.1 \times 10^6} = 0.9 + 16.3 = 17.2\text{M}$$

- (c) Total drawdown at end of 2 years pumping at 5,000 m³/day following by 2 years pumping at 3,600m³/day.

$$= 67.3 - 17.2$$

$$= 50.1 = 50M, \text{ say}$$

RL of groundwater level would be approximately:

$$= 158 - 50$$

$$= 108M$$

Dewatering flow required to dewater the deposit in 4 years (2.1) x 10⁶ minutes).

Try 4,600 m³/day.

$$S_{1,000} = \frac{.65 \times 4,600}{1,036} = 2.90M$$

$$S_{10^3} - 2.1 \times 10^6 = \frac{4 \times 4,600 \times 3.33}{1,036} = 59.1M$$

$$S_{2.1 \times 10^6} = 2.9 + 59.1 = 62M$$

RL water table = 158 - 62 = 96M approx, ok

5.2.3 Dewatering Wellfield

As indicated above, because of the high permeability of the deposit as revealed by pumping tests on YNDP 169 and 168, dewatering wells may be concentrated rather than being spread around the periphery of the pit.

Although YNDP 169 shows zero well loss at a discharge rate of 1,036 m³/day it will probably be prudent from the point of view of hydraulics to split the extraction system between sites A and B, see Figure 4.

Four 150mm cased bores should be adequate for the dewatering wellfield. Such a wellfield could give a capacity in excess of 8,000 m³/day which should provide adequate standby capacity.

Bores will need to be sited so that major fractures are intercepted at elevations lower than 86m AHD with reduced level of the bottom of the bore being at about 76m AHD. Unless these conditions are met, the wells will not be able to lower the groundwater adequately.

5.2.4 **Summary**

The deposit could be dewatered according to the two scenarios with adequate provision for standby capacity by installing 150mm cased bores. These bores could be located in area "A" and/or "B" depending upon site conditions and economics. Dewatering flows would be:-

(a) Dewater in 2 years – 5,000m³/day. Then pump process water requirement for 2 years at 3,600 m³/day.

(b) Dewater in 4 years – 4,600 m³/day.

5.3 **Process Water Supply**

This requirement (3,600 m³/day) can be easily met from the dewatering flows.

6.0 **CONCLUSIONS**

From the work it is concluded that the:-

- . deposit can be dewatered;
- . dewatering flows of either dewatering scenario can provide for the process water requirement of 3,600 m³/day.

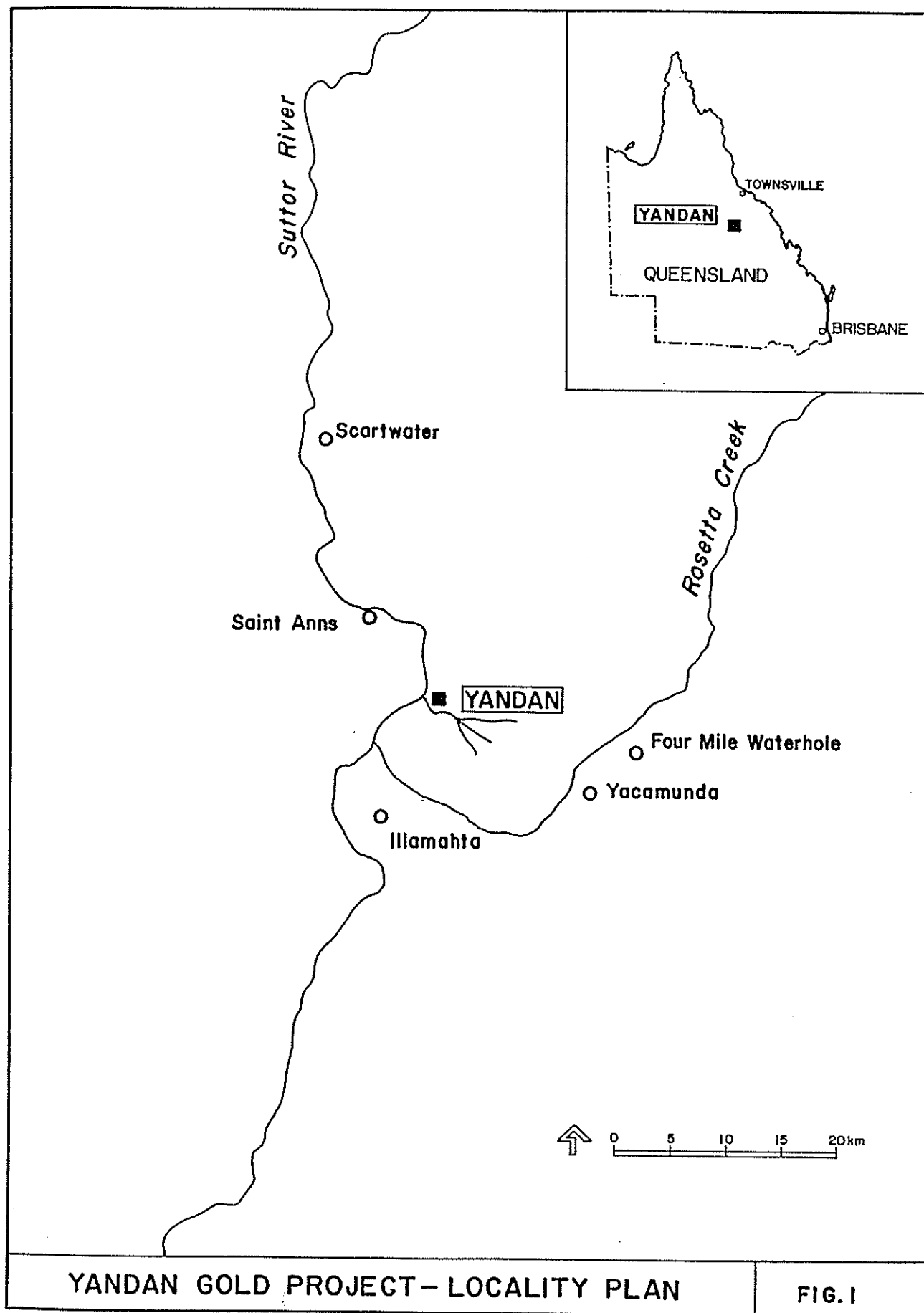
7.0

RECOMMENDATION

It is recommended that a detailed site geological and geophysical investigation be undertaken in area "A" in order to locate prospective sites for high yield bores.

Following this work, it is further recommended that an adequate number of bores of adequate depth be constructed at sites A and B to provide for the calculated maximum dewatering flow (5,000 m³/day) plus adequate standby.

This requirement should be met with four (4) 150mm cased bores each equipped to pump maximum of 25l/s.



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PO Box 242, Collinsville, QLD 4804

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Report No.: 6301/1/579

Wirralie Gold Mine

FINAL REPORT

**ENVIRONMENTAL GEOCHEMICAL ASSESSMENT
OF THE YANDAN HEAP LEACH DUMP**

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1.0 Introduction

Environmental Geochemistry International Pty Ltd (EGi) were commissioned by Wirralie Mines Pty Limited to perform a geochemical assessment of the Yandan Heap Leach dump for closure planning. The findings from this assessment are presented in this report.

1.1 Background

Details on the construction and operation of the Yandan heap leach have been provided by Wirralie Gold Mine personnel.

It is understood that placement of low-grade ore on the heap leach dump was completed in 1998. The dump currently consists of 3,200,000 m³ of ore comprising 6 pads and covering an area of 20.1 ha. The total pad thickness is approximately 26 m, comprising two 10 m benches and one 6 m bench. Gold and silver were extracted from the low-grade ore using conventional cyanide leach processes. The dump was irrigated with the cyanide leach solution at a pH of 10 and the pregnant solution was collected and pumped to the treatment plant for extraction of the gold and silver. Cyanide leaching ceased in August 2002 and the heap is currently being flushed.

A Plan of Operation submitted by Ross Mining Pty Limited (January, 2000) provides a preliminary rehabilitation strategy for the Yandan Heap Leach dump. This rehabilitation strategy includes:

- On completion of the cyanide leach, the dump will be flushed with a hypochlorite solution to treat the residual cyanide until the leachate quality is acceptable for direct release.
- The outer slopes of the dump will be reshaped to a 1:4 slope and contour banks and other drainage works will be installed as required.
- The dump will be covered with topsoil to a depth of about 0.15 m. The topsoil will be ripped, seeded and fertilised.
- The stormwater pond bunds, consisting of sub-soil, will be used to cover the pond's clay liner.

Wirralie Mines, as the operators of the mine, are currently preparing a new Environmental Management Overview Strategy, involving further investigations to refine the final closure strategy for the heap leach dump.

1.2 Study Objectives

The primary objectives of this study were to review the existing geochemical data and perform additional testing as required in order to identify any geochemical concerns for closure and rehabilitation of the dump. The specific objectives of the study were to:

- Assess the acid forming potential of the spent heap leach material.
- Identify any enriched and/or soluble elements that may present a concern for rehabilitation, water quality or contamination of surrounding areas.
- Provide recommendations for closure and rehabilitation of the spent heap leach dump.

This report presents the results and findings of the geochemical test work. The implications these findings have for environmental management of the site and recommendations for management and closure of the dump are also provided.

2.0 Geochemical Assessment Program

The results and findings from previous geochemical testing and the site water quality monitoring program, and the current geochemical testing program have been used for this geochemical assessment. An outline of the previous geochemical test work and water quality monitoring program is provided in Section 3 (Previous Investigations) and details of the current geochemical testing program are provided below.

2.1 Sample Selection and Preparation

Twenty heap leach samples were provided by Wirralie Mines personnel for the current geochemical characterisation program. The samples were collected from 20 different locations across the dump surface from a depth interval of 300 to 500 mm. Approximately 5 kg of samples was provided for testing and each sample was split, with 500 g being pulverised to minus 75µm. The pulverised and 'as received' portions of each sample were retaining for testing.

2.2 Analytical Program

The analytical program included the following geochemical tests:

- pH & EC determination
- Total S assay
- Acid Neutralising Capacity (ANC) determination
- Multi-element scans on solids
- Net Acid Generation (NAG) test
- Multi-element scans on water extracts and EDTA extracts
- Leach column tests and elemental analysis of leachates

The total S assays were performed by Sydney Environmental and Soil Laboratory Pty Limited (SESL) and the multi-element scans were performed by Genalysis Pty Limited in Perth. All other test work was carried out by EGi in Sydney. The NAG tests and EDTA extractions were performed on selected samples only. Leach column tests were performed on 2 composite heap leach samples for a period of 24 weeks at the EGi laboratory. An explanation of the testing program commonly used by EGi for the assessment of the acid forming characteristics of mine waste materials is provided in Appendix A.

Multi-element scans are performed on solid samples in order to identify any significantly enriched elements. The element concentrations are compared to nominated standard compositions, typically the average crustal abundance, in order to highlight significantly enriched elements. The extent of enrichment is reported as the Geochemical Abundance Index (GAI) which relates the actual concentration to the crustal abundance on a log 2 scale. The GAI is expressed in 7 integer increments (i.e. 0

through to 6), where a GAI of 0 indicates the element is present at a concentration similar to, or less than, average crustal abundance; and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above average crustal abundance. As a general rule, a GAI of 3 or greater signifies enrichment that warrants further examination.

The EDTA extraction procedure was used to obtain information on the readily available buffering capacity and composition of oxidation products on the surface of the spent heap leach particles. This procedure involves the extraction of metallic species by chelation using an EDTA (ethylene diamine tetra-acetic acid) solution. EDTA is a very strong chelating reagent. The extraction procedure involves mixing 1 g of sample with 125 ml of the EDTA solution in the absence of oxygen (N₂ used). The solution is extracted through a 0.2µm filter after being agitated for 2 hours. This extraction procedure is also performed using a deionised water solution. The EDTA and deionised water extract solutions are assayed and the composition of precipitates and oxidation products removed from the particle surfaces by the EDTA is determined by difference as shown below:

$$\text{net EDTA conc.} = \text{EDTA conc.} - \text{deionised water conc.}$$

Based on the geochemical characteristics of the solid samples, 2 heap leach samples were selected for free-draining leach column testing. The primary objective of this test was to further investigate the solubility and potential environmental risk of identified enriched or soluble elements in the heap leach material. This test involved cyclic wetting and drying of approximately 2 kg of the 'as received' sample, and stepped water flushing and leachate collection (weekly for first month then stepped out to monthly for remainder) for a 24 week period. The rate of cyclic wetting was 100 ml/kg/week and of water flushing was 400 ml/kg/week. The surface of the leach columns was maintained at 30 to 35°C to ensure sufficient drying between wetting events.

3.0 Previous Investigations

Previous geochemical investigations carried out on the Yandan heap leach include site water quality monitoring and geochemical characterisation of the leached material. The details and results from these investigations have been provided by Wirralie Mines for review.

3.1 Geochemical Characterisation

The acid-base and NAG test results of 20 samples collected from upper 5 to 10m of the Yandan heap leach dump were provided by Wirralie Mines personnel. The analyses were performed by Australian Laboratory Services Pty Ltd (ALS) in Brisbane and the results are presented in Appendix B (Table B1).

The saturated paste pH ($\text{pH}_{\text{sat.}}$) values were alkaline and generally ranged from 8.2 to 12.4 (except 1 sample that has a $\text{pH}_{\text{sat.}}$ of 6.0). These high pH values are most likely attributed to the high pH (pH 10) of the CN irrigation solution and the direct placement of lime on the surface of the ore lifts during construction of the pads. Generally, the saturated paste electrical conductivity ($\text{EC}_{\text{sat.}}$) values were below 1.0 dS/m and these samples are classified as non-saline. However, 2 samples had $\text{EC}_{\text{sat.}}$ greater than 2.0 dS/m (2.46 & 7.33 dS/m) and these samples are classified as slightly saline to saline. These 2 samples also had the highest $\text{pH}_{\text{sat.}}$ values (11.9 & 12.4), indicating a high lime content.

The results of the acid-base analyses performed by ALS indicate that the samples had a relatively low sulphur (S) content ranging from 0.01 to 0.35 %S (mean 0.15%S) and that a large proportion of this S occurred as sulphate (mean 80%). Samples with a total S content greater than 0.2%S were selected for further acid-base and NAG testing to determine their acid forming characteristics.

The ANC values were low to moderate ranging from 8 to 37 kg $\text{H}_2\text{SO}_4/\text{t}$. However, determination of the samples acid consumption (AC) using an acid titration method with a pH 3.5 end-point indicates that the available or effective ANC of these samples was higher than the reported total ANC. This unusual finding may reflect reactions caused by the lime added during construction. For this reason the NAPP shown on Table 1 has been calculated using the acid consumption values rather than the ANC. The NAPP values are all negative and range from minus 4 to minus 45 kg $\text{H}_2\text{SO}_4/\text{t}$. The NAGpH values for these samples are all greater than 4.5 (pH range 7.1 to 8.1) confirming a non-acid forming (NAF) classification for these samples.

3.2 Water Quality Monitoring

The chemical composition of run-off and bore-hole water samples collected from around the heap leach and from the heap leach launder and pad drainage are presented in Appendix B (Tables B2 and B3). The water samples are neutral to alkaline with a pH range of 7.0 to 9.0 (run-off and groundwater), and highly saline (TDS generally 5,000mg/L). Chloride (Cl) and sulphate (SO₄) are the dominant cations and calcium (Ca) and sodium (Na) are the dominant anions. Extremely high TDS values (>10,000mg/L) are reported for some groundwater samples and are characterised by having high concentrations of Na (approx. 2,000mg/L) and Cl (approx. 5,000mg/L). Additional to the major elements, cobalt (Co) is shown to be relatively soluble (<0.01 to 8.77mg/L) in the majority of the samples including the run-off, groundwater and pad leachate. The water chemistry results presented indicate that As is not highly soluble in the run-off, groundwater or pad leachates (<0.001 to 0.099mg/L).

Cyanide (CN) and nitrogen (N) concentration data for the run-off and groundwater samples are also presented in Appendix B (Table B3). These results indicate that total CN concentrations in the run-off range from 0.1 to 0.4 mg/L and detectable concentrations occur in some of the groundwater samples (0.005 to 0.05 mg/L). Cyanide leaching ceased in August 2002 and the latest water monitoring results from the launder (29 October 2002) indicates a significant reduction in total CN (0.26 mg/L) through the process of natural decay (pers comm Glenn Creed). These results indicate that CN release is not likely to be a concern for dump closure.

The concentration of N in the run-off and groundwater is variable with some samples having concentrations as high as 200 to 500 mg/L. The source of this N is most likely from the decomposition of CN. High N concentrations in run-off and seepage may have implications for water quality (excess nutrient) during decommissioning and after closure of the dump. However, high N concentrations may have a beneficial effect on rehabilitation if the leach solution is to be recycled during decommissioning.

4.0 Geochemistry of Heap Leach Material

Based on the findings from the previous geochemical investigation, 20 additional heap leach samples were subjected to detailed geochemical characterisation to confirm the NAF nature of the heap leach materials and to further investigate salinity and metal contamination concerns. The results from this work are provided below.

4.1 Acid Forming Potential

The acid-base analyses and NAG test results for the Yandan heap leach samples are presented on Table 1. These results confirm the NAF nature of the heap leach materials as represented by sample tested.

The sulphur concentrations are low ranging from 0.02 to 0.42 %S with a mean value of 0.15 %S. Fifty percent of the samples have a total S content at or below 0.1 %S. The ANC values range from 5 to 341 kg H₂SO₄/t and the mean value is 65 kg H₂SO₄/t. Three samples had ANC values greater than 100 kg H₂SO₄/t (175 to 341 kg H₂SO₄/t) and these samples (1L2, 7L2 & 10L2) were most likely collected from areas of the pad where lime was added during construction. Excluding these samples the ANC values are low to moderate ranging from 5 to 89 kg H₂SO₄/t with a mean value of 31 kg H₂SO₄/t.

Figure 1 is an acid-base plot showing total S content compared to ANC. The ANC/MPA¹ ratio lines of 1 (NAPP=0), 2 and 3 are also shown on the plot. This plot shows that all of the samples tested are NAPP negative and have an excess capacity to neutralise acid over the potential to generate acid. The ANC/MPA can be used as a measure of the 'factor of safety' in terms of acid rock drainage (ARD) risk. Ratios values greater than 3 indicate that the material has a significant excess capacity to neutralise acid and therefore it is highly unlikely to generate acid. Hence, the samples with an ANC/MPA ratio of 3 or less (1L3, 2L3, 6L3, 9L3) and the highest S sample (8L2) were selected for NAG testing to confirm their geochemical classification. All of these samples had NAGpH values greater than 4.5 (NAGpH 6.8 to 7.9) confirming that these samples non-acid forming (NAF).

Based on these results, the samples collected from the upper 0.5m of the Yandan heap leach dump are alkaline and NAF.

¹ The Maximum Potential Acidity (MPA) is calculated by multiplying the total S content by 30.6.

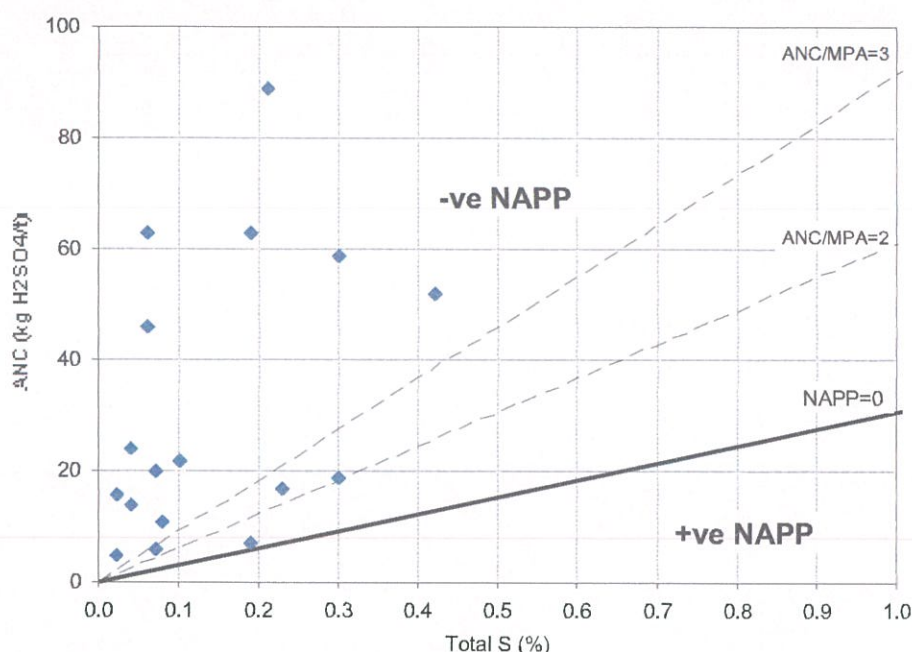


Figure 1: Acid-base plot for the Yandan Heap Leach Dump samples.

4.2 Existing pH and Salinity

The $pH_{1:2}$ and $EC_{1:2}$ results for the Yandan heap leach samples are also presented on Table 1. These results indicate that the samples are alkaline with $pH_{1:2}$ values ranging from 8.7 to 11.5. These high pH values are most likely due to a combination of the high pH of the CN irrigation solution and the direct placement of lime during pad construction. The $EC_{1:2}$ values range from 0.232 to 2.73 dS/m and the samples are classified as non- to highly saline based on the criteria provided below:

$EC_{1:2}$ Range	Salinity Rating	Proportion of Samples
0 - 0.5 dS/m	Non-saline	25 %
0.5 - 1.0 dS/m	Slightly saline	25 %
1.0 - 1.5 dS/m	Moderately saline	20 %
> 1.5 dS/m	Highly saline	30 %

4.3 Element Composition and Solubility

The results of the multi-element scans performed on the solid samples are presented on Table 2 and the respective geochemical abundance indices (GAI) are presented in Table 3. These results indicate that arsenic (As), mercury (Hg), antimony (Sb) and selenium (Se) are significantly enriched in the majority of the samples tested. Silver (Ag) and

lead (Pb) were also significantly enriched in 1 or 2 of the samples. The concentration range and average crustal abundance of these elements are provided below:

<i>Element</i>	<i>Concentration Range (mg/kg)</i>	<i>Average Crustal Abundance² (mg/kg)</i>	<i>Proportion of Samples Enriched</i>
As	31 to 257	1.5	100%
Hg	0.06 to 2.66	0.05	45%
Sb	15.6 to 144.9	0.2	100%
Se	0.47 to 7.31	0.05	100%
Ag	<0.1 to 4.1	0.07	10%
Pb	11 to 121	14	5%

Elemental scans were performed on the water extracts (1 sample:2 water) from 5 selected samples. The results from these scans are presented on Table 4 and indicate that the dominant soluble cations are Ca and Na. These results also indicate that, under the test conditions, As, Co, Cu, Sb and Se are slightly soluble in some of the samples and Ag and Hg are not soluble in any of the samples.

EDTA extraction tests were performed on the same five samples that were selected for elemental analyses on 1: 2 water extracts. The EDTA and deionised water assay data are provided in Appendix C. The deionised water, EDTA and net EDTA extracted element loads are presented on Table 5 and the extracted element load proportional to the total element content are presented on Table 6. Histograms of the average results for these are presented on Figures 2 and 3, respectively.

These results indicate that the heap leach materials contain a significant quantity of oxidation product or other secondary mineral precipitates. Calcium is the major cation in both the water and EDTA extracts and dominates the surface precipitate composition. Other cations that occur in significant quantities in this form include; Al, Fe, K and Mg, along with As, Mn and Cu. Due to the large quantity of stored oxidation products and precipitates in the heap leach material it is likely that the solubility of some of the stored elements will increase during decommissioning and post-closure as the pH reverts to more neutral conditions. NOTE: Based on the samples tested it is expected that the bulk of the heap leach materials are NAF and that the pH of the dump will revert to relatively neutral conditions post closure.

Nearly all of the Ca contained in the solid phase of the heap leach material occurs in an EDTA soluble form and it is likely that a significant proportion of this is due to lime dosing and direct lime addition to the heap leach material rather than from oxidation processes. This readily available form of Ca will buffer the heap leach interstitial water and may stabilise elements such as As and limit long-term leaching.

2 from Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, New York, p 36-37.

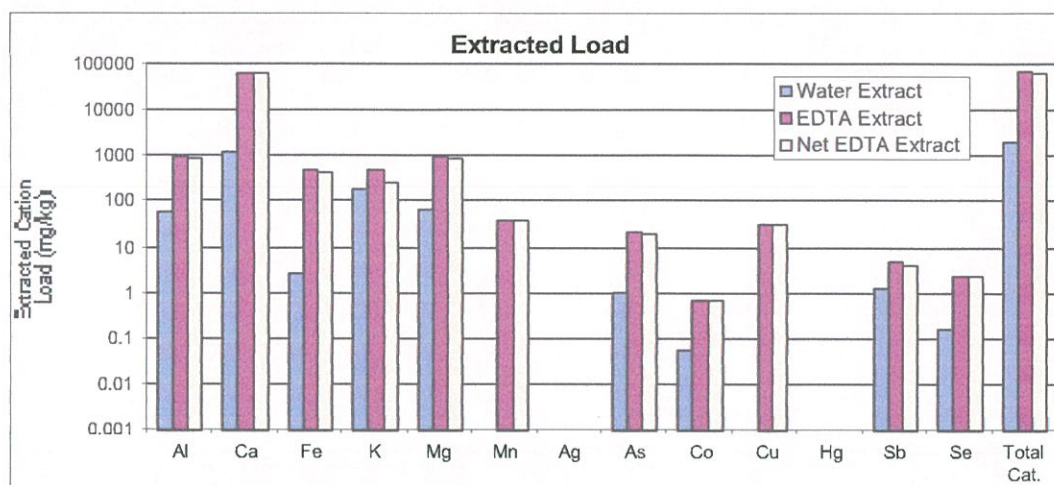


Figure 2: Histogram of extracted cation loads in the deionised water, EDTA and net EDTA extracts.

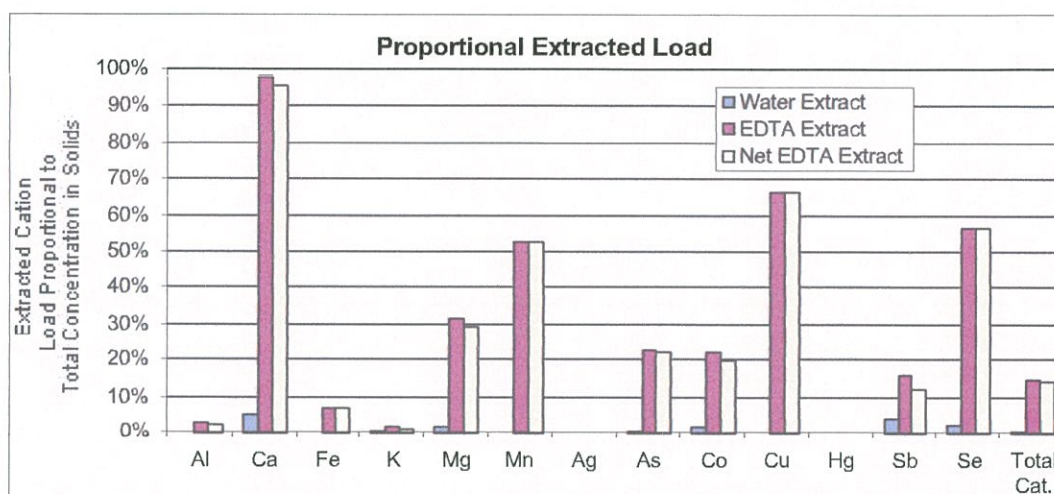


Figure 3: Histogram of proportion of cations in the solid sample extracted using EDTA procedure.

Silver and Hg were not detected in the EDTA or deionised water solution indicating that these cations occur in their primary mineral form and are not likely to present a solubility concern during decommissioning and post-closure.

Two leach column tests were operated for a 24 week period to further investigate the leaching behaviour and predicted metal release from the heap leach material. The selected samples represent material with a relatively low content of EDTA extractable material (sample 5L3) and material with a relatively high content of EDTA extractable material (sample 10L2).

The results from the leach column tests are presented on Tables 7 and 8 for sample 5L3 and 10L2, respectively. These results indicate relatively rapid flushing of the dominant soluble constituents including Ca, Na, Cl and SO₄. Figure 4 is a line plot of the

electrical conductivity (EC) of the leachates over time and shows the rapid depletion of EC caused by flushing of readily soluble salts from these materials. Using irrigation water criteria³ leachates from these material initially had a high to extreme rating and after 2 weeks for sample 5L3 and 24 weeks for sample 10L2 the rating dropped to low.

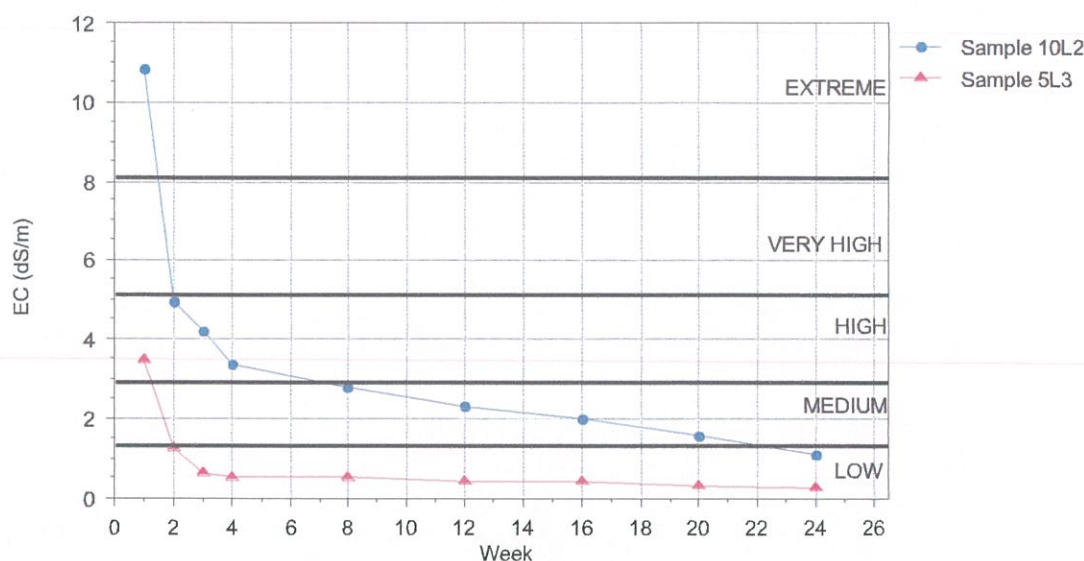


Figure 4: Line plot showing the electrical conductivity (EC) of column leachates through time. Irrigation water salinity ratings are also shown (Ref. ANZECC 2000).

Line plots showing As, Co, Mo and Se concentrations in the column leachates over time are presented on Figures 5 to 8, respectively. These plots show that, as with the EC values, Co, Mo and Se occur in lower concentrations in sample 5L3 compared to sample 10L2 (NOTE: sample 5L3 has a lower content of EDTA extractable material than sample 10L2). Additionally, these plots show a rapid decreasing trend in Co, Mo and Se concentrations during the initial phase of the leaching program. This trend indicates rapid flushing of readily soluble Co, Mo and Se phases such as secondary surface precipitates and oxides.

Cobalt, Mo and Se concentrations exceeded the ANZECC (2000) irrigation water criteria during the initial phase of the leaching program. However, the concentration of elements in sample 5L3 decreased to below the respective criteria within the first few weeks of leaching, and for sample 10L2 showed a trend that indicates the concentrations will decrease to below these criteria within 24 to 48 weeks of leaching.

Differing from these trends, the As concentrations (Figure 5) were an order of magnitude higher in leachates from 5L3 compared to 10L2 and no marked decreasing trends were evident. Leachates from sample 10L2 had As concentrations well below the irrigation water criteria, however those for sample 5L3 remained above the criteria throughout the leaching period. These trends indicate continual release of moderate

³ ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

concentrations of As from sample 5L3 rather than flushing of high concentrations during the initial phase of leaching as with the other identified soluble elements.

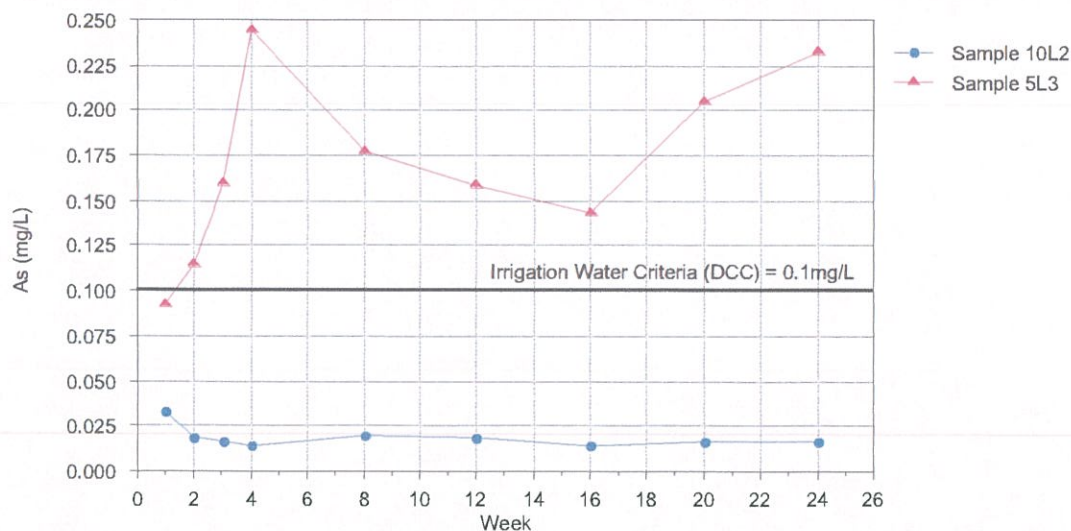


Figure 5: Line plot showing arsenic concentration in column leachates through time. Irrigation water criteria for Desirable Contamination Concentration (DCC) is also shown (Ref. ANZECC 2000).

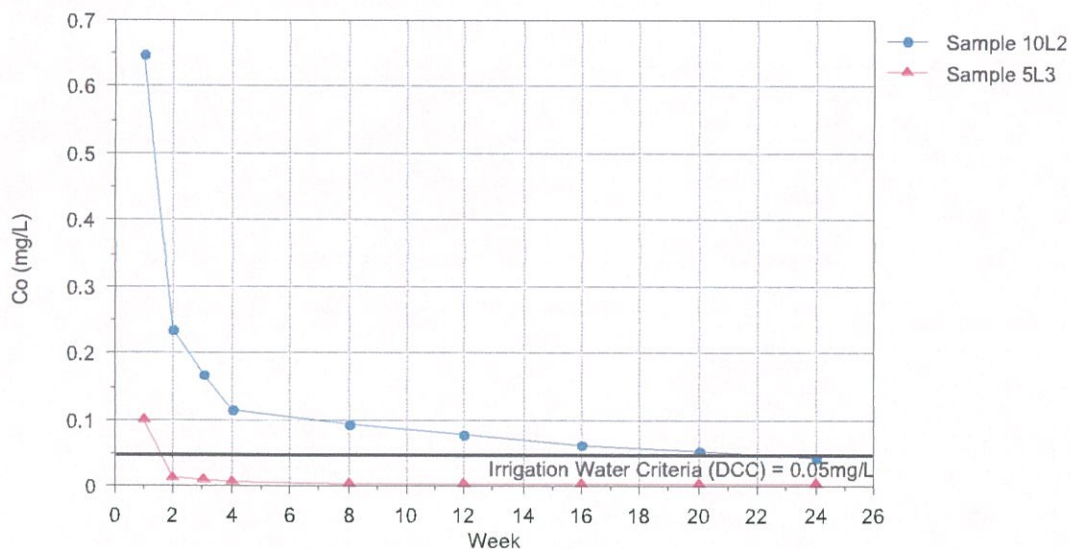


Figure 6: Line plot showing cobalt concentration in column leachates through time. Irrigation water criteria for Desirable Contamination Concentration (DCC) is also shown (Ref. ANZECC 2000).

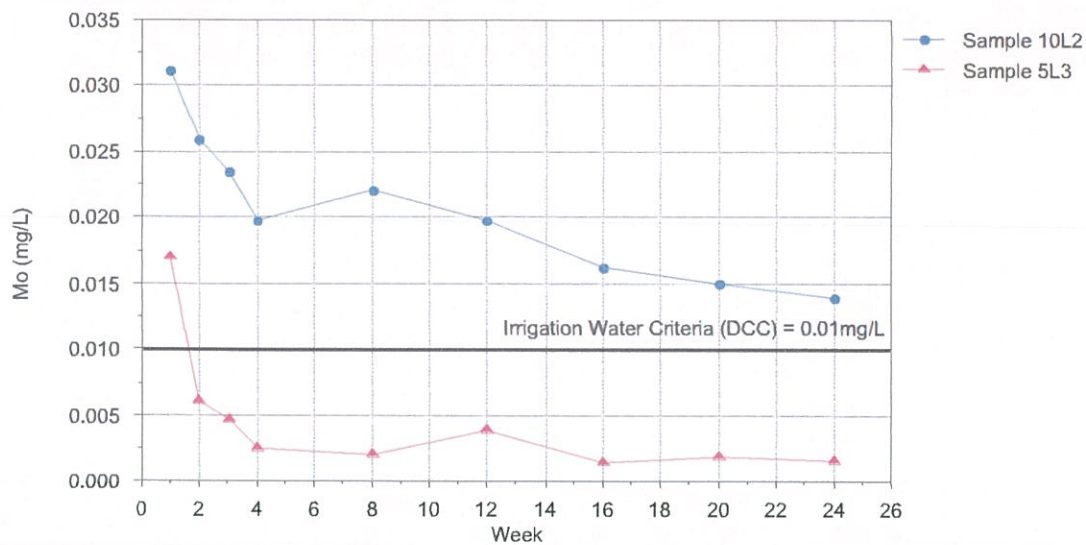


Figure 7: Line plot showing molybdenum concentration in column leachates through time. Irrigation water criteria for Desirable Contamination Concentration (DCC) is also shown (Ref. ANZECC 2000).

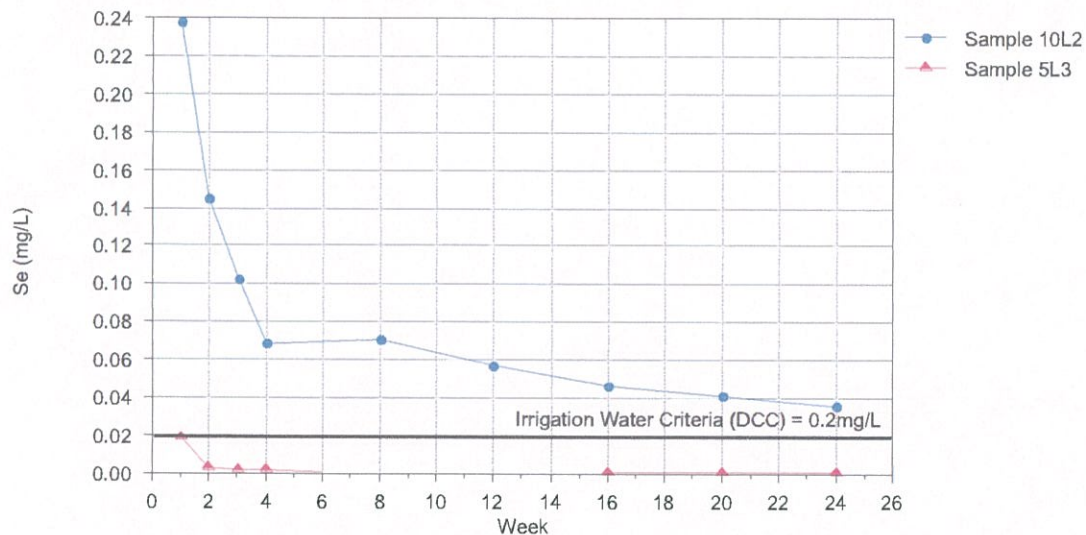


Figure 8: Line plot showing selenium concentration in column leachates through time. Irrigation water criteria for Desirable Contamination Concentration (DCC) is also shown (Ref. ANZECC 2000).

Figure 9 is a plot of SO_4 compared to Ca in leachates from both columns. The relationship between Ca and SO_4 indicates strong gypsum control on the solubility of these constituents in sample 10L2, whereas there is no indication of gypsum solubility control in sample 5L3. Following on from this, Figure 10 is a plot of As compared to Ca in leachates from the columns. This plot shows that the sample containing high soluble Ca, which is currently under gypsum solubility control (sample 10L2), has relatively low As solubility. This relationship confirms that the solubility of As in this material type is being partially controlled through Ca buffering mechanisms and this

control is expected to continue while gypsum solubility control is in effect. However, once gypsum dissolution is complete, Ca solubility control will be lost and therefore increased As release, similar to sample 5L3, can be expected.

These results indicate a likely primary mineral source for the soluble As in sample 5L3. This sample has a total As concentration of 141 mg/kg in the solid phase (see Table 2) and an EDTA extractable concentration (ie As that occurs in oxidation products or other secondary mineral precipitates) of 7.9 mg/kg (see Table 5). After 24 weeks of leaching less than 1 % of the total As in the sample had been released.

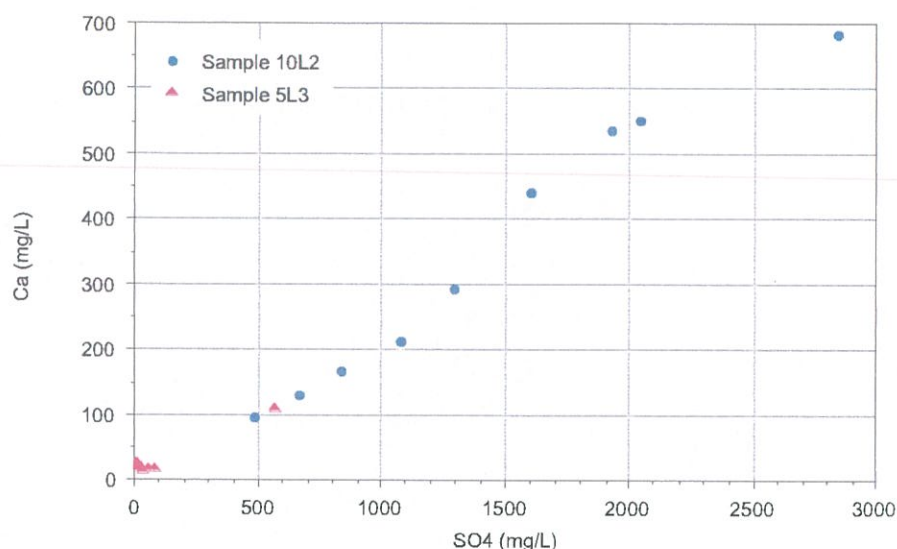


Figure 9: Scatterplot showing sulphate concentrations compared to calcium concentrations in leachates from both columns.

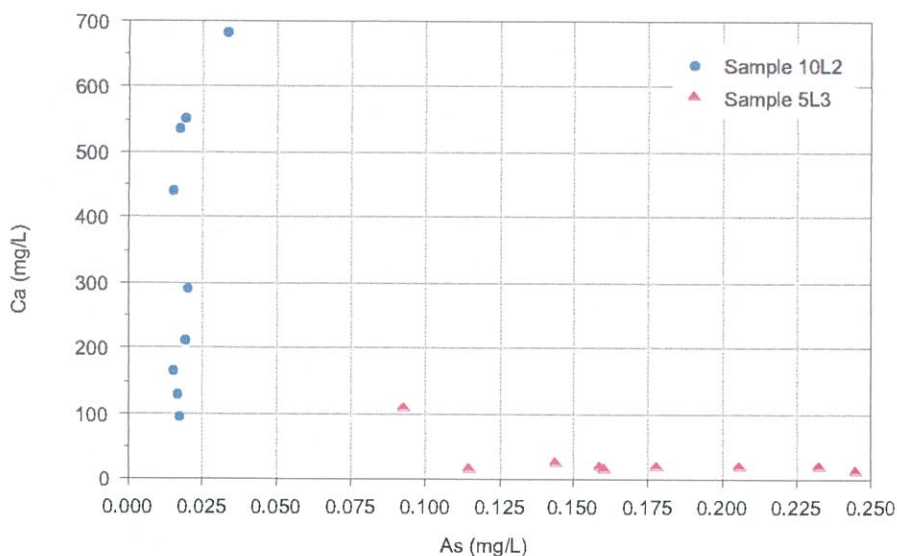


Figure 10: Scatterplot showing arsenic concentrations compared to calcium concentrations in leachates from both columns.

5.0 Conclusions and Recommendations

Previous and current geochemical test work results from the Yandan heap leach have been used to identify the geochemical concerns for closure and rehabilitation of the dump. Based on the results available to-date the following conclusions and recommendations for closure planning are provided:

- Based on the samples tested and the information provided, the spent heap leach materials are expected to be non-acid forming.
- The heap leach is expected to generate highly saline run-off and seepage for a period after decommissioning, however, as the heap is flushed post-closure the salinity will stabilise and run-off and seepage is expected to have a low irrigation rating.
- Based on the samples tested, arsenic (As), mercury (Hg), antimony (Sb) and selenium (Se) are enriched in the solid phase of the heap leach materials.
- The heap leach materials contain significant quantities of surface precipitate (oxidation product or other secondary mineral precipitates) consisting primarily of Ca and other cations including; Al, Fe, K and Mg, along with As, Mn and Cu. Nearly all of the Ca contained in the solid samples occurs as a secondary product (mostly gypsum – CaSO_4) which is most likely a product of lime dosing and direct lime addition to the heap leach pads. This available form of Ca, by buffering the heap leach interstitial water, helps stabilise elements such as As therefore controlling its solubility and release. However, this control on As solubility will only occur while gypsum solubility control is an active process (ie until gypsum dissolution is complete).
- Water chemistry results from the site water quality monitoring program confirm that run-off and seepage from the heap leach is neutral to alkaline and highly saline comprising predominantly soluble salts of Ca, Na, Cl and SO_4 . Additionally, the concentration of N in solution is high which may have implications for water quality. Relatively high concentrations of Co and to a lesser degree As were also detected in the site water.
- An initial flush of high Co, Mo and Se from secondary mineral products in the heap leach material is likely to occur after closure of the heap. However, after a relatively short period the local release concentrations (not allowing for dilution or concentration) are expected to decrease to below the ANZECC (2000) irrigation water criteria. Mercury is not expected to present a solubility concern during decommissioning or post-closure.
- Arsenic release may be a concern for water quality during and post-closure. The results from the leaching program indicate that some materials are likely to release As concentrations that exceed the ANZECC irrigation criteria, however this does not take into consideration dilution effects and therefore a detailed monitoring program will be required during and post-closure to establish the overall As release from the dump.

- These investigations indicate that the Yandan heap leach dump will require re-profiling and a relatively simple soil cover to reduce the risk of As contaminated dust impacting the surrounding area, and adverse salinity effects on re-vegetation and water quality. Additionally, controlled release of water, whereby dump drainage is released during periods of high flow due to increased dilution, may be required due to the flushing of Co, Mo and Se, after closure and expected longer-term release of As. To determine the need for controlled water release a detailed monitoring program will be required. This program should primarily be designed to monitor the overall initial release loads of Co, Mo and Se during closure and the longer-term release load of As, and therefore will need to include rainfall and flow monitoring.

Appendix A

Assessment of Acid Forming Characteristics

Appendix A

Assessment of Acid Forming Characteristics

Introduction

Acid rock drainage (ARD) is produced by the exposure of sulphide minerals such as pyrite to atmospheric oxygen and water. The ability to identify in advance any mine materials that could potentially produce ARD is essential for timely implementation of mine waste management strategies.

A number of procedures have been developed to help assess the acid forming characteristics of mine waste materials. The most widely used assessment methods for ARD characterisation are the Acid-Base Account (ABA) and the Net Acid Generation (NAG) test. These methods are referred to as static procedures because each involves a single measurement in time.

Acid-Base Account

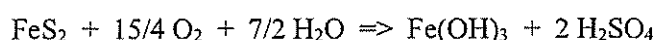
The acid-base account involves static laboratory procedures that evaluate the balance between acid generation processes (oxidation of sulphide minerals) and acid neutralising processes (dissolution of alkaline carbonates, displacement of exchangeable bases, and weathering of silicates).

The values arising from the acid-base account are referred to as the maximum potential acidity (MPA) and the acid neutralising capacity (ANC), respectively. The difference between the MPA and ANC value is referred to as the net acid producing potential (NAPP).

The chemical and theoretical basis of the ABA are discussed below.

Maximum Potential Acidity

The MPA that can be generated by a sample is determined from the sample sulphur content. The total sulphur content of a sample is commonly determined by the Leco high temperature combustion method. The calculation assumes that all the sulphur measured in the sample occurs as pyrite (FeS₂) and that the pyrite reacts under oxidising conditions to generate acid according to the reaction:



According to this reaction, the MPA of a sample containing 1 %S as pyrite would be 30.6 kilograms of H₂SO₄ per tonne of material (*i.e.* kg H₂SO₄/t). Hence the MPA of a sample is calculated from the total sulphur content using the following formula:

$$\text{MPA (kg H}_2\text{SO}_4\text{/t)} = (\text{Total \%S}) \times 30.6$$

The use of the total sulphur assay to estimate the MPA is a conservative approach because some sulphur may occur in forms other than pyrite. Sulphate-sulphur and native sulphur, for example, are non-acid generating sulphur forms. Also, some sulphur may occur as other metal sulphides (e.g. covellite, chalcocite, sphalerite, galena) which yield less acidity than pyrite when oxidised or, in some cases, may be non-acid generating.

The total sulfur content is commonly used to assess MPA because of the difficulty and costs involved in routinely determining the speciation of sulfur forms within samples and determining reactive sulphide-sulfur contents. However, if the sulphide mineral forms are known then allowance can be made for non- and lesser acid generating sulfur forms to provide a better estimate of the MPA.

Acid Neutralising Capacity

The acid formed from pyrite oxidation will to some extent react with acid neutralising minerals contained within the sample. This inherent acid buffering is quantified in terms of the ANC.

The ANC is commonly determined by the Modified Sobek method. This method involves the addition of a known amount of standardised hydrochloric acid (HCl) to an accurately weighed sample, allowing the sample time to react (with heating), then back-titrating the mixture with standardised sodium hydroxide (NaOH) to determine the amount of unreacted HCl. The amount of acid consumed by reaction with the sample is then calculated and expressed in the same units as the MPA, that is kg H₂SO₄/t.

Net Acid Producing Potential

This is a theoretical calculation commonly used to indicate if a material has potential to produce acidic drainage. It represents the balance between the capacity of a sample to generate acid (MPA) and its capacity to neutralise acid (ANC). The NAPP is also expressed in units of kg H₂SO₄/t and is calculated as follows:

$$\text{NAPP} = \text{MPA} - \text{ANC}$$

If the MPA is less than the ANC then the NAPP is negative, which indicates that the sample may have sufficient ANC to prevent acid generation. Conversely, if the MPA exceeds the ANC then the NAPP is positive, which indicates that the material may be acid generating.

ANC/MPA Ratio

The ANC/MPA ratio is frequently used as a means of assessing the risk of acid generation from mine waste materials. The ANC/MPA ratio is another way of looking at the acid base account. A positive NAPP is equivalent to an ANC/MPA ratio less than 1, and a negative NAPP is equivalent to an ANC/MPA ratio greater than 1. A NAPP of zero is equivalent to an ANC/MPA ratio of 1.

The purpose of the ANC/MPA ratio is to provide an indication of the relative margin of safety (or lack thereof) within a material. Various ANC/MPA values are reported in the literature for indicating safe values for prevention of acid generation. These values typically range from 1 to 3. As a general rule, a ANC/MPA ratio of 2 or more generally signifies that there is a high probability that the material will remain circum-neutral in pH and thereby should not be problematic with respect to acid rock drainage.

Acid-Base Account Plot

Sulphur and ANC data are often presented graphically in a format similar to that shown in Figure 1. This figure includes a line indicating the division between NAPP positive samples from NAPP negative samples. Also shown are lines corresponding to ANC/MPA ratios of 2 and 3.

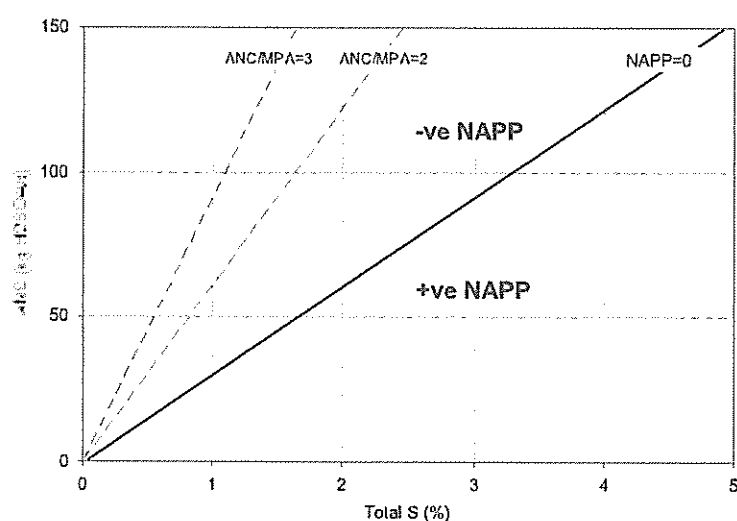


Figure A-1. Acid-base account (ABA) plot

Net Acid Generation (NAG) Test

The NAG test is used in association with the NAPP to classify the acid generating potential of a sample. The NAG test involves reaction of a sample with hydrogen peroxide to rapidly oxidise any sulphide minerals contained within a sample. During the NAG test both acid generation and acid neutralisation reactions can occur simultaneously. Therefore, the end result represents a direct measurement of the net amount of acid generated by the sample. This value is commonly referred to as the NAG capacity and is expressed in the same units as NAPP, that is kg H₂SO₄/t.

Several variations of the NAG test have been developed to accommodate the wide geochemical variability of mine waste materials. The three main NAG test procedures currently used by EGI are the single addition NAG test, the sequential NAG test, and the kinetic NAG test.

Single Addition NAG Test

The single addition NAG test involves the addition of 250 mL of 15% hydrogen peroxide to 2.5 gm of sample. The peroxide is allowed to react with the sample overnight and the following day the sample is gently heated to accelerate the oxidation of any remaining sulphides, then vigorously boiled for several minutes to decompose residual peroxide. When cool, the pH and acidity of the NAG liquor are measured. The acidity of the liquor is then used to estimate the net amount of acidity produced per unit weight of sample.

An indication of the form of the acidity is provided by initially titrating the NAG liquor to pH 4.5, then continuing the titration up to pH 7. The titration value at pH 4.5 includes acidity due to free acid (*i.e.* H_2SO_4) as well as soluble iron and aluminium. The titration value at pH 7 also includes metallic ions that precipitate as hydroxides at pHs between 4.5 and 7.

Sequential NAG Test

When testing samples with high sulphide contents it is not uncommon for oxidation to be incomplete in the single addition NAG test. This can sometimes occur when there is catalytic breakdown of the hydrogen peroxide before it has had a chance to oxidise all of the sulphides in a sample. To overcome this limitation, a multi-stage sequential NAG test is often carried out. This test may also be used to assess the relative geochemical lag of PAF samples with high ANC.

The sequential NAG test is a multi-stage procedure involving a series of single addition NAG tests on the one sample (*i.e.* 2.5 g of sample is reacted two or more times with 250 mL aliquots of 15% hydrogen peroxide). At the end of each stage, the sample is filtered and the solution is used for measurement of NAGpH and NAG capacity. The NAG test is then repeated on the solid residue. The cycle is repeated until such time that there is no further catalytic decomposition of the peroxide, or when the NAGpH is greater than pH 4.5. The overall NAG capacity of the sample is then determined by summing the individual acid capacities from each stage.

Kinetic NAG Test

The kinetic NAG test is the same as the single addition NAG test except that the temperature, pH and sometimes EC of the liquor are recorded. Variations in these parameters during the test provide an indication of the kinetics of sulphide oxidation and acid generation during the test. This, in turn, can provide an insight into the behaviour of the material field under field conditions. For example, the pH trend gives an estimate of relative reactivity and may be related to prediction of lag times and oxidation rates similar to those measured in leach columns. Also, sulphidic samples commonly produce a temperature excursion during the NAG test due to the

decomposition of the peroxide solution, catalysed by sulphide surfaces and/or oxidation products.

Sample Classification

The acid forming potential of a sample is classified on the basis of the acid-base and NAG test results into one of the following categories:

- Barren,
- Non-acid forming (NAF),
- Potentially acid forming (PAF), and
- Uncertain (UC).

Barren

A sample classified as barren essentially has no acid generating capacity and no acid buffering capacity. This category is most likely to apply to highly weathered materials. In essence, it represents an 'inert' material with respect to acid generation. The criteria used to classify a sample as barren may vary between sites, but for hard rock mines it generally applies to materials with a total sulfur content $\leq 0.1\%$ S and an ANC ≤ 5 kg H₂SO₄/t.

Non-acid forming (NAF)

A sample classified as NAF may, or may not, have a significant sulfur content but the availability of ANC within the sample is more than adequate to neutralise all the acid that theoretically could be produced by any contained sulphide minerals. As such, material classified as NAF is considered unlikely to be a source of acidic drainage. A sample is usually defined as NAF when it has a negative NAPP negative and the final NAG pH ≥ 4.5 .

Potentially acid forming (PAF)

A sample classified as PAF always has a significant sulfur content, the acid generating potential of which exceeds the inherent acid neutralising capacity of the material. This means there is a high risk that such a material, even if pH circum-neutral when freshly mined or processed, could oxidise and generate acidic drainage if exposed to atmospheric conditions. A sample is usually defined as PAF when it has a positive NAPP and a final NAGpH < 4.5 .

Uncertain (UC)

An uncertain classification is used when there is an apparent conflict between the NAPP and NAG results (*i.e.* when the NAPP is positive and NAGpH > 4.5 , or when the NAPP is negative and NAGpH ≤ 4.5). Uncertain samples are generally given a tentative classification that is shown in brackets *e.g.* UC(NAF).

Figure A-2 shows the format of the ARD classification plot which is commonly typically used for presentation of geochemical data. Marked on this plot are the quadrat representing the NAF, PAF and UC classifications.

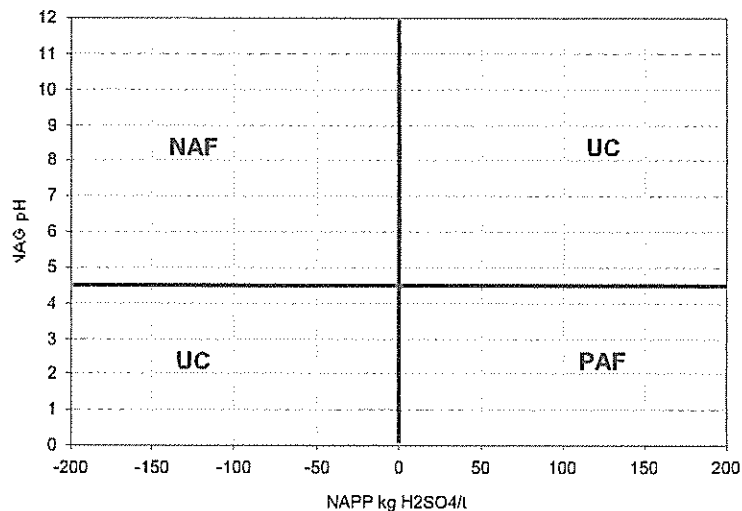


Figure A-2 ARD classification plot

Other Methods

Other test procedures may be used to define the acid forming characteristics of a sample.

pH and Electrical Conductivity

The pH and electrical conductivity (EC) of a sample is determined by equilibrating the sample in deionised water for a minimum of 1 hour, typically at a solid to water ratio of 1:2 (w/w). This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Acid Buffering Characteristic Curve (ABCC) Test

The ABCC test involves slow titration of a sample with acid while continuously monitoring pH. This data provides an indication of the portion of ANC within a sample that is readily available for acid neutralisation.

Appendix B

Results from Previous Geochemical Investigations

Table B1: Acid forming characteristics of the Yandan Heap Leach samples from the ALS results.

Sample Code	pH _{sat.}	EC _{sat.} (uS/cm)	ACID-BASE ANALYSIS							NAG TEST	
			Total S	SO ₄ -S (%S)	Sulph-S	MPA	ANC	AC	NAPP	NAGpH	NAG (kg H ₂ SO ₄ /t)
			(kg H ₂ SO ₄ /t)								
1 L2	8.9	428	0.10	0.07	0.03	1	-	-	-	-	-
1 L3	10.0	820	0.35	0.21	0.14	4	11	14	-4	7.6	0
2 L2	10.4	490	0.20	0.16	0.04	1	-	-	-	-	-
2 L3	10.0	901	0.19	0.19	0.00	0	-	-	-	-	-
3 L2	9.7	248	0.01	0.01	0.00	0	-	-	-	-	-
3 L3	9.1	614	0.23	0.15	0.08	3	8	11	-4	7.1	0
4 L2	9.7	152	0.03	0.02	0.01	0	-	-	-	-	-
4 L3	10.1	800	0.13	0.13	0.00	0	-	-	-	-	-
5 L2	12.4	7330	0.23	0.23	0.00	0	37	52	-45	8.1	0
5 L3	9.4	297	0.08	0.06	0.02	1	-	-	-	-	-
6 L2	9.5	380	0.10	0.09	0.01	0	-	-	-	-	-
6 L3	9.5	328	0.14	0.13	0.01	0	-	-	-	-	-
7 L2	11.9	2460	0.10	0.10	0.00	0	-	-	-	-	-
7 L3	8.2	592	0.09	0.04	0.05	2	-	-	-	-	-
8 L2	9.5	835	0.28	0.24	0.04	1	14	24	-15	7.9	0
8 L3	6.0	467	0.05	0.03	0.02	1	-	-	-	-	-
9 L2	10.1	718	0.18	0.18	0.00	0	-	-	-	-	-
9 L3	9.5	722	0.18	0.08	0.10	3	-	-	-	-	-
10 L2	8.2	1010	0.18	0.18	0.00	0	-	-	-	-	-
11 L2	9.3	362	0.05	0.02	0.03	1	-	-	-	-	-

KEY

sat. - Saturation Paste Extract
 MPA - Maximum Potential Acidity calculated using Sulphide S content
 ANC - Acid Neutralising Capacity
 AC - Acid Consumption
 NAPP - Net Acid Producing Potential
 NAGpH - pH of NAG test solution
 NAG - Net Acid Generation

Table B2: Chemical composition of runoff and bore-hole water samples from the Yandan Heap Leach.

Parameter	Units	Detection Limit*	RUNOFF SAMPLES			BORE-HOLE SAMPLES													
			HL Runoff		Leak	HL1			HL2		HL3			HL4		HL5	HL6		HL7
			Feb-01	Aug-01	Aug-01	Feb-01	Jul-01	Aug-01	Jan-00	Aug-01	Jan-00	Jul-01	Jan-00	Feb-01	Jul-01	Jan-00	Jan-00	Jul-01	Jan-00
pH		0.1	8.8	8.0	7.4	8.0	8.0	7.9	8.2	7.6	7.8	9.0	8.0	9.0	7.9	7.0	7.0	8.0	7.1
TDS	mg/l	1	5000	4950	4970	5370	4580	10700	4600	436	1780	1970	10900	11900	5410	4630	1250	5550	7460
CO3	mg/l	1	<	<	<	<	-	<	-	<	-	-	-	<	<	-	-	-	-
HCO3	mg/l	1	44	32	131	320	-	2070	-	282	-	-	-	491	325	-	-	-	-
SO4	mg/l	1	1290	1070	1060	870	-	447	-	16	-	-	-	760	920	-	-	-	-
Cl	mg/l	1	1270	1300	1280	1600	-	5520	-	110	-	-	-	5300	2090	-	-	-	-
N	mg/l	1	226	317	281	165	1.4	503	-	31.5	-	1.9	-	2.2	145	-	-	151	-
Al	mg/l	0.05	0.14	<	<	0.22	<	<	0.02	<	<	<	<	0.18	<	<	<	<	0.42
As	mg/l	0.001	0.022	0.099	0.003	0.003	0.006	0.024	0.014	0.012	0.004	0.011	0.018	0.005	0.001	0.01	0.009	0.001	0.013
B	mg/l	0.1	<	<	0.1	0.2	0.5	0.8	0.3	0.1	0.4	<	1.1	0.8	0.8	0.5	0.3	0.7	1.2
Ba	mg/l	0.1	0.1	<	<	<	<	0.2	0.12	<	0.02	<	0.07	<	<	0.02	0.05	<	0.02
Ca	mg/l	1	217	235	231	54	151	69	41	6	18	39	167	161	57	146	22	54	51
Cd	mg/l	0.001	<	0.009	0.001	<	<	<	0.0003	0.007	0.0008	<	0.013	0.008	0.006	0.0031	0.0004	0.0004	0.0023
Co	mg/l	0.01	0.3	0.45	0.45	0.28	0.04	<	0.01	<	<	1.37	<	<	0.27	<	<	1	<
Cr	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Cu	mg/l	0.001	0.01	0.008	0.003	0.007	0.037	0.018	0.012	0.004	0.006	0.003	0.014	0.011	0.008	0.004	0.004	0.007	0.01
Fe	mg/l	0.1	0.04	0.11	0.16	0.07	<	0.64	0.4	<	<	0.07	<	0.14	<	<	<	<	0.09
Hg	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	mg/l	1	104	98	70	8	14	85	57	7	5	4	32	50	7	12	4	7	34
Mg	mg/l	1	20	12	53	205	426	581	352	26	81	157	836	782	199	397	114	207	458
Mn	mg/l	0.01	<	0.01	1.0	0.05	0.01	0.97	0.6	0.65	<	<	0.22	0.22	0.15	0.07	0.22	0.06	0.05
Mo	mg/l	0.01	<	0.02	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Na	mg/l	1	1480	1400	1310	1420	900	1650	939	88	477	552	2510	2300	1590	892	234	1560	1970
Ni	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
P	mg/l	1	<	<	<	<	<	2	2.54	<	0.39	<	<	<	<	<	<	<	<
Pb	mg/l	0.01	<	<	<	<	<	<	0.002	<	<	<	0.022	0.004	<	<	<	<	0.001
Si	mg/l	0.01	5.48	13	14.1	9.84	7.76	13.9	6.1	12.2	11.1	9.93	6.2	9.09	9.05	6.7	4.9	8.92	9.3
Sr	mg/l	0.01	2.10	2.50	2.00	1.60	2.10	3.50	2.07	0.20	0.46	0.70	3.98	4.00	1.70	2.13	0.35	1.60	2.65
V	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	4.40
Zn	mg/l	0.001	0.008	0.011	0.009	0.021	0.107	0.037	0.073	0.004	0.081	0.002	0.273	0.132	0.063	0.108	0.038	0.012	0.163
Total CN	mg/l	0.005	0.09	0.365	0.455	0.105	<	<	0.005	<	0.005	<	<	<	0.045	<	<	<	<
Free CN	mg/l	0.005	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
WAD CN	mg/l	0.005	0.035	0.025	0.06	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<

* The highest detection limit reported has been used.

Table B3: Chemical composition of leach water samples from the Yandan Heap Leach.

Parameter	Units	Detection Limit	Lauder		PAD 2	PAD 3	PAD 4	PAD 5
			Aug-01	Sep-01	Oct-01	Oct-01	Oct-01	Aug-01
pH	mg/l	0.1	-	-	-	-	-	-
TDS	mg/l	1	<	<	5780	5150	5770	6290
CO3	mg/l	1	<	<	<	<	<	<
HCO3	mg/l	1	13	13	<	<	<	<
SO4	mg/l	1	1100	1100	953	968	1010	1050
Cl	mg/l	1	1310	1310	3080	2480	2980	3480
N	mg/l	1	264	-	252	247	245	237
Al	mg/l	0.05	0.44	0.44	<	<	<	<
As	mg/l	0.001	0.022	0.022	0.088	0.069	0.081	<
B	mg/l	0.1	<	<	<	<	<	<
Ba	mg/l	0.1	<	<	0.1	<	<	<
Ca	mg/l	1	12	12	236	225	247	277
Cd	mg/l	0.001	<	<	<	<	<	<
Co	mg/l	0.001	0.44	0.44	0.43	0.43	0.44	0.44
Cr	mg/l	0.01	<	<	<	<	<	<
Cu	mg/l	0.001	0.072	0.072	0.018	0.024	0.019	0.001
Fe	mg/l	0.001	0.23	0.23	0.14	0.31	0.09	0.08
Hg	mg/l	0.0001	0.0005	0.0005	<	0.0018	0.0003	0.0009
K	mg/l	1	85	85	74	80	78	71
Mg	mg/l	1	12	12	22	16	11	13
Mn	mg/l	0.01	0.03	0.03	0.05	0.06	<	0.04
Mo	mg/l	0.01	0.03	0.03	<	0.02	0.03	0.02
Na	mg/l	1	1320	1320	1410	1380	1430	1400
Ni	mg/l	0.01	<	<	<	0.02	<	<
P	mg/l	1	<	<	<	<	<	<
Pb	mg/l	0.001	<	<	<	<	<	<
Si	mg/l	0.1	12.1	12.1	13.4	11.7	11.7	11.8
Sr	mg/l	0.1	2.5	2.5	1.7	2.2	2.7	2.6
V	mg/l	0.01	<	<	1.05	1.05	1.05	1.05
Zn	mg/l	0.001	0.009	0.009	0.007	0.010	0.007	<

Appendix C

EDTA Extraction Test Data

Multi-element assay data for the EDTA and deionised water extracts.

Water	5L3		7L2		8L3		10L2		BLANK	
	EDTA	D/Water	EDTA	D/Water	EDTA	D/Water	EDTA	D/Water	EDTA	D/Water
1001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
46	3.56	0.35	10.59	0.37	5.74	0.37	19.25	0.61	0.03	0.02
104	0.103	0.024	0.142	0.002	0.132	0.019	0.447	0.007	<0.001	<0.001
31	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01
387	0.2644	0.0108	0.4150	0.0108	0.4904	0.0125	0.6261	0.0225	0.0009	0.0005
301	0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001
39	66.42	6.31	998.45	15.81	93.83	6.76	1348.83	20.8	0.79	0.64
1002	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	0.0004	<0.0002	<0.0002	<0.0002
2	6	<2	12	6	6	<2	8	2	4	<2
101	0.002	<0.001	0.007	0.001	0.004	<0.001	0.011	0.001	<0.001	<0.001
.01	0.01	<0.01	0.05	<0.01	0.01	<0.01	0.07	<0.01	<0.01	<0.01
.01	0.07	<0.01	0.31	<0.01	0.03	<0.01	0.98	<0.01	0.02	<0.01
2	<0.2	0.2	<0.2	0.2	<0.2	0.2	0.2	0.2	<0.2	0.2
301	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
0	5.1	2.5	4.8	2.2	4.2	1.5	4.7	1.6	0.4	<0.1
51	2.11	0.16	14.69	0.61	3.17	0.24	18.52	2.03	0.20	0.03
.01	0.09	<0.01	0.37	<0.01	0.30	<0.01	0.77	<0.01	<0.01	<0.01
101	0.0008	<0.0005	0.0022	<0.0005	0.0007	<0.0005	0.0041	<0.0005	<0.0005	<0.0005
.6	-	0.9	-	9.9	-	2.9	-	3.2	-	1.3
.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	0.12	<0.01	<0.01	<0.01
1.1	0.3	0.1	1.4	<0.1	0.4	<0.1	2.6	<0.1	0.2	<0.1
305	0.052	<0.005	0.895	<0.005	0.038	<0.005	0.212	<0.005	<0.005	<0.005
124	0.0047	0.0010	0.0419	0.0085	0.0030	0.0008	0.1684	0.0464	0.0002	<0.0001
305	<0.005	<0.005	0.030	<0.005	<0.005	<0.005	0.080	0.008	<0.005	<0.005
46	3.70	1.32	18.98	2.68	6.38	1.50	33.10	1.54	0.39	<0.05
301	0.004	<0.001	0.005	0.001	0.005	<0.001	0.005	<0.001	0.005	<0.001
.7	6.3	2.4	46.3	28.1	8.5	3.3	62.6	35.7	3.2	<0.3
34	1.38	0.02	4.18	0.02	0.89	<0.01	9.99	0.05	0.30	<0.01
.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	0.13	<0.01	<0.01	<0.01
31	0.03	0.01	0.09	0.01	0.03	0.01	0.14	0.02	0.03	0.02

PRELIMINARY MINE RECLAMATION
AND CLOSURE PLAN
MINING LEASES ML 1095 & ML 1096
YANDAN GOLD MINE

Prepared for

Ross Mining NL

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HLA-Envirosciences Project No R1039/1

by

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18 August 2000

This document was prepared for the sole use of Ross Mining NL and the regulatory agencies that are directly involved in this project, the only intended beneficiaries of our work. No other party should rely on the information contained herein without the prior written consent of HLA-Envirosciences Pty Limited and Ross Mining NL.

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

1.1 Background

Ross Mining N.L. (Ross Mining) commissioned HLA-Envirosciences Pty Limited (HLA) in April 2000 to prepare a Preliminary Mine Closure Plan (MCP) for the Yandan Gold Mine in Central Queensland. The Yandan Gold Mine comprises Mining Leases ML1095 and ML 1096 and is located approximately 220 km south of Townsville and 230 km west of Mackay, as shown in Figure 1.

The Yandan Gold Deposit was a greenfields discovery by Western Mining Corporation (WMC) in early 1986. An Impact Assessment Study (IAS) was prepared for the project in December 1988 and the Department of Minerals and Energy subsequently granted with Mining Leases 1095 and 1096. The areas of Mining Leases 1095 and 1096 are 320 ha and 80 ha respectively.

Ross Mining acquired these Mining Leases from WMC in July 1992. Based upon the IAS, Ross Mining prepared an Environmental Management Overview Strategy (EMOS) in December 1992 that incorporated some variations from commitments given by the IAS due to changes in the initial development program that included the inclusion of dump leaching. Mining and milling operations subsequently took place between September 1993 and early 1999. Dump leach operations were anticipated to continue at the site to at least the end of 2000.

To assist with the preparation of the MCP, HLA staff undertook a field visit to the mine in April 2000 to assess the physical environment at the Yandan Gold Mine and surrounds. This Report represents the MCP that was subsequently prepared to conform with the Corporate Environmental Guidelines for Ross Mining, the objectives outlined in the IAS and EMOS approval documents and the requirements for mine closure and decommissioning established by the Queensland Department of Mines and Energy (DME) and Queensland Environmental Protection Agency (EPA).

1.2 Project Objective

Ross Mining was seeking to establish an overall framework for the decommissioning and rehabilitation of the Yandan Gold Mine site that would follow an agreed process for the relinquishment of Mining Leases ML 1095 and ML 1096 to the Queensland Government without any ongoing liabilities. At the time this MCP was prepared the anticipated timeframe for relinquishment of the mine leases was between 2 and 5 years. The primary objective of the MCR Plan was to provide an umbrella document for use by Ross Mining that:

- Links and confirms with all existing mine closure commitments described within existing mine approval and operation documentation
- Assessed potential contaminated sites and their subsequent rehabilitation or long-term management
- Provided a fully integrated closure plan for the Yandan Gold Mine as an entire unit in accordance with an agreement to be sought with the landowner on land use and water quality guidelines

Where it was identified that there was insufficient information available to commit to a particular rehabilitation strategy, the MCP provides action plans (be it research, trials, etc) to fill the identified knowledge gaps.

It was also acknowledged that the MCP would be used, where required, as the basis for obtaining regulator “*sign-off*” for the proposed mine closure process and the eventual relinquishment of the mine leases.

1.3 Scope Of Work

The Scope of Work for the preparation of the MCP was developed following consultation between Ross Mining's Environmental Coordinator and HLA. Works were carried out in three stages:

- Site Inspection
- Data Review, identification of data gaps, design of sampling plan
- Preparation of the Preliminary Mine Closure Plan.

1.3.1 Site Visit

The site visit included:

- Identification of compliance documentation (EMOS, Plan of Operations, etc)
- Identification of monitoring data
- Identification of specific studies that relate to the behaviour of the mine during mine life and post closure such as:
 - Geochemical studies of the Heap leach Pads
 - Final Void hydro-geochemistry/hydrology study
 - Tailings geochemistry
 - Revegetation trials
 - Materials suitability/capability studies (i.e. suitability of materials for rehabilitation)
- Site walk-over of the identified facilities requiring closure and rehabilitation
- Identification of correctly located base maps/plans of the site including air photos (and if available time based air photos, depicting changes in the site during mine life)
- Identification of the Site Water Balance and any updates relating to shifts in climate
- Identification of the site Water Management Plan
- Discussions with site personnel on the history of the site and how it has behaved under the different climatic events that may have occurred during life of the mine

The assistance of Mr. Tony Dwyer, Environmental Coordinator for the Wirralie Mine Operation, that includes the Yandan Mine site, is gratefully acknowledged.

1.3.2 Data Review

The review phase involved an assessment of the available data identified from the site visit. The purpose was to identify deficiencies in the database that were relevant to the design and closure of each facility on the mine site and lease relinquishment. It incorporated the design of sample collection to provide the necessary information, were found to be deficient, to design the rehabilitation, closure and sign-off by the regulatory authority (DME, EPA) of each respective facility within the mining lease area.

1.3.3 Mine Closure Plan

Decommissioned Site Water Balance

- Assess the overall water balance for the site with particular emphasis for each final void
- Management of potentially contaminated water through sediment traps and wetlands (including discharges from the tailings dam).

Decommissioning schedule of activities

- Identification of all affected stakeholders, both government and local.
- Development of lease hand-back criteria.
- Propose a review schedule to ensure that the rehabilitation and decommissioning plans are kept up to date and relevant, reflecting the current state of the operations and rehabilitation.

Long-term Monitoring and Maintenance

- Assessment of monitoring activities required after mine closure
- Development and nomination of appropriate achievable and acceptable closure criteria for all aspects of the operations. Develop a process for achieving sign off of the completion criteria with the appropriate regulators
- Development of a post-decommissioning monitoring plan to measure progress towards meeting agreed completion criteria
- Propose a post-decommissioning annual environmental management reporting format
- Produce a timetable that proposes a realistic post-decommissioning monitoring period and a schedule for lease relinquishment and a staged return of security deposits that recognises achievement of agreed decommissioning milestones

Specific Mine Closure Issues

- Land Use Capabilities
- Water Quality Criteria
- Mine Pits
 - Confirm the suitability of the selected rehabilitation options for final voids with particular emphasis on management of acid mine drainage.
- Tailings Impoundment Rehabilitation – Compartment B
 - Confirm the suitability of existing rehabilitation works undertaken for Compartment A
 - Final landform plans with particular emphasis on addressing the long-term stability
 - Erosion control measures
- Dump Leach
 - Confirm water quality following hypochlorite flushing
 - Final landform plans with particular emphasis on addressing the long-term stability
 - Erosion control measures
- Pit Bund Wall
 - Comply with Waterworks Licence Requirements
 - Final landform plans with particular emphasis on addressing the long-term stability
 - Erosion control measures

1.3.4 Project Team

Mr. Peter Scott, Principal Scientist with HLA, produced the preliminary plan. Peer Review was provided by Mr Tom Farrell, Principal Environmental Scientist (Mining) with HLA-Envirosciences Pty Limited.

1.4 Definitions

In order to ensure consistent terminology, the following definitions have been used for key terms in this report.

<i>Closure:</i>	Permanent cessation of operations at a mine or mineral processing site after completion of the decommissioning process.
<i>Care and Maintenance:</i>	The state of a mining or mineral processing operation which has been temporarily closed, typically for economic reasons, but where operations may recommence some time in the future. Therefore equipment is kept in such a state, with continuing maintenance, that it can be easily restarted.
<i>Completion Criteria:</i>	A set of agreed actions or targets which, upon being met, will demonstrate successful reclamation of a site.
<i>Decommissioning:</i>	The activity or process that begins after cessation of prospecting activities or mineral production (including metallurgical plant production) and ends with tenement relinquishment. It involves, among other things, the removal of unwanted infrastructure, making excavations and waste repositories safe and stable and surface reclamation with a view to minimising any adverse environmental impacts remaining after cessation of mineral production. It includes the after-care or maintenance that may be needed until relinquishment of the tenement.
<i>Inactive Site:</i>	A mining or mineral processing area, which is currently not being operated, but which is still held under some form of title, typically a lease. Frequently, such operations are referred to as being under “care and maintenance”.
<i>Mine site:</i>	The total area encompassed in a Mining Lease, as defined by the Mine Close Out Criteria of the EPA and DME
<i>Non-Acid Forming:</i>	Refers to mine waste, either waste rock or tailings, or ore that contains no reactive sulphides that when oxidised will generate acid; or contains sufficient available neutralising minerals that will suppress permanently any acid generated from oxidation of contained sulphides.
<i>Oxide Waste:</i>	Waste rock material that has been mined from above the base of <i>total</i> oxidation that contains no reactive sulphides and is non-acid forming.
<i>Potentially Acid Forming:</i>	Refers to mine waste, either waste rock or tailings, or ore that contains reactive sulphides that when oxidised will generate acid, and contains insufficient available neutralising minerals to counter and suppress any acid generated.
<i>Primary Waste:</i>	Waste rock that has been mined from below the base of <i>total</i> oxidation. This material may be devoid of sulphides or may contain reactive sulphides and may be potentially acid forming.
<i>Reclamation:</i>	The return of disturbed land to a stable, productive and self-sustaining condition, after taking into account beneficial uses of the site and surrounds.
<i>Relinquishment:</i>	Formal approval by the relevant regulating authority indicating that the completion criteria for the mine have been met to the satisfaction of the authority, via issue of a certificate or other written instrument or cancellation of the lease.
<i>Safe:</i>	The condition of a closed mine such that the risk of adverse effects to people, livestock, other fauna and the environment in general has been reduced to a level acceptable by all stakeholders.
<i>Stable:</i>	The condition of a closed mine such that the rate of change of reference parameters does not exceed those rates occurring on the site prior to mining or on comparable unmined land in the same locality. Stability is dependent on the geomorphology of the surrounding landform and the proposed post-mining land use. The reference parameters can cover fields such as geotechnical slope stability, soil erosion, downstream water quality or sustainability of revegetation.

2.0 LEGISLATIVE AND REGULATORY FRAMEWORK

This section includes a discussion of the legislative requirements for mine decommissioning and closure in Queensland and other related matters.

Over the last four years the Queensland Government and mining industry have cooperated in the development of the Environmental Protection Policy - Mining (EEP - Mining) under the Environmental Protection Act (EP Act). As part of this initiative, the government has decided to transfer environmental management on all mining tenements from the Department of Mines and Energy (DME) to the Environmental Protection Authority (EPA). A number of DME environmental personnel have now been transferred to the EPA and amendments to the Mineral Resources Act and EP Act are now being prepared to give effect to the expected administrative and policy changes.

The changes proposed by the EPA for environmental management on mining leases with particular reference to transitional arrangements and mine closure are outlined in this section. While the actual form of the requirements for lease closure have not yet been formalised, it is apparent that the aim of the mine decommissioning/closure plan will be to effectively decouple the land or mining operation from all legislation that affects the lease.

As formal legislation and administrative requirements are still being developed, it is apparent that liaison should be maintained with the EPA officers who will be responsible for determining approaches for lease surrender to ensure that they understand the site specific situation and all matters are effectively covered. The legislation is silent on the standards which should apply to mine closure and it is considered that the minimum standards will relate to long term stability of the post mining landform, establishment of sustainable vegetation cover, no off site impacts and zero or minimal maintenance requirements.

Other relevant legislation is also discussed.

2.1 Transitional Arrangements

The transfer of responsibilities for environmental management on mining leases to the EPA will require the eventual amalgamation of the EMOS / Plan of Operation system into the Environmental Authority for Environmentally Relevant Activities (ERA) system used by the EPA. This will require transitional arrangements and the proposals suggested by the EPA are outlined below. It should be noted that these have no legal status and are included so that the mine closure strategy developed will have regard to the likely changes.

All mining leases now have an environmental licence or approval (granted with the tenure or deemed.) This approval is expected to become the transitional authority on commencement of the new provisions under the amended EP Act and Mineral Resources Act. The conditions of the transitional authority will be:

- Those of the existing approval;
- Conditions of the tenure that would normally be environmental conditions under the EP Act;
- Commitments or requirements of the most recent EMOS / Plan of Operations.
- The transitional authority will be level 1 ERA under the EP Act.
- Annual fees will be waived for at least the first year.
- Projects, which comply with requirements for a standard mining activity and comply with standard environmental conditions, may convert the transitional authority to a level 2 ERA - standard mining authority.

- Such an application would be free of charge and not trigger any notification or objection provisions.
- Where an ERA is being undertaken under a transitional authority and not covered by that authority, they will be protected from prosecution provided:
 - Written notice is given to the EPA
 - Application for an amendment to appropriately modify the authority is made within 30 days.

It has been proposed that the EPA / Minister may have the power to amend conditions of transitional authorities and fix anomalies, e.g. where:

- The current conditions cannot be reliably determined;
- The conditions are too vague or generally unenforceable;
- It is necessary to prevent environmental harm.

2.2 Surrender of Environmental Authority

Operations on the lease will require an Environmental Authority and this will need to be surrendered or cancelled by the EPA. It is likely that the DME will not accept surrender of a mining tenure without formal advice that the EPA has accepted surrender of the Environmental Authority.

The EPA position is that it will not surrender an Authority without submission of a Final Rehabilitation Report (FRR). The FRR will describe the extent of rehabilitation against the requirements of the Environmental Authority and will need to be accompanied by an audit statement. On receipt of a FRR, the EPA may:

- Accept the FRR and surrender and advise DME accordingly so that the lease may be formally surrendered and the security deposit returned;
- Require further information to complement the FRR submitted;
- Refuse to accept surrender until further rehabilitation work is completed or other arrangements for management of the site after surrender are agreed; or
- Require development of an Environmental Management Program prior to surrender.

Further, it should be noted that under the EP Act there are provisions for review and appeal of administrative decisions by the EPA.

2.3 Mining Lease Conditions/EMOS/Plan of Operations

While responsibility will be transferred to the EPA, the transitional and likely long term Environmental Authority will contain the conditions and standards incorporated in the Mining Lease, EMOS and Plan of Operations for site. In addition, the Environmental Authorities issued by the EPA contain standard conditions, which routinely are applied for water, air and noise etc. It is expected that standard conditions that apply to mining tenements will be developed. This may or may not apply to non-operational sites that are in the process of being rehabilitated. It is considered that in the decommissioning phase the following mining lease conditions will be important in the FRR process. In summary these conditions may continue to apply to non-operational mines and the aim of rehabilitation and associated monitoring will be to show long-term stability and compliance with the condition.

Lease Condition	Comment
Note - Only relevant parts are given and paraphrased / abbreviated to highlight the more important points The lessee shall at all times take all steps to prevent mineralised or impure water or sludge interfering with any watercourse or land.	
The lessee shall dispose of all overburden, waste rock and tailings in a manner such that: 1. Surface water or ground waters are not polluted 2. Oxidation and leaching of material, which may cause surface or ground water pollution, is minimised.... 3. Tailings deposited within storage.... to facilitate decommissioning and rehabilitation. 4. Upon decommissioning no ongoing maintenance is required to ensure that surface or ground waters are not polluted.	Surrender will depend on effectively demonstrating that with minimal maintenance quality of water leaving the mine site will be acceptable. Self-explanatory. Compliance will need to be demonstrated in the plan to have an acceptable FFR
The lessee shall with respect to dams... 1. Each dam designed and constructed in accordance with good engineering practice; 2. Unless otherwise approved, each dam is provided with an adequate spillway; 3. Capacity of the storage is adequate for the purpose for which it is used.	Discussed in the following sub-section.
The lessee shall fence those parts of the lease area where adjoining land use or the presence of fauna warrants the isolation of operations.	
The lessee shall ensure that dust / nuisance factors generated on the lease are minimised.	While the condition mostly applies to the operating mine, dust from the site will need to be minimised.
The lessee shall rehabilitate all disturbed areas progressively. Such rehabilitation shall be carried out by: 1. Shaping areas so that it conforms as reasonably as practicable with the surrounding topography; 2. Reforming all drainage lines, waterways and creek beds to stable contours and as near as practicable to the situation which existed prior to mining; 3. Returning any surface material or arable soil removed to the contoured surface, except where that surface is frequently inundated by water flowing in a stream; 4. Stabilising the restored areas against the natural forces of erosion in order that ongoing maintenance after termination of the lease is not required.	Similarly there is an expectation that drainage lines will be similar to the situation, which existed prior to mining. A high standard / low erosion rate will be expected to maintain covers over potential acid sources on the site.

In addition to the above, there is a general requirement that lessees comply with all legislation. The EMOS and Plan of Operations are consistent with the lease conditions and therefore the effects of the commitments in the document on future mine closure are generally as outlined above.

With regard to mine closure, the most important element of the EMOS relates to the commitment on post mining land use. This is summarised in Table 2 - Proposed End Land Uses for Mine Components. In summary, the mine closure plan will need to ensure that the nominated post mining land uses are achieved.

2.4 Water Resource Act Provisions

Ten waterworks licences apply to the lease area, which covers tailings and water dams, a levee bank, a diversion channel and water harvesting. The licence conditions for all activities follow a similar format. In summary, these involve following set operational procedures, appropriate monitoring and regular inspections.

For mine closure the most significant point is that the licence conditions assume that that all structures require maintenance and hence the standard provision for these structures to be inspected annually by an experienced professional engineer acceptable to the Water Resources Commission. These licences will need to be surrendered or cancelled as part of the mine decommissioning process. Thus the immediate aim should be to define all activities required to ensure long term stability with no or minimal maintenance. As these activities / works are implemented the next task should be to include a section in the engineer's report that the works are in place, the structures are or are becoming "stable". Ultimately the engineer should report that no further inspections are required and recommend that the licences be cancelled. It is suggested that liaison be maintained with Water Resources personnel during this process.

2.5 Other Legislation/Matters

The other legislation / matters relevant to mine closure are outlined below.

2.5.1 Contaminated Lands

It is understood that legislation covering contaminated land is currently under review. A provision of the legislation is that mining leases by definition be deemed to be "contaminated" within the terms of the legislation. After rehabilitation, the status of the land is likely to change and this should be taken into account in the planning process so that the status of the land can be demonstrated when the FRR is submitted.

2.5.2 Civil Liabilities / Public Risk

The conditions of the mining lease provide for the operational areas to be fenced. These require maintenance and features such as former pits, highwalls and dams may pose a public risk. Common law liability is constantly evolving and therefore it is not possible to precisely specify the standards, which should be applied. Reasonable precautions to prevent accidental injury or harm will be taken as part of the rehabilitation plan for the site including earth bunding and fencing with signage around pit areas to discourage access, in line with current best practice for decommissioning mine sites

2.5.3 Archaeological Relics

It was noted that relics are present on the site and that as these are remote from operational areas, damage was unlikely. On surrender, a future landholder will be responsible for any archaeological sites. The planning process should identify the manner in which these sites should be recorded, if at all, and appropriate reference made in the FRR.

2.6 Regulatory And Other Requirements

Requirements for mine rehabilitation and closure comprise the conditions Pursuant of the *Queensland Mineral Resources Act (1989)*, terms of Mineral Lease ML1095 and ML1096, conditions of approval of the EMOS (March 1993), Plan of Operations (January 2000), the *Environmental Protection Act (1994)* and the *Water Resources Act (1979)*.

3.0 MINE SITE ENVIRONMENTAL APPROVAL STATUS

3.1 Mining Lease Conditions

The environmental management and closure of the Yandan Gold Mine was planned prior to commencement of mining activities. Documents prepared as part of the mine approval process included:

- Kinhill (Oct 1988), *Yandan Gold Project, Impact Assessment Study*, Prepared for Western Mining Corporation Limited (IAS)
- Ross Mining (Nov 1992), *Interim Plan of Operations (covered ancillary works prior to operations)*
- Ross Mining (Dec 1992), *Yandan Gold Deposit, Environmental Management Overview Strategy (EMOS)*

The EMOS incorporated some variations from commitments given by the IAS due to changes in the initial development program that included the inclusion of dump leaching. The project development included the construction of a bund to protect the main pit from potential flooding of the adjacent Suttor River and a potential 5 m increase of the Lake Dalrymple Dam wall. It is likely that the pit water quality would become academic if Stage 2 of the Burdekin Dam proceeds.

Following the commencement of mining operations, all mine site activities have been subject to ongoing planning and performance monitoring as set out in the following Plan of Operations and Amendments:

- Ross Mining (Mar 1993), *Plan of Operations: Yandan Gold Project, March 1993 to May 1995*
- Ross Mining (Feb 1994), *Yandan Gold Project. Plan of Operations. Amendment to include water harvesting from Suttor River*
- Ross Mining (Mar 1994), *Yandan Gold Project. Plan of Operations. Amendment to include Dump Leaching and research schedule*
- Ross Mining (Jun 1995), *Plan of Operations: Yandan Gold Mine, June 1995 to May 1997*
- Ross Mining (Aug 1995), *Plan of Operations: Yandan Gold Mine, Amendment to Include the Yandan South Pit*
- Ross Mining (Aug 1997), *Plan of Operations: Yandan Gold Mine, July 1997 to June 1998*
- Ross Mining (Apr 1998), *Plan of Operations: Yandan Gold Mine, April 1998 to April 1999*
- Ross Mining (Mar 1999), *Plan of Operations: Yandan Gold Mine, Amendment to Allow Flooding of Yandan Pit*
- Ross Mining (Jan 2000), *Plan of Operations: Yandan Gold Mine, January 2000*

The Mine Lease conditions are dealt with in the above documentation. Based upon the management plans in place and environmental performance of the mine, the Yandan Gold Mine has been assessed with a Category 3 Performance Discount (i.e. Demonstrated Environmental Compliance Capability). The Yandan Gold Mine was audited by the Department of Mines and Energy in July 1999. The outcomes of this audit were reported in the following document:

- Department of Mines and Energy (July 1999), *Environmental Compliance Assessment, Yandan Gold Mine, PJ 100545.*

3.2 Environmental Licence

The Yandan Gold Mine is subject to Environmental Authority No. 110011, under the provisions of the Environmental Protection Act. It is understood that there are no specific conditions required by this Environmental Authority.

3.2.1 Waterworks Licences

The mine site is subject to 10 waterworks licences and Ross Mining has submitted an application for an additional licence. These licences are summarised in Table 1.

Table 1: Waterworks Licences

Licence Number	Purpose
G-55018	Levee Bank
G-55019	Diversion Channel
G-55020	Licence Cancelled
G-55021	Tailings Dam
G-55022	Return Water Dam
G-55023	Mine Water Pond No. 1
	Water Storage Dam and Channel
G-55720	Water Harvesting
G-57328	Water Harvesting
G-57383	Water Harvesting
“Pending Approval”	Heap Leach Stormwater Pond

Licences for water containment structures are subject to conditions relating to engineering suitability and inspection and wet season storage capacity. The tailings dam and return water dam must be monitored for deterioration in water quality and rehabilitated in accordance with the requirements of the Water Resources Commission.

4.0 ENVIRONMENTAL AND SOCIAL SETTING

Based upon the standard of reporting of the environment and social setting of the Yandan Gold Mine contained in the IAS, EMOS and Plans of Operations, no additional baseline or background information studies were considered to be required to prepare the MCP.

Relevant background information contained in these reports have been summarised in the following sections. For more detailed information please refer to the actual documents.

4.1 Topography and Land Use

The mine site occupies an area at the confluence of the Suttor River and Yandan Creek. The relief at the mine site is approximately 30 m, which is approximately 20 m higher than the surrounding undulating terrain, with flatter floodplains along the Suttor River at approximately RL165 m and raised hills up to RL 200 m. The Suttor River, which flows into the Lake Dalrymple, is a braided stream within a broad depression.

The Mine Lease Area is located within the Rosetta Park pastoral property held under crown leasehold. The predominant land use prior to mining was beef and cattle grazing that within naturally occurring open forest and cleared woodlands. As a result of low fertility, degraded soils and low rainfall, the area was considered to have a low stock carrying capacity.

4.2 Climate

The mine site area is located approximately 230 km from the nearest coast and 100 km east of the Great Dividing Range within a semi-arid tropic savannah climate. The climate is characterised by a hot wet season and mild dry season, highly variable rainfall, high evaporation rates and low humidity. The average rainfall is 585 mm, falling mostly during the wet season (November to March). Drought is regarded as a common occurrence in the region, however, the area can be subject to heavy rainfall and flooding as tropical cyclones cross the coast and become rain-bearing depressions.

Average daily maximum temperatures range between 35°C in the summer months and 22°C in the winter months. The optimal seeding time for rehabilitation planting is in September before the period of high intensity storms.

4.3 Flora and Flora

A detailed investigation of the mine site area that was undertaken as part of the IAS recorded the natural vegetation as highly disturbed, with the original open forest and woodland communities having been mostly cleared. There was no commercial timber present. A thick regrowth of shrubs was evident between fallen timbers. There was a sparse ground cover of grasses and herbs, particularly in areas that had been disturbed. Biennial or Triennial burning of native pasture was commonly practiced by graziers in the region. Land degradation, mainly in the form of soil erosion, was significant over much of the site. This had further affected the species quality and diversity. None of the species identified at the site was considered rare or endangered.

Field studies of the terrestrial biology of the mine site indicated a low population density and species diversity of vertebrate fauna compared with other areas on the station property. Species identified were:

- Forty seven species of birds, all considered relatively common in the region

- Eight species of mammals, all considered common in the open grazing land environment in Central Queensland
- Eight species of reptiles and amphibians, all considered common throughout the Central Queensland semi-arid environment

The IAS did not consider that the mine development would impact upon the regional status of any flora or fauna species.

4.4 Archaeology and Historic Sites

Archaeological surveys undertaken as part of the IAS identified 24 aboriginal archaeological sites consisting entirely of stone artefacts. The identified sites exhibited a wide range of raw materials and implement types, with the small amount of material collected providing valuable information on past Aboriginal occupation of the region. Many of the sites had been previously disturbed by land clearing or during the course of previous mining or exploration activities. Generally, those sites that were likely to have been impacted by the Yandan Gold Mine were either so disturbed, had been adequately recorded or were sufficiently represented elsewhere, that preservation was not recommended. Further archaeological investigation was recommended for three sites located along the Suttor River bank in the vicinity of the mine.

No recorded items or sites of European historical significance were identified within the mining lease areas.

4.5 Soils and Geology

Almost all the soils within the mining leases were classified as regional group RF4, shallow alkaline red bleached duplex soils, with the exception of the alluvial soil on the floodplain of the Suttor River. The surface horizons were generally neutral hard setting loams with a high proportion of quartz gravel. The A₂ horizon was bleached and underlain by red structured clay soils and strongly alkaline deeper sub soils. The clay horizon presents a barrier to penetration of plant roots and water, potentially resulting formation of a perched water table during the wet season and erosion of liquefied soils above the clay. The fertility of the soils within the mine leases was considered inherently low. Extensive erosion had further reduced the productive value of the soils.

The Yandan Gold Mine is situated on the Anakie High, with rocks forming the Anakie Inlier considered the oldest in the area. The mine deposits had been formed within the Saint Anns Formation, a complex suite of rocks comprising acid and intermediate lavas with tuff, arkosic and lithic sandstones, conglomerate and assorted mudstones. Outcrop geology within 10 km of the deposit includes an intrusive formation comprising granite, granite porphyry and minor rhyolite. The main mineralised area is coincident with a broadly stratabound zone of the Saint Anns Unit 2 which occupies a low, flat topped rise immediately east of the Suttor River.

4.6 Surface Water and Groundwater

The mining leases lie within the catchment of the Suttor River, which drains into Lake Dalrymple, formed by the damming of the Burdekin River. The Yandan Gold Mine lies on the eastern bank of the Suttor River near the junction with two minor tributaries, Yandan Creek and Sandy Creek. Yandan Creek has a catchment area of approximately 7,200 hectares and Sandy Creek approximately 900 hectares, with both being ephemeral with significant flows occurring during heavy rainfall periods.

The Burdekin Dam water supply is used mainly for irrigation of cropland and is proposed for the domestic supply to Townsville and other urban areas. Between the mine site and the ponded area of the dam, there is general usage of the Suttor River for rural pursuits, mainly in the form of crop irrigation and a small number of water harvesting schemes.

Surface water quality monitoring undertaken during the operation of the Yandan Gold Mine did not identify any significant impacts or changes to results obtained prior to the commencement of mining. Groundwater investigations undertaken prior to the commencement of mining identified:

- The existence of a zone of higher permeability within the Saint Anns Formation
- That the aquifer contained within the mine deposit is not in hydraulic connection with any adjacent highly permeable groundwater systems, including alluvial deposits underlying the Suttor River
- Groundwater movement was towards the west, however, flow rates and volumes were very small

Groundwater identified within the mine site aquifer was relatively saline, with concentrations ranging from 4,020 mg/L to 15,300 mg/L, and was considered equivalent to poor quality stockwater and unsuitable for either irrigation or domestic use. The pH levels recorded varied between 7.1 and 9.0. All of the groundwater extracted to dewater the mine pits was used for processing requirements.

Monitoring of groundwater quality within the mine site was commenced prior to the start of mining activities. Monitoring bores were installed adjacent to the Tailings Dam, Dump Leach Facility and Water Storage Dams. Monitoring results obtained during the mining operations have identified the following potential impacts:

- Dump Leach
 - Total cyanide concentrations of 0.01 mg/L in two bores adjacent to the Dump Leach Facility and 0.5 mg/L under the Dump Leach Barren Pond were measured during monitoring undertaken in 1999. However, WADCN concentrations for these locations were <0.005 mg/L (Dump Leach) and 0.075 mg/L (Barren Pond) respectively, indicating that the cyanide detected is in the form of ferrous cyanides that are not readily dissociated under ambient temperatures and near neutral pH.
- Tailings Dam
 - The monitoring data from the groundwater bores adjacent to the Decant Pond (TD1-4), at the northern perimeter of the Tailings impoundment (TD5) and along the eastern boundary of Compartment B (TD6) and the decant (TD7) indicated:
 - Less than ANZECC levels for arsenic;
 - Less than natural background levels for lead;
 - Slightly elevated levels (above ANZECC Guidelines) of cadmium which likely to be contained by the elevated hardness of the tailings groundwater;
 - Trace TCN levels in TD2 which is associated with increase in TCN levels in the Run-off Pond;
 - TCN levels in TD5 have stabilised at 0.05mg/L;
 - WADCN levels are very low suggesting the cyanide is present as the more stable ferrocyanide complexes probably ferric ferrocyanide; this is supported by low metal concentrations other than iron;
 - Chloride ion concentrations are elevated in TD6 and TD4 suggesting a saline groundwater condition prevailing in these two bores are related to the saline groundwater aquifer identified by baseline studies prior to commencement of mining activity.
 - Surface water monitoring of the Return Water Pond shows a decrease in WADCN levels from an initial concentration of 7.05mg/L in 24-11-98 to current levels at time of reporting of <0.005mg/L
- Water Storage Dams

- Monitoring results were comparable with baseline water quality results.

5.0 MINE COMPONENTS

5.1 Operation History

Ross Mining commenced mining and milling operations at Yandan in June 1993. Initial development of the site included the construction of infrastructure to permit open cut mining of the Main Pit and processing of ore on-site. Higher-grade ore was processed using a CIL facility and lower grade ore was placed within a lined area for future dump leaching. Subsequent mine developments included:

- South Pit opened in 1995 (low grade ore placed on Dump Leach Facility)
- East Hill Pit opened in 1998.

Additional ore was trucked to the site for processing from Ross Mining's Mt Coolon and Glen Eva operations.

The Dump Leach facility, including the construction of a cyanide pond was completed and made operational in May 1994. This facility will remain operational until at least the end of 2000.

Mining operations ceased in late 1998, with processing of stockpiles ore being completed in April 1999. Most mine infrastructure (i.e. Accommodation Village, CIL Process Plant, etc.) was subsequently removed to Ross Mining's Wirralie Operations.

The layout of the Yandan Mine operation and mine lease areas is shown in Figure 2.

5.2 Open Pits

5.2.1 Main Pit

The Main Pit was the predominant source of higher-grade ore for the CIL processing plant and was operated from 1993 to 1998. This pit covers an area of approximately 17.1ha, is approximately 680 m long, 200 m wide and 50 m deep. Approximately 119,500 tonnes of mineralised/mineralised waste rock was placed within limited areas at the base of the pit in 1998-99. This material was encapsulated in accordance with the approved Plan of Operations.

A bund wall was constructed around the western and southern perimeter of the pit in 1997 to provide protection from flooding of the Suttor River.

Ross Mining commissioned SRK Consulting to undertake a study to predict water quality within the pit should it be flooded. Based upon this study an amendment to the Plan of Operations was completed in March 1999. Regulatory approval was subsequently granted and flooding of the pit took place in 1999-2000.

5.2.2 South Pit

Operation of the South Pit commenced in 1995 and continued until November 1996. The pit covered an area of approximately 1.7 ha and was roughly circular with an approximate diameter of 75 m with a maximum depth of 45 m. Approximately 1,000,000 tonnes of low-grade ore was excavated and transported to the Dump Leach Facility along a constructed haul road, along with some high-grade ore that was processed through the CIL plant.

Following completion of mining the South Pit was backfilled with sulphide-bearing/mineralised waste rock from the Main Pit. This material was subsequently encapsulated with oxidised waste rock and clay material sourced from the excavation of the South Pit and flood bund.

Rehabilitation works for the South Pit and haul road have predominantly been completed. Such works included placement of topsoil stockpiled prior to mining, seeding and placement with nitrogen and phosphorous fertiliser at 150 kg/ha. An ongoing groundwater-monitoring program is currently being carried out by Ross Mining to identify any deterioration in water quality.

5.2.3 East Hill Pit

East Hill Pit operated from September 1998 to December 1998. The pit covered an area of approximately 1.7 ha and was roughly circular with an approximate diameter of 80 m with a maximum depth of 30m. Approximately 140,000 tonnes of ore was mined in total, of which approximately 90,000 tonnes was processed through the CIL/CIP plant with the balance transported to the Dump Leach Facility along a constructed haul road.

Following completion of mining, an earthen bund was constructed around the perimeter to deter entry. Groundwater is exposed at the base of the pit during the wet season.

5.3 Processing Facilities

Ore from the mine pits was delivered to the ROM stockpile where it was directed to the mill for recovery of gold by Carbon in Leach processing.

5.3.1 ROM Stockpile

The ROM Stockpile was constructed from oxide waste as a base keyed into the existing ground surface and served as an area for stockpiling both oxide and sulphide ore.

The Environmental Compliance Assessment of the Yandan Gold Mine by the DME (1999) identified that a sediment run-off collection dam was required to be constructed on the western side of the ROM.

The ROM stockpile area will be rehabilitated. The options available are:

- Remove any existing ore material to the Dump Leach Pad for reprocessing and incorporating in the rehabilitation of the Dump Leach pad; reshape the batters on the remaining ROM pad, ripping hard and compacted areas of the Pad, and seeding surface of the pad to encourage a vegetated cover; and
- Capping the top surface of the ROM pad with oxide waste material reshape the batters, ripping the surface and seeding.

Depending on the availability topsoil should be incorporated in the rehabilitation of the ROM pad to encourage a growth medium.

5.3.2 Processing Plant

The gold was won CIL circuit. The processing circuit comprised a primary jaw crusher that crushes to <150 mm. The ore from the crushers passed via elevated conveyors to the SAG mill, and then to a hydro-cyclone circuit. The cyclone underflow was used as feed to a ball mill for finer grinding of the ore. The discharge from the ball mill was transferred to a series of leach and adsorption tanks. Gold was recovered from the loaded carbon contained within the adsorption tanks through electro-winning and bullion smelting within a high security gold room.

Tailings from the circuit were pumped directly via a bunded aboveground pipeline to the tailings impoundment.

The processing plant was removed to the Wirralie Operation in 1999.

Rehabilitation works for the remaining Plant site will involve:

- Dismantling removal of concrete footings. Dismantled (broken-up) concrete footing material could be incorporated in the rehabilitation of the Dump leach Pads or disposal to the existing pit areas;
- Assessment of presence of contaminated soils resulting from spillage of processed ore material, followed removal and rehabilitation of contaminated material as deemed necessary by the assessment. Spilt or material could be disposed to the dump leach pad for reprocessing or be incorporated in the rehabilitation works of the Dump Leach Pad.
- Assessment and clean up of hydrocarbons associated with the processing plant. This material could be removed and treated by land farming methods. It is recommended to wash down and collect the hydrocarbon spillage (greases) that accumulated on some of the concrete footings during the operation of the Plant prior to removal of the footings.
- The conveyor tunnel should be sealed and secured to prevent access and made safe. The options are to collapse and fill in the tunnel or to seal the access portals.
- The final rehabilitation of the Plant site will be subject to negotiation with the landowner.

5.4 Waste Rock Dumps

The EMOS and original Plan of Operations made allowance for the construction of a waste rock dump at the Yandan Gold Mine. The waste rock dump was to be placed to contain mineralised or sulphide waste rock within oxidised waste rock as part of the acid mine drainage management strategy. However, the mining operations were subsequently managed without the construction of the waste rock dump. Waste rock was placed as follows:

- Oxidised Waste
 - Haul Road construction
 - Capping of sulphide/mineralised waste rock within the South Pit.
- Mineralised Waste
 - Encapsulated in the base of the Main Pit in 3 distinct areas.

5.5 Tailings Storage Facility

The Tailings Storage Facility was located approximately 3 km from the CIL processing plant site and 3.5 km from the Suttor River at an elevation above RL180m AHD to provide protection from potential flooding by Stage 2 of the Burdekin Dam. This impoundment was constructed using a combination of embankments, and natural features, and currently occupies an area of just over 100 hectares. Approximately 7,500,000 tonnes of Tailings were pumped to the tailings dam along a buried pipeline that was bunded to impound any tailings spillages.

The TSF was divided into two compartments (Compartment A and Compartment B) with a downstream return water pond. The division of the TSF enabled the decant level in the active compartment to be kept as low as possible to ensure sub-aerial deposition by pumping water to the non-active compartment or to the return water pond. The use of two compartments also enabled the area affected by primary tailings during the later stages of the project to be minimised.

Compartment A only contains oxide tailings. Compartment B contained a sequence of oxide, sulphide and oxide tailings.

Ross Mining undertook chemical and physical characterisation studies of the TSF in 1998. Based upon the findings of these studies Ross Mining commenced rehabilitation trials. ***The characterisation studies and field trials are documented in the Ross Mining Report “Rehabilitation of Yandan Tailings Facility and Return Water Dam, Waterworks Licences G-55021 and G-55022”.***

At present water run-off from both Compartment A and Compartment B flows to the TSF spillway and in turn to the tailings run-off dam.

5.6 Dump Leach Facility

At the completion of ore placement on the Dump Leach pad in 1998 the facility covered an area of 20.1 ha and had reached a height of approximately 26 m, comprising two 10 m benches and one 6 m bench. Low-grade ore placed on the dump leach was sourced from each of the three open cut pits. Associated infrastructure included a pregnant pond, a barren pond and a stormwater overflow pond.

Initially the operation of the dump leach involved pumping pregnant dump leach liquor into the CIL plant circuit for gold recovery. Decant water from the tailings storage facility was pumped into a barren pond as makeup water, mixed with lime and cyanide and placed over the ore using spray irrigators.

Following removal of the CIL Plant from Yandan, the Dump Leach Facility operates as a closed system whereby the pregnant liquor is passed through carbon adsorption tanks for gold extraction and drained to the barren pond, mixed with cyanide and lime and placed over the ore using spray irrigators. Makeup water is sourced from the No. 2 Water Storage Dam.

5.7 Flood Bund

Planning for the mine operations identified a requirement to construct a bund around the western and southern perimeters of the Main Pit to provide protection from flooding of the Suttor River and the planned raising of the Burdekin Dam. This bund was constructed in 1997 to a lower crest elevation than originally planned.

5.8 Associated Infrastructure

5.8.1 Water Supply

At the commencement of mining operations the plan was to initially draw the water for processing from the Main Pit dewatering bores. However, the aquifer within the pit area was depleted within a short period of time. An alternative potable water supply was sourced from a groundwater bore field located 42 km to the north at Ross Mining’s Wirralie Operations. A number of water-harvesting licences were obtained to pump water from the Suttor River to a new water storage dam starting in late 1993.

5.8.2 Water Storage

The two main water storage structures built for mine operations were the No. 1 Mine Water Dam (MWD) and the No. 2 Water Storage Dam (WSD).

The MWD was used to collect any surface water run-off and spillages from the mine processing area (approximately 12 ha) and any water pumped from the mine pits. Water collected was used as makeup

for the CIL processing plant. Following closure of the mines and removal of the CIL processing plant there are now no potential contaminants entering the MWD and the dam.

The WSD receives rainfall run-off from the catchment surrounding the mine site (5.25 sq km) and any water harvested from the Suttor River. This storage was used to provide process water and is now used to provide make-up water for the dump leach processing.

Other constructed water storages are:

- Compartment A, Compartment B, run-off dam for the TSF
- Barren Pond, Pregnant Pond and stormwater pond for the dump leach facility

5.8.3 Roads and Haul Roads

Numerous roads were constructed from compacted waste rock around the mine site. These are used mainly for access to the open pits, ROM and waste rock dumps by light vehicles and heavy haul trucks. It is understood that the haul roads were sheeted with oxide waste rock. Road dust was managed using watering as required.

Rehabilitation works have commenced on the access roads and haul roads that are no longer required. Works undertaken to date include:

- Ripping the road surface
- Placement of topsoil stockpiled along the road alignments, when required
- Seeding and use of fertiliser

5.8.4 Chemical Storage

Current dump leaching operations require the storage of cyanide and lime. The cyanide is transferred directly from a transport tanker into a storage tank located atop of a HDPE covered bund between the dump leach pregnant liquor and barren ponds. Lime is contained within an above ground silo and is discharged by a shrouded screw feeder.

5.8.5 Airstrip

An airstrip was constructed to service the mine site. The airstrip is not sealed and it is intended that it will remain in place for use by the landholder.

5.8.6 Mine Village

An accommodation village was constructed within the mine lease to service the mining operations. The village comprised typical infrastructure including accommodation, meals area, etc. The village was removed from the mine site in 1999 and transferred to the Wirralie Operations.

The remaining infrastructure from the village comprising concrete footings, pathways, and unsealed roadways and parking areas is in the process of being rehabilitated.

5.8.7 Contractors Area

Limited areas of hydrocarbon staining are evident within the Contractors area.

5.8.8 Fire Break

A firebreak was maintained around the mine site fence during the mining operations. As mining activities have ceased the firebreak is no longer maintained and it is anticipated it will become less effective with time.

5.8.9 Archaeological Sites

The three identified aboriginal archaeological sites are adequately protected as no vehicle access or mine development within these areas was constructed.

6.0 CLOSURE PLAN

This section comprises the Mine Reclamation and Closure Plan for the Yandan Gold Mine.

6.1 Reclamation Objectives And Proposed End Land Use

- Meet Ross Mining's corporate objectives for closure. The final Closure Plan to be submitted to DME will include Ross Mining's corporate objectives for closure.
- Meet Mines Department and EPA close out criteria.
- Develop stable landforms, which blend with surrounding environment on which expected erosion would be no more than what occurs on undisturbed land, and which would support a similar vegetation population.
- Develop a landform for the main pit that will not lead to long-term contamination downstream from generation of acidic and metal laden (including arsenic, zinc, aluminium and iron) surface and groundwater.

6.1.1 Reclamation Objectives

The following principles are proposed and have been adopted for reclamation of areas disturbed by mining at Yandan:

- Vehicular access to open pits will be inhibited by closing off access tracks;
- Acid generation from exposed reactive waste rock has been inhibited through placement within pit areas (South Hill Pit and Main Pit) and capping with benign waste material and soil to promote vegetated cover, or in the case of Main Pit to cover with water;
- Drainage on exposed surfaces liable to erosion will be controlled by surface preparation, catch drains and direction to adjacent vegetated and natural undisturbed areas or control structures;
- Silt dams will be constructed on drainage lines where sediment transport from exposed surfaces is likely;
- There will be no further clearing of land to retrieve topsoil;
- Plant species used in reclamation will be appropriate to the proposed end use;
- Pre-mining watercourses have been maintained or will be re-established wherever possible;
- Clean and dirty water will be identified and kept separate wherever possible;
- Dirty water will be directed through saltation ponds/dams into existing vegetated areas; and
- Clean runoff will be directed to existing watercourses.

6.1.2 Proposed End Land Uses

The proposed end land uses for the Mining Lease area, dependent on the physical nature of the area and substrate, are:

- Mixed native forest and grassland, specifically for limited agricultural use and nature conservation;
- Grazing for beef cattle, and
- Degraded or non-restorable land that is physically and chemically stable and does not affect surrounding areas.

It is expected that much of the area directly impacted by mining is unlikely to be returned to the same level of biological productivity as existed before mining. Areas where a productive end use cannot be achieved will be stabilised in such a way that colonisation by plants will occur; some areas may eventually return to secondary forest.

The proposed end land uses for various components of the mined land are shown in Table 2. It must be pointed out that these are ideals and the final land uses may differ from these because of unforeseen circumstances.

Table 2: Proposed End Land Uses for Mine Components

Mine Facility	Estimated Area (ha)	Proposed Land Use
Tailings Storage Facility	102.4	Mixed grassland for limited agricultural use and landform stability
Main Pit	17.1	No use; safe and stable; mostly non-restorable land; filled with water
South Hill Pit	1.7	Grassland and limited tree cover, limited agricultural use
East Hill Pit	1.7	No use; made safe and stable; mostly non-restorable land;
ROM Pad	0.3	Mixed grassland and native forest specifically for agricultural use and nature conservation
Dump Leach Pad and Storm Ponds	20.1	Mixed grassland and native forest specifically for agricultural use and nature conservation
Processing Plant and Contractors Area	8	Mixed grassland and native forest specifically for agricultural use and nature conservation
Mine Village	11	Mixed grassland and native forest specifically for agricultural use and nature conservation
Decant Return Dam	24.4	Dam to be breached and rehabilitated as per Plan of Operations Undertaking
Water Storage Dam	59.6	Water supply for establishment of rehabilitated land; stock water use medium to long
Mine Water Pond No.1	19.8	Water supply for establishment of rehabilitated land; stock water use medium to long
Water Channel	1	Retain for recharging Storage Ponds
Airstrip	13	Retained as-is
Pipeline	3	Rehabilitated to mixed grassland and native forest specifically for agricultural use and nature conservation
Roads	2	Retain as required in consultation with landowner
Haul Roads (external to pits)	3.1	Retain as required in consultation with landowner

6.2 Socio-Economic Considerations For Closure

6.2.1 Post-Mining Land Use

The mining lease area is remote from most established and permanent settlement, with the dominant land use being similar to pre-mining activity comprising beef cattle grazing.

6.2.2 Security Aspects

Ross Mining has no formal large presence on the lease area. The site is surrounded by active farmland and much of the site is fenced, so security during the decommissioning phase, which could take some years, can be controlled. This is necessary also to protect the well-being of members of the public who may not understand that some areas would still be hazardous.

Access to mined-out pit voids is to be controlled by construction of steep-sided earth bund walls around the full pit perimeter. Barbed-wire fencing may also be erected to control access by cattle and wildlife, if deemed necessary. 'Danger' signs are to be erected around the perimeter of the Pits, the Tailings Dam and Dump Leach Pads to warn members of the public of the potential hazards.

6.3 Acid Drainage Identification And Control

6.3.1 Presence of Acid Forming Minerals at Yandan

The principal ingredient for acid drainage generation in the host rocks and ore at Yandan is pyrite. Pyrite occurs as disseminated fine mineral grains generally less than 0.5 mm in diameter, as fine veinlets (less than 1 mm in width) and as fracture fill or coatings on fracture faces. The control on the pyrite distribution within the host rocks (waste rock) and ore is unclear, but appears to be related to faulting and shearing as well as pervasive disseminated pyrite alteration within the host rocks.

Pyritic waste rock, when exposed to the climatic conditions that prevail at Yandan, can be very reactive, resulting in rapid oxidation and the production of acid salts. These acid salts are dissolved by rainfall, resulting in acid drainage. The pyritic waste rock is referred to as "reactive waste" or "potentially acid-forming waste".

Pyritic wall rock was exposed in the main pit during mining. Pyritic waste rock was deposited in the bottom sections of the Main Pit area and South Hill Pit. Flooding of the Main Pit has covered the exposed pyritic wall rocks and encapsulated waste with water. The exposure of pyritic wall rocks and water in the east Hill Pit appears to be limited.

Some pyritic low-grade ore has been placed on the dump leach pads. It is located at one end of the pad and is surrounded by an apron and sits on a base of oxide low-grade ore. The dump pads are generally free draining and the exposure to oxidation of any sulphides on the surfaces of rock fragments may be high.

ROM pad was constructed on a base of screened low-grade ore. Any sulphide-bearing material (such as remnant sulphide-bearing ore) present in the surface layer of the pad will need to be assessed and rehabilitated.

Some sulphide-bearing ore was processed during mining and sulphide-bearing tailings have been disposed to Compartment B. The sulphide-bearing material appears to be located in the northwestern portion of Compartment B.

6.3.2 Implications of Acid Drainage for Yandan

Acid drainage by itself can lead to acidification of surface and ground water, resulting in changes in aquatic communities and deterioration in water quality in receiving waters. Of more concern generally is the resultant mobilisation of sulphate and heavy metals, as many metals have their greatest solubility in low pH water. Some metals present in waste rock and tailings would therefore be mobilised, leading to contamination of water and potential adverse environmental effects.

Wherever possible, acid drainage will be controlled at the origin by proper handling and management.

6.4 Decommissioning and Closure of Facilities

Facilities related to mining that will be subject to, or form part of, the rehabilitation plan at Yandan mine site include two pits (Main and East Hill), dump leach pad, tailings storage facility, ROM pad, Plant site, Contractors area, administrative buildings, access roads and haul roads, water storage ponds, water harvesting drain, Decant water Pond, Leach Ponds, mine village and air strip. The decommissioned site layout plan is shown in Figure 2. The following sections detail the specific requirements for decommissioning and closure of these parts of the site. The reclamation methods incorporate as much as possible current and proposed practices adopted by Ross Mining.

6.4.1 Open Pits

6.4.1.1 Main Pit

The Main Pit has been flooded to RL 169m AHD. The current water is acidic with a pH of 3.1 and contains dissolved iron. Iron levels, based on field measurements, appear to be partitioned with an increase below a depth of 35 metres. Contribution to the acidity in the Pit is likely to be from two main sources:

- Wall rock sulphide-bearing material particularly the partially oxidised material and
- Iron sludge, which would have formed on the dumped sulphide-bearing waste, in low pH ponded water prior to flooding and also sludge that blanketed the bottom profile of the Pit after it was flooded.

Treatment of the water for long-term management of water quality should involve decoupling the Pit wall and floor areas from the water column of the Pit Lake. This may be achieved by adding clay in slurry form either broadcast using spray irrigation or allowing natural runoff and flood flow from the Suttor River to transport clay and silt to the pit to blanket the pit surface.

Once the water is decoupled, the acid water can be neutralised through the addition of lime to raise the pH to an acceptable level or other water additives such as the VIROTEC Red Mud or Bauxsol. The disadvantage of using lime is that it does not provide a coating that will adhere to the steep pit sides and therefore cannot be relied upon to decouple the water body from the pit substrate. The other issue with lime is its insolubility, which when applied in powder form commonly leads to overdosing with lime. The extra lime often acts to decouple the water column from the flatter surfaces of the Pit.

There may be a need to add a further layer of clay slurry to remove the precipitated but potentially reactive sludge generated from the neutralising reaction from interacting with the water column.

Rehabilitation of the Main Pit will relate to maintaining and improving the quality of the water body. There are several options available:

OPTION 1

Install spillways in the eastern and northwestern corners of the Pit to provide water management for the upper layer of the Pit water. The eastern spillway will replace or augment the current spillway in the eastern side of the Pit. It is understood that the rationale is to attract “dirty” (high clay) or turbid floodwater that would act to decouple the water column from the Pit subsurface. This will lead to change and most likely improvement in water quality over the long term. The water level in the Pit needs to be sufficient to maintain a water cover over any sulphide-bearing wall rocks.

OPTION 2

Adopt strategy of Option 1 but supplement the flooding with neutralising the water column with lime. The lime plant currently used for the Dump Leach Operation could be used to generate the lime slurry. Lime could be applied statically through single point discharge or more effectively utilising several strategically positioned spray irrigation canons to broadcast the lime slurry across the surface of the Dam.

OPTION 3

Adopt Options 1 and 2 but supplement with the addition of clay as a slurry and broadcast over the pit lake surface using the irrigation canons.

OPTION 4

Utilise a proprietary product such as the VIROTEC Red Mud to neutralise and remove metals from the water column in conjunction with OPTION 1.

OPTION 5a

This is a variation on the OPTIONS discussed but requires treating the water body in isolation to the flood waters of the Suttor River to an appropriate water quality standard and maintaining the treated water body at that level.

OPTION 5b

This is the same as OPTION 5a but would involve discharge of the treated water during high flood flows of the Suttor River

The rehabilitation plan also provides for the construction of a safety bund around the Pit and a fence of construction configuration to existing stock fences of the surrounding rural property (four strand wire fence topped with a strand of barb-wire). These measures are designed to discourage access of livestock and the public. Bunds have been constructed around most of the Pit perimeter.

The positioning and construction of the bunds should be based on a geotechnical investigation of the pit wall stability to define the potentially unstable pit edge zone (*if relevant geotechnical data are not already available for the pit areas*). To maximise the long term effectiveness of the bunds they must be constructed at least 10 metres outside the area designated as being potentially unstable rock mass. That is the pit-toe of the bund should be positioned a distance not less than the total width of the potentially unstable pit edge zone plus an additional 10 metres away from the existing pit edge. The geotechnical investigation will need to determine the presence within the pit walls of major unfavourably oriented geological features, which could induce failure.

The bund walls should be constructed with the minimum height 2 metres and a base width of 5 metres. They should be constructed, where possible, from unweathered, free draining, benign (non-polluting), end-dumped rockfill. Where only oxidised material is available for bund construction care needs to be taken to ensure that the least weathered or hardest material is used. Where oxidised material is used the bund wall may need to be supplemented with appropriate surface stabilisation or a properly constructed fence. Suitable signs, clearly stating the risk to public safety and prohibiting public access, should be erected at appropriate locations around the safety bund wall.

6.4.1.2 East Hill Pit

The East Hill Pit will remain open as a final void. It is understood that there are no long term plans for rehabilitating or backfilling the Pit. The Pit should be bunded and fenced and signage added as identified for the Main Pit.

The Pit contains a small pond of acid water. It is understood that the pit is not likely to fill and overtop.

6.4.1.3 South Hill Pit

The South Hill Pit was backfilled with sulphide-bearing waste capped with compacted clay, a rock armour and topsoil added and profiled. The profiled surface was vegetated with mixed grasses. No further rehabilitation works are required.

Three 102mm ground water monitoring bores have been drilled to a depth of 25m within 50-100m of the southern and southwestern edges of the South Hill pit crest (Figure 2). The location of the bores was chosen based on the proximity of Yandan Creek. A bi-monthly water sampling and analysis program was established to detect any changes in groundwater chemistry.

Groundwater monitoring will be continued. The frequency of sampling was based on the stability of water quality i.e. changes in water quality do not appear to occur over short periods of time. The water quality parameters are based on metals identified in the results of a full ICP metal scan undertaken on groundwater sampled on the 27/09/1999. Only metals that pose any real potential risk to the environment have been included in the analysis program.

The frequency and parameters monitored will be reviewed regularly and may be altered, with approval of the Department, should results indicate stability in groundwater quality. Revegetation monitoring will be undertaken on an annual basis in accordance with procedures outlined in Ross Mining (1999).

There are some indications that seepage from South Hill pit has occurred into the surrounding local groundwater. The potential for impact from the seepage is limited due to the isolation of backfilled sulphide-bearing material from groundwater leaching. The potential for environmental risk is summarised as follows:

Potential environmental impact(s) – localised impact on groundwater

Possible causes and effects – the cause of poor quality groundwater is either the exposure of sulphide waste prior to capping resulting in low pH water from the South Hill pit disseminating into surrounding groundwater, or natural processes that have resulted in poor quality groundwater of the area in general, or a combination of both. Importantly the quality of the groundwater appears to be stable with no visual indication of impacting on the environment. There are no users of groundwater within the local area.

Potential exposure pathways – limited exposure pathways exist. The Suttor River is a perched system, some 8 metres above groundwater. The groundwater levels recorded for the South Hill bores are some 10m below riverbed level. Pre-mine groundwater assessments suggested no hydraulic connection between the clay and silt alluvium of the Suttor and fractured rock aquifers, such as those that may be open to the South Hill pit. It has been assumed that Yandan Creek, which South Hill abuts, has similar bedding to that of the Suttor River.

The geographical distribution of poor quality groundwater, assuming the source is the oxidation of backfilled sulphide-bearing waste, would presumably be confined to the local area surrounding the South Hill pit.

Potential receptors – local groundwater

Site characterisation strategies – characterisation of potentially acid-producing waste was undertaken during operations and presented in the 1997 Plan of Operations. In situ geotechnical testwork and capping material characterisations were undertaken in September 1998. Oxide capping material was visually characterised by the site geologist.

Potential for causes and effects to be reversed – realistically there is little scope for remediating poor quality groundwater that may be sourced from the oxidisation of pre capped sulphide-bearing waste. To date no effects have been recorded. It is not possible to state whether possible future effects may be reversible.

Mitigation/remediation measures – capping of sulphide-bearing waste; establishment of a vegetative cover on final land surface; monitoring of groundwater bores and revegetation.

Environmental risks – low

Caution should be taken with baseline water comparisons due to: -

1. The difference in bore hole depths i.e. South Hill bores (25m depth) to Main Pit bores (100m depth),
2. The observation that the perched Suttor River groundwater has little connection to surrounding, deeper, groundwater, and
3. The bores presented are those containing the highest quality water out of all the bores drilled i.e. averages may overstate the quality of groundwater that exists in the area. An example of this is sulfate that averages 430 mg/L from the bores presented yet regularly exceeded 1700 mg/L in other bores

6.4.2 Dump Leach Pad

Placement of low-grade ore on the dump leach pads was completed in late 1999. A total of 3,200,000 m³ of ore was placed on the pads. It is expected that irrigation with cyanide solution will continue until December 2000 at least. The dump will be rinsed and irrigated with an appropriate treatment solution such as hypochlorite, ferrous sulphate or peroxide solution on the completion of gold extraction to remove any residual cyanide. The rehabilitation requirements of this site will depend on the ongoing leachate quality following flushing, and (it is understood) that a program to determine this will be conducted in late 2000.

It is noted that cyanide is not the only contaminant that is present in dump leach pads; other potentially toxic constituents such as acid drainage and heavy metals, may be present in the waste material and present potential problems after decommissioning.

The decommissioning strategy for the pads is outlined below.

6.4.2.1 Rinsing to Remove Residual Cyanide Solution

The recommended approach to reclamation of the dump leach is to rinse the pile with cyanide-free water until such time as the quality of the rinsate meets an acceptable standard. In the early stages of rinsing it may also contain gold in solution and therefore it may be economic to treat this through the gold recovery circuit. The existing equipment can be used to circulate and collect the water. Raw water from the #2 Storage Dam may be used as the rinsate.

The rinsate will contain residual concentrations of cyanide and therefore cannot be discharged directly to the environment. This residual cyanide can be denatured using a hydrogen peroxide system. While continuous rinsing is feasible, it may prove necessary to rinse a section of the heap and then to “rest” it while another section is rinsed. Depending on the ore character and treatment method, the rinsing requirement could range from less than one-half to greater than five pore volumes of the heap.

6.4.2.2 Closure Criterion

Rinsing should continue until the concentration of WAD cyanide in the rinsate is less than 0.6 mg/L and total cyanide is less than 1.0 mg/L. The heap should then be left for at least six months, or until after a substantial precipitation event, to confirm that further cyanide does not drain from the heap.

6.4.2.3 Detoxification and Removal of Equipment

Once the pad has been adequately detoxified, rehabilitation of the area can commence. All tanks, plants, launders and pipelines and other processing equipment that have contained or possibly contacted cyanide solution should be rinsed with oxidising solution (eg. hydrogen peroxide) before dismantling and disposal.

Once rinsing is complete, the dump leach ponds should be decommissioned, either by filling them with non-reactive waste rock to cover the liners, or removal of the liners before filling. Any sludge, which accumulates in the ponds, should be neutralised. At least one of these ponds could be used for the encapsulation of contaminated materials.

6.4.2.4 Reshaping and Reclamation of the Heap

The oxide heap should be spread so that the material covers any exposed HDPE liner. Once leachate quality is acceptable for release, the sulphide-bearing material will be flattened and encapsulated with the oxide leach pad material. The outer slopes will be reshaped to a 4:1 or 14⁰ grade and contour banks and other drainage works will be installed as required.

The options for the stormwater pond are to rehabilitate or to retain the pond as a detention pond for containment of stormwater runoff during the rehabilitation period. If the pond is to be rehabilitated the sides will be pushed in so that the clay liner is covered by subsoil. The water balance of the heap leach area should be reviewed and appropriate sedimentation ponds constructed and/or retained until vegetation establishment and stabilisation of seepage and runoff water quality.

The topsoil will be stripped from the base of the dump for placement on the outer surface of the dump. Topsoil will be spread to a depth of about 0.15 m. The topsoil will be ripped, seeded and fertilised. As the heap is free draining, establishment of vegetation on the final surface should be relatively easy.

6.4.2.5 Assessment for Acid Generation Potential

There is potential for the heap leach material to generate acid once leaching has ceased. Once the heap is at neutral pH, any contained pyrite will readily oxidise because of its free-draining nature. The rehabilitation plan will consider containment of potential acid generating material. A programme for monitoring of the leachate water quality should be established to assess trends (if any) in acid generation after flushing and post decommissioning and prior to rehabilitation. The monitoring the success rehabilitation should be continued post completion rehabilitation works and reviewed annually.

6.4.2.6 Fallback Closure Strategy

If the monitoring program shows that the spent ore in the heap is likely to produce acid drainage, an alternative closure procedure will need to be developed in order to reduce the acid generation and possible heavy metal mobilisation. However this procedure may involve placement of clay cover, which would prove considerably more expensive to implement.

6.4.2.7 Environmental Monitoring

Environmental monitoring will include:

1. Water monitoring of groundwater bores will continue on a six monthly basis
2. Periodic inspections by Ross Mining employees
3. Annual inspection by a qualified engineer if the stormwater pond is retained

A full time Ross Mining employee is stationed at the Yandan Gold Mine during operation of the dump leach process.

A detailed rehabilitation strategy for the pads will be submitted in an amendment to the Plan of Operations prior to decommissioning of the heap.

6.4.2.8 Risk Assessment

The dump leach pads are conventional in design. A clay-lined stormwater pond is provided for overflow resulting from extreme rainfall events. Both the barren and pregnant pond will overflow to this pond. Although this pond is technically undersized, the risk of overflow is extremely low. Any such overflow would be highly diluted.

A more likely loss pathway is overflow due to slumping of ore into the perimeter launder. Some slumping has occurred on the northern side of the heap. Any overflow at this point has the potential to drain to Rosetta Station via the drain that runs along the northern edge of the heap. The dump leach launder will be cleaned out if required to allow unimpeded flow of leachate.

Most leach pads could be expected to leak. Generally, this would not be associated with significant environmental impact, due to the rapid attenuation of cyanide with distance from the pad. Recent monitoring data from the boreholes indicates that minor seepage is occurring under the barren liquor pond but it is not a significant issue.

Potential receptors of seepage— local groundwater

Potential for causes and effects to be reversed – cyanide concentrations can be rapidly reduced using hypochlorite or similar alternative

Mitigation/remediation measures – flushing with hypochlorite or similar alternative; re-contouring to 4:1 slopes; revegetating

Environmental risks – low

6.4.3 ROM Pad

The ROM stockpile has been retained pending a final rehabilitation decision.

There are two rehabilitation options that are time based.

Option 1

This involves rehabilitation of the ROM during current operation of the Dump Leach Pads. The sulphide-bearing low-grade ore on the surface of the ROM identified by sampling and analysis will be reclaimed and placed at the base of the ROM, probably in the crusher foundation excavation for capping. Any remaining (non-acid forming) ROM pad material should be graded flat or into a low mound and vegetated with mixed grasses and trees.

Option 2

This involves the retention of the ROM until resource exploration and assessment of the Yandan Region has been completed. Option 2 has two outcomes

1. Is where no resource has been located which would require the sulphide-bearing material to be removed to either the Dump Leach pads if they are still operating or disposal to the East Hill pit and rehabilitation of the remainder of the ROM as discussed below;
2. Requires retention of the ROM for stockpiling ore prior to processing;

A small sediment dam will be constructed on the western side of the ROM to aid in retaining sediment loads from rainfall runoff. Runoff from the rest of the ROM will be directed to the mine water pond.

Representative samples of the ROM will be characterised to determine the materials acid producing potential and metal concentrations in residual sulphide-bearing low-grade ore in surface layer of the ROM.

6.4.3.1 Sampling and Analysis

The extent of sulphide-bearing ore material and hence potential for acid formation from residual ore materials in the ROM pad is not known. The presence of sulphide-bearing material in the upper layer should be undertaken prior to commencing rehabilitation works using a limited sampling program. This can be undertaken with the use of a backhoe or similar type equipment to excavate 3 or 4 shallow (<1m) pits to assess the presence of sulphide-bearing material and its extent (principally depth. It is likely that there would be limited sulphide-bearing material present within the surface layer of the ROM pad based on brief site inspection. Site inspection showed no large-scale evidence of acid drainage within the surface of the ROM, no evidence of acid seepage from the toe of the ROM was observed, small patches of sulphides partly oxidising on the surface of the ROM pad. The surface of the ROM pad could be easily (and quickly) mapped for sulphide material and the recommended shallow pitting undertaken in the areas where sulphides were identified for the collection of samples for confirmatory laboratory analysis.

6.4.4 Waste Rock Dumps

There are no waste rock dumps to be rehabilitated.

6.4.5 Tailings Impoundment

6.4.5.1 Revegetation Trials

Sampling was undertaken of *in situ* tailings to enable chemical and physical characterisation of the material. The characterisation of tailings is necessary to determine the long-term behaviour of the tailings, which in itself gives an indication of appropriate rehabilitation techniques.

Revegetation trials were established to determine the species most suited for revegetation of the tailings surface. Pasture grasses growing directly into tailings material were analysed to determine their suitability for the site's final land use, low intensity grazing.

Ground and surface water monitoring commenced at start of mine operation. Groundwater monitoring bores and surface waters, from the return water pond and runoff dam, are now sampled on a bi-monthly basis.

The trial data review is contained in the report on Rehabilitation of Yandan Tailings Facility and Return Water Dam Waterworks Licences G-55021 and G-55022.

Katembora rhodes grass will be used in the revegetation of the TSF based on the trials.

Buffel, rhodes and couch grasses were the dominant species present in the trial treatments. Couch grass was particularly dominant on the straight tailings treatment where it established and formed a thick vegetative covering.

The findings of the trial suggest that in terms of the establishment of a groundcover on the tailings, there is no quantifiable advantage in the placement of oxide and soil layers onto the tailings.

Saltbush establishment has, to date, been very low. Only two specimens of *Atriplex vesicaria* and *Atriplex nummularia* were recorded for the trial. The lack of establishment is most likely due to the inadequate pre treating of the saltbush seed prior to sowing. It is common to 'rinse' the seed prior to sowing to simulate heavy rainfall. The revegetation program utilising the appropriate saltbush species will incorporate the appropriate pre-sowing treatment.

Limited amounts of saltbush may be incorporated in the revegetation of the dams due to their value as feed for cattle.

The trials identified that the number of germinations per species generally rose when the tailings material was disturbed (for example by cattle). The disturbance aided in reducing crusting allowing germinants to rise above the tailings surface. Revegetation program will incorporate crust reducing disturbance or hoeing to propagate growth.

The species that recorded the highest number of germinants were Wynn Cassia, Speedy Couch, Native Grass and Rhodes grass. These species are seen as being appropriate for the tailings dam revegetation.

Based on the findings of trials it is suggested that *Eucalyptus argophloia* and *E. camaldulensis* be used as the primary species for tree revegetation. Local tree species, such as narrow and silver-leaved ironbarks, are not expected to be tolerant of the tailings.

6.4.5.2 Rehabilitation Works

The final tailings beach is predominantly oxide and non-acid producing. Geochemical testwork has confirmed this for all tailings deposited in Compartment A, and for all tailings deposited Compartment B up to mid-1997. Oxide ore was retained to provide the final cover on Compartment B of fully oxide material.

Approximately 13 hectares of sulphide-bearing tailings (or ~12% of total surface area of the TSF) remain uncapped. On this basis, the majority of tailings dam should not require a low permeability cover to

control acid mine drainage. Likewise the need for a capillary break layer is in doubt. The cover system is designed as a water storage layer. The thirteen hectares of exposed sulphide-bearing tailings will be covered with 300mm of clay or similar material to control acid mine drainage. The cover material will be obtained from stockpiled material temporarily stored on the perimeter of the TSF Compartment B.

The proposed decommissioning strategy for Compartment B is to cap exposed areas of sulphide-bearing tailings with 300mm of clay or similar material and plant vegetation directly onto the capped and uncapped tailings surface. The long-term stability of soil windrows placed at intervals around Compartment B has been assessed by a registered engineer as part of the annual inspection of referable dams. The report generated from the inspection included recommendations for the windrows.

The rehabilitation strategy adopted and the climatic conditions of central Queensland suggest that the use of a capillary-break layer is likely to be inappropriate. There is a need to retain a moist soil cover to sustain the growth medium which in Compartment A is essentially drained oxide tailings, and a need to protect the clay capping in Compartment B from desiccation under severe drought conditions. A capillary-break layer may affect the integrity of the clay cap and the growth medium by promoting drainage through its inherent permeability during extended periods of drought.

The overall rehabilitation strategy for the tailings dam differs from that proposed in previous documentation (i.e. the EMOS). The characterisation of the tailings, along with revegetation trials, has shown that the tailings material comprises suitable characteristics for vegetative substrate material. Studies to date indicate that a long-term stable, and self sustaining, vegetative community can be established directly into the tailings material.

Earthworks will be undertaken to install permanent drainage ensure that the tailings facility is stable and self-draining. Areas of low relief within the TSF that promote ponding of water during high rainfall events will be drained and the rehabilitation works will be designed to manage this drainage, i.e. to prevent 'silting-up'.

The proposed decommissioning strategy for Compartment A is to plant vegetation directly onto the tailing surface. The vegetation trials have demonstrated that vegetation will grow in untreated oxide tailings. The trials did demonstrate that better strike rate for planted vegetation occurred on the coarser drained tailings with some topsoil.

Grasses such as *Cenchrus* spp. and *Chloris* spp. will be sown, at 10kg/ha, directly into tailings material. Grass will be sown within the annual wet season to ensure early establishment of a vegetative groundcover that will reduce water and wind erosion. Both species are fast growing, of economic value to grazing and establish readily in the tailings environment. Coated and uncoated seed will be used for the revegetation.

Tree species such as the Western White Gum and River Red Gum, both with environmental and commercial value, will be planted on Compartment A of the tailings dam. Trees will be planted on a per hectare basis in accordance with the surrounding tree densities of undisturbed lands. Trees will be planted in windrows running north south. This places the treelines at a 90-degree angle to the prevailing easterly wind pattern, refer WMC (1988). Planting the trees in such a way gives the benefit of windbreaks over the tailings surface. The reduction in wind speed results in a lower potential for the erosion of the surface of the tailings and a better environment for the establishment and maintenance of pasture between the windbreaks.

6.4.5.3 Drainage Works

Compartment A currently has a depression situated in the compartments northwest corner. The lowest point of the depression is 1.1 m below the level of the nearest retaining wall. A condition of the tailings waterworks licence is that the rehabilitated surface of the tailings must be free draining. To meet this condition it is proposed to excavate a drainage line from the lowest point in the depression to the northwestern corner of the compartment. Water flowing through the drain and away from the tailings dam would report to the tailings return water dam. The drain would have appropriate dimensions for the catchment, in general a wide shallow drain, approximately 200 m in length, with less than a 0.5:100 fall. This drain will be suitably lined to reduce erosion from water flows.

Compartment B has a depression near the decant point (Figure 3) on its southern perimeter. To prevent ponding the level of the wall encompassing the decant dam will be lowered to near tailings surface level upon the establishment of a vegetative cover on compartment. The decant dam will be backfilled with the wall material. Surface water will report directly to the existing spillway feeding into the tailings return water dam.

The long-term fate of the return water dam will be to breach and rehabilitated as defined in the Plan of Operations. However the dam may act as a detention pond during the initial stages of revegetation of the TSF as deemed necessary

Supplementary water for irrigation of the revegetation works will be obtained from Water Storage Ponds and the Return Water Dam.

Environmental monitoring will include:

- Annual assessment of revegetation works.
- Water monitoring of groundwater bores will continue on a six monthly basis as process chemicals are no longer being deposited in the TSF
- Periodic inspections by Ross Mining employees
- Annual inspection of referable dams by a qualified engineer

6.4.5.4 Revegetation Monitoring

Initially visual monitoring will be undertaken to determine if there is a need for follow up seed sowing and or tree planting.

Long term revegetation monitoring will be undertaken on an annual basis in accordance with the vegetation assessment methodology for sites under rehabilitation outlined in the 1999 Yandan Gold Mine Plan of Operations. The tailings surface will be deemed rehabilitated when the rehabilitation criteria set out in the Plan of Operations are met.

Water Monitoring

The surface water and groundwater-monitoring program established for the TSF should be continued during the rehabilitation works on a six monthly basis. The monitoring should assess water quality prior to- and post-wet season. The monitoring program will assess the effectiveness of the rehabilitation works to sustain vegetative cover i.e. minimise salt rise, and seepage of cyanide, metals and acidic drainage.

6.4.5.5 Risk Assessment

The EIS addresses the risk of seepage from the tailings dam. Given estimated seepage movement rates, it was concluded that the risk of cyanide contamination extending past the water return dam was very low.

This dam is located 2.5 km from the Suttor River. Water sampling from the Suttor River indicates no contamination.

Indications of cyanide have been recorded however in bores downstream of the water return dam. The cyanide is likely to have originated from tailings water stored in the water return dam rather than from seepage from the tailings dam itself.

Some seepage is evident during wet seasons at the toe of the eastern saddle dam. A small area of saturated ground exists in this area and appears to be saline. An indicator of the soils salinity is the establishment of *Typha sp.* in the area. The area is entirely within the confines of the return water dam.

Currently the tailings system does not provide sufficient space capacity to meet the required wet season runoff allowance. Water will overflow from the tailings compartments into the return water dam, via the design spillway, during the 2000/01 wet season.

The cyanide concentration in the tailings dam was historically relatively low (about 5-10 ppm).

Since July 1997, the only recorded deaths in the dam are three kangaroos, which appear to have died from exhaustion after being entrapped in mud (tailings), (six swans died following collision with the powerline near the dam).

The area in which water ponds on the tailings are limited. The tailings have a high consolidation and are able to be traversed on foot. There is only a low risk of animals being caught on the tailings surface.

These failures were largely attributed to a lack of slack in the tailings line resulting in the victaulic joints being pulled apart under tension. Spillage from these events were cleaned up and placed into the tailings facility.

Sulphide-bearing tailings are exposed over approximately 13 hectares of the Compartment B surface area. These areas are concentrated on the perimeter of the compartment. The sulphides have the potential to produce acidic leachate whilst remaining exposed. Water quality data indicate that acidic leachate, if being generated, is being neutralised prior to discharging or seeping by surrounding acid neutralising tailings.

Potential receptors of seepage/overflow – Local groundwater; wildlife

Site characterisation strategies – water monitoring; tailings characterisation

Potential for causes and effects to be reversed – cyanide degradation due to effect of sunlight. Reduction in movement of tailings sediment with a vegetative cover.

Mitigation/remediation measures – establishment of vegetation on tailings surface

Environmental risks – moderate-low.

6.4.6 Roads and Haul Roads

Most roads will be progressively rehabilitated as they become available. Sections of major haul roads have been re-contoured and ripped. Ripping and seeding of haul roads will be undertaken progressively until the completion of all earthworks related to rehabilitation program.

There are no significant environmental risks associated with the roads and haul roads.

6.4.7 Water Storage Dam and Mine Water Pond

6.4.7.1 Rehabilitation

These structures will be retained as stock watering dams and will not require rehabilitation. The structures are stable with significant vegetative covers on their embankments. There is evidence of seepage from both dams that is not significant enough to warrant concern. Vegetation in a small area below the water storage dam has died due to waterlogging and the rising of salts.

Environmental Monitoring

Groundwater monitoring will continue on a six monthly basis. Annual referable dam inspections will be undertaken until waterworks licence relinquishment. The Mine Water Pond may be included in the SAR if deemed necessary.

There are no significant environmental risks associated with the water storage dam and mine water pond.

6.4.8 Water Harvesting Channel

The water-harvesting channel can be retained to allow future water harvesting by the landholder, subject to discussion with the landowner. There are no significant environmental risks associated with the water channel.

6.4.9 Airstrip

The airstrip will remain for the use of the landholder and will not be rehabilitated.

6.4.10 Mine Village

6.4.10.1 Rehabilitation

All buildings have been relocated to Wirralie Gold Mine. Most of the concrete footings and pathways have been buried and all disturbed areas not required by the landholder, including roads and parking areas, will be rehabilitated. The disturbed areas will be spread with topsoil and ripped, seeded and fertilised.

Grassed areas, such as the oval and landscaped gardens, will be left to re-colonise with native species and *parthenium*. Septic distributors have been contacted regarding the disused ENVIROFLOW system remaining at the village site. If possible the system will be sold or otherwise buried. Sewage pond is shown in Plate 8.

There are no significant environmental risks associated with the village site.

6.4.11 Pipeline Bund

6.4.11.1 Rehabilitation

The Pipeline bund has been partially rehabilitated by re-contouring. A number of sumps remain along the pipeline route. These sumps will be backfilled by dozing the originally excavated material into the sumps.

There are no significant environmental risks associated with the pipeline bund.

6.4.12 Contaminated Land

Although not considered a major problem at Yandan, contamination of land does exist. The majority of this appears to be associated with the Plant site, refuelling areas, contractor's area and stores facilities. The most likely contaminants are hydrocarbons, either oils and greases or residual fuel. Any identified areas of hydrocarbon contamination can be excavated and the soil either buried in a lined excavation or placed on a concrete pad as a "land farm". Land farm soil should be regularly broken up and mixed to encourage break down of the hydrocarbons by natural biological processes. This can typically take up to six months before residual concentrations reach acceptable levels. The soil can then be used in reclamation.

An audit should be undertaken during the reclamation period to assess the extent of contaminated land. The process chemicals used and where they were stored on site should be evaluated, if it has not already been undertaken.

6.4.13 Contractors Area

6.4.13.1 Rehabilitation

The contractor's area will be assessed for hydrocarbon contamination in the SAR in late 2000. The assessment will involve grid sampling of the soil in the area and analysis for hydrocarbons. Should significant levels of contamination be found the preferred option for rehabilitation is *in situ* treatment for hydrocarbon breakdown, including ripping of compacted areas followed by revegetation.

The size of the contractor's area is small with only some sections being visibly affected by hydrocarbon contamination. There has been no visible evidence of hydrocarbon contamination affecting environments external to the contractor's area.

Environmental risks are considered to be low.

6.4.14 Plant Site

6.4.14.1 Rehabilitation

The plant has been relocated to Wirralie Gold mine. All concrete footings not required by the landholder will be removed on confirmation that no future processing will be undertaken at the site. The concrete footings will be first decontaminated of hydrocarbons. The hydrocarbon sludge will be recovered and treated with the hydrocarbon-contaminated material in the contractor's area or treated *in situ*. Once the footings are clean of hydrocarbons they will be broken up and placed around the base of the Dump Leach pad for rehabilitation. The conveyor tunnel will be secured back filling the entrance of the tunnel with benign waste rock or broken footings, the surface re-profiled to the existing profile of the immediate area. After removal of the concrete footings and closure and re-profiling of the conveyor tunnel, the area will be deep ripped to relieve compaction. Topsoil will be spread over the entire plant site to a depth of 100-150 mm. The area will be seeded and fertilised.

The infrastructure required for the ongoing irrigation of the dump leach pads and the ongoing processing of the heap leach liquor will be retained until completion of the dump leach operation and decommissioning of the Leach pads.

All infrastructure required for ongoing water management will be retained. The small site office and storage sheds will be retained at least for a period of two years after completion of rehabilitation works.

Environmental Monitoring

There are no ongoing monitoring requirements for the plant site area. The area will however be assessed as part of the Site Assessment Report (SAR) for contaminated lands. A third party at the completion of dump leach operations will undertake the site inspection for contaminated lands.

Risk Assessment

The plant site area shows signs of soil contamination from process slurry and hydrocarbons. The exact extent of contamination will be determined in the SAR. The majority of surface water runoff from the plant site reports to the mine water pond, which has a zero discharge. Possible contaminated sediment from the plant site will be retained within this dam.

The area of the plant not reporting to the dam is relatively small and generally removed from areas of visible contamination. Runoff from this area generally runs south around the dump leach and eventually reports to Yandan Creek. Sediment will be present in the runoff from the plant area due to the absence of a vegetative surface cover.

Potential receptors of runoff – Mine water pond; Yandan Creek

Site characterisation strategies – SAR

Potential for causes and effects to be reversed – High

Mitigation/remediation measures – Ripping, topsoil placement, vegetation establishment; some in situ treatment of contaminated soil may be required.

Environmental risks – Low

6.5 Water Management

6.5.1 Water Management Features

Wherever feasible, the pre-mining drainage of the area should be restored after mine closure. The following summarises key water management features of the decommissioned mine (refer also Figure 2):

- It is recommended that the raw water storage ponds be maintained for stock watering post decommissioning. Likewise smaller water dams and sediment ponds should be retained both for long-term stock watering and to provide sediment ponds during the rehabilitation process.
- All runoff from the rehabilitated mine processing areas would be directed into the existing dams to the naturally vegetated lands downstream.
- Runoff from the rehabilitated surface of the tailings impoundment will flow to the low point of the tailings surface via constructed permanent drainage lines, in Compartments A and B of the storage. The water will flow to the decant dam for retention.
- Runoff from the rehabilitated dump leach pads will be directed off via berm drains (for the dump batters) and surface drains (for the top surface) to rock armoured drains, which would direct runoff to a stormwater pond.

- Seepage/leachate (rinsate) from the dump leach pads will be collected in constructed toe drains around the perimeter of leach pad. The seepage will then be directed to the Leach Ponds for treatment or to the Stormwater Pond if likely to be of adequate quality for discharge.
- Runoff from areas undisturbed by mining will generally be diverted away from pit areas and rehabilitated areas as practicable.
- The water quality of the final Main Pit void water is a serious and significant issue with the mine closure plan. The water quality of the void water is impacted upon largely by the contained sulphide-bearing waste rock, wall rock and reactive sludge within the pit area. The strategy adopted in the closure Options outlined in Section 6.4.1 is based on improving the water quality by mixing with Suttor River floodwaters, introducing silt and clay to the pit area via Suttor River floodwaters to decouple potential sources of acidity and metals from the Pit water column, and discharging excess pit water to the Suttor River during flood conditions.

6.5.2 Water Balance Modelling

A final water balance for the whole of the Mine site and its facilities will be undertaken as part of the Rehabilitation and Closure Plan for the Yandan Mine site. The Water balance modelling will be undertaken to predict the behaviour of the water ponds contained within the pits following decommissioning.

6.6 Waste Materials

Wastes will be generated during decommissioning of the mine and infrastructure. These can be divided into non-hazardous (eg. packaging, paper, scrap steel and drums) and hazardous (residual chemicals, sludges containing chemicals etc.).

6.7 Fire Protection

Rehabilitated areas will require a fire protection strategy at least for the first few years to enable establishment and stabilisation of vegetative cover. The strategy will combine maintaining constructed fire breaks with controlled burning.

It is understood that a fire used to be maintained around the perimeter fence of the Mining Lease in accordance with EMOS conditions and general local farming and Country Fire Brigade practice whichever is appropriate. It is desirable that this firebreak should be maintained until Lease is relinquished.

6.8 Reclamation Research Program

A significant amount of research work including revegetation trials, water quality monitoring, pit water modelling, ecological risk assessment and waste rock characterisation has been carried out by the Company on the Yandan Lease area and also at the nearby Wirralie Gold Mine. Trial work and environmental monitoring will be continued for the remainder of the rehabilitation works period to ensure effective and current practices are applied to minimise off-site environmental impacts.

6.9 Proposed Closure Endpoints

It is important to establish, as early as possible, agreed indicators of effective mine decommissioning and reclamation. These indicators, or closure endpoints, will provide certainty that the closure process has

been effective in implementing the reclamation objectives outlined in Section 4.1.1. Indicators should be agreed between all stakeholders so that this certainty can be assured.

The following are the proposed endpoints for the Yandan Gold Mine:

- Water quality in surrounding streams and rivers not adversely impact upon by seepage or drainage from rehabilitated mine facilities including dump leach pad, tailings storage facility, pits, infrastructure, processing plant and ROM pad areas during the operating period over a full wet season;
- Mine components rehabilitated according to the procedures specified in this MRC Plan;
- Erosion gullies on disturbed land less than 300 mm deep over a full wet season; and
- Vegetation established to the satisfaction of the EPA and DME.
- A post-mining land use objective will be agreed with the EPA and DME, local government, and private landholders;
- The agreed land use objective must be compatible with the climate, soils and topography of the final landform and the degree of management available after rehabilitation;
- The introduction of noxious weeds and pests will be controlled as practicable;
- The final rehabilitated landforms will be stable, adequately drained, suitable for the desired long-term land use and compatible with the surrounding landscape where practicable;
- Downstream beneficial uses for surface and ground water will be protected.

6.10 POST-DECOMMISSIONING MONITORING

A monitoring program will be necessary to demonstrate the effectiveness of the decommissioning on controlling continuing environmental impacts and success in reaching the proposed closure criteria.

Yandan Gold Mine has adopted the following Principles for decommissioning, closure and rehabilitation of the mine:

- Monitoring the introduction of noxious weeds and pests will be undertaken to effect their control where practicable;
- The stability of the final rehabilitated landforms will be monitored, to ensure they are adequately drained, suitable for the desired long-term land use and compatible with the surrounding landscape where practicable;
- Water quality of discharge to the natural drainage will be monitored to ensure downstream beneficial uses for surface and ground water are protected; and
- Monitoring and management of the site will continue until the landform, hydrology and vegetation are self-sustaining and meet agreed criteria consistent with the post-mining land use.

7.0 RESOURCES AND SCHEDULE OF OPERATIONS

Implementation of this Mine Rehabilitation and Closure Plan will require commitment of resources, financial, human and capital, during the remaining life of the mining operation and for some years after mine closure until such time as effective decommissioning can be demonstrated. This section presents a summary of the resources required and a schedule for closure.

7.1 Resources Required

The following commitments by Ross Mining for resources are required for successful implementation of this MRC Plan:

- Management of the decommissioning process by an engineer experienced in movement and reshaping of bulk materials, and dismantling of infrastructure;
- Support from environmental personnel in monitoring (water, vegetation and erosion), provision of fertiliser, seeds and plants for revegetation;
- Adequate resources to contract assistance from local communities in, for example, planting of species for revegetation; and
- Co-ordination of analysis of waste rock samples for acid base accounting by suitably qualified geochemist.

Therefore we recommend that, as soon as possible, a Mine Reclamation and Closure Coordinator be identified and appointed. This individual should report to the Operations Manager and be charged with the implementation of the MRC Plan. While operations continue at the site, resources to assist this individual will come primarily from those currently available.

Following closure, this individual will assume control of the site while the various decommissioning activities are taking place. While these may continue to be the responsibility of the departmental manager (eg. decontamination of the process plant and arranging sale or removal of equipment) the MRC Coordinator will manage the overall direction of the process and provide “sign-off” that work has been done to the appropriate standard.

At the end of site decommissioning, the MCD Coordinator will manage reclamation and monitoring activities with support personnel as required.

7.2 Schedule Of Operations

The schedule (to be provided by Tony Dwyer) outlines the various activities identified in this MRC Plan and allocate them by year. Under this schedule, we estimate that the Closure and decommissioning activities will take between two and three years, provided that some activities are commenced immediately. This schedule is indicative only and activities may be completed in less or more time. However, we expect that it will be a minimum of three years after mine closure before the site can be considered for partial relinquishment. Experience with other projects that have been decommissioned suggests that it is likely that the tailings impoundment will take a significantly longer period to drain to allow for cover placement and rehabilitation. The final timeframe for the plan of activities needs to be determined by Ross Mining and submitted with the final Closure Plan to be presented to the Governing Authorities.

8.0 MINE CLOSURE PLAN COST ESTIMATES

The 2000 Plan of Operations included a cost estimate and schedule to undertake the rehabilitation works. Issues and items identified through the preparation of this MCP that vary from the 2000 Plan of Operations are discussed in the following sections. The table of rehabilitation costs has been updated and is presented as Table 3.

Table 3 Rehabilitation Cost Estimate

<i>Disturbance</i>	<i>Area (ha)</i>	<i>\$/ha</i>	<i>\$/item</i>	<i>Total Cost (\$)</i>
Main Pit				
Water harvesting structure	-	-	4,000	4,000
Water monitoring			5,000	5,000
Plant Site & Contractors Area				
removal of footings	-	-	12,000	12,000
topsoil replacement	8	2,400	-	19,200
Ripping, seeding and fertilising	8	750	-	6,000
Dump Leach & Storm Pond				
Removal of lines	-	-	1,000	1,000
Dozing outer slopes	-	-	28,800	160,000
Topsoil replacement	25 approx.	2,400	-	60,000
Ripping, seeding and fertilising	25 approx.	750	-	18,750
Tailings Dam				
Grass seeding	110	115	-	12,650
Tree planting	110	203	-	22,275
Earthworks				35,000
Decant Return Dam				
Breaching the wall	-	-	5,000	5,000
Topsoil replacement	24	2,400	-	57,600
Ripping, seeding and fertilising	24	750	-	18,000
Water Storage Dam	60	-	-	-
Mine Water Pond No.1	20	-	-	-
Water Channel	1	-	-	-
Airstrip	13	-	-	-
Roads	2	750	-	1,500
Haul Roads (external to pits)	3	750	-	2,250
Road Reserve	2	-	-	-
Soil Stockpiles	17	750	-	12,750
				452,975

9.0 REFERENCES



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ABN 34 060 204 702

21 November 2001

Q733

Mr Gareth Thomas
Wirralie Gold Mine
PO Box 242
Collinsville QLD 4804

30-10-2001

Yandan Pit Water Study

Dear Gareth

Debbie

Find enclosed 2 copies of the report of the Yandan Pit Water Study. The original "Certificates of Analysis" are contained in the unmarked report, whereas the report marked "copy" contains photocopies of them.

Lo retained by gwt

Should you require additional copies or assistance in any other matter please contact me at your earliest convenience.

Yours faithfully

HLA-ENVIROSCIENCES PTY LIMITED

Rex Singline
Manager Mackay Office

Shane Stuart BAppSc
QC Reviewer

Q733/Yandan Pit Water Study/RS:ae

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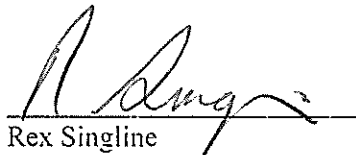
**Study of the Impact of Occasional
Releases of Yandan Pit Water into the
Suttor River**

Prepared for

Wirralie Mines Pty Ltd
PO Box 242
Collinsville, Qld 4804

HLA-Envirosciences Project No Q733

by



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30 October 2001

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Study of the Impact of Occasional Releases of
Yandan Pit Water into the Suttor River

30 October 2001

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Project File

Quality Control Reviewer

Shane Stuart BAppSc
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EXECUTIVE SUMMARY

- Although Pit waters have a relatively low pH of 3.0, their actual acidity of only 120mg/L CaCO₃ equivalent and general composition reveal them to be only slightly contaminated.
- Historical records of the alkalinity of the natural flows in Suttor River reveal an average value of 54mg/L CaCO₃ equivalent. This equates to 2.5 volumes of river water being capable of neutralising 1 volume of Pit water. The catchment of the river above the mine site is of the order of 50,000 sq km, and the 2-year ARI flood flow is 850cumecs.
- As previous studies have determined the volume of Pit discharge would contribute no more than 0.25% of the 2-year ARI flow, complete assimilation of the discharge to the extent that it will be undetectable is assured.
- Simple field monitoring of pH and electrical conductivity (EC) of the actual Pit discharge, and of upstream and downstream river samples, will confirm that the Pit discharge has no observable adverse effect. Occasional laboratory analysis of samples for acidity, sulphate and selected metals should also be conducted during each discharge event.
- It is also recommended that upstream and downstream sites are established for biological monitoring to provide the means to assess the long-term ecological impact of Pit discharges.
- To safeguard against the exposure of Pit wall sulphides due to excessive water losses during periods of sustained drought, it is strongly recommended that the bund separating the Pit from Suttor River is removed to allow more frequent inflow of river water to maximise the Pit water level.

1.0 INTRODUCTION

HLA-Envirosciences was commissioned by Wirralie Mines to undertake a study of the waters accumulated in the mine pit of their Yandan Operations. The purpose of the study was – (1) to generate a 3-dimensional image of the composition of the waters; (2) to assess the environmental impact of further releases of the waters due to flooding by Suttor River waters and; (3) to propose a manageable strategy to monitor such impacts.

2.0 BACKGROUND

Prior to its rapid filling in late February 2000 by Suttor River flood waters a small volume of contaminated, acidic water had accumulated in the base of the Yandan Pit. They had however, been partially neutralised by a campaign of treatment with quick lime in late 1999.

These waters were the product of the reaction of sulphidic materials in the Pit and “introduced” waters. There were 3 possible sources of the water. It was either rainfall runoff or groundwater seepage which had flowed into the Pit, or it had been intentionally pumped into the Pit to provide a water cover over emplaced sulphide-bearing wastes. To minimise the potential for acid generation, a compacted cover of benign material was placed over the wastes prior to commencing pumping. Some additional sulphides were also present in the exposed Pit walls.

3.0 APPLICATION OF WATER QUALITY GUIDELINES

The new Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000) introduces the terminology of “environmental values”, which is an extension of the beneficial use concept used in earlier environmental management literature, but is intended to have less anthropocentric exploitation connotations. Environmental values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health, and warrant protection from the effects of pollution, waste discharges and deposits.

The Guidelines recognises the 6 environmental values listed below:

- Aquatic ecosystems;
- Primary industries (irrigation and stock water, aquaculture and human consumption of aquatic foods);
- Recreation and aesthetics;
- Drinking water;
- Industrial water;
- Cultural and spiritual values.

The new Guidelines encompass a more holistic approach to water quality management, and encourage the setting of appropriate region/site-specific guideline trigger values that flag the need for intervention to protect the agreed environmental value. The appropriate region/site-specific values are determined by working through a detailed investigative process that involves input from all legitimate stakeholders. In the absence of such, the Guidelines proposes default values which, invariably, will be more conservative.

In the case of the Suttor River, the “primary industries” environmental value applies. As appropriate, Pit water quality, or more correctly the impact of Pit water releases, are compared to published Guideline values aimed at the protection of that environmental value.

4.0 STUDY OF COMPOSITION OF MINE PIT WATERS

Two sets of samples (YP1 series and YP2 series) were collected at 5m depth intervals extending from the surface to a depth of 40m using a Van Dorn Bottle sampler. The samples were collected from a fibreglass dinghy. Field measurements of electrical conductivity (EC) and pH were taken before samples were processed and delivered to ALS’ Brisbane laboratory for chemical analysis. All sampling and analysis was conducted in accordance with the protocols detailed in *Water Quality Sampling Manual* (Queensland Department of Environment and Heritage, 1995). ALS is a NATA certified laboratory for such analysis.

Two samples, one from the surface and one from the maximum depth (YP1-0 and YP1-40), were analysed by ICP MS for a broad suite of metals to determine the likely range of concentrations of key metals in the remaining samples. This was done to ensure that the most appropriate analytical technique was employed for subsequent analysis. Based on the those results, the remaining samples were analysed by ICP AES for Cu, Zn, Fe, Al, Ni, Co and As. All samples were also analysed for sulphate (SO₄), acidity, pH and EC. Once preliminary results were received, it was also decided to analyse all samples for major cations Na, K, Ca and Mg. A summary of strategically important results are presented in the Table 1 below, and the formal “Certificates of Analysis” of all results are presented in Appendix A. The stock watering (primary industries) and aquatic ecosystems limits are also listed for comparison.

Table 1
Summary of Key Results

Sample Id	pH	EC (μ S/cm)	SO ₄ (mg/L)	Acidity (mg/L)	Fe (mg/L)	Al (mg/L)	Mn (mg/L)	Zn (mg/L)
YP1-0	2.98	955	292	115	8.8	7.4	1.1	0.9
YP1-5	3.01	948	300	150	8.5	7.7	1.0	0.97
YP1-10	3.02	948	283	117	8.2	7.9	1.1	0.98
YP1-15	3.01	951	278	120	7.9	7.8	1.1	0.89
YP1-20	3.01	956	275	119	8.2	7.9	1.1	0.91
YP1-25	3.01	956	279	119	8.5	8.1	1.1	0.92
YP1-30	3.04	955	287	113	8.3	7.9	1.1	0.9
YP1-35	3.04	956	283	117	8	7.8	1.1	0.88
YP1-40	3.34	5540	2890	595	670	55.7	5.1	15.2
YP2-0	2.97	1010	292	116	7.4	7.8	1.1	0.87
YP2-5	2.99	989	281	122	7.9	7.8	1.1	0.87
YP2-10	2.98	975	284	114	7.8	7.8	1.1	0.88
YP2-15	2.98	974	286	117	7.9	7.8	1.1	0.88
YP2-20	2.97	970	283	115	8.1	7.9	1.1	0.87
YP2-25	2.97	961	292	115	8.3	8	1.1	0.88
YP2-30	2.97	951	291	115	8.3	7.9	1.1	0.89
YP2-40	3.18	4560	2320	702	525	52.1	3.7	9.42
ANZECC/ARMCANZ Water Quality Guideline Trigger Values								
ANZECC ^a		<5000	1000		N/a	5.0	N/a	20
ANZECC ^b	6-7.5	20-250	-	-	ID	0.055	1.9	0.008

ANZECC^a stockwatering limits (Primary industries)

ANZECC^b aquatic ecosystems limits ID – insufficient data to establish values

4.1 Interpretation of Results

The results reveal that the pit waters are highly homogeneous to a depth of around 40 metres. Whilst the pH of these waters are acidic, ranging 2.97-3.04, the actual acidity when measured as CaCO₃ equivalent was found to be relatively low, being on average 110-120mg/L. These levels compare with sulphate values of the order of 280-300mg/L. These sulphate levels are well below the ANZECC stock watering limit of 1000mg/L.

As the sulphate, in the original form of sulphuric acid, is the source of the acidity, it can be derived that 60% of the original acid [ie. (280-110)/280, noting that CaCO₃ equivalent and H₂SO₄ equivalent are virtually interchangeable due to their similar molecular weights, 98 cf. 100] has been consumed. The fate of the acid becomes apparent when attention is directed to the major cations. Ca and Na ions account for the bulk of consumed acid. There is little doubt that much of the acid was consumed when a water treatment campaign involving lime treatment with Neutra Mill plant was undertaken late 1999.

Other than iron (Fe), aluminium (Al) and manganese (Mn), metal levels are low. Reference to the relevant Guideline limits reveals that the Fe and Mn pose no risk, as both metals are considered "not sufficiently toxic". An aluminium trigger level of 5mg/l applies. Although the Pit water Al concentration of 7-9mg/L slightly exceeds that value, Al and the other metals will precipitate as the acidity of the waters is neutralised.

Yandan Pit Water Study

The 2 samples collected from a depth of 40m were much more polluted. The acidity ranged 600-700mg/L CaCO_3 equivalent, with corresponding sulphate levels 2300-2900mg/L. Metal levels are proportionately higher. It is interesting to note that whilst these waters are more polluted than the "surface" waters, their pH is actually higher (ie. 3.2 cf 3.0).

The composition of these waters and their management implications are discussed further in the section below which compares current results with those from a like exercise performed last year.

4.2 Comparison with Available Like Data

A similar survey of accumulated Pit waters was undertaken shortly after the flooding event of February 2000. A series of samples was collected with a Van Dorn Bottle sampler at the following depths: 0.5m, 5m, 10, 20m, 30m and 40m. The composition of the waters was found to be relatively uniform to a depth below 30m, with the sulphate and acidity values ranging 180-220mg/L and 70-80mg/L respectively. The uniformity in the composition of these waters is undoubtedly a consequence of the rapid manner in which the pit filled, with the turbulence of the incoming flood waters creating excellent mixing conditions. Corresponding metal concentrations ranged as follows: Fe 1.7-2.0mg/L, Al 4.7-4.8mg/L, Mn 0.56-0.57mg/L and Zn 0.51-0.55mg/L.

All of these above values represent considerable reductions on the respective concentrations measured recently. For example, sulphate has increased from 200mg/L to 290mg/L, with an accompanied acidity increase from 75mg/L to 120mg/L. Metal concentrations also display a similar trend, with the current respective Fe and Al ranges of 7.4-8.8mg/L and 7.4-8.1mg/L comparing with February 2000 ranges of 1.7-2.0 and 4.5-5.0mg/L.

The primary source of contamination, if in fact not the only source of contamination, is the polluted waters in the base of the Pit at the time of the flooding. The only other possibility is continuing acid generation due to the reaction of sulphidic materials in either the Pit walls or emplaced materials at the base of the Pit. But this is most unlikely, as the water cover will act as a barrier allowing insufficient oxygen flux to fuel such reactions.

The sample of water collected from a depth of 40m shortly after flooding returned sulphate and acidity concentrations of 450 and 260mg/L respectively. Corresponding key metals values were as follows: Fe 34mg/L, Al 13mg/L, Mn 0.98mg/L and Zn 1.8mg/L. These waters vary greatly with the current waters collected from that depth (see Table 1). The recent sulphate and acidity concentrations ranged 2500-3000mg/L and 600-700mg/L respectively. The Fe and Al values were likewise much higher, being of the order of 670 and 50mg/L respectively. It is difficult to rationalise the variation in the composition of the deeper waters over time. As stated above, continuing acid generation to such an extent under the 40m deep water cover is most unlikely. The most probable scenario is that earlier sample was not representative of the deeper pit waters, which were in fact much more polluted than realised.

Of greater relevance in respect of the impact of further Pit releases, is the increase in contamination of the waters above the 35m depth level, notwithstanding that the levels of contamination remain low. The significant concentration gradient between the deeper and shallower waters (ie. below and above 35m) would induce a transfer of contaminants into the upper water column by ionic diffusion. Wind wave action, thermal convective currents and other physical transfer mechanisms have resulted in the uniform mixing of these contaminants throughout the upper 35m water column. Theoretically, ionic diffusive transfer of contaminants will persist until the entire content of the Pit is chemically homogenous. This potential "worst case" scenario is considered in the following section dealing with subsequent additional releases from Pit.

5.0 ENVIRONMENTAL IMPACT OF FUTURE RELEASES CAUSED BY PIT FLOODING

It is inevitable that the Pit will flood on other occasions spilling water into the Suttor River. Inlet and outlet spillways have been established, both at RL 169.0m, which equates to the 2-year ARI river flood low level. The surrounding bund separating the Pit from the river has a 10-year ARI design capacity rating. Any adverse environmental impact on the receiving waters will arise from acidity of the Pit waters. As indicated above, even though the waters are of moderately low pH (3.0), their innate acidity is relatively low, being of the order of 115-120mg/L. Detail on the alkalinity of the flow in Suttor River was sought and received from the Dept. Natural Resources and Mines. This was done to acquire an understanding of the buffering capacity of the river flow and its capability to assimilate any pit discharge. A total of 54 measurements had been recorded over a period extending from June 1968 to present (Source: data provided by DNR&M). The average of all data [expressed as CaCO_3] was 54mg/L, with the 25-percentile and 75-percentile range extending 40-62mg/L. The innate alkalinity of the receiving Suttor River water is therefore almost half the expressed acidity of the Pit waters. Summary sheets of available data for the Suttor River are included in **Appendix B** for information.

In simple terms, the acidity of the Pit waters will be neutralised by a little more than twice an equivalent volume of "average" river water, and even a 1:1 dilution will reduce the acidity by almost 75% (ie half the value in twice the volume). As there is at present approximately 4m freeboard in the Pit considerable neutralisation and dilution of Pit waters will occur before the Pit commences to discharge. **The provision of a mixing zone within the Pit is most convenient**, as the neutralisation of Pit waters will be accompanied by the chemical precipitation of the dissolved metals including Fe, Al, and the trace quantities of heavy metals. Due to their ability to form bulky, quick settling flocs, iron and aluminium compounds are widely used in water treatment plants, and their presence in the Pit waters will both facilitate and accelerate the metal removal process; notwithstanding that metal levels are low anyhow. It therefore follows that if the current freeboard situation persists, the next **actual** discharge of Pit waters will most probably be of good quality in all respects, and represents little if any risk at all.

In any case, any discharge from the Pit will occur at times of flood flow in the Suttor River. The catchment of the Suttor River above the St Anns gauging station, which is nearby to Yandan, is of the order of 50,000 sq km, and R&D Environmental (1999) determined the 2-year ARI flood flow to be 850cumecs. In the course of undertaking a detailed hydrological study of the effect of any Pit discharge R&D Environmental determined that the volume of Pit discharge would contribute no more than 0.25% of the river flow. The point must also be stressed that flood flows usually contain high suspended solids loadings, which are invariably rich in iron and aluminium. Pre mine development data collected from the Suttor River at points both downstream and upstream of the mine site confirm this to be so. Fe concentrations for all samples collected ranged 11-19mg/L. Should any precipitated iron and aluminium (the main metal contaminants) be carried out of the Pit it is doubtful that it could be detected above existing background levels. In any case the precipitated metals will not be biologically available and therefore pose little risk.

The "worst case" scenario would involve the discharge of waters of worst possible quality. This would arise if the highly contaminated waters at the base of the Pit were mixed through the entire body of Pit water at the time of discharge. This scenario is modelled below taking account of the existing water quality and the relevant Pit volumes presented in the **Table 2** below (from RL~volume data provided by Wirralie Gold Mines).

Table 2
Pit Storage Volume Details

Description	Water Level RL (metres)	Water Storage Volume (ML)
Pit Spillways (inlet & outlet)	169.0	3428
Water Level @ sampling	165.61	2919
37m below sampling surface	128.61	212
38m below sampling surface	127.61	191

Taking account the deeper water having an acidity of 650mg/L, compared to 120mg/L for the shallower water (ie. <35m deep), the final acidity of the entire Pit (filled to spillway level) will be 132mg/L if the interface is assumed to be at 38m depth, or 135mg/L if a shallower interface of 37m depth is assumed. In either case, the relative increase above the existing level of contamination is small, ranging 10-12%. If the neutralising capacity of the inflowing river water is accounted for as well, the range of relative increase lowers to only 3-6%. It therefore follows that, even in this worst case scenario, the neutralising and dilution capacity of the receiving flood waters will assimilate any Pit discharge to the point that its effect and impact will be immeasurable. As already stated, it is the innate acidity of the discharge alone that poses the risk. As the neutralisation of the acidity will be accompanied by the chemical precipitation of dissolved metals, the metals present no cause for concern.

6.0 MONITORING THE IMPACT OF FUTURE DISCHARGES

Notwithstanding the fact that subsequent discharges of Pit water present little, if any, environmental risk, validation monitoring data need to be collected at times of discharge to confirm this. pH and EC measurements are capable of telling the complete story, and provide a simple and most effective means of monitoring the effect of Pit discharges. pH will confirm the extent to which the Pit water has been neutralised, and EC will provide a measure of its relative contribution to the total flow. A major attraction is that data for both parameters can be collected instantaneously in the field. As well as monitoring the actual discharge itself, an effective monitoring regime will also involve collecting data from the Suttor both upstream and downstream of the Pit. This approach is consistent with that promoted in the recently released Water Quality Guidelines. While the main focus will be on pH and EC, the collection of occasional samples for laboratory determination of metals, sulphate and acidity must also be undertaken.

Taking account of the composition of the Pit water and capacity of the Suttor River to assimilate any Pit discharge, it is envisaged that daily monitoring (ie. once each day) during periods of discharge will suffice. Perhaps 2 or 3 samples could also be collected during each discharge event for laboratory analyses, including checks on pH and EC. **But clearly there is no need to establish expensive, real-time monitoring capability** which, in any case, would pose a significant maintenance challenge. It is known from first hand experience that loss or damage to such a system by prevailing flood flow conditions can only be safeguarded by undertaking very costly installations. There is simply no need for such and, for that reason, manual monitoring is preferred. The provision of safe access to the monitoring sites under flood flow conditions must be a principle factor in site selection. The above program will clearly demonstrate whether or not the "primary industries" environmental value has been protected.

The protection of "aquatic ecosystems" is the highest environmental value proposed in the Guidelines and, wherever possible, protection of this environmental value is encouraged. The fact has already been established that the Pit waters are only slightly contaminated and that releases can be easily neutralised and assimilated by the receiving natural flows in the Suttor River. Key relevant "aquatic ecosystems" trigger values are presented in Table 1 for information. There is no reason to suspect that the "aquatic ecosystems" environmental value will be compromised by the release of Pit water and comparison of monitored data with that presented in Table 1 should confirm that.

The Guidelines place much emphasis on the value of biological monitoring in respect of safeguarding "aquatic ecosystems". As there is good reason to suspect that the authorities and other legitimate stakeholders may desire some means of monitoring the long-term ecological impact of continuing, occasional releases, it may be wise to pre-empt that probability and establish suitable upstream and downstream biological monitoring sites. It is therefore recommended that a survey of nearby persistent waterholes be undertaken to select suitable sites to serve that purpose. Of course, the monitoring of chemical and physico/chemical parameters at those sites should be also undertaken as part of that extended program.

7.0 OUTSTANDING ISSUES

The above analysis clearly reveals that subsequent releases of the Pit water, in its current state, pose little environmental risk. The only issue of concern arises in respect of the potential for further degradation of water quality within the pit. Some sulphides are present in the pit walls which, should the water level lower to expose them, could oxidise and generate acid. Average rainfall for the area ranges from 576mm at Mt Coolon (64years of records) to 594mm at Yacamunda (58years of records). The nearest long-term evaporation data is available at Collinsville, being 1860mm (27years of records). Factoring in an evaporation pan factor of 0.8, there is a deficit of approximately 900mm. But of course, as the catchment area of the pit will exceed the area of water pondage, the deficit will be considerably less.

By design, the deficit is made up by harvesting flow in the Suttor River, with the inlet and outlet pit spillways set at the 2-year ARI flood flow level. Additional security could be achieved by removing the bund that separates the Pit from the Suttor River. Realistically, it now serves no useful purpose. Although its crest is set at the 10-year ARI flood level, in some areas its base is more or less at the river bedlevel. If it was removed, the Pit would receive inflow on just about every occasion there was flow in the Suttor. As the discharge of Pit water poses little environmental risk, it is strongly recommended that the bund be removed to allow more frequent pit inflow from the river. This will effectively eliminate the risk of exposing Pit wall sulphides and will ensure the most secure, self-maintaining solution.

8.0 REFERENCES

SRK Consulting, 1999: *Yandan Gold Mine Pit Water Quality Prediction*.

R&D Environmental, 1999; *Assessment of the Introduction of Yandan Pit Water into the Suttor River System*.

APPENDIX A

Certificates of Analysis & Chain of Custody Forms



CERTIFICATE OF ANALYSIS

CONTACT: MR R SINGLINE
CLIENT: HLA-ENVIROSCIENCES PTY LTD
ADDRESS:
P O BOX 3263
NTH MACKAY QLD 4740
ORDER No.: 115567
PROJECT: Q733

BATCH: EB39443
SUB BATCH: 0
LABORATORY: BRISBANE
DATE RECEIVED: 16/08/2001
DATE COMPLETED: 27/08/2001
SAMPLE TYPE: WATER
No. of SAMPLES: 17

COMMENTS

Results apply to sample(s) as submitted.

NOTES

This is the Final Report and supersedes any preliminary reports with this batch number.
All pages of this report have been checked and approved for release.

ISSUING LABORATORY: BRISBANE

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Signatory

LABORATORIES

AUSTRALASIA

Brisbane
Melbourne
Sydney
Newcastle
Auckland

Hong Kong
Singapore
Kuala Lumpur
Bogor

AMERICAS

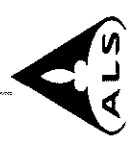
Vancouver
Santiago
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Lima

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Batch: EB39443
 Sub Batch: 0
 Date of Issue: 27/08/2001
 Client: HLA-ENVIROSCIENCES PTY LTD
 Client Reference: Q733

CERTIFICATE OF ANALYSIS



			SAMPLE IDENTIFICATION										
		Laboratory I.D.	1	2	3	4	5	6	7	8	9	10	
		Date Sampled											
METHOD	ANALYSIS DESCRIPTION	UNIT	LOR	YP2-0	YP2-5	YP2-10	YP2-15	YP2-20	YP2-25	YP2-30	YP2-40	YP1-0	YP1-40
EA-005-P	pH Value		0.01	2.97	2.99	2.98	2.98	2.97	2.97	2.97	3.18	2.98	3.34
EA-010-P	Conductivity @ 25°C	uS/cm	1	1010	989	975	974	970	961	951	4560	955	5540
ED-038	Acidity as CaCO3	mg/L	1	116	122	114	117	115	115	115	702	115	595
ED-040F	Sulphate - Filtered	mg/L	1	292	281	284	286	283	292	291	2320	292	2890

Batch: EB39443
Sub Batch: 0
Date of Issue: 27/08/2001
Client: HLA-ENVIROSCIENCES PTY LTD
Client Reference: Q733

CERTIFICATE OF ANALYSIS



METHOD		ANALYSIS DESCRIPTION	SAMPLE IDENTIFICATION														
			Laboratory I.D.		11	12	13	14	15	16	17						
			Date Sampled														
			UNIT	LOR	YP1-5	YP1-10	YP1-15	YP1-20	YP1-25	YP1-30	YP1-35						
EA-005-P	pH Value	0.01	3.01	3.02	3.01	3.01	3.01	3.01	3.01	3.04	3.04	3.04					
EA-010-P	Conductivity @ 25°c	1	948	948	951	956	956	956	956	955	955	956					
ED-038	Acidity as CaCO3	1	150	117	120	119	119	119	119	113	113	117					
ED-040F	Sulphate - Filtered	1	300	283	278	275	275	279	287	287	283	283					

Batch: EB39443

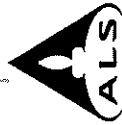
Sub Batch: 0

Date of Issue: 27/08/2001

Client: HLA-ENVIROSCIENCES PTY LTD

Client Reference: Q733

QUALITY CONTROL REPORT



METHOD			ANALYSIS DESCRIPTION	SAMPLE IDENTIFICATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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CERTIFICATE OF ANALYSIS

CONTACT: MR R SINGLINE
CLIENT: HLA-ENVIROSCIENCES PTY LTD
ADDRESS:
P O BOX 3263
NTH MACKAY QLD 4740
ORDER No.: 115567
PROJECT: Q733

BATCH: EB39443
SUB BATCH: 1
LABORATORY: BRISBANE
DATE RECEIVED: 16/08/2001
DATE COMPLETED: 27/08/2001
SAMPLE TYPE: WATER
No. of SAMPLES: 2

COMMENTS

Results apply to sample(s) as submitted.

NOTES

This is the Final Report and supersedes any preliminary reports with this batch number.
All pages of this report have been checked and approved for release.

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Batch: EB39443
Sub Batch: 1
Date of Issue: 27/08/2001
Client: HLA-ENVIROSCIENCES PTY LTD
Client Reference: Q733

CERTIFICATE OF ANALYSIS



		SAMPLE IDENTIFICATION									
METHOD	ANALYSIS DESCRIPTION	Laboratory I.D.		9		10					
		Date Sampled		YP1-0		YP1-40					
		UNIT	LOR								
EG-005F	Boron - Filtered	ug/L	100	<100		<100					
EG-005F	Iron - Filtered	ug/L	10	8800		670mg/L					
EG-020F	Silver - Filtered	ug/L	1	<1		<1					
EG-020F	Aluminium - Filtered	ug/L	50	7360		55.7mg/L					
EG-020F	Arsenic - Filtered	ug/L	10	10		9550					
EG-020F	Barium - Filtered	ug/L	1	61		30					
EG-020F	Beryllium - Filtered	ug/L	1	12		144					
EG-020F	Bismuth - Filtered	ug/L	1	<1		<1					
EG-020F	Cadmium - Filtered	ug/L	1	4		23					
EG-020F	Cerium - Filtered	ug/L	1	52		261					
EG-020F	Cobalt - Filtered	ug/L	1	266		2750					
EG-020F	Chromium - Filtered	ug/L	1	3		18					
EG-020F	Caesium - Filtered	ug/L	1	<1		14					
EG-020F	Copper - Filtered	ug/L	1	76		91					
EG-020F	Dysprosium - Filtered	ug/L	1	16		102					
EG-020F	Erbium - Filtered	ug/L	1	7		46					
EG-020F	Europium - Filtered	ug/L	1	4		22					
EG-020F	Gallium - Filtered	ug/L	1	<1		2					
EG-020F	Gadolinium - Filtered	ug/L	1	19		113					
EG-020F	Hafnium - Filtered	ug/L	10	<10		<10					
EG-020F	Mercury - Filtered	ug/L	1	<1		2					
EG-020F	Holmium - Filtered	ug/L	1	3		19					
EG-020F	Indium - Filtered	ug/L	1	<1		<1					
EG-020F	Lanthanum - Filtered	ug/L	1	16		79					
EG-020F	Lithium - Filtered	ug/L	1	13		244					
EG-020F	Lutetium - Filtered	ug/L	1	<1		4					
EG-020F	Manganese - Filtered	ug/L	1	1060		5050					
EG-020F	Molybdenum - Filtered	ug/L	1	<1		<1					
EG-020F	Neodymium - Filtered	ug/L	1	45		247					
EG-020F	Nickel - Filtered	ug/L	1	258		2660					

Batch: EB39443

Sub Batch: 1

Date of Issue: 27/08/2001

Client: HLA-ENVIROSCIENCES PTY LTD

Client Reference: Q733

CERTIFICATE OF ANALYSIS



SAMPLE IDENTIFICATION									
Laboratory I.D.		9	10						
Date Sampled									
METHOD	ANALYSIS DESCRIPTION	UNIT	LOR						
EG-020F	Lead - Filtered	ug/L	1	<1	2				
EG-020F	Praseodymium - Filtered	ug/L	1	9	46				
EG-020F	Rubidium - Filtered	ug/L	1	18	154				
EG-020F	Antimony - Filtered	ug/L	1	<1	5				
EG-020F	Selenium - Filtered	ug/L	10	<10	18				
EG-020F	Samarium - Filtered	ug/L	1	16	80				
EG-020F	Tin - Filtered	ug/L	1	<1	<1				
EG-020F	Strontium - Filtered	ug/L	1	306	3470				
EG-020F	Terbium - Filtered	ug/L	1	3	19				
EG-020F	Tellurium - Filtered	ug/L	5	<5	<5				
EG-020F	Thorium - Filtered	ug/L	1	<1	<1				
EG-020F	Titanium - Filtered	ug/L	10	<10	24				
EG-020F	Thallium - Filtered	ug/L	1	9	144				
EG-020F	Thulium - Filtered	ug/L	1	<1	5				
EG-020F	Uranium - Filtered	ug/L	1	18	48				
EG-020F	Vanadium - Filtered	ug/L	10	<10	184				
EG-020F	Yttrium - Filtered	ug/L	1	74	564				
EG-020F	Ytterbium - Filtered	ug/L	1	5	30				
EG-020F	Zinc - Filtered	ug/L	1	899	15.2mg/L				
EG-020F	Zirconium - Filtered	ug/L	5	<5	18				



CERTIFICATE OF ANALYSIS

CONTACT: MR R SINGLINE
CLIENT: HLA-ENVIROSCIENCES PTY LTD
ADDRESS:
P O BOX 3263
NTH MACKAY QLD 4740
ORDER No.: 115567
PROJECT: Q733

BATCH: AEB39678
SUB BATCH: 0
LABORATORY: BRISBANE
DATE RECEIVED: 28/08/2001
DATE COMPLETED: 20/11/2001
SAMPLE TYPE: WATER
No. of SAMPLES: 15

COMMENTS

Results apply to sample(s) as submitted. This report supersedes any previous preliminary reports of the same batch number. This batch supersedes EB39678.

NOTES

This is the Final Report and supersedes any preliminary reports with this batch number. All pages of this report have been checked and approved for release.

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LABORATORIES

AUSTRALASIA

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AMERICAS

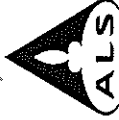
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Batch: AEB39678
Sub Batch: 0
Date of Issue: 20/11/2001
Client: HLA-ENVIROSCIENCES PTY LTD
Client Reference: Q733

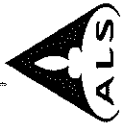
CERTIFICATE OF ANALYSIS



		SAMPLE IDENTIFICATION											
Laboratory I.D.		1	2	3	4	5	6	7	8	9	10		
Date Sampled													
METHOD	ANALYSIS DESCRIPTION	UNIT	LOR	YP2-0	YP2-5	YP2-10	YP2-15	YP2-20	YP2-25	YP2-30	YP2-40	YP1-5	YP1-10
ED-005F	Calcium - Filtered	mg/L	1	46	47	47	47	47	47	47	309	46	47
ED-010F	Magnesium - Filtered	mg/L	1	13	13	13	13	13	14	14	149	13	14
ED-015F	Sodium - Filtered	mg/L	1	42	42	42	42	42	43	42	457	41	42
ED-020F	Potassium - Filtered	mg/L	1	8	8	8	8	8	8	8	31	8	9
EG-005F	Aluminium - Filtered	mg/L	0.1	7.8	7.8	7.8	7.8	7.9	8.0	7.9	52.1	7.7	7.9
EG-005F	Arsenic - Filtered	mg/L	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	4.29	0.02	0.02
EG-005F	Cobalt - Filtered	mg/L	0.01	0.26	0.27	0.27	0.27	0.27	0.28	0.27	2.20	0.27	0.27
EG-005F	Copper - Filtered	mg/L	0.01	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.16	0.12	0.13
EG-005F	Iron - Filtered	mg/L	0.01	7.43	7.87	7.82	7.87	8.07	8.34	8.28	525	8.50	8.16
EG-005F	Manganese - Filtered	mg/L	0.01	1.05	1.05	1.07	1.06	1.05	1.07	1.05	3.69	1.04	1.09
EG-005F	Nickel - Filtered	mg/L	0.01	0.27	0.27	0.27	0.27	0.27	0.27	0.27	2.16	0.27	0.27
EG-005F	Zinc - Filtered	mg/L	0.01	0.87	0.87	0.88	0.88	0.87	0.88	0.89	9.42	0.97	0.98

Batch: AEB39678
Sub Batch: 0
Date of Issue: 20/11/2001
Client: HLA-ENVIROSCIENCES PTY LTD
Client Reference: Q733

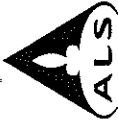
CERTIFICATE OF ANALYSIS



METHOD		ANALYSIS DESCRIPTION	Laboratory I.D.		11	12	13	14	15	SAMPLE IDENTIFICATION				
			Date Sampled		UNIT	LOR	YP1-15	YP1-20	YP1-25	YP1-30	YP1-35			
ED-005F		Calcium - Filtered	mg/L	1			47	47	47		47			
ED-010F		Magnesium - Filtered	mg/L	1			13	13	13		13			
ED-015F		Sodium - Filtered	mg/L	1			41	42	43		42			
ED-020F		Potassium - Filtered	mg/L	1			9	8	9		8			
EG-005F		Aluminium - Filtered	mg/L	0.1			7.8	7.9	8.1		7.9			
EG-005F		Arsenic - Filtered	mg/L	0.01			0.01	0.02	0.01		0.01			
EG-005F		Cobalt - Filtered	mg/L	0.01			0.27	0.28	0.28		0.27			
EG-005F		Copper - Filtered	mg/L	0.01			0.10	0.11	0.12		0.12			
EG-005F		Iron - Filtered	mg/L	0.01			7.92	8.16	8.46		8.26			
EG-005F		Manganese - Filtered	mg/L	0.01			1.05	1.07	1.10		1.07			
EG-005F		Nickel - Filtered	mg/L	0.01			0.27	0.27	0.28		0.27			
EG-005F		Zinc - Filtered	mg/L	0.01			0.89	0.91	0.92		0.90			

Batch: AEB39678
Sub Batch: 0
Date of Issue: 20/11/2001
Client: HLA-ENVIROSCIENCES PTY LTD
Client Reference: Q733

QUALITY CONTROL REPORT



SAMPLE IDENTIFICATION										
Laboratory I.D.			200	201						
Date Sampled										
UNIT			LOR	Method Blank	LCS % Rec					
METHOD	ANALYSIS DESCRIPTION									
CHECKS AND SPIKES										
ED-005F	Calcium	- Filtered	mg/L	1		<1				
ED-010F	Magnesium	- Filtered	mg/L	1		<1				
ED-015F	Sodium	- Filtered	mg/L	1		<1				
ED-020F	Potassium	- Filtered	mg/L	1		<1				
EG-005F	Aluminium	- Filtered	mg/L	0.1		<0.1				
EG-005F	Arsenic	- Filtered	mg/L	0.01		<0.01				
EG-005F	Cobalt	- Filtered	mg/L	0.01		<0.01				
EG-005F	Copper	- Filtered	mg/L	0.01		<0.01				
EG-005F	Iron	- Filtered	mg/L	0.01		<0.01				
EG-005F	Manganese	- Filtered	mg/L	0.01		<0.01				
EG-005F	Nickel	- Filtered	mg/L	0.01		<0.01				
EG-005F	Zinc	- Filtered	mg/L	0.01		<0.01				

ANALYSIS REQUEST FORM

CLIENT INFORMATION				SAMPLE INFORMATION				CHAIN OF CUSTODY			
Project number		Q733		Date sampled:		14/8/01		Relinquished by:		Date: 15/8/01	
Company name (to be reported):		Warrake Gold Mine		Sampled by:		☐ HLA-Enviro ☐ Client		Received by:		Date: 16/8	
Contact:		Rex Singline		Special storage requirements		☒ ☐ N		Relinquished by:		Date:	
Address:		c/- HLA ENVIROSCIENCES		Please list HLA Quotation No.: P				Relinquished by:		Date:	
Ph:		49530866		HLA LAB USE ONLY				Received by:		Date:	
Results to:		Rex Singline		Sample forwarded to external:		metals on 0.45µ filtered samples		Relinquished by:		Date:	
External Client Sample ID (to be reported)	Matrix water, soil, etc.	Preservation Used (Y/N)	List Required Test eg. pH	HLA	SA	acidity	metals	Total Cost	Accepted (HLA LAB USE ONLY)	Relinquished (HLA LAB USE ONLY)	
1 YP2-0	water	1	pH	✓	✓	✓	✓		5339443	5339443	
2 YP2-5	..	2		✓	✓	✓	✓		1618	1618	
3 YP2-10	..	3		✓	✓	✓	✓		URGENT	URGENT	
4 YP2-15	..	4		✓	✓	✓	✓				
5 YP2-20	..	5		✓	✓	✓	✓				
6 YP2-25	..	6		✓	✓	✓	✓				
7 YP2-30	..	7		✓	✓	✓	✓				
8 YP2-35	..	8		✓	✓	✓	✓				
9 YP2-40	..	9		✓	✓	✓	✓				
10											
11											
12											

ADDITIONAL INFORMATION: metals on 0.45µ filtered samples. Request completed by: Rex Singline Page of

NATA endorsed report required ☒ Y ☐ N External labs please report both External Client Sample ID and Lab ID (see shaded areas)

ANALYSIS REQUEST FORM

CLIENT INFORMATION				SAMPLE INFORMATION				CHAIN OF CUSTODY			
Project number 0733		Purchase order no.		Date sampled: 14/8/01		Relinquished by: <i>[Signature]</i> (TAKE A COPY)		Date: 15/8/01		Accepted (HLA LAB USE ONLY)	
Company name (to be reported): Wirralie Gold Mine		Sampled by: ☒ HLA-Enviro ☐ Client		Special storage requirements ☒ Y ☐ N		Received by: <i>[Signature]</i>		Date: 16/8		Total Cost	
Contact: Rex Singline		Please list HLA Quotation No.: P		HLA LAB USE ONLY		Relinquished by: (TAKE A COPY)		Date:		12/6/01 (HLA LAB USE ONLY)	
Address: CL- HLA-Envirosciences		Sample forwarded to external:		Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
Ph: 49530866		Fax: 49530868		Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
Results to: Rex Singline		List Required Test eg. pH		Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
Matrix water, soil, etc.		Preservation Used (Y/N)		Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
1 YPI-0 water				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
2 YPI-40 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
3 YPI-5 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
4 YPI-10 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
5 YPI-15 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
6 YPI-20 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
7 YPI-25 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
8 YPI-30 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
9 YPI-35 "				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
10				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
11				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			
12				Sample forward to external:		Relinquished by: (TAKE A COPY)		Date:			

ADDITIONAL INFORMATION:

Request completed by: *Rex Singline* Page of

all metal analyses to be performed on 0.45µ filtered samples

NATA endorsed report required ☒ Y ☐ N External labs please report both External Client Sample ID and Lab ID (see shaded areas)

APPENDIX B

Summary Sheet of DNR Suttor River Data

Summary of Water Quality Data by Station

Variable	Number Of Results	10		Median	90		Mean	Std Dev	Date Range		
		Minimum	Percent		Percent	Maximum			From	To	
*** Station=120303A Suttor River at St. Anns											
2401.00 Sulphate as SO4 (mg/L)	43	1	1.856	3.3	7.02	14	3.99093	2.65564	29/08/1968	21/03/2000	
2502.00 Aluminium as Al soluble	19	0	0	0.08	0.79	3.8	0.40684	0.86962	06/09/1988	21/03/2000	
2551.00 Boron as B (mg/L)	41	0	0	0.03	0.1	0.15	0.04634	0.03904	15/05/1973	21/03/2000	
2622.00 Copper as Cu soluble mg/L	19	0	0	0.01	0.042	0.06	0.01737	0.01881	06/09/1988	21/03/2000	
2641.00 Fluoride as F (mg/L)	52	0.02	0.1	0.105	0.2	0.9	0.14712	0.11884	29/08/1968	21/03/2000	
2682.00 Iron as Fe soluble (mg/L)	44	0	0.01	1.1	4.15	5.4	1.52955	1.58769	29/08/1968	21/03/2000	
2712.00 Manganese as Mn soluble	33	0	0	0.01	0.028	0.04	0.01091	0.01071	15/06/1983	21/03/2000	
2762.00 Silica as SiO2 soluble	53	5.7	10.18	19.6	45	73	23.18113	14.19645	15/05/1973	21/03/2000	
2822.00 Zinc as Zn soluble (mg/L)	21	0	0	0.01	0.02	0.02	0.00857	0.00793	06/09/1988	21/03/2000	

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Yandan Gold Mine TSF Cell B Conceptual Cover System Design Update

11 December 2019



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

Yandan Gold Mine

TSF Cell B Conceptual Cover System Design Update

956-007-005

December 2019

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A	26/11/2019	SL/RMB	RES/RB/AO	AO
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EXECUTIVE SUMMARY

Okane Consultants Pty Ltd. (Okane) has been retained by Straits Gold Pty Ltd (Straits Gold) to assist with developing a cover system design for Cell B of the tailings storage facility (TSF) at the Yandan Gold Mine (Yandan) in Central Queensland. The overarching project objective is to inform Straits Gold on suitable cover system options that incorporates a barrier layer for rehabilitation of the TSF Cell B at Yandan. Cell B of the TSF comprises oxide tailings of variable thickness over sulfidic tailings material. The DES requirement for a 'low permeability' layer stems from the need to limit potential for acid and metalliferous drainage (AMD) occurring through control of atmospheric interactions with the sulfidic tailings material.

In order to achieve the project objective, Okane has completed the following scope of work:

- Phase 1: Material Characterisation and Sampling;
- Phase 2: Laboratory Analysis of Potential Cover System Materials;
- Phase 3: Numerical Modelling and Detailed Cover System Design; and
- Phase 4: Cost Benefit Comparison of Cover System Variations

Okane completed a site visit in July 2019 to collect material samples and make observations relating to the suitability of the available materials for use in a suitable cover system. Geotechnical, and limited geochemical, testing was completed over a two stage approach to develop a database of the available material's physical and hydraulic characteristics on which a subsequent numerical modelling program was based. Materials were placed into four main groups; topsoil, growth medium, coarse rock and clay. A review of the clayey material was undertaken to assess the ability of available sources capable of producing a low permeability layer within the cover system.

Outcomes of the material characterisation program indicated:

- Material from the cores of the Tailings Return Water Dam and the Mine Water Dam embankments contain considerable oversize material and is therefore not considered suitable for constructing the barrier layer unit of a cover system designed to control infiltration into the underlying tailings material.
- Materials sampled from the Heap Leach Pond embankment core, upstream of the Mine Water Dam and upstream of the Water Storage Dam were found to have generally good consistency and are considered suitable for constructing a barrier layer. However further investigations will need to be completed to confirm the required volume of material can be won from these locations.
- Material from the offsite clay borrow location were found to be suitable for construction a barrier layer.

- The material adjacent to Cell A is generally coarser than the material adjacent to the Cell B and would be suitable for use in a capillary break layer. Waste rock from the heap leach pad also demonstrated appropriate physical characteristics for use in a capillary break layer.
- Several locations were considered suitable for use as a growth medium. However, as this unit of the cover system requires the most material to construct, the available volumes should be further investigated.
- Fertility testing of potential topsoil material did not identify any significantly limiting factors for vegetation growth or establishment.

Following material characterisation works, a 1-D numerical modelling program was utilised to investigate the following four cover system designs:

- 1) The previously proposed store-and-release cover system design (Base Case);
- 2) A double capillary break cover system;
- 3) A single capillary break cover system using the Queensland Government Department of Environment and Science's (DES) minimum prescribed cover system layer thicknesses; and
- 4) A single capillary break cover system using alternative cover system layer thicknesses based on Okane's experience and knowledge of the region.

These cover system alternatives were assessed in three categories:

- 1) Net Percolation (NP) Assessment: each cover system alternative was simulated to determine the water balance, including the amount of water that enters the underlying tailings (i.e. NP).
- 2) Water Stored within cover system available for vegetation: defined as the volume of water that is stored within the growth medium and topsoil component of the cover system, helps determine which cover system alternatives are best to provide sufficient water for vegetation establishment and survival.
- 3) Salt Uptake Assessment: determines relative potential for salt uptake into the cover system based on the alternatives.

The numerical modelling program concluded:

- The double capillary break and single capillary break with DES minimum thickness provided a moderate reduction in NP under a scenario modelled without established vegetation. The single capillary break with alternative layer thicknesses provided the greatest reduction in NP (4% of average annual rainfall) and was classified as a low NP system. Without established vegetation, the Base Case design only limited NP to approximately 54% of average annual rainfall and was classified as a very high NP system.

- Modelling with an established vegetation cover reduced NP for all three alternative cover system designs to low level NP systems. The introduction of established vegetation to the Base Case design reduced NP for this design from 54% to 8%, or from a very high to a moderate NP system.
- The double capillary break and both single capillary break designs can store more water within the cover system compared to the Base Case design.
- The single capillary break with the DES minimum thicknesses performed the best in terms of limiting salt uptake into the root zone of the cover systems. All three alternative cover system designs are expected to provide adequate control of salt uptake into the growth medium. The Base Case design resulted in moderate salinity levels at average tailings electrical conductivity levels and high to very high salinity levels when modelled using maximum potential tailings electrical conductivity values.

A cost benefit comparison was undertaken following the numerical modelling program to provide an indication of the relative difference between alternative cover system designs in terms of NP performance. The comparison provided an indication of the cost burden associated with a performance improvement relative to the Base Case. The estimated construction costs for all three alternative designs were considerably higher than those estimated for the Base Case. The cost benefit comparison identified the single capillary break with alternative layer thicknesses as the design providing the greatest relative improvement (47%) in NP performance and lowest construction costs when compared to the Base Case under the scenario with no vegetation coverage (bare surface).

However, when compared under the scenario with established vegetation coverage, the difference in performance between the Base Case design and the much higher cost alternatives was greatly reduced. Established vegetation coverage was modelled at 28% and is considered achievable based on observations made during the site visit. Under the established vegetation scenario, the predicted reduction in NP provided by the higher cost alternative cover system designs, when compared to the Base Case, is limited to 5-6%. As the construction costs remain the same under both scenarios, the relative costs accompanying the much smaller improvements achieved by the alternative cover systems designs are approximately eight times greater under an established vegetation scenario than a bare surface scenario.

Based on the results and findings from the material characterisation program, numerical modelling and cost benefit comparison, Okane recommend Straits Gold adopt the single capillary break with alternative layer thicknesses design to address both the DES requirement for a cover system incorporating a barrier layer and the rehabilitation objectives defined in the Yandan Post Mine Land Use Plan (AARC, 2015) for Cell B of the TSF.

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1 INTRODUCTION

Okane Consultants Pty Ltd. (Okane) was retained by Straits Gold Pty Ltd (Straits Gold) to assist with further developing a cover system design for Cell B of the tailings storage facility (TSF) at the Yandan Gold Mine (Yandan) located in Central Queensland. Previous work, completed by Okane in 2015 (Okane, 2015), developed a conceptual cover system design, suitable of meeting the following objectives:

- 1) Create clean surface runoff from the TSF Cell B surface;
- 2) Limit upward movement of oxidation products and salts;
- 3) Limit net percolation to restrict flushing of stored acidity;
- 4) Form a stable landform with limited erosion; and
- 5) Support vegetation and end land use:
 - a. Cattle grazing
 - b. Avoid deep rooted vegetation (trees).

Okane understands that during discussions between Straits Gold and the Queensland Government Department of Environment and Science (DES) in 2019, the 2015 conceptual cover system design was identified as unsuitable by DES as it did not incorporate a 'low permeability' unit within the cover system of Cell B.

1.1 Project Objective and Scope

The overarching project objective is to inform Straits Gold on suitable cover system options that incorporates a barrier layer for rehabilitation of the TSF Cell B at Yandan. Cell B of the TSF comprises oxide tailings of variable thickness over sulfidic tailings material. The DES requirement for a 'low permeability' layer stems from the need to limit potential for acid and metalliferous drainage (AMD) occurring through control of atmospheric interactions with the sulfidic tailings material.

Throughout this report Okane refers to the cover system unit designed to limit AMD as a barrier layer. The term 'low-permeability' layer is typically associated with, and is used by Okane, to define a specific level of performance, in terms of permeability (field saturated hydraulic conductivity $<1 \times 10^{-9}$ m/s). A barrier layer performs the same function as a 'low-permeability' layer but is not tied to a specific level of performance. The barrier layers investigated in this project would be constructed using a compacted clay type material identified during the material characterisation phase.

In order to achieve the project objective, Okane has completed the following scope of work:

- Phase 1: Material Characterisation and Sampling;

- Phase 2: Laboratory Analysis of Potential Cover System Materials;
- Phase 3: Numerical Modelling and Detailed Cover System Design; and
- Phase 4: Cost Benefit Comparison of Cover System Variations

Material sampling was undertaken during a four day site visit in July 2019. Samples collected during the site visit were subjected to a two-stage laboratory analysis program to characterise the available materials and identify their potential for use in a cover system.

Following material characterisation, a numerical modelling program evaluated the relative performance of the following four cover system designs in terms of NP, water storage and salt uptake:

- 1) The previously proposed 2015 conceptual cover system design (base case cover design);
- 2) A double capillary break cover system;
- 3) A single capillary break cover system using the Queensland Government Department of Environment and Science (DES) minimum layer thickness; and
- 4) A single capillary break cover system using alternative layer thicknesses for cover system layers.

A cost benefit comparison was completed to assess the relative cost increases associated with improvement in performance, measured as a percentage improvement, achieved by the alternative configurations when assessed against the original conceptual design from 2015.

1.2 Report Organisation

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

- Section 1 – Introduction, objectives and scope;
- Section 2 – Background information;
- Section 3 – Field sampling and material characterisation;
- Section 4 – Cover system design filters/site attributes;
- Section 5 – Modelling program and inputs;
- Section 6 – Modelling results;
- Section 7 - Cost benefit comparison;
- Section 8 – Findings and recommendations; and
- Section 9 – References.

2 BACKGROUND

The following section provides:

- A brief description of the Yandan mine site and its current rehabilitation objectives;
- Definition and classification of performance indicators; and
- Summary of cover system design filters and site attributes.

2.1 Site Background and Closure Objectives

The Yandan Gold Mine is located in central Queensland, approximately 50 km west of the township of Mount Coolon and 150 km south-east of Charters Towers. The project encompasses Mining Leases (ML) 1095 and ML 1096 and is authorised by Environmental Authority (EA) EPML00771913 (formerly MIN100902609). The Yandan deposit was originally discovered in 1986 before its acquisition by Ross Mining NL in 1992. Gold mining operations commenced in 1993 (GHD Pty Ltd, 2008). Ownership of Yandan has mostly recently been transferred to Straits Gold Pty Ltd, a subsidiary of Aeris Resources.

A total of three pits, Main Pit, South Hill Pit and East Hill Pit, were mined and other site facilities were constructed to support mining operations including a heap leach, a carbon-in-leach processing plant and a two-cell Tailings Storage Facility (TSF) (GHD Pty Ltd, 2008). The site has been under a period of care and maintenance since its closure in 1998 (Straits Gold, 2013). Figure 2.1 shows a satellite image of the main facilities / landforms within Yandan.

The north-west region of the Project site is characterised by undulating low hills and foot slopes with rock outcrops, while the south-east section is characterised by clay plains with temporary minor lakes during wet seasons being a feature. Yandan is situated on the east bank of the Suttor River in proximity to a junction with two minor ephemeral tributaries – Yandan Creek and Sandy Creek. Yandan Creek has a catchment of approximately 7,200 ha, while Sandy Creek has a catchment of approximately 900 ha. The Suttor River drains into Lake Dalrymple, formed by the damming of the Burdekin River.



Figure 2.1: Annotated Satellite image of Yandan.

Aeris Resources, 2010

The Main Pit is situated adjacent to the Suttor River is considered to require no further works to rehabilitate and decommission (AARC, 2015). Two spillways have been installed on the north-west and south-east walls on the pit such that inflows are allowed at least once in two years. Previous calculations have indicated that there is low potential for the Main Pit to fill to the level of the spillway and discharge water to the Suttor River. The South Pit has been filled in and rehabilitated. Minor work was conducted to stabilise a rock-lined waterway draining the upper slope (AARC, 2015).

The TSF is located in the north-eastern part of the site and contains two cells, Cell A and Cell B. The TSF covers a maximum surface area of 100 ha, holds a maximum volume of 9,000,000 m³ and has a maximum depth of 9m (GHD Pty Ltd, 2008). A return water pond is located immediately to the west of TSF Cell A, designed to collect runoff from the TSF.

Establishing a comprehensive closure plan requires the identification of clear closure objectives and articulation of the necessary design criteria required to meet those objectives. Design criteria typically take the form of specific numerical limitations that are required to be met, such as a maximum contaminant concentration at a monitoring location or a limitation of acceptable erosion volumes. The conceptual and detailed cover systems and landforms are then designed to meet these criteria.

Rehabilitation objectives developed for Yandan in accordance with the *Guidelines: Rehabilitation Requirements for Mining Projects* (EHP, 2014) that incorporate the principles of Ecologically Sustainable Development (ESD) include:

- 1) Ensure mine sites are rehabilitated to sound environmental and safety standards, and to a level at least consistent with the condition of surrounding land;
- 2) Provide appropriate community returns for using mineral resources and achieve better environmental protection and management in the mining sector; and
- 3) Improve community consultation and information. Improve performance in occupational health and safety and achieve social equity objectives.

In addition to the ESD objectives, site-specific rehabilitation objectives developed for Yandan in order to satisfy rehabilitation goals include (AARC, 2015):

- Sites are safe for humans and animals now and in the foreseeable future;
- Hazardous and contaminated material adequately managed;
- Polluted runoff and seepage contained on site;
- Acid and metalliferous drainage (AMD) will not cause serious environmental harm;
- Dams to remain on closure will not contribute contaminants to the environment;
- Rehabilitated dams will not contribute contaminants to the environment;
- Establish safe and stable waterbody with a low risk of environmental harm;
- Landform design achieves appropriate erosion rates;
- Minimal probability of wall failure or rock falls that will cause significant environmental harm;
- Adequate vegetation cover to minimise erosion;
- Very low probability of slope slippage with serious consequences;
- Soil properties that support and will continue to support desired land use; and
- Self-sustaining vegetation cover and species similar to adjoining undisturbed areas.

The layout of the Yandan TSF is shown in Figure 2.2. Previous rehabilitation works have been completed at TSF Cell A where vegetation has established directly on the tailings. Except for a central zone exhibiting poor drainage, rehabilitation of Cell A has largely been considered effective in establishing vegetation and adequate drainage (Straits Gold, 2013a).

Cell B comprises oxide tailings of variable thickness over sulfidic tailings material. Several cover system trials have been initiated on Cell B of the TSF. The first trial involved gravelly topsoil spread directly onto the tailings in varying thickness. However, the surface was not adequately graded to shed runoff and lead to ponding with capillary salt rise occurring in

these areas. Another trial was established in 2009, but again, inadequate surface drainage led to inconsistent results (Okane, 2015).

Recent discussions between Straits Gold and the DES have resulted in the requirement for a barrier layer to be incorporated within the cover system design for Cell B so as to limit NP into the underlying sulfidic tailings material and prevent AMD causing serious environmental harm. A conceptual cover system design developed in 2015 (Okane, 2015) was deemed unsuitable by the DES as it operates on the moisture 'store-and-release' principle and does not incorporate a barrier layer.

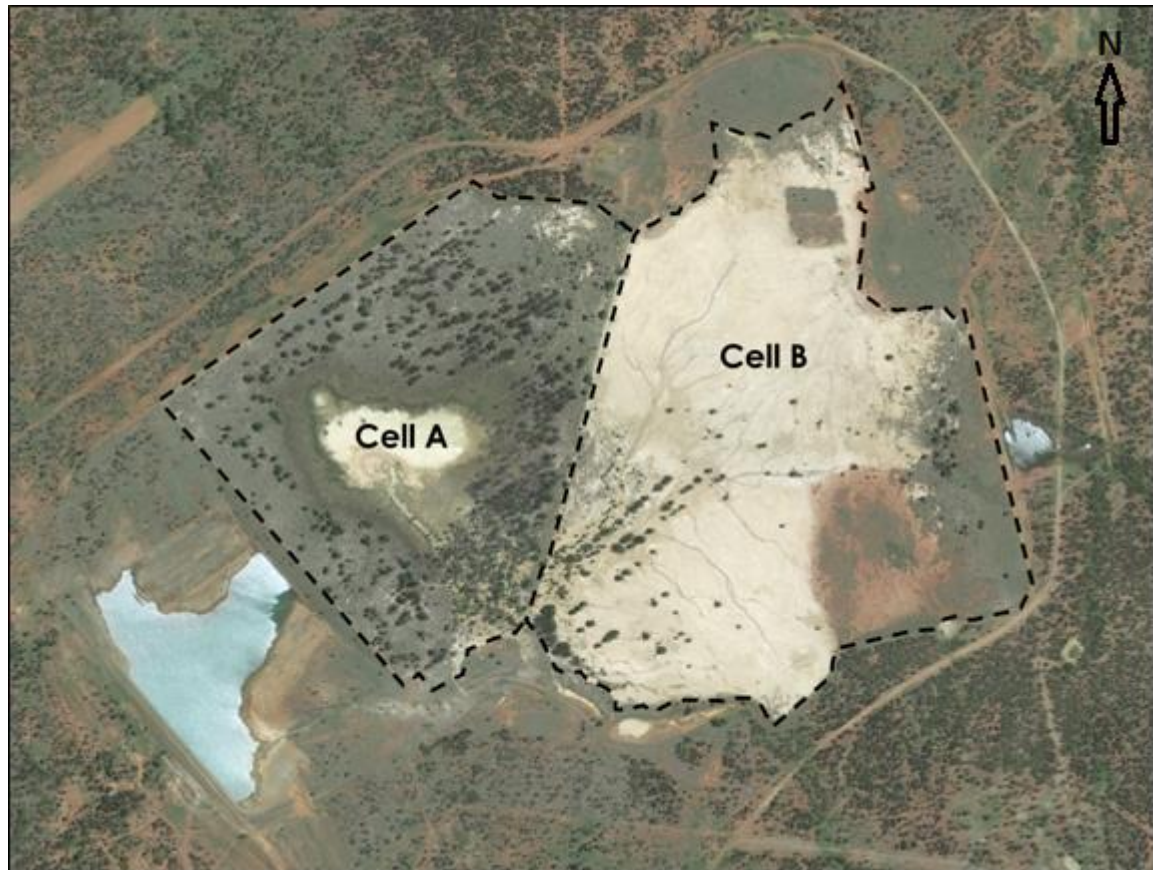


Figure 2.2: Cell A and Cell B approximate location for TSF cover system design.

The Tailings Return Water Dam (TRWD), located to the west of the TSF, will be decommissioned and the embankment removed. Material from the embankment and dam floor of this structure was identified as potential source for cover system construction and was sampled during the site visit.

2.2 Cover System Performance Indicators/Classifications

Cover system performance, within this scope of work, has been assessed using the following three performance indicators:

- Net percolation (NP);

- Soil water deficit; and
- Salt uptake.

These performance indicators, as well as their classifications, are defined herein.

2.2.1 Net Percolation

The term net percolation (NP) is used throughout this report and is defined as presented in Figure 2.3. Rainfall (R) will either be intercepted by vegetation, runoff (RO), or infiltrate into the surface. A portion of the water that infiltrates will be stored in the active zone (ΔS) and subsequently exfiltrate back to the surface and evaporate (E) or be removed by transpiration (ET). Infiltration can also move laterally downslope within and below the active zone (referred to as interflow). A percentage of the infiltrating water will migrate beyond the active zone as a result of gravity overcoming the influence of atmospheric forces (i.e. evaporation) and result in NP to the underlying material.

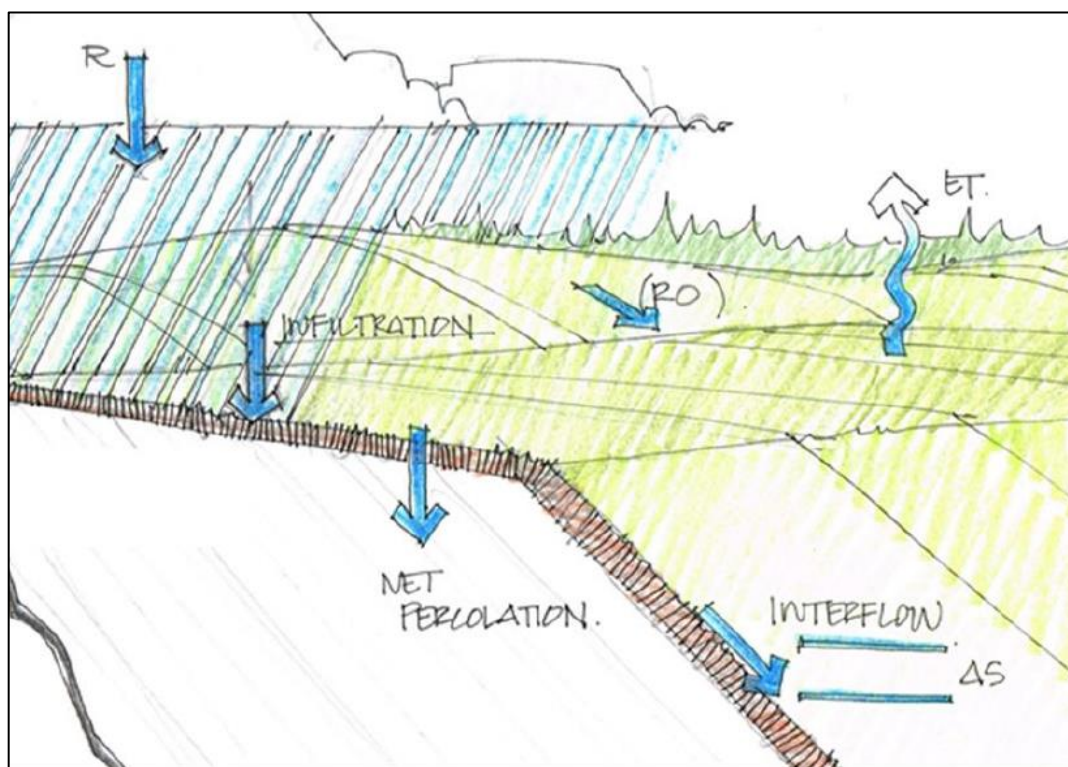


Figure 2.3: Schematic of hydrologic processes that influence performance of cover systems.

The following NP classifications have been adapted from the INAP guide (Figure 2.4) for Yandan based on the anticipated climate, whereby NP is expressed as a percentage of rainfall:

- Very low (<1 %): Cover systems with geosynthetic materials;
- Low (1 – 5 %): Barrier-type cover systems;
- Moderate (5 – 10 %): Enhanced store and release;
- High (10 – 20 %): Store and release;
- Very high (>20 %): Erosion Protection – Vegetation.

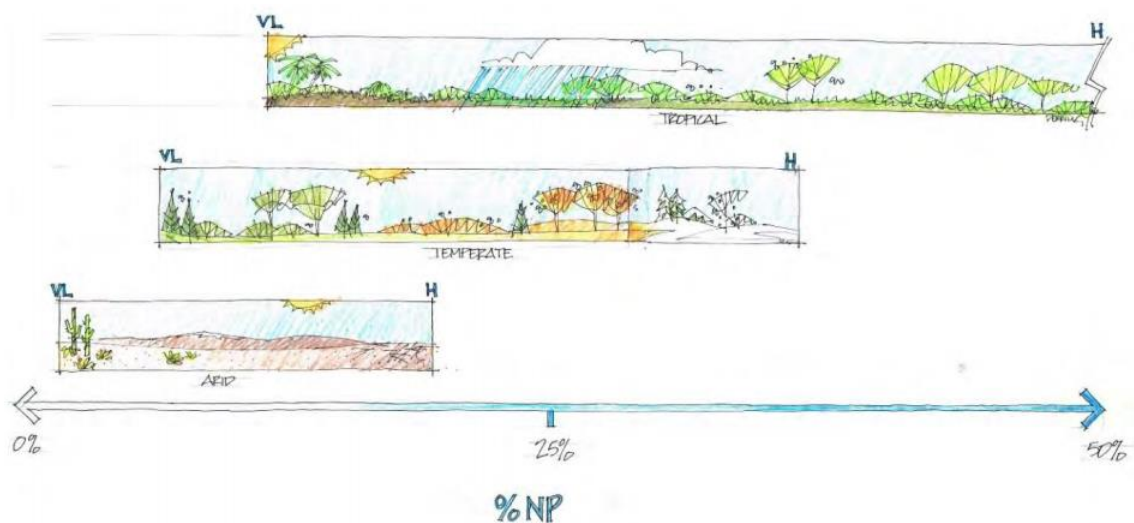


Figure 2.4: Qualitative NP rates for arid, temperate, and tropical regimes.

INAP, 2017

2.2.2 Water Stored within Cover System

The water stored within a cover system has been defined as the total volume of water within the growth medium and topsoil that can be utilised by vegetation and removed through evapotranspiration. This volume is largely governed by texture with some influence from organic matter. Generally, soils with smaller particle sizes have larger surface area and retain more water when compared to larger particle sizes. The amount of water stored within this section of the cover system is generally shown contrasted to the permanent wilting point (PWP), defined as the minimum soil water required for a plant to resist wilting. Additionally, the saturation of the soil is used to provide a guide as comparison for the total potential volume of water stored.

2.2.3 Salt Uptake

The primary objective of the salt uptake analysis is to assess whether transport of solutes from the tailings into the overlying cover system material may present a critical failure of the cover system design. A critical flaw from a solute transport perspective would be

where concentrations of solutes in the overlying cover system increased to a point where cover system performance would be adversely affected. For example, increased concentrations of solutes could have an adverse effect on plant growth or could alter the hydraulic characteristics of the cover material; leading to performance that differs from design values. Electrical conductivity (EC) is used as the parameter by which salt uptake is assessed. Modelled EC is then compared against soil salinity criteria prepared by the former Queensland Department of Environment and Resource Management (DERM) (Table 2.1).

Table 2.1: Soil salinity criteria.

Plant salt-tolerance	Corresponding EC range (dS/m)	Soil salinity rating
Sensitive vegetation	< 0.95	Very low
Moderately sensitive vegetation	0.95 – 1.9	Low
Moderately tolerant vegetation	1.9 – 4.5	Medium
Tolerant vegetation	4.5 – 7.7	High
Very tolerant vegetation	7.7 – 12.2	Very high
Generally, too saline for vegetation	> 12.2	Extreme

DERM, 2011

3 FIELD SAMPLING AND MATERIAL CHARACTERISATION

A field sampling and materials characterisation program was undertaken to characterise available materials at targeted locations both on and offsite. A material testing program was developed with the results used to inform numerical modelling, as further discussed in Section 5.2.2.

3.1.1 Sampling Methodology

Between 16 and 19 July 2019, two Okane personnel visited the Yandan Gold Mine and a potential offsite clay and topsoil borrow source approximately 25 km northeast of the site. During the site works samples of clay, topsoil, heap leach waste rock, gravel and tailings were collected for geotechnical and fertility analysis. A site walkover was completed to gather information including but not limited to the types of materials available, access to these materials, vegetation coverage, remnant facilities and signs of surface contamination likely to prevent a material being suitable for using in cover system construction. A total of 25 test pits were excavated across both the Yandan Mine site and an offsite borrow source, with samples collected from 23 of the test pits (as depicted in Dwg's 0956-007-001 to 0956-007-003 provided as Appendix A). Two test pits, TP#9A and TP#9B, were excavated to assess material homogeneity around TP#9, no samples were collected from these pits.

Based on discussions between Okane and Straits Gold, and the review of available background documentation and site plans, materials considered to have potential for use in a cover system were targeted prior to arriving onsite. The offsite clay and topsoil borrow source was also sampled and tested for suitability should materials on-site not exhibit appropriate geotechnical characteristics or be available in sufficient quantities.

Table 3.1 details the samples collected and their corresponding test pits, collection date, material type, sample depth, total excavation depth and their coordinates in UTM. Sampling locations are provided in Appendix A and stratigraphic logs and photographs of each test pit are provided in Appendix B.

Test pits were excavated to variable depths using a 35 Tonne excavator, reaching a maximum depth of 4 m at YAN-011. Due to localised rainfall near the offsite clay and topsoil borrow source prior to commencement of site work, boggy conditions on the track leading into the clay borrow source prohibited access by the excavator/float. For this reason, a telehandler was parked adjacent to the dam and used to loosen soil and access the underling clay for YAN-002 and YAN-003, and a shovel was used to access topsoil at YAN-001. All other test locations at Yandan Mine were accessible with the excavator.

Table 3.1: Summary of samples collected for geotechnical analysis.

Sample ID	Test Pit	Location (Material)	Sample Depth (m)	Total Excavation Depth (m)	Easting	Northing
YAN-001-(A/B/C/D)	TP#1	Offsite Dam (Topsoil)	0.1	0.1	522472	7650127
YAN-002-(A/B/C/D)	TP#2	Offsite Dam (Clay)	0.4	0.4	522472	7650127
YAN-003-(A/B/C/D)	TP#3	Offsite Dam (Clay)	0.3	0.3	522452	7650100
YAN-004-(A/B/C/D)	TP#4	Heap Leach Rock	0.5	0.5	497399	7645374
YAN-005-(A/B/C/D)	TP#5	HL Pond Embankment (Clay)	1.2	1.2	498191	7644949
YAN-006-(A/B/C/D)	TP#6	HL Pond Embankment (Clay)	3.5	3.5	498104	7644883
YAN-007-(A/B/C/D)	TP#7	Mine Water Embankment (Clay)	1.7	1.7	497846	7646133
YAN-008-(A/B/C/D)	TP#8	Mine Water Embankment (Clay)	3.0	3.0	497715	7645987
YAN-009-(A/B/C/D)	TP#9	Downstream Mine Water Embankment (Clay)	1.5	2.2	498035	7645730
YAN-010-(A/B/C/D)	TP#10	East Mine Water (Clay)	0.3	1.2	498884	7646389
YAN-011-(A/B/C/D)	TP#11	East Mine Water (Clay)	2.4	4.0	498777	7646386
YAN-012-(A/B/C/D)	TP#11	East Mine Water (Clay)	3.9	4.0	498777	7646386
YAN-013-(A/B/C/D)	TP#13	Tailings Embankment (Clay)	2.0	2.0	499303	7646818
YAN-014-(A/B/C/D)	TP#14	Tailings Embankment (Clay)	1.8	1.8	499384	7646721
YAN-015-(A/B/C/D)	TP#15	Tailings Embankment (Gravel and Topsoil)	1.2	1.2	499556	7646462
YAN-016-(A/B/C/D)	TP#16	Tailings Embankment (Topsoil)	0.4	0.4	499605	7646590
YAN-017-(A/B/C/D)	TP#17	Tailings Embankment (Topsoil)	0.4	0.4	499412	7646940

Sample ID	Test Pit	Location (Material)	Sample Depth (m)	Total Excavation Depth (m)	Easting	Northing
YAN-018-(A/B/C/D)	TP#18	Tailings Embankment (Topsoil)	0.8	0.8	499382	7646961
YAN-019-(A/B/C/D)	TP#19	Tailings Embankment (Gravel)	1.0	1.0	499373	7647253
YAN-020-(A/B/C/D)	TP#20	Tailings Embankment (Gravel)	0.7	0.7	499872	7647632
YAN-021-(A/B/C/D)	TP#21	Tailings Embankment (Gravel and Topsoil)	0.5	1.3	500359	7647808
YAN-022-(A/B/C/D)	TP#22	Tailings Embankment (Gravel)	1.8	1.8	500872	7647441
YAN-023-(A/B/C/D)	TP#23	Tailings Embankment (Tailings)	1.1	2.0	500548	7647328
YAN-024-(A/B/C/D)	TP#23	Tailings Embankment (Tailings)	2.0	2.0	500548	7647328
YAN-025-(A/B/C/D)	TP#24	Tailings Embankment (Gravel)	1.2	1.2	500670	7646736

Bulk samples comprising four 20 L pails were collected from each test pit, with two bulk samples collected from both YAN-011 and YAN-023. Four pails for each sample were half filled (approximately 10 kg) with material collected either directly from the base of test pits or from the excavator bucket. Additionally, two 500 g plastic bag samples were collected alongside each bulk sample for select fertility and Water Retention Curve (WRC) testing.

Stratigraphic logs of each test pit are provided as Appendix B, each detailing the soil profile at each location, samples collected, presence of organic material / roots in the soil, results of the paste pH/EC testing and a photograph of the test pit. Select photographs showing each different material sampling type are included herein for reference (Figure 3.1 to Figure 3.10).

Generally, any roots or organic material was confined to the upper topsoil layer (if present) to a depth of up to 0.1 m in the material with higher clay content. Topsoil at the offsite dam was light to dark brown and comprised predominantly silty sand with traces of clay and organics. Topsoil adjacent to the tailings embankment comprised orange brown sandy clay with some gravel and organic material tending towards gravel and cobble content at the southern side of the runoff dam.

In situ pH and EC test results are provided in Table 3.2. pH and EC testing were completed for each sample collected for geotechnical testing. Results collectively indicate the materials sampled at Yandan are of very low salinity and suitable for establishment of sensitive vegetation in accordance with the soil salinity criteria developed by DERM (Table 2.1). The exception comprises a tailings sample collected from TP23 which measured an EC value of 5.8 dS/m. This value is comparable with previous testing of the tailings where an average EC value of 5.19 dS/m was measured (Dwyer, 2014).

Table 3.2: pH / EC Testing Results

Test Pit	Material Type	Sample	Sample Depth (m)	SP Cond (dS/m)	pH
TP#1	Topsoil	YAN-001E	0.0-0.1	0.028	4.93
TP#2	Sandy Silt Clay	YAN-002E	0.3 – 0.4	0.015	6.03
TP#3	Gravelly Clay	YAN-003E	0.2-0.3	0.034	6.56
TP#4	Sandy Clay	YAN-004E	0.4-0.5	0.030	8.90
TP#5	Sandy Silty Clay	YAN-005E	1.1-1.2	0.019	7.98
TP#6	Sandy Silty Clay	YAN-006E	3.4-3.5	0.013	8.37
TP#7	Silty Clay	YAN-007E	1.6-1.7	0.106	8.15
TP#8	Sandy Gravelly Clay	YAN-008E	2.9-3.0	0.011	8.45
TP#9	Silty Clay	YAN-009E	1.4-1.5	0.251	7.41
TP#10	Silty Sandy Clay	YAN-010E	0.3-0.4	0.410	9.04
TP#11	Sandy Silty Clay	YAN-011E	2.3-2.4	0.310	8.75
TP#11	Silty Sandy Clay	YAN-012E	3.9-4.0	0.032	9.17
TP#13	Gravelly Sandy Clay	YAN-013E	1.9-2.0	0.010	7.67
TP#14	Gravelly Sandy Clay	YAN-014E	1.7-1.8	0.016	7.73
TP#15	Gravelly Sandy Topsoil	YAN-015E	1.1-1.2	0.138	7.0
TP#16	Sandy Clay with Shale/Basalt	YAN-016E	0.3-0.4	0.314	7.68
TP#17	Sandy Clay with Shale/Basalt	YAN-017E	0.3-0.4	0.027	8.91
TP#18	Sandy Clay Topsoil	YAN-018E	0.7-0.8	0.015	7.74
TP#19	Silty Sand Topsoil	YAN-019E	0.9-1.0	0.011	6.56

Test Pit	Material Type	Sample	Sample Depth (m)	SP Cond (dS/m)	pH
TP#20	Silty Sand Topsoil	YAN-020E	0.6-0.7	0.003	6.63
TP#21	Silty Sandy Topsoil	YAN-021E	0.4-0.5	0.494	7.02
TP#22	Gravel	YAN-022E	1.7-1.8	0.181	6.34
TP#23	Oxide Tailings	YAN-023E	1.0-1.1	5.813	3.59
TP#23	Sulfide Tailings	YAN-024E	1.9-2.0	0.295	5.92
TP#24	Gravel	YAN-025E	1.1-1.2	0.851	7.0



Figure 3.1: Test Pit #13, tailings water dam embankment (clay core)



Figure 3.2: Test Pit #23, Tailings.



Figure 3.3: Test Pit #5, HL Pond Embankment



Figure 3.4: Test Pit #7, MWD Embankment (Clay Core)



Figure 3.5: Test Pit 1, off-site clay borrow material.



Figure 3.6: Test Pit #11, on-site clay borrow material.



Figure 3.7: Test Pit #18, Topsoil.



Figure 3.8: Test Pit #20, gravel borrow source.



Figure 3.9: Test Pit #15, gravel and topsoil borrow source.



Figure 3.10: Test Pit #4, Heap Leach Pad.

3.1.2 Geotechnical Material Characterisation

To ensure a high degree of confidence in any cover system design, a thorough understanding of the materials available for construction and how they perform is required. A preliminary material characterisation analysis was completed (Phase 1) including; particle size distributions (PSD) and gravimetric moisture content testing on all 23 samples collected during the 2019 sampling program. Of these samples the following subset was selected for Phase 2 analysis:

- Six (6) to determine Atterberg limits (AL);
- Seven (7) for Emerson aggregate testing;
- Five (5) for modified compaction testing;
- Three (3) for moisture retention (or soil-water characteristic curves, SWCC); and
- Six (6) for permeability (falling-head and constant-head) testing.

Samples selected for additional testing were based on Phase 1 preliminary laboratory characterisation results which gave an indication of which sampled materials would most likely be suitable within a cover system.

The majority of testing was completed by Trilab Pty Ltd at their Brisbane laboratory. SWCCs were completed by the University of Queensland in Brisbane and fertility testing was completed by ALS Environmental, also located in Brisbane. All laboratory testing was

completed to applicable and relevant standards. Testing certificates are presented in Appendix C.

The following section outlines the results from the material characterisation testing, with stratigraphic logs of the soil profiles encountered at each test pit provided in Appendix B. During the field sampling program attention was paid to physical soil properties including material type, grain size, colour, presence of organic material, greater than 100 mm size fraction and any other observations. Photographs of each test pit were taken and added to the final test pit logs (Appendix B), as well as the results of *in situ* field permeability and pH/EC testing.

3.1.2.1 Particle Size Distribution

The particle size distribution (PSD) curve indicates the relative proportions of the different particle sizes that make up the material on a mass basis. Testing was completed according to AS 1289.3.6.1 and AS 1289.3.6.3. The standard size fractions include:

- Cobble and Gravel: > 4.75 mm;
- Sand: 0.075 – 4.75 mm;
- Silt: 0.005 – 0.075 mm; and
- Clay: < 0.005 mm.

The PSD can be used to develop material texture, as an indicator of erosion, water holding capacity or the suitability of a material for a low permeability layer. Fine soils such as clays or silts will hold more water and generally have a lower hydraulic conductivity, while coarser materials will tend to erode less. Furthermore, PSD curves may be used as a guide for material consistency, if a major part of the curve is steep then the soil has a size distribution extending over a limited range with most particles being approximately the same size. However, if the soil exhibits a flat section or plateau, then the soil is considered gap graded and a large percentage of it is bigger and smaller particles with less intermediate particles in between.

Results from Phase 1 testing, including oversize estimation, particle density and percentages of particle size are shown in Table 3.3. All test pits maintained their stability during excavation, with no side-wall collapses encountered. In the absence of a grizzly screen, material was passed through an excavator sieve bucket with 115 mm spacings. The >115 mm fraction was placed aside and estimated. Generally, the gravel borrow sources contained the most material with a size fraction >100mm. The clay borrow source at the tailings runoff dam embankment, topsoil borrow source areas and heap leach generally contained few particles >100mm.

The PSD curves for potential topsoil borrows (Figure 3.11) indicate finer options located at the offsite dam (YAN-001), to more coarse options located to the north adjacent the tailings embankment (YAN-017).

For potential coarse rock sources (Figure 3.12), the light brown / light grey heap leach waste rock (YAN-004) provides well graded material, as do the borrows located adjacent to the south and east of TSF Cell B (YAN-022 and YAN-025). Potential growth medium (Figure 3.12) consisting of slightly finer material than the coarse rock is available adjacent to the north of the TSF Cell A (YAN-019 and YAN-021).

Examining potential clay sources (Figure 3.13), it can be seen that based on the test results the finest material is located upstream of the Water Storage Dam (WSD) (YAN-011) and upstream of the Mine Water Dam (MWD) (YAN-009). Two distinct layers of clay were present at YAN-011, a grey brown sandy silty clay and a dark grey mottled light brown silty sandy clay. The fine grained, dark red brown silty clay material available in the vicinity of TP#9 is located upstream of the MWD in the flow path between the previous processing areas and dam. The MWD is considered a hazardous dam and therefore it is recommended if material is used from this location it should be subjected to further geochemical analysis to determine if contamination of this material has occurred and if so, does it prohibit the use of the material for certain purposes, e.g. as a growth medium.

The red brown mottled grey silty clay, light grey brown mottled red sandy gravelly clay and the red brown gravelly sandy clay sampled from the MWD embankment (YAN-007 and YAN-008) and the TRWD embankment (YAN-013 and YAN-014) had the coarsest PSD curves from the potential clay sources. This indicates these materials are likely to have a higher saturated hydraulic conductivity than the clays from YAN-009 and YAN-011. The PSD of the red/grey/brown sandy silty clay core of the Heap Leach (HL) Pond embankment (YAN-005 and YAN-006) placed in between these two end members.

Table 3.3: Phase 1 testing results, including oversize estimation.

Sample ID	Particle Density (t/m ³)	Moisture (%)	% > 115 mm	Oversize (%)	Coarse (>4.75 mm) (%)	Sand (4.75 mm - 0.075 mm) (%)	Clay and Silt (<0.075 mm) (%)
YAN-001	2.55	3.0	0%	0	1	57	42
YAN-002	2.58	4.1	0%	0	6	54	40
YAN-003	2.66	3.6	0%	0	9	49	42
YAN-004	2.57	7.3	~ 40%	57	80	14	6
YAN-005	2.64	6.9	0%	0	14	69	17
YAN-006	2.64	8.1	0%	0	16	42	42
YAN-007	2.68	9.0	0%	0	43	33	24
YAN-008	2.73	8.5	~ 5%	0	40	40	20
YAN-009	2.65	16.2	0%	0	5	28	67
YAN-010	2.65	10.6	0%	0	25	30	45
YAN-011	2.66	7.6	0%	0	3	38	59

Sample ID	Particle Density (t/m ³)	Moisture (%)	% > 115 mm	Oversize (%)	Coarse (>4.75 mm) (%)	Sand (4.75 mm - 0.075 mm) (%)	Clay and Silt (<0.075 mm) (%)
YAN-012	2.72	11.3	0%	0	26	45	29
YAN-013	2.64	8.9	~ 10%	16	40	30	30
YAN-014	2.70	9.1	~ 10%	0	43	28	29
YAN-015	2.64	7.4	~ 15%	5	46	27	28
YAN-016	2.71	10.6	0%	0	33	21	46
YAN-017	2.68	7.7	0%	0	61	29	10
YAN-018	2.69	15.5	~ 5%	0	8	63	29
YAN-019	2.60	10.4	~ 5%	5	43	17	40
YAN-020	2.63	6.3	~ 30%	30	58	23	18
YAN-021	2.67	9.7	0%	0	19	47	34
YAN-022	2.61	6.5	~ 45%	45	73	20	7
YAN-023	2.53	12.2	0%	0	0	32	68
YAN-024	2.60	13.1	~ 80%	0	0	45	55
YAN-025	2.65	9.7	0%	80	43	44	13

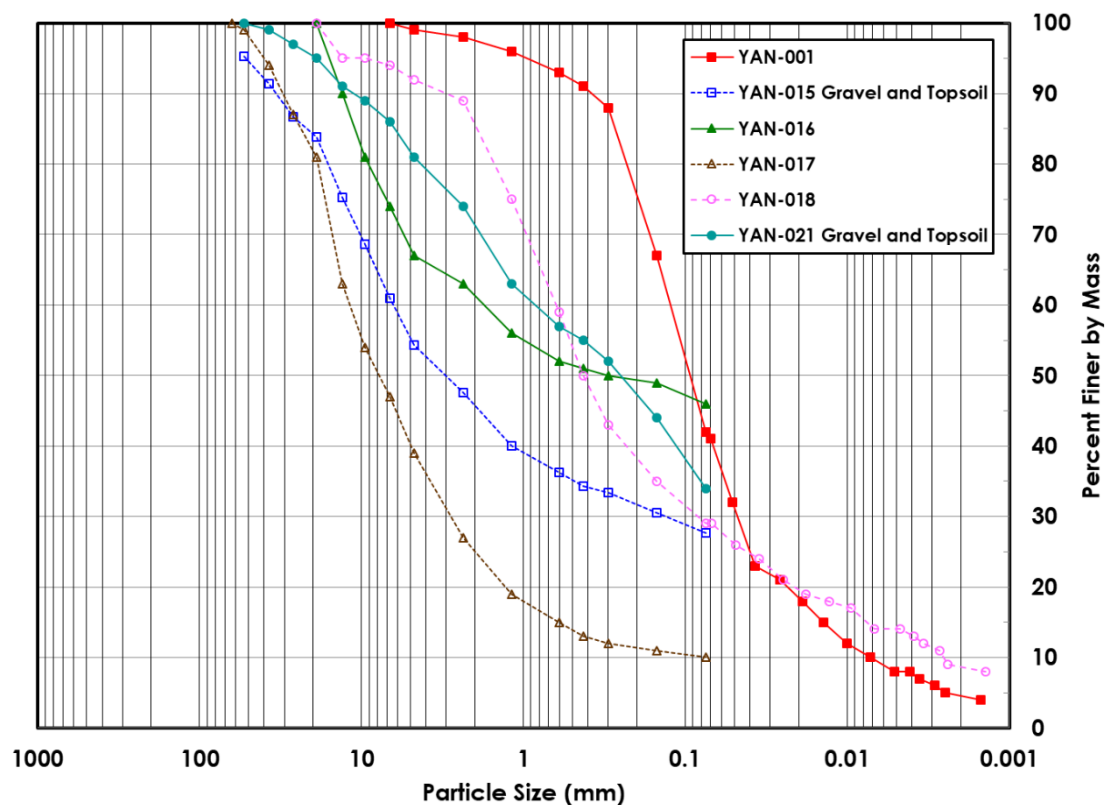


Figure 3.11: PSD curve for potential topsoil borrows.

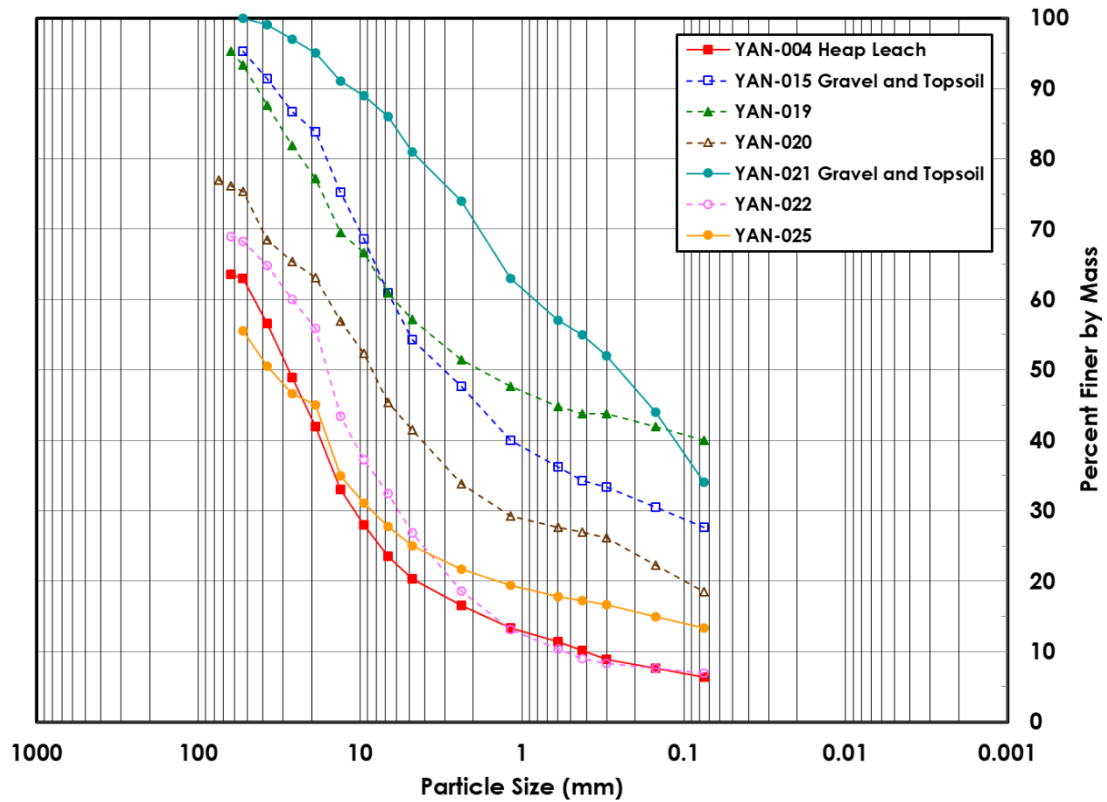


Figure 3.12: PSD curves for potential coarse rock and growth medium borrows.

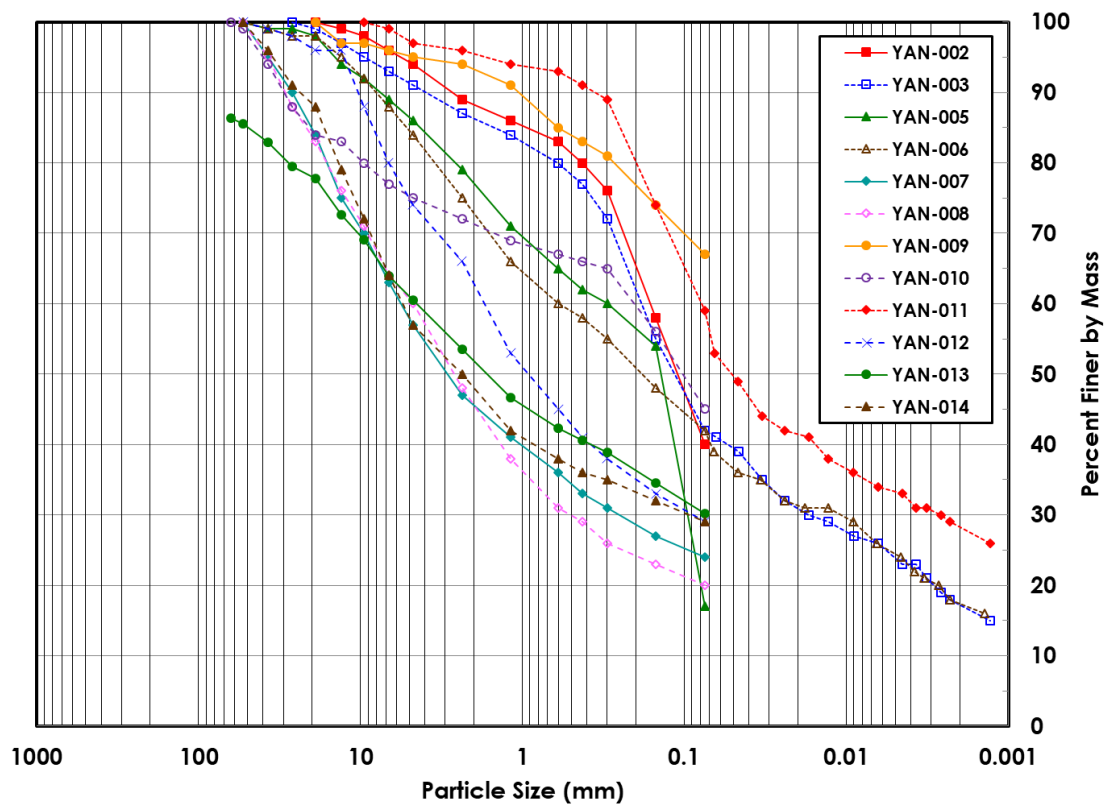


Figure 3.13: PSD curves for potential clay borrows.

3.1.2.2 Atterberg Limits

The physical behaviour of soil changes with increasing moisture content. To describe how the properties of soils change with moisture content, such as becoming more plastic, or cohesionless, critical moisture limits have been defined using the Atterberg limits. The Atterberg limits are used primarily in classifying fine-grained cohesive soil materials and tests the limits of these various soil states. These include the plastic limit (PL), where the soil is no longer brittle and cracks, but instead begins to mould easily and display plastic behaviour and the liquid limit (LL), where soil no longer displays plastic behaviour but instead flows like a liquid. The plastic index (PI) is the difference between LL and PL and defines the range of water content a material is plastic. Testing was completed according to AS 1289.3.1.1, AS1289.3.1.1 and AS 1289.3.2.1. Figure 3.14 shows the plasticity index (PI) and liquid limit (LL) for each test pit sample as developed from Atterberg limit tests.

The characteristics of various fine-textured materials, such as clay content and mineralogy, can be determined through the relationship between the LL and PI. The plot of LL-PI can be used to identify clay mineralogy of a sample. Montmorillonites are highly active clay minerals and plot above the A-line near the U-line. Illites plot directly above the A-Line and are less active than Montmorillonites, and Kaolinites plot below the A-Line and are relatively inactive. Active clay minerals provide additional water storage capacity as a bound water volume. Figure 3.14 shows that the Yandan samples plot above the A-Line and below the U-Line with low plastic and inorganic clays (CL), indicating moderately active clays containing predominately illites and montmorillonites.

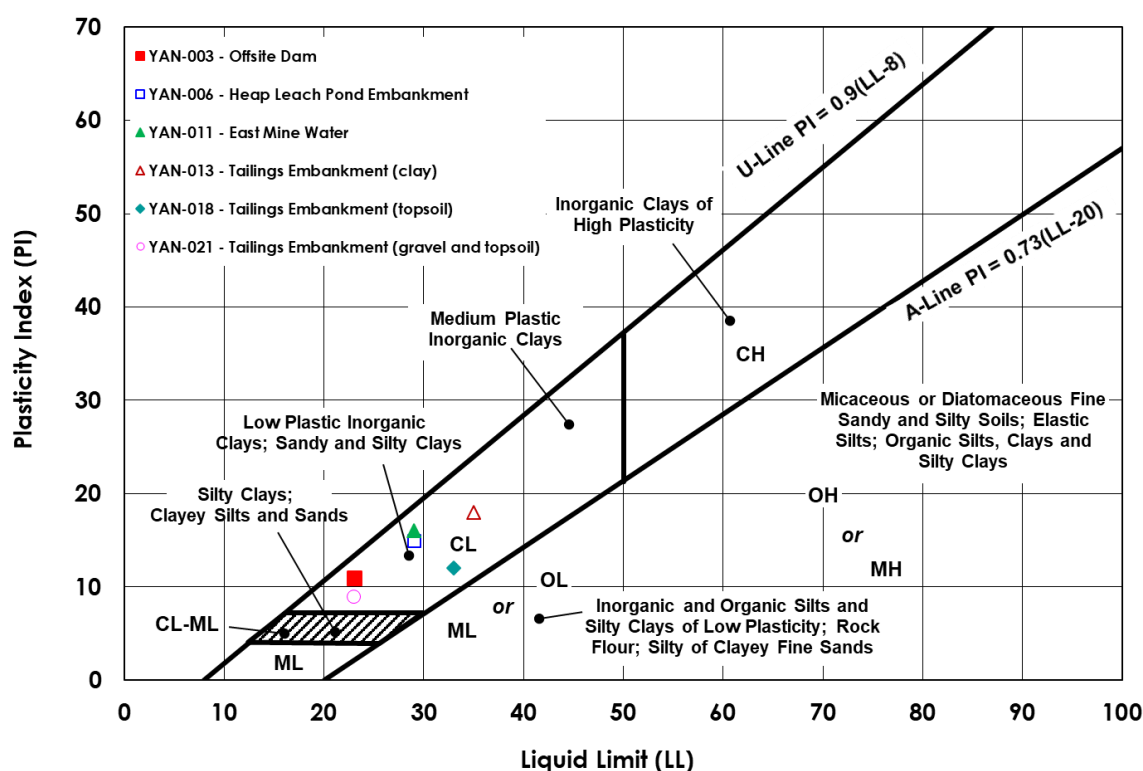


Figure 3.14: Atterberg limit results for fine-grained material tested as potential clay source.

3.1.2.3 Emerson Aggregate

Emerson tests are used to classify the behaviour of soil aggregates, when immersed, on the coherence in water. Once aggregates are immersed in water, an osmotic stress arises between the negatively charged particles, this stress increases gradually as the soluble salts present in the aggregates diffuse out. The increase may be sufficient to cause dispersion. Soils are divided into seven classes based on their dispersion and slaking behaviour. Class 1 disperses completely, Class 2 partially. Classes 3-6 do not disperse initially but may do so upon remoulding and may also exhibit flocculation or slaking behaviour. Class 7 involves no slaking or dispersion but swelling instead, typical of organic matter. Testing was completed according to AS 1289.3.8.1.

All samples placed in Classes 2 to 5 (Table 3.4). The only sample that dispersed without remoulding (Class 2) was YAN-015, collected from the area identified as a gravel/topsoil located to the south of the TRWD embankment. Gravel (YAN-020) from the area north of Cell A of the TSF demonstrated the least amount of dispersion and was the only sample to be classified as Class 5.

Table 3.4: Emerson Aggregate results.

Samples	Depth (m)	Description	Class
YAN-001	0.1	Sandy Silt	3
YAN-013	2.0	Sandy Clay	4
YAN-015	1.2	Silty Sand	2
YAN-018	0.8	Clayey Sand	4
YAN-020	0.7	Silty Sandy Gravel	5
YAN-021	0.5	Silty Sand	4
YAN-025	1.2	Silty Sandy Gravel	4

3.1.2.4 Modified Compaction

When soils are used as construction materials in any type of fill or embankment, they nearly always require compaction, this helps to prevent settlement, increase strength and slope stability and reduce permeability. This is particularly relevant when the aim of the soil layer is to reduce permeability to as low as practical, such as a clay barrier layer within a cover system. However, there is a limit to the density that can be achieved by compaction under a given effort. This maximum density can be attained only at a particular moisture content, known as the optimum moisture content (OMC). Below the OMC the soil is stiff and difficult to compact, above the OMC, pore pressure begins to develop, and the water tends to keep the soil particles apart (Smith, 2014).

A compaction test is used to determine the OMC to achieve a maximum dry density (MDD), resulting in a Proctor curve. For the Yandan samples a modified compaction test was used in accordance with AS 1289.5.2.1. In general, fine-textured materials have a

higher OMC and lower MDD than coarse-textured materials. Thus, as a material becomes coarser, the Proctor Curve will move towards the top left of the chart (see Figure 3.15). This trend is shown whereby material sampled from upstream of the WSD (YAN-011) contains 59% clay and silt size particles, resulting in this sample being the lowest (with regards to dry density) relative to the other samples. In contrast, the gravel and topsoil material collected from the area to the north of the TSF (YAN-021), which contains 34% of clay and silt size particles plots above the curves measured for the other sampled materials.

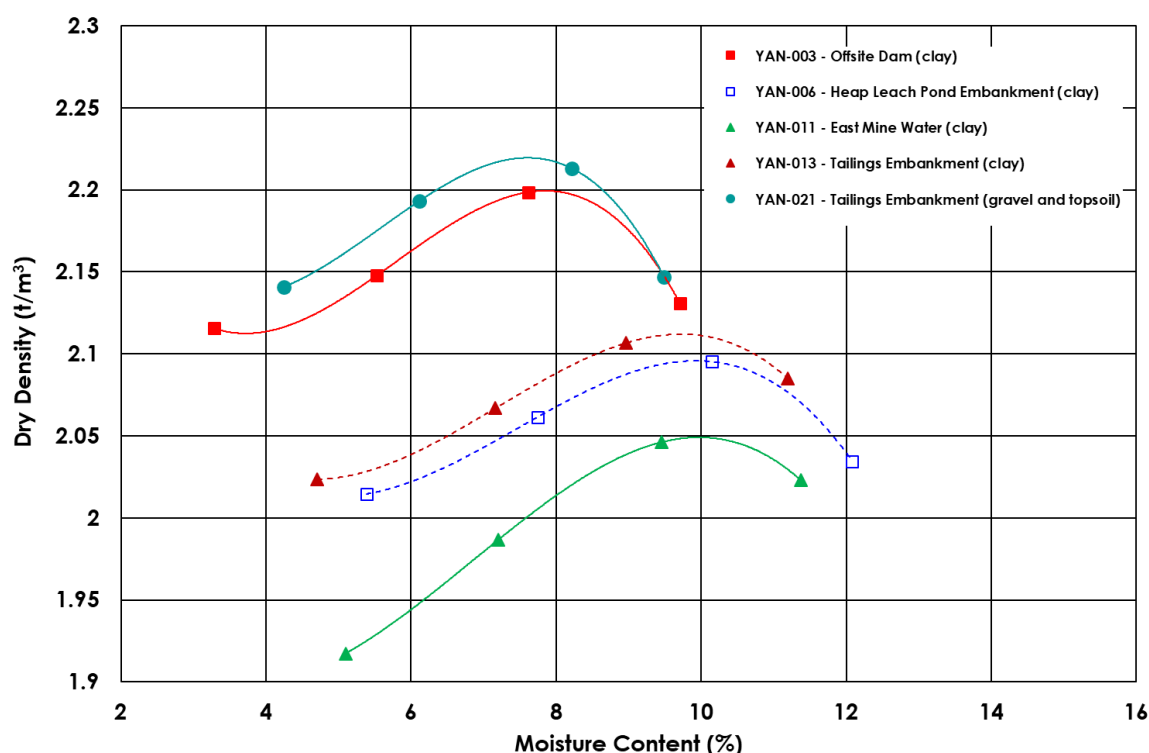


Figure 3.15: Modified Proctor Curves for potential cover materials.

3.1.2.5 Hydraulic Conductivity (Falling-head and Constant-head)

Hydraulic conductivity is a measurement or rate of a soil's ability to let water flow through it. Hydraulic conductivity is often measured using the falling-head and constant-head tests. Results can be used as a guide to further refine the expected performance of a cover system design. Hydraulic conductivity is not a fundamental property but depends on a number of factors such as particle size and shape, texture, mineralogical composition, void ratio, saturation and even temperature (Steffen, 2014). Testing was focused on potential low permeability materials and potential topsoil sources (Table 3.5) and was conducted in accordance with Australian Standards AS 1289 3.6.3., 3.5.1 and 2.1.1.

A 'low permeability' layer is typically considered to be a layer with a field saturated hydraulic conductivity of less than 1×10^{-9} m/s. Falling head testing of samples YAN-003 and YAN-011 indicated these materials may be able to achieve this level of performance, or close to, when tested under laboratory conditions. Whilst not achieving a performance

level considered 'low permeability', results for YAN-013 indicated this material could achieve a relatively low level of saturated hydraulic conductivity (7.6×10^{-8} m/s) when compared to the remaining materials. However, sample YAN-013 contained particles greater than 19 mm in diameter. This makes the material unsuitable for use as a 'low permeability' layer as the ability to compact the material is reduced and the larger grain sizes present weaknesses to the unit which overtime may lead to preferential cracking and desiccation, thereby allowing localised preferential flowpaths.

The offsite clay source (YAN-003) and onsite clay source located upstream of the WSD (YAN-011) recorded no oversize material. Whilst both samples resulted in similar OMCs, the compactive effort required to achieve this level of hydraulic conductivity is greater for sample YAN-003.

Table 3.5: Falling-head and constant-head test results

Sample	Location and material	Hydraulic conductivity, k_{20} (m/s)	Oversize (%)	Corrected k_{20} (m/s)
YAN-003	Offsite Dam (Clay)	5.6×10^{-10}	0 / 9.5 mm	5.6×10^{-10}
YAN-006	HL Pond Embankment (Clay)	6.6×10^{-10}	2 / 19 mm	6.5×10^{-10}
YAN-011	Upstream of WSD (Clay)	2.4×10^{-9}	0 / 9.5 mm	2.4×10^{-9}
YAN-013	TRWD Embankment (Clay)	7.6×10^{-8}	10 / 19 mm	6.8×10^{-8}
YAN-018*	TRWD (Topsoil)	2.8×10^{-5}	0 / 19 mm	2.8×10^{-5}
YAN-021	North of TSF (Gravel and Topsoil)	8.7×10^{-7}	14 / 19 mm	7.5×10^{-7}

*Constant-head test was performed.

Guelph Hydraulic Conductivity tests were performed during the site visit to estimate the *in situ* hydraulic conductivity of several materials (Section 3.1.3).

3.1.2.6 Soil Water Characteristic Curve

The SWCC is a continuous function relating energy and the state of water and describes the water content of a material as a function of soil suction, or negative pore-water pressure. SWCC testing was completed by the University of Queensland using a SWC-150 Fredlund device. Results for samples YAN-003, YAN-006 and YAN-011 are shown in Table 3.6 and Figure 3.16. The results display good consistency between borrow sources with a porosity and air entry value (AEV) that would be expected from a clayey material capable of producing a barrier layer. Results were used to develop an estimate of the SWCC input for the modelling program (as discussed in Section 5.2).

Table 3.6: Laboratory SWCC of Yandan materials.

Sample	Location and material	Particle Density (t/m ³)	Dry Density (t/m ³)	Porosity	AEV (kPa)
YAN-003	Offsite Dam (Clay)	2.68	1.645	0.40	5 – 10
YAN-006	HL Pong Embankment (Clay)	2.71	1.578	0.42	5 – 10
YAN-011	Upstream of WSD (Clay)	2.67	1.545	0.42	5 – 10

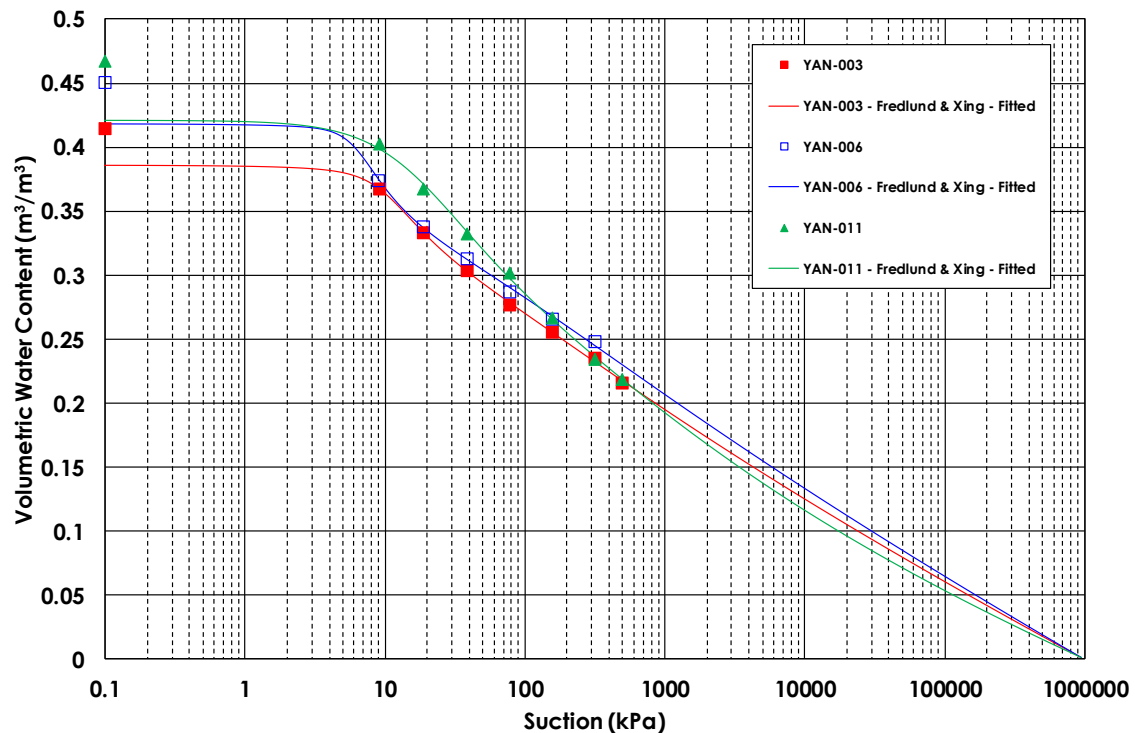


Figure 3.16: SWCC results and fitted curves for potential low permeability layer material.

3.1.3 Guelph Hydraulic Conductivity

During the site visit, a total of seven (7) Guelph Hydraulic Conductivity tests were performed both on-site and at the offsite clay borrow source (Table 3.7). Field permeability testing is completed to provide an estimate of the *in situ* hydraulic conductivity of materials and provides further data to support a material's suitability for use in a cover system. Field testing allows evaluation of a material in field conditions rather than laboratory conditions where samples have been disturbed during the collection process and are then remoulded and compacted to a level reflective of the compaction anticipated to be applied when constructing the cover system.

In situ hydraulic conductivity of material tested onsite ranged between 4.17×10^{-8} m/s for the compacted gravelly clay material within the TRWD Embankment and 4.26×10^{-6} m/s for material on the MWD embankment. The *in situ* hydraulic conductivity of the offsite clay borrow source was measured at 8.51×10^{-7} m/s. Generally, clays with higher gravel and

sand contents showed higher soil hydraulic conductivity and denser, more homogeneous clays showed lower soil hydraulic conductivity. The *in situ* results were reasonably consistent with the laboratory results where testing was completed on areas previously subjected to compaction forces, such as dam embankments. For other, non-compacted or virgin areas, *in situ* hydraulic conductivity was greater than that observed in laboratory conditions. This is expected due to the *in situ* tests being generally conducted on near surface materials that have been subjected to weathering processes and which have not been mechanically compacted. For example, clay from upstream of the WSD was measured as having an *in situ* hydraulic conductivity of 8.51×10^{-7} . Under laboratory conditions, where sample preparation involved imparting a compaction force intended to reflect the compactive effort the material is likely to be subjected to when used as a compacted clay layer within a barrier type cover system, this material achieved a hydraulic conductivity of 2.4×10^{-9} .

Table 3.7: Guelph Hydraulic Conductivity.

Test Number	Location	Material Type	Hydraulic Conductivity (m/s)
GP1	Offsite Dam	Sandy clay	8.51×10^{-7}
GP2	HL Pond Embankments	Gravel/clay	1.31×10^{-7}
GP3	MWD Embankment	Sandy/clay	4.26×10^{-6}
GP4	Upstream of MWD	Topsoil/clay	8.51×10^{-7}
GP5	Upstream of WSD	Clay	1.34×10^{-7}
GP6	TRWD Embankment	Compacted gravel/clayey material	4.17×10^{-8}
GP7	Tailings	Tailings	6.31×10^{-7}

3.1.4 Soil Fertility

Soil fertility relates to the chemical properties of the soils and their influence on vegetation growth and establishment. Properties analysed to assess soil fertility include pH, electrical conductivity (related to salinity), nitrogen, phosphorus, potassium and sulfur. If these properties are either too high or too low, depending on the property in question, plant growth can be significantly inhibited. The soil fertility testing focused on potential topsoil and growth medium sources and was completed by ALS Environmental at their Brisbane laboratory. Results, including assessment against ranges published by Hazelton and Murphy (2016), are provided in Table 3.8. Multiple results were found to be marginally out of optimal ranges but still within growth ranges. The results indicate the materials sampled are generally suitable to support vegetation and could be used for as a topsoil and/or growth medium layer of a cover system.

Table 3.8: Soil fertility results.

Test	Units	YAN-001	YAN-018	YAN-021	Comments
pH	-	5.7	8.3	6.5	Ranging from moderately acidic to moderately alkaline, all within suitable range for plant growth
Electrical Conductivity	µS/cm	67	562	637	All considered non-saline, with negligible effects.
Exchange Sodium	%	2.6	9.7	3.7	0-6 is non-sodic, 6-14 is considered sodic. YAN-018 is sodic but still within acceptable range.
Sulfur	%	0.01	0.02	0.02	Negligible impact.
Total Nitrogen	mg/kg	690	450	800	Negligible impact.
Total Kjeldahl Nitrogen	mg/kg	660	450	780	Negligible impact.
Total Phosphorus	mg/kg	283	872	160	Negligible impact.
Organic Matter	%	1.4	0.5	1.2	Negligible impact.
Total organic carbon	%	0.8	< 0.5	0.7	Negligible impact.
Exchangeable Aluminium	meq/100g	<0.1	-	-	Within desirable range.
Exchangeable Calcium	meq/100g	2.9	12	3.3	YAN-001 and YAN-021 are lower than desired.
Exchangeable Magnesium	meq/100g	1.1	1.9	2.7	YAN-001 is lower than desired.
Exchangeable Potassium	meq/100g	0.2	<0.2	0.2	All samples are lower than desired
Exchangeable Sodium	meq/100g	0.1	1.5	0.2	YAN-018 is higher than desired.
Cation Exchange Capacity	meq/100g	4.3	15.6	6.6	Within desirable range.
Calcium/Magnesium Ratio		2.6	6.3	1.2	1-4 is low Calcium, 6-10 is low Magnesium.
Magnesium/Potassium Ratio		6.4		10.9	Within desirable range.

Hazelfon and Murphy, 2016

3.1.5 Estimated Material Volumes

High-level estimates of available material volumes were calculated based on field observations of approximate areas and depths reached during test pit excavations. The estimates provided are based on limited exploration and should be considered indicative only. The available volumes of each material should be investigated more thoroughly prior to commencing design and construction activities.

- TRWD Embankment (Clay core): Based on an approximate total length of the L-shaped embankment of 600 m and an assumed average clay core cross sectional area of 9 m², the estimate of clay available at this location is approximately **5,000 – 6,000 m³** bank cubic meters (BCM).

- MWD Embankment (Clay core): Based on an approximate total length of the L-shaped embankment of 460 m and an assumed average clay core cross sectional area of 16 m², the estimate of clay available at this location is approximately **7,00 – 8,000 m³ BCM**.
- HL Pond Embankment (Clay core): Based on an approximate total perimeter of the embankment of 530 m, and an assumed average clay core cross sectional area of 9 m², the estimate of clay available at this location is approximately **4,000 – 5,000 m³ BCM**.
- Upstream MWD (Clay borrow): Based on visual observations and the three test pits excavated in this area, the clay appears variable and localised primarily to lower lying gullies and could be accurately quantified in the time available during the site visit. However, based on a total surface area of approximately 5,000 m², and a clay thickness ranging between 0.2 m and 1.6 m, the estimate volume of clay is between approximately **1,000 m³ and 8,000 m³ BCM**.
- Upstream of WSD (Clay borrow): Based on visual observations, satellite imagery and the two test pits excavated in this area, the clay in this area appears variable and could be accurately quantified in the time available during the site visit. However, based on a total surface area of approximately 100,000 m² determined using satellite imagery, and a clay thickness ranging between 0.2 m and 3.8 m, the estimated volume of clay is between approximately **20,000 m³ and 380,000 m³ BCM**.
- Offsite Dam (Clay borrow): Developing an estimate of any real value for the volume of clay available from this source was not possible. Due to ground conditions at the time of the site visit, it was not possible to float the excavator to this location and sampling was limited to the near surface (<0.4 m). However, based on anecdotal information from the excavator operator, visual observations and the dam footprint, it is expected a significant volume of clay material is available and would likely satisfy volume requirements for at least a 0.3 m compacted clay barrier layer.
- Topsoil (borrow): The areas previously identified as topsoil borrow areas, north and south of the TRWD have a total surface area of approximately 155,000 m². Test pits were excavated in these areas to between 0.4 m and 0.8 m. Based on site observations and historical aerial imagery, approximately 55,000m² of this area appears to have been previously stripped and has not been included in the volume estimate. Based on test pit results and observations, it is estimated between **40,000 m³ and 80,000 m³ BCM** of material from this location has physical properties suitable for use as a topsoil. However, the depth to which material from this area could be considered reasonably likely to also contain a viable seed bank and/or organic matter is limited to 0.2 m. The estimated volume of currently viable topsoil from this area is **20,000m³ BCM**.
- Gravel and topsoil (borrow): Based on visual observations, satellite imagery and test pits excavated in the gravel and topsoil borrow areas, the topsoil gravel source areas

have a collective surface area of approximately 50,000 m². Test pits were excavated to between 0.5 and 1.2 m, giving an estimated total volume of topsoil between approximately **25,000 m³** and **60,000 m³** BCM.

- Gravel (borrow): Based on visual observations, satellite imagery and test pits excavated in the gravel and topsoil areas, the gravel source areas have a collective surface area of approximately 300,000 m². Four test pits were excavated into gravel material, comprising gravel beds between 0.55 m and 1.7 m thick, giving an estimated total volume of gravel between **165,000 m³** and **510,000 m³** BCM.

3.1.6 Summary Material Characterisation

A material characterisation program was carried out to determine site-specific geotechnical and hydraulic properties for potential cover materials for the Yandan TSF Cell B. The materials characterisation program comprised materials sampling, field testing, *in situ* permeability testing and a full laboratory testing program. The main findings of the material characterisation program are summarised herein, with discussion grouped based on potential material usage/s:

- Potential Clay Sources: Clay sources were investigated as potential material for constructing a barrier layer within the cover system to limit net percolation into the underlying sulfidic tailings. The TRWD embankment core (YAN-013 and YAN-014) and the MWD embankment core (YAN-007 and YAN-008) contain a significant amount of oversize material and are considered to be quite coarse. Approximately 30% of particles in these materials were found to be greater than 10 mm. The potential clay borrow located upstream of the WSD (YAN-010 and YAN-11) was found to contain fine material with good consistency. Similar results were found in the core of the HL Pond (YAN-005 and YAN-006), upstream of the MWD (YAN-009) and at the offsite clay borrow (YAN-002 and YAN-003).
- Potential Topsoil Sources: Important characteristics for a topsoil resource include providing a supply of beneficial nutrients, minimal plant growth limiting properties, and having a good water holding capacity. Ideally, topsoils will also show low erosion potential and no dispersive qualities. When examining the potential topsoil sources, Emerson testing results indicated material represented by YAN-015 exhibited dispersive potential. The PSD curve for YAN-017 is quite coarse and as such the water holding capacity of this source is limited. However, given the proximity of YAN-017 to YAN-018 and the heterogeneity nature of soil, the material from this borrow may still be suitable for usage in topsoil. YAN-001, YAN-018 and YAN-021 were subjected to fertility testing and all displayed acceptable fertility characteristics and grading.
- Potential Growth Medium Sources: Materials located immediately adjacent to the north of Cell A are a suitable source for a growth medium based on their particle sizes (YAN-019 and YAN-020). One potential growth medium source (YAN-015) displayed

slight dispersive characteristics, however given the growth medium is generally located below a topsoil layer and the relatively shallow grades anticipated for the cover system, this property should not be a concern. YAN-018 and YAN-021 both provide a mix with topsoil that displays positive permeability and fertility characteristics.

- Potential Gravel Sources: PSD is the key property used to identify sources with potential for use as capillary break layers. Material sources adjacent to the TSF Cell B (YAN-022 and YAN-025) and the Heap Leach waste rock (YAN-004) were assessed as being coarse, well-graded material suitable for use as a capillary break layer.

4 COVER SYSTEM DESIGN FILTERS/SITE ATTRIBUTES

The purpose of a cover system is to aid in the reclamation of surface mine waste storage facilities to provide a stable, reliable and sustainable engineered interface between the receiving environment and the mine waste (INAP, 2017). It supports agreed-upon land uses while minimising degradation of the surrounding environment. To support this aim, the cover system design requires analysis of all site attributes that constrain design alternatives to achieve desired performance. Four main site attributes that constrain design alternatives include climate, hydrogeological setting, materials and vegetation, shown in Figure 4.1 with each discussed in more detail herein.

The post mining land use and classification for the Yandan YSF is Open Pasture VII, with acceptance criteria stating the rehabilitated TSF must accommodate the following (Straits Gold, 2013b):

- Controlled grazing;
- Runoff shedding landform with no obvious erosion gullies;
- No obvious acid generation or runoff;
- Pasture grass cover >40%; and
- Landowner acceptance.

More specifically for the Yandan TSF Cell B, closure aims to address the following identified hazards related to closure of Cell B (AARC, 2015):

- “AMD resulting from oxidation of sulfide tailings material, leading to mobilisation (and enhancing the bio-availability) of metals into the receiving environment”;
- “Temporary rise of the water table, allowing water characterised by low pH to come into contact with cover vegetation. This results in failure to sustain a grass pasture on the cell surface”; and
- “Salt rise from the tailings into the growth medium due to capillary action, resulting in failure of vegetation”.

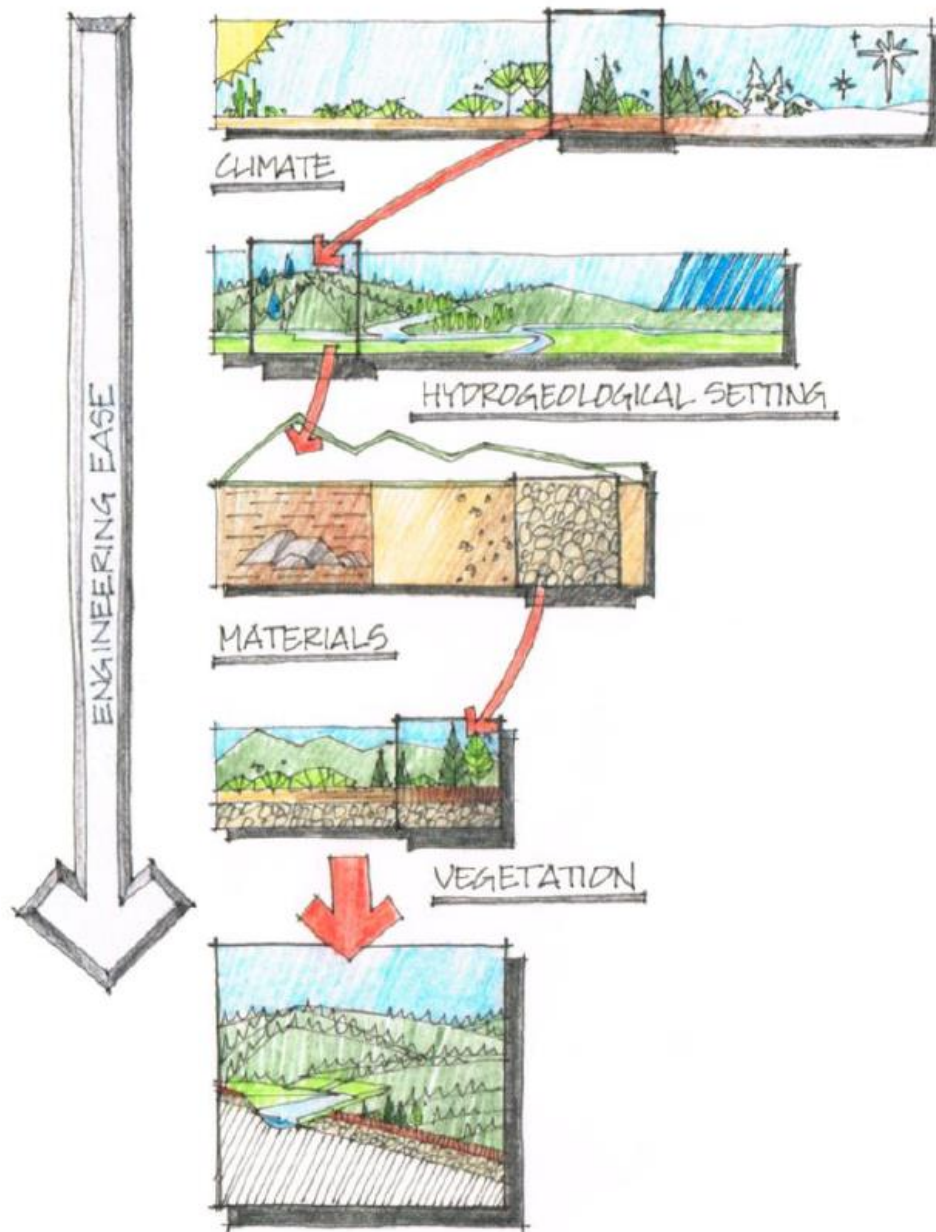


Figure 4.1: Cover system design framework displaying four filters.

INAP, 2017

4.1.1 Climate

A climate database is required as input for numerical models. This section describes the development of the climate database for the Yandan mine site and summarises the estimated climate conditions.

Based on the Köppen-Geiger climate classifications, Yandan is classified BSh, a local steppe or semi-arid climate. Rainfall in the region typically occurs during the November to March wet season, with between 75% and 80% of mean annual rain occurring during this period. Climatic data was obtained from the Scientific Information for Land Owners (SILO)

database, based on data from the Bureau of Meteorology (BOM), (Table 4.1). The daily dataset provides data for temperature, precipitation, relative humidity, solar radiation and potential evapotranspiration. This dataset was used to generate a 118-year period of climatic data for Yandan for the purposes of modelling seepage rates utilising site-specific conditions. The Yandan climate dataset begins 1 January 1900 and finishes 31 December 2018. The average annual rainfall during the 118-year period is 552 mm. A maximum recorded rainfall of 1,173 mm and minimum recorded rainfall of 169 mm indicate rainfall can be highly variable between years (Figure 4.2). The climate database indicates extended periods of wetting and drying can be experienced.

Table 4.1: Monthly and annual climate averages for the Yandan climate dataset.

Month	Maximum Air Temperature (°C)	Minimum Air Temperature (°C)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)	Rainfall (mm)	Potential Evapotranspiration (mm)
January	35	22	90	45	111	180
February	34	22	93	48	103	151
March	33	20	95	47	66	153
April	31	17	96	44	32	129
May	28	13	96	43	25	107
June	25	10	96	41	24	89
July	25	8	95	38	18	99
August	27	10	94	36	13	122
September	30	13	92	35	10	150
October	33	17	89	35	26	183
November	35	20	86	36	47	191
December	36	21	88	40	78	196
Annual Average	31	16	92	40	552	1,749

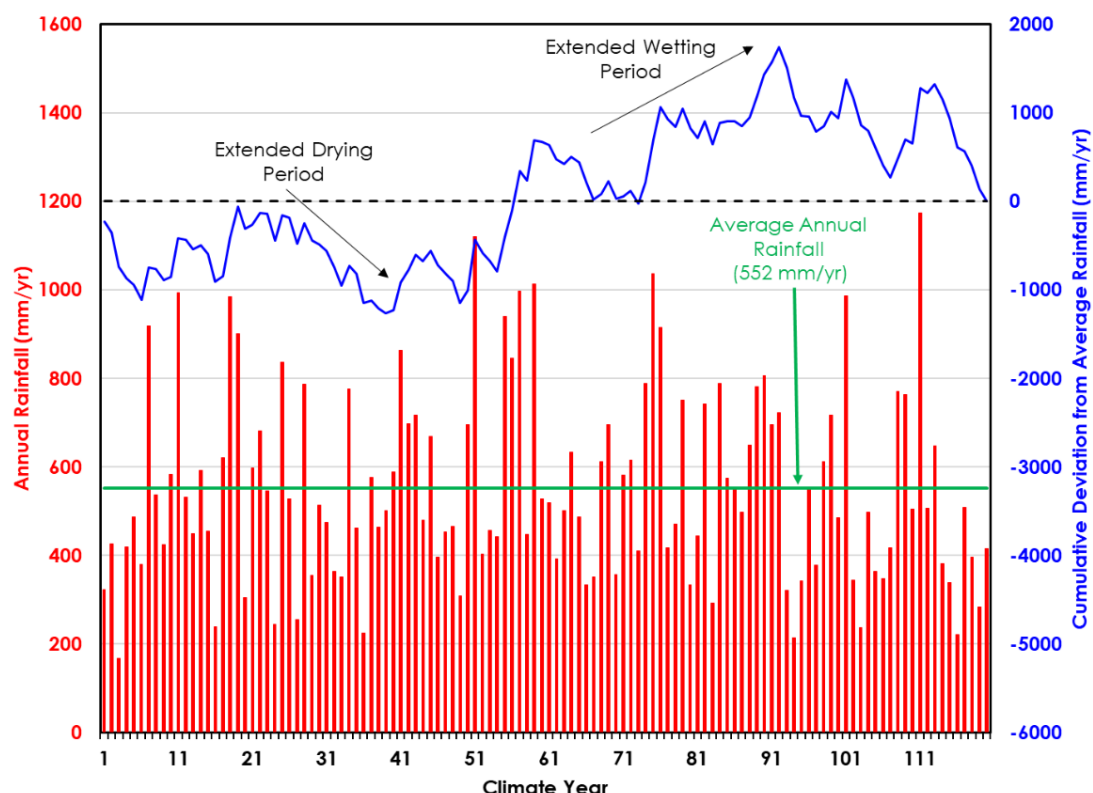


Figure 4.2: Annual rainfall and cumulative deviation from average rainfall for Yandan.

Based on GARD (2011), the cover system that best fits with the site's climate (Figure 4.3) utilises the store-and-release principle. Cover systems which utilise moisture store-and-release principles can be simple or complex, ranging from a single layer of earthen material to several layers of different materials. A store-and-release cover system aims to reduce NP to underlying waste material by increasing the available water storage capacity, while also limiting surface erosion of the material.

However, as discussed in Section 1 and Section 2.1 and owing to the presence of sulfidic tailings in Cell B, the DES have communicated to Straits Gold a requirement for a barrier layer to be incorporated into the Cell B cover system design. The conceptual store-and-release cover system design proposed in 2015 (Okane, 20105) was determined to not be robust enough and infiltration control in the form of a barrier layer would also be required.

Whilst the site's climate indicates a store-and-release cover system is appropriate, when plotted against the criteria provided in GARD (2011) (Figure 4.3), the site's climatic characteristics fall towards the outer edge of the suitable range for store-and-release covers systems and close to the transition point where infiltration control is recommended.

For these reasons the three alternative cover system designs all include a barrier layer.

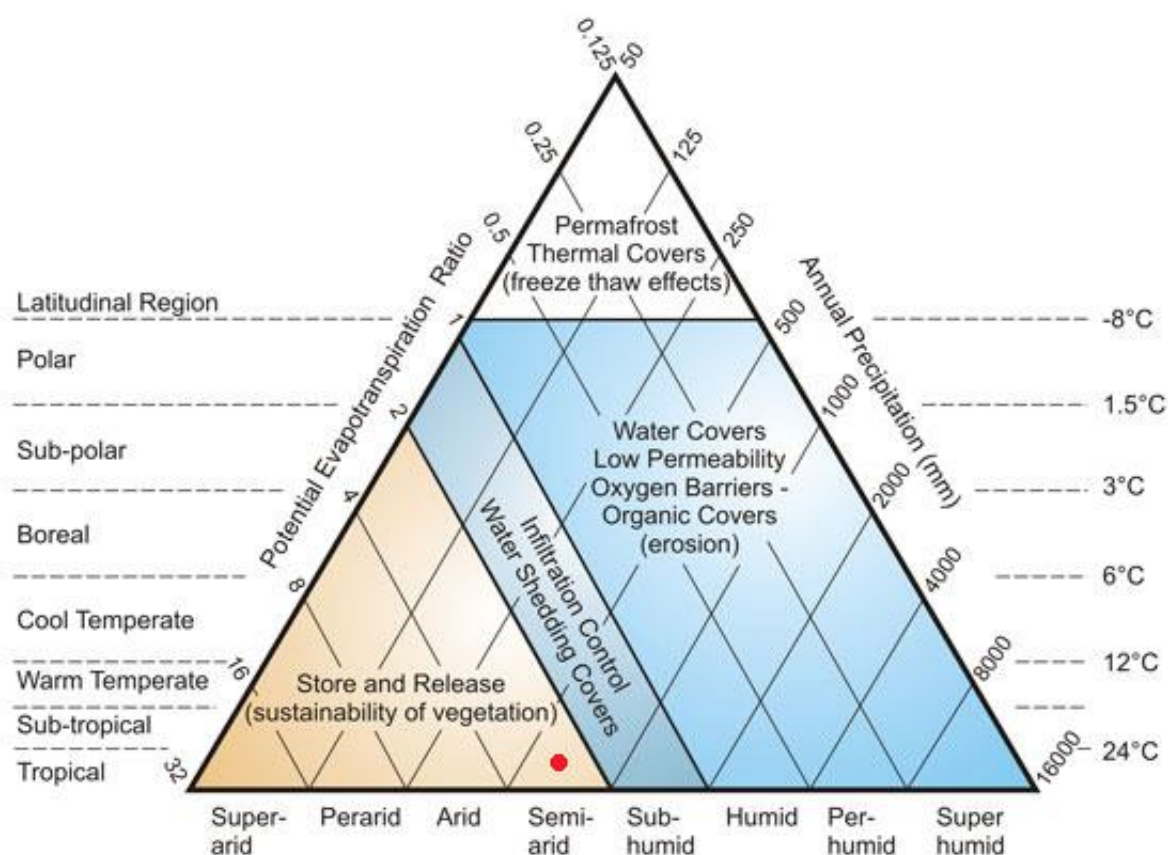


Figure 4.3: Cover systems and climate types. Red dot indicates approximate performance for Yandan.

GARD, 2011

4.1.2 Hydrogeological Setting

The regional hydrogeological setting focuses on several physical processes, including recharge, discharge rates, locations, volumes and rates of water movement, in addition to water flow pathways. The hydrogeological setting constrains the residence time and flux of water movement and while it can be altered, this requires substantial effort and expense, as such it is more advantageous to understand the hydrogeological setting prior to design and construction of any cover system design.

The hydrogeological setting can act as a passive treatment method or negatively impact remediation if the hydrogeology or associated chemistry is not fully understood. Although characterising the hydrogeological setting is important, changes will occur as the cover system matures and this must be anticipated.

The geological setting and landform geometry affect geotechnical stability and influences the overall NP mechanisms and rates. Therefore, consideration must be given to the shallow grades of a cover system constructed on Cell b as this impacts runoff, run-on, interflow, basal flow, seepage, evapotranspiration either directly or indirectly (INAP, 2017).

Groundwater in the area is of poor quality for stock watering and is considered unsuitable for irrigation and domestic use (GHD, 2008). Groundwater flow is towards the Suttor River, the water table is approximately 8 m below the riverbed at RL 158 m and there is no significant connection between groundwater and surface water in this area. Hence, the groundwater table is assumed to not influence any potential cover system performance, and as a result for modelling purposes the lower boundary within this study is simulated as a unit hydraulic gradient, further discussed in Section 5.2.4.

4.1.3 Materials

The material properties used to represent the cover system materials were key elements in the numerical modelling program. The behaviour of the soil cover system is largely influenced by material physical properties, including the PSD, permeability and water holding properties.

The physical properties used in the modelling were derived from laboratory testing of materials as part of a targeted materials characterisation program (as discussed in Section 3.1.2). The textural triangle, based on the PSD results, is shown in Figure 4.4.

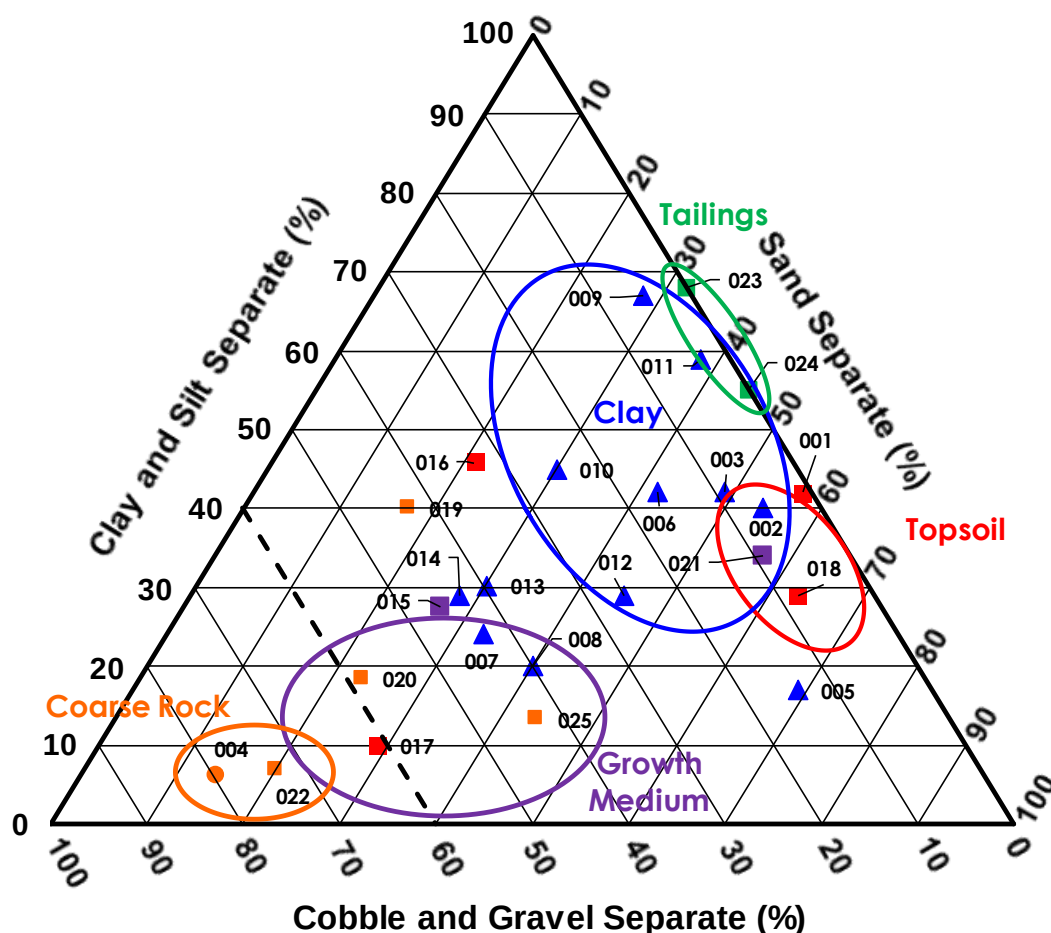


Figure 4.4: Textural triangle for potential Yandan cover system materials.

For the purposes of modelling the cover system, the materials were categorised into five zones on the textural triangle: coarse rock, growth medium, clay, topsoil and tailings. The growth medium and coarse rock were informed based on the gravel results. Further discussion on the specific textural zones is provided below:

- Coarse rock (orange circle): A consistent 70-80% cobble and gravel separate with 10% or less clay and silts, entirely grain supported. Indicates decreased water holding capacity due to the coarse texture of the material with decreased erodibility.
- Growth medium (purple circle): Comprises between 40-70% cobble and gravel separate and 20-50% sand fraction. It is predominately matrix supported with some fraction being grain supported. Matrix supported generally has increased erodibility over grain supported, with increased water holding capacity. Both growth medium and coarse rock are anticipated to contain some gravel.
- Clay (blue circle): A substantial range of between 30-70% clays and silts and is matrix supported. Typically used to form a barrier layer. The decreased coarse material would typically suggest increased erodibility and good water holding capacity.
- Topsoil (red circle): A mix of clays, silts and sands with almost no cobbles and gravel. While some samples were coarser, the selection highlighted are consistent and it has been assumed material will be taken from these locations.
- Tailings (green circle): Comprises no cobbles and gravel and a substantial portion of clays and silts mixed with 30-45% sands. The higher fines fraction indicates good water holding capacity. As the tailings will be below the other components of the cover system the high erosivity of this material is not of concern.

4.1.4 Vegetation

Yandan vegetation consists of persistent buffel grass pastures with the terrain characterised by undulating low hills and foot slopes with rocky outcrops (GHD, 2008). Towards the south-east of the site the terrain differs and can broadly be characterised by clay plains with some gilgai microrelief in low areas. The primary land use for the district is beef cattle grazing as much of the naturally occurring open forest and woodlands have been historically cleared for this purpose. However, due to the limitations imposed by the low fertility and degraded nature of the soil, low rainfall levels and high rainfall variability in the area, there is a low stock capacity. Natural vegetation communities on and adjacent to the site include (GHD, 2008):

- Blackwood (*Acacia argyrodendron*) and false sandalwood (*Eremophila mitchellii*);
- Brigalow (*Acacia harpophylla*) low forest with Dawson gum (*Eucalyptus cambageana*) emergent);

- Coolabah (*Eucalyptus microtheca*) woodlands with areas of brigalow (*Acacia harpophylla*), gidgee (*A. cambagei*) and Blackwood (*A. argyrodendron*); and
- Narrow leaf ironbark (*E. crebra*)/bloodwood (*E. dichromophora*) open woodland.

5 MODELLING PROGRAM

5.1 Model Description

The GeoStudio suite of modelling tools were used to model the behaviour of the Yandan cover system designs. The GeoStudio suite includes a fully coupled heat and mass transfer model capable of modelling saturated-unsaturated moisture conditions. Specifically, the VADOSE Bundle, capable of two-dimensional (2D) finite element modelling, in addition to one-dimensional (1D) modelling. It predicts suction in a given material profile in response to climatic forcing (such as evaporation) and lower boundary conditions (such as a water table). Based on these calculations, NP of water through a cover system and into the underlying material is predicted. A key feature of the software is the ability of the model to predict actual evapotranspiration based on potential evaporation and predicted suction, as opposed to the user being required to input these surface flux boundary conditions.

The CTRAN/W and SEEP/W modules of the GeoStudio suite were coupled to simulate the upward movement of saline pore water from the tailings into the cover system during periods of net upward flux across the cover material/tailings boundary. CTRAN/W accounts for both advective and diffusive transport. As such the modelling only requires minor modifications to the SEEP/W models built for the seepage assessment; mainly, applying salt concentration inputs to the tailings and cover system materials, and estimating diffusion coefficient curves for each material.

5.2 Modelling Inputs

The numerical modelling inputs can be divided into five categories: geometry, material properties, upper boundary conditions, lower boundary conditions, and initial conditions. Brief descriptions of these model inputs are presented in the following sections.

5.2.1 Geometry

All simulations were completed with a 1D column consisting of 99 nodes, representing a 7.1 m thick profile of cover system (ranging from 1.1 m to 3.1 m) overlying tailings material (4 m to 6 m). Figure 5.1 depicts the current base case cover system, as developed within the 2015 Okane project. This cover system comprises a store-and-release design of topsoil over coarse rock. As previously discussed, DES require a barrier layer unit be incorporated within the cover system to control infiltration and further limit potential NP reporting to the underlying tailings materials. As such, three alternative cover system designs have been proposed and addressed through numerical modelling:

- 1) *Base Case Cover System Design for Cell B (Zone 2)*: The store-and-release cover system originally designed by Okane in 2015. Not considered satisfactory by DES due to not incorporating a barrier layer. Included as a base case from which to assess the relative

performance of the alternative cover system configurations. The cover from the surface down comprises:

- Topsoil – 0.4 m;
- Coarse rock – 0.3 m; and
- Oxide tailings – 0.4 m.

2) *Double Capillary Break Cover System*: Most complex cover system suitable for Cell B. A capillary break unit is placed between the oxide tailings and the barrier layer to reduce potential for salt uptake from the tailings. A second capillary break unit is placed between the barrier layer and the growth medium to reduce potential for desiccation of the barrier layer from atmospheric forcings. The cover from the surface down comprises:

- Topsoil – 0.1 m;
- Growth medium/store-and-release - 1 m;
- Coarse rock – 0.3 m;
- Barrier layer – 0.3 m;
- Coarse rock – 0.3 m; and
- Oxide tailings – 0.4 m.

3) *Single Capillary Break Cover System – DES Min. Thickness*: Cover system unit thicknesses for this configuration comply with the minimum thickness prescribed in DES's Estimated Rehabilitation Cost (ERC) Calculator and includes both a barrier layer and a capillary break layer to reduce potential for salt uptake from the tailings. The cover from the surface down comprises:

- Topsoil – 0.15 m;
- Growth medium/store-and-release – 1.5 m;
- Barrier layer – 0.5 m;
- Coarse rock – 0.6 m;
- Working layer - +0.1 m (0.5 m separation between tailings and cover system); and
- Oxide tailings – 0.4 m.

4) *Single Capillary Break Cover System – Alternative Min. Thickness*: Same single capillary break cover system with barrier layer configuration as design 3. Unit thickness have been modified from those prescribed in DES's ERC Calculator based on results of the material characterisation program and Okane's experience. The cover from the surface down comprises:

- Topsoil – 0.1 m;
- Growth medium/store-and-release - 1 m; and
- LP layer – 0.3 m;
- Coarse rock – 0.3 m; and
- Oxide tailings – 0.4 m.

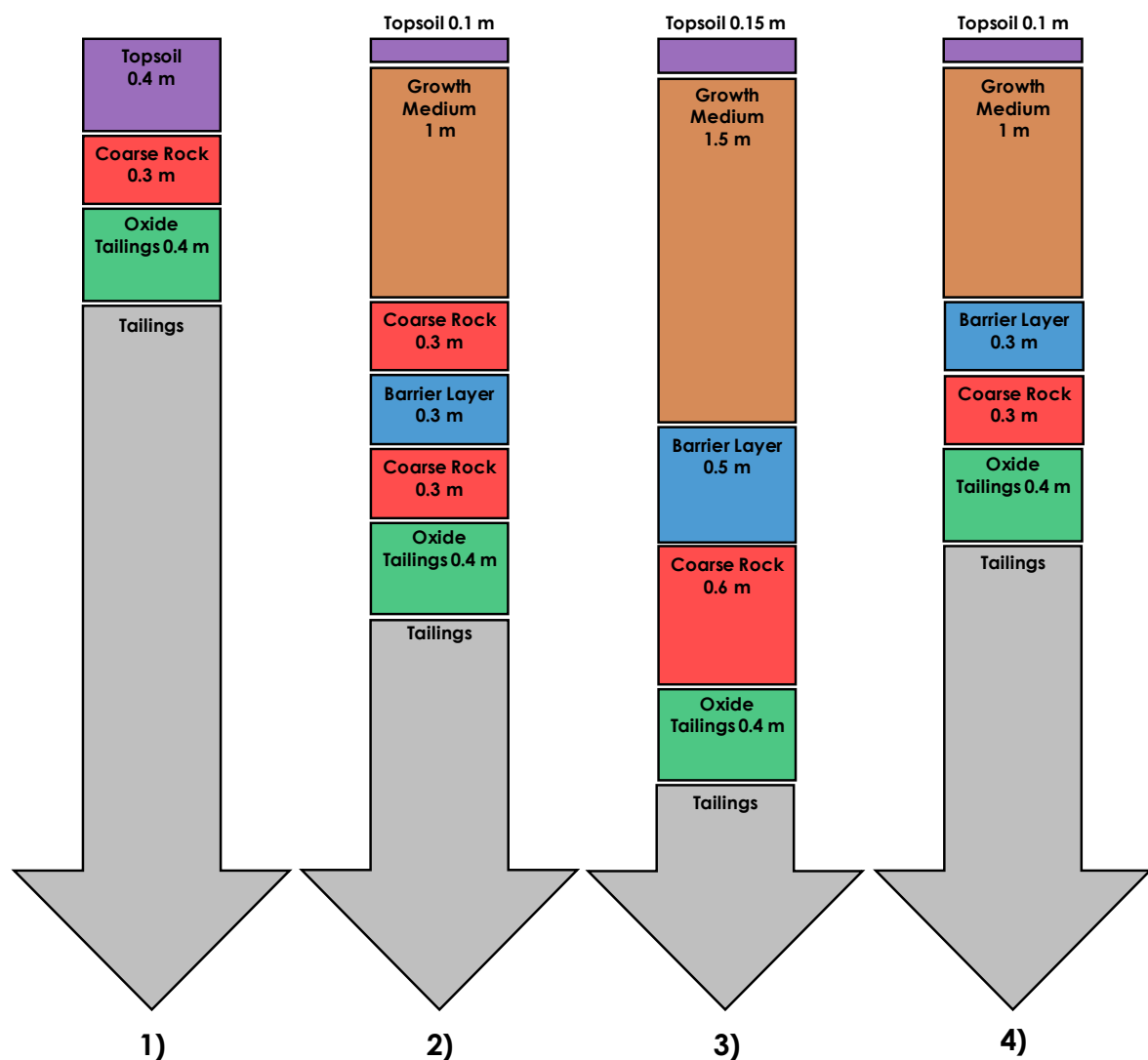


Figure 5.1: Cover system alternatives analysed in the modelling program; 1) Base Case Cover System Design, 2) Double Capillary Break, 3) Single Capillary Break – DES Min., 4) Single Capillary Break – Alternative Min.

5.2.2 Material Properties

The following section provides the hydraulic properties derived from the material characterisation program (discussed within Section 3.1.2), historical sampling and testing and Okane's experience with similar materials and cover system designs, as well as the mass transport material properties and source terms estimated for Yandan using the functions defined by Aachib *et al.* (2004).

5.2.2.1 Hydraulic Properties

SWCCs and saturated hydraulic conductivity (k_{sat}) estimates were developed based on testing conducted by the University of Queensland and PSD testing conducted by Trilab Pty Ltd. The term saturated hydraulic conductivity is used to describe the rate of water movement through the medium (or material) when saturated. The SWCC estimates are shown in Figure 5.2 and the estimated saturated hydraulic conductivities in Table 5.1.

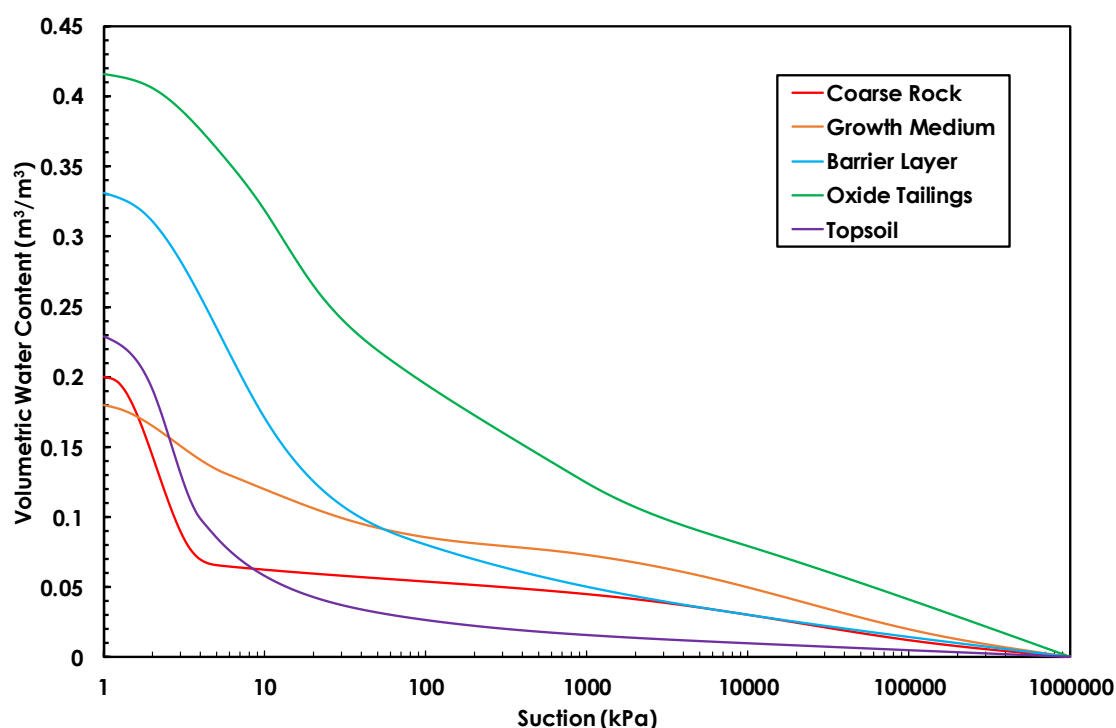


Figure 5.2: SWCC functions for the cover system materials used in the numerical modelling program.

Table 5.1: Estimated saturated hydraulic conductivity.

Material	Saturated hydraulic conductivity (m/s)
Coarse Rock	5×10^{-3}
Growth Medium	1×10^{-4}
Topsoil	5×10^{-6}
Oxide Tailings	1×10^{-7}
Barrier Layer	1×10^{-9}

5.2.2.2 Mass Transport Material Properties and Source Terms

The relationships between diffusion coefficient and volumetric water content were estimated for the materials using the functions defined by Aachib *et al.* (2004), shown in Figure 5.3. This method utilises a closed-form semi-empirical expression based on numerous test results and previously determined models proposed by Millington and Quirk (1961) and Millington and Shearer (1971). The free-water diffusion coefficient for NH_4 ($1.78 \times 10^{-9} \text{ m}^2/\text{s}$) was used in the model (Krom and Berner, 1980). The diffusion coefficient for NH_4 was used for the salt uptake modelling to represent a high estimate of diffusive mass transport from the waste rock. NH_4 has a relatively low molecular weight and, consequently, a relatively high diffusion coefficient. Salinity from the tailings was simulated with a constant concentration boundary applied to the entirety of the tailings material. The relative concentration throughout the profile into the cover system was tracked through time.

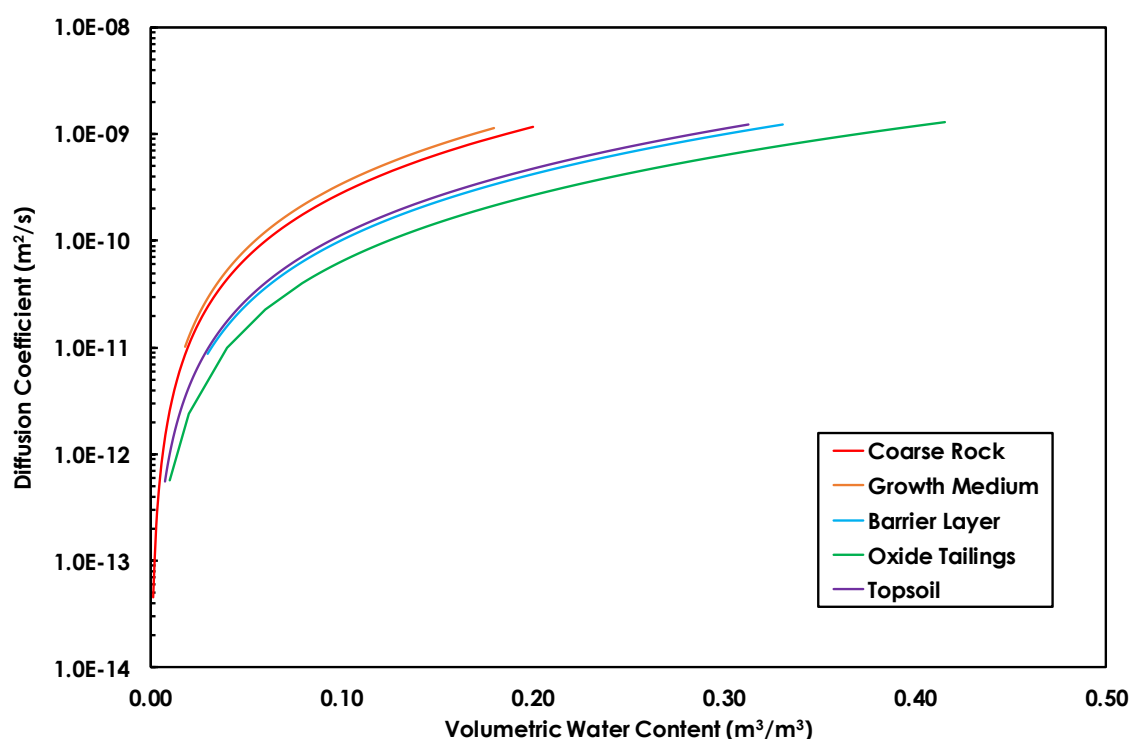


Figure 5.3: Estimated diffusion coefficients for the Yandan cover system materials.

5.2.3 Upper Boundary

5.2.3.1 Climate

A description of the long-term (118-year) climate database can be found in Section 4.1.1. This was applied using a Land-Climate Interaction (LCI) and Surface Energy Balance boundary (SEB) condition. The LCI boundary condition was used to simulate the water ingress from the top of the cover, computing the NP rates and water balance. The SEB boundary condition was used with air temperature, wind speed and net radiation values, which utilises the mass balance equation and is useful for including evaporation into the

simulation. Together both boundary conditions can be used to simulate Soil-Plant-Atmosphere transfers across the ground surface.

5.2.3.2 Vegetation

Vegetation establishment on the Cell B cover system is expected to be, at least during the initial stages, sparse and is not expected to provide high surface coverages. Jackson *et al.* (1996) estimated a typical root distribution based on a database of 250 root studies, subdivided into 11 biomes, using the following formula:

$$Y = 1 - \beta^d$$

Where Y is the cumulative root fraction from the soil surface to depth, d (cm), and β is the fitted "extinction coefficient", the results are shown in Figure 5.4. β is the only parameter estimated in the model and provides a simple numerical index rooting distribution. For a base case analysis, no vegetation was assumed within any of the numerical models. This approach allows any numerical modelling results to be conservative. However, additional modelling was undertaken which included established vegetation within the various cover system alternatives. Vegetation coverage was modelled at 28%. Observations recorded during the site visit indicate this is likely a conservative estimate. 28% coverage was considered reasonable for observations made of vegetation growth on Cell A, however greater vegetation coverage was observed on the areas immediately surrounding the TSF indicate vegetation coverage greater than 28% are achievable in this region. Jackson *et al.* (1996) recommend a β value of 0.972 for a 'Tropical grassland savanna' and this value was adopted for vegetation modelling purposes for Yandan. High β values (e.g. 0.98) correspond to a greater proportion of roots at depth and low β values (e.g. 0.92) imply a greater proportion of roots near the surface. Vegetation parameters used in the numerical modelling program representative of anticipated maximum vegetation establishment are summarised in Table 5.2. A rooting depth of 3.0 m was selected to represent the maximum value, however as shown in Figure 5.4, over 90% of cumulative root distribution occurs in the top 1 m of the cover system, with approximately 99% occurring within the top 2 m.

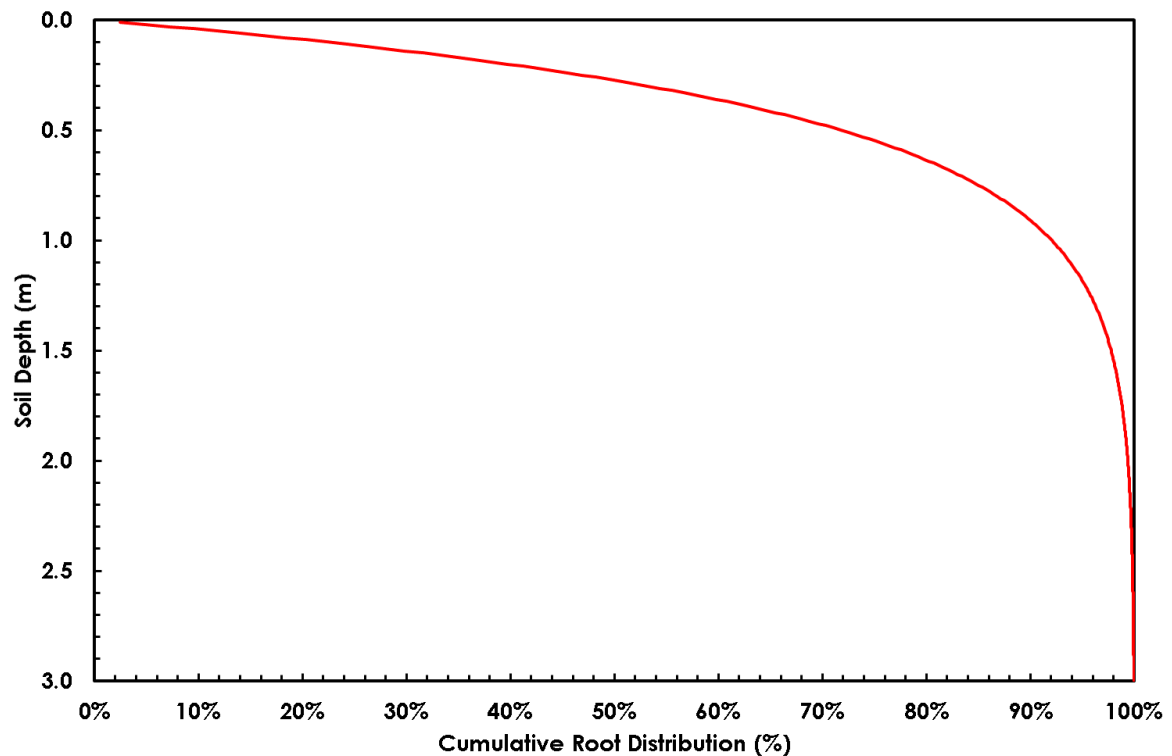


Figure 5.4: Cumulative root distribution for Yandan (not used in base case).

Table 5.2: Summary of vegetation parameters.

Model Parameters	Value
Root Depth (m)	3.0
Soil Cover Fraction	28%
Field Capacity (kPa)	10
Permanent Wilting Point (kPa)	1,500

In general, field capacity (FC) is defined as the water content of soil at a suction of 33 kPa, and the Plant Wilting Point (PWP) is defined as the minimum soil water required for a plant to resist wilting at a suction of 1,500 kPa. However, this range is generalised and does not account for differences in soil and plant characteristics. Based on the estimated properties for the topsoil and the anticipated vegetation, the FC and PWP for this project were defined at suctions of 10 kPa and 1,500 kPa, respectively.

5.2.4 Lower Boundary

The lower boundary of the models was simulated as a unit hydraulic gradient. A unit hydraulic gradient boundary condition assumes that at the lower boundary the suction (and as a result, water content and hydraulic conductivity) are constant with depth. For this situation, the total head equals the gravitational head, which results in a unit hydraulic gradient. In other words, it is assumed that the water table under the tailings is at sufficient depth that it does not influence the potential cover systems water balance.

5.2.5 Initial Conditions

Initial conditions were established by simulating the 1D model with the entire 118-year climate database and then using the resultant final conditions of that simulation as the initial conditions for the simulations presented in this report. Through this method initial conditions are more objective.

5.2.6 Model Limitations

The following limitations should be noted when interpreting the results for the cover system numerical modelling program.

- The model assumes movement of water in the unsaturated zone can be represented as Darcian flow in a porous media. The model does not account for any potential non-Darcian flow in macropores and/or cracks within the cover system. This is a key assumption because the model assumes that "flushing" of salt will result during infiltration events because it is assumed that all flow occurs as matrix flow. If macropores exist in the cover material, then infiltration through these macropores during rainfall events will bypass the matrix, and thus salt flushing may be much less than predicted by the model.
- The model assumes the cover system can be represented by various material types with homogenous material properties. The potential influence of local heterogeneity (within a given material type) was not investigated.
- The water movement within the cover systems is defined by the unsaturated hydraulic conductivity versus matric suction relationship. This relationship is extremely difficult to measure *in situ* in a field condition and consequently is derived by a theoretical algorithm based on the value input for k_{sat} . The theoretical relationship defines the hydraulic conductivity function over several orders of magnitude, while a single or half order of magnitude change can greatly affect the predicted NP results from a simulation.

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

6 MODELLING RESULTS

Numerical modelling assessed the performance of the cover system design alternatives in three categories:

- 1) Net Percolation (NP) Assessment: each cover system alternative was simulated to determine the water balance.
- 2) Water Stored within cover system: defined as the volume of water that is stored within the growth medium and topsoil component of the cover system, helps determine which cover system alternatives best provide sufficient water for vegetation establishment and survival.
- 3) Salt Uptake Assessment: determines relative potential for salt uptake into the cover system based on the alternatives.

The alternatives, described in detail in Section 5.2.1, include:

- Base Case Cover System Design;
- Double Capillary Break Cover System;
- Single Capillary Break Cover System – DES Min. thickness; and
- Single Capillary Break Cover System – Alternative thickness.

6.1 NP Assessment

Simulations were completed to evaluate the NP performance of each potential cover system alternative. Results are provided in Table 6.1 for scenarios without vegetation and Table 6.2 for scenarios that included established vegetation. Exceedance probability results are shown in Figure 6.1 for scenarios without vegetation and Figure 6.2 for scenarios that included established vegetation. The results indicate:

- The introduction of established vegetation results in much higher ET and lower NP, particularly for the Base Case design as available water within the cover system is removed by vegetation;
- The double capillary break and single capillary break using the DES minimum thickness limited NP the greatest when compared to the Base Case design and single capillary break using the alternative thickness. However, the single capillary break using alternative thicknesses limits NP to within 1% of the double capillary break and single capillary break using DES thickness cover systems; and
- Without established vegetation the single capillary break cover system utilising alternative thicknesses limits NP the most. The reason for this would likely be due to the shallower depth of the barrier layer when compared to the double capillary break cover system and the single capillary break cover system using DES thicknesses (see Figure 5.1 in Section 5.2.1). A shallower barrier layer in the single capillary break system

with alternative thicknesses would hold moisture for longer within the zone where moisture cycling, as a result of evaporation can still reach and remove water from the system. Moisture in the double capillary break system and the single capillary break system with DES thicknesses could infiltrate past this zone and be out of reach of evaporation resulting in a larger proportion reporting as NP.

- The three alternative designs would be expected to perform much better than the Base Case during extreme wet periods. For example, under the modelled scenario with no established vegetation there is approximately 5% probability that in any given year NP through the single capillary break with alternative thicknesses would result in an INAP NP Classification of very high. This probability jumps to approximately 90% for the Base Case. Under the established vegetation scenario there is approximately 5% probability all three alternative designs would result in a classification of very high and 25% probability the Base Case would result in a classification of very high in any given year.

Table 6.1: Summary of simulated NP results for cover system alternatives as a percentage of average annual rainfall (552 mm/year).

Cover System	Description	E	NP	RO	INAP NP Classification ¹
1)	Base Case Design	44%	54%	2%	Very High
2)	Double Capillary Break	77%	7%	16%	Moderate
3)	Single Capillary Break – DES Min. thickness	76%	7%	17%	Moderate
4)	Single Capillary Break – Alternative thickness	76%	4%	20%	Low

INAP (2017) classification are: Very Low: < 1% of rainfall; Low: between 1% and 5% of rainfall; Moderate: between 5% and 10% of rainfall; High: between 10% and 20% of rainfall; and Very High: > 20% of rainfall.

Table 6.2: Summary of simulated NP results for cover system alternatives with vegetation as a percentage of average annual rainfall (552 mm/year).

Cover System	Description	ET	NP	RO	INAP NP Classification ¹
1)	Base Case Design	87%	8%	5%	Moderate
2)	Double Capillary Break	87%	2%	11%	Low
3)	Single Capillary Break – DES Min. thickness	87%	3%	10%	Low
4)	Single Capillary Break – Alternative thickness	84%	2%	14%	Low

INAP (2017) classification are: Very Low: < 1% of rainfall; Low: between 1% and 5% of rainfall; Moderate: between 5% and 10% of rainfall; High: between 10% and 20% of rainfall; and Very High: > 20% of rainfall.

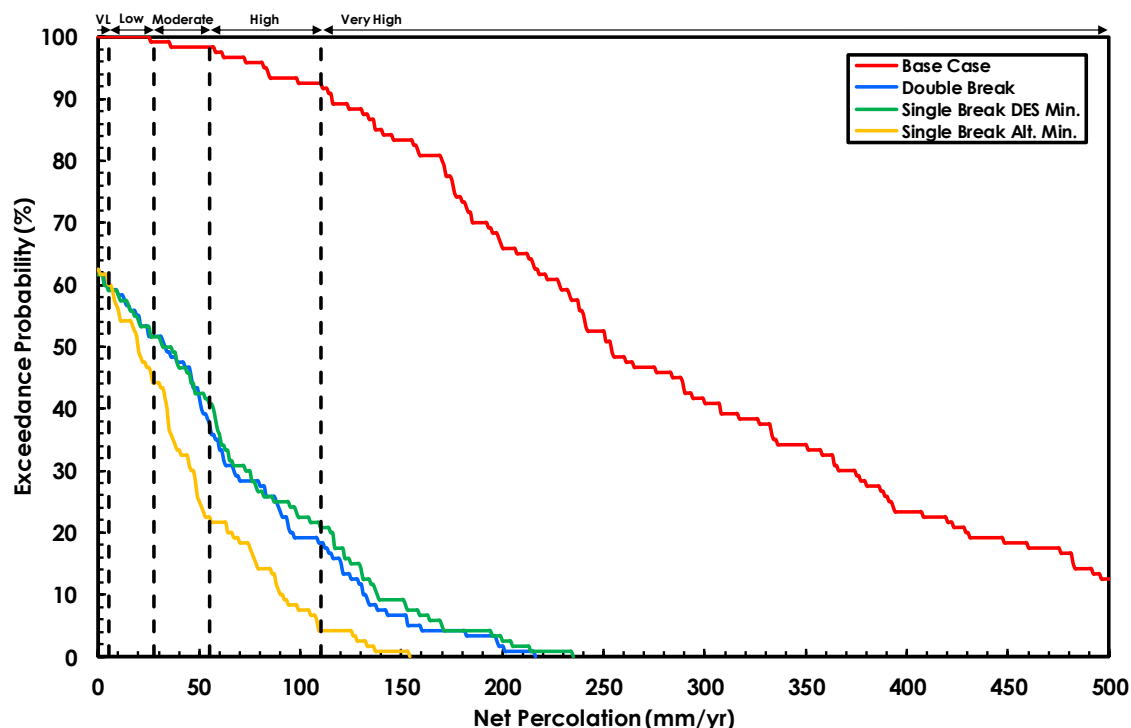


Figure 6.1: Exceedance probability chart for NP comparing cover system alternatives without vegetation modelled.

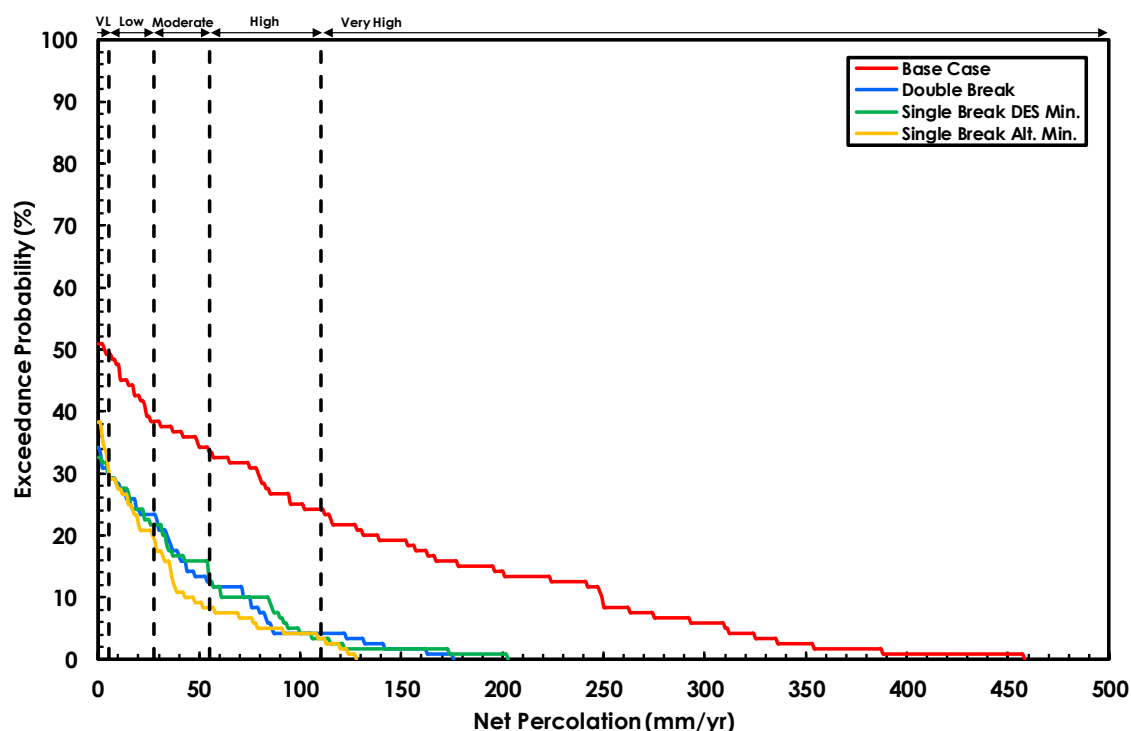


Figure 6.2: Exceedance probability chart for NP comparing cover system alternatives with vegetation modelled.

6.2 Water Storage

The volume of water stored within the upper section of a cover system provides a guide to the water that may be removed via evapotranspiration forces. The results displayed in

Table 6.3 and Figure 6.3 display the stored water (mm) per centimetre of topsoil and growth medium. Results indicate the Base Case design stores the least amount of water. This cover system design contains 0.4 m of topsoil with an absence of growth medium. The double capillary break and both the single capillary break with DES minimum thickness and alternative minimum thickness display a similar volume of water stored for each centimetre of topsoil and growth medium.

The performance of the Base Case design is to be expected due to the lack of impediment of downflow of the water. As a result, water is not stored within the upper portion of the cover system for similar durations as the other cover system designs and therefore is not available for uptake via evapotranspiration.

Table 6.3: Statistical analysis of water storage within the topsoil and growth medium for cover system design alternatives (mm/cm).

Cover System	Description	Average	Standard Deviation	Maximum	Minimum
1)	Base Case Design	0.19	0.24	2.39	-0.09
2)	Double Capillary Break	0.84	0.29	2.10	0.53
3)	Single Capillary Break – DES Min. thickness	0.85	0.27	2.03	0.60
4)	Single Capillary Break – Alternative thickness	0.85	0.28	1.96	0.57

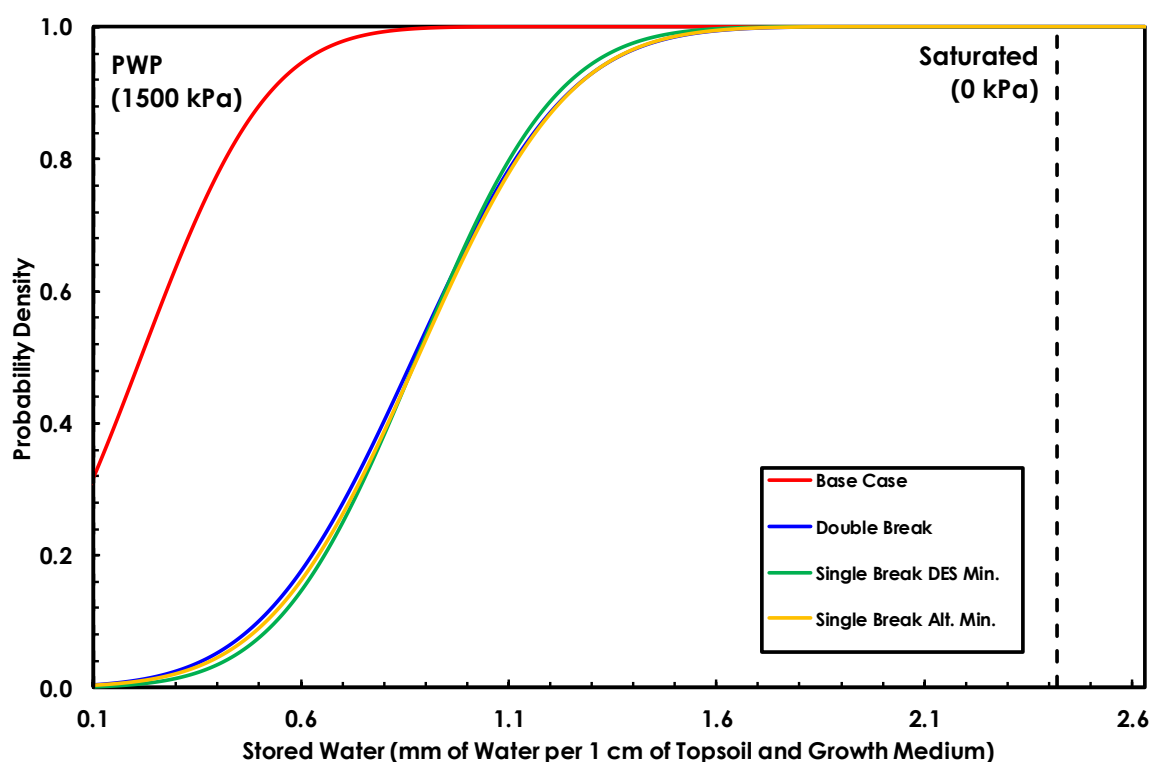


Figure 6.3: Cumulative normal distribution of water storage within topsoil and growth medium layers for each cover system alternative.

6.3 Salt Uptake Assessment

The four cover system alternatives were assessed for salt uptake. Figure 6.4 and Figure 6.5 present the anticipated EC values within the cover system profiles at the end of the simulations if the tailings had a surface EC value of 11.2 dS/m (Figure 6.4) and 5.19 dS/m (Figure 6.5). These values were the highest and the average EC values recorded during previous testing of the tailings (Dwyer, 2014). In situ testing during the site visit supported these values. An EC value of 5.8 dS/m was recorded for tailings tested from Test Pit 23 and are comparable with the average EC value recorded by Dwyer (2014). The following results represent both a conservative estimate by utilising the maximum recorded EC value, and a less conservative estimate by utilising the average recorded EC value. However, it should be noted that vegetation with tolerance to salinity will still grow in the maximum recorded EC range, should the salts be mobilised through upwards movement. The EC range presented corresponds to the soil salinity criteria developed by DERM (2011) (refer to Table 2.1). The salt uptake results indicate:

- For the Base Case design, adopting the maximum EC value results in the rooting zone (upper 3 m) being classified as having high, to very high salinity. Adopting the average EC values results in the rooting zone being classified as having moderate salinity;
- When the maximum EC value (Figure 6.4) is adopted, the single capillary break with DES minimum thicknesses is the only design capable of keeping salinity to very low levels within the rooting zone;
- When the average EC value (Figure 6.5) is used both single capillary break cover system designs and the double capillary break cover system design results in low and very low salinity within the rooting zone; and
- The key conclusion drawn from the salt uptake modelling is salt uptake within the growth medium reduces with an increase in cover system thickness, in particular during low rainfall climate years.

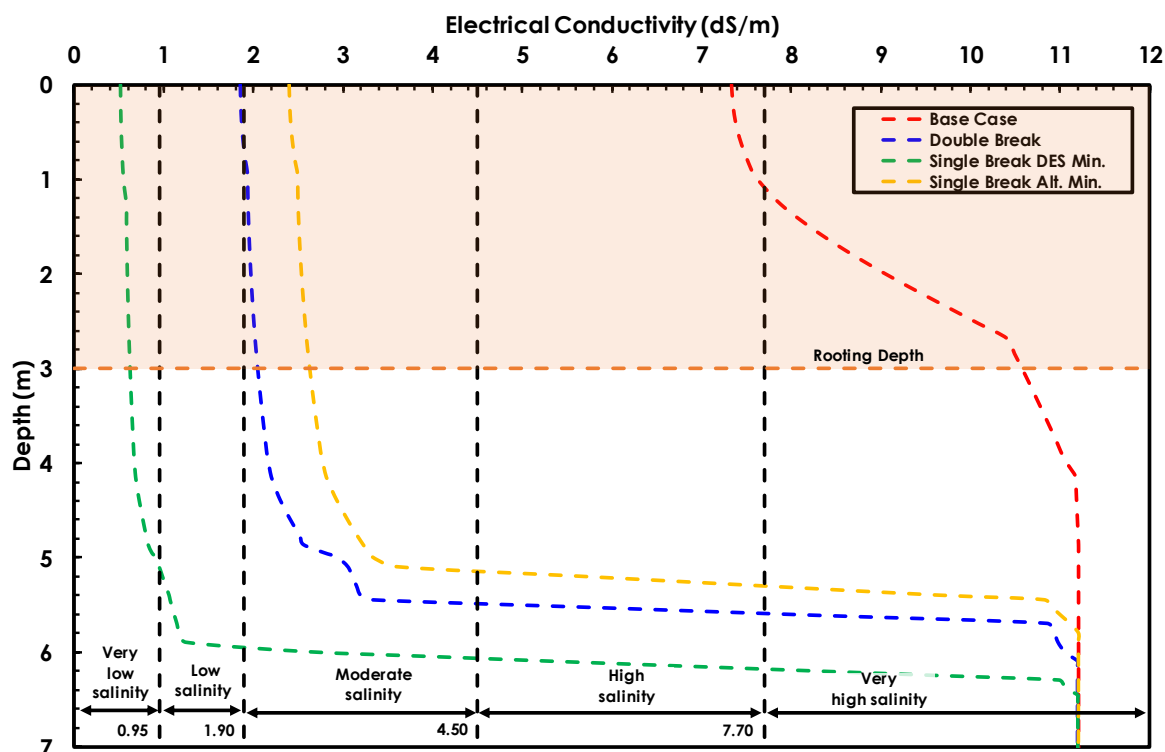


Figure 6.4: Anticipated electrical conductivity versus depth from the surface for the cover system alternatives assuming a tailings EC value of 11.2 dS/m.

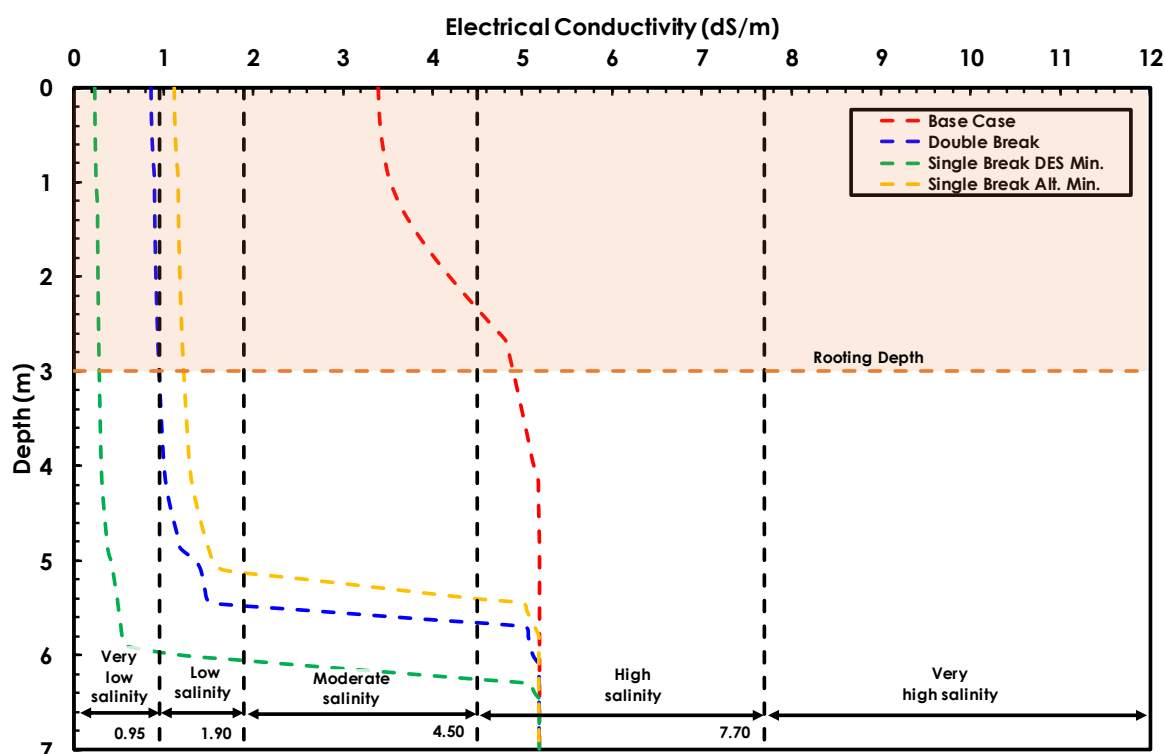


Figure 6.5: Anticipated electrical conductivity versus depth from the surface for the cover system alternatives assuming a tailings EC value of 5.19 dS/m.

7 COST BENEFIT COMPARISON

High-level cost estimates were developed to compare construction costs for each of the cover system alternatives considered in this study. The costing data utilised in this comparison was sourced from the DES Estimated Rehabilitation Cost (ERC) Calculator. Where the DES ERC Calculator was not able to provide adequate rates, alternative costings were sourced from previous works Okane had completed at an operational, open cut mine in North Queensland.

Key rates used in the cost benefit comparison are summarised in Table 7.1. These costings should only be used to assess the relative difference between alternative cover system designs in terms of NP performance. The comparison provides an indication of the cost burden associated with a performance improvement relative to the Base Case model. The costs are not to be considered complete costs for cover construction and budgeting purposes. The comparison only considers costs that are expected to vary between cover system designs. Costs considered common to all design alternatives, such as engineering design, haul road maintenance (grading, dust suppression, etc) and costs related to revegetation have been excluded.

Table 7.1: Key rates.

Task	Description ¹	Rate(\$/m ³)
Haulage & placement of Coarse Rock (gravel surrounding Cell B)	DES # 4.90 - Source local material, cart and spread to cap and/or cover (>200 m to <=500 m Rock) - small fleet	\$4.14
Haulage & placement of Coarse Rock (Heap Leach Pad)	DES # 4.94 - Source local material, cart and spread to cap and/or cover (>2000 m to <=2500 m Rock) - small fleet	\$5.57
Haulage & placement of Growth Medium (material surrounding TSF)	DES # 4.90 - Source local material, cart and spread to cap and/or cover (>200 m to <=500 m Rock) - small fleet	\$4.14
Haulage & placement of Clay (Upstream of WSD)	DES # 4.96 Source local material, cart and spread to cap and/or cover (>3000 m to <=4000 Rock) - small fleet	\$6.38
Haulage & placement of Topsoil (material surrounding TSF)	DES # 4.90 - Source local material, cart and spread to cap and/or cover (>200 m to <=500 m Rock) - small fleet	\$4.14
Haulage of Clay (offsite borrow)	DES – Miscellaneous Activities - Long distance carting of clay	\$0.22
Task	Description ²	Rate(\$/ha)
Compaction of <i>in situ</i> clay layer (3 passes per 0.3m of cover)	3 passes per 0.3m of material using 2 x 825H soil compactors	\$4,200

¹ Rates sourced from DES ERC Calculator.

² Rate sourced from operational open cut mine in North Queensland.

Table 7.2 summarises the estimated construction costs in total, and per square meter, for each cover system design. The Base Case design is the lowest cost design by a significant margin owing primarily to the smaller material volume requirement and, to a lesser extent, no requirement to construct a compacted clay barrier layer. Construction costs for the alternative cover designs are also driven largely by the volume of material required to be handled during construction, with the single capillary break with alternative layer thicknesses being the lowest cost design and the single capillary break using DES minimum thicknesses being the highest cost design.

Table 7.2: Estimated construction costs for cover system designs.

Cover System Design	Estimated Construction Cost (\$)	Estimated Construction Cost per m ² (\$)
Base Case	\$1,884,000	\$2.90
Double Capillary Break	\$6,092,000	\$9.37
Single Capillary Break – DES Min. thickness	\$8,402,000	\$12.93
Single Capillary Break – Alternative thickness	\$5,285,000	\$8.13

The alternative cover system designs investigated in this study include a barrier layer at the request of the DES in order to reduce NP through the cover system to a greater extent than would a simple store-and-release cover system, such as the Base Case. As discussed in Section 1 and Section 2.1, Okane understand the DES requested a low permeability layer be incorporated. A 'low permeability' is typically understood to be a layer with a saturated hydraulic conductivity of less than 1×10^{-9} m/s. Incorporating a geomembrane, such as HDPE, into the cover system design would provide the greatest confidence in achieving a level of permeability consistent with this interpretation. Table 7.3 summarises the percentage increase in costs that could be expected by incorporating a geomembrane into the three alternative cover system designs.

Table 7.3: Increase in costs related to incorporating a geomembrane into cover system designs.

Cover System Design	Estimated Construction Cost with Geomembrane (\$) ¹	% Increase in Cost
Double Capillary Break	\$13,583,000	123%
Single Capillary Break – DES Min. thickness	\$14,505,000	73%
Single Capillary Break – Alternative thickness	\$12,218,000	131%

¹ Rates for cost of geomembrane purchase and install sourced from DES ERC Calculator (\$13/m²).

Whilst a source of clay suitable for constructing the barrier layer has been identified onsite, and until a detailed material survey is completed to more accurately assess the volume available, there remains a risk this source will not be available in the quantities required. Table 7.4 provides an indication of the percentage increase in costs that could be expected should the offsite clay source be used as the sole borrow source for the barrier

layer. It should be noted this is a worst case scenario. It is much more likely all suitable onsite sources would be exhausted prior to sourcing clay from the offsite location and the volumes required would be less than those used to calculate the costs in Table 7.4.

Table 7.4: Additional estimated costs using clay from the offsite borrow source.

Cover System Design	Additional Estimated Construction Cost (\$)	% Increase in Cost
Double Capillary Break	\$3,500,000	57%
Single Capillary Break – DES Min. thickness	\$6,000,000	71%
Single Capillary Break – Alternative thickness	\$3,500,000	66%

Costs in relation to relative NP performance improvements were assessed against model results both excluding and including established vegetation. Figure 7.1 presents the percent increase in modelled cover performance and cost compared to the Base Case design without established vegetation and Figure 7.2 presents the percent increase in modelled cover performance and cost compared to the Base Case design with established vegetation.

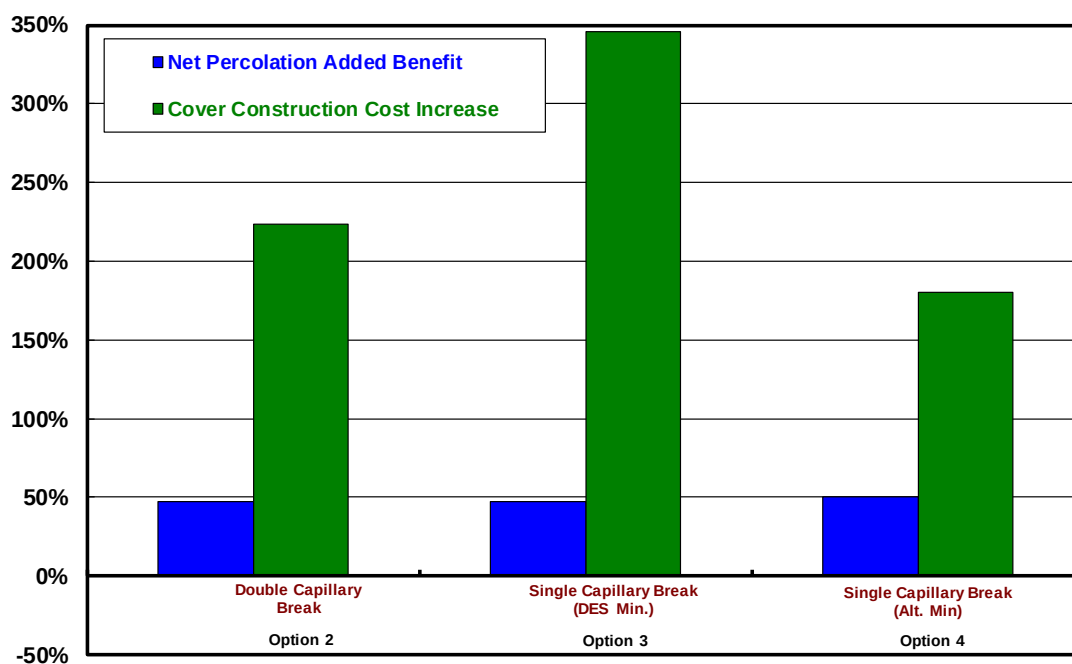


Figure 7.1: Percent increase in modelled cover performance and cost compared to the Base Case design without established vegetation.

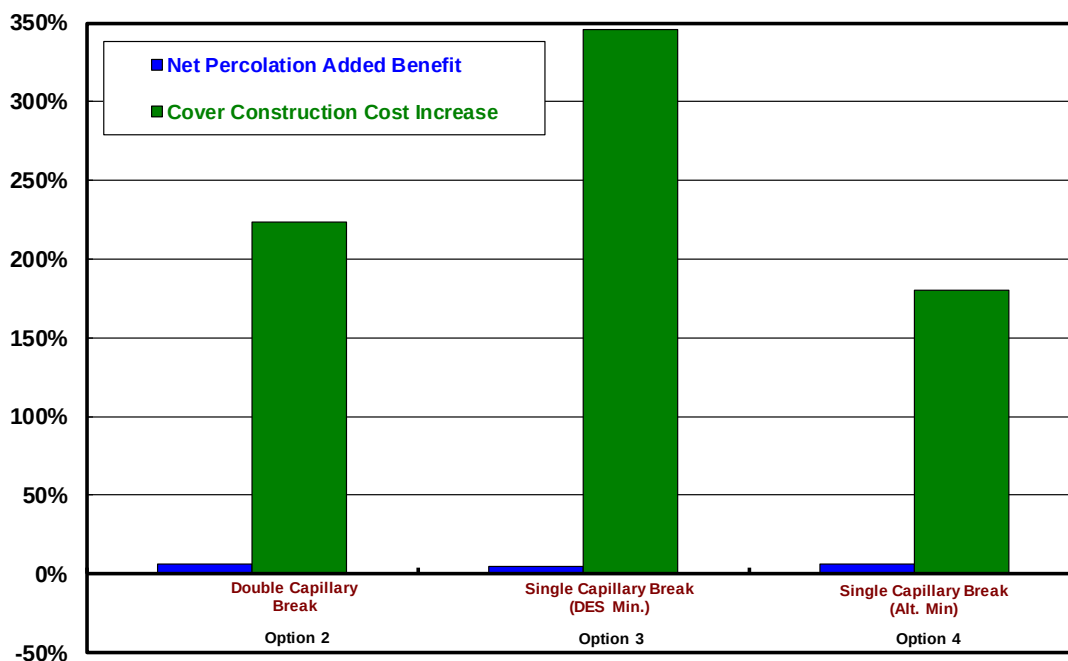


Figure 7.2: Percent increase in modelled cover performance and cost compared to the Base Case design with established vegetation.

When evaluating performance improvements against cost increases on a bare surface, the greatest performance improvement compared to the Base Case is provided by the single capillary break with alternative thickness design with a predicted improvement in NP of approximately 50%. The performance improvement from both the double capillary break and single capillary break with DES minimum thicknesses was modelled to be approximately 47% for both designs. When considering the cost of these performance improvements, the single capillary break with DES minimum thicknesses is the highest cost design and the single capillary break with alternative thicknesses is the lowest cost design. The 50% performance improvement achieved with the single capillary break with alternative thicknesses is estimated to cost at least 180% more than the Base Case. The 47% performance improvement achieved with the single capillary break with DES minimum thicknesses is expected to be accompanied by a cost increase in the order of 350% above the Base Case cost estimate.

When evaluating performance of the alternative designs in a scenario where 28% established vegetation coverage is assumed the costs remain the same, but the performance improvements are considerably reduced. The greatest performance improvement under these modelled conditions is achieved by both the single capillary break with alternative thicknesses and the double capillary break designs at 6% less NP than what is achieved with the Base Case design. The single capillary break with DES minimum thicknesses provides the least improvement, albeit only 1% less than the other alternatives.

Evaluation of modelled performance improvements versus high-level cost estimates for the three alternative cover system designs against the Base Case design indicates the single capillary break with alternative thicknesses design provides the greatest performance improvement at the lowest cost under both the bare surface model scenario and the 28% vegetation coverage model scenario. The improvements are in the order of approximately 50% under the bare surface scenario, but only 6% under a scenario that includes vegetation.

When assessing the relative performance improvements versus estimated construction costs provided by the alternative designs the following points should be considered:

- The DES has requested a barrier layer be incorporated in the cover system design and as such the current Base Case design is not considered suitable.
- A cover system will have a bare surface immediately following construction and would be expected to revegetate in the following years. Both the bare surface scenario and the vegetated scenario will occur at stages. Assessing the performance of a design under only one scenario would be misleading.
- The vegetated scenario assumed an established vegetation coverage of 28%. Based on observations during the site visit this is considered very achievable and potentially conservative.
- Modelled performance is based on average NP. The maximum NP that was predicted for the three alternative designs during the wettest periods was modelled as substantially less than the maximum NP expected through the Base Case design.
- The three alternative designs are less influenced by vegetation coverage than the Base Case design. In the event vegetation is adversely impacted, e.g. fire, the alternative designs will maintain a performance that cannot be matched by the Base Case design.

8 KEY FINDINGS AND RECOMMENDATIONS

The following key findings and recommendations are based on the results of the field sampling and material characterisation program:

- The clay borrow located upstream of the WSD was found to contain suitable material of good consistency capable of restricting hydraulic conductivity to an acceptable level for use within a barrier layer cover system unit. Similar results were found in the clay core of the HLP, upstream of the MWD and at the offsite clay borrow. The location upstream of the WSD looks to be the most promising source of clay material based on distance to the TSF and the potential volumes available. However, during detailed design and prior to construction, further investigatory work should be performed to more accurately determine available material volumes from this source and if it will satisfy construction volumes. Without considering shrink/swell/compaction factors, material volumes required for construction of a barrier layer are in the order of 195,000 m³ and 325,000 m³, depending on the cover system configuration chosen. The offsite clay borrow is expected to be capable of providing sufficient material of acceptable quality. However, this material is located approximately 45 km from the TSF by road. Material from the HLP embankment is limited in volume and the material upstream of the MWD should be investigated for contamination prior to being used in a cover system design.
- The TRWD embankment core and the MWD embankment core contain considerable oversize material that would likely make it unsuitable for a use in a barrier layer. This material may however be suitable for use as a source for a growth medium layer.
- The material adjacent to Cell A was found to be coarser than the material adjacent to Cell B and as such is more suitable for use in a coarse rock capillary break layer than as growth medium layer. Due to the finer nature of the material adjacent Cell B, this material is more suited for use as a growth medium. The physical properties of the heap leach pad waste rock are considered acceptable for use as a coarse rock capillary break layer. Should waste rock from the heap leach pad be used, a stringent quality control / quality assurance and testing program should be developed to provide evidence this material has not been contaminated by the leach process. High-level volume estimates suggest sufficient coarse rock material is available onsite to construction the capillary break layers.
- Several locations historically referred to as gravel, topsoil or gravel and topsoil mixes proved suitable for use as a growth medium layer of a cover system. However, when considering this layer will require the greatest volume of material, the high-level volume estimates of the areas investigated indicate additional sources may need to be identified to meet the volume requirements. Alternatively, blending with coarser material may also be an option.

- The topsoil borrow sources investigated were found to have suitable physical characteristics for use as a topsoil layer. Soil fertility testing of selected locations indicate that, whilst not particularly fertile, should not inhibit vegetation growth and establishment. High-level volume estimates suggest the topsoil sources investigated may not be sufficient to construct topsoil layers to the depths desired. Should topsoil inventories prove to be insufficient, options to address the shortfall could include blending with the gravel and topsoil mix areas or reducing the topsoil layer thickness.
- A more detailed material survey should be completed during detailed design works and prior to construction to ensure sufficient volumes of key materials will be available to meet the cover system design specification.

The following key findings and recommendations are based on the results of the numerical modelling program:

- Without established vegetation, modelling indicates NP will be limited to less than 7% of average annual rainfall for the double capillary break and DES minimum thickness single capillary break cover system alternatives. Based on the NP classifications adopted for Yandan (Section 2.2.1), these cover system designs provide a moderate NP system. The single capillary break with alternative layer thicknesses provided the greatest reduction in NP (4% of average annual rainfall) and was classified as a low NP system. Without established vegetation, the Base Case design only limited NP to approximately 54% of average annual rainfall and was classified as a very high NP system.
- The introduction of a, potentially conservative, 28% established vegetation coverage reduced NP for all three alternative cover system designs to low level NP systems. The introduction of established vegetation to the Base Case design reduced NP for this design from 54% to 8%, or from a very high to a moderate NP system.
- Whilst all three alternative cover system designs outperformed the base case design in terms of limiting NP, they also result in an increase in runoff. For example, for the non-vegetated scenario, 2% of average annual rainfall results in runoff for the base case. Runoff for the same scenario increases to 16%, 17% and 20% for the double capillary break, single capillary break with DES minimum thicknesses and single capillary break with alternative thicknesses respectively. Runoff would be considered clean and would not require containment. However, managing this runoff in a manner that will not result in erosion of the cover system or the ponding of water will require effective surface water management designs, construction and maintenance. It should be noted inadequate surface water management has previously been identified as key a reason behind the poor performance of earlier cover system trials on Cell B and isolated areas of Cell A (Okane, 2015).
- The double capillary break and both single capillary break designs can store more water within the cover system compared to the Base Case design. The increased

volume of water stored enables a potentially higher rate of moisture removal via evapotranspiration forces rather than infiltrating and as a result reduces NP. A greater water storage capacity will also delay the growth medium and topsoil reaching the PWP and reduce the time during which vegetation is subjected to water stress.

- The single capillary break with the DES minimum thicknesses performed the best in terms of limiting salt uptake into the root zone of the cover systems. This can be attributed to the greater overall cover thickness of this design. All three alternative cover system designs are expected to provide adequate control of salt uptake into the growth medium under both average and maximum likely tailings EC levels according to DERM (2011). Whilst the Base Case design results in moderate salinity levels at average tailings EC levels and is unlikely to significantly limit vegetation growth, at maximum tailings EC levels high to very high salinity levels are projected and would likely impact vegetation growth.

The following key findings and recommendations are based on the results of the cost benefit comparison:

- The single capillary break with alternative layer thicknesses to that prescribed by the DES provided the greatest relative performance improvement for the least cost. If a barrier layer must be incorporated into the cover system in order to receive DES support, this design should be adopted. However, the estimated construction costs for this design, and the other two alternative designs, were considerably higher than the Base Case design. A more detailed cost estimate should be developed for this design to fully appreciate the cost of this performance improvement over the Base Case.
- The single cover break with DES minimum layer thicknesses proved to provide the least performance improvement when compared to the Base Case design as well as being estimated as the highest cost design to construct.
- The improvements in modelled performance for all three alternative designs were substantially more under the bare surface modelled scenario than under the scenario modelled with conditions that included 28% vegetation coverage. Consideration should be given to the period of time during which the bare surface scenario would be most representative of expected conditions and the period of time during which at least 28% vegetation coverage would be most representative of expected conditions. Quantifying this risk would further inform the value of constructing a more costly cover system design.
- Performance comparisons are based on average modelled NP. Relative performance of the alternative designs may differ under the wetter extremes expected under closure timeframes. The performance of the alternative designs at the wet extremes, and the associated risk during these events, should be explored to further inform the value of constructing a more costly cover system design.

Based on the results and findings from the material characterisation program, numerical modelling and cost benefit comparison, Okane recommend Straits Gold adopt the single capillary break with alternative layer thicknesses design to address both the DES requirement for a cover system incorporating a barrier layer and the rehabilitation objectives defined in the Yandan Post Mine Land Use Plan (AARC, 2015) for Cell B of the TSF.

To further progress this conceptual cover system design towards detailed design, Okane recommend the following technical studies and investigations be considered:

- A detailed material survey should be completed to develop accurate material inventories. Material surveys will inform borrow locations and allow for cover system design refinements, if necessary. Accurate costings can be developed once borrow locations have been confirmed.
- If material surveys indicate additional clay sources are required to supplement clay from the borrow location upstream of the WSD, the clay material from the sampling location upstream of the MWD should be considered. If intending to use this material, it should be assessed for contamination from contact with process water. Existing samples of this material are stored onsite and could be shipped to a laboratory for analysis.
- Assess the suitability of the TRWD and MWD embankment material for use as a growth medium.
- Investigate the risk surrounding not being able to establish or maintain vegetation coverage of 28% or greater on the cover system. If the risk is high and establishing or maintaining 28% vegetation coverage for significant periods of time is likely to be difficult, this will further support adopting an alternative design which is less influenced by vegetation coverage than the Base Case.
- Develop more accurate cost estimates for construction of the single capillary break with alternative layer thicknesses option to fully understand the cost implications of adopting this design over the Base Case.
- Consider conducting a cover system trial to validate the preferred cover system alternative. In addition to validating the design and calibrating the existing numerical model, cover system trial objectives could be designed to investigate revegetation options with the view to selecting a revegetation species mix that will satisfy rehabilitation objectives, meet post mining land use goals and provide vegetation coverage greater than 28%.
- Integrate final cover system designs with an adequate surface water management system. A trade-off for limiting NP through the cover system with a barrier layer is the generation of increased runoff. Increased runoff can result in erosion damaging the

integrity of the cover system and increasing NP in addition to the potential to expose the underlying tailings. Runoff that cannot be effectively removed from the cover system can also result in areas of ponded water impacting vegetation growth and establishment. Removing runoff from the cover system in a manner that will limit erosion and the ponding of water on the cover will be critical to the success of a cover system for Cell B. Ineffective surface water management has previously been identified as a key factor leading to poor cover system performance on Cell A and on the previous cover system trials undertaken on Cell B.

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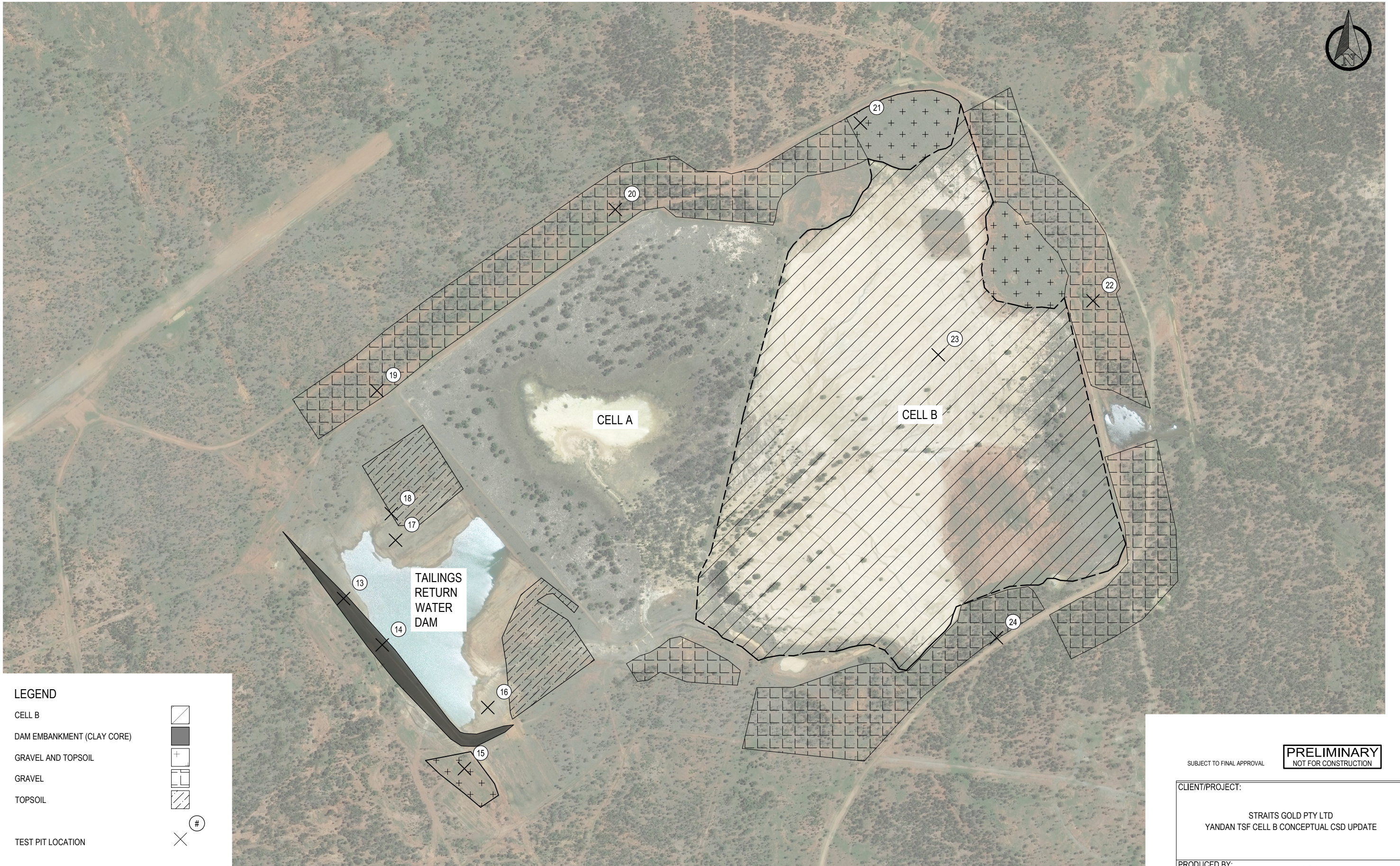
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Appendix A

Sampling Locations



LEGEND

- CELL B

DAM EMBANKMENT (CLAY CORE)

GRAVEL AND TOPSOIL

GRAVEL

TOPSOIL

TEST PIT LOCATION
-

- NOTES:
- 1. ALL UNITS IN METERS U.N.O.
 - 2. DO NOT SCALE.
 - 3. AERIAL IMAGE PROVIDED BY STRAITS RESOURCES.

SUBJECT TO FINAL APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

CLIENT/PROJECT:

STRAITS GOLD PTY LTD
YANDAN TSF CELL B CONCEPTUAL CSD UPDATE

PRODUCED BY:


OKC PROJECT NO.: 956/007

TSF CELL B
MATERIAL LOCATIONS

DWG. NO.: 956-007-001 REV.: D

REFERENCE	DWG. NO.	DESCRIPTION	REVISIONS	NO.	DESCRIPTION	DRN. BY:	APPD. BY:	DATE	DRN. BY:	APPD. BY:	DATE	SCALE:	PAGE SIZE:	OKC RPT. NO.:
				A	ISSUED FOR CLIENT REVIEW	HSC	SL	06.13.19	H. COOPER		06.13.19			
				B	TEST PIT LOCATIONS ADDED	JMD	RB	07.29.19	A. OSBORN		06.13.19			
				C	UPDATED TITLEBLOCK	JMD	AO	12.05.19				AS SHOWN	A3	956-007-01
				D	UPDATED TITLEBLOCK	JMD	AO	12.10.19						



PROPOSED CLAY BORROW



LEGEND

- CLAY BORROW SOURCE
- ROADS
- TEST PIT LOCATION

- NOTES:
- 1. ALL UNITS IN METERS U.N.O.
 - 2. DO NOT SCALE.
 - 3. AERIAL IMAGE RESOURCED FROM GOOGLE.

SUBJECT TO FINAL APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

CLIENT/PROJECT:

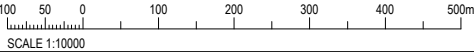
STRAITS GOLD PTY LTD
YANDAN TSF CELL B CONCEPTUAL CSD UPDATE

PRODUCED BY:


OKC PROJECT NO.: 956/007

PROPOSED CLAY BORROW

DWG. NO.: 956-007-002 REV.: C



REFERENCE	DWG. NO.	DESCRIPTION	REVISIONS	NO.	DESCRIPTION	DRN. BY:	APPD. BY:	DATE	DRN. BY:	APPD. BY:	DATE	SCALE:	PAGE SIZE:	OKC RPT. NO.:
				A	ISSUED FOR CLIENT REVIEW	HSC	SL	07.03.19	H. COOPER		07.03.19			
				B	TEST PIT LOCATIONS ADDED	JMD	RB	07.24.19	A. OSBORN		07.03.19			
				C	UPDATED TITLEBLOCK	JMD	AO	12.10.19	AS SHOWN	A3				956-007-01



LEGEND

DAM EMBANKMENT (CLAY CORE)

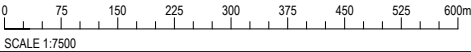
HEAP LEACH COARSE WASTE ROCK

TEST PIT LOCATION

- NOTES:
1. ALL UNITS IN METERS U.N.O.

2. DO NOT SCALE.

3. AERIAL IMAGE PROVIDED BY STRAITS RESOURCES.



REFERENCE	DWG. NO.	DESCRIPTION	REVISIONS	NO.	DESCRIPTION	DRN. BY:	APPD. BY:	DATE	DRN. BY:	J. DAND	DATE:	07.08.19
				A	ISSUED FOR CLIENT REVIEW	JMD	SL	07.09.19	APPD. BY:	S. LINES	DATE:	07.09.19
				B	TEST PIT LOCATIONS ADDED	JMD	RB	07.24.19	SCALE:	AS SHOWN	OKC RPT. NO.:	956-007-01
				C	UPDATED TITLEBLOCK	JMD	AO	12.10.19	PAGE SIZE:	A3	REV.:	C

SUBJECT TO FINAL APPROVAL

PRELIMINARY
NOT FOR CONSTRUCTION

CLIENT/PROJECT:

STRAITS GOLD PTY LTD
YANDAN TSF CELL B CONCEPTUAL CSD UPDATE

PRODUCED BY:

okane

OKC PROJECT NO.: 956/007

ONSITE CLAY SOURCE AND
HEAP LEACH LOCATION

DWG. NO.: 956-007-003

Appendix B

Test Pit Logs

		TEST PIT LOG		TEST PIT # TP#1	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION OFFSITE CLAY BORROW SOURCE		SURFACE LEVEL 221 m	
EASTING 522472		NORTHING 7650127		PROJECT NUMBER 956-007	

RIG TELEHANDLER / SHOVEL	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – light to dark brown silty sand topsoil, fine to medium grained sand, trace clay, some organic material.	BUCKET	YAN-001A	0.0-0.1	NA	Shovel sample scraped surface. Paste pH and EC testing completed.
			BUCKET	YAN-001B	0.0-0.1		
			BUCKET	YAN-001C	0.0-0.1		
			BUCKET	YAN-001D	0.0-0.1		
			BAG	YAN-001E	0.0-0.1		
			BAG	YAN-001 SWCC	0.0-0.1		
	0.1	Test pit discontinued at 0.1m					

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <thead> <tr> <th>Sample</th> <th>TP1</th> </tr> </thead> <tbody> <tr><td>Date</td><td>17/09/2019</td></tr> <tr><td>Time</td><td>10:29</td></tr> <tr><td>Temp (°C)</td><td>13.56</td></tr> <tr><td>SP Cond (µS/cm)</td><td>28</td></tr> <tr><td>Cond (µS/cm)</td><td>22</td></tr> <tr><td>TDS (g/L)</td><td>0.018</td></tr> <tr><td>DO Sat (%)</td><td>91</td></tr> <tr><td>DO (mg/L)</td><td>9.47</td></tr> <tr><td>pH</td><td>4.93</td></tr> <tr><td>pH (mV)</td><td>74.3</td></tr> <tr><td>ORP (mV)</td><td>162.8</td></tr> </tbody> </table>	Sample	TP1	Date	17/09/2019	Time	10:29	Temp (°C)	13.56	SP Cond (µS/cm)	28	Cond (µS/cm)	22	TDS (g/L)	0.018	DO Sat (%)	91	DO (mg/L)	9.47	pH	4.93	pH (mV)	74.3	ORP (mV)	162.8
Sample	TP1																								
Date	17/09/2019																								
Time	10:29																								
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Cond (µS/cm)	22																								
TDS (g/L)	0.018																								
DO Sat (%)	91																								
DO (mg/L)	9.47																								
pH	4.93																								
pH (mV)	74.3																								
ORP (mV)	162.8																								

		TEST PIT LOG		TEST PIT # TP#2	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION OFFSITE CLAY BORROW SOURCE		SURFACE LEVEL 221 m	
EASTING 522472		NORTHING 7650127		PROJECT NUMBER 956-007	

RIG TELEHANDLER / SHOVEL	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – light to dark brown silty sand topsoil, fine to medium grained sand, trace clay, some organic material.				NA	Telehandler excavated test-pit, sampled by shovel.
	0.3	SANDY SILTY CLAY – Firm to stiff grey brown sandy silty clay, fine to medium grained sand, trace organic material, dry.	BUCKET BUCKET BUCKET BUCKET BAG BAG	YAN-002A YAN-002B YAN-002C YAN-002D YAN-002E YAN-002 SWCC	0.3-0.4 0.3-0.4 0.3-0.4 0.3-0.4 0.3-0.4 0.3-0.4		Paste pH and EC testing completed GP#1 completed at this location.
	0.4	Test pit discontinued at 0.1m					

PHOTO LOG



COMMENTS / LEGEND

Paste pH Testing:

Sample	TP2
Date	17/09/2019
Time	10:39
Temp (°C)	14.06
SP Cond (µS/cm)	15
Cond (µS/cm)	12
TDS (g/L)	0.01
DO Sat (%)	81.2
DO (mg/L)	8.36
pH	6.03
pH (mV)	13.7
ORP (mV)	162.2

		TEST PIT LOG		TEST PIT # TP#3	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION OFFSITE CLAY BORROW SOURCE		SURFACE LEVEL 219m	
EASTING 522452		NORTHING 7650100		PROJECT NUMBER 956-007	

RIG SHOVEL	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	GRAVELLY CLAY – light brown / grey gravelly clay, fine to medium grained sand, fine to coarse grained gravel with some cobbles, crumbly (dry).	BUCKET	YAN-003A	0.2-0.3	NA	Shovel sample collected on dam embankment, in an erosion gully
			BUCKET	YAN-003B	0.2-0.3		
			BUCKET	YAN-003C	0.2-0.3		
			BUCKET	YAN-003D	0.2-0.3		
			BAG	YAN-003E	0.2-0.3		
			BAG	YAN-003 SWCC	0.2-0.3		
	0.3	Test pit discontinued at 0.3 m					Paste pH and EC testing completed

PHOTO LOG	COMMENTS / LEGEND																								
	Paste pH Testing: <table border="1"> <thead> <tr> <th>Sample</th> <th>TP3</th> </tr> </thead> <tbody> <tr><td>Date</td><td>18/09/2019</td></tr> <tr><td>Time</td><td>19:39</td></tr> <tr><td>Temp (°C)</td><td>17.52</td></tr> <tr><td>SP Cond (µS/cm)</td><td>34</td></tr> <tr><td>Cond (µS/cm)</td><td>29</td></tr> <tr><td>TDS (g/L)</td><td>0.022</td></tr> <tr><td>DO Sat (%)</td><td>88.3</td></tr> <tr><td>DO (mg/L)</td><td>8.44</td></tr> <tr><td>pH</td><td>6.56</td></tr> <tr><td>pH (mV)</td><td>-15.2</td></tr> <tr><td>ORP (mV)</td><td>98.5</td></tr> </tbody> </table>	Sample	TP3	Date	18/09/2019	Time	19:39	Temp (°C)	17.52	SP Cond (µS/cm)	34	Cond (µS/cm)	29	TDS (g/L)	0.022	DO Sat (%)	88.3	DO (mg/L)	8.44	pH	6.56	pH (mV)	-15.2	ORP (mV)	98.5
Sample	TP3																								
Date	18/09/2019																								
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pH	6.56																								
pH (mV)	-15.2																								
ORP (mV)	98.5																								

		TEST PIT LOG		TEST PIT # TP#4	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION TOE OF HEAP LEACH PAD		SURFACE LEVEL 180 m	
EASTING 497399		NORTHING 7645374		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SANDY GRAVEL – light brown / light grey, weathered at the surface (orange) gravel, some fine to medium grained sand, some cobbles and boulders, dry. Heap leach material.	BUCKET	YAN-004A	0.4-	NA	>115 mm fraction estimated at 15%, >100 mm fraction estimated at 40%.
			BUCKET	YAN-004B	0.5		
			BUCKET	YAN-004C	0.4-		
			BUCKET	YAN-004D	0.5		
			BAG	YAN-004E	0.4-		
			BAG	YAN-004	0.5		
	0.5	Test pit discontinued at 0.5 m		SWCC	0.4-		Test pit excavated into side of stockpile. Paste pH and EC testing completed.
					0.5		
					0.4-		
					0.5		
					0.5		

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1" style="width: 100%; margin-top: 10px;"> <tr> <th>Sample</th> <th>TP4</th> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>19:41</td> </tr> <tr> <td>Temp (°C)</td> <td>14.93</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>30</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>24</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.02</td> </tr> <tr> <td>DO Sat (%)</td> <td>98.2</td> </tr> <tr> <td>DO (mg/L)</td> <td>9.92</td> </tr> <tr> <td>pH</td> <td>8.9</td> </tr> <tr> <td>pH (mV)</td> <td>-146.4</td> </tr> <tr> <td>ORP (mV)</td> <td>13</td> </tr> </table>	Sample	TP4	Date	18/09/2019	Time	19:41	Temp (°C)	14.93	SP Cond (µS/cm)	30	Cond (µS/cm)	24	TDS (g/L)	0.02	DO Sat (%)	98.2	DO (mg/L)	9.92	pH	8.9	pH (mV)	-146.4	ORP (mV)	13
Sample	TP4																								
Date	18/09/2019																								
Time	19:41																								
Temp (°C)	14.93																								
SP Cond (µS/cm)	30																								
Cond (µS/cm)	24																								
TDS (g/L)	0.02																								
DO Sat (%)	98.2																								
DO (mg/L)	9.92																								
pH	8.9																								
pH (mV)	-146.4																								
ORP (mV)	13																								

		TEST PIT LOG		TEST PIT # TP#5	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION HEAP LEACH POND EMBANKMENT		SURFACE LEVEL 179 m	
EASTING 498191		NORTHING 7644949		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – orange brown gravelly sand topsoil, fine to medium grained sand, some fine to coarse grained gravel, trace organic material.				NA	Test pit excavated into plateau of embankment.
	0.05	SANDY SILTY CLAY – stiff to very stiff, grey brown mottled red silty clay, some fine to medium grained sand and gravel, some cobbles, trace organics.	BUCKET	YAN-005A	1.1-1.2		Paste pH and EC testing completed.
			BUCKET	YAN-005B	1.1-1.2		
			BUCKET	YAN-005C	1.1-1.2		
			BUCKET	YAN-005D	1.1-1.2		
			BAG	YAN-005E	1.1-1.2		
			BAG	YAN-005 SWCC	1.1-1.2		
	1.2	Test pit discontinued at 1.2 m					GP#2 completed at this location.

PHOTO LOG	COMMENTS / LEGEND																								
	Paste pH Testing: <table border="1"> <tr> <th>Sample</th> <th>TP5</th> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>19:44</td> </tr> <tr> <td>Temp (°C)</td> <td>19.1</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>19</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>16</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.012</td> </tr> <tr> <td>DO Sat (%)</td> <td>80.2</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.57</td> </tr> <tr> <td>pH</td> <td>7.98</td> </tr> <tr> <td>pH (mV)</td> <td>-95.8</td> </tr> <tr> <td>ORP (mV)</td> <td>78.3</td> </tr> </table>	Sample	TP5	Date	18/09/2019	Time	19:44	Temp (°C)	19.1	SP Cond (µS/cm)	19	Cond (µS/cm)	16	TDS (g/L)	0.012	DO Sat (%)	80.2	DO (mg/L)	7.57	pH	7.98	pH (mV)	-95.8	ORP (mV)	78.3
Sample	TP5																								
Date	18/09/2019																								
Time	19:44																								
Temp (°C)	19.1																								
SP Cond (µS/cm)	19																								
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pH	7.98																								
pH (mV)	-95.8																								
ORP (mV)	78.3																								

		TEST PIT LOG		TEST PIT # TP#6	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION HEAP LEACH POND EMBANKMENT		SURFACE LEVEL 181 m	
EASTING 498104		NORTHING 7644883		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SANDY SILTY CLAY – stiff to very stiff red grey brown mottled red silty sandy clay mixed with silty sandy gravel matrix, some fine to coarse gravel, some fine to coarse cobbles, trace organics.	BAG	YAN-006F	0.9-1.0	NA	Test pit excavated into plateau of embankment. Paste pH and EC testing completed. Sample YAN-006F contains less clay and more gravel than sample E.
			BUCKET	YAN-006A	3.4-3.5		
			BUCKET	YAN-006B	3.4-3.5		
			BUCKET	YAN-006C	3.4-3.5		
			BUCKET	YAN-006D	3.4-3.5		
			BAG	YAN-006E	3.4-3.5		
			BAG	YAN-006 SWCC	3.4-3.5		
	3.5	Test pit discontinued at 3.5 m					

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr> <th>Sample</th><th>TP6</th></tr> <tr> <td>Date</td><td>18/09/2019</td></tr> <tr> <td>Time</td><td>19:46</td></tr> <tr> <td>Temp (°C)</td><td>16.13</td></tr> <tr> <td>SP Cond (µS/cm)</td><td>13</td></tr> <tr> <td>Cond (µS/cm)</td><td>11</td></tr> <tr> <td>TDS (g/L)</td><td>0.08</td></tr> <tr> <td>DO Sat (%)</td><td>85.7</td></tr> <tr> <td>DO (mg/L)</td><td>8.43</td></tr> <tr> <td>pH</td><td>8.37</td></tr> <tr> <td>pH (mV)</td><td>-116.8</td></tr> <tr> <td>ORP (mV)</td><td>55.4</td></tr> </table>	Sample	TP6	Date	18/09/2019	Time	19:46	Temp (°C)	16.13	SP Cond (µS/cm)	13	Cond (µS/cm)	11	TDS (g/L)	0.08	DO Sat (%)	85.7	DO (mg/L)	8.43	pH	8.37	pH (mV)	-116.8	ORP (mV)	55.4
Sample	TP6																								
Date	18/09/2019																								
Time	19:46																								
Temp (°C)	16.13																								
SP Cond (µS/cm)	13																								
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DO Sat (%)	85.7																								
DO (mg/L)	8.43																								
pH	8.37																								
pH (mV)	-116.8																								
ORP (mV)	55.4																								

		TEST PIT LOG		TEST PIT # TP#7	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION MINE WATER POND EMBANKMENT		SURFACE LEVEL 183 m	
EASTING 497846		NORTHING 7646133		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SILTY CLAY – red brown mottled grey silty clay, firm, within a clayey sandy gravel matrix (less matrix than at TP#5 and TP#6), fine to medium grained sand, fine to coarse gravel.	BUCKET	YAN-007A	1.6-	NA	Test pit excavated into plateau of northern arm of embankment.
			BUCKET	YAN-007B	1.7		
			BUCKET	YAN-007C	1.6-		
			BUCKET	YAN-007D	1.7		
			BAG	YAN-007E	1.6-		
			BAG	YAN-007	1.7		
				SWCC	1.6-		
	1.7	Test pit discontinued at 1.7m			1.7		Higher clay content than at the Heap Leach Pond Embankment.
					1.6-		
					1.7		
					1.6-		
					1.7		

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1" style="width: 100%;"> <tr> <th>Sample</th> <th>TP7</th> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>19:48</td> </tr> <tr> <td>Temp (°C)</td> <td>19.04</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>106</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>94</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.069</td> </tr> <tr> <td>DO Sat (%)</td> <td>75.2</td> </tr> <tr> <td>DO (mg/L)</td> <td>6.97</td> </tr> <tr> <td>pH</td> <td>8.15</td> </tr> <tr> <td>pH (mV)</td> <td>-105.1</td> </tr> <tr> <td>ORP (mV)</td> <td>50.7</td> </tr> </table>	Sample	TP7	Date	18/09/2019	Time	19:48	Temp (°C)	19.04	SP Cond (µS/cm)	106	Cond (µS/cm)	94	TDS (g/L)	0.069	DO Sat (%)	75.2	DO (mg/L)	6.97	pH	8.15	pH (mV)	-105.1	ORP (mV)	50.7
Sample	TP7																								
Date	18/09/2019																								
Time	19:48																								
Temp (°C)	19.04																								
SP Cond (µS/cm)	106																								
Cond (µS/cm)	94																								
TDS (g/L)	0.069																								
DO Sat (%)	75.2																								
DO (mg/L)	6.97																								
pH	8.15																								
pH (mV)	-105.1																								
ORP (mV)	50.7																								

		TEST PIT LOG		TEST PIT # TP#8	SHEET 1/1
PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION				CLIENT AERIS RESOURCES	
DATE 17/07/2019		LOCATION MINE WATER POND EMBANKMENT		SURFACE LEVEL 181 m	
EASTING 497715		NORTHING 7645987		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SANDY GRAVELLY CLAY – light grey brown mottled red sandy gravelly clay, stiff to very stiff, fine to medium grained sand, some fine to coarse gravel and cobbles. Clay within sandy gravel matrix (approx. 60% matrix and 40% clay), becoming moist with depth.	BUCKET	YAN-008A	2.9-	NA	Test pit excavated into plateau of northern arm of embankment. Higher clay content than at the Heap Leach Pond Embankment. Paste pH and EC testing completed. Sample F is the shallowest sample and contains more matrix, less clay. >100mm fraction estimated at 5%.
			BUCKET	YAN-008B	3.0		
			BUCKET	YAN-008C	2.9-		
			BUCKET	YAN-008D	3.0		
			BAG	YAN-008E	2.9-		
			BAG	YAN-008F	3.0		
				YAN-008 SWCC	2.9-		
	3.0	Test pit discontinued at 3.0 m			3.0		
					0.9–1		

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr> <th>Sample</th><th>TP8</th></tr> <tr> <td>Date</td><td>18/09/2019</td></tr> <tr> <td>Time</td><td>19:51</td></tr> <tr> <td>Temp (°C)</td><td>18.82</td></tr> <tr> <td>SP Cond (µS/cm)</td><td>11</td></tr> <tr> <td>Cond (µS/cm)</td><td>9</td></tr> <tr> <td>TDS (g/L)</td><td>0.007</td></tr> <tr> <td>DO Sat (%)</td><td>73.6</td></tr> <tr> <td>DO (mg/L)</td><td>6.85</td></tr> <tr> <td>pH</td><td>8.45</td></tr> <tr> <td>pH (mV)</td><td>-122.1</td></tr> <tr> <td>ORP (mV)</td><td>46.9</td></tr> </table>	Sample	TP8	Date	18/09/2019	Time	19:51	Temp (°C)	18.82	SP Cond (µS/cm)	11	Cond (µS/cm)	9	TDS (g/L)	0.007	DO Sat (%)	73.6	DO (mg/L)	6.85	pH	8.45	pH (mV)	-122.1	ORP (mV)	46.9
Sample	TP8																								
Date	18/09/2019																								
Time	19:51																								
Temp (°C)	18.82																								
SP Cond (µS/cm)	11																								
Cond (µS/cm)	9																								
TDS (g/L)	0.007																								
DO Sat (%)	73.6																								
DO (mg/L)	6.85																								
pH	8.45																								
pH (mV)	-122.1																								
ORP (mV)	46.9																								

		TEST PIT LOG		TEST PIT # TP#9A	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION MINE WATER POND CLAY BORROW		SURFACE LEVEL 181 m	
EASTING 498036		NORTHING 7645791		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – dark grey brown silty sand topsoil, fine to medium grained sand, trace fine to medium grained gravel, trace organics.	NA	NO SAMPLES COLLECTED	NA	NA	Clay similar to TP#9 but a larger amount. No samples collected here.
	0.5	SILTY CLAY – dark red brown mottled grey silty clay, est. very stiff, moist, some silty sand matrix.					
	2.1	BASALT – grey brown basalt					
	2.3	Test pit discontinued at 2.3 m.					

PHOTO LOG 	COMMENTS / LEGEND
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		TEST PIT LOG		TEST PIT # TP#9B	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION MINE WATER POND CLAY BORROW		SURFACE LEVEL 181 m	
EASTING 497968		NORTHING 7645782		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLE TYPE	SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION		SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – dark grey brown silty sand topsoil, fine to medium grained sand, trace fine to medium grained gravel, trace organics.	NA	NO SAMPLES COLLECTED	NA	NA	Clay similar to TP#9 but a much lower amount. Higher clay volumes found in gully. No samples collected here.
	0.3	SILTY CLAY – dark red brown mottled grey silty clay, est. very stiff, moist, some silty sand matrix.					
	0.5	BASALT – grey brown basalt					
	1.4	Test pit discontinued at 1.4 m.					

PHOTO LOG 	COMMENTS / LEGEND
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		TEST PIT LOG		TEST PIT # TP#10	SHEET 1/1
PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION				CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION ON-SITE CLAY BORROW		SURFACE LEVEL 175 m	
EASTING 498884		NORTHING 7646389		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – dark brown silty sand topsoil, fine to medium grained sand, trace fine to coarse gravel, some organics.	BAG	YAN-010F	0.0-0.1	NA	Low clay volume. Paste pH and EC testing completed. GP#5 completed at this location.
	0.2	SILTY SANDY CLAY – dark orange brown mottled red silty sandy clay, fine to medium grained sand, trace fine to medium grained gravel.	BUCKET	YAN-0010A	0.3-0.4		
			BUCKET	YAN-0010B	0.3-0.4		
			BUCKET	YAN-0010C	0.3-0.4		
			BUCKET	YAN-0010D	0.3-0.4		
			BAG	YAN-0010E	0.3-0.4		
			BAG	YAN-0010	0.3-0.4		
	0.4	BASALT – grey brown basalt, increasing hardness with depth.		SWCC			
	1.2	Test pit discontinued at 1.2 m.					

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr> <th>Sample</th> <th>TP10</th> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>20:00</td> </tr> <tr> <td>Temp (°C)</td> <td>18.14</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>410</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>356</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.266</td> </tr> <tr> <td>DO Sat (%)</td> <td>78.6</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.41</td> </tr> <tr> <td>pH</td> <td>9.04</td> </tr> <tr> <td>pH (mV)</td> <td>-155.1</td> </tr> <tr> <td>ORP (mV)</td> <td>52.2</td> </tr> </table>	Sample	TP10	Date	18/09/2019	Time	20:00	Temp (°C)	18.14	SP Cond (µS/cm)	410	Cond (µS/cm)	356	TDS (g/L)	0.266	DO Sat (%)	78.6	DO (mg/L)	7.41	pH	9.04	pH (mV)	-155.1	ORP (mV)	52.2
Sample	TP10																								
Date	18/09/2019																								
Time	20:00																								
Temp (°C)	18.14																								
SP Cond (µS/cm)	410																								
Cond (µS/cm)	356																								
TDS (g/L)	0.266																								
DO Sat (%)	78.6																								
DO (mg/L)	7.41																								
pH	9.04																								
pH (mV)	-155.1																								
ORP (mV)	52.2																								

		TEST PIT LOG		TEST PIT # TP#11	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION ON-SITE CLAY BORROW		SURFACE LEVEL 176 m	
EASTING 498777		NORTHING 7646386		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – dark brown silty sand topsoil, fine to medium grained sand, trace fine to coarse gravel, some organics.	BAG	YAN-011F	0.0-0.1	NA	Two distinct clay layers. Large volume of clay. Paste PH / EC testing completed here.
	0.2	SANDY SILTY CLAY – grey brown sandy silty clay, very stiff, dry, fine to medium grained sand, trace fine to coarse gravel.	BUCKET	YAN-0011A	2.3-2.4		
			BUCKET	YAN-0011B	2.3-2.4		
			BUCKET	YAN-0011C	2.3-2.4		
			BUCKET	YAN-0011D	2.3-2.4		
			BAG	YAN-0011E	2.3-2.4		
			BAG	YAN-0011 SWCC	2.3-2.4		
	2.5	SILTY SANDY CLAY – dark grey mottled light brown sandy silty clay, fine to medium grained sand, higher sand content, trace fine to coarse gravel.	BUCKET	YAN-0012A	3.9-4.0		
			BUCKET	YAN-0012B	3.9-4.0		
			BUCKET	YAN-0012C	3.9-4.0		
			BUCKET	YAN-0012D	3.9-4.0		
			BAG	YAN-0012E	3.9-4.0		
			BAG	YAN-0012 SWCC	3.9-4.0		
	4.0	Test pit discontinued at 4.0 m.					

PHOTO LOG	COMMENTS / LEGEND																																				
	Paste pH Testing: <table border="1"> <thead> <tr> <th>Sample</th> <th>TP11</th> <th>TP12</th> </tr> </thead> <tbody> <tr> <td>Date</td> <td>18/09</td> <td>18/09</td> </tr> <tr> <td>Time</td> <td>18:58</td> <td>20:03</td> </tr> <tr> <td>Temp (°C)</td> <td>18:21</td> <td>17.82</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>310</td> <td>32</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>270</td> <td>28</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.202</td> <td>0.021</td> </tr> <tr> <td>DO Sat (%)</td> <td>76.7</td> <td>73.9</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.23</td> <td>7.02</td> </tr> <tr> <td>pH</td> <td>8.75</td> <td>9.17</td> </tr> <tr> <td>pH (mV)</td> <td>-138.9</td> <td>-162.7</td> </tr> <tr> <td>ORP (mV)</td> <td>57.2</td> <td>53.2</td> </tr> </tbody> </table>	Sample	TP11	TP12	Date	18/09	18/09	Time	18:58	20:03	Temp (°C)	18:21	17.82	SP Cond (µS/cm)	310	32	Cond (µS/cm)	270	28	TDS (g/L)	0.202	0.021	DO Sat (%)	76.7	73.9	DO (mg/L)	7.23	7.02	pH	8.75	9.17	pH (mV)	-138.9	-162.7	ORP (mV)	57.2	53.2
Sample	TP11	TP12																																			
Date	18/09	18/09																																			
Time	18:58	20:03																																			
Temp (°C)	18:21	17.82																																			
SP Cond (µS/cm)	310	32																																			
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pH	8.75	9.17																																			
pH (mV)	-138.9	-162.7																																			
ORP (mV)	57.2	53.2																																			

		TEST PIT LOG		TEST PIT # TP#13	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION TAILINGS WATER DAM EMBANKMENT		SURFACE LEVEL 186 m	
EASTING 499303		NORTHING 7646818		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	GRAVELLEY SANDY CLAY – red brown gravelly clay, firm, fine to medium grained sand, fine to coarse grained gravel, some cobbles and few boulders, trace organic material.	BUCKET	YAN-0013A	1.9-2.0	NA	Sieve bucket used. >100mm fraction estimated at 10%.
			BUCKET	YAN-0013B	1.9-2.0		
			BUCKET	YAN-0013C	1.9-2.0		
			BUCKET	YAN-0013D	1.9-2.0		
			BAG	YAN-0013E	1.9-2.0		
			BAG	YAN-0013 SWCC	1.9-2.0		
	2.0	Test pit discontinued at 2.0 m.					Paste PH / EC testing completed here.

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr> <td>Sample</td> <td>TP13</td> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>20:02</td> </tr> <tr> <td>Temp (°C)</td> <td>17</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>10</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>9</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.007</td> </tr> <tr> <td>DO Sat (%)</td> <td>77.9</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.53</td> </tr> <tr> <td>pH</td> <td>7.67</td> </tr> <tr> <td>pH (mV)</td> <td>-77.9</td> </tr> <tr> <td>ORP (mV)</td> <td>68.5</td> </tr> </table>	Sample	TP13	Date	18/09/2019	Time	20:02	Temp (°C)	17	SP Cond (µS/cm)	10	Cond (µS/cm)	9	TDS (g/L)	0.007	DO Sat (%)	77.9	DO (mg/L)	7.53	pH	7.67	pH (mV)	-77.9	ORP (mV)	68.5
Sample	TP13																								
Date	18/09/2019																								
Time	20:02																								
Temp (°C)	17																								
SP Cond (µS/cm)	10																								
Cond (µS/cm)	9																								
TDS (g/L)	0.007																								
DO Sat (%)	77.9																								
DO (mg/L)	7.53																								
pH	7.67																								
pH (mV)	-77.9																								
ORP (mV)	68.5																								

		TEST PIT LOG		TEST PIT # TP#14	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION TAILINGS WATER DAM EMBANKMENT		SURFACE LEVEL 186 m	
EASTING 499384		NORTHING 7646721		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	GRAVELLEY SANDY CLAY – red brown gravelly clay, firm, fine to medium grained sand, fine to coarse grained gravel, some cobbles and few boulders, trace organic material.	BUCKET	YAN-0014A	1.7-1.8	NA	Sieve bucket used. >100mm fraction estimated at 10%.
			BUCKET	YAN-0014B	1.7-1.8		
			BUCKET	YAN-0014C	1.7-1.8		
			BUCKET	YAN-0014D	1.7-1.8		
			BAG	YAN-0014E	1.7-1.8		
			BAG	YAN-0014 SWCC	1.7-1.8		
	1.8	Test pit discontinued at 1.8 m.					Paste PH / EC testing completed here.

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr> <td>Sample</td> <td>TP14</td> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>20:01</td> </tr> <tr> <td>Temp (°C)</td> <td>16.86</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>16</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>14</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.01</td> </tr> <tr> <td>DO Sat (%)</td> <td>80.2</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.77</td> </tr> <tr> <td>pH</td> <td>7.73</td> </tr> <tr> <td>pH (mV)</td> <td>-81.2</td> </tr> <tr> <td>ORP (mV)</td> <td>75.7</td> </tr> </table>	Sample	TP14	Date	18/09/2019	Time	20:01	Temp (°C)	16.86	SP Cond (µS/cm)	16	Cond (µS/cm)	14	TDS (g/L)	0.01	DO Sat (%)	80.2	DO (mg/L)	7.77	pH	7.73	pH (mV)	-81.2	ORP (mV)	75.7
Sample	TP14																								
Date	18/09/2019																								
Time	20:01																								
Temp (°C)	16.86																								
SP Cond (µS/cm)	16																								
Cond (µS/cm)	14																								
TDS (g/L)	0.01																								
DO Sat (%)	80.2																								
DO (mg/L)	7.77																								
pH	7.73																								
pH (mV)	-81.2																								
ORP (mV)	75.7																								

		TEST PIT LOG		TEST PIT # TP#16	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION TOPSOIL BORROW SOURCE		SURFACE LEVEL 185 m	
EASTING 499605		NORTHING 7646590		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SANDY CLAY WITH SHALE/BASALT – fine to medium grained sand, dark grey brown sandy clay, fine to coarse grained gravel, considerable rock fragments.	BUCKET	YAN-0016A	0.3-0.4	NA	This area appears to have been stripped of topsoil, so available topsoil is minimal. Mostly clay and rock present. Rock < 100 mm. Paste PH / EC testing completed here.
			BUCKET	YAN-0016B	0.3-0.4		
			BUCKET	YAN-0016C	0.3-0.4		
			BUCKET	YAN-0016D	0.3-0.4		
			BAG	YAN-0016E	0.3-0.4		
			BAG	YAN-0016 SWCC	0.3-0.4		
	0.4	Test pit discontinued at 0.4 m.					

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr><td>Sample</td><td>TP16</td></tr> <tr><td>Date</td><td>18/09/2019</td></tr> <tr><td>Time</td><td>20:06</td></tr> <tr><td>Temp (°C)</td><td>17.01</td></tr> <tr><td>SP Cond (µS/cm)</td><td>314</td></tr> <tr><td>Cond (µS/cm)</td><td>266</td></tr> <tr><td>TDS (g/L)</td><td>0.204</td></tr> <tr><td>DO Sat (%)</td><td>76.3</td></tr> <tr><td>DO (mg/L)</td><td>7.36</td></tr> <tr><td>pH</td><td>7.68</td></tr> <tr><td>pH (mV)</td><td>-78.7</td></tr> <tr><td>ORP (mV)</td><td>59.2</td></tr> </table>	Sample	TP16	Date	18/09/2019	Time	20:06	Temp (°C)	17.01	SP Cond (µS/cm)	314	Cond (µS/cm)	266	TDS (g/L)	0.204	DO Sat (%)	76.3	DO (mg/L)	7.36	pH	7.68	pH (mV)	-78.7	ORP (mV)	59.2
Sample	TP16																								
Date	18/09/2019																								
Time	20:06																								
Temp (°C)	17.01																								
SP Cond (µS/cm)	314																								
Cond (µS/cm)	266																								
TDS (g/L)	0.204																								
DO Sat (%)	76.3																								
DO (mg/L)	7.36																								
pH	7.68																								
pH (mV)	-78.7																								
ORP (mV)	59.2																								

		TEST PIT LOG		TEST PIT # TP#17	SHEET 1/1
PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION				CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION TOPSOIL BORROW SOURCE		SURFACE LEVEL 184 m	
EASTING 499412		NORTHING 7646940		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SANDY CLAY WITH SHALE/BASALT – fine to medium grained sand, dark grey brown sandy clay, fine to coarse grained gravel, considerable rock fragments.	BUCKET	YAN-0017A	0.3-0.4	NA	This area appears to have been stripped of topsoil, so available topsoil is minimal. Mostly clay and rock present. Rock < 100 mm. Paste PH / EC testing completed here.
			BUCKET	YAN-0017B	0.3-0.4		
			BUCKET	YAN-0017C	0.3-0.4		
			BUCKET	YAN-0017D	0.3-0.4		
			BAG	YAN-0017E	0.3-0.4		
			BAG	YAN-0017 SWCC	0.3-0.4		
	0.4	Test pit discontinued at 0.4 m.					

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr> <td>Sample</td> <td>TP16</td> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>20:06</td> </tr> <tr> <td>Temp (°C)</td> <td>17.01</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>314</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>266</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.204</td> </tr> <tr> <td>DO Sat (%)</td> <td>76.3</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.36</td> </tr> <tr> <td>pH</td> <td>7.68</td> </tr> <tr> <td>pH (mV)</td> <td>-78.7</td> </tr> <tr> <td>ORP (mV)</td> <td>59.2</td> </tr> </table>	Sample	TP16	Date	18/09/2019	Time	20:06	Temp (°C)	17.01	SP Cond (µS/cm)	314	Cond (µS/cm)	266	TDS (g/L)	0.204	DO Sat (%)	76.3	DO (mg/L)	7.36	pH	7.68	pH (mV)	-78.7	ORP (mV)	59.2
Sample	TP16																								
Date	18/09/2019																								
Time	20:06																								
Temp (°C)	17.01																								
SP Cond (µS/cm)	314																								
Cond (µS/cm)	266																								
TDS (g/L)	0.204																								
DO Sat (%)	76.3																								
DO (mg/L)	7.36																								
pH	7.68																								
pH (mV)	-78.7																								
ORP (mV)	59.2																								

		TEST PIT LOG		TEST PIT # TP#18	SHEET 1/1
PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION				CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION TOPSOIL BORROW SOURCE		SURFACE LEVEL 185 m	
EASTING 499382		NORTHING 7646961		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING					OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS	
	0.0	SANDY CLAY TOPSOIL – orange brown sandy clay topsoil, fine to medium grained sand, trace fine to medium grained gravel, some organic material.	BUCKET	YAN-0018A	0.7-0.8	NA	This area has more topsoil than TP#15 and TP#16. >100 mm fraction estimated at 5%. Paste PH / EC testing completed here.	
			BUCKET	YAN-0018B	0.7-0.8			
			BUCKET	YAN-0018C	0.7-0.8			
			BUCKET	YAN-0018D	0.7-0.8			
			BAG	YAN-0018E	0.7-0.8			
			BAG	YAN-0018 SWCC	0.7-0.8			
	0.8	Test pit discontinued at 0.8 m.						

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1"> <tr> <td>Sample</td> <td>TP18</td> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>20:12</td> </tr> <tr> <td>Temp (°C)</td> <td>15.2</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>15</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>13</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.01</td> </tr> <tr> <td>DO Sat (%)</td> <td>79.2</td> </tr> <tr> <td>DO (mg/L)</td> <td>2.95</td> </tr> <tr> <td>pH</td> <td>7.74</td> </tr> <tr> <td>pH (mV)</td> <td>-81.7</td> </tr> <tr> <td>ORP (mV)</td> <td>83.6</td> </tr> </table>	Sample	TP18	Date	18/09/2019	Time	20:12	Temp (°C)	15.2	SP Cond (µS/cm)	15	Cond (µS/cm)	13	TDS (g/L)	0.01	DO Sat (%)	79.2	DO (mg/L)	2.95	pH	7.74	pH (mV)	-81.7	ORP (mV)	83.6
Sample	TP18																								
Date	18/09/2019																								
Time	20:12																								
Temp (°C)	15.2																								
SP Cond (µS/cm)	15																								
Cond (µS/cm)	13																								
TDS (g/L)	0.01																								
DO Sat (%)	79.2																								
DO (mg/L)	2.95																								
pH	7.74																								
pH (mV)	-81.7																								
ORP (mV)	83.6																								

		TEST PIT LOG		TEST PIT # TP#19	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION GRAVEL BORROW SOURCE		SURFACE LEVEL 196 m	
EASTING 499373		NORTHING 7647253		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING				OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SILTY SAND TOPSOIL – orange brown sandy clay topsoil, fine to medium grained sand, trace fine to medium grained gravel, some organic material.	BUCKET	YAN-0019A	0.9-1.0	NA	This area has more topsoil than TP#15 and TP#16. >100 mm fraction estimated at 5%. Paste PH / EC testing completed here.
			BUCKET	YAN-0019B	0.9-1.0		
			BUCKET	YAN-0019C	0.9-1.0		
			BUCKET	YAN-0019D	0.9-1.0		
			BAG	YAN-0019E	0.9-1.0		
			BAG	YAN-0019 SWCC	0.9-1.0		
	0.2	GRAVEL – red grey gravel, angular, fine to coarse grained sand matrix.					
	1.0	Test pit discontinued at 1.0 m.					

PHOTO LOG	COMMENTS / LEGEND																								
	Paste pH Testing: <table border="1"> <tr> <td>Sample</td> <td>TP19</td> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>20:10</td> </tr> <tr> <td>Temp (°C)</td> <td>16.34</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>11</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>9</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.007</td> </tr> <tr> <td>DO Sat (%)</td> <td>7.45</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.3</td> </tr> <tr> <td>pH</td> <td>6.56</td> </tr> <tr> <td>pH (mV)</td> <td>-15.3</td> </tr> <tr> <td>ORP (mV)</td> <td>56.7</td> </tr> </table>	Sample	TP19	Date	18/09/2019	Time	20:10	Temp (°C)	16.34	SP Cond (µS/cm)	11	Cond (µS/cm)	9	TDS (g/L)	0.007	DO Sat (%)	7.45	DO (mg/L)	7.3	pH	6.56	pH (mV)	-15.3	ORP (mV)	56.7
Sample	TP19																								
Date	18/09/2019																								
Time	20:10																								
Temp (°C)	16.34																								
SP Cond (µS/cm)	11																								
Cond (µS/cm)	9																								
TDS (g/L)	0.007																								
DO Sat (%)	7.45																								
DO (mg/L)	7.3																								
pH	6.56																								
pH (mV)	-15.3																								
ORP (mV)	56.7																								

		TEST PIT LOG		TEST PIT # TP#20	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 18/07/2019		LOCATION GRAVEL BORROW SOURCE		SURFACE LEVEL 196 m	
EASTING 499872		NORTHING 7647632		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLE TYPE	SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION		SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	SILTY SAND TOPSOIL – orange brown sandy clay topsoil, fine to medium grained sand, trace fine to medium grained gravel, some organic material.	BUCKET	YAN-0020A	0.6-0.7	NA	>100 mm fraction estimated at 30%. Paste PH / EC testing completed here.
			BUCKET	YAN-0020B	0.6-0.7		
			BUCKET	YAN-0020C	0.6-0.7		
			BUCKET	YAN-0020D	0.6-0.7		
			BAG	YAN-0020E	0.6-0.7		
			BAG	YAN-0020 SWCC	0.6-0.7		
	0.15	GRAVEL – grey fine to coarse gravel in a fine to coarse grained sandy matrix, considerable cobbles and boulders.					
	0.7	Test pit discontinued at 0.7 m due to refusal.					

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1" style="width: 100%;"> <tr> <td>Sample</td> <td>TP20</td> </tr> <tr> <td>Date</td> <td>18/09/2019</td> </tr> <tr> <td>Time</td> <td>20:09</td> </tr> <tr> <td>Temp (°C)</td> <td>16.53</td> </tr> <tr> <td>SP Cond (µS/cm)</td> <td>3</td> </tr> <tr> <td>Cond (µS/cm)</td> <td>3</td> </tr> <tr> <td>TDS (g/L)</td> <td>0.002</td> </tr> <tr> <td>DO Sat (%)</td> <td>73.7</td> </tr> <tr> <td>DO (mg/L)</td> <td>7.19</td> </tr> <tr> <td>pH</td> <td>6.63</td> </tr> <tr> <td>pH (mV)</td> <td>-19.3</td> </tr> <tr> <td>ORP (mV)</td> <td>33.8</td> </tr> </table>	Sample	TP20	Date	18/09/2019	Time	20:09	Temp (°C)	16.53	SP Cond (µS/cm)	3	Cond (µS/cm)	3	TDS (g/L)	0.002	DO Sat (%)	73.7	DO (mg/L)	7.19	pH	6.63	pH (mV)	-19.3	ORP (mV)	33.8
Sample	TP20																								
Date	18/09/2019																								
Time	20:09																								
Temp (°C)	16.53																								
SP Cond (µS/cm)	3																								
Cond (µS/cm)	3																								
TDS (g/L)	0.002																								
DO Sat (%)	73.7																								
DO (mg/L)	7.19																								
pH	6.63																								
pH (mV)	-19.3																								
ORP (mV)	33.8																								

		TEST PIT LOG		TEST PIT # TP#23	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 19/07/2019		LOCATION TSF CELL B		SURFACE LEVEL 196 m	
EASTING 500548		NORTHING 7647328		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA	SAMPLING AND TESTING					OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS	
	0.0	TAILINGS (ASSUMED OXIDE) – fine grained, light grey brown tailings with some discolouration.	BUCKET	YAN-0023A	1.0-1.1	NA	Layer boundaries between oxide and sulfide tailings not clearly defined.	
			BUCKET	YAN-0023B	1.0-1.1			
			BUCKET	YAN-0023C	1.0-1.1			
			BUCKET	YAN-0023D	1.0-1.1			
			BAG	YAN-0023E	1.0-1.1			
			BAG	YAN-0023 SWCC	1.0-1.1			
	1.1	TAILINGS (ASSUMED SULFIDE) – fine grained, darker grey brown tailings with some discolouration.	BUCKET	YAN-0024A	1.9-2.0		GP#7 completed at this location.	
			BUCKET	YAN-0024B	1.9-2.0			
			BUCKET	YAN-0024C	1.9-2.0			
			BUCKET	YAN-0024D	1.9-2.0			
			BAG	YAN-0024E	1.9-2.0			
			BAG	YAN-0024 SWCC	1.9-2.0			
	2.0	Test pit discontinued at 1.8 m.					Paste PH / EC testing completed on both samples here.	

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Sample</th><th>TP23 (oxide)</th><th>TP23 (sulfide)</th></tr> </thead> <tbody> <tr> <td>Date</td><td>19/07/2019</td><td>19/07/2019</td></tr> <tr> <td>Time</td><td>10:08</td><td>10:12</td></tr> <tr> <td>Temp (°C)</td><td>15.33</td><td>16.57</td></tr> <tr> <td>SP Cond (µS/cm)</td><td>5813</td><td>295</td></tr> <tr> <td>Cond (µS/cm)</td><td>4744</td><td>248</td></tr> <tr> <td>TDS (g/L)</td><td>3.778</td><td>0.192</td></tr> <tr> <td>DO Sat (%)</td><td>90.7</td><td>84.2</td></tr> <tr> <td>DO (mg/L)</td><td>8.9</td><td>8.2</td></tr> <tr> <td>pH</td><td>3.59</td><td>5.92</td></tr> <tr> <td>pH (mV)</td><td>150.3</td><td>20.4</td></tr> <tr> <td>ORP (mV)</td><td>279.6</td><td>249.2</td></tr> </tbody> </table>	Sample	TP23 (oxide)	TP23 (sulfide)	Date	19/07/2019	19/07/2019	Time	10:08	10:12	Temp (°C)	15.33	16.57	SP Cond (µS/cm)	5813	295	Cond (µS/cm)	4744	248	TDS (g/L)	3.778	0.192	DO Sat (%)	90.7	84.2	DO (mg/L)	8.9	8.2	pH	3.59	5.92	pH (mV)	150.3	20.4	ORP (mV)	279.6	249.2
Sample	TP23 (oxide)	TP23 (sulfide)																																			
Date	19/07/2019	19/07/2019																																			
Time	10:08	10:12																																			
Temp (°C)	15.33	16.57																																			
SP Cond (µS/cm)	5813	295																																			
Cond (µS/cm)	4744	248																																			
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pH	3.59	5.92																																			
pH (mV)	150.3	20.4																																			
ORP (mV)	279.6	249.2																																			

		TEST PIT LOG		TEST PIT # TP#24	SHEET 1/1
		PROJECT DESCRIPTION YANDAN MATERIAL CHARACTERISATION		CLIENT AERIS RESOURCES	
DATE 19/07/2019		LOCATION GRAVEL BORROW SOURCE		SURFACE LEVEL 198 m	
EASTING 500670		NORTHING 7646736		PROJECT NUMBER 956-007	

RIG 35 T EXCAVATOR	LOGGED BY RMB
OPERATOR CENTRAL HIGHLANDS PLANT HIRE	

LEVEL		STRATA		SAMPLING AND TESTING			OTHER
RL (m)	DEPTH (m)	MATERIAL DESCRIPTION	SAMPLE TYPE	SAMPLE ID	DEPTH (m)	GW LEVEL	COMMENTS
	0.0	TOPSOIL – dark brown silty sand topsoil, fine to medium grained sand, some fine to medium grained gravel and some organic material.				NA	>100 mm fraction in the gravel estimated at 80%. Paste PH / EC testing completed on both samples here.
	0.2						
			BUCKET	YAN-0025A	1.1-1.2		
			BUCKET	YAN-0025B	1.1-1.2		
			BUCKET	YAN-0025C	1.1-1.2		
		GRAVEL – coarse gravel within a sandy matrix, larger angular and subangular gravel fractions compared to other gravel sources with higher >100mm fractions.	BUCKET	YAN-0025D	1.1-1.2		
			BAG	YAN-0025E	1.1-1.2		
			BAG	YAN-0025 SWCC	1.1-1.2		
	1.2	Test pit discontinued at 1.2 m due to refusal.					

PHOTO LOG 	COMMENTS / LEGEND Paste pH Testing: <table border="1" style="width: 100%; margin-top: 10px;"> <thead> <tr> <th>Sample</th> <th>TP24</th> </tr> </thead> <tbody> <tr><td>Date</td><td>19/07/2019</td></tr> <tr><td>Time</td><td>10:16</td></tr> <tr><td>Temp (°C)</td><td>17.86</td></tr> <tr><td>SP Cond (µS/cm)</td><td>851</td></tr> <tr><td>Cond (µS/cm)</td><td>735</td></tr> <tr><td>TDS (g/L)</td><td>0.553</td></tr> <tr><td>DO Sat (%)</td><td>79.5</td></tr> <tr><td>DO (mg/L)</td><td>7.53</td></tr> <tr><td>pH</td><td>7</td></tr> <tr><td>pH (mV)</td><td>-40.2</td></tr> <tr><td>ORP (mV)</td><td>241</td></tr> </tbody> </table>	Sample	TP24	Date	19/07/2019	Time	10:16	Temp (°C)	17.86	SP Cond (µS/cm)	851	Cond (µS/cm)	735	TDS (g/L)	0.553	DO Sat (%)	79.5	DO (mg/L)	7.53	pH	7	pH (mV)	-40.2	ORP (mV)	241
Sample	TP24																								
Date	19/07/2019																								
Time	10:16																								
Temp (°C)	17.86																								
SP Cond (µS/cm)	851																								
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pH (mV)	-40.2																								
ORP (mV)	241																								

Appendix C

Laboratory Certificates of Analysis

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19070866-G
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	6256
		Report Date	15/08/2019

Project 0956-007 - Yandan Material Characterisation

Sample No.	19070866	19070851	19070852	19070859	19070858	19070856	19070857
Test Date	13/08/2019	13/08/2019	13/08/2019	13/08/2019	13/08/2019	13/08/2019	13/08/2019
Client ID	TP#20 - YAN-020A/B	TP#5 - YAN-005A/B	TP#6 - YAN-006A/B	TP#13 - YAN-013A/B	TP#12 - YAN-012A/B	TP#10 - YAN-010A/B	TP#11 - YAN-011A/B
Depth (m)	0.70	1.20	3.50	2.00	3.90	0.30	2.40
Moisture (%)	6.3	6.9	8.1	8.9	11.3	10.6	7.6
AS SIEVE SIZE (mm)	PERCENT PASSING						
150							
75	100						
63	99			100		100	
53	98	100	100	99	100	99	
37.5	89	99	99	96	99	94	
26.5	85	99	98	92	98	88	
19	82	98	98	90	96	84	
13.2	74	94	95	84	96	83	
9.5	68	92	92	80	88	80	100
6.7	59	89	88	74	80	77	99
4.75	54	86	84	70	74	75	97
2.36	44	79	75	62	66	72	96
1.18	38	71	66	54	53	69	94
0.600	36	65	60	49	45	67	93
0.425	35	62	58	47	41	66	91
0.300	34	60	55	45	38	65	89
0.150	29	54	48	40	33	56	74
0.075	24	47	42	35	29	45	59

NOTES/REMARKS:

Sample/s supplied by the client

Page 1 of 1 REP01103

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Tested at Trilab Brisbane Laboratory

Authorised Signatory



C. Park



Laboratory No. 9926

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Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING



PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19070853-G
		Workorder No.	6256
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Report Date	20/08/2019

Project 0956-007 - Yandan Material Characterisation

Sample No.	19070853	19070849	19070850	19070854	19070855	19070847	19070848
Test Date	13/08/2019	19/08/2019	19/08/2019	19/08/2019	19/08/2019	19/08/2019	19/08/2019
Client ID	TP#7 - YAN-007A/B	TP#3- YAN-003A/B	TP#4 - YAN-004A/B	TP#8 - YAN-008A/B	TP#9 - YAN-009A/B	TP#1 - YAN-001A/B	TP#2 - YAN-002A/B
Depth (m)	1.70	0.30	0.50	3.00	1.50	0.10	0.40
Moisture (%)	9.0	3.6	7.3	8.5	16.2	3.0	4.1
AS SIEVE SIZE (mm)	PERCENT PASSING						
150							
75							
63			100				
53	100		99	100			
37.5	95		89	95			
26.5	90	100	77	88			
19	84	99	66	83	100		100
13.2	75	97	52	76	97		99
9.5	70	95	44	71	97		98
6.7	63	93	37	64	96	100	96
4.75	57	91	32	60	95	99	94
2.36	47	87	26	48	94	98	89
1.18	41	84	21	38	91	96	86
0.600	36	80	18	31	85	93	83
0.425	33	77	16	29	83	91	80
0.300	31	72	14	26	81	88	76
0.150	27	55	12	23	74	67	58
0.075	24	42	10	20	67	42	40

NOTES/REMARKS:

Sample/s supplied by the client

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19070864-G
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	6256
		Report Date	20/08/2019

Project 0956-007 - Yandan Material Characterisation

Sample No.	19070864	19070870	19070869	19070865			
Test Date	19/08/2019	19/08/2019	19/08/2019	19/08/2019			
Client ID	TP#18 - YAN-018A/B	TP#24 - YAN-024A/B	TP#23 - YAN-023A/B	TP#19 - YAN-019A/B			
Depth (m)	0.80	2.00	2.00	1.00			
Moisture (%)	15.5	13.1	12.2	10.4			
AS SIEVE SIZE (mm)	PERCENT PASSING						
150							
75							
63				100			
53				98			
37.5				92			
26.5				86			
19	100			81			
13.2	95			73			
9.5	95			70			
6.7	94			64			
4.75	92			60			
2.36	89			54			
1.18	75			50			
0.600	59	100	100	47			
0.425	50	99	99	46			
0.300	43	97	98	46			
0.150	35	76	88	44			
0.075	29	55	68	42			

NOTES/REMARKS:

Sample/s supplied by the client

Page 1 of 1 REP01103

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING



PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19070863-G
		Workorder No.	6256
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Report Date	20/08/2019

Project 0956-007 - Yandan Material Characterisation

Sample No.	19070863	19070871	19070868	19070867	19070861	19070862	19070860
Test Date	19/08/2019	19/08/2019	19/08/2019	19/08/2019	19/08/2019	19/08/2019	19/08/2019
Client ID	TP#17 - YAN-017A/B	TP#25 - YAN-025A/B	TP#22 - YAN-022A/B	TP#21 - YAN-021A/B	TP#15 - YAN-015A/B	TP#16 - YAN-016A/B	TP#14 - YAN-014A/B
Depth (m)	0.40	1.20	1.80	0.50	1.20	0.40	1.80
Moisture (%)	7.7	9.7	6.5	9.7	7.4	10.6	9.1
AS SIEVE SIZE (mm)	PERCENT PASSING						
150							
75							
63	100				100		
53	99	100	100	100	99		100
37.5	94	91	87	99	98		96
26.5	87	84	79	97	95		91
19	81	81	76	95	92	100	88
13.2	63	63	66	91	81	90	79
9.5	54	56	60	89	75	81	72
6.7	47	50	55	86	69	74	64
4.75	39	45	50	81	65	67	57
2.36	27	39	43	74	58	63	50
1.18	19	35	38	63	48	56	42
0.600	15	32	34	57	43	52	38
0.425	13	31	32	55	41	51	36
0.300	12	30	30	52	40	50	35
0.150	11	27	24	44	35	49	32
0.075	10	24	19	34	30	46	29

NOTES/REMARKS:

Sample/s supplied by the client

Page 1 of 1 REP01103

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

SOIL PARTICLE DENSITY TEST REPORT

Test Method: AS 1289 3.5.1

Client	O'Kane Consultants Pty Ltd	Report No.	19070866-SG
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006256
		Report Date	19/08/2019

Project 0956-007 - Yandan Material Characterisation

Sample No.	19070866	19070851	19070852	19070859	19070858	19070856	19070857
Test Date	14/08/2019	14/08/2019	14/08/2019	14/08/2019	14/08/2019	14/08/2019	14/08/2019
Client ID	TP#20 - YAN-020A/B	TP#5 - YAN-005A/B	TP#6 - YAN-006A/B	TP#13 - YAN-013A/B	TP#12 - YAN-012A/B	TP#10 - YAN-010A/B	TP#11 - YAN-011A/B
Depth (m)	0.70	1.20	3.50	2.00	3.90	0.30	2.40
Soil Particle Density (t/m³) (-2.36mm)	2.63	2.64	2.64	2.64	2.72	2.65	2.66

Sample No.	19070853	19070849	19070850	19070854	19070855	19070847	19070848
Test Date	14/08/2019	14/08/2019	14/08/2019	14/08/2019	14/08/2019	14/08/2019	14/08/2019
Client ID	TP#7 - YAN-007A/B	TP#3 - YAN-003A/B	TP#4 - YAN-004A/B	TP#8 - YAN-008A/B	TP#9 - YAN-009A/B	TP#1 - YAN-001A/B	TP#2 - YAN-002A/B
Depth (m)	1.70	0.30	0.50	3.00	1.50	0.10	0.40
Soil Particle Density (t/m³) (-2.36mm)	2.68	2.66	2.57	2.73	2.65	2.55	2.58

NOTES/REMARKS:

Sample/s supplied by the client

Page 1 of 1 REP04603

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

SOIL PARTICLE DENSITY TEST REPORT

Test Method: AS 1289 3.5.1

Client	O'Kane Consultants Pty Ltd	Report No.	19070863-SG
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006256
		Report Date	22/08/2019

Project 0956-007 - Yandan Material Characterisation

Sample No.	19070863	19070871	19070868	19070867	19070861	19070862	19070860
Test Date	19/08/2019	19/08/2019	19/08/2019	21/08/2019	21/08/2019	21/08/2019	21/08/2019
Client ID	TP#17 - YAN-017A/B	TP#25 - YAN-025A/B	TP#22 - YAN-022A/B	TP#21 - YAN-021A/B	TP#15 - YAN-015A/B	TP#16 - YAN-016A/B	TP#14 - YAN-014A/B
Depth (m)	0.40	1.20	1.80	0.50	1.20	0.40	1.80
Soil Particle Density (t/m³) (-2.36mm)	2.68	2.65	2.61	2.67	2.64	2.71	2.70

Sample No.	19070864	19070870	19070869	19070865			
Test Date	21/08/2019	21/08/2019	21/08/2019	21/08/2019			
Client ID	TP#18 - YAN-018A/B	TP#24 - YAN-024A/B	TP#23 - YAN-023A/B	TP#19 - YAN-019A/B	-	-	-
Depth (m)	0.80	2.00	2.00	1.00	-	-	-
Soil Particle Density (t/m³) (-2.36mm)	2.69	2.60	2.53	2.60			

NOTES/REMARKS:

Sample/s supplied by the client

Page 1 of 1 REP04603

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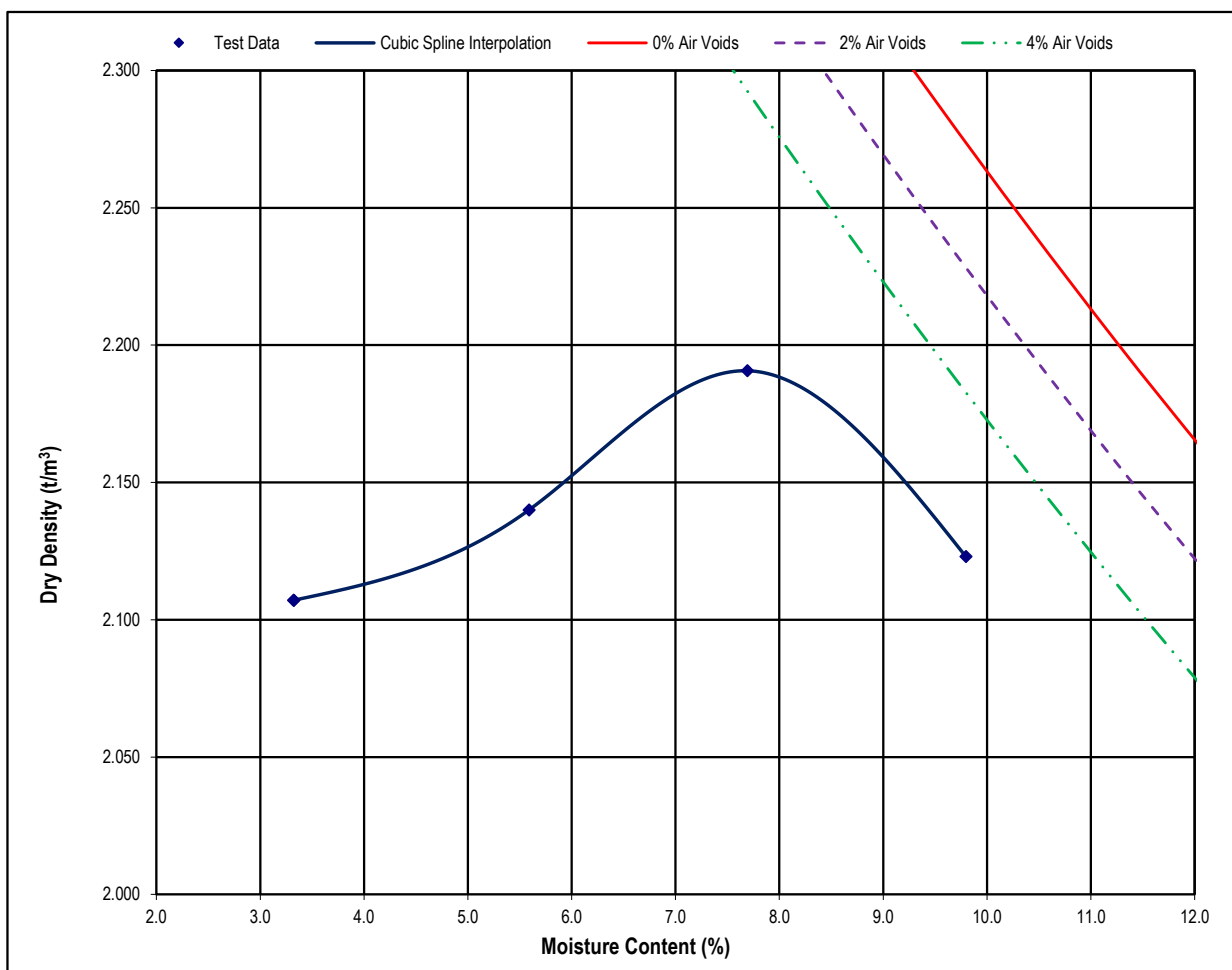
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081546-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#3- YAN-003A/B	Depth (m)	0.30



Maximum Dry Density (t/m³)	2.191	Optimum Moisture Content (%)	7.7
Moisture Content (%)	3.6	Percentage of Oversize/Sieve Size (mm)	1 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.93

Page 1 of 1 REP01304

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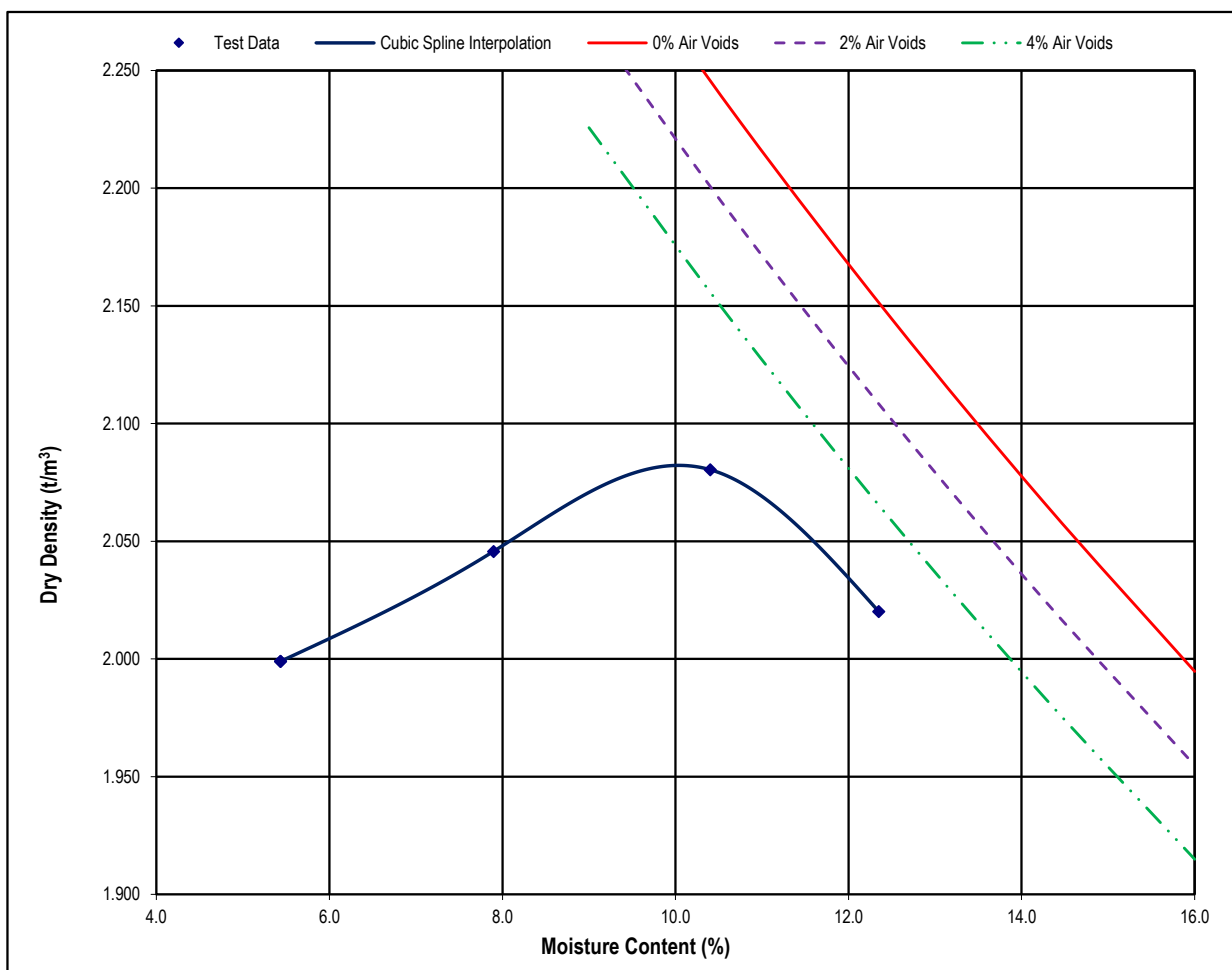
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081547-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#6 - YAN-006A/B	Depth (m)	3.50



Maximum Dry Density (t/m³)	2.082	Optimum Moisture Content (%)	10.0
Moisture Content (%)	8.1	Percentage of Oversize/Sieve Size (mm)	2 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.93

Page 1 of 1 REP01304

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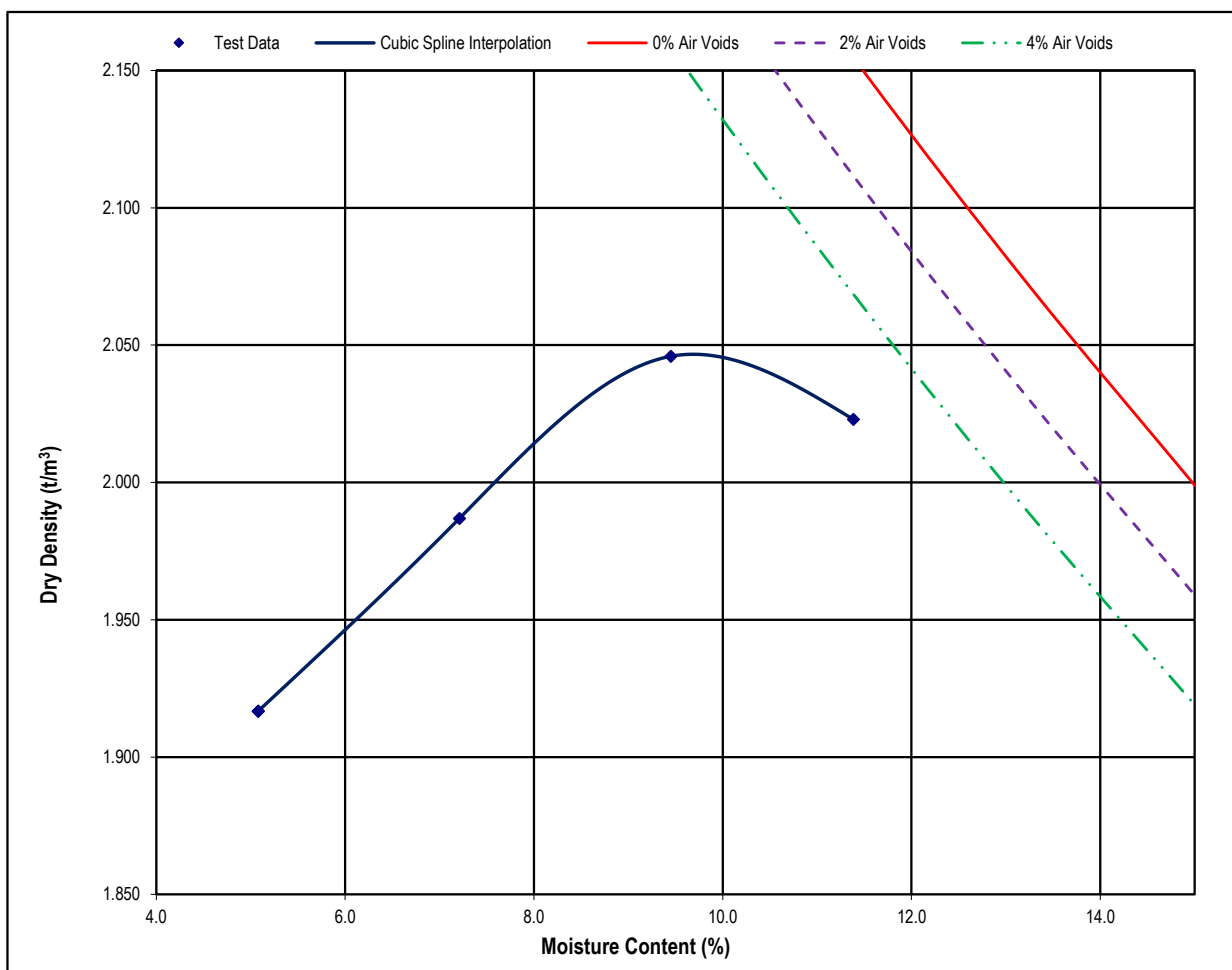
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081548-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#11 - YAN-011A/B	Depth (m)	2.40



Maximum Dry Density (t/m³)	2.047	Optimum Moisture Content (%)	9.7
Moisture Content (%)	7.6	Percentage of Oversize/Sieve Size (mm)	0 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.86

Page 1 of 1 REP01304

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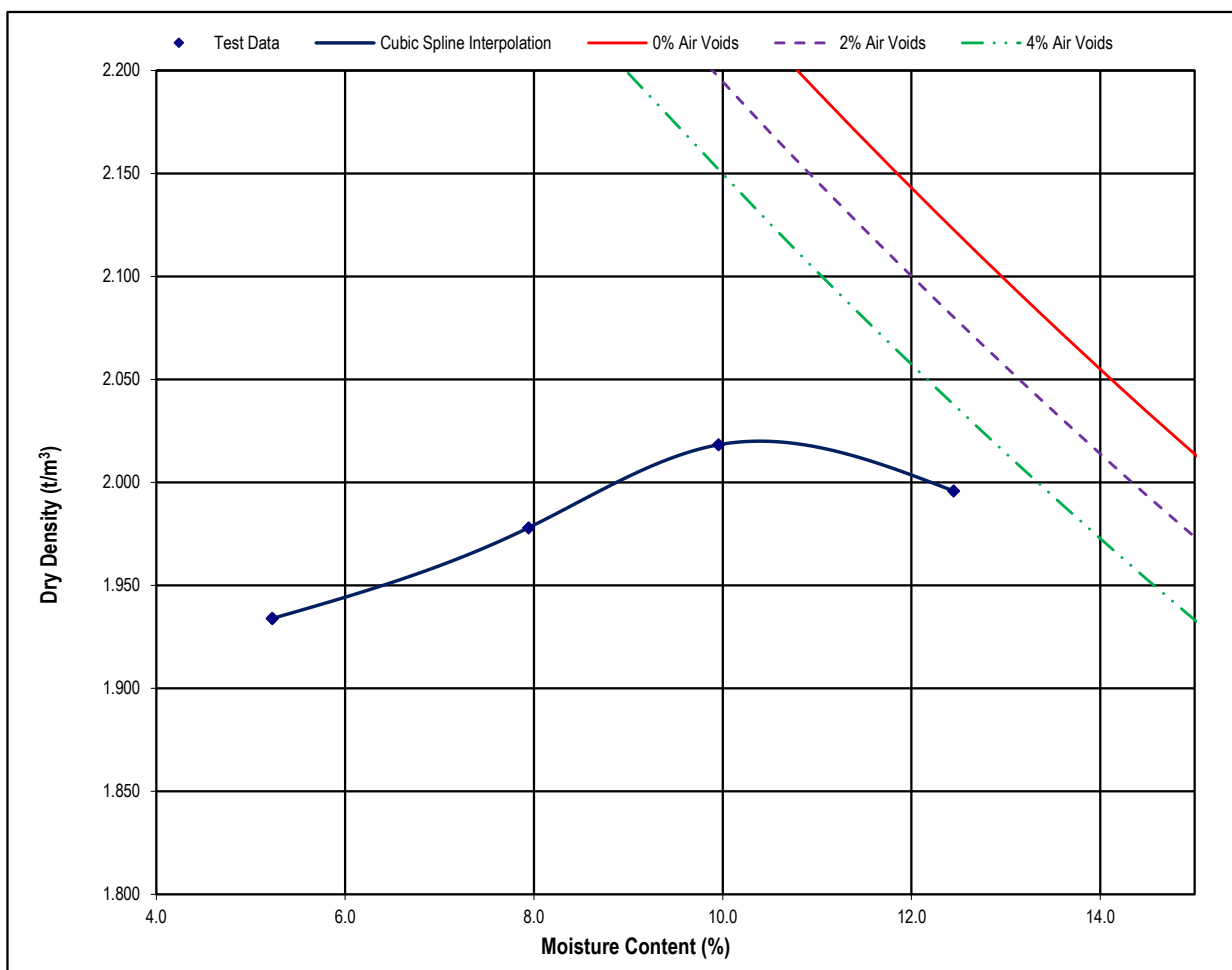
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081549-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#13 - YAN-013A/B	Depth (m)	2.00



Maximum Dry Density (t/m³)	2.020	Optimum Moisture Content (%)	10.4
Moisture Content (%)	8.9	Percentage of Oversize/Sieve Size (mm)	10 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.88

Page 1 of 1 REP01304

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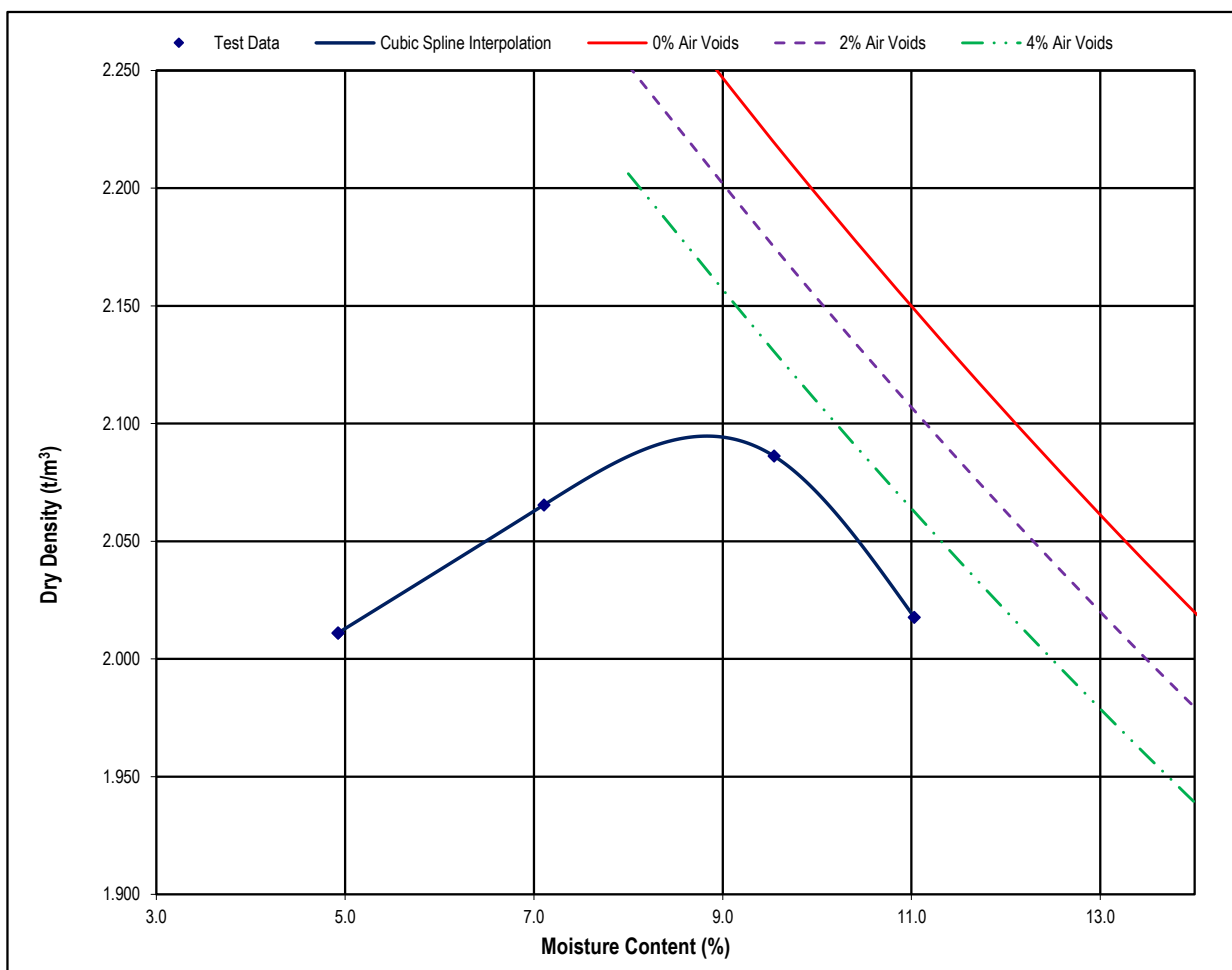
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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081553-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#21 - YAN-021A/B	Depth (m)	0.50



Maximum Dry Density (t/m³)	2.095	Optimum Moisture Content (%)	8.8
Moisture Content (%)	9.7	Percentage of Oversize/Sieve Size (mm)	14 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.82

Page 1 of 1 REP01304

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

EMERSON CLASS NUMBER TEST REPORT

Test Method: AS 1289 3.8.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081545-EM
		Workorder No.	6403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	01/10/2019
		Report Date	03/10/2019
Project	0956-007 - Yandan Material Characterisation		

Sample No.	19081545	19081549	19081550	19081551	19081552	19081553	19081554
Client ID	TP#1 - YAN-001A/B	TP#13 - YAN-013A/B	TP#15 - YAN-015A/B	TP#18 - YAN-018A/B	TP#20 - YAN-020A/B	TP#21 - YAN-021A/B	TP#25 - YAN-025A/B
Depth (m)	0.10	2.00	1.20	0.80	0.70	0.50	1.20
Description	Sandy SILT - brown	Sandy CLAY - brown with gravel	Silty SAND - brown with gravel	Clayey SAND - brown with gravel	Silty Sandy GRAVEL - pale brown	Silty SAND - brown with gravel	Silty Sandy GRAVEL - pale brown
Emerson Class Number	3	4	2	4	5	4	4

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	-	-	-	-	-	-	-

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Description	-	-	-	-	-	-	-
Emerson Class Number	-	-	-	-	-	-	-

NOTES/REMARKS:

Sample/s supplied by the client

Tested with Distilled water at 21.6°C

Page 1 of 1 REP00402

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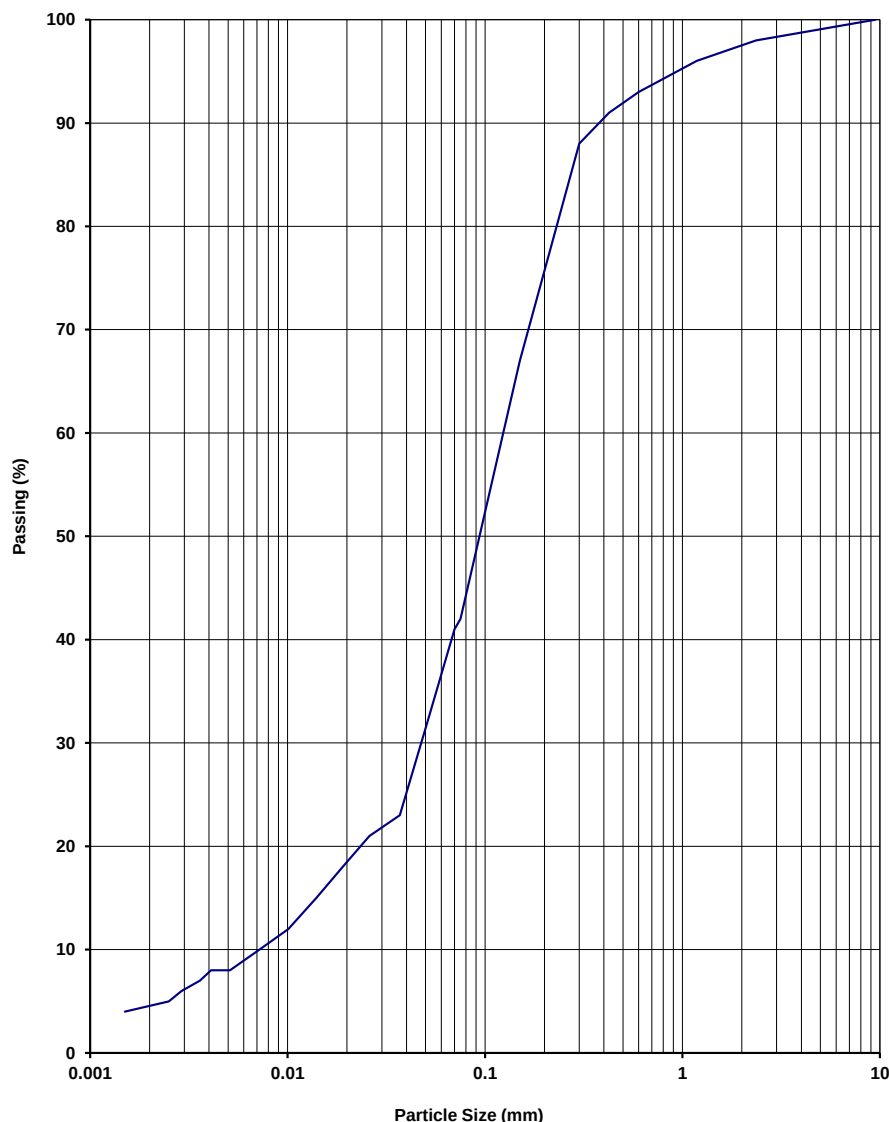
ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081545-G
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#1 - YAN-001A/B	Test Date	6/9/19-16/9/19
		Report Date	17/9/2019
Depth (m)	0.10		

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	
6.7	100
4.75	99
2.36	98
1.18	96
0.600	93
0.425	91
0.300	88
0.150	67
0.075	42
0.07	41
0.051	32
0.037	23
0.026	21
0.019	18
0.014	15
0.0101	12
0.0072	10
0.0051	8
0.0041	8
0.0036	7
0.0029	6
0.0025	5
0.0015	4



NOTES/REMARKS:

-
Moisture Content 3% -2.36mm Soil Particle Density(t/m^3) 2.55
Sample/s supplied by the client

Page 1 of 1 REP03904

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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081546-AL
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Report Date	04/10/2019
Project	0956-007 - Yandan Material Characterisation		

Sample No.	19081546	19081547	19081548	19081549	19081551	19081553
Test Date	25/09/2019	25/09/2019	25/09/2019	25/09/2019	25/09/2019	25/09/2019
Client ID	TP#3- YAN-003A/B	TP#6 - YAN-006A/B	TP#11 - YAN-011A/B	TP#13 - YAN-013A/B	TP#18 - YAN-018A/B	TP#21 - YAN-021A/B
Depth (m)	0.30	3.50	2.40	2.00	0.80	0.50
Liquid Limit (%)	23	29	29	35	33	23
Plastic Limit (%)	12	14	13	17	21	14
Plasticity Index (%)	11	15	16	18	12	9
Linear Shrinkage (%)	4.5	8.5	9.0	9.5	8.0	4.0
Moisture Content (%)	3.6	8.1	7.6	8.9	15.5	9.7

Sample No.						
Test Date						
Client ID						
Depth (m)						
Liquid Limit (%)						
Plastic Limit (%)						
Plasticity Index (%)						
Linear Shrinkage (%)						
Moisture Content (%)						

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

Page 1 of 1 REP00102

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PERMEABILITY BY FALLING HEAD TEST REPORT

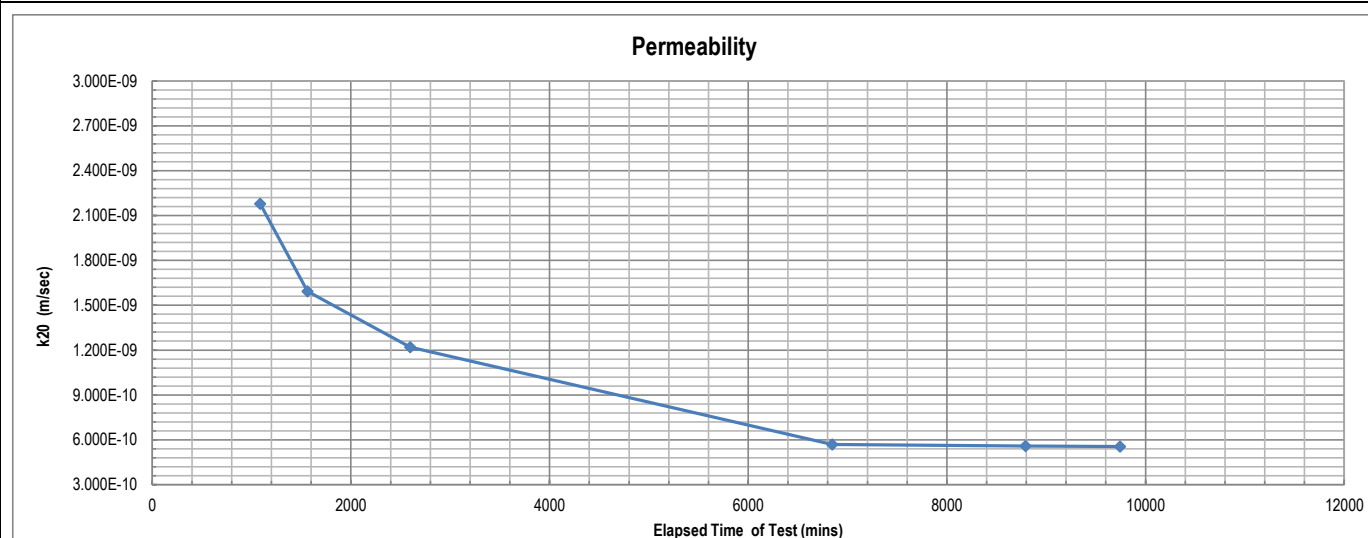
Test Method AS 1289 6.7.2, 5.2.1, KH2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	O'Kane Consultants Pty Ltd	Report No.	19081546-FHPT
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation	Test Date	23/09/2019
Client ID	TP#3- YAN-003A/B	Report Date	8/10/2019
Description	SANDY SILTY CLAY-brown	Depth (m)	0.30
		Sample Type	Remoulded Soil Specimen

RESULTS OF TESTING

Compaction Method	AS1289.5.2.1 - Modified Compaction		
Maximum Dry Density (t/m ³)	2.19	Hydraulic Gradient	9.4
Optimum Moisture Content (%)	7.7	Surcharge (kPa)	2.9
Placement Moisture Content (%)	8.3	Head Pressure Applied (kPa)	10.79
Moisture Ratio (%)	107.5	Water Type	Deaerated
Placement Wet Density (t/m ³)	2.24	Percentage Material Retained/Sieve Size (mm)	0 % / 9.5 mm
Density Ratio (%)	94.6	Sample Height and Diameter (mm)	116.51 / 101.48 mm

PERMEABILITY $k_{(20)} = 5.6 \times 10^{-10}$ (m/sec)



Remarks: The above specimen was remoulded to a target of 95% of Modified Maximum Dry Density and at Optimum Moisture Content.

Sample/s supplied by client

Page: 1 of 1

REP06301

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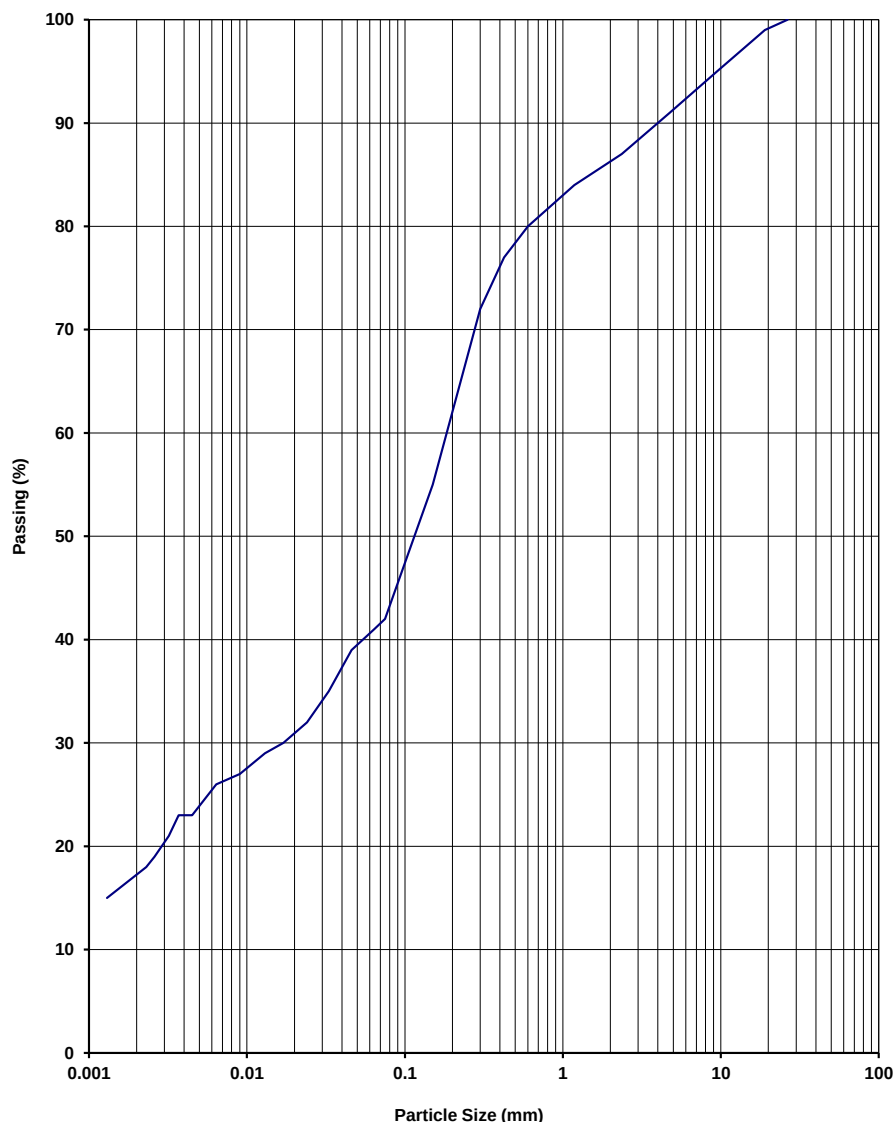
ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081546-G
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#3- YAN-003A/B	Test Date	6/9/19-16/9/19
		Report Date	17/9/2019
Depth (m)	0.30		

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	100
19.0	99
13.2	97
9.5	95
6.7	93
4.75	91
2.36	87
1.18	84
0.600	80
0.425	77
0.300	72
0.150	55
0.075	42
0.064	41
0.046	39
0.033	35
0.024	32
0.017	30
0.013	29
0.009	27
0.0064	26
0.0045	23
0.0037	23
0.0032	21
0.0026	19
0.0023	18
0.0013	15



NOTES/REMARKS:

-
Moisture Content 3.6% -2.36mm Soil Particle Density(t/m³) 2.66
Sample/s supplied by the client

Page 1 of 1 REP03904

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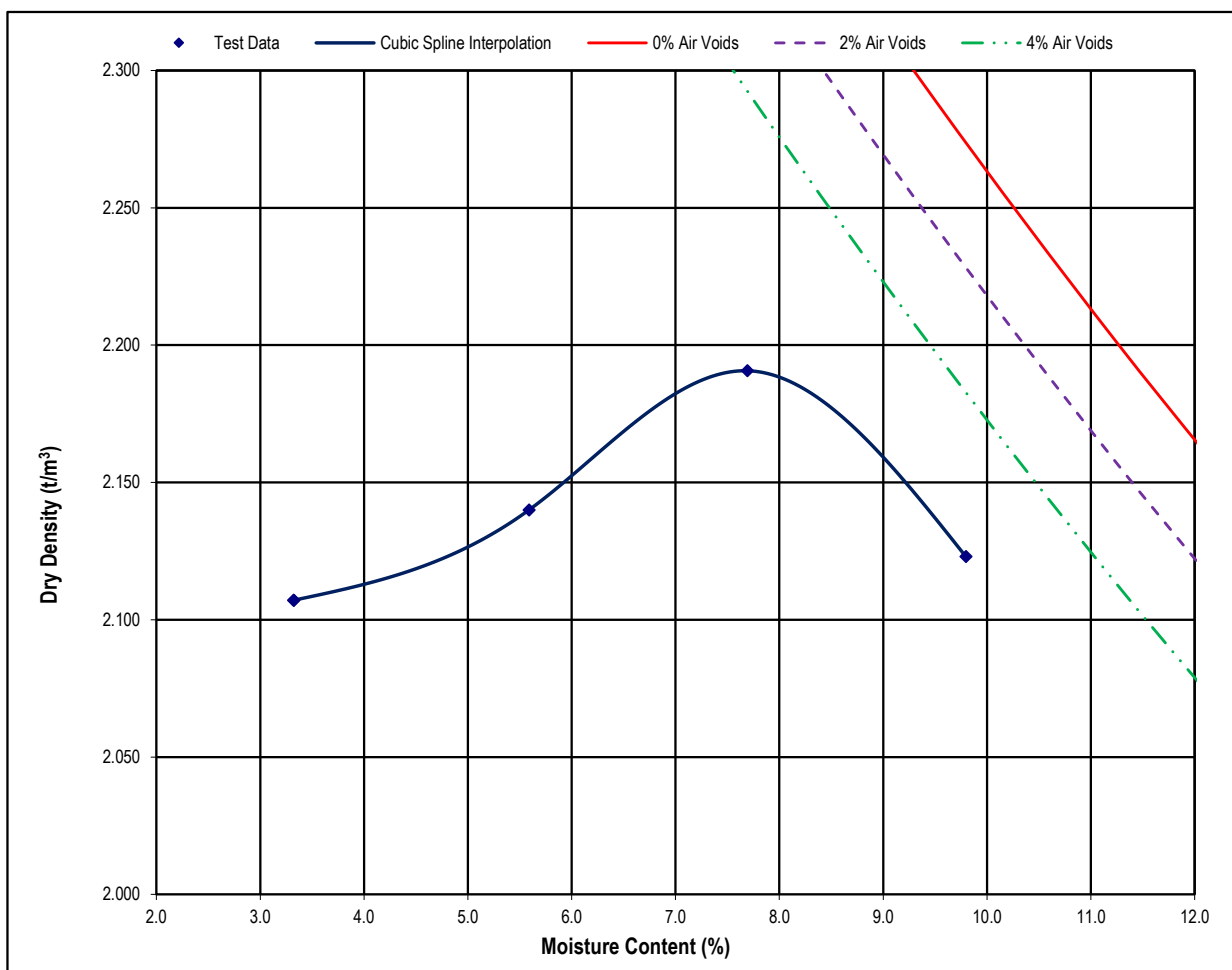
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MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081546-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#3- YAN-003A/B	Depth (m)	0.30



Maximum Dry Density (t/m³)	2.191	Optimum Moisture Content (%)	7.7
Moisture Content (%)	3.6	Percentage of Oversize/Sieve Size (mm)	1 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.93

Page 1 of 1 REP01304

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PERMEABILITY BY FALLING HEAD TEST REPORT

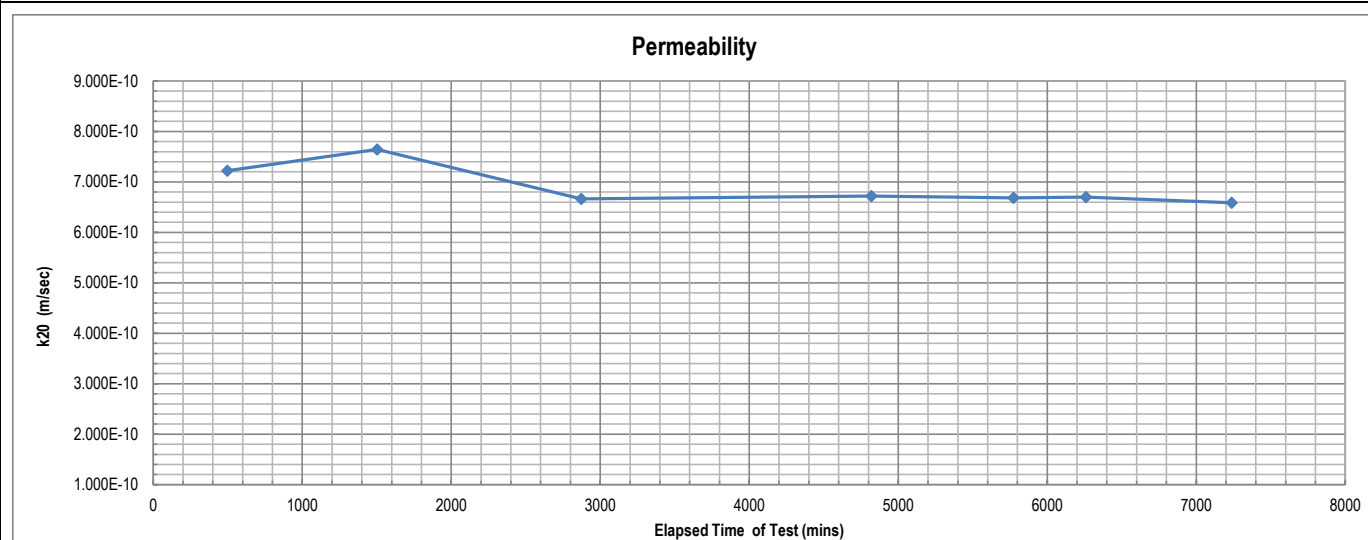
Test Method AS 1289 6.7.2, 5.2.1, KH2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	O'Kane Consultants Pty Ltd	Report No.	19081547-FHPT
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation	Test Date	27/09/2019
Client ID	TP#6 - YAN-006A/B	Report Date	8/10/2019
Description	GRAVELLY CLAYEY SAND -pale brown	Depth (m)	3.50
		Sample Type	Remoulded Soil Specimen

RESULTS OF TESTING

Compaction Method	AS1289.5.2.1 - Modified Compaction		
Maximum Dry Density (t/m ³)	2.08	Hydraulic Gradient	9.5
Optimum Moisture Content (%)	10.0	Surcharge (kPa)	3.7
Placement Moisture Content (%)	10.5	Head Pressure Applied (kPa)	10.79
Moisture Ratio (%)	105.1	Water Type	Deaerated
Placement Wet Density (t/m ³)	2.17	Percentage Material Retained/Sieve Size (mm)	2 % /19 mm
Density Ratio (%)	94.5	Sample Height and Diameter (mm)	116.39 / 152.44 mm

PERMEABILITY $k_{(20)} = 6.6 \times 10^{-10}$ (m/sec)



Remarks: The above specimen was remoulded to a target of 95% of Modified Maximum Dry Density and at Optimum Moisture Content.

Sample/s supplied by client

Page: 1 of 1

REP06301

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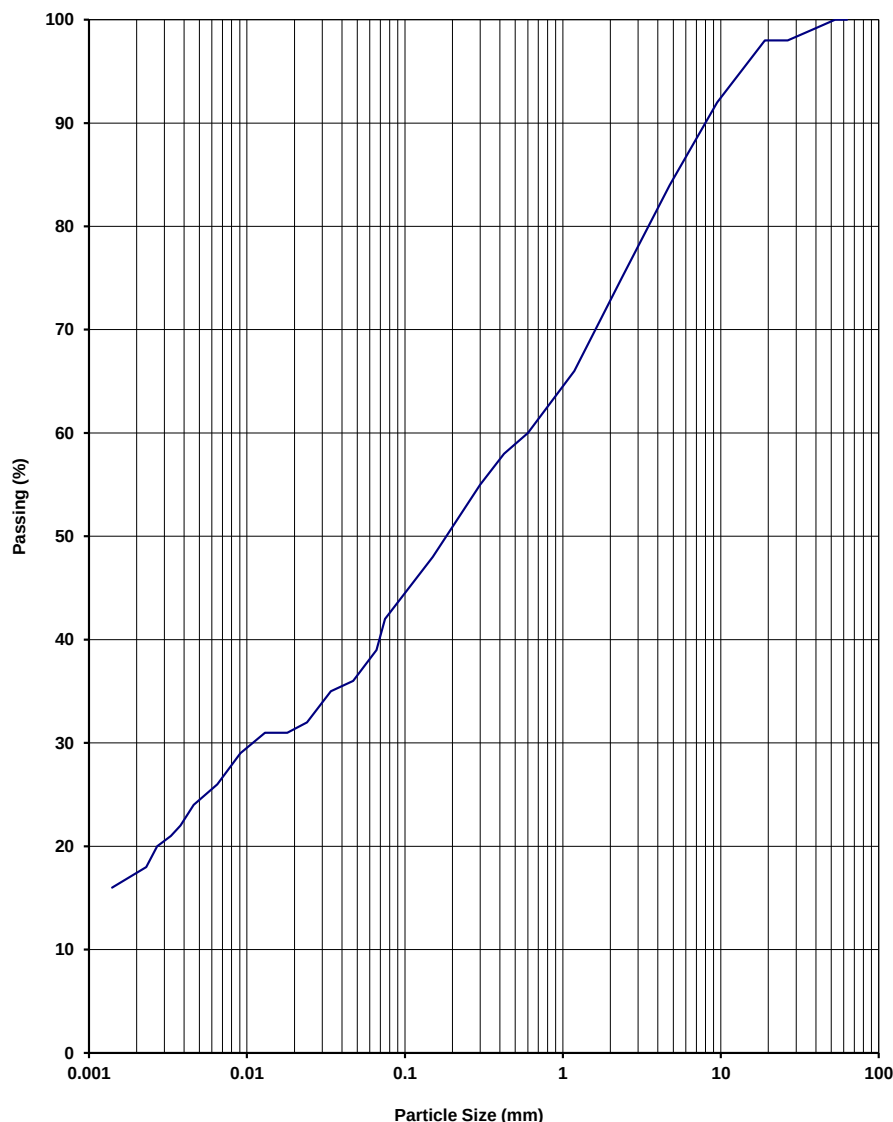
ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081547-G
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#6 - YAN-006A/B	Test Date	6/9/19-16/9/19
		Report Date	17/9/2019
Depth (m)	3.50		

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	100
37.5	99
26.5	98
19.0	98
13.2	95
9.5	92
6.7	88
4.75	84
2.36	75
1.18	66
0.600	60
0.425	58
0.300	55
0.150	48
0.075	42
0.066	39
0.047	36
0.034	35
0.024	32
0.018	31
0.013	31
0.0091	29
0.0065	26
0.0046	24
0.0038	22
0.0033	21
0.0027	20
0.0023	18
0.0014	16



NOTES/REMARKS:

-
Moisture Content 8.1% -2.36mm Soil Particle Density(t/m³) 2.64
Sample/s supplied by the client

Page 1 of 1 REP03904

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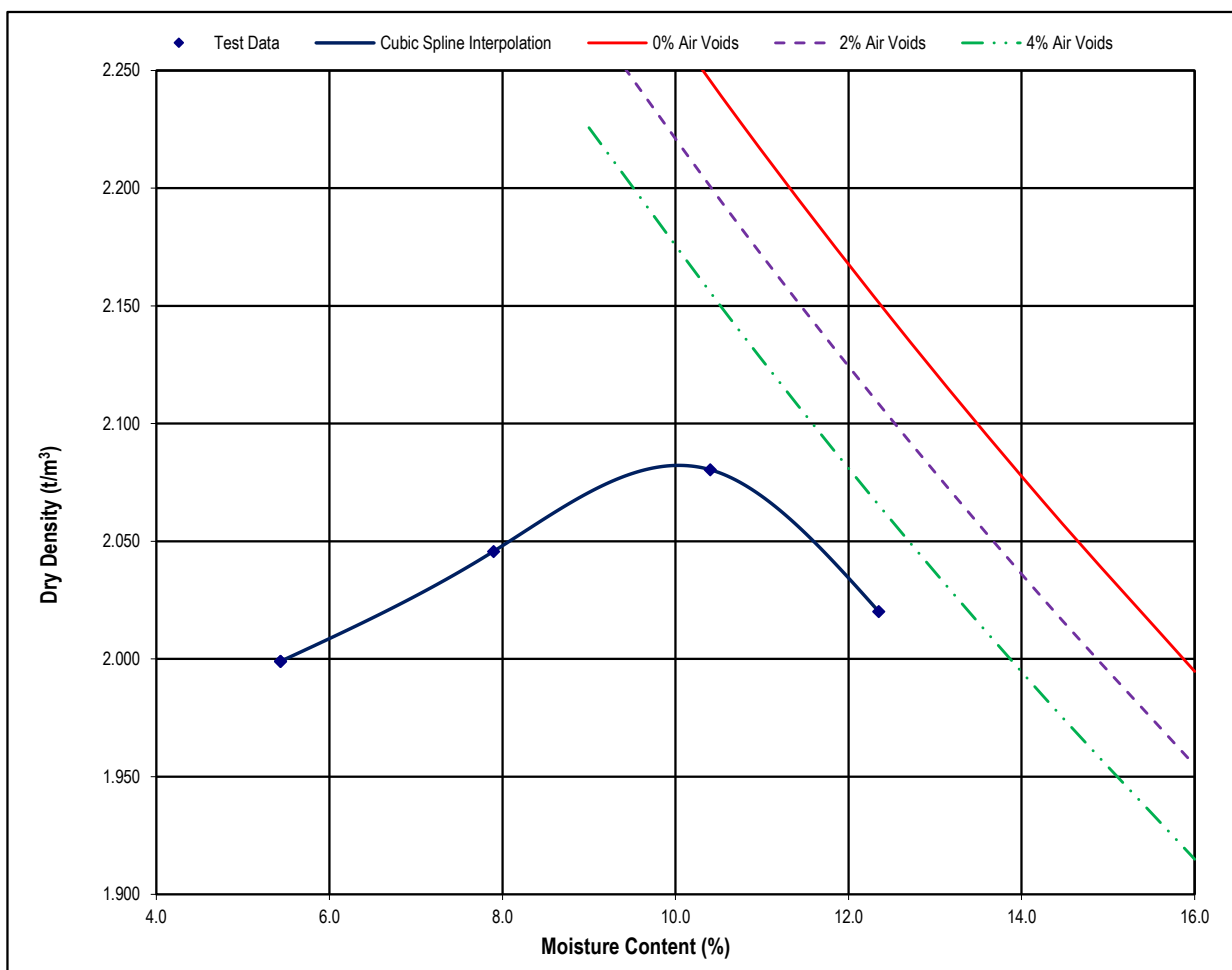
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Trilab Pty Ltd ABN 25 065 630 506

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081547-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#6 - YAN-006A/B	Depth (m)	3.50



Maximum Dry Density (t/m³)	2.082	Optimum Moisture Content (%)	10.0
Moisture Content (%)	8.1	Percentage of Oversize/Sieve Size (mm)	2 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.93

Page 1 of 1 REP01304

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PERMEABILITY BY FALLING HEAD TEST REPORT

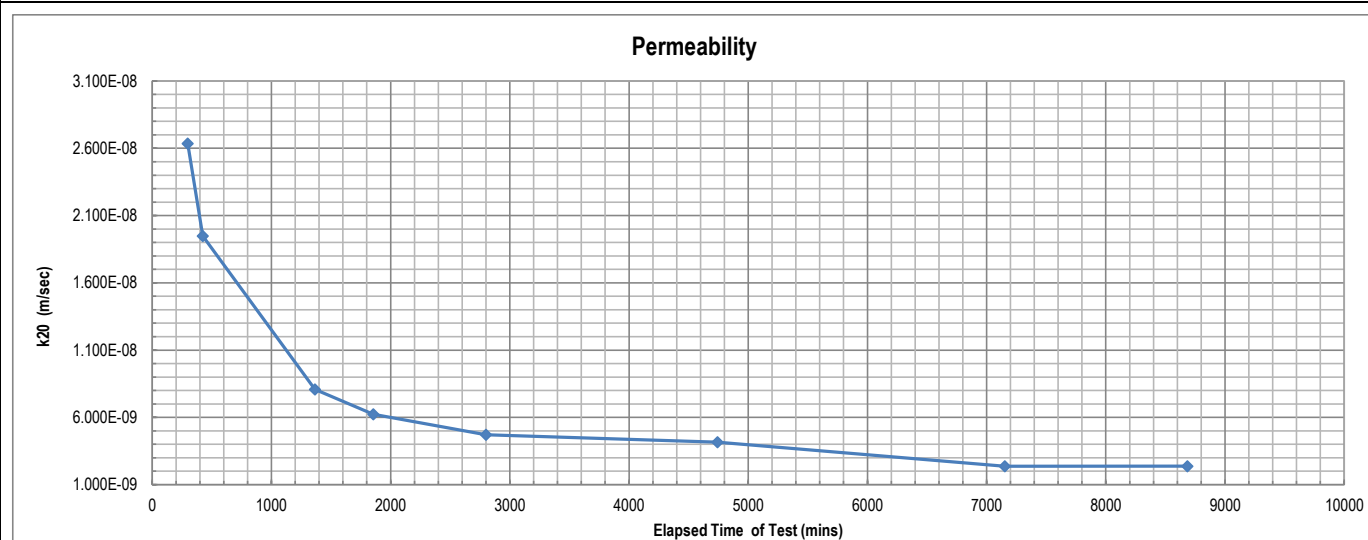
Test Method AS 1289 6.7.2, 5.1.1, KH2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	O'Kane Consultants Pty Ltd	Report No.	19081548-FHPT
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation	Test Date	28/08/2019
Client ID	TP#11 - YAN-011A/B	Report Date	8/10/2019
Description	SANDY CLAY-brown	Depth (m)	2.40
		Sample Type	Remoulded Soil Specimen

RESULTS OF TESTING

Compaction Method	AS1289.5.1.1 - Standard Compaction		
Maximum Dry Density (t/m ³)	2.05	Hydraulic Gradient	9.5
Optimum Moisture Content (%)	9.7	Surcharge (kPa)	2.9
Placement Moisture Content (%)	9.7	Head Pressure Applied (kPa)	10.79
Moisture Ratio (%)	100.1	Water Type	Deaerated
Placement Wet Density (t/m ³)	2.13	Percentage Material Retained/Sieve Size (mm)	0 % / 9.5 mm
Density Ratio (%)	94.9	Sample Height and Diameter (mm)	116.21 / 101.52 mm

PERMEABILITY $k_{(20)} = 2.4 \times 10^{-09}$ (m/sec)



Remarks: The above specimen was remoulded to a target of 95% of Modified Maximum Dry Density and at Optimum Moisture Content.

Sample/s supplied by client

Page: 1 of 1

REP06301

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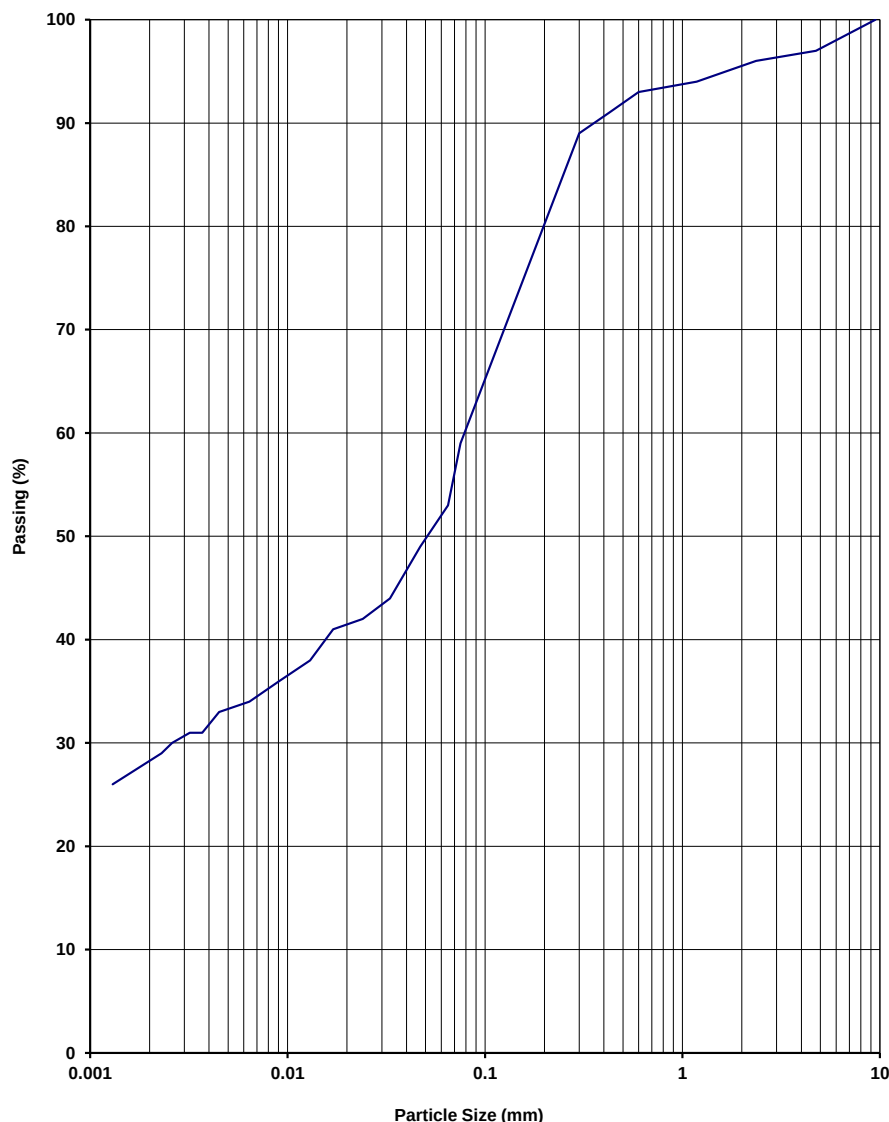
ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081548-G
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#11 - YAN-011A/B	Test Date	6/9/19-16/9/19
		Report Date	17/9/2019
Depth (m)	2.40		

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
13.2	
9.5	100
6.7	99
4.75	97
2.36	96
1.18	94
0.600	93
0.425	91
0.300	89
0.150	74
0.075	59
0.065	53
0.047	49
0.033	44
0.024	42
0.017	41
0.013	38
0.0091	36
0.0064	34
0.0045	33
0.0037	31
0.0032	31
0.0026	30
0.0023	29
0.0013	26



NOTES/REMARKS:

-
Moisture Content 7.6% -2.36mm Soil Particle Density(t/m³) 2.66
Sample/s supplied by the client

Page 1 of 1 REP03904

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Authorised Signatory


C. Park



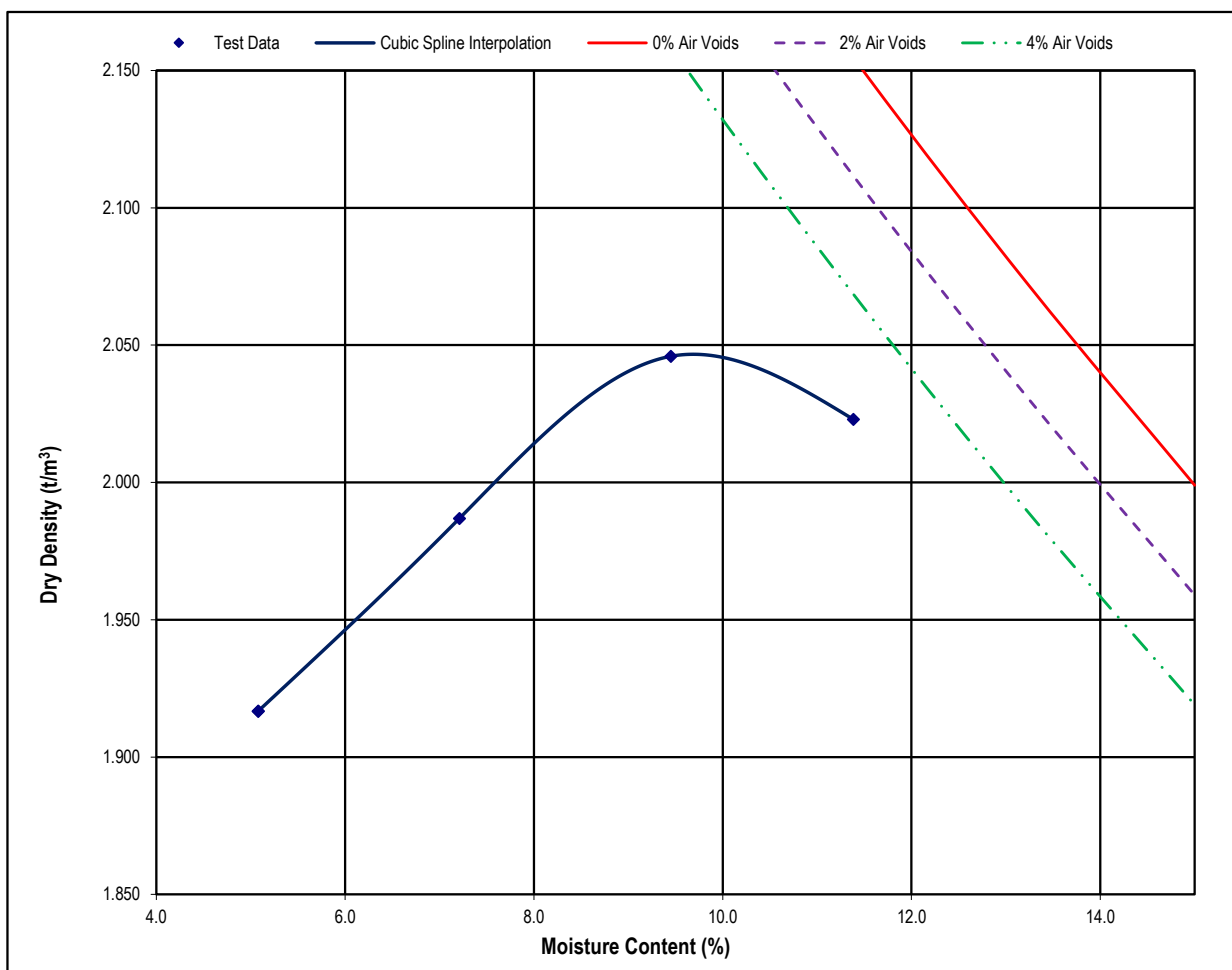
Laboratory No. 9926

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Trilab Pty Ltd ABN 25 065 630 506

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081548-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#11 - YAN-011A/B	Depth (m)	2.40



Maximum Dry Density (t/m³)	2.047	Optimum Moisture Content (%)	9.7
Moisture Content (%)	7.6	Percentage of Oversize/Sieve Size (mm)	0 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.86

Page 1 of 1 REP01304

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Tested at Trilab Brisbane Laboratory

Authorised Signatory



C. Park



Laboratory No. 9926

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Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PERMEABILITY BY FALLING HEAD TEST REPORT

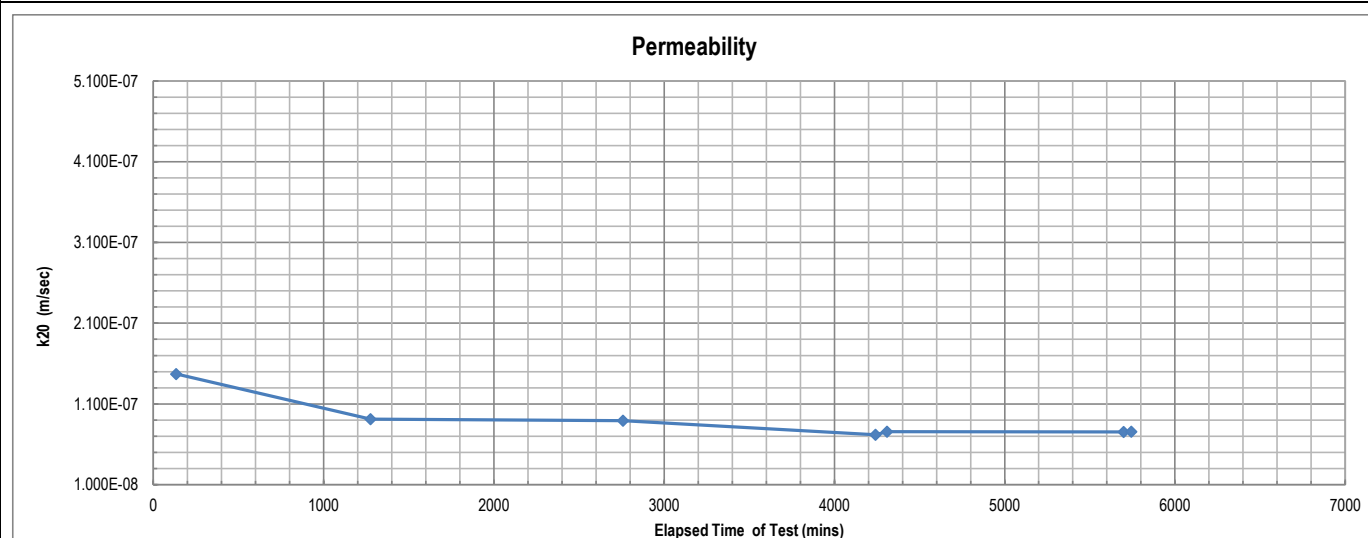
Test Method AS 1289 6.7.2, 5.2.1, KH2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	O'Kane Consultants Pty Ltd	Report No.	19081549-FHPT
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation	Test Date	27/09/2019
Client ID	TP#13 - YAN-013A/B	Report Date	8/10/2019
Description	SANDY CLAY- brown	Depth (m)	2.00
		Sample Type	Remoulded Soil Specimen

RESULTS OF TESTING

Compaction Method	AS1289.5.2.1 - Modified Compaction		
Maximum Dry Density (t/m ³)	2.02	Hydraulic Gradient	9.4
Optimum Moisture Content (%)	10.4	Surcharge (kPa)	3.7
Placement Moisture Content (%)	10.2	Head Pressure Applied (kPa)	10.79
Moisture Ratio (%)	98.0	Water Type	Deaerated
Placement Wet Density (t/m ³)	1.89	Percentage Material Retained/Sieve Size (mm)	10 % /19 mm
Density Ratio (%)	85.1	Sample Height and Diameter (mm)	116.46 / 152.4 mm

PERMEABILITY $k_{(20)} = 7.6 \times 10^{-08}$ (m/sec)



Remarks: The above specimen was remoulded to a target of 85% of Modified Maximum Dry Density and at Optimum Moisture Content.

Sample/s supplied by client

Page: 1 of 1

REP06301

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Authorised Signatory


C. Channon



Laboratory No. 9926

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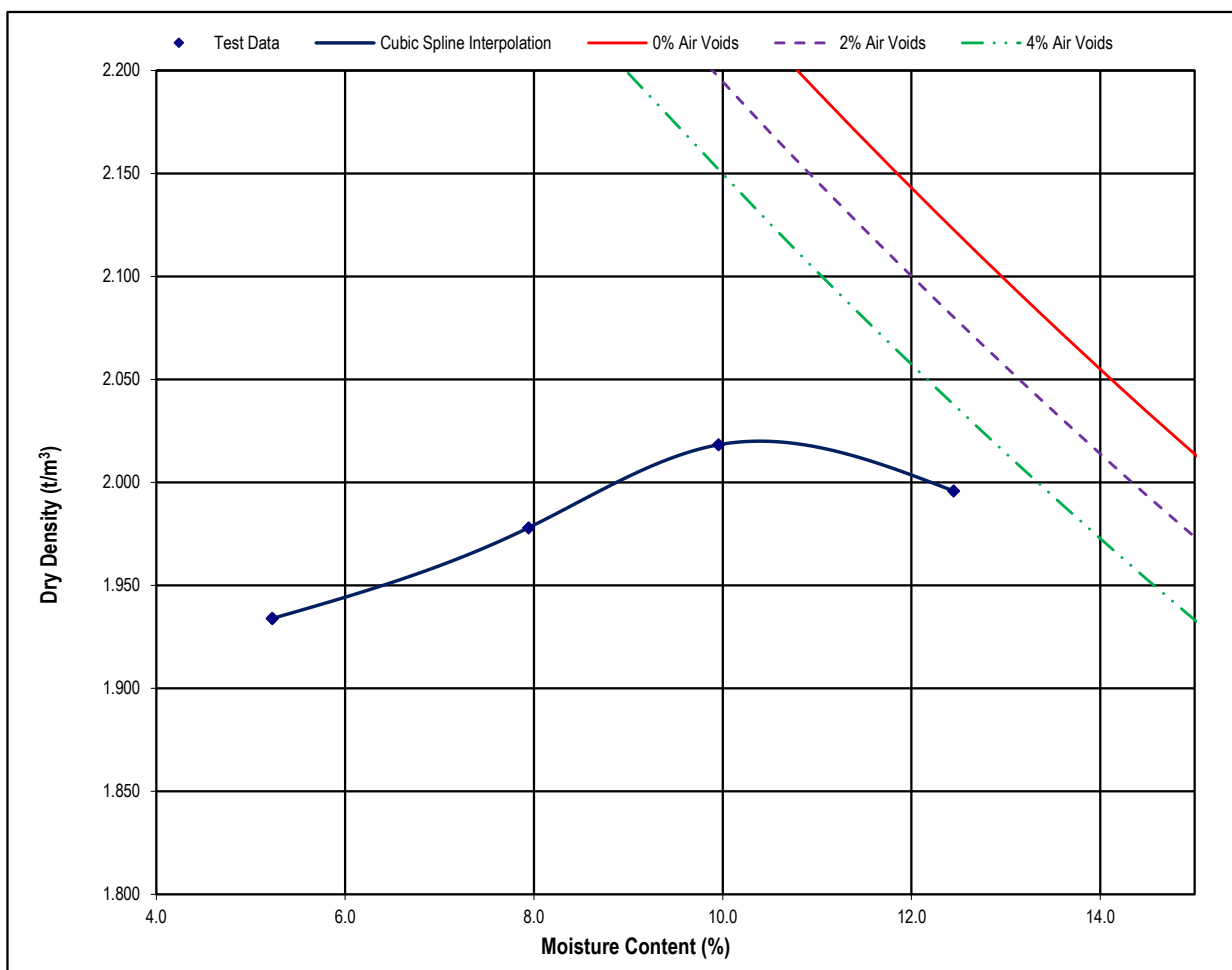
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081549-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#13 - YAN-013A/B	Depth (m)	2.00



Maximum Dry Density (t/m³)	2.020	Optimum Moisture Content (%)	10.4
Moisture Content (%)	8.9	Percentage of Oversize/Sieve Size (mm)	10 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.88

Page 1 of 1 REP01304

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C. Park



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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PERMEABILITY BY CONSTANT HEAD TEST REPORT

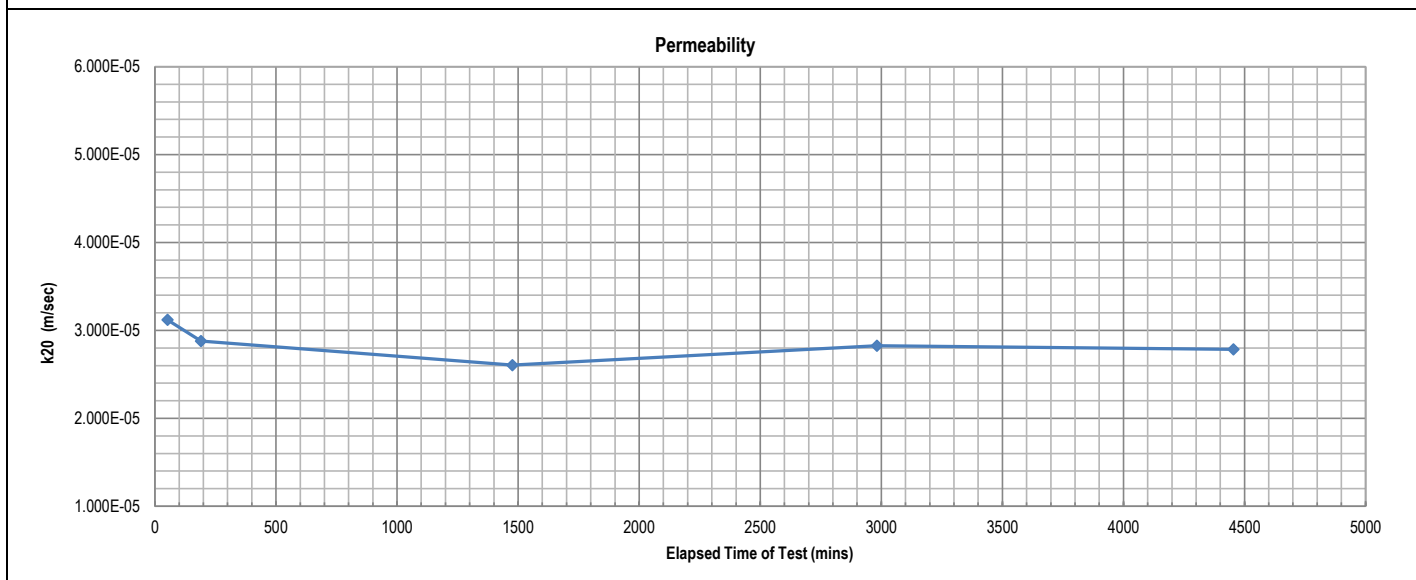
Test Method AS 1289 6.7.1, 5.1.1, KH2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	O'Kane Consultants Pty Ltd	Report No.	19081551-CHP
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation	Test Date	16/09/2019
Client ID	TP#18 - YAN-018A/B	Report Date	25/09/2019
Description	CLAYEY SAND -brown with gravel	Depth (m)	0.80
		Sample Type	Remoulded Soil Specimen

RESULTS OF TESTING

Compaction Method	AS1289.5.1.1 - Standard Compaction		
Maximum Dry Density (t/m ³)	N/A	Hydraulic Gradient	0.9
Optimum Moisture Content (%)	N/A	Surcharge (kPa)	3.7
Placement Moisture Content (%)	15.5	Head Pressure Applied (kPa)	0.98
Moisture Ratio (%)	N/A	Water Type	Deaerated
Placement Wet Density (t/m ³)	1.76	Percentage Material Retained/Sieve Size (mm)	0 % / 19 mm
Density Ratio (%)	N/A	Sample Height and Diameter (mm)	116.39 / 152.44 mm

PERMEABILITY $k_{(20)} = 2.8 \times 10^{-05}$ (m/sec)



Remarks: The above specimen was remoulded as loose as possible at Field Moisture Content as advised by the client

Sample/s supplied by client

Page: 1 of 1

REP06401

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Authorised Signatory



C. Channon



Laboratory No. 9926

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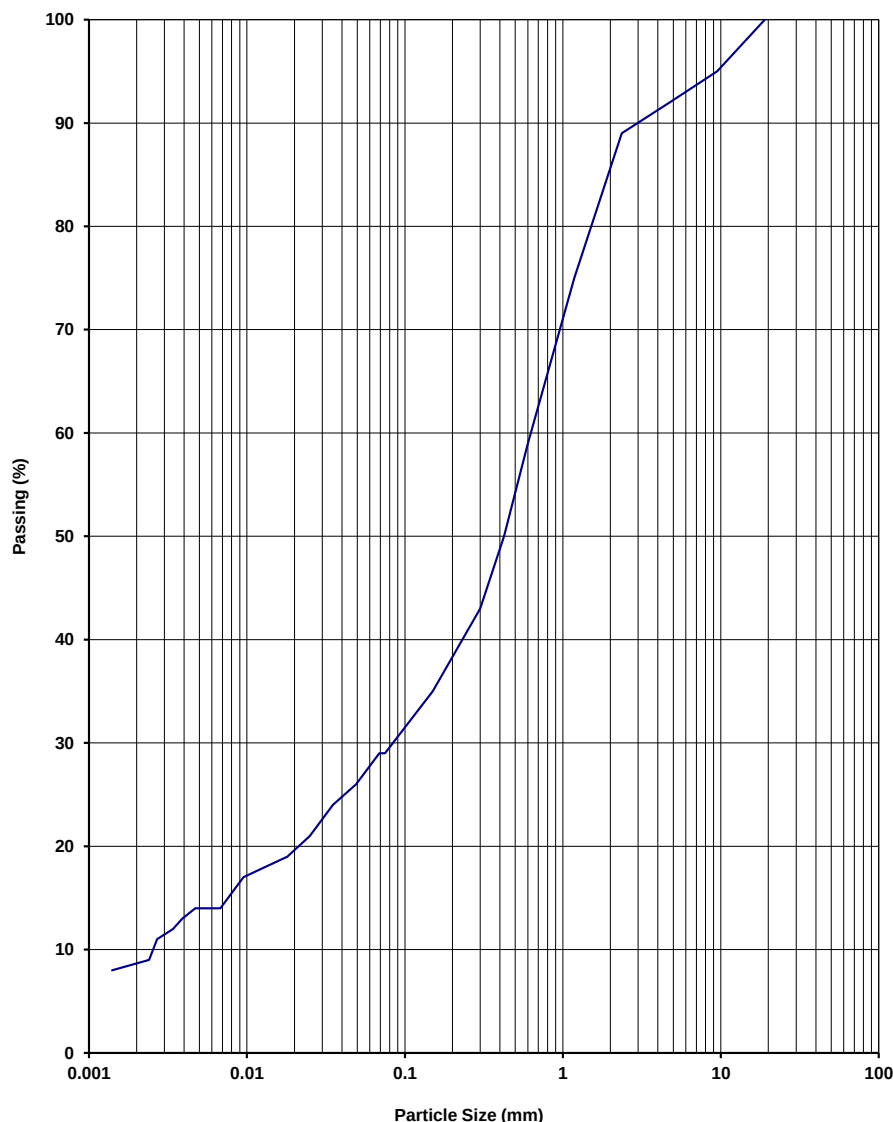
Trilab Pty Ltd ABN 25 065 630 506
ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081551-G
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#18 - YAN-018A/B	Test Date	6/9/19-16/9/19
		Report Date	17/9/2019
Depth (m)	0.80		

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	100
13.2	95
9.5	95
6.7	94
4.75	92
2.36	89
1.18	75
0.600	59
0.425	50
0.300	43
0.150	35
0.075	29
0.069	29
0.049	26
0.035	24
0.025	21
0.018	19
0.013	18
0.0095	17
0.0068	14
0.0047	14
0.0039	13
0.0034	12
0.0027	11
0.0024	9
0.0014	8



NOTES/REMARKS:

-
Moisture Content 15.5% -2.36mm Soil Particle Density(t/m^3) 2.69
Sample/s supplied by the client

Page 1 of 1 REP03904

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Authorised Signatory

C. Park
C. Park



Laboratory No. 9926

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Trilab Pty Ltd ABN 25 065 630 506

PERMEABILITY BY FALLING HEAD TEST REPORT

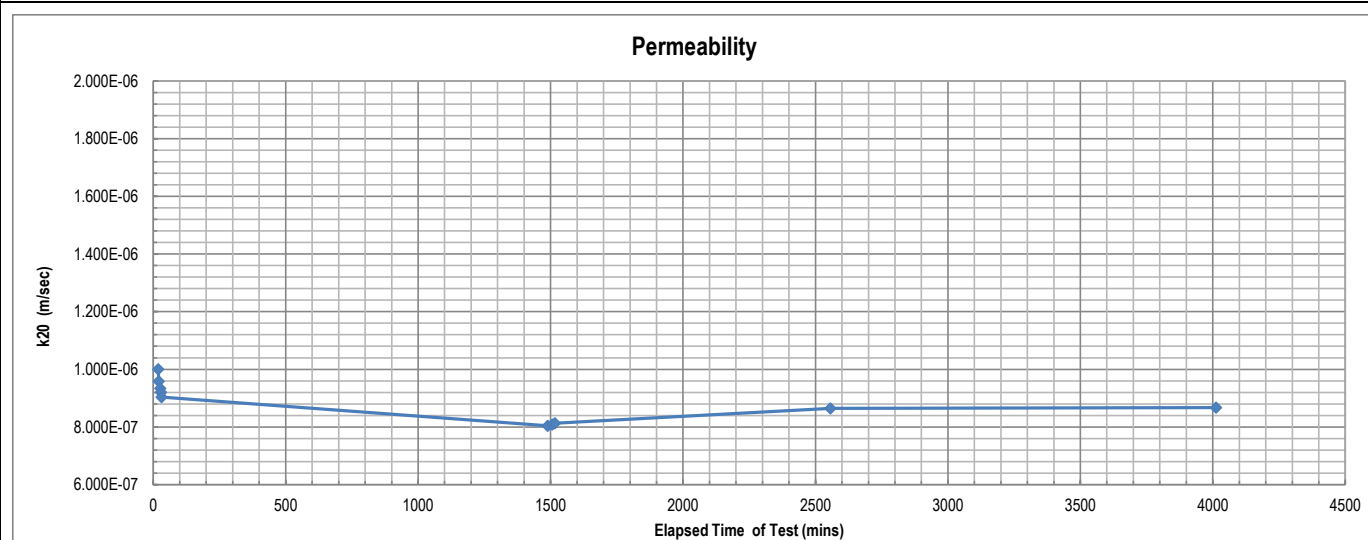
Test Method AS 1289 6.7.2, 5.1.1.1, KH2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client	O'Kane Consultants Pty Ltd	Report No.	19081553-FHPT
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Workorder No.	0006403
Project	0956-007 - Yandan Material Characterisation	Test Date	30/09/2019
Client ID	TP#21 - YAN-021A/B	Report Date	8/10/2019
Description	SILTY SAND -brown	Depth (m)	0.50
		Sample Type	Remoulded Soil Specimen

RESULTS OF TESTING

Compaction Method	AS1289.5.1.1 - Standard Compaction		
Maximum Dry Density (t/m ³)	2.10	Hydraulic Gradient	9.5
Optimum Moisture Content (%)	8.8	Surcharge (kPa)	3.7
Placement Moisture Content (%)	9.3	Head Pressure Applied (kPa)	10.79
Moisture Ratio (%)	106.1	Water Type	Deaerated
Placement Wet Density (t/m ³)	1.94	Percentage Material Retained/Sieve Size (mm)	14 % /19 mm
Density Ratio (%)	84.5	Sample Height and Diameter (mm)	116.24 / 152.44 mm

PERMEABILITY $k_{(20)} = 8.7 \times 10^{-07}$ (m/sec)



Remarks: The above specimen was remoulded to a target of 85% of Modified Maximum Dry Density and at Optimum Moisture Content.

Sample/s supplied by client

Page: 1 of 1

REP06301

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Tested at Trilab Brisbane Laboratory

Authorised Signatory


C. Channon



Laboratory No. 9926

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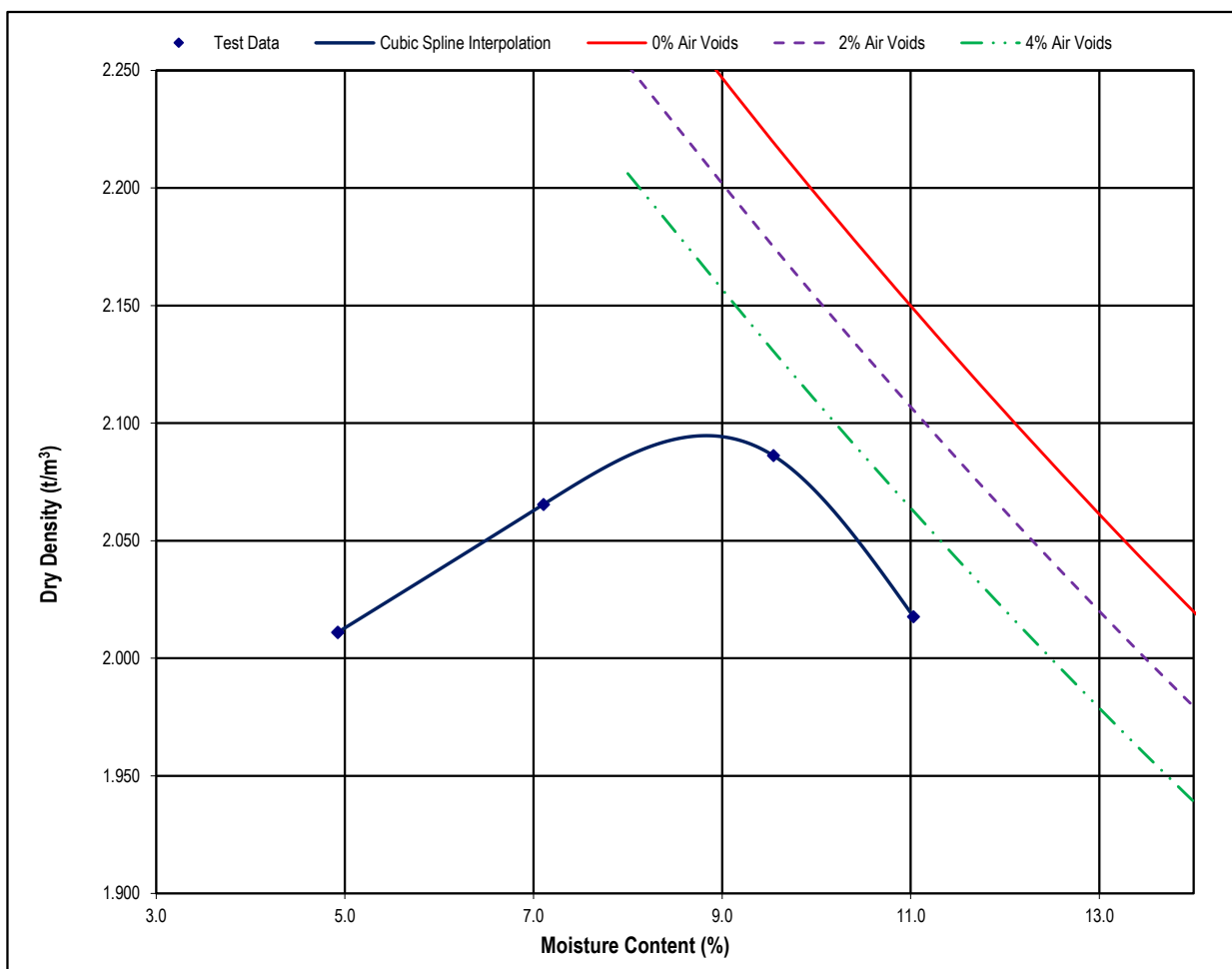
Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

MOISTURE/DENSITY RELATIONSHIP TEST REPORT

Test Method: AS 1289 5.2.1 (Modified) & AS 1289.2.1.1

Client	O'Kane Consultants Pty Ltd	Report No.	19081553-MDD
		Workorder No.	0006403
Address	202 Petrie Terrace, Petrie Terrace QLD 4074	Test Date	13/09/2019
		Report Date	17/09/2019
Project	0956-007 - Yandan Material Characterisation		
Client ID	TP#21 - YAN-021A/B	Depth (m)	0.50



Maximum Dry Density (t/m³)	2.095	Optimum Moisture Content (%)	8.8
Moisture Content (%)	9.7	Percentage of Oversize/Sieve Size (mm)	14 / 19

NOTES/REMARKS:

Sample/s supplied by the client

% Voids based on assumed SG of 2.82

Page 1 of 1 REP01304

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Tested at Trilab Brisbane Laboratory

Authorised Signatory



C. Park



Laboratory No. 9926

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Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

17/11/2014



THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

School of Civil Engineering

GEOTECHNICAL LABORATORY - SOIL WATER CHARACTERISTIC CURVES

Client name	Scott Lines	Phone Number	
Company Name	Okane Consultants	Date	12/11/2019
Address	Unit 3, 202 Petrie Terrace, Petrie Terrace	Sample Name	TP#11 - OKC YAW 011 18/07/2018 - 0956-007
Email address	slines@okc-sk.com		

TEST RESULTS

Suction	Corrected Suction	Burette level*	Sample height	V _T	M _w	V _w	VWC	GMC
(kPa)	(kPa)	(mls)	(mm)	(mm ³)	(g)	(mm ³)	(%)	(%)
u _a	u' = u _a - u _w	* Burette level here is the sum of the 2 tubes * scale adjustment						
0.1	0.10	4.21	31.22	99823.02	46.64	46640.8	46.72%	30.24%
10	9.095	10.67	31.22	99823.02	40.18	40182.4	40.25%	26.06%
20	18.845	14.18	31.22	99823.02	36.67	36672.4	36.74%	23.78%
40	38.595	17.69	31.22	99823.02	33.16	33162.4	33.22%	21.50%
80	78.375	20.78	31.22	99823.02	30.07	30073.6	30.13%	19.50%
160	158.125	24.29	31.22	99823.02	26.56	26563.6	26.61%	17.23%
320	317.895	27.52	31.22	99823.02	23.33	23334.4	23.38%	15.13%
500	497.785	29.06	31.22	99823.02	21.79	21790.0	21.83%	14.13%

Porous Plate Rating (bar)	5
Cell diameter (mm)	63.81

AFTER TEST CALCULATIONS

Tin Weight	97.55	g
Tin + Wet Soil	273.55	g
Tin + Dry Soil	251.76	g
M _T	176.00	g
M _S	154.21	g
M _w	21.79	g
w	14.130	%
γ _d	1.545	t/m ³

Comments

- Sample soaked under water. MC reached was 25.5%
- The software used to obtain the fitted curve values is Soilvision. The equation used in this estimation is Fredlund and Xing
- The measured specific gravity of the composite sample is 2.6736 g/cm³. The test to obtain this value was Helium Pycnometer test
- Sample was placed on three layers each one compacted with a static load of approx. 20kPa

17/11/2014



THE UNIVERSITY
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AUSTRALIA

School of Civil Engineering

GEOTECHNICAL LABORATORY - SOIL WATER CHARACTERISTIC CURVES

Client name	Scott Lines	Phone Number	
Company Name	Okane Consultants	Date	13/11/2019
Address	Unit 3, 202 Petrie Terrace, Petrie Terrace	Sample Name	TP#006 - OKC YAW 011 17/07/2018 -
Email address	slines@okc-sk.com		0956-007

TEST RESULTS

Suction	Corrected Suction	Burette level*	Sample height	V _T	M _w	V _w	VWC	GMC
(kPa)	(kPa)	(mls)	(mm)	(mm ³)	(g)	(mm ³)	(%)	(%)
ua	u'=ua-uw	* Burette level here is the sum of the 2 tubes*scale adjustment						
0.1	0.10	4.91	31.22	99823.02	44.94	44937.6	45.02%	28.52%
10	8.965	12.50	31.22	99823.02	37.36	37356.0	37.42%	23.71%
20	18.705	16.15	31.22	99823.02	33.71	33705.6	33.77%	21.39%
40	38.525	18.67	31.22	99823.02	31.18	31178.4	31.23%	19.79%
80	78.345	21.20	31.22	99823.02	28.65	28651.2	28.70%	18.18%
160	158.195	23.31	31.22	99823.02	26.55	26545.2	26.59%	16.85%
320	318.065	25.13	31.22	99823.02	24.72	24720.0	24.76%	15.69%

Porous Plate Rating (bar)	5
Cell diameter (mm)	63.81

AFTER TEST CALCULATIONS

Tin Weight	246.74	g
Tin + Wet Soil	429.02	g
Tin + Dry Soil	404.30	g
M _T	182.28	g
M _S	157.56	g
M _w	24.72	g
w	15.689	%
r _d	1.578	t/m3

Comments

- Sample soaked under water. MC reached was 25.5%
- The software used to obtain the fitted curve values is Soilvision. The equation used in this estimation is Fredlund and Xing
- The measured specific gravity of the composite sample is 2.7110 g/cm³. The test to obtain this value was Helium Pycnometer test
- Sample was placed on three layers each one compacted with a static load of approx. 20kPa

17/11/2014



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GEOTECHNICAL LABORATORY - SOIL WATER CHARACTERISTIC CURVES

Client name	Scott Lines	Phone Number	
Company Name	Okane Consultants	Date	4/10/2019
Address	Unit 3, 202 Petrie Terrace, Petrie Terrace	Sample Name	TP#3 - OKC - 0956-007
Email address	slines@okc-sk.com		

TEST RESULTS

Suction	Corrected Suction	Burette level*	Sample height	V _T	M _w	V _w	VWC	GMC
(kPa)	(kPa)	(mls)	(mm)	(mm ³)	(g)	(mm ³)	(%)	(%)
ua	u'=ua-uw	* Burette level here is the sum of the 2 tubes*scale adjustment						
0.1	0.10	6.04	31.22	98855.46	40.95	40946.0	41.42%	25.19%
10	9.095	10.67	31.22	98855.46	36.31	36312.8	36.73%	22.34%
20	18.855	14.04	31.22	98855.46	32.94	32943.2	33.32%	20.26%
40	38.645	16.99	31.22	98855.46	29.99	29994.8	30.34%	18.45%
80	78.455	19.66	31.22	98855.46	27.33	27327.2	27.64%	16.81%
160	158.305	21.76	31.22	98855.46	25.22	25221.2	25.51%	15.51%
320	318.165	23.73	31.22	98855.46	23.26	23255.6	23.52%	14.30%
500	498.025	25.69	31.22	98855.46	21.29	21290.0	21.54%	13.10%

Porous Plate Rating (bar)	5
Cell diameter (mm)	63.50

AFTER TEST CALCULATIONS

Tin Weight	185.31	g
Tin + Wet Soil	369.17	g
Tin + Dry Soil	347.88	g
M _T	183.86	g
M _S	162.57	g
M _w	21.29	g
w	13.096	%
γ _d	1.645	t/m3

Comments

- Sample soaked under water. MC reached was 25.2%
- The software used to obtain the fitted curve values is Soilvision. The equation used in this estimation is Fredlund and Xing
- The measured specific gravity of the composite sample is 2.6795 g/cm³. The test to obtain this value was Helium Pycnometer test
- Sample was placed on three layers each one compacted with a static load of approx. 20kPa

CERTIFICATE OF ANALYSIS

Work Order : **EB1922743**
Client : **O'KANE CONSULTANTS PTY LTD**
Contact : **SCOTT LINES**
Address : **UNIT 2 202 Petrie Terrace,
PETRIE TERRACE QLD, AUSTRALIA 4000**
Telephone : **----**
Project : **956-007 Yandan**
Order number : **----**
C-O-C number : **----**
Sampler : **----**
Site : **----**
Quote number : **EN/222**
No. of samples received : **3**
No. of samples analysed : **3**

Page : 1 of 4
Laboratory : Environmental Division Brisbane
Contact : Customer Services EB
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61-7-3243 7222
Date Samples Received : 29-Aug-2019 15:50
Date Analysis Commenced : 30-Aug-2019
Issue Date : 06-Sep-2019 12:47



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



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

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- ED006 (Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio result as required Potassium and/or Magnesium results are less than the limit of reporting.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity ($H^+ + Al^{3+}$).



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	YAN-001	YAN-018	YAN-021	----	----
Client sampling date / time					17-Aug-2019 00:00	18-Aug-2019 00:00	18-Aug-2019 00:00	----	----
Compound	CAS Number	LOR	Unit		EB1922743-001	EB1922743-002	EB1922743-003	-----	-----
				Result	Result	Result	Result	----	----
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		5.7	8.3	6.5	----	----
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		67	562	637	----	----
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	0.1	%		3.4	18.8	8.7	----	----
ED005: Exchange Acidity									
Ø Exchange Acidity	----	0.1	meq/100g		<0.1	----	----	----	----
Ø Exchangeable Aluminium	----	0.1	meq/100g		<0.1	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils									
Ø Exchangeable Calcium	----	0.2	meq/100g		----	12.0	----	----	----
Ø Exchangeable Magnesium	----	0.2	meq/100g		----	1.9	----	----	----
Ø Exchangeable Potassium	----	0.2	meq/100g		----	<0.2	----	----	----
Ø Exchangeable Sodium	----	0.2	meq/100g		----	1.5	----	----	----
Ø Cation Exchange Capacity	----	0.2	meq/100g		----	15.6	----	----	----
Ø Exchangeable Sodium Percent	----	0.2	%		----	9.7	----	----	----
Ø Calcium/Magnesium Ratio	----	0.2	-		----	6.3	----	----	----
ED007: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		2.9	----	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g		1.1	----	----	----	----
Exchangeable Potassium	----	0.1	meq/100g		0.2	----	----	----	----
Exchangeable Sodium	----	0.1	meq/100g		0.1	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g		4.3	----	----	----	----
Exchangeable Sodium Percent	----	0.1	%		2.6	----	----	----	----
Calcium/Magnesium Ratio	----	0.1	-		2.6	----	----	----	----
Magnesium/Potassium Ratio	----	0.1	-		6.4	----	----	----	----
ED008: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		----	----	3.3	----	----
Exchangeable Magnesium	----	0.1	meq/100g		----	----	2.7	----	----
Exchangeable Potassium	----	0.1	meq/100g		----	----	0.2	----	----
Exchangeable Sodium	----	0.1	meq/100g		----	----	0.2	----	----
Cation Exchange Capacity	----	0.1	meq/100g		----	----	6.6	----	----
Exchangeable Sodium Percent	----	0.1	%		----	----	3.7	----	----
Calcium/Magnesium Ratio	----	0.1	-		----	----	1.2	----	----
Magnesium/Potassium Ratio	----	0.1	-		----	----	10.9	----	----



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	YAN-001	YAN-018	YAN-021	----	----
Client sampling date / time					17-Aug-2019 00:00	18-Aug-2019 00:00	18-Aug-2019 00:00	----	----
Compound	CAS Number	LOR	Unit		EB1922743-001	EB1922743-002	EB1922743-003	-----	-----
					Result	Result	Result	----	----
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.01	0.02	0.02	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		26.2	0.2	15.5	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		660	450	780	----	----
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		690	450	800	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		283	872	160	----	----
EP004: Organic Matter									
Organic Matter	----	0.5	%		1.4	0.5	1.2	----	----
Total Organic Carbon	----	0.5	%		0.8	<0.5	0.7	----	----



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Assessment of the Introduction of Yandan Pit Water into the Suttor River System

For Ross Mining NL



December 1999
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Executive Summary

This study was undertaken to assess the potential environmental consequences of outflow of Yandan pit waters into the Suttor River via either designed spillways, or bund failure under flood conditions. The study also considered the geomorphology and biology of the Suttor River system in order to provide the context for any potential environmental risks that were identified. To simplify the hydrological modelling of spillway outflow, a limited number of "worst case" scenarios were considered, which included failure of the bund separating the pit waters from the Suttor River, and outflow via constricted spillways at levels equivalent to the 25 year, five year and two year average recurrence interval (ARI) flood height at St Anne's Station.

A key finding was that the rates of flood recession in the Suttor River are slow, and therefore the river tailwater following a flood would control the rate of outflow of water from the pit for any spillway or bund breach of at least 15 m in width (the narrowest spillway width considered) to a flow of $2.7 \text{ m}^3 \text{ s}^{-1}$ (cumecs) or less.

It was considered that bund failure would be most likely to occur during the rising water phase of a flood rather than during recession, but that the unlikely event of pit waters being released into the Suttor River at low flow levels following catastrophic failure of the bund would be likely to have undesirable environmental consequences, and could be readily avoided by construction of a spillway.

Chemical modelling of the water quality of mixed pit and river waters was limited in this study to simple mass-balance calculations. This will have over-estimated the likely resultant metal concentrations, as the effect of changed pH on the solubility of metals in the pit waters was not considered. This approach was considered appropriate for a preliminary risk assessment, as it was highly conservative in terms of the estimation of risk. However, this approach would not provide an accurate quantification of risk, except where no risk was indicated.

The chemical modelling indicated that acute toxicity would not be likely to occur in the river channels as a result of the outflow of pit waters, except in the very limited circumstances of passage of unmixed pit waters. The potential extent of unmixed pit waters in the Suttor River would be less than 0.3% of the total river flow, which would decrease as mixing occurred downriver.

The mass-balance modelling undertaken as part of this study indicated that the contributions of aluminium, copper and zinc from the pit waters to the single river anabranch adjacent to the pit may exceed the Australian and New Zealand guidelines for protection of aquatic

ecosystems, and that the contribution of zinc to the full flow of the Suttor River may exceed that guideline under the assumption that the pit zinc concentration is that predicted for RL 164 m prior to outflow. Therefore, some potential risk for chronic toxicity resulting from aluminium, zinc and copper additions to the river waters may exist if outflow lasts for sufficient periods for chronic toxicity to occur, and in the unlikely circumstances that these metals remain fully bioavailable after mixing. It should be noted however that the measured filtered (passing 0.45 µm) concentrations of aluminium, copper, zinc and lead in the Suttor River exceeded the Australian guideline values, and the concentrations of aluminium and copper exceeded the United States acute guidelines, probably due at least in part to high concentrations of colloidal material. It is recommended that the risk of chronic toxicity occurring be better quantified by conducting mixing experiments with pit and river waters, and using finer filters or ultra-filtration techniques to better define the dissolved metal concentrations in the river waters.

The geomorphology of the Suttor River is that of a large, braided sand-bed river that is dominated by the influence of catastrophic flood events.

The Burdekin River system is characterised by low biological and habitat diversity overall, and the Suttor-Belyando sub-catchment is typical of the semi-arid zone parts of the river system. Permanent water bodies, and particularly aquatic macrophyte stands within them, have been greatly reduced in extent over the last century, presumably due to increased erosion rates resulting from widespread grazing in the catchment. The dry-season refugia for aquatic biota have thus become increasingly important as sources of recolonisation following inundation. No such permanent water bodies exist in the Suttor River between the Yandan Gold Mine and St Anne's Station, including the anabranch that would receive pit water outflows.

The biota of the Suttor River system is comprised of widespread species that are adapted to recovery from the naturally extreme conditions of drought and flood. The potential for environmental impacts to occur as a result of pit water outflow should be considered in that context, but should also take into account the major system-wide impacts to the aquatic communities that have resulted from grazing pressure and translocation of non-native predatory and competitive species.

The study concludes that an engineered inflow/outflow structure (spillway) combined with removal of all or part of the bund will:

- (1) Maximise dilution of pitwater discharging to river floodwater; and
- (2) Minimise the risk of bund failure.

Preliminary calculations indicate that one (or more) spillways constructed at the RL169 level (equivalent to the 2-year ARI flood

event) would achieve acceptable minimum dilution. Spillway dimensions should be sufficient to allow the pit water level to rise and fall at the same rate as the river to maximise tailwater effects and prevent excessive spillway velocities from occurring. Construction of two spillways, including inlet and outlet, could provide an additional benefit of within-pit mixing of river and pit waters both during inflow and outflow. Our preliminary calculations indicate that a spillway width of 15 m would allow both the pit and river levels to fall at the same rate during recession, while a spillway width of 30 m (or 2 x 15 m structures) would also allow both the pit and river levels to increase at the same rate during a rising flood, providing the pit and river levels are approximately equal at the start of the flood.

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Introduction and Scope of Work

The Yandan Gold Mine, operated by Ross Mining N.L., is located to the east of the Sutor River and north of Yandan Creek (see cover page). The mine was commissioned in September 1993, but at the time of this study, mining operations had ceased apart from leaching of a low-grade stockpile.

The mining operations had developed a large open pit adjacent to the eastern bank of the Sutor River. Sulphide rich rocks remained exposed in some sections of the pit wall, and sulphide rich waste rock materials had been placed in piles in some parts of the pit. The pit was separated from the Sutor River by an earthen bund (Plate 1), and had been partially flooded, to reduced level (RL) 148 m, by pumping water from the Sutor River. Dissolution of oxidised sulphides during the flooding had resulted in poor water quality within the pit.

This study was undertaken to assess the potential environmental consequences of outflow of Yandan pit waters into the Sutor River via either designed spillways, or bund failure under flood conditions. The study included:

- 1 Preliminary assessments of the ecological and morphological conditions of the Sutor River system in the vicinity of the Yandan Gold Mine;
- 2 Consideration of the existing pit water quality;
- 3 Estimation of the release magnitude resulting from flood events and a limited number of outflow spillway options under "worst-case" hydrological conditions;
- 4 Consideration of the potential for and potential consequences of catastrophic release of pit water under low river flow conditions due to bund failure;
- 5 Preliminary river water quality risk assessments for the modelled outflows; and
- 6 Consideration of release options to mitigate adverse environmental impacts in the receiving waters.

The approach taken was to consider "worst-case" scenarios suitable for a preliminary risk assessment. This approach reduced the number of options that needed to be considered and the need for background studies to provide input parameters for all conditions. In this way, the assessment

Flood Frequency Analysis

A flood frequency analysis was undertaken using the annual maximum flood series derived from the DNR (Ayr) database for St. Annes gauging station. A log-Pearson type-III distribution was applied to the annual maximum series.

The equivalent flood elevations (RL) for the 50-year, 25-year, 5-year and 2-year flood events were computed using the stage-discharge relation from the St. Anne's gauging station. This relation was assumed to be typical of channel form for the whole reach and was applied to the reach adjacent to the Yandan Pit. The results of the flood frequency analysis, the equivalent flood RL's and a summary of the scenarios considered are presented in Figure 1 and Table 1.

Figure 1. Flood Frequency Analysis, Suttor River at St Annes.

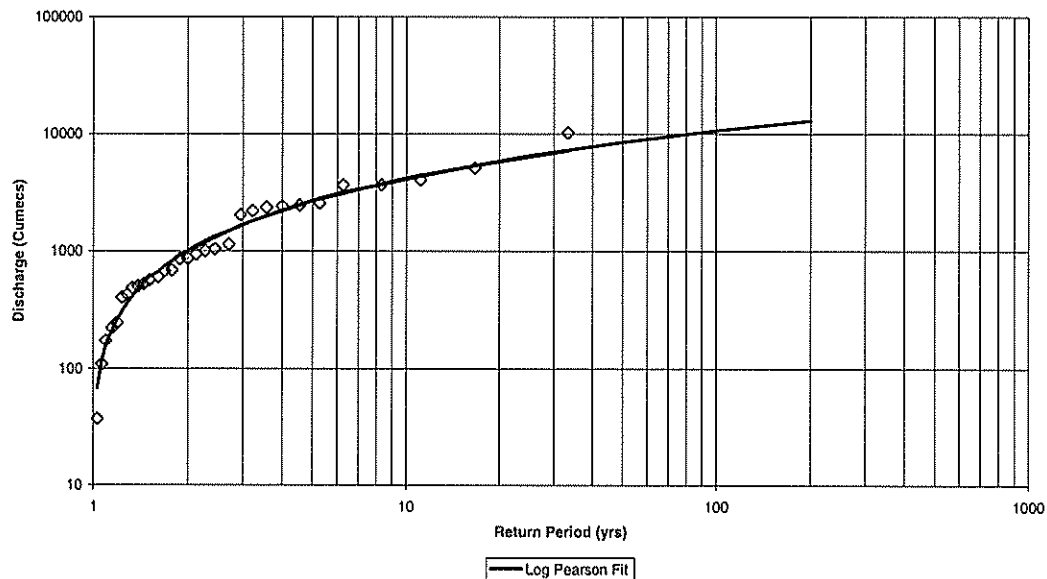


Table 1. Flood flow rates and heights, Suttor River at St Annes (assumed to be equivalent at Yandan)

Flood Average Recurrence Interval (ARI, years)	Suttor Discharge (cumecs)	Flow Depth (from St Annes rating curve)	Spillway invert RL (m)	Other scenarios
50	8,458	7.6	N/A	Complete Failure of bund (dambreak)
25	6,490	7.2	172	
5	2,652	6.0	171	
2	850	4.1	169	

The invert of the Sutor river channel is estimated to occur at RL 165 m. This is also the level in the pit below which the majority of the sulphidic wall material occurs. Location of a spillway at RL 165 m was not considered because under this scenario, pit water would continue to discharge as the river dropped to zero flow and therefore dilution would not occur.

Flood Recession Rates

The hydrological record from St. Anne's gauging station was reviewed to determine the likely maximum rate of recession of floods of different magnitudes. Maximum recession rates for a range of 9 floods with peak discharges varying between 800 and 5,000 m³s⁻¹ were computed. The results showed that, for larger flows, the water level would normally recede over several days, and that the maximum rate of recession observed from the record was 6.3 cm per hour for a storm of approximately 3,000 m³s⁻¹, which occurred on February 5th 1991 (approximately ARI 6-year event). These data indicated that flood recession rates were relatively slow, and a key finding was that river tailwater during flood recession would control the rate of release of pit water providing the spillway width was sufficient to allow the pit water level to draw down at the same rate. This is desirable not only to maximise downstream dilution, but also to minimise high velocity discharges across the spillway and thus reduce the likelihood of structural failure. The flood recession rate was rounded up to 7.5 cm per hour in subsequent analyses, to provide for the potential for some smaller or unusual flood peaks to recede more rapidly. A scan of the data found that only instances of presumed instrument error resulted in greater recession rates. The data also indicated that the maximum rate of river rise is approximately 50 cm per hour.

Water Quality

For the preliminary risk assessment purposes of this study, it was decided to use a simple, mass-balance approach to estimate potential water quality effects of a pit water outflow.

SRK Consulting has undertaken pit water quality modelling for Ross Mining (SRK Consulting 1999). Pit water quality is currently being assessed by Dr Steven Dobos. Therefore, no further modelling of the pit water quality was undertaken as part of this study. Additionally, the results of water quality measurements of pit waters undertaken in August and November 1999 were provided by Tony Dwyer, Environmental Coordinator, Yandan Gold Mine. The August water quality measurements were for total concentrations, but the pit waters are very clear and acidic (Plate 2). Therefore, the majority of the measured total concentrations would likely be for dissolved ions.

Ross Mining has conducted water quality monitoring in the Suttor River downstream of the mine and some pre-development water quality measurements are available for river waters (SRK Consulting 1999). However, the river waters are typically very turbid, particularly during flood flows, and only total concentrations were determined except for the November 1999 samples. Several key parameters that would be required for modelling of metal partitioning between dissolved and solid phases in the river waters, such as buffering capacity, total suspended solids concentrations, particle cation exchange capacities, and dissolved organic carbon concentrations, are poorly- or un-characterised for the river waters, particularly for flood events. Therefore, detailed chemical modelling of river water quality during an outflow event was not possible within the scope of this study.

Rather, "worst-case" predictions were made using simple mass-balance methods assuming that:

- 1 All dissolved ions would remain in solution during the mixing of pit and river waters; and
- 2 No additional release of ions from particulate phases would occur.

Mixing was generally assumed to include the complete pit outfall and river flow, but the potential for impacts to occur in the anabranch adjacent to the pit was examined by assuming mixing of the pit water outflow with one third of the total river flow at the ARI two year level, when flows would be confined to the channel network. Note that the river anabranches are connected approximately five kilometres downstream.

This simple modelling will have over-estimated the potential dissolved concentrations of most metals. The Suttor River waters tend to be mildly alkaline (average pH 7.5 in 1998) and with some residual bicarbonate buffering capacity (SRK Consulting 1999), while the pit waters are acidic (measured pH in August 1999 of 2.68 and 3.0). The increase in pH that would result from mixing of the pit waters with river waters would result in precipitation of dissolved metals from the pit waters, including the formation of iron hydroxides that would further scavenge other metals from solution. It is also likely that the natural sediments transported by the flood flows would have considerable metal adsorption capacity and would also remove some metals from solution.

However, these processes could not be fully quantified with the information available. The approach taken in this study is therefore conservative with respect to prediction of the risk of toxicity.

The pit water modelling conducted by (SRK Consulting 1999) indicated that the quality of the pit waters would vary with depth of inundation. The

level of inundation achieved at the time of the site inspection of RL 148 m was below the planned final inundation level of RL165 m. At RL 165 m the majority of the sulphidic materials in the pit walls would be flooded, and further oxidation of sulphides to produce acidic leachates would be minimised. Consideration has been given to raising the pit water level to RL 165 m by pumping during the coming wet season.

The water quality in the pit in August and November 1999 was similar to that predicted by (SRK Consulting 1999) for that level of inundation, but somewhat worse than that predicted for RL 165 m. Both the measured November 1999 and predicted RL165 m water qualities were used as initial conditions in the receiving water quality assessments for this study. Where the measured concentrations were below the detection limit, a value of half the detection limit was used in the calculations. Additionally, the cases that the outflow water quality matched that of the measured November and predicted RL 165 m concentrations, or that these concentrations were diluted by river water inflows to RL 173 m prior to outflow were considered. Both the combined river and pit derived concentrations and the pit water induced additions to the river water concentrations were estimated.

Receiving Ecosystem Impact Assessments

The potential for adverse receiving water ecosystem impacts were assessed by comparison of the predicted "worst-case" water quality with ecosystem protection guidelines. The (ANZECC 1992) guidelines were used in the first instance, but these are chronic guidelines intended to provide ecosystem protection over long-term exposures. As flood induced outflows from the Yandan pit would be expected to be restricted to time periods of a few hours to a few days, the USEPA acute guidelines were used to indicate the potential for ecosystem impacts to result from short-term exposures.

If the predicted mixed water concentrations exceeded the guideline values for a parameter, that would indicate a potential risk of adverse impact. However, due to the assumptions used in the predictions this could not be taken as an indication that adverse impacts would occur. Rather it would indicate that more detailed modelling or analysis of water quality would be required to better quantify the risk. If the predicted mixed water concentrations were below the guidelines values adverse impacts would be very unlikely to result from those concentrations.

As the mixing of the pit and river waters would not be instantaneous, some sections of the river would be exposed to unmixed or partially mixed pit waters. The extent of such exposure was not modelled, but comparisons between the pit outflow rate and the river flows permitted assessment of the potential relative extent of the flows.

The potential risks of adverse receiving water ecosystem impacts were also set in the context of the composition of the ecosystems, and the presence or absence of sensitive species, or species of restricted abundance or distribution.

Plate 2. View of the pit water near the main access ramp, showing the high water clarity.



Results

Geomorphology of the Suttor River Near Yandan

The Burdekin River system is the fifth largest in Australia, with a total catchment area of about 130,000 km², of which the Suttor and Belyando Rivers contribute about 74,000 km² combined. The Suttor River is a sand bed river exhibiting fluvial features commensurate with a highly variable flow and discharge regime. The flood magnitude index (defined as the standard deviation of the log₁₀ of the annual maximum series) is 0.53, which is high by Australian standards and extreme by world standards. This is partly due to cyclonic activity.

The form of the river is also dominated by catastrophic flooding, with a peak flood of over 10,000 cubic metres per second recorded in February 1974 (from data between 1967 and 1999). Four separate floods of over 5,000 m³s⁻¹, and 14 of over 2,000 m³s⁻¹ have been recorded. Eighty-three percent of the mean annual discharge occurs between January and April. The data indicate that the large floods normally persist for periods of days, although most of the channel re-working and sediment transport would occur at the start of the flood (the "rising limb" of the hydrograph), when the energy gradient, boundary shear stress and sediment transport rates are highest. Anecdotal data from the Burdekin (Fielding and Alexander 1996) indicate that a flood wave will often arrive as a "bore", travelling at high velocity and carrying a variety of large debris. Unpublished research, by A.J. Markham, for the Don River indicates that 90% of the sediment load is transported during 20% of the total time, and this is expected to be similar for the Suttor. Conversely, the Suttor has zero flow for approximately 45% of the time. Flood recession tends to occur slowly over several days.

The sediment load is expected to be predominantly a silty-clay washload, and a bed material load of medium-fine sand. The form of rivers that are characterised by peak floods of more than 10 times the mean annual flood (as is the case for the Suttor) is dominated by such extreme events. Work by Erskine and Livingstone (1999) indicated that such events totally re-work the pre-flood channel, and consequently such rivers are continually recovering from the most recent extreme flood event. Thus, true dynamic channel equilibrium, which is characteristic of rivers in temperate and less variable climates, is rarely achieved for a river like the Suttor.

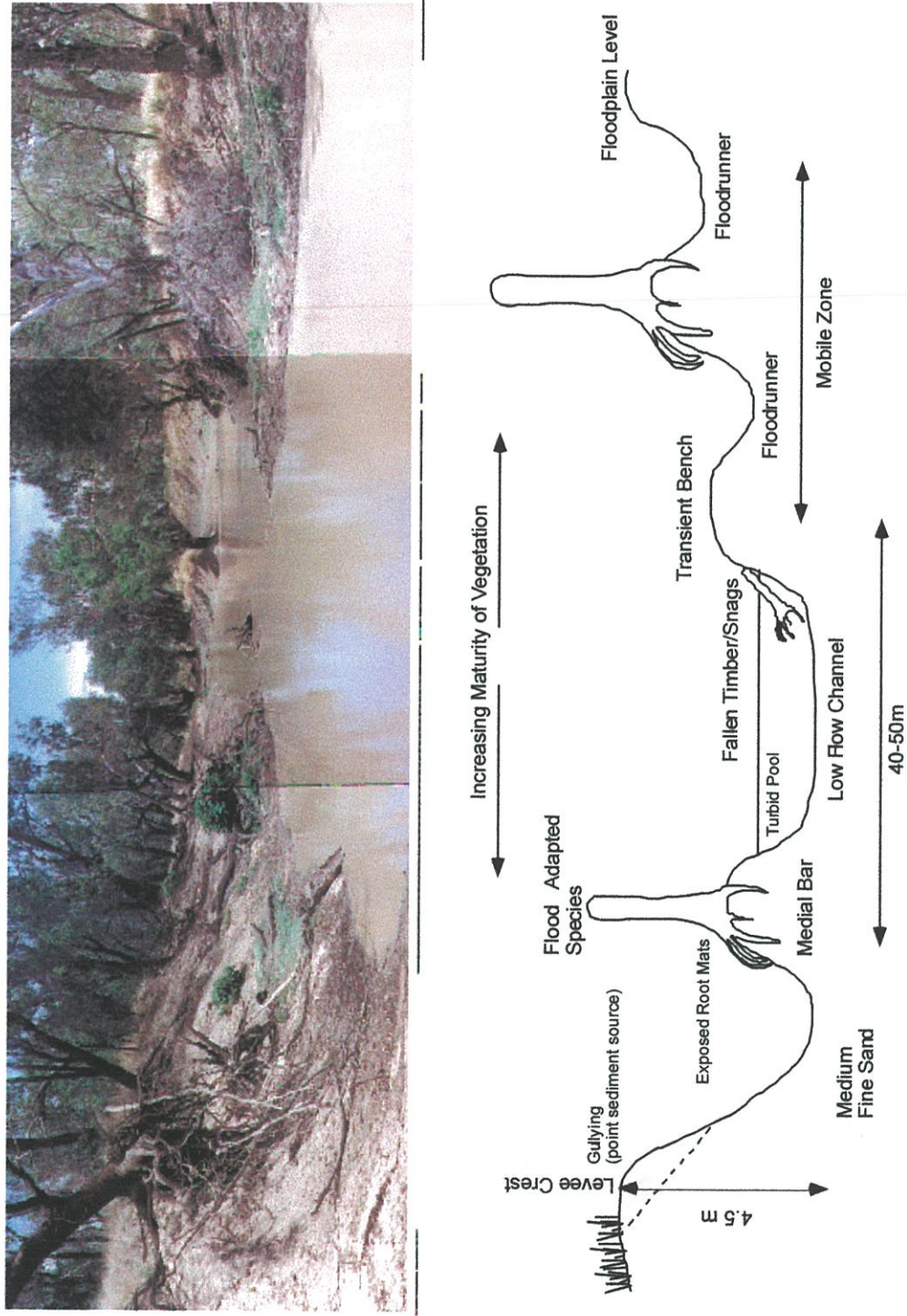
The fluvial features of the Suttor River can be interpreted in the context of the preceding discussion (refer Figure 2). The following section is based on a site inspection approximately 500 m upstream from the diversion inlet. The river is characterised by a low flow channel, with a series of 2-3

benches existing between the low flow channel and the floodplain. "Floodrunners", or elevated secondary channels were observed between the bench sets. The low flow channel and bench sequence were indicative of variable flows, and demonstrated the effect of different bands of "dominant flow". During intermediate floods, the bench sets would generally become mobilised and a single channel slot would form in the floodplain. Typically, as the flow recedes new deposits are formed and a new low flow channel is formed. The boundary material of the Suttor River was observed to be well-sorted and non-cohesive medium to fine sands. These are readily mobile and there is a ready source of sediment from the generally dispersive and sodic soils of the region. Erosion of the banks is ongoing (from fluvial erosion and gully erosion, rather than mass failures) and a large amount of woody debris was observed in the low flow channel. Well-developed levees were observed at the floodplain, formed from the deposition of flood-borne silt in floodplain grasses near the main channel. Flood-adapted vegetation grows in and around the channel with more mature trees found on the outer benches and floodplain.

Habitat Quality of the Suttor River adjacent to the Yandan Gold Mine

(QDNR 1999) state that for the upper Burdekin River system as a whole *"Habitat heterogeneity is low throughout the catchment ...The most common habitat is long stretches of shallow water over a sandy substrate with few aquatic plants and limited presence of snags, instream cover or other structural elements."* (Pearson 1991) found from an aerial video survey that overall the distribution of major habitat types in the upper Burdekin River was 49.9% sand, 7.8% rock, 22.2% riparian vegetation and 27% water. Sand dominated the riverbed, and there were low incidences of large, deep pools and aquatic macrophytes. Similar broad scale habitat assessments for the Suttor River system are not available, but the observations made during the site visit and discussions with other workers indicated that the results of such an assessment for the Suttor River would not differ greatly from that of the upper Burdekin, with the exception that dry-season cover by water would be lower.

Figure 2. Typical geomorphology of the Suttor River anabranch in the vicinity of the Yandan Gold Mine. Average channel width at this site was estimated to be 40 m.



During our site visit, time restrictions permitted only one formal habitat assessment of the Suttor River anabranch adjacent to the mine. The site selected was typical of the channel form in the region examined, but included a large body of standing water. Advice from several mine workers who have been longer-term residents of the area was that no permanent water holes existed in the area upstream of St Anne's Station. Therefore, it can be expected that the standing water observed at the habitat assessment site would dry out for a time in most years.

The findings of the habitat assessment are summarised in Table 2, and the site surveyed is shown in Figure 2. The reach was affected by grazing pressure, which had presumably influenced bank and bed erosion rates, and probably increased the water turbidity. The high erosion rates had resulted in increased scour around tree roots and had contributed to the accumulation of woody debris, which provided the only instream cover apart from open water. The generally sandy sediments and lack of macrophytes would have limited the available micro-habitats for macroinvertebrates and smaller fishes.

Table 2 Summary of the findings of an habitat assessment of the Suttor River approximately 500 m upstream of the Yandan Gold Mine pit

Characteristic	Observation
Reach Environs Disturbance	High Influenced by grazing, mine operations (landscape alteration) and the channel diversion
Channel Habitat Types	20% Run, 80% Pool at the water mark
Bank Instability	Moderate
Bank Susceptibility to Erosion	High
Bed and Bar Condition	Moderate erosion Influenced by bank erosion, fallen trees, channel diversion
Passage for fish and others	No passage at time of sampling, partly restricted passage at the water mark.
Riparian Zone	10% bare left bank, 30 % bare right bank Grasses dominant. Also trees <10 m & trees 10-30 m
Aquatic vegetation	Too turbid for complete survey. None observed
Instream cover types	Individual logs (5% cover), branch piles (1%), tree roots (5%), pool (ephemeral, 80%)
Overall Habitat Rating	Poor

Note however that the habitat description for the reach near the mine would also be applicable for much of the Suttor River system. The channel diversion constructed to keep river flows away from the pit bund was eroding, and had resulted in increased aggradation of the

channel bed downstream of the diversion, but otherwise the mine activities have not noticeably altered the habitat diversity of the Suttor River. Rather, widespread landscape management practices have altered the erosional regime, and contributed to a system wide change in the river morphology since white settlement. (Leichhardt 1847) noted on 20 March 1845, "*The whole river seemed to divide into chains of dry water holes, scarcely connected by hollows.*" This chain-of-pools morphology is no longer typical of the Suttor River. Although isolated large waterholes still exist, their habitat status has changed, particularly with regard to macrophyte distributions, as noted below. This change in morphology has resulted in a reduced extent of dry season refugia, which in turn makes those refugia that remain more critical to overall ecosystem maintenance.

Suttor-Burdekin River System Aquatic Flora and Fauna

Fishes and Crustaceans

Despite its large size, the Burdekin River system is characterised by a low diversity of fishes and crustaceans. (Pusey et al. 1998) collected 25 fish species from the river system, including one introduced species, and noted that other surveys had collected an additional five species. They also noted that many other north Queensland river systems of smaller size support as many or more fish species. They attribute the relatively low diversity in the Burdekin to the barrier to upstream movement formed by the Burdekin Falls and Gorge, an ancient feature that is now the site of the Burdekin Falls dam, and possibly to the present and past extreme environmental conditions of the inland sections of the river system.

The fish and crustacean faunas of the Burdekin River system have been influenced by the recent translocation of non-resident species from other parts of north Queensland. Sleepy cod, *Oxyeleotris lineolatus*, were translocated from the lowland reaches to above the Burdekin Falls in the 1970s (Pusey et al. 1998). Anecdotally, these are continuing to spread through the system as a "wave" (Pusey pers. comm.), and have become locally extremely abundant (Tait pers. comm.).

The yellowbelly, *Macquaria ambigua*, has been translocated into the Burdekin River system probably since 1976, as it was not recorded at that time from the Mount Douglas region (Midgley, cited in Australian Centre for Tropical Freshwater Research ((ACTFR 1999), but is now widespread in the Suttor-Belyando river system (ACTFR 1999). The source of the translocated specimens of this species was probably from the western flowing streams of the Lake Eyre drainage division in north Queensland.

The red-claw crayfish, *Cherax quadricarinatus*, a native of the Gulf of Carpentaria drainage division, is also now widespread in the Suttor-

Belyando river system, and may be displacing the resident *Cherax ? destructor*¹ (ACTFR 1999)).

(ACTFR 1999) collected 12 fish species and four crustacean species from five sites in the Belyando River catchment. In addition, they noted that four species had been recorded from that area by Midgley (*op. cit.*) but were not included in their collections. The combined species are listed in Table 3. (ACTFR 1999) noted that the absence of eels was consistent with a long-term trend in the reduction of their abundance in the Burdekin upstream of the Burdekin Falls dam since its construction in 1987. They suggest that the decline in the abundance of this top-level predator has facilitated the proliferation of red-claw crayfish in the river system, to the detriment of the native crayfish. Red-claw crayfish attain larger sizes than do *C. ? destructor*, and may not be as prone to predation by fish predators other than large eels.

Table 3 Fish and Crustacean Species Recorded from the Sutor-Belyando River System. Species highlighted in bold were not collected by (ACTFR 1999). * indicates species not native to the catchment.

Family	Species	Common Name
<i>Fishes</i>		
Ambassidae	<i>Ambassis agassizi</i>	Agassiz's glassfish
Anguillidae	<i>Anguilla reinhardtii</i>	Long-finned eel
Atherinidae	<i>Craterocephalus stercusmuscarum</i>	Fly-specked hardyhead
Clupeidae	<i>Nematalosa erebi</i>	Bony bream
Eleotrididae	<i>Hypseleotris galii</i>	Firetail gudgeon
	<i>Mogurnda adspersa</i>	Purple-spotted gudgeon
	<i>Oxyeleotris lineolatus</i> *	Sleepy cod
	<i>Philypnodon grandiceps</i>	Flathead gudgeon
Melanotaeniidae	<i>Melanotaenia splendida</i>	Eastern rainbowfish
Percichthyidae	<i>Macquaria ambigua</i> *	Yellowbelly
Plotosidae	<i>Neosilurus ater</i>	Narrow-fronted tandan
	<i>Neosilurus hyrtlii</i>	Hyrtl's tandan
	<i>Porochilus rendahlui</i>	Rendahl's tandan
Terapontidae	<i>Leiopotherapon unicolour</i>	Spangled perch
	<i>Scortum parviceps</i>	Small-headed grunter
Toxotidae	<i>Toxotes chatareus</i>	Seven-spot archerfish
<i>Crustaceans</i>		
Parastacidae	<i>Cherax ? destructor</i>	Native crayfish
	<i>Cherax quadricarinatus</i> *	Red-claw crayfish
Atyidae	<i>Caridina</i> sp.	Brush-claw shrimp
Palaemonidae	<i>Macrobrachium australiense</i>	Big-arm prawn

Similarly, they suggest that the introduction of the predatory sleepy cod and yellowbelly may have adversely affected the populations of smaller prey fish species such as glassfishes, rainbowfishes, hardyheads and small gudgeons. Pusey (pers. comm. and cited in ACTFR 1999) has

¹ The taxonomy of the *Cherax destructor* species complex is undergoing revision. The populations of the Burdekin catchment may represent a distinct species or sub-species.

observed that the introduction of sleepy cod has resulted in the loss or reduction in the abundance of purple-spotted gudgeons in the upper Burdekin River.

Another factor suggested by (ACTFR 1999) that may have contributed to the decline in the abundances of small fish species was the limited extent of macrophytes, that are often favoured by such species as breeding, feeding and predation refuge sites (see below). Increased turbidity and reduced riparian vegetation cover caused by grazing pressure were suggested as possible causes of the absence of seven-spot archerfish in the recent collections. Archerfish are visual predators that consume terrestrial insects dislodged from overhanging vegetation via water ejected from the mouth.

Conservation status of fishes and crustaceans

None of the fish species in Table 3 are listed by the Australian Society for Fish Biology as endangered, threatened or vulnerable (ASFB Threatened Fishes Committee 1998), although the small-headed grunter is listed as restricted (or IUCN category - data deficient) because it is restricted to the Burdekin River system. Depending on its taxonomic status, the Burdekin River native crayfish, *Cherax ? destructor*, may also have a restricted distribution, and it may represent a species or sub-species that is currently threatened by the spread of the competitive red-claw crayfish. Note that it is not currently restricted to the Suttor River sub-catchment.

Macroinvertebrates

Studies of the macroinvertebrate fauna of the Burdekin River system have been very limited in extent, and for the section of the catchment above the Burdekin Falls and Gorge appear to have been limited to the studies described by (Pearson 1991). Those studies were limited to collections at eight sites in the upper Burdekin River and five sites below the Burdekin Falls. This literature review was unable to locate any published results of sampling of the Suttor-Belyando River system.

The macroinvertebrate fauna of the upper Burdekin River was found by Pearson (1991) to have low diversity, but high abundance of some taxa. The fauna was typically dominated by the mayfly, *Tasmanocoenis*, the midge families Ceratopogonidae and Chironomidae, Ecnomidae caddisflies, beetles, particularly Helminthidae, mites, mussels and worms (Oligochaeta). Some other taxa, such as the mayfly *Baetis* sp., blackflies, *Simulium* sp., and Hydroptilidae caddisflies had restricted distributions but were locally very abundant. Macroinvertebrate community composition differences between sites were found to be related mostly to sediment type and particle size, current velocity, and the amount of particulate organic matter in the sediment. The more abundant species were benthic detritus feeders.

No plankton were found apart from the larvae of the shrimps *Caridina* sp. and *Macrobrachium australiense*.

The Suttor-Belyando macroinvertebrate fauna can be expected to be similar to that of the upper Burdekin, with some modification due to the more ephemeral river flow in the southern part of the catchment. Studies of ephemeral streams in north Queensland have shown that the macroinvertebrate fauna tends to be dominated by species that readily disperse between isolated water bodies, particularly via flighted adult stages, including beetles, such as *Dytiscidae*, and bugs, such as *Notonectidae* and *Corixidae*, (eg (Smith and Pearson 1987). This high dispersal capacity is obviously advantageous for recolonisation after re-flooding of dried water holes.

Conservation status of macroinvertebrates

No threatened or endangered macroinvertebrate species have been identified from the Burdekin River system above the Burdekin Falls and Gorge, although some species have been found to be rare components of the macroinvertebrate fauna. All the taxa listed by (Pearson 1991) have widespread distributions.

Aquatic Flora

(QDNR 1999) state that there have been no studies of the aquatic flora of the Burdekin River, but cite (Cribb 1984) as listing 25 algal species from the Big Bend area of the upper Burdekin. (CSIRO and Department of National Development and Energy 1980) listed 39 species of aquatic plants found in the lower Burdekin area. The relevance of these species lists to the aquatic flora of the Suttor-Belyando River system is not known, as the region is climatically distinct and biogeographically separated from the lower Burdekin (see above), and freshwater algae assemblages tend to be highly diverse and variable, despite the wide geographic distributions of many species. Pearson (1991) stated that aquatic macrophytes other than filamentous algae were virtually absent from the upper Burdekin River.

(ACTFR 1999) noted that macrophytes had minor distributions at all the sites they sampled in the Suttor-Belyando river system, including a waterhole named Long Weed Lagoon. The name of the latter suggests that macrophytes were once in greater abundance there. In his journal of the expedition from Moreton Bay to Point Essington, (Leichhardt 1847) noted "*The bed of the Suttor was rather shallow, sandy and irregular with occasional patches of reeds; its left bank was covered with scrub; but well grassed flats with bastard-box and ironbark were on its right.*" Earlier he had noted of a tributary stream that "*Its bed was sandy, occasionally filled with reeds and contained numerous water holes particularly where the sandstone rock formed more retentive basins.*" The higher turbidity experienced by the river system in more recent times has probably contributed to reduced

macrophyte abundance, and therefore reduced habitat availability for small fish and other macrophyte dependant species.

Conservations status of aquatic flora

As very little is known about the aquatic plant species resident in the Suttor River system, the conservation status of them cannot be assessed. However, anecdotal and historical evidence suggests that the extent and abundance of aquatic macrophytes has been severely reduced. Macrophyte stands may now constitute an important habitat of limited distribution, which in turn is limiting the abundance of fauna dependant upon such habitats.

Hydrology of Pit Water Outflow

The following section provides an analysis of pit outflow rates for the spillway elevations described in Table 1, in addition to consideration of a breach of the bund wall when the pit is full of water and the river level is relatively low.

Scenario: Breach of bund wall due to overtopping and scouring.

This scenario assumes no spillway, and that floodwaters in the Suttor River overtop the bund at RL173 m to fill the pit during an ARI 50-year event. The floodwater in the main river then recedes, leaving the pit full of water. The perched water storage breaches the bund at RL173 m and initiates a catastrophic release.

The US National Weather Service program SMPDBK (simplified dambreak) program was used to simulate the above scenarios. As the elevation of the base of the bund varies around the pit between RL 164.7 m and RL169 m, breaches of the bund from RL 173 m to both these heights were assumed.

Table 4 Hydrological modelling parameters.

	Parameters for breach from RL173 m to RL 169 m	Parameters for breach from RL173 m to RL 164.7 m
Breach development time (minutes)	1.3	2.6
Breach width (metres)	12	24
Maximum Discharge (cumecs)	170	883

The dilution of pit water by Suttor River water during a breach will clearly vary depending on the stage of flow. However, as the elevation (RL) of the base of the lowest part of the bund wall is approximately equal to the elevation (RL) of the invert of the Suttor River channel adjacent to the pit, negligible dilution may be expected under this scenario. We note that our visual observations of the bund indicate

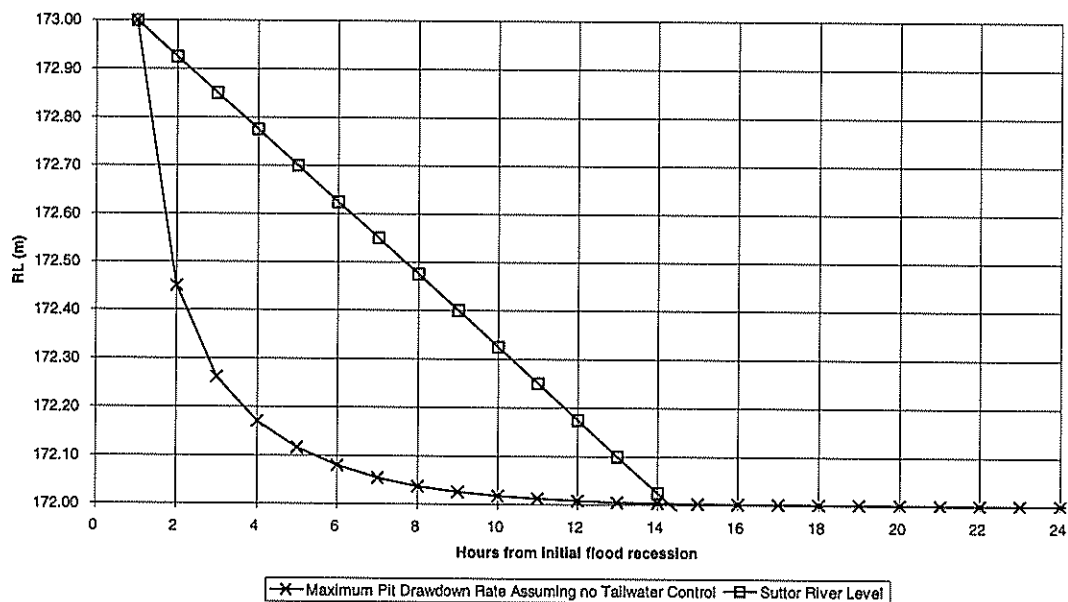
that failure of the bund may be expected during the first over-topping event in the absence of a controlled inlet-outlet structure. The bund is constructed from borrow material which appears to be dispersive and extremely susceptible to water erosion. Rilling, piping and gulying are clearly occurring on the bund. However, failure is likely to occur during inflow when the bund is overtopped from the river side, thus mitigating the potential for catastrophic release during outflow.

The following scenarios consider the outflow of pit water for flood events of different magnitudes. As described above, pit water outflow is expected to be controlled by river tailwater during slow river recession at a draw-down rate of 0.075 m per hour. Therefore, pit outflow is established by computing the pit water volume change.

Analysis indicates that a 15 m wide spillway would be sufficient to allow the pit to draw-down at a rate of 0.075 m per hour. Figure 3 shows the rate of drop of river and pit water levels at 0.075 m per hour, compared with the rate of drop down of the pit water level under free outfall conditions.

spillway
drawdown
river
level

Figure 3. Yandan Pit Maximum Draw-down Rate for 15 m Spillway at RL 172 m.



Scenario: Pit spillway at RL 172 m

Under this scenario, a spillway would be constructed 1 m below the bund crest, at RL 172 m at the ARI 25-year flood level. Results indicate that the river level would drop from RL173 m to the spillway level (RL 172 m) from the ARI 50-year level over approximately 14 hours. Assuming the pit draws down at the same rate, the mean discharge to the Sutor River from the pit is estimated to be $2.7 \text{ m}^3\text{s}^{-1}$. The river discharge after 14 hours is estimated to be approximately $6,500 \text{ m}^3\text{s}^{-1}$. No change to the results is expected to occur for a larger spillway width because the rate of pit discharge is controlled by river tailwater.

Scenario: Pit spillway at RL 171 m

Under this scenario, a spillway would be constructed 2 m below the bund crest, at RL 171 m at the ARI 5-year flood level. The rate of pit discharge and the main river discharge are estimated to be $2.7 \text{ m}^3\text{s}^{-1}$ and $2,600 \text{ m}^3\text{s}^{-1}$ respectively. Draw-down to spillway level from the ARI 50-year level would occur over approximately 28 hours.

Scenario: Pit spillway at RL 169 m

Under this scenario, a spillway would be constructed 4 m below the bund crest, at RL 169 m at the ARI 2-year flood level. The rate of pit discharge and the main river discharge are estimated to be $2.7 \text{ m}^3\text{s}^{-1}$ and $850 \text{ m}^3\text{s}^{-1}$ respectively. Draw-down to spillway level would occur over approximately 54 hours.

Water Quality of Mixed River and Pit Waters

The measured filtered (passing $0.45 \mu\text{m}$) concentrations of aluminium, copper, iron, zinc and lead in the Suttor River waters exceeded the ANZECC (1992) guidelines for ecosystem protection, while the measured concentrations of aluminium and copper exceeded the USEPA acute guideline values. These exceedances of the guideline values by metal concentrations in the river water probably reflected the high clay content, and possibly high dissolved organic carbon concentrations of the turbid waters of the Suttor River, rather than providing a true indication of bioavailable metal concentrations in the river water. Colloidal clay particles can pass through a $0.45 \mu\text{m}$ filter and carry substantial concentrations of these metals. Ponded pools of water on the floodplain of the Suttor were noted to be darkly stained with tannins from *Eucalyptus* and *Melaleuca* leaf litter, indicating a high dissolved organic carbon content in those pools, and therefore potentially in the main river waters as well.

(Hunter et al. 1999) noted *"It is now generally accepted that the fundamental interaction of most metal ions with, for example, metalloenzymes and cell membranes is controlled by the concentration of the free aquo metal cation"*. That is, dissolved free metal ions are the major biologically active form of metals, rather than dissolved metal complexes or particle associated metals. In turbid rivers, the majority of the total metal load in the water column will typically be associated with the particle phase, and dissolved organic molecules can bind much of the truly dissolved metals into biologically inactive forms. As the apparently high metal concentrations in the Suttor River waters do not appear to be toxic to the resident aquatic species, it is likely that either or both of these mechanisms are ameliorating the toxicity of these metals.

The results of the calculated mixed water quality under the scenarios considered are listed in Table 5. However, since the apparently high river water metal concentrations provide a potentially misleading

indication of toxicity, it is more instructive to consider the potential incremental contribution of metals from the pit waters.

The incremental contribution of dissolved metals from the predicted discharge of pit waters (river water concentrations assumed to be 0 in Table 5) is at most about 60% of the ANZECC guideline value for fully mixed pit and river waters except for zinc, but is typically much less. The predicted incremental contributions of metals from the pit water are an order of magnitude or more lower than the USEPA acute guideline values for fully mixed waters. The zinc concentration potentially contributed by pit waters containing the predicted concentration for RL 164 m was calculated to be 9.5 µg/L, which is greater than the hardness dependent ANZECC guideline of 7.5 µg/L.

Where the pit waters are considered to only mix with the river waters in the single anabranch of the Suttor River adjacent to the pit (assumed to be one third of the total flow) the incremental contribution of dissolved aluminium to the river water could exceed the ANZECC guideline value, but not the USEPA acute value, based on the measured concentration of aluminium in the pit waters in November. Also, the calculated concentrations of zinc based on the measured concentration in pit waters in November, and copper and zinc based on the predicted concentration at RL 164 m could exceed the hardness dependent ANZECC guidelines of 3 µg/L for copper and 7.5 µg/L for zinc.

These potential contributions of metals to the Suttor River in excess of the ANZECC guidelines should be considered to imply only that there is the potential for adverse impacts, not as definite indications that environmental impacts would occur. The potential toxicity of these metal contributions would be expected to be ameliorated because:

1. The short duration of outflow would make chronic impacts unlikely to occur. Note that the aluminium, zinc and copper contributions are all well below the USEPA acute guidelines.
2. The change of pH and general water geochemistry between the pit and river waters would be likely to substantially alter the partitioning of metals contained in the pit waters between bioavailable and non-bioavailable forms. The resulting bioavailable fractions can be expected to be much lower than the concentrations predicted by this modelling exercise.
3. For an outflow of pit waters to occur, river water inflow would be required to raise the pit level to at least the spillway level. The resulting mixing of river and pit waters within the pit would dilute the pit waters prior to outflow into the Suttor River.

Table 5. Mass Balance Estimates of Metal Concentrations in the Sutor River Under Several Discharge Scenarios. Predicted concentrations above the ANZECC (1992) guideline values for protection of aquatic ecosystems are highlighted in bold. Predicted concentrations above the USEPA (various) acute guidelines are highlighted in bold-italic-underlined font.

Scenario	Pit Discharge Rate	Minimum River Flow	Resulting river concentrations (µg/L)										Cd	Cr	Ni	Hg
<i>River concentrations assumed to be 0. Pit WQ = maximum measured concentrations of November 1999</i>																
Pit spillway at RL 172m	2.7	6500	7.8	0.1	13.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.00
Pit spillway at RL 171m	2.7	2653	19.2	0.3	32.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.00
Pit spillway at RL 169	2.7	850	59.8	0.8	101.3	5.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.6	0.00
single anabranch	2.7	283	178.4	2.5	302.1	15.6	0.0	0.0	0.2	0.1	0.1	0.1	0.1	0.1	4.9	0.00
<i>River concentrations assumed to be as measured (dissolved). Pit WQ = measured concentrations.</i>																
Pit spillway at RL 172m	2.7	6500	<u>1576.7</u>	<u>8.1</u>	1808.9	31.7	5.0	2.0	2.0	0.1	5.0	5.0	0.1	5.0	5.2	0.00
Pit spillway at RL 171m	2.7	2653	<u>1586.4</u>	<u>8.2</u>	1821.8	32.7	5.0	2.0	2.0	0.1	5.0	5.0	0.1	5.0	5.5	0.00
Pit spillway at RL 169	2.7	850	<u>1621.1</u>	<u>8.8</u>	1867.8	36.3	5.0	2.1	2.1	0.1	5.0	5.0	0.1	5.0	6.7	0.00
single anabranch	2.7	283	<u>1722.3</u>	<u>10.3</u>	2002.0	46.8	5.0	2.3	2.3	0.2	5.0	5.0	0.2	5.0	10.0	0.00
<i>River concentrations assumed to be 0. Pit WQ assumed to be as predicted for RL 164</i>																
Pit spillway at RL 172m	2.7	6500	3.7	0.2	19.9	1.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.00
Pit spillway at RL 171m	2.7	2653	9.2	0.4	48.8	3.1	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.9	0.00
Pit spillway at RL 169	2.7	850	28.5	1.3	152.0	9.5	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	2.8	0.00
single anabranch	2.7	283	85.0	3.8	453.1	28.3	0.0	1.9	1.9	0.0	0.0	0.0	0.0	0.0	8.5	0.00
<i>River concentrations assumed to be as measured (dissolved). Pit WQ assumed to be as predicted for RL 164.</i>																
Pit spillway at RL 172m	2.7	6500	<u>1573.1</u>	<u>8.2</u>	1819.2	32.2	5.0	2.1	2.1	0.1	5.0	5.0	0.1	5.0	5.4	0.00
Pit spillway at RL 171m	2.7	2653	<u>1577.6</u>	<u>8.4</u>	1847.0	34.0	5.0	2.2	2.2	0.1	5.0	5.0	0.1	5.0	5.9	0.00
Pit spillway at RL 169	2.7	850	<u>1593.5</u>	<u>9.2</u>	1946.3	40.4	5.0	2.6	2.6	0.1	5.0	5.0	0.1	5.0	7.8	0.00
single anabranch	2.7	283	<u>1640.1</u>	<u>11.7</u>	2236.1	59.0	5.0	3.9	3.9	0.1	5.0	5.0	0.1	5.0	13.4	0.00
<i>Pit WQ assumed to be measured concentrations diluted to RL 173 by river water.</i>																
Pit spillway at RL 172m	2.7	6500	<u>1574.6</u>	<u>8.1</u>	1806.1	31.5	5.0	2.0	2.0	0.1	5.0	5.0	0.1	5.0	5.2	0.00
Pit spillway at RL 171m	2.7	2653	<u>1581.3</u>	<u>8.2</u>	1815.0	32.2	5.0	2.0	2.0	0.1	5.0	5.0	0.1	5.0	5.4	0.00
Pit spillway at RL 169	2.7	850	<u>1605.3</u>	<u>8.5</u>	1846.9	34.7	5.0	2.1	2.1	0.1	5.0	5.0	0.1	5.0	6.1	0.00
single anabranch	2.7	283	<u>1675.3</u>	<u>9.6</u>	1939.7	41.9	5.0	2.2	2.2	0.2	5.0	5.0	0.2	5.0	8.4	0.00
<i>Pit WQ assumed to be RL 164 prediction diluted to RL 173 by river water</i>																
Pit spillway at RL 172m	2.7	6500	<u>1572.1</u>	<u>8.1</u>	1813.3	31.9	5.0	2.1	2.1	0.1	5.0	5.0	0.1	5.0	5.3	0.00
Pit spillway at RL 171m	2.7	2653	<u>1575.2</u>	<u>8.3</u>	1832.5	33.1	5.0	2.1	2.1	0.1	5.0	5.0	0.1	5.0	5.6	0.00
Pit spillway at RL 169	2.7	850.0	<u>1586.3</u>	<u>8.9</u>	1901.2	37.5	5.0	2.4	2.4	0.1	5.0	5.0	0.1	5.0	7.0	0.00
single anabranch	2.7	283.3	<u>1618.5</u>	<u>10.6</u>	2101.6	50.4	5.0	3.3	3.3	0.1	5.0	5.0	0.1	5.0	10.8	0.00
River water alone			<u>1570</u>	<u>8</u>	1800	31	5	2	2	0.1	5	5	0.1	5	5	
ANZECC (1992) guidelines			100	2-5	1000	5-50	1-5	50	0.2-2.0	0.3	10	15-150	0.10			
Hardness dependent figures				3.0		7.5	1.5								22.4	
USEPA Acute guidelines			750	7.0	--	64.3	32.1	360.0	2.0	16.0	28.0	1.69				

The high measured total metal concentrations in the river waters result in the estimated mixed water concentrations of aluminium, copper, iron, and lead exceeding the ANZECC guideline values and the mixed water concentrations of aluminium and copper exceeding the USEPA acute guideline. However, these calculated exceedances were little affected by the incremental contribution of metal from the pit waters.

Overall then, at the calculated potential outflow rate of pit water at all modelled spillway elevations it is unlikely that the quality of the pit water would adversely affect the water quality of the receiving ecosystems once fully mixed.

As the pit water outflow is much smaller in volume than the river water flows, ranging from a volume ratio of about 1:400 to 1:3,000, even in the absence of mixing the pit outflow would constitute a small proportion of the total river flow (<0.3%). Although the pit water is potentially highly toxic, being highly acidic and containing metal concentrations exceeding the USEPA acute guidelines, any potential impacts to such a small proportion of the total receiving water ecosystems within the mixing zone would be unlikely to result in community or population level impacts, particularly under flood conditions when most species would undergo dispersal.

Therefore our preliminary calculations indicate that a spillway located at RL 169 m (equivalent to the 2-year ARI flow event) would:

- (1) Provide acceptable dilution with river floodwater; and
- (2) Minimise the risk of bund failure through either:
 - (i) A sudden release; or
 - (ii) Gradual erosion.

Although an estimated minimum spillway width of 15 m would allow the pit water level to draw down at the same rate as the falling river level, spillway dimensions should be sufficient to allow the pit water level to rise at the estimated maximum rate of 0.5 m/hr and thereby provide tailwater conditions to prevent excessive velocities across the spillway. Therefore we estimate that a spillway width of 30 m (or 2 x 15 m spillways) would be sufficient for this purpose providing both pit and river levels are approximately equal at the start of the flood. These figures should be verified during spillway final design.

Discussion

Geomorphic and Biological Characteristics of the Suttor River System

The Suttor River is a large, braided sand-bed river that experiences highly variable flows. Because of this high flow variability, the channel form is dominated by the influence of catastrophic flood events. Our brief inspection of the river reach adjacent to the Yandan Gold Mine, coupled with a literature review, indicated that much of the Suttor River channel is experiencing ongoing erosion, that has probably been exacerbated by grazing activities over most of the catchment. Certainly, the channel form has altered greatly from that observed by (Leichhardt 1847) last century, and this has resulted in a reduction in the extent of standing water habitat. In ephemeral rivers, such habitats are crucial to ecosystem maintenance during drought periods, and the reduction in their extent will have reduced the sources of recolonisation of aquatic habitats following re-flooding.

The Burdekin River system is characterised by low biological diversity and low habitat diversity overall, and the few studies of the fauna and flora of the Suttor-Belyando River system suggest that this is true also for that part of the catchment. The fish and crustacean faunas of the Suttor-Belyando have been adversely impacted by the introduction of non-native predators and competitive species, and the exclusion of eels, the top-level predator, by construction of the Burdekin Falls dam. Macrophyte distribution and abundance has been reduced by the increased turbidity since last century, and macrophyte stands are now minor habitat components. This in turn has affected the distribution and abundance of small fishes, and presumably macroinvertebrates, that are dependant upon macrophytes for feeding, breeding sites and avoidance of predators.

No threatened or endangered aquatic species have been recorded for the Suttor-Belyando catchment, but some native species are in low abundance due to the effects noted above. One endemic fish species, the small-headed grunter, occurs in the Burdekin River system, but it is not restricted to the Suttor-Belyando sub-catchment.

Hydrological Modelling of Pit Water Outflow

A key finding of this study was that because of the slow rate of fall of the river level following flood flows, the potential rate of outflow of the Yandan Pit water following flood incursion will be low provided the outflow spillway is of sufficient size to permit the pit water level to fall at the same rate as the river level. Our modelling indicates that any spillway design with a width of 15 m or more would be sufficient for this purpose, including complete removal of the existing bund. However, a spillway width of 30 m (or 2 x 15 m spillways) would allow the pit water

level to rise at the same rate as the river, utilising tailwater conditions during a rising flood and preventing excessive spillway velocities.

Failure of that bund would be most likely to occur during the rising stage of a flood, when the current velocities are greatest, the differential between the river and pit levels would be greatest and therefore the potential erosion rates would be greatest. This would not result in a catastrophic outflow of pit water as the subsequent river tailwater would control the pit water outflow rate as would occur for a designed spillway.

Nevertheless, it is recommended that construction of an engineered spillway or complete removal of the bund would be preferable to bund failure.

As the pit water quality is currently very poor, the unlikely scenario of incomplete scour of the bund during overtopping by a flood flow, followed by catastrophic failure of the bund and release of the contained pit waters into the river during a period of low flow, would have unquantified but undoubtedly detrimental environmental effects. That scenario could be readily avoided by construction of a spillway of at least 15 m width. Construction of a larger spillway (30 m) would allow the pit water level to rise at the same rate as the river during a rising flood.

Mass Balance Modelling of Pit and River Water Quality

Although the pit waters are of poor quality and potentially acutely toxic to aquatic organisms, at the calculated potential mixing rates they would not be expected to cause acute, or short term ecosystem impacts once mixed with the river waters during outflow. As the mixing models used assumed no precipitation of metals in the mixed waters, this result can be considered to be highly conservative.

However, there may be some unquantified, but presumed low, potential for chronic aluminium, copper and zinc toxicity to occur during outflow, if the outflow were to occur over sufficient duration for the development of chronic toxicity. This risk is largely confined to outflows restricted to the single anabranch adjacent to the Yandan pit, except under the assumption that the pit water zinc concentration is that predicted for RL 164 m prior to outflow.

This potential for chronic toxicity is based upon simple mass balance modelling, and would be likely to be eliminated by the geochemical changes that would occur during mixing of the pit and river waters both within the pit prior to outflow and in the river channel during outflow. It is recommended that the potential concentrations of these metals in the receiving waters be better estimated by conducting laboratory-based mixing of pit and river waters.

Unmixed pit waters could cause localised impacts, but this would constitute a minor proportion of the total river flood flow. Construction of two spillways, including inlet and outlet, could provide an additional benefit of within-pit mixing of river and pit waters both during inflow and outflow. This would ensure at least partial mixing of pit and river waters, and would ameliorate the minor potential for adverse impacts of un-mixed pit waters released into the river channel.

The measured river water filtered metal concentrations exceeded a number of ecosystem protection guidelines. This was not due to mine influence, but rather was probably caused by the high turbidity and/or dissolved organic carbon concentrations of the river waters. It is recommended that dissolved, rather than total, metal concentrations should be continue to be monitored in future to provide a better indication of the potentially bioavailable metal fraction in the river waters than is provided by total metal concentration determinations.

Finer than 0.45 µm filters or ultra-filtration may be required to eliminate the majority of the colloidal sized particles that may be substantially contributing to the observed metal concentrations. Better characterisation of the river water quality will be required to enable improved prediction of the potential for ecosystem impacts from pit water outflow. It is also recommended that during an outflow event, the pit and river water quality should be monitored, particularly as the river level approaches the spillway level on the falling hydrograph, and the extent of dilution of pit water with river water is at a minimum.

The potential for environmental impacts to occur as a result of pit water outflow should be considered in the context of a biota comprised of species with widespread distributions that are adapted to recovery from the naturally extreme conditions of drought and flood, and should also take into account the major system-wide impacts to the aquatic communities that have resulted from grazing pressure and translocation of non-native predatory and competitive species. It should also be noted that the anabranch that would receive any outflow from the Yandan pit does not contain permanent water holes that would serve as the sources of recruits for recovery from natural or anthropogenic impacts, nor does it contain any aquatic macrophyte stands, a limiting habitat in the river system. Furthermore, any discharge from the pit would be expected to occur during a flood event, a period of high natural ecosystem stress and a period during which widespread re-dispersal of aquatic species would occur.

Acknowledgements

We wish to thank Ross Mining N.L. for the opportunity to undertake this study, and particularly for the assistance and support provided by Tony Dwyer.

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0018-5158

8 October 2013
Project Number 111207

LRS Environmental Pty Ltd
PO Box 44
James Cook University
QLD 4818

Attention: Gil Fletcher – Managing Director

Dear Gil,

Subject: Geochemical Assessment of TSF Cell B cover materials, tailings and heap leach rocks at Yandan Gold Mine

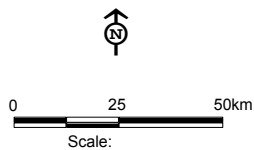
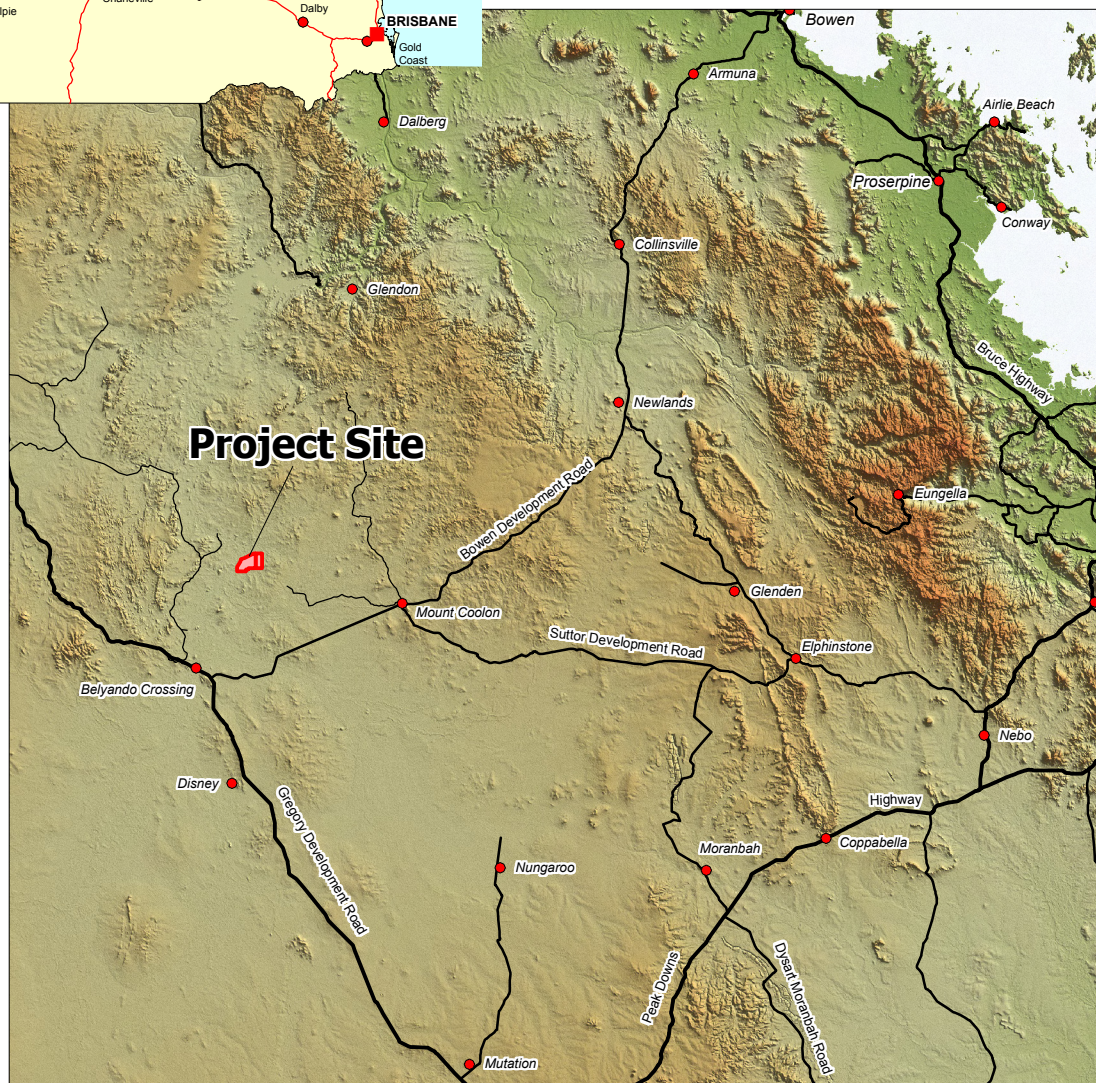
1.0 INTRODUCTION

RGS Environmental Pty Ltd (RGS) was commissioned by LRS Environmental Pty Ltd (LRS) on behalf of Straits Gold Pty Ltd to complete a geochemical assessment of Tailings Storage Facility (TSF) Cell B cover materials, underlying tailings and heap leach material from Yandan gold mine. The mine (now decommissioned) is located in the northern Drummond Basin of North Queensland, 230 km west of Mackay (**Figure 1**). The TSF is divided into two cells (Cells A and B) and Cell B has a trial rehabilitation cover system at the south eastern corner of the facility comprising oxidised waste rock material (**Figure 2**). RGS has been provided with representative samples of the TSF cover, tailings and heap leach materials for geochemical assessment.

2.0 SCOPE OF WORK

The RGS scope of work comprised:

1. Coordination of static geochemical tests for 32 TSF Cell B cover samples, 15 tailings samples and 6 heap leach rock samples supplied by LRS.
2. Completion of a kinetic geochemical test (kinetic leach column (KLC) test on a composite sample of heap leach rock.
3. Tabulation and interpretation of acquired static and kinetic geochemical test data against applied environmental guidelines.
4. Provision of a letter report (this report), which provides the geochemical test results and the RGS interpretation of the results.
5. Provision of preliminary recommendations for the management of selected mine materials with respect to potential Acid and Metalliferous Drainage (AMD) issues.



Source: This product incorporates data which is:
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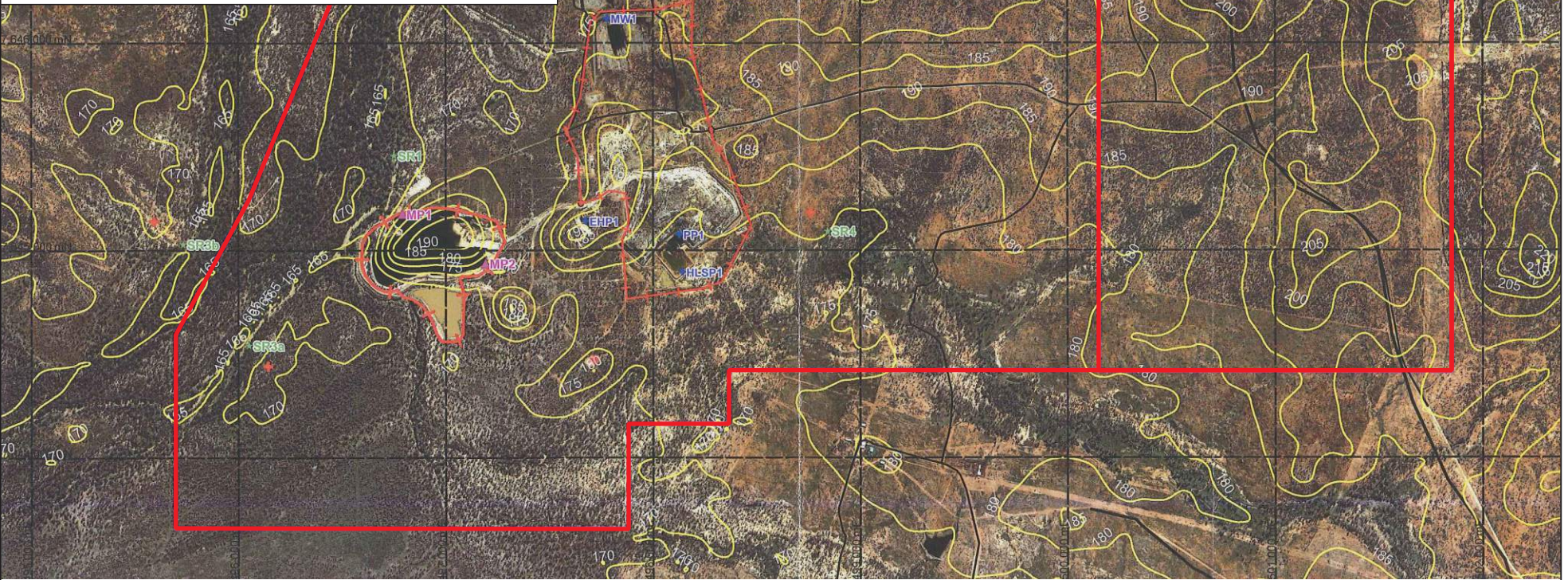
RGS Environmental Pty Ltd
18 Inglis Street, Grange, QLD 4051
Tel/Fax +61 7 3856 5591
Mobile 0431 620623
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File: 111207 001 A4
Date: 08/10/2013

LRS ENVIRONMENTAL PTY LTD

YANDAN PROJECT

Figure: 1
LOCATION MAP

INSET: Geochemical Sample Locations



**Yandan
Tailings
Storage
Facility**

SEE INSET

3.0 METHODOLOGY

A brief explanation the parameters typically involved in undertaking a geochemical assessment of mine waste materials using static and kinetic geochemical tests is provided at **Attachment A**.

3.1 Sampling

A total of 32 TSF Cell B cover samples, 15 tailings samples and 6 heap leach rock samples were supplied to RGS by LRS in August 2012. The TSF Cell B cover and tailings samples were selected to represent cover and underlying tailings materials at the rehabilitation trial (**Figure 1**) and were obtained at selected intervals along a transect at the south eastern corner of TSF Cell B (**Figure 2**). The heap leach rock samples were taken to represent the range of heap leach rock types present at the mine site.

3.2 Laboratory Testing

Static Tests

The 53 samples received and viewed by RGS and then transferred to ALS in Brisbane for geochemical testing using standard methods and guidelines accepted in the mining industry (AMIRA, 2002; DITR, 2007; DME, 1995, Parker and Robertson, 1999; and INAP 2009). All samples were pulverised and tested for:

- pH (1:5 w:v),
- Electrical Conductivity (EC) (1:5 w:v).

The 6 heap leach rock samples were also tested for

- Total sulfur [LECO method];
- Acid Neutralising Capacity [AMIRA, 2002]
- Net Acid Producing Potential (NAPP).

This range of tests is called Acid-Base Account (ABA) tests and is a useful method for screening of samples prior to completing additional multi-element testing on a smaller number of composite samples.

The results of the initial geochemical tests were used to select a composite sample of heap leach rock material (comprising equal proportions of the 6 individual samples) for multi-element (total metal) testing. The composite heap leach rock sample was tested for:

- Total metals (Al, As, B, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, N, Ni, Sb, Se, V, Zn) in solids [HCl and HNO₃ acid digest followed by ICP-AES and selected ICP-MS];
- Total chromium [HCl and HNO₃ acid digestion with ICP-AES analyses];
- Total mercury [FIMS method];
- Total cations (Ca, Mg, Na, K) and Exchangeable cations (Ca, Mg, Na, K);
- Cation Exchange Capacity (eCEC); and
- Exchangeable Sodium Percentage (ESP).

Kinetic Leach Column Tests

The intent of the kinetic leach column (KLC) program was to characterise the leachate from the composite heap leach rock sample when subjected to routine wetting and drying, simulating exposure to ‘atmospheric conditions’. The leachate collected from the column was analysed to determine various water quality parameters including concentration of soluble metals/metalloids, salts and nutrients. The KLC method generally followed the AMIRA (2002) guideline method. Some modifications were necessary, and justified, to suit the type of materials being analysed. The KLC set up used in this project is described and illustrated at **Attachment A**.

For the KLC test approximately 2,000 cm³ (1.562 kg) of crushed rock was loosely packed into a Buchner column, connected above a Buchner funnel. The base of the column (above the funnel) was lined with a filter membrane. The membrane acted to retain fine sediment from flushing into the collection bottle. The entire unit was supported on a shelf to allow a collection bottle to sit under the funnel and a heat lamp was mounted approximately 25 cm above the column and maintained a surface temperature of approximately 30-35°C.

The column was subjected to routine de-ionised water addition and subsequent heating using a heat lamp to simulate the effects of rainfall and sunshine on solids. During leaching events water was initially applied monthly for four leaching events and then quarterly for the final three leaching events (ie. a total leaching period of 12 months). The applied water was allowed to free-drain through the solid samples and was collected and analysed at ALS Brisbane (refer to list of analytes below). At leaching events 1,000 mL of deionised water was slowly added to the top surface of the sample.

The KLC tests commenced in September 2012 and continued until September 2013. Leachate from the composite sample was analysed for:

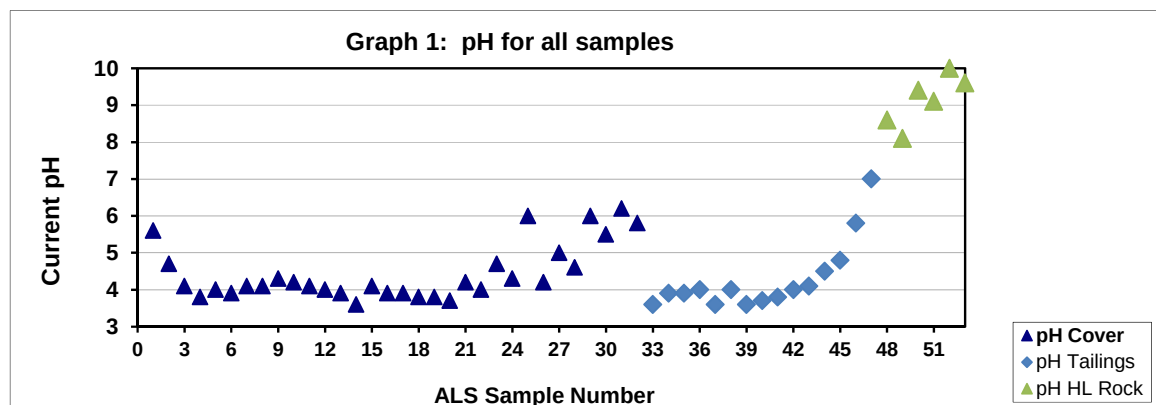
- pH and EC (at RGS sample collection and at ALS Brisbane);
- Alkalinity and acidity (titration as mgCaCO₃/L);
- Soluble metals and metalloids (25 elements) [ICP-AES];
- Soluble mercury [FIMS method];
- Soluble hexavalent chromium [discrete analyser];
- Soluble major cations [ICP-AES];
- Soluble sulfate [ICP-AES];
- Soluble chloride [discrete analyser].

The KLC tests were completed at the RGS Environmental in-house leaching laboratory. Analyses of collected leachates were undertaken at ALS Brisbane. The results for the static and KLC test programs are reported in **Section 4.0** and the laboratory results from ALS Brisbane on all samples are provided at **Attachment B**.

4.0 RESULTS AND DISCUSSION

4.1 pH and EC

- pH:** The pH values for the samples range from acidic to alkaline (3.6 to 10.0). The TSF cover material and tailings typically have reduced pH values with the majority less than pH 5. For the cover materials, there appears to be a strong correlation between sample pH and depth (see **Table 1**) and given that most of the tailings materials have a low pH value, this suggests migration of acidity from the tailings up through the one metre cover profile. In contrast, the pH values for heap leach rock are alkaline and range from 8.1 to 10 (Graph 1).



- EC:** The EC values for the samples range from 48 $\mu\text{S}/\text{cm}$ to 2,620 $\mu\text{S}/\text{cm}$. The TSF cover material and tailings typically have elevated EC values with the majority greater than 500 $\mu\text{S}/\text{cm}$. Again there appears to be a strong correlation between sample EC and depth for cover materials (see **Table 1**), which suggests migration of salts from the tailings up through the one metre cover profile. The few cover samples with relatively low EC values (< 500 $\mu\text{S}/\text{cm}$) are from the top surface of the cover. In contrast, the EC values for heap leach rock are all less than 500 $\mu\text{S}/\text{cm}$ (Graph 2).

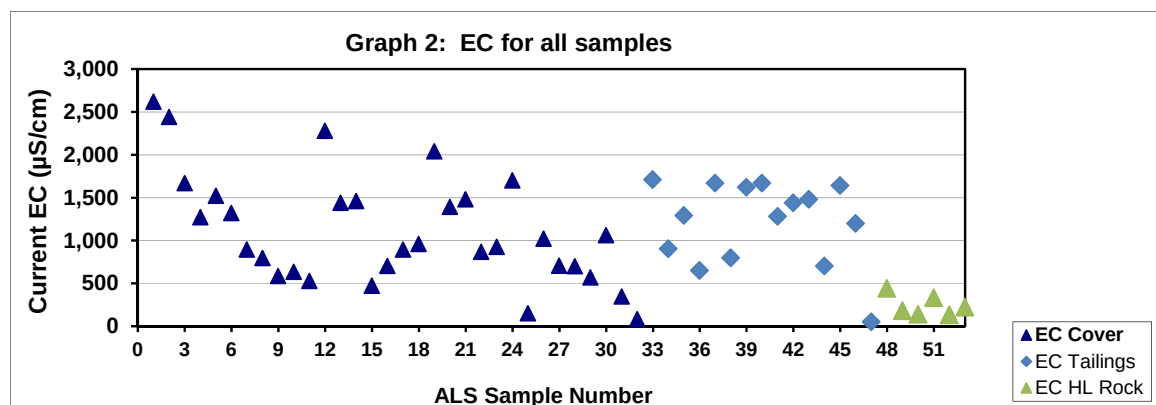


Table 1: Static Gechemical Results for Yandan Project

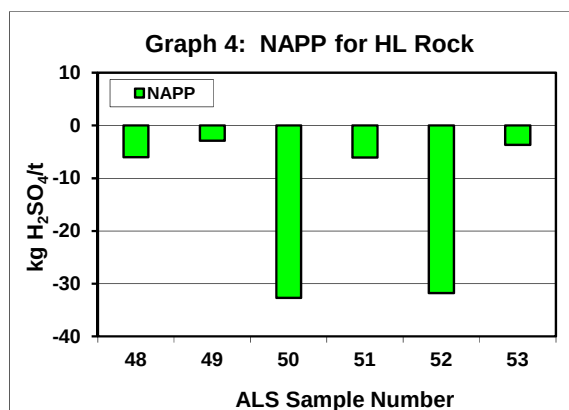
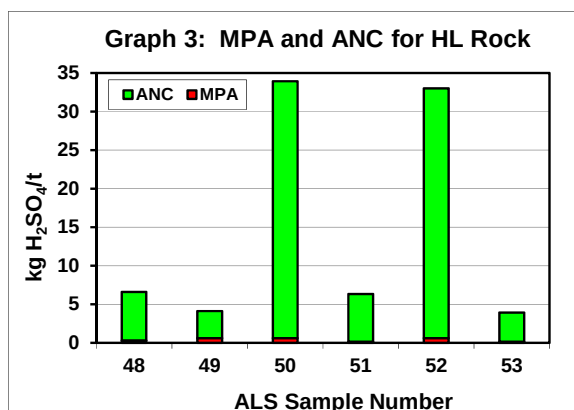
ALS Sample Number	Sample Type & Name/ID	Depth Interval (m)	Sample Location No.	pH ¹	EC ¹ (μS/cm)	Total Sulfur (%)	CRS ²	MPA ²	ANC ² (kg H ₂ SO ₄ /t)	NAPP ²	ANC:MPA Ratio	Classification
TSF CELL B COVER MATERIAL												
EB1221303001	TRT	0-250	1	5.6	2620							
EB1221303002	TRT	250-500	1	4.7	2440							
EB1221303003	TRT	500-750	1	4.1	1670							
EB1221303004	TRT	750-1000	1	3.8	1270							
EB1221303005	TRT	0-250	2	4.0	1520							
EB1221303006	TRT	250-500	2	3.9	1320							
EB1221303007	TRT	0-200	3	4.1	892							
EB1221303008	TRT	200-400	3	4.1	795							
EB1221303009	TRT	0-250	4	4.3	585							
EB1221303010	TRT	250-500	4	4.2	632							
EB1221303011	TRT	500-600	4	4.1	525							
EB1221303012	TRT	0-250	5	4.0	2280							
EB1221303013	TRT	250-500	5	3.9	1440							
EB1221303014	TRT	500-600	5	3.6	1460							
EB1221303015	TRT	0-250	6	4.1	473							
EB1221303016	TRT	250-500	6	3.9	701							
EB1221303017	TRT	0-250	7	3.9	892							
EB1221303018	TRT	250-500	7	3.8	960							
EB1221303019	TRT	0-150	8	3.8	2040							
EB1221303020	TRT	150-300	8	3.7	1390							
EB1221303021	TRT	0-150	9	4.2	1480							
EB1221303022	TRT	150-300	9	4.0	866							
EB1221303023	TRT	0-150	10	4.7	924							
EB1221303024	TRT	150-300	10	4.3	1700							
EB1221303025	TRT	0-250	11	6.0	149							
EB1221303026	TRT	250-500	11	4.2	1020							
EB1221303027	TRT	0-100	12	5.0	704							
EB1221303028	TRT	100-200	12	4.6	698							
EB1221303029	TRT	0-75	13	6.0	568							
EB1221303030	TRT	75-150	13	5.5	1060							
EB1221303031	TRT	0-75	14	6.2	343							
EB1221303032	TRT	0-10	15	5.8	81							
TSF CELL B TAILINGS												
EB1221303033	TRT	0-250	1 (T)	3.6	1710							
EB1221303034	TRT	0-250	2 (T)	3.9	905							
EB1221303035	TRT	0-250	3 (T)	3.9	1290							
EB1221303036	TRT	0-250	4 (T)	4.0	649							
EB1221303037	TRT	0-250	5 (T)	3.6	1670							
EB1221303038	TRT	0-250	6 (T)	4.0	796							
EB1221303039	TRT	0-250	7 (T)	3.6	1620							
EB1221303040	TRT	0-250	8 (T)	3.7	1670							
EB1221303041	TRT	0-250	9 (T)	3.8	1280							
EB1221303042	TRT	0-250	10 (T)	4.0	1440							
EB1221303043	TRT	0-250	11 (T)	4.1	1480							
EB1221303044	TRT	0-250	12 (T)	4.5	701							
EB1221303045	TRT	0-250	13 (T)	4.8	1640							
EB1221303046	TRT	0-250	14 (T)	5.8	1200							
EB1221303047	TRT	0-250	15 (T)	7.0	48							
HEAP LEACH ROCK												
EB1221303048	Heap Leach	-	1	8.6	440	0.01	N/A	0.31	6.3	-6.0	20.6	NAF (Barren)
EB1221303049	Heap Leach	-	2	8.1	181	0.02	N/A	0.61	3.5	-2.9	5.7	NAF (Barren)
EB1221303050	Heap Leach	-	3	9.4	140	0.02	N/A	0.61	33.3	-32.7	54.4	NAF (Barren)
EB1221303051	Heap Leach	-	4	9.1	332	0.005	N/A	0.15	6.2	-6.0	40.5	NAF (Barren)
EB1221303052	Heap Leach	-	5	10.0	131	0.02	N/A	0.61	32.4	-31.8	52.9	NAF (Barren)
EB1221303053	Heap Leach	-	6	9.6	221	0.005	N/A	0.15	3.8	-3.6	24.8	NAF (Barren)

Notes

1. Current pH, EC, Alkalinity and Acidity provided for 1:5 sample:water extracts
2. CRS = Chromium Reducible Sulfur; MPA = Maximum potential acidity; ANC = Acid neutralising capacity; and NAPP = Net acid producing potential.
3. Sample classification detail provided in report text.
4. TRT = Tailings Rehabilitation Trial.

4.2 Acid Base Account

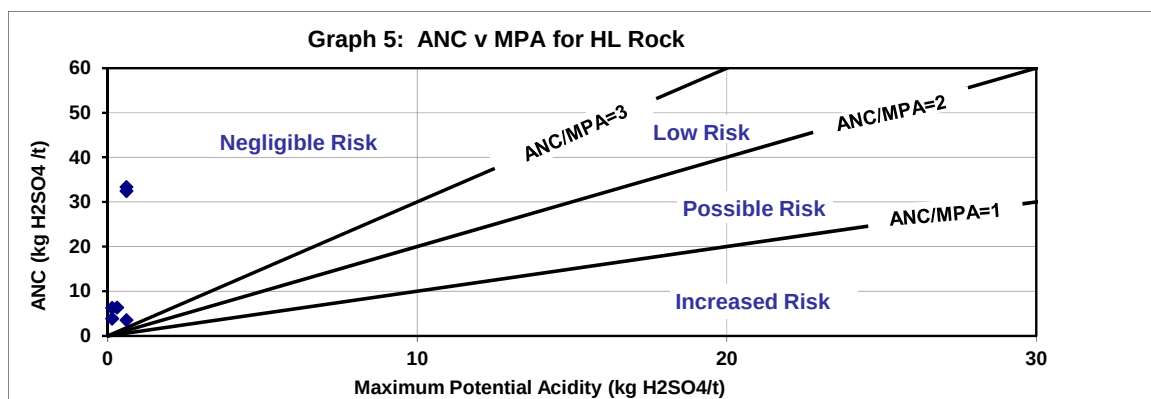
- **Total Sulfur:** The total sulfur contents of the Heap Leach Rock samples range from 0.005% to 0.02% and are typically very low. Mine waste samples with total sulfur content less than 0.1 % are essentially barren of sulfur, generally represent background concentrations, and have negligible capacity to generate acid¹.
- **MPA:** The maximum potential acidity (MPA) that could be generated from these samples through sulfide oxidation ranges from 0.15 to 0.61 kg H₂SO₄/t and is typically very low (**Graph 3**).
- **ANC:** The ANC of the samples ranges from 3.5 to 33.3 kg H₂SO₄/t and is typically moderate and far in excess of the MPA (**Graph 3**).
- **NAPP:** The calculated NAPP value for all of the samples is negative and ranges from -2.9 to -32.7 kg H₂SO₄/t (**Graph 4**). The NAPP is basically the balance between the capacity of a sample to generate acid (MPA) minus its capacity to neutralise acid (ANC).



Graph 5 shows a plot of ANC versus MPA for the Heap Leach Rock samples. The ANC/MPA ratio of the samples ranges from 5.7 to 54.4 and is typically elevated. ANC/MPA ratio lines have been plotted on the graph to illustrate the factor of safety associated with the samples. Generally those samples with an ANC/MPA ratio of greater than 2 are considered to have a low to negligible risk of acid generation and a high factor of safety in terms of potential for acid generation (DITR, 2007; INAP, 2009)². The results shown in **Graph 5** indicate that all of the Heap Leach Rock samples tested have a negligible risk acid generation and a high factor of safety.

¹ The average crustal abundance of sulfur is approximately 0.07 % (INAP, 2009).

² INAP considers that mine materials with an ANC/MPA ratio greater than 2 are likely to be NAF unless significant preferential exposure of sulphides along fracture planes occurs in combination with insufficiently reactive ANC.



4.3 Multi-Element Scans

Multi-element scans were carried out on a single composite sample made up from equal amounts of the six Heap Leach Rock samples, to identify any elements (particularly metals/metalloids) present at concentrations that may be of environmental concern with respect revegetation and groundwater and surface water quality. The assay result for each element was compared to median soil abundance and/or potentially relevant soil guideline criteria to determine any environmental concerns with these materials related to rehabilitation. Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality, or public health, but their significance was evaluated. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (*e.g.* low pH) the geochemical behaviour of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

The multi-element results for the composite Heap Leach Rock rock sample are presented at **Table 2**. The results have been presented alongside:

- median crustal abundance and geochemical abundance index data (in order to provide a comparison against typical background concentrations) (Bowen, 1979); and
- NEPC health based investigation levels (in order to provide a comparison against metal concentrations, which may warrant further investigation) (NEPC, 1999a).

Geochemical Abundance Index

Total metal/metalloid concentrations in mine materials are relevant for revegetation activities or where the potential exists for human contact (*eg.* if the material was to be used off-site). In order to provide relevant context, the total metal concentration of each element reported in the waste rock samples has been compared to median crustal abundance for unmineralised soils (Bowen, 1979; INAP, 2009). The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration with a median (or average) abundance on a $\log_{10}$ scale. The GAI is expressed in integer increments from 0 to 6, where a GAI value of 0 indicates that the

element is present at a concentration less than, or similar to, the median crustal abundance; and a GAI value of 6 indicates approximately a 100-fold enrichment above median crustal abundance. As a general rule, a GAI of 3 or greater signifies enrichment that may warrant further examination.

Table 2 provides total metal/metalloid concentrations for the composite Heap Leach Rock sample. The relative enrichment of metals in the composite sample compared to median crustal abundance (the Geochemical Abundance Index - GAI) is also presented at **Table 2**. The results indicate that the composite sample has no significant element enrichment relative to median crustal abundance apart from antimony (Sb) and arsenic (As).

Australian Guidelines

The assay results for the composite Heap Leach Rock sample can also be compared to potentially relevant guideline criteria to determine any environmental concerns related to rehabilitation. There are no specific guidelines and/or regulatory criteria related to total metal/metalloid concentrations in these materials. In the absence of these and to provide relevant context, RGS has also compared the total metal/metalloid concentration in these materials to NEPC (1999a) background and health-based investigation levels (HIL (E)) for parks and recreational open spaces. The applicability of the NEPC (1999a) health based guideline values stems from the potential final land use of the mine following closure (*eg.* a return to low intensity grazing).

The composite sample has an arsenic concentration (67 mg/kg) that marginally exceeds the NEPC environmental guideline for this element (50 mg/kg) in background soils, but is much less than the HIL (E) guideline value (200 mg/kg). There is no NEPC background and/or HIL(E) guideline value for antimony. The remainder of the metals/metalloids tested are either present at a concentration well within the relevant NEPC guideline value or NEPC guideline values do not exist. Hence, heap leach materials represented by the composite sample should not present a significant risk to the environment with respect to total metal concentrations in solids and rehabilitation.

4.4 Exchangeable Cations and Sodicity

The exchangeable cation results presented in **Table 2** indicate that the effective Cation Exchange Capacity (eCEC) of the composite sample is 21.6 meq/100g, the exchangeable sodium percentage (ESP) is 0.3 %, and the calcium:magnesium ratio is 41.4. From a soil chemistry viewpoint, the materials represented by the composite heap leach sample rock sample are likely to be alkaline and will generally have relatively low salinity levels. The exchangeable cation and sodicity characteristics of the composite sample are also favourable and unlikely to result in any structural stability problems related to potential dispersion and erosion. Hence, materials represented by the composite sample are likely to be suitable for rehabilitation activities at the site.

Table 2: Multi-Element Results and Enrichment for Heap Leach Rock Composite - Yandan Project

Parameters	Detection Limit	NEPC ¹ Background and Health-Based Investigation Levels	Average Crustal Abundance ¹	Concentration	Geochemical Abundance Index (GAI)
Metals/Metalloids	All units mg/kg				No units
Aluminium (Al)	50	-	82,000	850	0
Antimony (Sb)	5	-	0.2	8	5
Arsenic (As)	5	50 (200)	1.5	67	5
Cadmium (Cd)	1	1 (40)	0.11	0.5	2
Calcium (Ca)	50	-	41,000	13000	0
Chromium (Cr) total *	2	(200)	100	4	0
Cobalt (Co)	2	40 (200)	20	1	0
Copper (Cu)	5	100 (2,000)	50	2.5	0
Iron (Fe)	50	-	41,000	9000	0
Lead (Pb)	5	200 (600)	14	2.5	0
Magnesium (Mg)	50	-	23,000	1080	0
Manganese (Mn)	5	850 (3,000)	950	45	0
Mercury (Hg)	0.1	0.03 (30)	0.05	0.05	0
Molybdenum (Mo)	2	-	1.5	1	0
Nickel (Ni)	2	500 (600)	80	2	0
Potassium (K)	50	-	21,000	590	0
Selenium (Se)	5	-	0.05	2.5	0
Sodium (Na)	50	-	23,000	60	0
Vanadium	5	500	160	2.5	0
Zinc (Zn)	5	300 (14,000)	75	6	0
Exchangeable Cations	All units in meq/100g (except ESP in %)				
Exch. Calcium	0.1	-	-	20.7	-
Exch. Magnesium	0.1	-	-	0.5	-
Exch. Potassium	0.1	-	-	0.3	-
Exch. Sodium	0.1	-	-	<0.1	-
Cation Exchange Capacity	0.1	-	-	21.6	-
Exchangeable Sodium Percentage (ESP)	0.1 %	-	-	0.3	-
Calcium/Magnesium Ratio	0.1 %	-	-	41.4	-

Notes < indicates less than the analytical detection limit. Shaded cells exceed applied guideline limit.

1. NEPC (1999). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM). Guideline on investigation levels for soil and groundwater. Environmental Investigation Level with Health Investigation Level HIL(E); parks, recreation open space and playing fields shown in parenthesis of Site Contamination) Measure (NEPM). Guideline on investigation levels for soil and groundwater. Background and HIL(E); parks, recreation open space and playing fields.

* Guideline level for Cr(VI) = 200 mg/kg. Guideline level for Cr(III) = 24% of total Cr.

GAIs greater than or equal to 3 are highlighted.

1. Bowen H.J.M.(1979) Environmental Chemistry of the Elements, Academic Press, New York, p36-37.

4.5 Water Quality

In order to evaluate the likely initial water quality and solubility of metals/metalloids from heap leach materials, water extract (1:5 w/v sample:water) tests were completed for the composite heap leach rock sample and results are provided in **Table 3**.

The water extract has a neutral pH of 7.4 and a relatively low EC/salinity value of 551 $\mu\text{S}/\text{cm}$. The current total alkalinity of the water extract is 10 mg/L CaCO_3 , mainly due to the presence of bicarbonate. The dominant major soluble ions are potassium, bicarbonate, and sulfate although the concentration of all major soluble ions is relatively low. The soluble sulfate concentration is low (22 mg/L) and well below the applied water quality guideline criterion (1,000 mg/L; ANZECC, 2000).

There are no specific regulatory criteria for metal/metalloid concentrations in leachate from mine rock materials on mine sites in Queensland. As such, RGS has compared the multi-element results in water extracts from the composite heap leach rock sample with Australian guidelines to provide some context for discussion of test results (ANZECC, 2000; and NEPC, 1999b). The concentration of all trace metals/metalloids tested in the water extracts is low, predominantly below the laboratory limit of reporting, and below the applied water quality guideline criteria, where these exist. Hence, the risk of potential impact on the quality of surface and groundwater from heap leach rock materials at Yandan should be very low, although if this material is used for rehabilitation, this finding should be confirmed by the site water quality monitoring program.

Table 3: Multi-Element Results for Water Extracts from Heap Leach Rock Composite - Yandan Project

Parameters	Detection Limit	Guideline Levels ¹	Heap Leach Rock Composite
pH	0.1 pH unit	-	7.4
Electrical Conductivity	1 µS/cm	-	551
Total Alkalinity (mgCaCO ₃ /L)	0.2 mg/L	-	10
Bicarbonate Alkalinity (mgCaCO ₃ /L)	0.2 mg/L	-	10
Carbonate Alkalinity (mgCaCO ₃ /L)	0.2 mg/L	-	<0.2
Major Ions	All element concentrations in mg/L		
Calcium (Ca)	0.2	1,000	4
Magnesium (Mg)	0.2	-	1
Potassium (K)	0.2	-	15
Sodium (Na)	0.2	-	7
Chloride (Cl)	0.2	-	5
Sulfate (SO ₄)	0.2	1,000	22
Metals/Metalloids	All element concentrations in mg/L		
Aluminium (Al)	0.002	5	0.016
Antimony (Sb)	0.0002	-	0.0008
Arsenic (As)	0.0002	0.5	0.0134
Cadmium (Cd)	0.00002	0.01	<0.002
Chromium (Cr)	0.0002	1 / -	<0.002
Cobalt (Co)	0.0002	1	0.0012
Copper (Cu)	0.0002	1 / 0.5	0.0020
Iron (Fe)	0.01	-	<0.2
Lead (Pb)	0.0002	0.1	<0.002
Manganese (Mn)	0.0002	-	0.0004
Mercury (Hg)	0.00002	0.002	<0.002
Molybdenum (Mo)	0.0002	0.15	0.0014
Nickel (Ni)	0.0002	1	0.0002
Selenium (Se)	0.002	0.02	<0.002
Vanadium (V)	0.002	- / 0.1	<0.002
Zinc (Zn)	0.001	20	<0.002

Notes: < Indicates concentration less than the detection limit.

Shaded cells indicate values which exceed applied ANZECC/NEPC guideline values.

1. The first guideline level shown refers to ANZECC (2000) and the second to NEPC (1999). Where the two guidelines limits for a given element are in agreement, only one value is shown. A 'dash' represents no trigger value provided for this element.

a. ANZECC and ARMCA NZ, Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000). Livestock drinking water (cattle).

b. NEPC (1999b). National Environment Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM) Guideline on investigation levels for soil and groundwater. Groundwater Investigations Levels (Agricultural: Livestock).

4.6 Kinetic Leach Column (KLC) Tests

A KLC test program was completed from September 2012 to September 2013 for the composite heap leach rock sample using the methodology described in **Section 3.2** and **Attachment A**. The geochemical results obtained for the KLC test are presented at **Table 4** and **Figures KLC1a to KLC1d**. The results of the static and KLC test program available to date indicate that:

- Leachate from heap leach rock should be pH neutral (to slightly alkaline) and contain relatively low concentrations of soluble salts (**Figure KLC1a**).
- Heap leach rock will generate negligible acidity in leachate, much less than the inherent alkalinity value, leading to a positive net alkalinity value (**Figure KLC1b**);
- The dominant major ions in leachate from heap leach rock tend to be calcium, potassium, bicarbonate and sulfate. Overall, the concentration of major ions in leachate is relatively low.
- The concentrations of soluble calcium and magnesium in leachate from the KLC tests have been used to calculate the residual ANC in this material. The residual ANC appears to remain high (>99.3 %) after 12 months of leaching (**Figure KLC1c**);
- The concentration of soluble sulfate in leachate from the KLC tests has been used to calculate the residual sulfur content of the sample materials. The results indicate that about half of the sulfur content of the heap leach rock material remains (49.8 %) after 12 months of leaching;
- The molar ratio of soluble sulfate to calcium plus magnesium ($\text{SO}_4:\text{Ca}+\text{Mg}$) in KLC test leachate is elevated for the first two leach events indicating flushing of soluble sulfate salts from the column material. However, the sulfate to calcium plus magnesium molar ratio reduces significantly after the first two leach events indicating that soluble sulfate is being flushed from the heap leach rock at a slower rate than calcium and magnesium (**Figure KLC1c**); and
- The concentration of soluble trace metals/metalloids in KLC leachate from the heap leach rock sample is very low, typically below the laboratory limit of reporting, and well within the applied water quality guideline criteria (**Figure KLC1d**).

Table 4: KLC Test Results for Heap Leach Rock Composite Sample

Sample Weight (kg)	1.56	Total S (%)	0.01	ANC (kg H ₂ SO ₄ /t)	14.25			
pH(1:5)	8.7	CRS (%)	-	NAPP (kg H ₂ SO ₄ /t)	-13.8			
EC(1:5) (µS/cm)	241	MPA (kg H2SO4/t)	0.41	ANC:MPA ratio	34.9			
Date	21-Sep-12	19-Oct-12	20-Nov-12	21-Dec-12	19-Mar-13	20-Jun-13	20-Sep-13	
Leach Number	1	2	3	4	5	6	7	
Volume Collected (L)	0.682	0.776	0.839	0.788	0.765	0.714	0.799	
Cum. Volume (L)	0.68	1.46	2.30	3.09	3.85	4.56	5.36	
Pore Volumes	0.5	1.1	1.7	2.3	2.9	3.4	4.0	
pH	7.24	8.43	8.27	8.38	7.48	7.19	7.43	
EC (mS/cm)	558	110	66	78	59	244	74	
Acidity (mg/L)*	3	<1	<1	2	3	5	2	
Alkalinity (mg/L)*	52	27	22	24	19	58	43	
Net Alkalinity (mg/L)*	49	27	22	22	16	53	41	
Dissolved elements (mg/L)								Guideline Levels ¹
Aluminium (Al)	0.08	0.22	0.20	0.15	0.08	0.08	0.18	5
Arsenic (As)	0.067	0.025	0.02	0.016	0.011	0.082	0.022	0.5
Calcium (Ca)	19	8	7	7	5	14	8	1,000
Cadmium (Cd)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.01
Chloride (Cl)	26	2	<1	4	9	9	1	-
Cobalt (Co)	0.006	<0.001	<0.001	<0.001	<0.001	0.00	<0.001	1
Chromium (Cr)	<0.001	<0.001	0.005	0.002	<0.001	<0.001	<0.001	1 / -
Copper (Cu)	0.01	<0.001	0.001	<0.001	<0.001	0.004	0.001	1 / 0.5
Iron (Fe)	<0.05	0.08	0.15	<0.05	0.06	0.07	0.12	-
Mercury (Hg)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.002
Potassium (K)	75	8	5	5	4	35	7	-
Magnesium (Mg)	3	<1	<1	<1	1	2	2	-
Manganese (Mn)	0.002	0.001	0.002	0.001	0.001	0.002	0.002	-
Molybdenum (Mo)	0.007	0.002	0.001	<0.001	<0.001	0.005	<0.001	0.15 / 0.01
Sodium (Na)	37	4	2	3	7	14	5	-
Nickel (Ni)	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1
Lead (Pb)	<0.001	0.001	0.001	<0.001	<0.001	0.00	0.001	0.1
Sulphate (SO ₄)	108	137	12	9	8	39	5	1,000
Antimony (Sb)	0.004	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	-
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Vanadium (V)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	- / 0.1
Zinc (Zn)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	20
RESULTS**								
SO ₄ Release Rate	47	68	6	5	4	18	3	
Cumulative SO ₄ Release	47	115	122	126	130	148	151	
Ca Release Rate	8	4	4	4	2	6	4	
Cumulative Ca Release	8	12	16	20	22	28	33	
Mg Release Rate	1.3	0.2	0.3	0.3	0.5	0.9	1.0	
Cumulative Mg Release	1.3	1.6	1.8	2.1	2.6	3.5	4.5	
Residual ANC (%)	99.8	99.7	99.7	99.6	99.5	99.4	99.3	
Residual Sulfur (%)	84.3	61.5	59.4	57.9	56.6	50.6	49.8	
SO ₄ /(Ca+Mg) molar ratio	1.9	6.5	0.6	0.5	0.5	0.9	0.2	

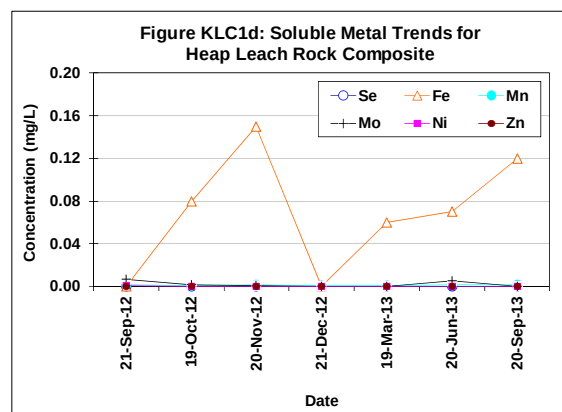
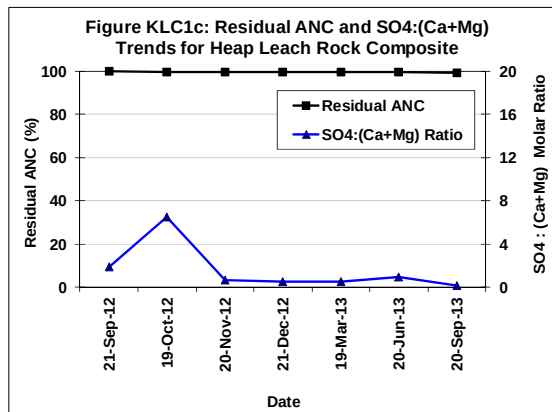
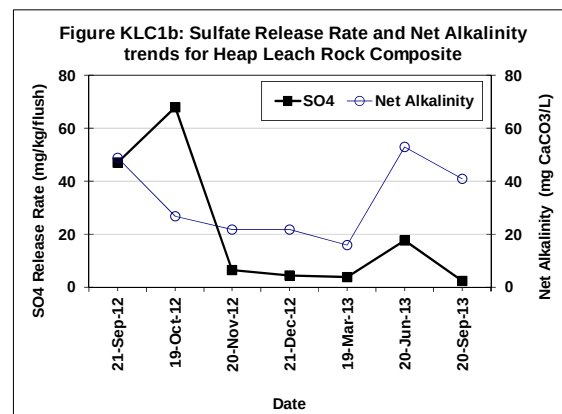
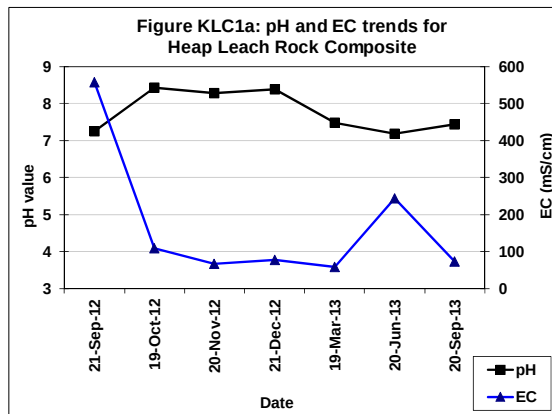
< indicates less than the analytical detection limit.

* Acidity and Alkalinity data calculated in mg CaCO₃/L

** SO₄, Ca and Mg release rates calculated in mg/kg/flush.

Total S = Total Sulfur, SCR = Chromium Reducible Sulfur, MPA = Maximum Potential Acidity, ANC = Acid Neutralising Capacity, and NAPP = Net Acid Producing Potential

1. The first guideline level shown refers to ANZECC (2000) and the second to NEPC (1999). Where the two guidelines limits for a given element are in agreement, only one value is shown. A 'dash' represents no trigger value provided for this element.



5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

RGS has completed a geochemical assessment of representative samples of TSF Cell B cover and tailings materials and heap leach rock material from Yandan gold mine. The geochemical test results obtained to date indicate that:

- Cell B tailings materials have a reduced pH and elevated salinity value, and acidity and salts appear to be migrating from the tailings into the 1m cover at the tailings rehabilitation trial area, probably due to capillary rise effects. It is unlikely that a 1m cover will be sufficiently thick to prevent this capillary effect and this could impact upon the potential success of any rehabilitation efforts at the cover surface. It is possible that a thicker cover could assist to reduce or eliminate the rise of acid and salts from the tailings to the tailings cover surface; and
- The heap leach rock material appears to be geochemically benign and, on the basis of the samples provided and results received, is classified as NAF and therefore there is negligible risk of acid generation from these materials. This type of rock material should not present any significant risk to the environment with respect to total metal concentrations in solids and poses negligible risk of potential impact on the quality of surface and groundwater. In addition, heap leach rock is unlikely to have structural stability problems related to potential dispersion and erosion and may be suitable for rehabilitation activities at the site.

5.2 Recommendations

As a result of the findings of this geochemical assessment program it is recommended that Straits Resources considers:

- A site visit by RGS personnel to assess the status of the current TSF, collect and review available site information (*eg.* surface runoff and seepage quality monitoring data), and take representative samples of tailings materials;
- A static and kinetic geochemical test program on representative samples of tailings materials. A description of a typical geochemical assessment program for mine waste materials (*eg.* tailings) is provided at **Attachment A**;
- Preparation of a review report to include the findings of the site visit, an interpretation of the geochemical test program, conclusions and recommendations for potential management measures to mitigate the AMD currently being generated from the TSF; and
- An alternative method of covering/rehabilitating tailings at the TSF (such as a thicker cover) to reduce or eliminate the current upward migration of acidity and salts into the cover system.

6.0 REFERENCES

ANZECC (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000). Livestock drinking water (cattle).

AMIRA (2002). *ARD Test Handbook: Project 387A Prediction and Kinetic Control of Acid Mine Drainage*. Australian Minerals Industry Research Association, Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd, May 2002.

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INAP (2009). *Global Acid Rock Drainage Guide(GARD Guide)*. Document prepared by Golder Associates on behalf of the International Network on Acid Prevention (INAP). June 2009 (<http://www.inap.com.au/>).

NEPC (1999a). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM). Guideline on investigation levels for soil and groundwater. HIL(E); parks, recreation open space and playing fields.

NEPC (1999b). National Environment Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM). Guideline on investigation levels for soil and groundwater. Groundwater Investigations Levels (Agricultural: Livestock).

Parker G. and Robertson A. M. (1999). *Acid Drainage*. Occasional paper published by the Australian Minerals and Energy Environment Foundation (AMEEF), November, 1999, Melbourne, Victoria, Australia.

7.0 LIMITATIONS

RGS Environmental Pty Ltd (RGS) has prepared this report for the use of LRS Environmental Pty Ltd (LRS) and Straits Gold Pty Ltd. It is based on accepted consulting practices and standards and no other warranty is made as to the professional advice included in this report. This report was prepared from August 2012 to October 2013 and is based on the information and samples provided by LRS at the time of preparation. RGS disclaims responsibility for any changes that may have occurred after this time.

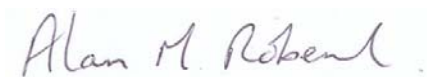
The sources of information and methodology used by RGS are outlined in this report and no independent verification of this information has been made. RGS assumes no responsibility for any inaccuracies or omissions, although no indication was found that any information contained in this report as provided to RGS was incorrect.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not provide legal advice, which can only be given by qualified legal practitioners.

If you have any questions regarding the information presented in this report, please contact the undersigned on 07 3856 5591 or 0431 620 623.

Yours sincerely,

RGS ENVIRONMENTAL PTY LTD



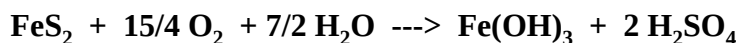
Dr. Alan Robertson
Principal Geochemist/Director

ATTACHMENT A

GEOCHEMICAL ASSESSMENT OF MINE WASTE MATERIALS

A1. ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the maximum acid that could be generated by the sample by either directly determining the pyritic S content or assuming that all sulfur not present as sulfate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the overall reaction:



According to this reaction, the maximum potential acidity (MPA) of a sample containing 1%S as pyrite would be 30.6 kg H_2SO_4 /t. The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralization, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Net Acid Producing Potential

The net acid producing potential (NAPP) is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulfide sulfur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4 /t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests that include:

Determination of pH and EC

pH and EC measured on 1:5 w/w water extract. This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Total sulfur content, sulfate sulfur content, and Maximum Potential Acidity (MPA)

Total sulfur content is determined by the Leco high temperature combustion method. The total sulfur content is then used (in conjunction with the sulfate sulfur content) to calculate the MPA, which is based on the assumption that the entire sulfur content, minus the non-reactive sulfate sulfur content, is present as reactive pyrite. Direct determination of the pyritic sulfur content can provide a more accurate estimate of the MPA.

Acid neutralising capacity (ANC)

By addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acid titration to a set end-point in the Acid Buffering Characteristic Curve (ABCC) test through calculation of the amount of acid consumed and evaluation of the resultant titration curve.

Net acid producing potential (NAPP)

Calculated from the MPA and ANC results. The NAPP represents the balance between a samples' inherent capacities to generate and neutralise acid. If the MPA is greater than the ANC then the NAPP is positive. If the MPA is less than the ANC then the sample then the NAPP is negative.

Net Acid Generation (NAG)

The net acid generation (NAG) test involves the addition of hydrogen peroxide to a sample of mine rock or process residue (tailings) to oxidise reactive sulfide, then measurement of pH and titration of any net acidity produced by the acid generation and neutralisation reactions occurring in the sample. A significant NAG result (*i.e.* final $\text{NAG}_{\text{pH}} < 4.5$) indicates that the sample is potentially acid forming (PAF) and the test provides a direct measure of the net amount of acid remaining in the sample after all acid generating and acid neutralising reactions have taken place. A $\text{NAG}_{\text{pH}} > 4.5$ indicates that the sample is non-acid forming (NAF). The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure and weathering and is used to refine the results of the theoretical NAPP predictions. The NAG test can be used as a stand-alone test, but is recommended that this only be considered after site specific calibration work is carried out.

A2. ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material (or readily leachable from a material) at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health. The samples are generally analysed for the following elements:

Major elements Al, Ca, Fe, K, Mg, Na and S.

Minor elements As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Se and Zn.

The concentration of these elements in samples can be directly compared with relevant state or national environmental and health based concentration guideline criteria to

determine the level of significance. Water extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. The following tests are normally carried out:

Multi-element composition of solids. Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Multi-element composition of water extracts (1:5 sample:deionised water). Multi-element composition of water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Under some conditions (*e.g.* low pH) the solubility and mobility of common environmentally important elements can increase significantly. If element mobility under initial pH conditions is deemed likely and/or subsequent low pH conditions may occur, kinetic leach column test work is generally undertaken on representative samples as described in **Section A3**.

A3. KINETIC LEACH COLUMN TESTS

Kinetic leach column tests can be used to provide information on the reaction kinetics of mine waste materials. The major objectives of kinetics tests are to:

- Provide time-dependent data on the kinetics and rate of acid generation and acid neutralising reactions under laboratory controlled (or onsite conditions);
- Investigate metal release and drainage/seepage quality; and
- Assess treatment options such as addition of alkaline materials.

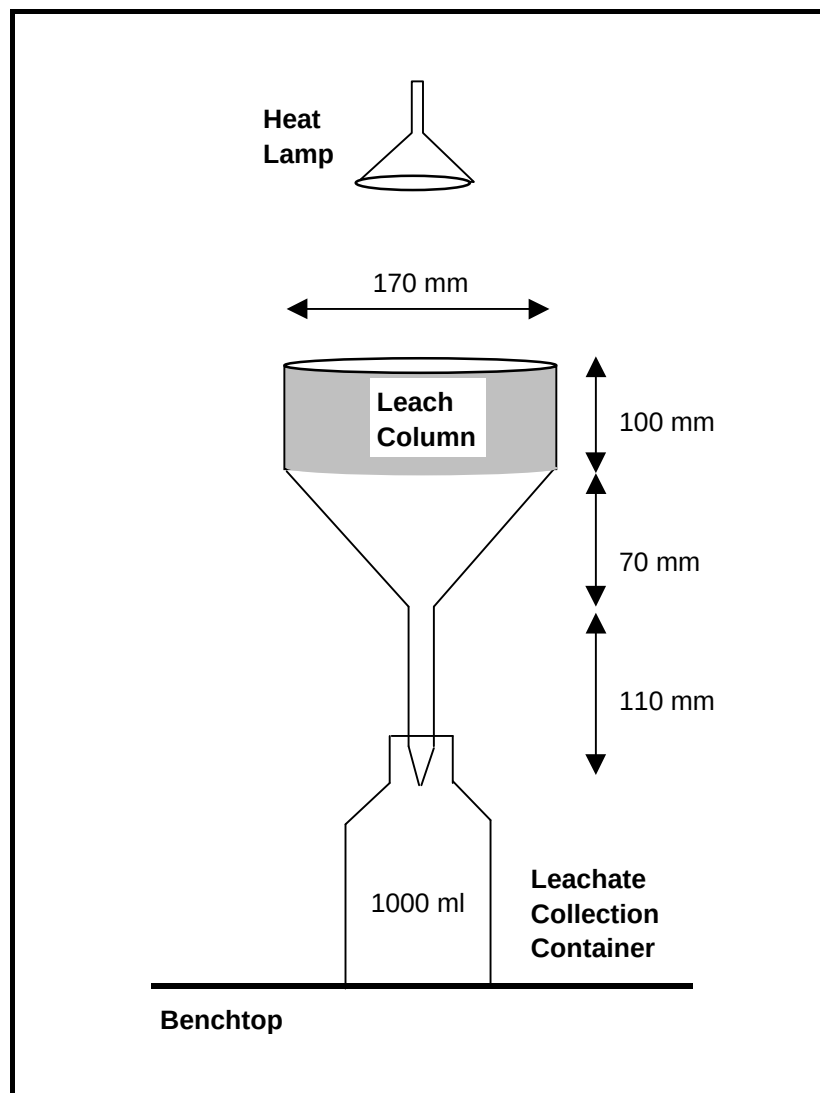
The kinetic tests simulate the weathering process that leads to acid and base generation and reaction under laboratory controlled or site conditions. The kinetic tests allow an assessment of the acid forming characteristics and indicate the rate of acid generation, over what period it will occur, and what management controls may be required.

In kinetic column leach tests, water is added to a sample and the mixture allowed to leach products and by-products of acid producing and consuming reactions. Samples of leachate are then collected and analysed. Intermittent water application is applied to simulate rainfall and heat lamps are used to simulate sunshine. These tests provide real-time information and may have to continue for months or years. Monitoring includes trends in pH, sulfate, acidity or alkalinity, and metals, for example. The pH of the collected leachate simulates the acid drainage process, acidity or alkalinity levels indicate the rate of acid production and acid neutralisation, and sulfate production can be related to the rate of sulfide oxidation. Metal concentration data provides an assessment of metal solubility and leaching behaviour.

Figure A1 shows the kinetic leach column set up used by RGS adapted from *AMIRA, 2002*. The columns are placed under heat lamps to allow the sample to dry between water additions to ensure adequate oxygen ingress into the sample material.

Approximately 2-3 kg of sample is generally used in the leach columns and depending on the physical nature of the material and particle size can be used on an as-received basis (*i.e.* no crushing as with process residues) or crushed to nominal 5-10 mm particle size (as with overburden). The sample in the column is initially leached with deionised water at a rate of about 500 ml/kg of sample and the initial leachate from the columns collected and analysed. Subsequent column leaching is carried out at a rate of about 500 ml/kg per month and again collected and analysed. The leaching rate can be varied to better simulate expected site conditions or satisfy test program data requirements. The column must be exposed to drying conditions in between watering events. The residual water content and air void content in the column can be determined by comparing the wet and dry column weights. A heat lamp is generally used above the sample during daylight hours to maintain the leach column surface temperature at about 30°C.

Figure A1
Kinetic Leach Column Setup



Reference:

AMIRA (2002). AMIRA International. *ARD Test Handbook. Project P387A Prediction & Kinetic Control of Acid Mine Drainage*. Ian Wark Institute and Environmental Geochemistry International Pty Ltd. May 2002, Melbourne, VIC.

ATTACHMENT B

ALS LABORATORY RESULTS

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1221303	Page	: 1 of 14
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
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Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 111207	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 13-AUG-2012
Sampler	: Gill Fletcher	Issue Date	: 28-AUG-2012
Site	: Yandan		
Quote number	: BN/413/12	No. of samples received	: 53
		No. of samples analysed	: 53

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



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
Andrew Epps	Metals Production Chemist	Brisbane Inorganics
Andrew Epps	Metals Production Chemist	Stafford Minerals - AY
SATISH.TRIVEDI	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils



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

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**



Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)

Client sample ID

Client sampling date / time

				HL 1	HL 2	HL 3	HL 4	HL 5
				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-048	EB1221303-049	EB1221303-050	EB1221303-051	EB1221303-052
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.6	8.1	9.4	9.1	10.0
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-6.0	-2.9	-32.7	-6.2	-31.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	440	181	140	332	131
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.3	3.5	33.3	6.2	32.4
ANC as CaCO3	----	0.1	% CaCO3	0.6	0.4	3.4	0.6	3.3
Fizz Rating	----	0	Fizz Unit	0	0	2	0	2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.02	0.02	<0.01	0.02



Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)

Client sample ID

				HL 6	----	----	----	----
				02-AUG-2012 15:00	----	----	----	----
				EB1221303-053	----	----	----	----
Compound	CAS Number	LOR	Unit					
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.6	----	----	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-3.8	----	----	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	221	----	----	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	3.8	----	----	----	----
ANC as CaCO3	----	0.1	% CaCO3	0.4	----	----	----	----
Fizz Rating	----	0	Fizz Unit	0	----	----	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 0-250 1	TRT 250-500 1	TRT 500-750 1	TRT 750-1000 1	TRT 0-250 2
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-001	EB1221303-002	EB1221303-003	EB1221303-004	EB1221303-005
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.6	4.7	4.1	3.8	4.0
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	2620	2440	1670	1270	1520



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 250-500 2	TRT 0-200 3	TRT 200-400 3	TRT 0-250 4	TRT 250-500 4
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-006	EB1221303-007	EB1221303-008	EB1221303-009	EB1221303-010
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	3.9	4.1	4.1	4.3	4.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	1320	892	795	585	632



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 500-600 4	TRT 0-250 5	TRT 250-500 5	TRT 500-600 5	TRT 0-250 6
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-011	EB1221303-012	EB1221303-013	EB1221303-014	EB1221303-015
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.1	4.0	3.9	3.6	4.1
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	525	2280	1440	1460	473



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 250-500 6	TRT 0-250 7	TRT 250-500 7	TRT 0-150 8	TRT 150-300 8
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-016	EB1221303-017	EB1221303-018	EB1221303-019	EB1221303-020
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	3.9	3.9	3.8	3.8	3.7
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	701	892	960	2040	1390



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 0-150 9	TRT 150-300 9	TRT 0-150 10	TRT 150-300 10	TRT 0-250 11
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-021	EB1221303-022	EB1221303-023	EB1221303-024	EB1221303-025
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.2	4.0	4.7	4.3	6.0
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	1480	866	924	1700	149



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 250-500 11	TRT 0-100 12	TRT 100-200 12	TRT 0-75 13	TRT 75-150 13
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-026	EB1221303-027	EB1221303-028	EB1221303-029	EB1221303-030
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.2	5.0	4.6	6.0	5.5
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	1020	704	698	568	1060



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 0-75 14	TRT 0-10 15	TRT 0-250 1 (T)	TRT 0-250 2 (T)	TRT 0-250 3 (T)
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-031	EB1221303-032	EB1221303-033	EB1221303-034	EB1221303-035
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	6.2	5.8	3.6	3.9	3.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	343	81	1710	905	1290



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 0-250 4 (T)	TRT 0-250 5 (T)	TRT 0-250 6 (T)	TRT 0-250 7 (T)	TRT 0-250 8 (T)
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-036	EB1221303-037	EB1221303-038	EB1221303-039	EB1221303-040
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.0	3.6	4.0	3.6	3.7
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	649	1670	796	1620	1670



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 0-250 9 (T)	TRT 0-250 10 (T)	TRT 0-250 11 (T)	TRT 0-250 12 (T)	TRT 0-250 13 (T)
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00	02-AUG-2012 15:00
Compound	CAS Number	LOR	Unit	EB1221303-041	EB1221303-042	EB1221303-043	EB1221303-044	EB1221303-045
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	3.8	4.0	4.1	4.5	4.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	1280	1440	1480	701	1640



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				TRT 0-250 14 (T)	TRT 0-250 15 (T)	----	----	----
Client sampling date / time				02-AUG-2012 15:00	02-AUG-2012 15:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1221303-046	EB1221303-047	----	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.8	7.0	----	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	1200	48	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1225133	Page	: 1 of 3
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: Yandan (111207)	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 21-SEP-2012
Sampler	: ----	Issue Date	: 28-SEP-2012
Site	: ----		
Quote number	: BN/413/12	No. of samples received	: 1
		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



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
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics



General Comments

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^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG005T (Total Metals): Sample EB1225062-001 shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.**
- **EG005T (Total Metals): Sample EB1225133-001 (Heap Leach Composite 1) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.**



Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

Client sample ID

Client sampling date / time

				Heap Leach Composite 1				
				21-SEP-2012 15:00	----	----	----	----
				EB1225133-001	----	----	----	----
Compound	CAS Number	LOR	Unit					
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	11.9	----	----	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	20.7	----	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	0.5	----	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.3	----	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	21.6	----	----	----	----
Exchangeable Sodium Percent	----	0.1	%	0.3	----	----	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	60	----	----	----	----
Potassium	7440-09-7	50	mg/kg	590	----	----	----	----
Calcium	7440-70-2	50	mg/kg	13000	----	----	----	----
Magnesium	7439-95-4	50	mg/kg	1080	----	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	850	----	----	----	----
Antimony	7440-36-0	5	mg/kg	8	----	----	----	----
Cobalt	7440-48-4	2	mg/kg	<2	----	----	----	----
Iron	7439-89-6	50	mg/kg	9000	----	----	----	----
Manganese	7439-96-5	5	mg/kg	45	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	----	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	----	----	----	----
Vanadium	7440-62-2	5	mg/kg	<5	----	----	----	----
Arsenic	7440-38-2	5	mg/kg	67	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	----	----	----	----
Chromium	7440-47-3	2	mg/kg	4	----	----	----	----
Copper	7440-50-8	5	mg/kg	<5	----	----	----	----
Lead	7439-92-1	5	mg/kg	<5	----	----	----	----
Nickel	7440-02-0	2	mg/kg	2	----	----	----	----
Zinc	7440-66-6	5	mg/kg	6	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1225112	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 111207-Yandan	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 21-SEP-2012
Sampler	: Mandie Matheson	Issue Date	: 27-SEP-2012
Site	: Yandan		
Quote number	: BN/413/12	No. of samples received	: 1
		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.

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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
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics



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Analytical Results

Sub-Matrix: **LEACHATE (Matrix: WATER)**

Client sample ID

				Yandan - 1	----	----	----	----
				21-SEP-2012 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1225112-001	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.38	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	551	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	52	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	52	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	3	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	108	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	26	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	19	----	----	----	----
Magnesium	7439-95-4	1	mg/L	3	----	----	----	----
Sodium	7440-23-5	1	mg/L	37	----	----	----	----
Potassium	7440-09-7	1	mg/L	75	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.08	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	0.004	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.067	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.010	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.006	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.002	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	0.007	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)

Client sample ID

Client sampling date / time

				Yandan - 1	----	----	----	----
				21-SEP-2012 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1225112-001	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1227325	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 111207	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 19-OCT-2012
Sampler	: Mandie Matheson	Issue Date	: 25-OCT-2012
Site	: ----		
Quote number	: BN/413/12	No. of samples received	: 1
		No. of samples analysed	: 1

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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
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics



General Comments

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LOR = Limit of reporting

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Analytical Results

Sub-Matrix: **LEACHATE (Matrix: WATER)**

Client sample ID

Client sampling date / time

				Yandan - 1	----	----	----	----
				[19-OCT-2012]	----	----	----	----
<i>Compound</i>	<i>CAS Number</i>	<i>LOR</i>	<i>Unit</i>	EB1227325-001	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	9.01	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	92	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	8	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	18	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	27	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	137	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	2	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	8	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	4	----	----	----	----
Potassium	7440-09-7	1	mg/L	8	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.22	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.025	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.001	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	0.002	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)

Client sample ID

Client sampling date / time

				Yandan - 1	----	----	----	----
				[19-OCT-2012]	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1227325-001	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Iron	7439-89-6	0.05	mg/L	0.08	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1230208	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 111207 Yandan	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 20-NOV-2012
Sampler	: Mandie Matheson	Issue Date	: 27-NOV-2012
Site	: ----		
Quote number	: BN/413/12	No. of samples received	: 1
		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



NATA Accredited Laboratory 825

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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
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics



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.

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LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting



Analytical Results

Sub-Matrix: **LEACHATE (Matrix: WATER)**

Client sample ID

				Yandan - 1	----	----	----	----
				20-NOV-2012 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1230208-001	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	9.09	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	67	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	6	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	16	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	22	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	<1	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	12	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	<1	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	7	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	2	----	----	----	----
Potassium	7440-09-7	1	mg/L	5	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.20	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.020	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	0.005	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.002	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Client sample ID	Yandan - 1	----	----	----	----
				Client sampling date / time	20-NOV-2012 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1230208-001	----	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----	----
Iron	7439-89-6	0.05	mg/L	0.15	----	----	----	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1233394	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 111207 Yandan	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 21-DEC-2012
Sampler	: Mandie Matheson	Issue Date	: 04-JAN-2013
Site	: ----		
Quote number	: BN/413/12	No. of samples received	: 1
		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.

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- Analytical Results



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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
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics



General Comments

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Where moisture determination has been performed, results are reported on a dry weight basis.

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LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting



Analytical Results

Sub-Matrix: **LEACHATE (Matrix: WATER)**

Client sample ID

				Yandan - 1	----	----	----	----
Client sampling date / time				21-DEC-2012 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1233394-001	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.36	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	76	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	23	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	24	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	2	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	9	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	4	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	7	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	3	----	----	----	----
Potassium	7440-09-7	1	mg/L	5	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.15	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.016	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.002	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.001	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)

Client sample ID

Client sampling date / time

				Yandan - 1	----	----	----	----
				21-DEC-2012 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1233394-001	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1306901	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 11207 Yandan	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 19-MAR-2013
Sampler	: Mandie Matheson	Issue Date	: 26-MAR-2013
Site	: ----		
Quote number	: BN/413/12	No. of samples received	: 1
		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.

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- Analytical Results



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Signatories

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Signatories	Position	Accreditation Category
Jonathon Angell	Inorganic Coordinator	Brisbane Inorganics
Jonathon Angell	Inorganic Coordinator	Brisbane Inorganics
Jonathon Angell	Inorganic Coordinator	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics



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LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)

Client sample ID

				Yandan - 1	----	----	----	----
Client sampling date / time				19-MAR-2013 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1306901-001	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.67	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	49	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	19	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	19	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	3	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	8	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	9	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	5	----	----	----	----
Magnesium	7439-95-4	1	mg/L	1	----	----	----	----
Sodium	7440-23-5	1	mg/L	7	----	----	----	----
Potassium	7440-09-7	1	mg/L	4	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.08	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.011	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.001	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Client sample ID	Yandan - 1	----	----	----	----
				Client sampling date / time	19-MAR-2013 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB1306901-001	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Vanadium	7440-62-2	0.01	mg/L		<0.01	----	----	----	----
Iron	7439-89-6	0.05	mg/L		0.06	----	----	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1314889	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 111207 YANDAN	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 20-JUN-2013
Sampler	: Mandie Matheson	Issue Date	: 28-JUN-2013
Site	: YANDAN		
Quote number	: BN/413/12	No. of samples received	: 1
		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.

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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
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics



General Comments

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LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)

Client sample ID

				Yandan - 1	----	----	----	----
				20-JUN-2013 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1314889-001	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.81	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	236	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L	58	----	----	----	----
Total Alkalinity as CaCO ₃	----	1	mg/L	58	----	----	----	----
ED038A: Acidity								
Acidity as CaCO ₃	----	1	mg/L	5	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA								
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L	39	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	9	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	14	----	----	----	----
Magnesium	7439-95-4	1	mg/L	2	----	----	----	----
Sodium	7440-23-5	1	mg/L	14	----	----	----	----
Potassium	7440-09-7	1	mg/L	35	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.08	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	0.002	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.082	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.004	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.002	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.002	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.002	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	0.005	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Client sample ID	Yandan - 1	----	----	----	----
				Client sampling date / time	20-JUN-2013 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB1314889-001	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Vanadium	7440-62-2	0.01	mg/L		<0.01	----	----	----	----
Iron	7439-89-6	0.05	mg/L		0.07	----	----	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	----	----	----	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB1323021	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services
Address	: 18 INGLIS STREET GRANGE QLD, AUSTRALIA 4051	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: +61 07 3856 5591	Telephone	: +61 7 3243 7222
Facsimile	: +61 07 3856 5591	Facsimile	: +61 7 3243 7218
Project	: 111207 Yandan	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 20-SEP-2013
Sampler	: Mandie Matheson	Issue Date	: 26-SEP-2013
Site	: ----		
Quote number	: BN/413/12	No. of samples received	: 1
		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



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
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics



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



Analytical Results

Sub-Matrix: LIQUID (Matrix: WATER)

Client sample ID

				Yandan - 1	----	----	----	----
				20-SEP-2013 10:50	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1323021-001	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.62	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	72	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	4	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	39	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	43	----	----	----	----
ED038A: Acidity								
Acidity as CaCO3	----	1	mg/L	2	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	5	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	1	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	8	----	----	----	----
Magnesium	7439-95-4	1	mg/L	2	----	----	----	----
Sodium	7440-23-5	1	mg/L	5	----	----	----	----
Potassium	7440-09-7	1	mg/L	7	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.18	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.022	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.002	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: LIQUID (Matrix: WATER)				Client sample ID	Yandan - 1	----	----	----	----
				Client sampling date / time	20-SEP-2013 10:50	----	----	----	----
Compound	CAS Number	LOR	Unit		EB1323021-001	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Vanadium	7440-62-2	0.01	mg/L		<0.01	----	----	----	----
Iron	7439-89-6	0.05	mg/L		0.12	----	----	----	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	----	----	----	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		0.99	----	----	----	----
Total Cations	----	0.01	meq/L		0.96	----	----	----	----

31 July 2015
Project Number 201434
Revision C – Final Report

Straits Gold Pty Ltd
Suite 1, Level 2, HQ South Tower
520 Wickham Street, Fortitude Valley
Queensland 4006 Australia

Attention: Mr Ian Sheppard – Chief Operating Officer

Yandan Oxide and Sulfide Tailings Assessment

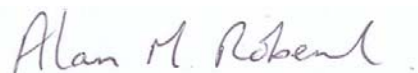
Dear Ian,

This letter report outlines the methods, results, findings, conclusions and recommendations of the geochemical assessment by RGS Environmental Pty Ltd (RGS) of 85 soil and oxide and sulfide tailings samples collected by Straits Gold Pty Ltd (Straits Gold) in October 2014.

We trust that this letter report fulfils your current requirements. Please contact Dr. Alan Robertson or Dr Greg Maddocks on 07 3344 1222 if you have any queries.

Yours sincerely,

RGS ENVIRONMENTAL PTY LTD



Dr. Alan Robertson
Principal Geochemist

1.0 INTRODUCTION

RGS Environmental Pty Ltd (RGS) was commissioned by Straits Gold Pty Ltd (Straits Gold) to complete a geochemical assessment of tailings from Cell B of the Yandan gold mine Tailings Storage Facility (TSF). The mine (now decommissioned) is located in the northern Drummond Basin of North Queensland, 230 km west of Mackay (**Figure 1-1**).



Figure 1-1: Site Location Map

1.1 Scope of Work

The RGS scope of work comprised:

- Coordination of static geochemical characterisation tests for 85 tailings samples.
- Completion of kinetic geochemical testing using kinetic leach columns (KLC) on both oxide and sulfide tailings.
- Tabulation and interpretation of static and kinetic geochemical test data.
- Provision of a letter report (this report), which provides the geochemical test results and the RGS interpretation of the results.
- Provision of recommendations for the management of selected mine materials with respect to potential Acid and Metalliferous Drainage (AMD) issues.

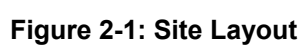
1.2 Purpose

The purpose of the testing program was to undertake static and kinetic testing on oxide and sulfide tailings samples to quantify the rate of acid production / consumption and the rate that major, minor and trace elements may be leached from free draining samples under laboratory conditions.

1.3 Objectives

The objectives included setting up small and large kinetic leach columns and testing them using a monthly leach cycling program. Leachate was collected from the columns each month and analysed for a range of chemical parameters to allow the rate of mineral dissolution to be quantified.

Yandan TSF is divided into two cells (Cells A and B) and Cell B has a trial rehabilitation cover at the south eastern corner of the facility comprising oxidised waste rock material (**Figure 2-1**).



YANDAN TAILINGS ASSESSMENT

Straits Gold personnel collected 85 samples in Cell B using a tractor mounted auger to dig holes to up to 600mm depth from 7 to 9 October 2014. Samples of 1-2 kg weight were then collected from the wall of the augered hole within what was visually inferred to be oxide or sulfide tailings.

In the field, samples were described as soil, oxide tailings, sulfide tailings or a combination of oxide and sulfide tailings. The designation of tailings as being oxide or sulfide was based on Straits knowledge of the genesis of the ore processed at the operation and the depositional history of the tailings. Samples were placed into plastic bags and excess air was removed before the bags were sealed. The samples were sent to the RGS laboratory in Brisbane. Sample locations and depth are in **Table 2-1**. A map of the site including the location of the samples is provided in **Figure 2-2**.

Table 2-1: Tailings sample co-ordinates and sample interval information

Sample ID	Easting	Northing	Description
1	500223	7646721	0-100mm oxide (O)
2			100-300mm O
3			400-500 sulphide S
4	500244	7646749	0-500mm O
5			500-600mm S
6	500091	7646889	0-500mm O/S 50/50 Roots present (R)
7	500099	7646932	0-500mm O/S 50/50 R
8	500111	7646956	0-500mm O R to 200mm
9	500112	7647002	0-500mm O R to 100mm
10	500129	7647029	0-500mm O R to 50mm Oxide very hard
11	500136	7647055	0-500mm O/Minor S at 400-500mm
12	500149	7647096	0-500mm O R to 20mm
13	500155	7647138	0-500mm O R to 25mm
14	500169	7647178	0-500mm O Sandy R to 50mm
15	500217	7647170	0-500mm O 20mm crust
16	500204	7647124	0-500mm O Minor crust, R to 200mm
17	500191	7647077	0-500mm O R to 25mm
18	500187	7647042	0-500mm O R to 150mm
19	500187	7647014	0-500mm O R tp 150mm
20	500177	7646987	0-500mm O Minot S Sandy and dry R to 250mm
21	500170	7646954	0-500mm O R to 250mm
22	500157	7646912	0-100mm O R to 50mm
23			100-500mm 50/50 O/S trending to 10/90 O/S
24	500145	7646870	0-200mm O R to 50mm
25			200-500mm S
26	500191	7646890	0-200mm O R nil
27			200-500mm O/S 50/50 interlayered
28	500217	7646863	0-300mm O Some S at base R nil
29			300-500mm O/S mixed
30	500241	7646843	0-300mm O R nil
31			300-500mm O/S mixed
32	500264	7646820	0-500mm O/S mixed
33	500283	7646797	0-400mm O
34			400-500mm S
35	500306	7646778	0-300mm O
36			300-500mm S
37	500327	7646755	0-400mm O
38			400-500mm S
39	500349	7646733	0-500mm O Traces of S
40	500300	7646734	0-400mm O
41			400-500mm S

YANDAN TAILINGS ASSESSMENT

Sample ID	Easting	Northing	Description
42	500278	7646752	0-350mm O R nil
43			350-500mm S
44	500254	7646770	0-500mm O/S mixed R nil
45	500232	7646790	0-300mm O/S mixed
46	500211	7646810	0-300mm O
47			300-500mm S
48	500181	7646834	0-400mm O
49			400-500mm S
50	500160	7646857	0-500mm O to 100mm, O/S 100-400mm, S 400-500mm
51	500169	7646908	0-500mm O to 150mm, O/S 150-400mm, S 400-500mm
52	500186	7646945	0-300mm O
53			300-500mm O/S mixed
54	500227	7646919	0-400mm O
55			400-500mm O/S mixed
56	500262	7646949	0-300mm O
57			300-500mm S clear change
58	500292	7646981	0-100mm O, 400-500mm mixed
59	500322	7647019	0-100mm O, 100-500 O/S interlayered
60	500560	7647408	0-400mm O
61			400-500mm S
62	500600	7647471	0-300mm O
63			300-500mm S
64 Trial (T)	500597	7647542	0-100mm Topsoil
65 T			250-350mm Topsoil
66 T			350-450mm Tails
67 T	500577	7647560	0-100mm Topsoil
68 T			100-400mm O
69 T			400-500mm S
70 T	500578	7647602	0-100mm Topsoil
71 T			350-450mm Topsoil R to 250mm
72 T			450-550mm O
73	500563	7647830	400-500mm S Note reverse numbering for this hole
74			300mm Topsoil
75			0-100mm Topsoil
76 OR	500687	7646993	0-100mm Topsoil of a 600mm topsoil layer over S tailings
77 OR	500703	7646915	0-200 Topsoil Salty surface with no ground cover
78 OR			200-500mm S
79	500208	7646998	0-300mm O R to 300mm
80			300-500mm S
81	500271	7647266	0-300mm O
82			300-500mm S
83	500298	7647387	0-50mm O, 50-100mm S, 100-500mm O (combined sample)
84	500315	7647483	0-150mm S, 150-300mm O, 300-500mm S (combined sample)
85	500340	7647589	0-150mm O, 150-500 S/O 80/20

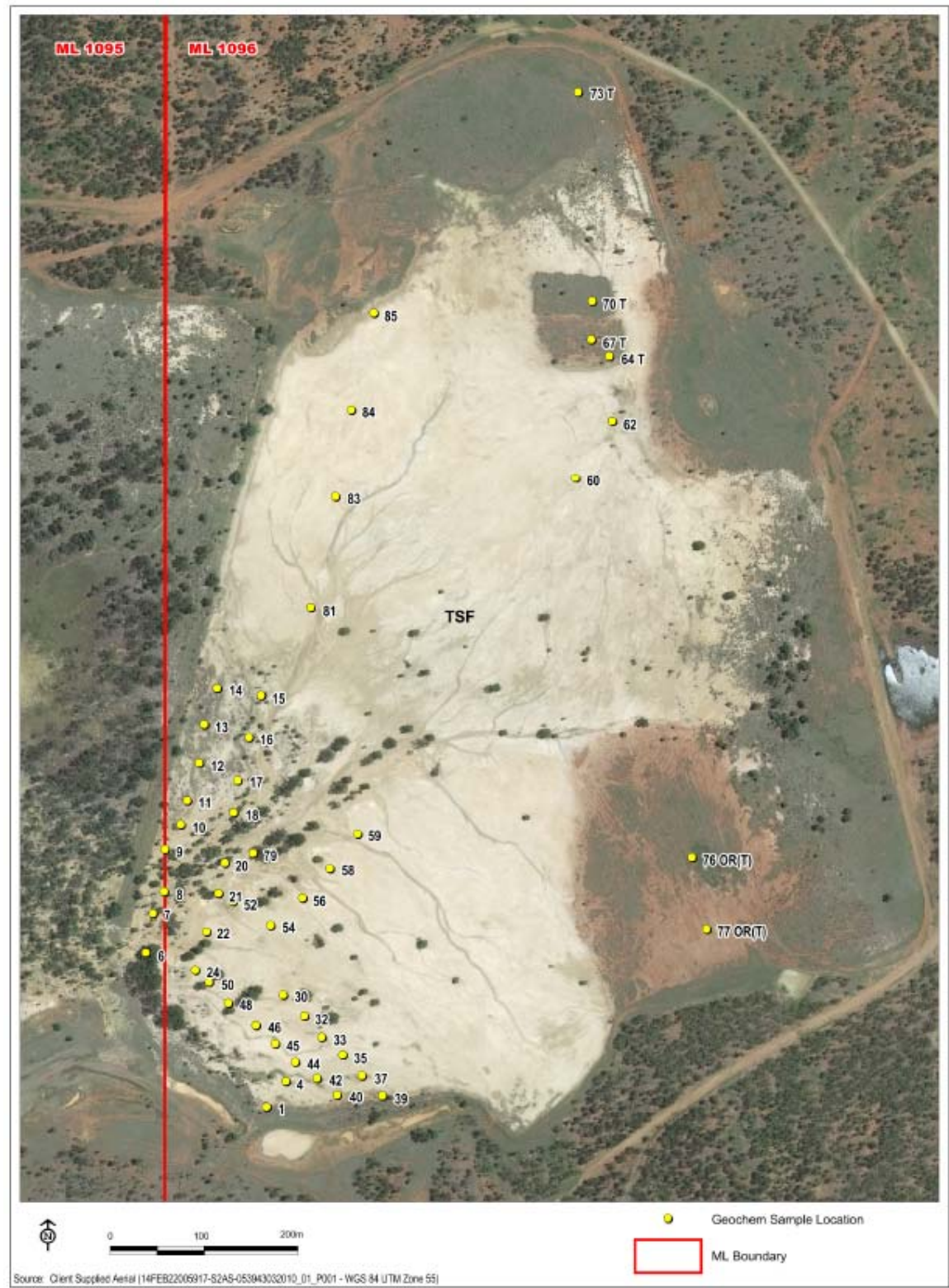


Figure 2-2: Sample Locations

3.0 STATIC TEST METHODS

3.1 Characterisation

Static geochemical tests provide a 'snapshot' of the geochemical characteristics of a sample at a single point in time. These tests were staged to screen a large number of samples before selecting either individual and/or composite samples for more detailed static test work. The Acid Base Account (ABA) was used as a screening procedure whereby the acid-neutralising and acid-generating characteristics of a material were assessed. The results of the screening assessment are discussed in **Section 5.0**.

The 85 samples received and viewed by RGS were transferred to ALS Laboratory in Brisbane for geochemical testing using standard methods and guidelines accepted in the mining industry (AMIRA, 2002; DITR, 2007; DME, 1995; and INAP 2009). All samples were pulverised and tested for:

- pH (1:5 w:v)
- Electrical Conductivity (EC) (1:5 w:v)
- Total sulfur [LECO high temperature method]
- Acid Neutralising Capacity [AMIRA, 2002]
- Net Acid Producing Potential (NAPP)

The results of the initial geochemical (screening) tests were used to select samples for supplementary testing including:

- Chromium reducible sulfur testing (Scr) [AS 4969.7-2008 method] (n=43)
- Net acid generating (NAG) analysis (n=26)
- Total metals (Al, As, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, N, Ni, Sb, Se, V, Zn) in solids [HCl and HNO₃ acid digest followed by ICP-AES and selected ICP-MS] (n=13)
- Total mercury [FIMS method] (n=13)
- Total cations (Ca, Mg, Na, K) and Exchangeable cations (Ca, Mg, Na, K) (n=13)
- 1:5 (solid to water) water soluble metals (Al, As, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Mo, N, Ni, Sb, Se, V, Zn) by ICP-AES or ICP-MS (n=13)
- 1:5 (solid to water) water soluble metals (Ca²⁺, Mg²⁺, K⁺, Na⁺, Cl⁻, SO₄²⁻, pH, EC, alkalinity and acidity) (n=13)
- Cation Exchange Capacity (eCEC) (n=7)
- Exchangeable Sodium Percentage (ESP) (n=7).

4.0 KINETIC TEST METHODS

A description of the KLC test methodology for the standard and large cells including a schematic of the KLC test arrangement is provided in **Attachment A**. The larger columns were used to better represent conditions within the top 60 cm of the tailings as the solid to solute ratio is more indicative of actual conditions in the field.

4.1 Sample Classification

The field description of the samples as soil, oxide, sulfide or oxide/sulfide tailings by Straits personnel was based on site knowledge and visual identification of the samples during sample collection. These descriptions are retained within the tables in this report.

Composite samples of these materials were selected for KLC tests after the static screening test results became available.

Samples used for KLC tests were initially classified using the static screening test results as Potentially Acid Forming (PAF) and therefore classified as being sulfide tailings if they had;

- Total Sulfur (TS) > 0.3 %
- Net Acid Producing Potential (NAPP) > 10 kg H₂SO₄/tonne
- ANC/MPA ratio < 1 (where ANC = Acid Neutralising Capacity and MPA = Maximum Potential Acidity)

The sulfide tailings were then composited into a single sample for the KLC test program. The remainder of the samples were classified as being oxide tailings (based on static screening test results) or topsoil (based on field descriptions), and these samples were also composited into bulk samples for KLC testing.

4.2 Standard KLC Test Cells

The two samples used in standard KLC test cells included one composite oxide and one composite sulfide tailings sample (based on NAPP values derived from TS and ANC).

Approximately 2 kg of each selected sample was accurately weighed and used in the KLC tests. Heat lamps were used approximately 30 cm above the columns on a daily basis to increase surface temperature to approximately 35 °C and ensure that the KLC test materials dried and were subject to oxidising conditions between leaching events (essentially an assumed 'worst case' scenario for sulfide oxidation and potential acid/salt generation). Small columns were packed to achieve a bulk density of approximately 1.3 kg/m³

A solid:solute ratio of 2:1 was targeted in the standard cells (ie. a 2 kg sample received 1L of laboratory grade distilled water as part of the leaching process). Due to the KLC column diameter and the volume of water added, each leach cycle was equivalent to 50 to 60 mm of rain. During leaching, deionised water was slowly added to the top of each KLC sample, and allowed to free-drain through the solids. The two standard KLC tests commenced on 19 December 2014 and were operated under a monthly watering and leaching regime for a six month test period (ie. a total of seven leaching events) until June 2015.

All leachate samples collected from the leach events in the KLC tests were sent to ALS Brisbane laboratory and analysed for various parameters including:

- pH and EC [PC titrator]
- Alkalinity and Acidity [PC titrator]
- Soluble metals and metalloids (Al, As, Cd, Cr, Co, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Se, V and Zn) [by ICP-MS]
- Dissolved mercury [FIMS method]

- Dissolved hexavalent chromium [discrete analyser]
- Major cations (Ca, Mg, K, Na) [by ICP-AES]
- Dissolved sulfate - turbidimetric [discrete analyser]
- Dissolved chloride and fluoride [discrete analyser and PC titrator]

4.3 Large KLC Test Cells

The “large” KLC test cell design (**Figure 4-1**) included approximately 20 kg of sample and a target solid:solute ratio of 10. Each leach cycle was equivalent to 65 mm of rain. The large cells were used to test three sample types including:

- Oxide Tailings
- Sulfide Tailings
- Oxide + Sulfide + Soil

Large columns were packed to achieve a bulk density of 1.3 kg/m³. An approximate configuration of the three large KLC samples is provided in **Figure 4-1**. A more detailed schematic of the large column design is provided in **Attachment A**. The three large KLC tests commenced on 19 December 2014 and were operated under a monthly watering and leaching regime for the six month test period (ie. a total of seven leaching events) until June 2015.

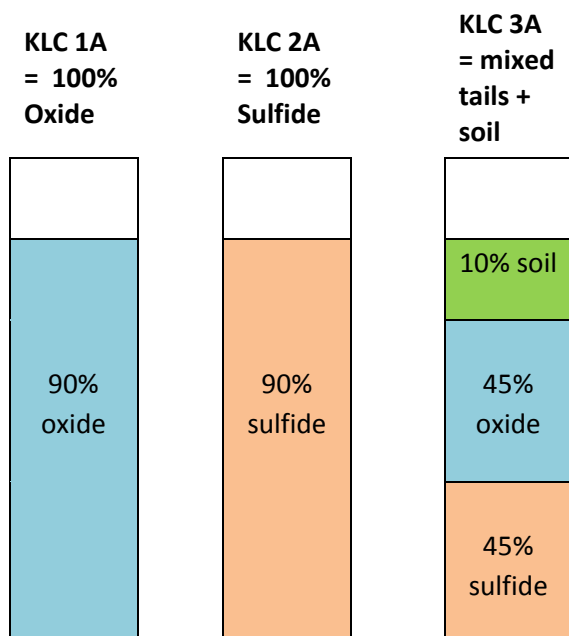


Figure 4-1: Large KLC Test Configuration

5.0 STATIC TEST RESULTS

5.1 Tailings Geochemistry

5.1.1 Total Sulfur (TS)

Total sulfur (TS) measurement includes all sulfur species (eg. organic S, sulfide S, sulfate minerals). The TS results indicate that the 85 samples.

- TS ranged from 0.02 to 0.53 %
- 18 samples had < 0.2 TS %
- 23 samples had > 0.2 and < 0.3 TS %
- 24 samples had > 0.3 and < 0.4 TS %
- 18 samples had > 0.4 and < 0.5 TS %
- 2 samples had > 0.5 and < 0.53% TS %

In general terms samples with > 0.2% TS may have some potential to generate acidity.

5.1.2 Sulfide Sulfur (SS)

TS is a standard method used to measure the maximum potential acidity (MPA) of a sample and assumes that all S is present as acid producing minerals such as Pyrite. As such TS can overestimate MPA and S speciation tests can be completed to verify the proportion of sulfide sulfur (SS) present in the TS mass. In the current work program, the chromium reducible sulfur (CRS) test method was used to measure reactive sulfide minerals on all 85 samples.

- 71 of the 85 samples had CRS % < 0.005 % verifying that the SS concentration is effectively zero
- Of the 14 samples that had measurable SS, the average percentage of SS in the TS mass was 4 %, as shown in **Figure 5-1**.

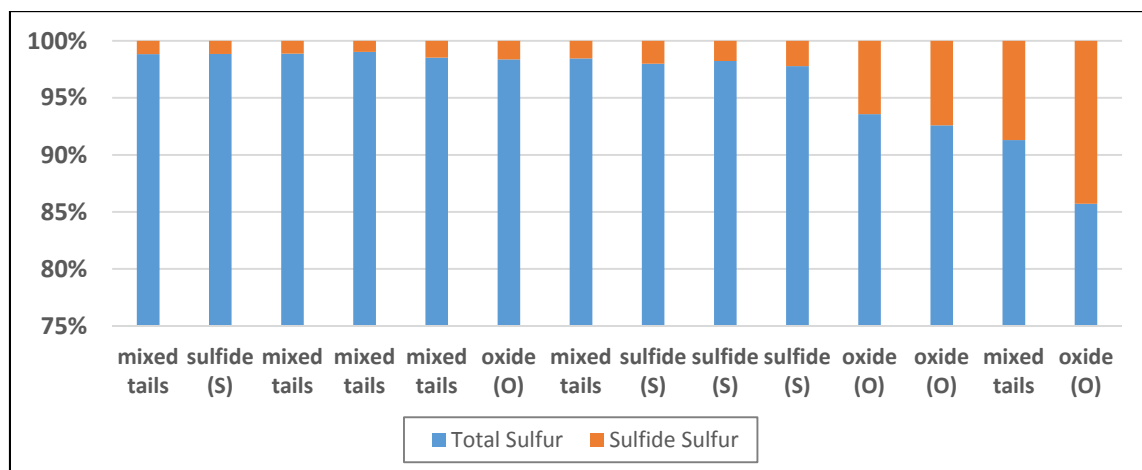


Figure 5-1: Sulfur Speciation Results for 14 Samples with Measurable Sulfide Sulfur

The CRS results have a significant bearing on the geochemical classification of the samples and this is discussed further in **Section 5.2.3**.

5.1.3 Acid Neutralising Capacity (ANC)

The ANC in the 85 samples was very low with a maximum value of 7 kg H₂SO₄/tonne; as a point of reference limestone (CaCO₃) theoretically has approximately 1,000 kg H₂SO₄/tonne of ANC per tonne of material.

5.1.4 Total Major, Minor and Trace Elements

Multi-element scans were carried out on 13 selected individual and composite samples of spoil to identify any elements (metals/metalloids) present in these materials at concentrations that may be of environmental concern with respect to materials handling, storage, and water quality.

The results were compared to guideline criteria to assess any concerns related to mine operation and final rehabilitation. To provide relevant context, RGS has compared the total metal/metalloid concentration in samples to National Environmental Protection Council (NEPC) Health-based Investigation Levels (HIL(C)) for soils in public open spaces (NEPC, 2013). Total (2 acid digest and analysis by ICP-AES or MS) elemental concentrations were measured on 4 soil and 9 tailings samples. The geochemical abundance index (GAI) method was used to evaluate elemental concentrations. The GAI quantifies an assay result for a particular element in terms of the average crustal abundance for that element. The index is based on a log (2) scale and is expressed in seven integer increments (0 to 6), which correspond to enrichment factors from 0 to over 96 times average crustal abundance, as shown in **Table 5-1**.

Table 5-1: Geochemical Abundance Index (GAI) values and Enrichment Factor

GAI	Enrichment factor	GAI	Enrichment factor
0	Less than 3-fold enrichment	4	24 – 48 fold enrichment
1	3 – 6 fold enrichment	5	48 – 96 fold enrichment
2	6 – 12 fold enrichment	6	Greater than 96 fold enrichment
3	12 – 24 fold enrichment		

As a general rule, a GAI greater than or equal to 3 indicates enrichment to a level that may warrant further investigation (INAP, 2009). This is the case with some environmentally important 'trace' elements, such as As, Cd, Cu and Zn, rather than with major rock-forming elements, such as Ca, Mg, K and Na. Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality or public health, but their significance should still be evaluated. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (eg. low pH) the solubility of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

The multi-element data for the Yandan tailings samples show that none of the measured elements exceed health criteria for public open spaces (**Table 5-2**), although the GAI values were greater than or equal to 3 for arsenic in the both the oxide and sulfide tailings and mercury in the sulfide tailings only, as shown in **Table 5-3**.

The solubility of trace metals in water extracts and KLC tests for tailings materials are investigated in **Section 5.2.3**.

YANDAN TAILINGS ASSESSMENT

Table 5-2: Whole Rock Elemental Assays and Exchangeable Cations

	Material Type →		Soil				Oxide Tailings			SulfideTailings		Mixed Tailings - Sulfide + Oxide			
	Multi-Element Sample Number →		1	2	3	4	5	6	7	8	9	10	11	12	13
	ALS Laboratory ID →		EB1446063037	EB1446063040	EB1446063039	EB1446063036	EB1446063001	EB1446063033	EB1446063006	EB1446063042	EB1446063003	EB1446063032	EB1446063043	EB1446063005	EB1446063020
	RGS sample ID number →		2	5	6	7	10	16	31	52	55	68	70	74	81
	Client sample ID →		67 T	77 OR(T)	76 OR(T)	65 T	1	52	10	82	3	51	85	6	27
Parameters	Detection Limit	NEPC ¹ Health-Based Investigation Level (HIL-C)													
Major Cations	All units mg/kg														
Calcium (Ca)	50	-	1,360	1,510	1,350	1,580	390	1,260	1,230	2,520	2,140	1,040	1,080	1,170	1,430
Magnesium (Mg)	50	-	4,140	2,060	2,830	2,710	170	260	310	90	100	80	180	230	170
Potassium (K)	50	-	1,460	1,590	1,670	1,750	960	1,120	1,240	1,580	1,440	910	1,560	1,380	1,440
Sodium (Na)	50	-	750	670	1,210	510	710	980	550	580	340	560	1,140	710	580
Minor Elements	All units mg/kg														
Aluminium (Al)	50	-	12,000	10,900	10,200	10,100	2,600	3,110	2,780	2,150	2,130	1,650	2,210	3,370	2,740
Antimony (Sb)	5	-	<5	<5	<5	<5	18	19	10	18	10	10	11	16	11
Arsenic (As)	5	300	11	14	16	20	148	172	103	209	129	130	167	167	170
Barium (Ba)	10	-	240	160	160	160	140	150	190	110	130	120	100	150	160
Beryllium (Be)	1	90	2	3	1	2	<1	<1	1	<1	<1	<1	<1	1	<1
Boron (B)	50	20,000	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cadmium (Cd)	1	90	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium (Cr) - hexavalent	2	300 **	45	47	53	50	58	45	51	45	50	24	68	56	40
Cobalt (Co)	2	300	22	18	26	20	4	6	4	2	<2	<2	5	5	4
Copper (Cu)	5	17,000	27	30	25	23	10	16	10	8	10	10	20	24	15
Iron (Fe)	50	-	34,000	45,500	41,400	29,700	13,500	14,800	10,100	11,100	8,090	9,960	11,500	13,400	12,400
Lead (Pb)	5	600	22	28	29	19	7	8	9	19	8	7	8	9	11
Manganese (Mn)	5	19,000	816	457	1,370	546	37	45	52	8	8	16	31	39	25
Mercury (Hg)	0.1	80	<0.1	<0.1	<0.1	<0.1	0	0	0	1	1	1	1	1	1
Molybdenum (Mo)	2	-	<2	<2	<2	<2	<2	<2	<2	3	<2	<2	2	<2	<2
Nickel (Ni)	2	1,200	34	35	45	31	8	9	9	3	3	3	8	9	6
Selenium (Se)	5	700	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Vanadium (V)	5	-	24	27	30	23	8	9	7	5	5	5	5	8	7
Zinc (Zn)	5	30,000	56	71	41	52	16	21	15	7	6	11	14	27	16
Exchangable Cations	All units meq/100g (except Exchangable Sodium Percentage (%))														
Exch. Calcium	0.1	-	3.4	1.9	3.5	3.0	1.0	1.6	1.7	-	-	-	-	-	-
Exch. Magnesium	0.1	-	2.2	0.3	2.1	0.5	0.4	0.2	0.3	-	-	-	-	-	-
Exch. Potassium	0.1	-	0.3	0.2	0.4	0.4	0.2	0.2	0.4	-	-	-	-	-	-
Exch. Sodium	0.1	-	0.1	<0.1	0.2	0.1	0.1	0.2	<0.1	-	-	-	-	-	-
Cation Exchange Capacity	0.1	-	5.9	2.5	6.2	4.0	1.8	2.1	2.5	-	-	-	-	-	-
Calcium:Magnesium Ratio	-	-	1.5	6.3	1.7	6.0	2.5	8.0	5.7	-	-	-	-	-	-
Exchangable Sodium Percentage	0.1%	-	1.7	0.9	2.9	1.8	6.2	5.7	2.8	-	-	-	-	-	-

Notes: < indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.

** Guideline level for Cr(VI) = 300 mg/kg. Guideline level for Cr(III) = 24% of total Cr.

1. NEPC (2013). National Environmental Protection Council (NEPC). *National Environmental Protection (Assessment of Site Contamination) Measure (NEPM)*, Amendment of Schedule B1-B7 of 1999 version. *Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.*

Table 5-3: Geochemical Abundance Indices

	Material Type →		Soil				Oxide Tailings			Sulfide Tailings		Mixed Tailings - Sulfide + Oxide			
	Multi-Element Sample Number →		1	2	3	4	5	6	7	8	9	10	11	12	13
	ALS Laboratory ID →		EB1446063037	EB1446063040	EB1446063039	EB1446063036	EB1446063001	EB1446063033	EB1446063006	EB1446063042	EB1446063003	EB1446063032	EB1446063043	EB1446063005	EB1446063020
	RGS sample ID number →		2	5	6	7	10	16	31	52	55	68	70	74	81
	Client sample ID →		67 T	77 OR(T)	76 OR(T)	65 T	1	52	10	82	3	51	85	6	27
Parameters	Detection Limit	Average Crustal Abundance ¹													
Major Elements	all units in mg/kg		Geochemical Abundance Index (GAI)												
Aluminium (Al)	50	71,000	0	0	0	0	0	0	0	0	0	0	0	0	0
Calcium (Ca)	50	15,000	0	0	0	0	0	0	0	0	0	0	0	0	0
Iron (Fe)	50	40,000	0	0	0	0	0	0	0	0	0	0	0	0	0
Magnesium (Mg)	50	5,000	0	0	0	0	0	0	0	0	0	0	0	0	0
Potassium (K)	50	14,000	0	0	0	0	0	0	0	0	0	0	0	0	0
Sodium (Na)	50	5,000	0	0	0	0	0	0	0	0	0	0	0	0	0
Minor Elements	all units in mg/kg		Geochemical Abundance Index (GAI)												
Antimony (Sb)	5	5	0	0	0	0	1	1	0	1	0	0	1	1	1
Arsenic (As)	5	6	0	1	1	1	4	4	4	5	4	4	4	4	4
Barium (Ba)	10	500	0	0	0	0	0	0	0	0	0	0	0	0	0
Beryllium (Be)	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Boron (B)	50	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium (Cd)	1	0.35	0	0	0	0	0	0	0	0	0	0	0	0	0
Chromium (Cr) - hexavalent	2	70	0	0	0	0	0	0	0	0	0	0	0	0	0
Cobalt (Co)	2	8	1	1	1	1	0	0	0	0	0	0	0	0	0
Copper (Cu)	5	30	0	0	0	0	0	0	0	0	0	0	0	0	0
Lead (Pb)	5	35	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese (Mn)	5	1000	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury (Hg)	0.1	0.06	0	0	0	0	2	2	2	3	3	2	3	3	3
Molybdenum (Mo)	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Nickel (Ni)	2	50	0	0	0	0	0	0	0	0	0	0	0	0	0
Selenium (Se)	5	0.4	2	2	2	2	2	2	2	2	2	2	2	2	2
Vanadium (V)	5	90	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinc (Zn)	5	90	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Average Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

1. When no GARD Guide value is available for particular element, then values are taken from Bowen H.J.M.(1979) Environmental Chemistry of the Elements, Academic Press, New York, p42-43.

5.1.5 Cation Exchange Capacity (CEC) and Exchangeable Sodium Percentage (ESP)

Cation exchange capacity (CEC) and the exchangeable sodium percentage (ESP) are parameters of relevance to rehabilitation materials. CEC is the capacity of the soil to hold and exchange cations. It provides a buffering effect to changes in pH, available nutrients, calcium levels and soil structural changes. As such it is a major controlling factor of soil structure, nutrient availability for plant growth, soil pH, and the soils reaction to fertilisers and other ameliorants. A low CEC means the soil has a low resistance to changes in soil chemistry (Hazleton and Murphy, 2007).

The five most abundant cations in soil are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and aluminium (Al^{3+}), although exchangeable Al only becomes significant at pH levels less than 5.5.

The CEC was measured on seven samples (four soil and three oxide tailings) and ranged from 1.8 to 6.2 meq/100g (**Table 5-2**). The CEC value in the soil samples was generally higher than in the oxide tailings (average values of 4.7 and 2.1 meq/100g, respectively).

The average CEC values for the soil and oxide tailings samples are in the “very low” range as shown in **Table 6**. The CEC results suggest that from a revegetation viewpoint, some fertiliser addition may be required to soil to provide a reasonable growth medium for vegetation roots.

Soils with CEC values less than 3 meq/100g can be low in fertility and susceptible to soil acidification. Hence, direct vegetation of oxide tailings is not recommended without a topsoil cover as part of rehabilitation activities.

Table 5-4: Ratings for Effective Cation Exchange Capacity

CEC Rating	CEC meq/100g
Very Low	<6
Low	6-12
Moderate	12-25
High	25-40
Very High	>40

The ESP results for the seven soil and oxide tailings samples range from 0.9 to 6.2 % and are generally lower in the soil samples compared to the oxide tailings samples (average values of 1.8 versus 4.9, respectively). Generally samples with ESP values less than 6 are considered non-sodic and unlikely to be susceptible to dispersion and erosion. Samples with ESP values greater than 6 are considered moderately sodic and greater than 14 are considered strongly sodic and may be susceptible to dispersion and erosion (Isbell, 2002; and Northcote and Skene, 1972). The ESP results show that the soil and oxide tailings samples have relatively low sodicity values and materials represented by these samples are unlikely to be susceptible to significant dispersion and erosion.

The exchangeable Ca:Mg ratio is a key parameter of good (fertile and structurally stable) soils. If the exchangeable Ca:Mg ratio in mine waste materials is less than 4, then these materials may require some amelioration before the materials can be used as part of a revegetation growth layer (Hazleton and Murphy, 2010). The exchangeable cation results are provided in **Table 5-2** and indicate that the sample materials have exchangeable Ca:Mg ratios ranging from 1.5 to 8.0 (average 4.5). Hence, some soil and oxide tailings materials may require amelioration (such as gypsum or fertiliser addition) to provide a reasonable growth medium for vegetation roots.

5.2 Soluble Tailings Chemistry

A 1:5 (solid:solute) method was used to measure the pH, EC, and the concentration of major ions and trace metals/metalloids in water extracts. It should be recognised that direct comparison of geochemical data from 1:5 water extracts with guideline values can be misleading.

For the purpose of this study, guideline values are only provided for broad context and should not be interpreted as arbitrary 'maximum' values or 'trigger' values. Using sample pulps (ground to passing 75 μm) provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. As such, the results of screening tests on water extract solutions represent an assumed 'worst case' scenario for undiluted leachate from tailings or soil materials.

Actual runoff and/or seepage water quality from tailings emplacement areas would be better than the multi-element results due to the less optimum conditions for leaching, and the significant dilution from fresh rainfall runoff. Further to this, water storages on the site are susceptible to the effects of evapo-concentration and dilution from rain and the proportion of water that comes from different sources such as direct rainfall, seepage from the TSF, surface runoff from the TSF, runoff from the embankment or runoff from the catchment around the TSF. Nevertheless the 1:5 results allow a good qualitative assessment of the samples to be made within the site and with other sites.

5.2.1 pH and Acidity

pH is a measure of the hydrogen ion (H^+) and hydroxyl ion (OH^-) concentration in a water solution and is used to measure the acidity or alkalinity of a sample. The optimum soil pH for the majority of agronomic field, pasture, vegetable and fruit crops in Australia is pH 5 to 7, with most plants able to grow in soils at pH 5.5 to 6 (Hazleton and Murphy, 2007). In Australia, topsoil pH ranges from 4 to 10 (median 6.5); ~ 50% of agricultural soils have a $\text{pH} \leq 5.5$ (Caritat *et al.*, 2011).

Samples with a pH value of less than 5 can be considered to be acidic, regardless of sulfide concentrations, as they are able to leach mildly acid water. The pH results for the 85 soil and tailing samples are presented in **Figure 5-2**.

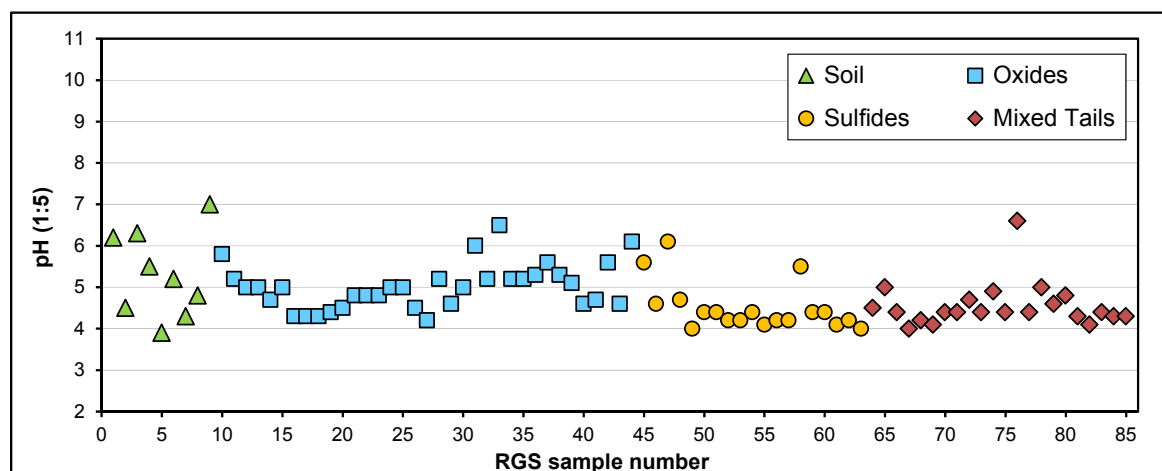


Figure 5-2: pH Results

Within the soil and tailings dataset;

- 1 sample is producing acidity and has a pH of < 4
- 54 samples are producing mild acidity and have a pH of > 4 and < 5
- 24 samples are producing negligible acidity and have a pH of > 5 and < 6, similar to the pH range found in the deionised water used in the water extract tests
- 6 samples are producing circum-neutral drainage and have a pH of > 6 and < 7

These pH results indicate that:

- 65 % of the samples produce mild acidity in contact with water
- there is no reactive ANC in the samples with a pH < 6 and hence no measured alkalinity (refer to **Table 5-5**)
- the tailings samples are generally not producing concentrated acidity in water extracts and the measured acidity in the 9 samples where acidity was tested ranged from 6 to 35 mg/L with an average value of 17 mg/L (refer to **Table 5-5**).

5.2.2 Salinity

Hazeltan and Murphy (2007) define soils with an EC of < 2,000 $\mu\text{S}/\text{cm}$ as having negligible effects on agronomic plants, but that at EC values of 2,000 to 4,000 $\mu\text{S}/\text{cm}$, yields of sensitive crops can be affected. The Authors state that water extracts with an electrical conductivity (EC) of:

- < 700 $\mu\text{S}/\text{cm}$ are considered suitable for irrigation and drinking water (8 samples)
- 700 to 2,000 $\mu\text{S}/\text{cm}$ are considered suitable for irrigation water (67 samples)
- < 3,000 $\mu\text{S}/\text{cm}$ are considered to have slight to moderate salinity (10 samples)

The EC values for the soil and tailings range from 159 to 2,950 $\mu\text{S}/\text{cm}$ as shown in **Figure 5-3**. The average EC of the tailings and soil samples is 1,498 $\mu\text{S}/\text{cm}$ and 1,017 $\mu\text{S}/\text{cm}$, respectively.

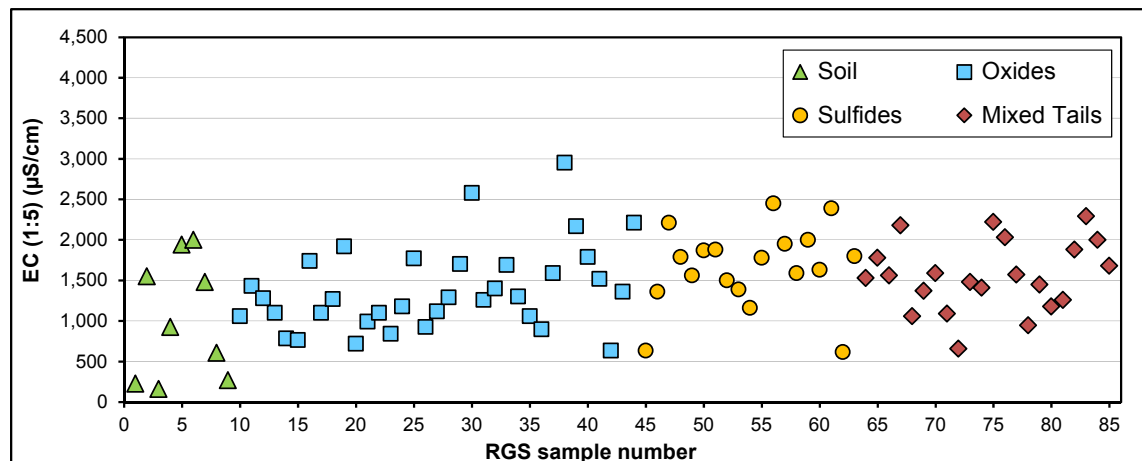


Figure 5-3: EC Results

The dominant major anion in the water extracts is sulfate (SO_4^{2-}) (**Table 5-5**) and there is a relationship between EC and TS as illustrated in **Figure 5-4**.

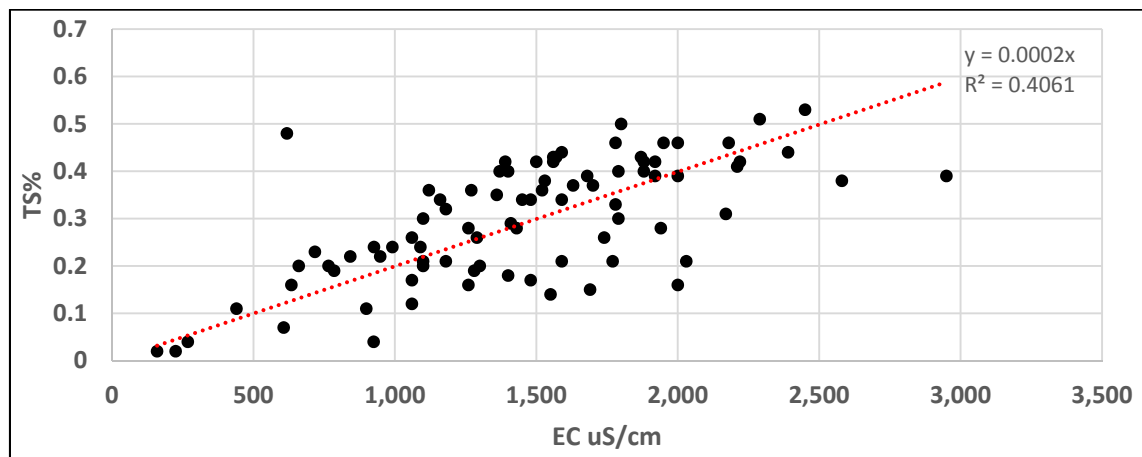


Figure 5-4: Correlation between TS and EC

5.2.3 Major Ions and Metals/Metalloids

RGS has compared the soluble major ion and metal/metalloid concentrations in water extracts from the 13 selected soil and tailings samples with Australian guidelines and relevant receiving water criteria and the results are presented in **Table 5-5**.

The concentrations of the major cations and anions in the water extracts are typically dominated by calcium and sulfate. For all but one sample (soil sample 77(OR)T), the sulfate concentration in the water extracts is below the livestock drinking water guideline for this anion (1,000 mg/L).

The concentration of most trace metals/metalloids tested in the water extracts is below the laboratory LoR and applied livestock drinking water guideline criteria in most samples (ANZECC & ARCANZ, 2000). The exceptions are aluminium and cadmium (one soil sample), iron (one sulfide tailings sample and one mixed oxide/sulfide tailings sample) and manganese (four soil samples, one oxide sample, and two mixed oxide/sulfide samples), which have concentrations in water extracts that can exceed the applied livestock drinking water guidelines values, where these exist.

The results indicate that dissolved metal/metalloid concentrations in initial surface runoff and seepage from soil and tailings materials are unlikely to significantly impact upon the quality of surface and groundwater resources at the TSF. Notwithstanding, it is recommended that the list of water quality monitoring parameters provided in **Table 5-5** be included in the water quality monitoring program at the site, from time to time.

Table 5-5: Tailings Water Extract Results

		Tailings Material Type →		Soil				Oxidic Tailings			Sulfidic Tailings		Mixed Tailings - Sulfide + Oxide			
		Multi-Element Sample Number →		1	2	3	4	5	6	7	8	9	10	11	12	13
		ALS Laboratory ID →		EB1446063037	EB1446063040	EB1446063039	EB1446063036	EB1446063001	EB1446063033	EB1446063006	EB1446063042	EB1446063003	EB1446063032	EB1446063043	EB1446063005	EB1446063020
		RGS sample ID number →		2	5	6	7	10	16	31	52	55	68	70	74	81
		Client sample ID →		67 T	77 OR(T)	76 OR(T)	65 T	1	52	10	82	3	51	85	6	27
Parameters	Detection Limit	Water Quality Guidelines:														
		Aquatic Ecosystems (freshwater) ¹	Livestock Drinking Water ²													
pH	0.01 pH unit	6 to 9	-	4.5	3.9	5.2	4.3	5.8	4.3	6.0	4.1	5.5	4.2	4.4	4.9	4.3
Electrical Conductivity	1 µS/cm	<1,000 [#]	3,580 [^]	1550	1940	2000	1480	1060	1740	1260	1780	1590	1060	1590	1410	1260
Carbonate Alkalinity (mgCaCO ₃ /L)	0.2 mg/L	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Bicarbonate Alkalinity (mgCaCO ₃ /L)	0.2 mg/L	-	-	<0.2	<0.2	1	<0.2	1	<0.2	3	<0.2	1	<0.2	<0.2	<0.2	<0.2
Total Alkalinity (mgCaCO ₃ /L)	0.2 mg/L	-	-	<0.2	<0.2	1	<0.2	1	<0.2	3	<0.2	1	<0.2	<0.2	<0.2	<0.2
Acidity (mgCaCO ₃ /L)	0.2 mg/L	-	-	17	240	10	46	12	17	6	12	8	19	35	13	29
Net Alkalinity (mgCaCO ₃ /L)	0.2 mg/L	-	-	-17	-240	-8	-46	-11	-17	-3	-12	-6	-19	-35	-13	-29
Major Ions		All units mg/L														
Calcium (Ca)	2	-	1,000	122	240	130	188	28	180	158	84	356	156	172	156	182
Magnesium (Mg)	2	-	-	74	42	92	28	8	20	22	6	8	6	24	20	12
Potassium (K)	2	-	-	14	14	22	26	16	10	44	16	30	4	18	14	12
Sodium (Na)	2	-	-	134	108	226	84	146	184	96	44	46	68	140	110	74
Chloride (Cl)	2	-	-	128	72	156	26	162	132	68	24	52	64	28	72	56
Fluoride (F)	0.2	-	2	<0.2	0.4	<0.2	0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	<0.2
Phosphate (PO ₄)	0.06	-	-	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.06
Sulfate (SO ₄)	2	-	1,000	704	1,104	968	788	196	722	614	302	928	476	754	584	588
Trace Metals/Metalloids		All units mg/L														
Aluminium (Al)	0.02	0.055	5	0.560	26.2	0.060	2.100	<0.02	0.420	<0.02	0.380	<0.02	0.960	1.880	0.460	1.280
Antimony (Sb)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.004	0.008	0.004	0.014	0.004	0.004
Arsenic (As) - pentavalent	0.002	0.013 **	0.5	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.02	0.006	0.006	0.016	0.022	0.004	0.012
Barium (Ba)	0.002	-	-	0.034	0.048	0.034	0.044	<0.002	0.010	0.030	0.008	0.014	0.002	0.002	0.006	0.008
Beryllium (Be)	0.002	-	-	0.004	0.046	<0.02	0.008	<0.002	0.004	<0.002	<0.002	<0.002	0.004	0.008	0.004	0.004
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cadmium (Cd)	0.002	0.0002	0.01	0.004	0.014	0.002	0.006	<0.002	0.006	<0.002	<0.002	<0.002	0.002	0.008	0.004	0.004
Chromium (Cr) - total	0.002	0.001 (hex)*	1 (total)	<0.002	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.004	<0.002	0.002
Cobalt (Co)	0.002	-	1	0.218	0.772	0.100	0.492	0.036	0.266	<0.002	0.060	0.022	0.072	0.328	0.208	0.172
Copper (Cu)	0.002	0.0014	1	0.006	0.018	0.004	0.006	<0.002	0.014	<0.002	0.008	<0.002	0.022	0.014	0.020	0.026
Iron (Fe)	0.2	-	1 (irrigation)	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	1.2	<0.2	0.2	1.6	0.4	0.8
Lead (Pb)	0.002	0.0034	0.1	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Manganese (Mn)	0.002	1.9	2 (irrigation)	15.5	22.6	23.6	15.8	1.176	3.340	0.726	1.204	0.296	1.350	3.900	2.900	1.802
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum (Mo)	0.002	-	0.15	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.02	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	0.286	0.882	0.434	0.530	0.060	0.386	0.040	0.096	0.022	0.130	0.482	0.306	0.276
Selenium (Se)	0.02	0.011	0.020	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	0.540	2.260	0.110	0.564	0.104	0.926	<0.01	0.124	0.022	0.652	0.960	1.128	0.548

* Cr (VI) = hexavalent. ** 0.024 mg/L for trivalent Arsenic (III).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm

[^] calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

Notes: < indicates concentration less than the detection limit. Shaded cells indicate values which exceed applied guideline values.

1. ANZECC & ARMICANZ (2000). Trigger values for aquatic ecosystems (95% species protection level)

2. ANZECC & ARMICANZ (2000). Recommended guideline limits for Livestock Drinking Water.

1 + 2. both taken from the "Australian and New Zealand Guidelines for Fresh and Marine Water Quality", National Water Quality Management Strategy, 2000, compilation by ANZECC and ARMICANZ.

5.3 Material Classification Method

A standard Acid Base Account scheme is typically used for the classification of mine waste samples is described in **Table 5-6**. This type of classification scheme assumes that the samples are fresh and have not already weathered/oxidised to generate acidity. The terminology used in this standard scheme infers that mine waste samples have the potential to **produce** acidity from sulfide oxidation at some point in the future.

Table 5-6: Standard ABA Classification Criteria

Geochemical Classification	Sulfide Sulfur ¹ (%)	NAPP (kg H ₂ SO ₄ /t)	ANC:MPA Ratio
Barren ²	≤ 0.1	-	-
Acid Consuming	> 0.1	> -50	≥ 2
Non-Acid Forming	> 0.1	≤ 0 and -50	≥ 2
Potentially Acid Forming - Low Capacity	> 0.1	> 0 and ≤ +10	<2
Potentially Acid Forming-Moderate Capacity	> 0.1	> +10 and ≤ +50	<1
Potentially Acid Forming – High Capacity	> 0.1	> +50	<1

Notes:

1. If total sulfur or sulfide sulfur is less than or equal to 0.1 %, the NAPP and ANC: MPA ratio is not required for material classification as the sample is essentially barren of oxidisable sulfur.
2. A sample classified as NAF can be further described as 'barren' if the total sulfur and/or sulfide sulfur content is less than or equal to 0.1 per cent, as the sample essentially has negligible acid generating capacity from future sulfide oxidation.

In instances where mine waste materials have already weathered/oxidised, and the inherent ANC has been consumed through neutralisation processes, some of these materials may have already generated acidity. This acidity may have already leached from the mine waste material or could still be temporarily stored within the material matrix and/or within secondary minerals.

The strength of the acidity is a function of the soluble concentrations of the H⁺ (measured by the pH) and the acidity from the H⁺ ion and metals such as Al, Cu, Fe, Mn and Zn can be measured as titratable acidity (see **Table 5-5**). The static tests used in this study to characterise the samples included TS and SS, ANC and pH. NAG analyses were also completed for 26 selected samples and the results provide similar material classifications to those derived from ABA and pH data. The results from these analytical methods verify that many of the samples had slightly acidic pH values between 4 and 6 and that all samples had < 0.1% sulfide sulfur and very little or no ANC.

Due to the fact that all of the soil and tailings samples had already weathered/oxidised *in situ*, pH criteria were used by RGS to describe the samples in terms of their existing acidity (**Table 5-6**). The classification used in this report ranges from Inert (where the pH is 6 to 7) to Mild Acid Forming Potential (MAFP) where the pH is 3 to 4. Only one of the 85 soil and tailings samples had a pH value less than 4 (topsoil sample 76 OR(T) had a pH value of 3.9).

Table 5-7: pH Classification Criteria Existing Acid Forming Samples

Existing Acid Forming Potential (AFP) (Sulfide minerals have oxidised and acid neutralising capacity is consumed)		AFP Criteria
No Acid Forming Potential	Inert	pH 6 to 7
Low Acid Forming Potential	LAFP	pH 4 to 6
Mild Acid Forming Potential	MAFP	pH 3 to 4

The geochemical results and material classification for the 85 soil and tailings samples is provided at **Table 5-8**

5.4 Sample Classification

5.4.1 Acid Producing Potential

All 85 soil and tailings samples were classified as Barren using the standard Acid Base Account classification scheme. Essentially, 71 samples had < 0.005% sulfide sulfur and the balance of the samples had < 0.04% sulfide sulfur. The CRS analyses results verify that any sulfide minerals present in the tailings at the time of deposition have completely weathered/oxidised and that any future acid generation will come from actual acidity from within the material matrix (pore water) and/or from contained secondary minerals such as Jarosite.

5.4.2 Actual Acid Forming Potential

Of the 85 samples analysed 79 samples had a pH of 4 to 6 and are classified as having low acid forming potential (LAFP), 6 samples had a pH between 6 and 7 and are classified as being Inert, and one sample had a pH less than 4 and is classified as having Mild Acid Forming Potential (MAFP). The measured acidity of the samples was also quite low and ranged from 6 to 46 mg/L with an average measured acidity of 19 mg/L.

Based on the analyses all 76 tailings samples are classified as being Barren (with no potential to produce acid through sulfide oxidation) and being Inert and having LAFP (ie. dominated by pH values of 4 to 6). The 9 soil samples were also classified as Barren and were comprised of Inert (3 samples), LAFP (5 samples) and MAFP (1 sample), materials.

Table 5-8: Static Sample Classification

RGS No.	ALS Laboratory Number	Client Sample ID	GDA 94 Easting & Northing		Field Description	Moisture Content (%)	pH ¹	EC ¹ (µS/cm)	pH based Acid Forming Potential	Total S (%)	ANC ² (kg H ₂ SO ₄ /t)	NAPP (TS – ANC) (kg H ₂ SO ₄ /t)	NAG pH	NAG capacity @ pH 4.5 (kg H ₂ SO ₄ /t)	NAG capacity @ pH 7.0 (kg H ₂ SO ₄ /t)	CRS (%)	NAPP (CRS-ANC) (kg H ₂ SO ₄ /t)	NAPP (CRS-ANC) Sample Classification
1	EB1444979075	75 T	500563	7647830	topsoil	7.6	6.2	225	Inert	0.02	2.6	-2.0	--	--	--	0.003	2.5	Barren
2	EB1444979067	67 T	500577	7647560	topsoil	12.3	4.5	1,550	LAFP	0.14	1.5	2.8	6.2	<0.1	0.7	0.003	1.4	Barren
3	EB1444979070	70 T	500578	7647602	topsoil	4.8	6.3	159	Inert	0.02	5.2	-4.6	--	--	--	0.003	5.1	Barren
4	EB1444979064	64 T	500597	7647542	topsoil	5.5	5.5	925	LAFP	0.04	4.0	-2.8	--	--	--	0.003	3.9	Barren
5	EB1444979077	77 OR(T)	500703	7646915	topsoil	7.0	3.9	1,940	MAFP	0.28	0.3	8.3	3.3	1.0	5.7	0.003	0.2	Barren
6	EB1444979076	76 OR(T)	500687	7646993	topsoil + sulfide tails	6.9	5.2	2,000	LAFP	0.16	1.8	3.1	6.7	<0.1	0.6	0.003	1.7	Barren
7	EB1444979065	65 T	500597	7647542	topsoil	7.5	4.3	1,480	LAFP	0.17	0.8	4.4	5.7	<0.1	1.0	0.003	0.7	Barren
8	EB1444979074	74 T	500563	7647830	topsoil	14.0	4.8	607	LAFP	0.07	0.3	1.9	--	--	--	0.003	0.2	Barren
9	EB1444979071	71 T	500578	7647602	topsoil	7.0	7.0	268	Inert	0.04	6.9	-5.7	--	--	--	0.003	6.8	Barren
10	EB1444979001	1	500223	7646721	oxide (O)	6.0	5.8	1,060	LAFP	0.12	0.3	3.4	4.6	<0.1	2.9	0.003	0.2	Barren
11	EB1444979022	22	500157	7646912	oxide (O)	11.6	5.2	1,430	LAFP	0.28	0.6	8.0	--	--	--	0.003	0.5	Barren
12	EB1444979024	24	500145	7646870	oxide (O)	9.3	5.0	1,280	LAFP	0.19	0.3	5.6	--	--	--	0.003	0.2	Barren
13	EB1444979026	26	500191	7646890	oxide (O)	10.6	5.0	1,100	LAFP	0.20	0.3	5.9	4.2	0.6	3.4	0.003	0.2	Barren
14	EB1444979035	35	500306	7646778	oxide (O)	9.9	4.7	785	LAFP	0.19	0.3	5.6	--	--	--	0.003	0.2	Barren
15	EB1444979046	46	500211	7646810	oxide (O)	6.3	5.0	765	LAFP	0.20	0.3	5.9	--	--	--	0.003	0.2	Barren
16	EB1444979052	52	500186	7646945	oxide (O)	16.1	4.3	1,740	LAFP	0.26	0.3	7.7	4.1	0.6	2.6	0.003	0.2	Barren
17	EB1444979056	56	500262	7646949	oxide (O)	10.6	4.3	1,100	LAFP	0.30	0.3	8.9	--	--	--	0.003	0.2	Barren
18	EB1444979062	62	500600	7647471	oxide (O)	8.6	4.3	1,270	LAFP	0.36	0.3	10.8	--	--	--	0.003	0.2	Barren
19	EB1444979079	79	500208	7646998	oxide (O)	14.0	4.4	1,920	LAFP	0.39	0.3	11.7	--	--	--	0.003	0.2	Barren
20	EB1444979081	81	500271	7647266	oxide (O)	4.7	4.5	717	LAFP	0.23	0.3	6.8	--	--	--	0.003	0.2	Barren
21	EB1444979042	42	500278	7646752	oxide (O)	10.6	4.8	991	LAFP	0.24	0.3	7.1	4.0	0.6	2.2	0.003	0.2	Barren
22	EB1444979033	33	500283	7646797	oxide (O)	12.6	4.8	1,100	LAFP	0.21	0.3	6.2	--	--	--	0.003	0.2	Barren
23	EB1444979037	37	500327	7646755	oxide (O)	8.4	4.8	842	LAFP	0.22	0.3	6.5	--	--	--	0.003	0.2	Barren
24	EB1444979040	40	500300	7646734	oxide (O)	7.7	5.0	1,180	LAFP	0.21	0.3	6.2	4.2	0.4	1.8	0.003	0.2	Barren
25	EB1444979048	48	500181	7646834	oxide (O)	12.3	5.0	1,770	LAFP	0.21	0.3	6.2	--	--	--	0.003	0.2	Barren
26	EB1444979054	54	500227	7646919	oxide (O)	14.1	4.5	926	LAFP	0.24	0.3	7.1	3.8	0.8	2.3	0.040	-1.0	Barren
27	EB1444979060	60	500560	7647408	oxide (O)	7.3	4.2	1,120	LAFP	0.36	0.3	10.8	--	--	--	0.006	0.1	Barren
28	EB1444979004	4	500244	7646749	oxide (O)	10.7	5.2	1,290	LAFP	0.26	0.3	7.7	--	--	--	0.003	0.2	Barren
29	EB1444979008	8	500111	7646956	oxide (O)	10.4	4.6	1,700	LAFP	0.37	0.3	11.1	--	--	--	0.003	0.2	Barren
30	EB1444979009	9	500112	7647002	oxide (O)	11.3	5.0	2,580	LAFP	0.38	0.3	11.4	--	--	--	0.003	0.2	Barren
31	EB1444979010	10	500129	7647029	oxide (O)	11.6	6.0	1,260	LAFP	0.16	0.6	4.3	6.0	<0.1	1.2	0.011	0.3	Barren
32	EB1444979012	12	500149	7647096	oxide (O)	15.2	5.2	1,400	LAFP	0.18	0.3	5.3	--	--	--	0.003	0.2	Barren
33	EB1444979013	13	500155	7647138	oxide (O)	11.6	6.5	1,690	Inert	0.15	0.3	4.3	--	--	--	0.012	-0.1	Barren
34	EB1444979014	14	500169	7647178	oxide (O)	11.5	5.2	1,300	LAFP	0.20	0.3	5.9	--	--	--	0.003	0.2	Barren
35	EB1444979015	15	500217	7647170	oxide (O)	13.4	5.2	1,060	LAFP	0.17	0.3	4.9	--	--	--	0.003	0.2	Barren
36	EB1444979016	16	500204	7647124	oxide (O)	10.1	5.3	899	LAFP	0.11	0.3	3.1	--	--	--	0.003	0.2	Barren
37	EB1444979017	17	500191	7647077	oxide (O)	11.7	5.6	1,590	LAFP	0.21	0.3	6.2	--	--	--	0.003	0.2	Barren
38	EB1444979018	18	500187	7647042	oxide (O)	13.4	5.3	2,950	LAFP	0.39	0.3	11.7	--	--	--	0.003	0.2	Barren
39	EB1444979019	19	500187	7647014	oxide (O)	14.6	5.1	2,170	LAFP	0.31	0.3	9.2	--	--	--	0.003	0.2	Barren
40	EB1444979020	20	500177	7646987	oxide (O)	8.9	4.6	1,790	LAFP	0.30	0.9	8.3	4.4	<0.1	3.2	0.003	0.8	Barren
41	EB1444979021	21	500170	7646954	oxide (O)	9.4	4.7	1,520	LAFP	0.36	0.3	10.8	--	--	--	0.003	0.2	Barren
42	EB1444979002	2	500223	7646721	oxide (O)	6.6	5.6	634	LAFP	0.16	0.3	4.6	4.2	0.2	2.5	0.003	0.2	Barren
43	EB1444979068	68 T	500577	7647560	oxide (O)	11.2	4.6	1,360	LAFP	0.35	0.3	10.4	--	--	--	0.003	0.2	Barren
44	EB1444979072	72 T	500578	7647602	oxide (O)	10.4	6.1	2,210	Inert	0.41	1.7	10.8	--	--	--	0.003	1.6	Barren
45	EB1444979025	25	500145	7646870	sulfide (S)	10.7	4.7	1,790	LAFP	0.40	0.3	12.0	--	--	--	0.003	0.2	Barren
46	EB1444979078	78 OR(T)	500703	7646915	sulfide (S)	10.5	4.0	1,560	LAFP	0.43	0.3	12.9	--	--	--	0.003	0.2	Barren
47	EB1444979036	36	500306	7646778	sulfide (S)	12.5	4.4	1,870	LAFP	0.43	0.3	12.9	--	--	--	0.005	0.1	Barren
48	EB1444979047	47	500211	7646810	sulfide (S)	9.2	4.4	1,880	LAFP	0.40	0.3	12.0	--	--	--	0.003	0.2	Barren
49	EB1444979057	57	500262	7646949	sulfide (S)	9.6	4.2	1,500	LAFP	0.42	0.3	12.6	--	--	--	0.003	0.2	Barren
50	EB1444979063	63	500600	7647471	sulfide (S)	8.7	4.2	1,390	LAFP	0.42	0.3	12.6	--	--	--	0.003	0.2	Barren
51	EB1444979080	80	500208	7646998	sulfide (S)	11.3	4.4	1,160	LAFP	0.34	0.3	10.1	--	--	--	0.003	0.2	Barren
52	EB1444979082	82	500271	7647266	sulfide (S)	13.5	4.1	1,780	LAFP	0.46	0.3	13.8	4.2	0.2	2.3	0.003	0.2	Barren
53	EB1444979066	66 T	500597	7647542	sulfide (S)	12.0	4.2	2,450	LAFP	0.53	0.3	15.9	--	--	--	0.003	0.2	Barren
54	EB1444979043	43	500278	7646752	sulfide (S)	10.7	4.2	1,950	LAFP	0.46	0.3	13.8	--	--	--	0.003	0.2	Barren
55	EB1444979003	3	500223	7646721	sulfide (S)	5.5	5.5	1,590	LAFP	0.34	0.3	10.1	4.4	<0.1	1.7	0.007	0.0	Barren
56	EB1444979034	34	500283	7646797	sulfide (S)	14.5	4.4	2,000	LAFP	0.46	0.3	13.8	--	--	--	0.003	0.2	Barren
57	EB1444979038	38	500327	7646755	sulfide (S)	12.7	4.4	1,630	LAFP	0.37	0.3	11.1	--	--	--	0.003	0.2	Barren
58	EB1444979041	41	500300	7646734	sulfide (S)	17.8	4.1	2,390	LAFP	0.44	0.3	13.2	--	--	--	0.010	-0.1	Barren
59	EB1444979049	49	500181	7646834	sulfide (S)	13.7	4.2	618	LAFP	0.48	0.3	14.4	--	--	--	0.003	0.2	Barren

RGS No.	ALS Laboratory Number	Client Sample ID	GDA 94 Easting & Northing		Field Description	Moisture Content (%)	pH ¹	EC ¹ (µS/cm)	pH based Acid Forming Potential	Total S (%)	ANC ² (kg H ₂ SO ₄ /t)	NAPP (TS – ANC) (kg H ₂ SO ₄ /t)	NAG pH	NAG capacity @ pH 4.5 (kg H ₂ SO ₄ /t)	NAG capacity @ pH 7.0 (kg H ₂ SO ₄ /t)	CRS (%)	NAPP (CRS-ANC) (kg H ₂ SO ₄ /t)	NAPP (CRS-ANC) Sample Classification
60	EB1444979061	61	500560	7647408	sulfide (S)	11.5	4.0	1,800	LAFP	0.50	0.3	15.0	--	--	--	0.009	0.0	Barren
61	EB1444979069	69 T	500577	7647560	sulfide (S)	12.0	4.5	1,400	LAFP	0.40	0.3	12.0	--	--	--	0.003	0.2	Barren
62	EB1444979073	73 T	500563	7647830	sulfide (S)	8.0	5.8	440	LAFP	0.11	0.3	3.1	4.3	0.2	2.0	0.003	0.2	Barren
63	EB1444979005	5	500244	7646749	sulfide (S)	13.6	4.6	1,920	LAFP	0.42	0.3	12.6	--	--	--	0.003	0.2	Barren
64	EB1444979083	83	500298	7647387	mixed tails	5.6	4.5	1,530	LAFP	0.38	0.3	11.4	--	--	--	0.006	0.1	Barren
65	EB1444979050	50	500160	7646857	mixed tails	10.3	5.0	1,780	LAFP	0.33	0.3	9.8	4.5	<0.1	1.4	0.003	0.2	Barren
66	EB1444979058	58	500292	7646981	mixed tails	10.2	4.4	1,560	LAFP	0.42	0.3	12.6	--	--	--	0.003	0.2	Barren
67	EB1444979059	59	500322	7647019	mixed tails	12.3	4.0	2,180	LAFP	0.46	0.3	13.8	--	--	--	0.003	0.2	Barren
68	EB1444979051	51	500169	7646908	mixed tails	8.2	4.2	1,060	LAFP	0.26	0.3	7.7	3.6	1.1	2.4	0.003	0.2	Barren
69	EB1444979084	84	500315	7647483	mixed tails	6.3	4.1	1,370	LAFP	0.40	0.3	12.0	--	--	--	0.006	0.1	Barren
70	EB1444979085	85	500340	7647589	mixed tails	11.0	4.4	1,590	LAFP	0.44	0.3	13.2	4.3	0.2	1.6	0.005	0.1	Barren
71	EB1444979028	28	500217	7646863	mixed tails	13.6	4.4	1,090	LAFP	0.24	0.3	7.1	3.9	1.0	2.7	0.003	0.2	Barren
72	EB1444979030	30	500241	7646843	mixed tails	9.1	4.7	660	LAFP	0.20	0.3	5.9	3.9	0.9	2.2	0.003	0.2	Barren
73	EB1444979045	45	500232	7646790	mixed tails	8.5	4.4	1,480	LAFP	0.34	0.3	10.1	--	--	--	0.003	0.2	Barren
74	EB1444979006	6	500091	7646889	mixed tails	8.2	4.9	1,410	LAFP	0.29	0.3	8.6	4.6	<0.1	1.4	0.003	0.2	Barren
75	EB1444979007	7	500099	7646932	mixed tails	8.6	4.4	2,220	LAFP	0.42	0.3	12.6	--	--	--	0.003	0.2	Barren
76	EB1444979011	11	500136	7647055	mixed tails	12.4	6.6	2,030	Inert	0.21	0.6	5.8	6.2	<0.1	0.7	0.020	0.0	Barren
77	EB1444979032	32	500264	7646820	mixed tails	9.6	4.4	1,570	LAFP	0.43	0.3	12.9	--	--	--	0.003	0.2	Barren
78	EB1444979039	39	500349	7646733	mixed tails	12.2	5.0	948	LAFP	0.22	0.3	6.5	4.2	0.5	1.8	0.003	0.2	Barren
79	EB1444979044	44	500254	7646770	mixed tails	9.8	4.6	1,450	LAFP	0.34	0.3	10.1	--	--	--	0.003	0.2	Barren
80	EB1444979023	23	500157	7646912	mixed tails	13.2	4.8	1,180	LAFP	0.32	0.3	9.5	3.9	0.4	1.9	0.003	0.2	Barren
81	EB1444979027	27	500191	7646890	mixed tails	18.6	4.3	1,260	LAFP	0.28	0.3	8.3	4.3	0.5	4.0	0.003	0.2	Barren
82	EB1444979029	29	500217	7646863	mixed tails	13.7	4.1	1,880	LAFP	0.42	0.3	12.6	--	--	--	0.005	0.1	Barren
83	EB1444979031	31	500241	7646843	mixed tails	14.8	4.4	2,290	LAFP	0.51	0.3	15.3	--	--	--	0.005	0.1	Barren
84	EB1444979053	53	500186	7646945	mixed tails	18.2	4.3	2,000	LAFP	0.39	0.3	11.7	--	--	--	0.003	0.2	Barren
85	EB1444979055	55	500227	7646919	mixed tails	15.4	4.3	1,680	LAFP	0.39	0.3	11.7	--	--	--	0.003	0.2	Barren

Red numerical values are below the laboratory limit of reporting. In each case a value equal to half of the actual limit of reporting has been selected for resultant calculations.

6.0 KINETIC TEST RESULTS

Kinetic leach column (KLC) tests are used to (1) verify the static classification of a sample, (2) quantify the rate of sulfide oxidation and acid consumption and (3) assess the leachate chemistry over time.

As discussed in **Section 2.0** tailings samples were described in the field as being oxide or sulfide based on the type of the ore that was processed and visual observations. Samples were selected for kinetic testing based on (1) the field description of the tailings and (2) the NAPP classification using TS and ANC.

In order to obtain sufficient sample mass for the KLC testing oxide and sulfide samples classified using TS and ANC were composited into the two material types to provide two bulk oxide and sulfide tailings samples.

Five KLC tests commenced in December 2014 (two standard columns and three large columns) and were operated using the methodology described in **Section 4.0**. KLC test results are presented in **Attachment B** and verify that there are no significant differences in the leachate chemistry of the standard oxide or sulfide tailings KLC tests whereas there are differences in the large KLC tests (**Figure 6-1**) (ie. there are discernible differences in leachate chemistry between the oxide and sulfide tailings samples).

Overall the KLC test findings are summarised as follows:

- Initial sample:solute ratios were 2.3 and 2.7:1 for the standard columns and 11 to 22:1 in the large columns (now that the samples have been saturated, the leachate ratio of the small and large columns will be targeted as 2:1 and 10:1, respectively).
- Differences in the concentrations of the leachate from the standard and large columns is primarily due to the different sample:solute ratios.
- The standard oxide and sulfide columns do not show significant differences in leachate chemistry, although the sulfide column does have slightly lower pH and higher acidity.
- The large sulfide column has a notably higher concentration of acidity, metals and salts in the first four (monthly) leach cycles than the oxide and sulfide-oxide-soil columns.
- All columns show high initial solute concentrations in leachate that generally decreases with subsequent leach events due to the leaching of readily soluble ions being flushed from the cells – this is a common occurrence in KLC tests commonly referred to as a “first flush” response. Whilst the solute concentrations for the large oxide and sulfide tailings columns increase on the third leach event, the general concentration trends are down.

In the large cells:

- pH of leachate from all columns is between pH 4 and 5 apart from the large sulfide column, which has a leachate pH slightly less than 4.
- soluble concentrations of major, minor and trace elements are higher in leachate from the large sulfide and oxide columns compared to the large mixed column and the two standard columns.
- The concentrations of most elements in column leachate decreases significantly over time for the standard columns but remains persistently elevated for column leachate from the large oxide and sulfide columns with respect to aluminium, manganese and nickel.

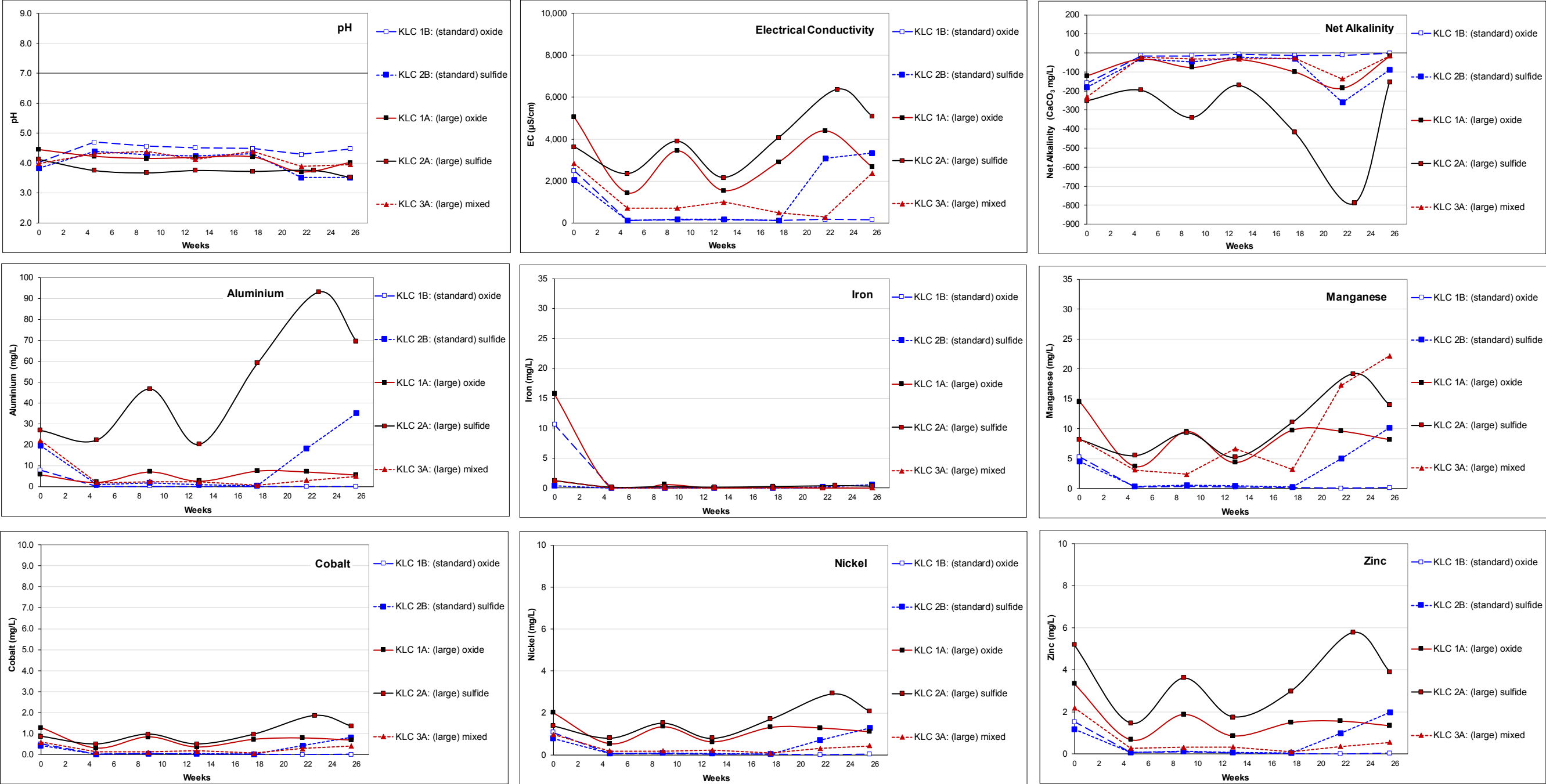


Figure 6-1: KLC Test Results

7.0 DISCUSSION

In this assessment, static geochemical tests have been used to quantify the Acid Base Account, measure the acid forming potential and geochemically classify soil and tailings samples. Static leach tests have been used to further evaluate the geochemistry of the sample materials and include measurement of the “total”, exchangeable and soluble concentrations of major ions and trace elements.

“Total” element concentrations have been used to determine whether elements are present in the sample materials at elevated concentrations compared to average crustal abundance and exchangeable cation data have been used to evaluate soil fertility and potential issues associated with sodicity. Soluble element concentrations have been used to infer potential solid/aqueous phase interactions and concentrations in surface runoff. Free draining KLC tests have been set up to provide an indication of the quality tailings pore water and any seepage.

7.1 Static Geochemistry

It has been assumed that the total sulfur concentration of 0.1 to 0.5 %TS in the 76 tailings samples (and nine soil samples) provides a reasonable representation of the initial sulfide sulfur concentration in both the oxide and sulfide tailings streams. The actual sulfide sulfur concentration of the tailings samples measured by CRS verifies that the samples have weathered/oxidised and the residual sulfide concentrations are now very low.

The oxidation of the acid producing sulfide minerals and generation of acidity has all but consumed the inherent acid consuming minerals in the tailings (there is essentially very little measureable ANC) and this has resulted in low to mild concentrations of acidity.

The absence, or very small proportion, of measured sulfide sulfur in the tailings samples verifies that since the initial placement of the tailings into the TSF, the sulfide minerals (to at least 600 mm depth) have undergone substantial or complete oxidation. As the samples oxidised, it is probable that the soluble ions precipitated in the unsaturated oxidation zones as secondary reaction products such as jarosite and schwermannite. These minerals can temporarily store acidity and metals or remove and immobilise contaminants through adsorption, co-precipitation, or structural incorporation, and can also slowly re-release both acidity and metals at pH values around pH 4. Due to their often poorly crystalline nature, schwermannite and jarosite particles continuously undergo transformation processes, which comprise dissolution/re-precipitation, solid-state recrystallization, and aggregation based crystal growth processes with release of their stored acidity (Li *et al.*, 2014). Whilst there is currently no mineralogical data to support the assumption that the source of the soluble major, minor and trace elements in the leachate from the kinetic leach cells is from the dissolution of minerals such as jarosite, it is reasonable to assume that this is the case as the vast majority of the sulfide minerals have oxidised and they are therefore no longer a source of acidity generation or metals.

The measured “total” element concentrations are generally low compared to average crustal abundance and applied health-based guideline criteria for public open spaces. Whilst the GAI values were elevated for arsenic in the both the oxide and sulfide tailings and mercury in the sulfide tailings, these elements were found to be sparingly soluble in the water extract and KLC tests on tailings materials.

The soluble and total elemental data suggest there has not been accumulation of soluble elements from the tailings into the trial soil cover through capillary action; if this had occurred the soluble concentrations of major ions (salts) would have been higher in the soil.

The multi-element data also indicate that the soil has not been adversely impacted by the accumulation of tailings through wind borne erosion processes; if this had occurred, the concentrations of the geochemical signature elements for tailings such as arsenic, mercury and antimony, for example, would have been higher in the soil.

The data suggest that depth of the soil cover (0.5 m depth) over the tailings is sufficient to not be affected by potential impacts from capillary rise of any acidity and salts in higher (and drier) topographical areas (ie in the northern and eastern areas of TSF Cell B). At the lower (and

wetter) topographical area towards the south-western side of TSF Cell B, a 1m cover depth may be more appropriate.

Anecdotal evidence from the aerial image provided in this report (**Figure 2-2**) suggests that the soluble concentrations of major ions and trace elements are not inducing chronic or acute eco-toxic effects as there is healthy vegetation growing on the tailings in drainage channels on the tailings in TSF Cell B; this suggests that the limiting factor to establishing vegetation may in fact be the availability of water; the drainage channels are likely to provide more water than the drier tailings beaches and thus more able to support vegetation.

7.2 Leach Tests, Rainfall, Surface Runoff and Seepage

Laboratory scale static and kinetic leach tests were used to assess the likely chemistry of the tailings under field conditions. The KLC cells are set up to be free draining so that adequate volumes of water can be collected and their primary application is to evaluate potential seepage quality under unsaturated freely oxidising conditions. However, there are significant differences between laboratory and field conditions such as the solid:solute ratio used, which is a function of rainfall and evaporation, soil moisture, the density and hydraulic conductivity of the tailings and the design of the TSF. On site, these factors contribute to differences in the proportion of rain that reports as runoff, water removed through evaporation/evapotranspiration, water that infiltrates into the tailings and reports to the water return dam, or water that drains to groundwater.

The climate in the region of the Yandan TSF is dominated by:

- long periods of little or no rain and irregular, short, but high intensity rainfall events, that can lead to a high proportion of runoff relative to infiltration; and
- occasional longer duration tropical depressions that may result in complete inundation and saturation of the tailings, and local or regional flooding.

Evaluation of rainfall data from the nearest available station (Moranbah) indicates that two weeks prior to the collection of the samples there was potentially 38 mm of rain at the site over two days. It is uncertain how this rainfall event contributed to the measured moisture in the samples, however it is considered unlikely that 38 mm of rain would be sufficient to wet the tailings to a depth of up to 600 mm if they had been completely dry prior to the rainfall event. It is therefore assumed that the tailings are not free draining and that they retain porewater in the 0 to 600 mm profile. The measured soil moisture in the tailings from surface to 500 mm depth was 4.7 to 18.6 % with an average of 10.7% and there were no readily discernible relationships between tailings depth and moisture.

To evaluate the effect of sample density on the permeability of the tailings, the tailings materials in the large columns were compacted to achieve a bulk density of 1.8 kg/m³ and this decreased permeability to a point where leachate could not be collected from the samples. Essentially, water remained at the top the tailings and did not penetrate significantly into the tailings mass. This required the large columns to be re-prepared with “loose” placement of the tailings and suggests that under field conditions where the tailings are consolidated, there is likely to be a significantly greater proportion of surface runoff compared to infiltration. A lower rate of infiltration would reduce the hydraulic gradient of pore water through the tailings towards the TSF sump and lead to low or even no seepage into groundwater.

In simplistic terms, this means that rainfall interaction with the tailings at TSF Cell B is generally restricted to surface tailings and results in a high proportion of surface runoff compared to infiltration. The action of disturbing and sampling the tailings and forcing water contact through re-disturbing and “loose” packing of tailings in order to get a leachate sample, has probably resulted in tailings/water interaction in the laboratory that will not occur in the field, even if the tailings mass remained uncovered.

7.2.1 Static Leach Tests and Surface Runoff

The 1:5 water extracts can be used to provide an indication of the chemistry of surface runoff from tailings. It is inferred that the extract results simulate water quality of “tailings on the tailings

beach” during a moderate rainfall event. A simplistic evaluation of the data suggests that surface runoff quality could exceed ANZECC aquatic ecosystem guidelines, but is likely to meet ANZECC stock water guidelines, other than for pH (**Table 5-5**). However, when tailings beach surface runoff mixes with runoff, direct rainfall and seepage from the TSF catchment the effect of dilution from these sources renders the water in the TSF return water dam suitable for consumption by grazing stock, and this quality may also meet aquatic ecosystem guidelines (**Table 7-1** and **Table 7-2**). It is also likely that during larger or more prolonged rainfall events, when the capacity of the TSF return water dam is exceeded and the water overflows, subsequent dilution results in aquatic ecosystem compliance in the freshwater dams down gradient of the TSF. The available surface water monitoring data for the TSF return water dam validates this assumption as measured water quality in the return water dam has neutral to alkaline pH with relatively low EC values that would make the water suitable for irrigation supply.

Given the elevated concentration of manganese in water extracts and KLC test leachate from some soil and tailings samples in the static and kinetic laboratory tests, it is recommended that this element also be included in the range of elements tests at the TSF return water dam.

Table 7-1: Yandan TSF Return Water Dam pH and EC data

Monitoring Site	Location Name	Month/year	Exact Date/Time* Sampled	Northing	Easting	pH	EC $\mu\text{S/cm}$
Tailings Runoff Dam	-	August 2011	30/08/2011	7646633	499456	6.90	960
Tailings Return Dam	TRD1	November 2011	24/11/11 07:00	7646637	499461	5.64	1,220
Tailings Return Dam	TRD1	May 2012	20/05/2012 9:35	7646637	499461	5.54	951
Tailings Return Dam	TRD1	October 2012	18/10/2012 13:00	7646637	499461	6.03	1,248
Tailings Return Dam	TRD1	April 2013	25/04/2013 14:20	7646637	499461	8.12	1,530
Tailings Return Dam	TRD1	October 2013	13/10/2013 14:10	7646637	499461	7.64	1,595
Tailings Return Dam	TRD1	May 2014	24/05/2014 10:15	7646637	499461	7.13	1,884

Table 7-2: Yandan TSF Return Water Dam Water Quality Data

Parameter	Tailings Return Dam - TRD1		
	April 2013	October 2013	May 2014
	ES1309755-030	EB1325140-031	EB1412585-020
	Value	Value	Value
pH	6.36	6.66	6.96
EC	1,590	1,930	3,020
Sulfate (SO_4)	471	728	928
Weak Acid Dissociable (WAD) Cyanide	<0.004	<0.004	<0.004
Metals (by ICP-MS)	Total	Total	Total
Aluminium (Al)	0.18	0.12	0.08
Arsenic (As)	0.002	0.002	0.001
Cadmium (Cd)	0.0006	0.0007	0.0002
Chromium (Cr)	<0.001	<0.001	<0.001
Copper (Cu)	0.003	0.002	0.002
Lead (Pb)	0.011	0.003	0.002
Nickel (Ni)	0.038	0.023	0.006
Zinc (Zn)	0.006	0.008	0.006

7.2.2 Kinetic Leach Tests and Tailings Porewater and Seepage

The KLC test results simulating potential tailings pore water or seepage quality from the tailings (under 100% permeability and following significant physical re-disturbance) verify that under these conditions, both “oxide” and “sulfide” tailings have the potential to produce mildly acidic drainage around pH 4-5. The measured acidity is dominated by acidity from aluminium, iron and manganese opposed to H^+ in sulfuric acid from sulfide oxidation.

The initial acidity level in the KLC test leachate samples was higher than for subsequent leaching events. These higher acidity concentrations probably resulted from the physical degradation of secondary minerals as the columns were set up. However, after the third leach event, the measured acidity in all the columns (apart from the large sulfide tailings column) decreased significantly and was generally consistent with the 1:5 static leach test results.

The initial major ion, trace element and acidity concentrations in the leachate from the KLC test samples are not considered to be indicative of *in situ* pore water chemistry, however longer term leachate data may be indicative once an equilibrium (relatively steady state) situation is reached. Essentially, during sample collection and preparation, the physical mixing of the samples can grossly affect the physical stability of minerals such as jarosite and increase their solubility. However, as the tailings return to, and reach, equilibrium after several leach events, the leachate chemistry is likely to be more indicative of oxidised tailings pore water under field conditions.

The solid:solute ratio is approximately 2:1 in the standard leach cells and 10:1 in the large leach cells. This can result in differences in the concentration and loads of major ions and trace elements in the leachate. The average volume of water added to the columns during each leach cycle is equivalent to 63 mm of rainfall and ranges from 49 to 77 mm.

8.0 CONCLUSIONS

Based on measured total sulfur data, the sulfide minerals and equivalent sulfide sulfur concentrations of the Yandan tailings were assumed to be in the order of 0.5% when originally placed into TSF Cell B. Since placement, the sulfide minerals have undergone substantial or complete oxidation. This means that in the tailings, to at least 600 mm depth, essentially no residual sulfide minerals are present.

The multi-element data for the soil and tailings samples indicate that metal/metalloid concentrations in solids are relatively low and/or are sparingly soluble under expected field conditions. The measured acidity in leachate from tailings is dominated by acidity from aluminium, iron and manganese as opposed to H^+ in sulfuric acid from sulfide oxidation and this is reflected in the quality of leachate from physically disturbed tailings materials.

The geochemical results indicate that secondary sulfide minerals (eg. jarosite) may be controlling solute chemistry. There are no significant differences between the small and large KLC tests except that the physical disturbance of the sulfide tailings in the large KLC tests may have adversely affected the physical stability of minerals such as jarosite and increase their solubility.

The soluble and total elemental data suggest there has not been an accumulation of soluble elements from the tailings into the trial soil cover through capillary action; if this had occurred the soluble concentrations of major ions (salts) would have been higher in the soil. The multi-element data also indicate that the soil has not been adversely impacted by the accumulation of tailings through wind borne erosion processes; if this had occurred, the concentrations of the geochemical signature elements for tailings would have been higher in soil.

Development of mitigation/rehabilitation methods for tailings, such as a cover system containing sulfide minerals, is typically undertaken to reduce the amount of:

- Oxygen ingress and subsequently sulfide mineral oxidation
- Rainwater and surface runoff that comes into contact with the tailings to ultimately control the amount of and quality of drainage.

There may be other objectives such as reducing dust from the materials, or providing a cover that will support vegetation. The sulfide mineral and total element content is relatively low in the Cell B tailings tested to date therefore (and assuming this occurs throughout the full depth of the TSF) the cover design objectives at Yandan should therefore be:

- to stop the tailings being blown from the TSF to adjoining land;
- provide a growth medium that is capable of supporting vegetation; and
- provide a stable soil surface that may include a coarse rock mulch to retain moisture from small rainfall events and protect the surface from erosion during large rainfall events.

Based on the results from this assessment it is considered unlikely that the tailings contain a sufficient mass of soluble ions (acid, salt and metals) to significantly affect the overlying soil due to the effects of capillary rise. This means that a capillary break in the cover system is unlikely to be required. The potential use if a capillary break for a TSF cover system is fundamentally questionable in any case due to potential for long term failure through differential settlement into the tailings mass and also migration of fines from the cover system into the capillary layer.

Compaction of the tailings at RGS laboratory demonstrates that the compacted Yandan tailings have very low permeability and for the initial large KLC tests, were found to be essentially impermeable. The cover system proposed for TSF Cell B could therefore utilise:

- mild grading of the current surface to smooth out any existing erosion and direct surface flow to a desired location ie. encouraging water to follow the geomorphic channels on the current surface of the TSF towards the spillway and then into the return water dam, or if water quality subsequently permits, directly to the environment;
- compaction of the regraded tailings beach profile to further decrease permeability; and
- placement of a 0.5m to 1 m deep soil cover over the tailings; a nominal minimal depth of 50 cm should be achieved in drier areas and 1m depth in wetter areas.

9.0 RECOMMENDATIONS

When the tailings materials from TSF Cell B are compacted they become virtually impermeable. In the field, the permeability of the tailings is likely to have a significant effect on the proportion of rainfall that reports as surface runoff versus infiltration.

To verify the assumptions in this report relating to runoff and infiltration RGS **recommends field permeability measurements** be undertaken using single ring or double ring infiltrometer tests. This should be done at:

- six tailings sites within Cell B
- three placed soil sited on Cell B
- three rehabilitated sites on Cell A
- three analogue soil sites outside the TSF.

At each site in-situ samples should be collected to measured specific gravity, bulk density porosity and initial soil moisture.

The test work completed in this study has verified that sulfide minerals in the top 600 mm of the TSF have undergone substantial or complete oxidation. The depth of the oxidation front into the tailings is currently unknown. To verify the depth of oxidation in the tailings profile **RGS recommends in-situ core sampling** of the tailings through the tailings profile in the deepest area of the TSF. Samples should ideally be collected from a single drill hole using push tube sampling methods to provide intact core samples. During sample retrieval pH, Eh, and EC would be measured on saturated tailings samples.

Event based water monitoring is recommended ie. collection of surface water samples prior to, during and directly after a major storm event. This could quantify surface water quality runoff from the tailings beach over a storm event and provide improve the understanding of whether water could be discharged directly to the environment. Routine sampling, on the other hand, defines water quality in the standing water bodies after the wet season, and at the end of the dry season to quantify the broader effects of dilution and evaporation.

Addition of alkaline material to acidic geological materials is a common approach to mitigate the impacts of AMD. RGS recommends adding agricultural lime (CaCO_3) to the surface of the small oxide and sulfide tailings samples to ascertain if the addition of alkalinity to the mildly acidic tailings would change the rate that metals (eg. Mn) or metalloids (eg. As) are released from the tailings if leachate chemistry is in fact dominated by secondary minerals such as jarosite that sorb metals and acid below pH 4 but can release them if the pH increases (refer to **Section 7.1**).

10.0 FORWARD WORKS COST ESTIMATE

RGS has obtained an approximate cost to drill one hole to 20 m using push tube methods; the cost estimate is \$7,000. The analytical cost would be approximately \$3,000 for 20 samples measured for CRS, TS, ANC, pH and EC.

RGS suggest that it would take approximately six days to complete field permeability testing (up to half a day per site). The main equipment requirements would include a tray back ute, a 1,000L intermediate small container (IBC) or small tank for holding water, a small generator and a pump. At each site the bulk density extracted using soil cores would also be measured.

Geochemical analyses should also be completed on surface samples at each site. The analytical cost would be approximately \$1,800 for 12 samples tested for CRS, TS, ANC, pH and EC.

11.0 REFERENCES

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12.0 LIMITATIONS AND SIGN-OFF

This report documents the work undertaken by RGS Environmental Pty Ltd (RGS).

This report should be read in full. While the findings presented in this report are based on information that RGS considers reliable unless stated otherwise, the accuracy and completeness of source information cannot be guaranteed, although RGS has taken reasonable steps to verify the accuracy of such source data. RGS has made no independent verification of this information beyond the agreed scope of works and RGS assumes no responsibility for any inaccuracies or omissions outside of RGS's direct control. Furthermore, the information compiled in this report addresses the specific needs of the Client, so may not address the needs of third parties using this report for their own purposes. Thus, RGS and their employees accept no liability for any losses or damage for any action taken or not taken on the basis of any part of the contents of this report. Those acting on information provided in this report do so entirely at their own risk.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Please contact Alan Robertson or Greg Maddocks at RGS if you have any questions regarding this report.

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Yours sincerely,

RGS Environmental Pty Ltd



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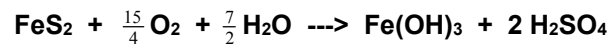
ATTACHMENT A

Geochemical Assessment Methodology for Mine Waste Materials

ATTACHMENT A

A1. Acid Generation and Prediction

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the maximum amount of acid that could be generated by the sample, as a direct stoichiometric function of either the pyritic sulfur content, or by assuming that all sulfur not present as sulfate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:



According to this reaction, the maximum potential acidity (MPA) of a sample containing one per cent sulfur as pyrite would be 30.6 kg $\text{H}_2\text{SO}_4/\text{t}$; *ie.* 30.6 kg of acid generated per tonne of rock.

The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralisation, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Determination of pH and Electrical Conductivity

pH and electrical conductivity (EC) are measured (and reported) on 1:5 weight/weight water extract. This gives an indication of the inherent acidity and salinity of the mineral waste material when initially exposed in an emplacement area.

Total sulfur (S), chromium-reducible sulfur (S_{CR}) and Maximum Potential Acidity (MPA)

Total sulfur concentration is determined by the LECO high temperature combustion method. The total sulfur is typically used to calculate the Maximum Potential Acidity (MPA), which is based on the assumption that all sulfur is present as reactive pyrite.

A more accurate estimate of the MPA can be achieved by determining pyritic sulfur and other sulfide forms directly, such as using the chromium-reducible sulfur (S_{CR}) test. S_{CR} is determined by the reduction of inorganic sulfur in a hot acidic chromous chloride solution, where evolved H_2S is carried in nitrogen gas and trapped in a zinc acetate trapping solution as zinc sulfide. This solution is then titrated with iodine. For the Project, S_{CR} was used instead of total sulfur to determine MPA, where S_{CR} data was available.

Acid neutralising capacity (ANC)

The ANC measures the capacity of a sample to react with and neutralise acid by addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC can be further evaluated by slow acid titration to a set end-point and then calculation of the amount of acid consumed and evaluation of the resultant titration curve, called an Acid Buffering Characteristic Curve (ABCC).

Net acid producing potential (NAPP)

The NAPP is calculated from the MPA and ANC results and represents the balance between the inherent capacity of a sample to generate acid (MPA) and neutralise acid (ANC). If the MPA is greater than the ANC (*ie.* a net excess of acidity) then the NAPP is positive. If the MPA is less than the ANC (*ie.* a net excess of alkalinity) then the NAPP is negative. A strongly positive NAPP result generally indicates that a sample is PAF, whereas a strongly negative NAPP generally indicates that a sample is NAF. The NAPP result is expressed in units of kg $\text{H}_2\text{SO}_4/\text{t}$ of sample.

Net acid generation (NAG)

The standard NAG tests can be used to confirm the acid forming nature for coal mine waste materials, but should generally be used with caution as it can generate incorrect results if the sample material contains a high concentration of sulfur or a significant amount of organic materials (ACARP, 2008). The sequential NAG or extended boil NAG test can address this issue, but are difficult to complete and acquired results can be difficult to interpret.

ATTACHMENT A

A2. Assessment of Element Enrichment and Solubility

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material at concentrations that may be of environmental concern with respect to surface water quality and revegetation. The samples are typically analysed for the following elements, although the actual suite of elements tested is project specific:

Major elements Al, Ca, Fe, K, Mg, Na, Si, and S

Minor elements As, B, Cd, Co, Cr, Cu, F, Mn, Mo, Ni, P, Pb, Sb, Se, Zn

The assay result for each element is compared to either average background concentrations to evaluate any potential concerns related to rock emplacement or process residue facility operation and final rehabilitation, or compared to soil quality guidelines where applicable.

Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality, or public health but their significance should be evaluated. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (eg. low pH) the geochemical behaviour of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

Water extracts or leaching tests can be used to determine the element solubilities under the existing pH conditions of the sample (eg. bottle leaching tests) or under changing conditions (eg. kinetic leach column tests). Where applicable, element concentrations in water extracts or leachates have been compared with applied water quality guidelines to determine their potential environmental significance.

A3. Kinetic Leach Column Tests

Kinetic leach column tests can be used to provide information on the reaction kinetics of mine waste materials. The major objectives of kinetics tests are to:

- Provide time-dependent data on the kinetics and rate of acid generation and acid neutralising reactions under laboratory controlled (or onsite conditions);
- Investigate metal release and drainage / seepage quality; and
- Assess treatment options such as addition of alkaline materials.

The kinetic tests simulate the weathering process that leads to acid and base generation and reaction under laboratory controlled or site conditions. The kinetic tests allow an assessment of the acid forming characteristics and indicate the rate of acid generation, over what period it will occur, and what management controls may be required.

In kinetic leach column tests, water is added to a sample and used to leach the products and by-products of acid producing and consuming reactions. Samples of leachate are then collected and analysed. Intermittent water application is applied to simulate rainfall and heat lamps are used to simulate sunshine. These tests provide real-time information and may have to continue for several months or years. Monitoring includes trends in pH, sulfate, acidity or alkalinity, and metals/metalloids, for example. The pH of the collected leachate simulates the acid drainage process, acidity or alkalinity levels indicate the rate of acid production and acid neutralisation, and sulfate production can be related to the rate of sulfide oxidation. Metal/metalloid concentration data provides an assessment of metal solubility and leaching behaviour.

Figure A1 shows the kinetic leach column set up used by RGS adapted from *AMIRA, 2002*. The columns are placed under heat lamps to allow the sample to dry between water additions to ensure adequate oxygen ingress into the sample material.

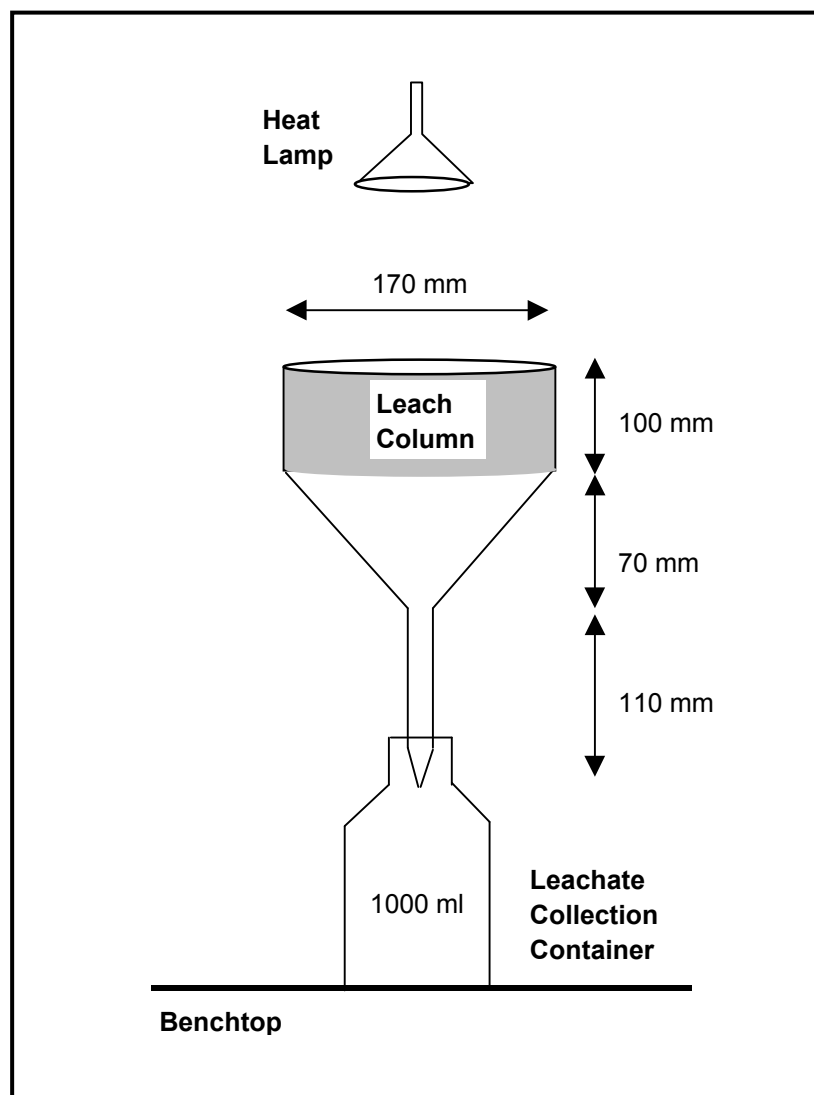
Approximately 2 kg of sample is generally used in the leach columns and depending on the physical nature of the material and particle size can be used on an as-received basis (*i.e.* no crushing as with fine rejects) or crushed to nominal 5 to 10 mm particle size (as with overburden).

ATTACHMENT A

The sample in the column is initially leached with deionised water at a rate of about 400 ml/kg of sample and the initial leachate from the columns collected and analysed. Subsequent column leaching is carried out at a rate of about 400 ml/kg per month and again collected and analysed. The leaching rate can be varied to better simulate expected site conditions or satisfy test program data requirements. The column must be exposed to drying conditions in between watering events. The residual water content and air void content in the column can be determined by comparing the wet and dry column weights. A heat lamp is generally used above the sample during daylight hours to maintain the leach column surface temperature at about 30°C.

Figure A2 shows the KLC set up used by RGS for the larger columns. No heat lamps were used for the larger KLC tests.

Figure A1
Kinetic Leach Column Setup



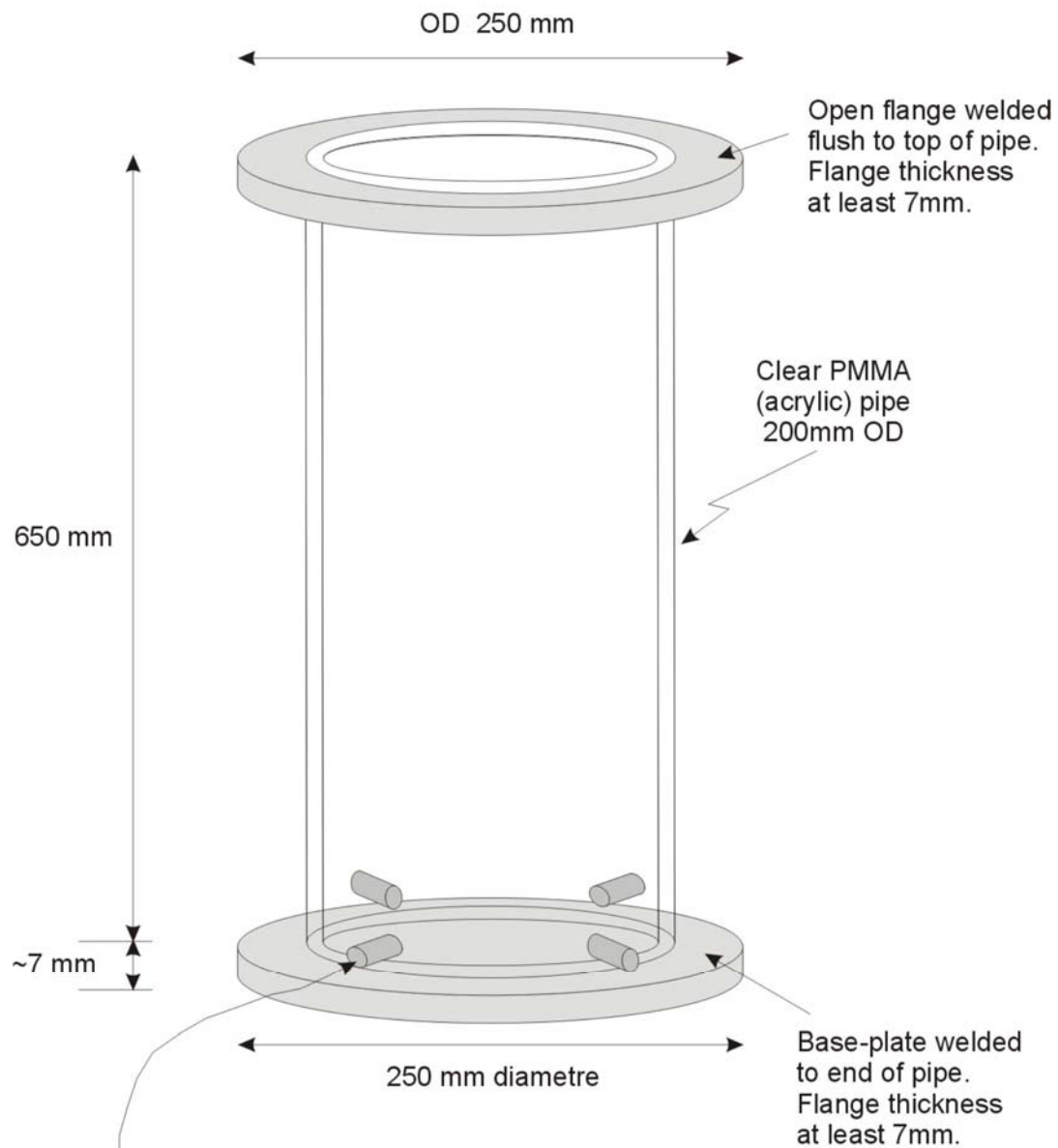
Reference:

AMIRA (2002). AMIRA International. *ARD Test Handbook. Project P387A Prediction & Kinetic Control of Acid Mine Drainage*. Ian Wark Institute and Environmental Geochemistry International Pty Ltd. May 2002, Melbourne, VIC.

ATTACHMENT A

Figure A2
Large Kinetic Leach Column Setup

3 columns. Each column as shown



- * 4 drain tubes, evenly spaced around bottom of pipe.
- * Each tube welded into pipe ~15mm up from base.
- * Each tube at least 10mm ID.
- * Each tube internally flush with inside wall of pipe.
- * Each tube protruding 15mm out from pipe.

ATTACHMENT B

Kinetic Leach Column Test Data

RGS-KLC # 1A : Yandan Straits Project (Oxide Tails)

KLC Test Results: Tailings comp (leachate = deionised water)

Weight (kg)	18.097	Total S (%)	0.251	ANC	0.27	NAG pH	4.03
pH (1:5)	4.71	Scr (%)	0.079	NAPP	2.14		
EC (µS/cm)	1,324	MPA	2.41	ANC:MPA	0.11	NAG capacity	0.58 kgH ₂ SO ₄ /t
Date	19-Dec-14	20-Jan-15	19-Feb-15	19-Mar-15	21-Apr-15	19-May-15	16-Jun-15
Week	0	5	9	13	18	22	26
Leach Number	1	2	3	4	5	6	7
ALS Laboratory Number	EB1448978	EB1511069	EB1513237	EB1515129	EB1517151	EB1519626	EB1521030
Volume Added (L)	4.0	2.0	1.8	1.8	1.8	1.8	1.8
Volume Collected (L)	1.125	1.656	1.681	1.438	1.071	0.541	1.286
Cum. Volume (L)	1.13	2.78	4.46	5.90	6.97	7.51	8.80
Solid:Solute Ratio-recovered	16.09	10.93	10.77	12.58	16.90	33.45	14.07
Solid:Solute Ratio-added	4.52	9.05	10.05	10.05	10.05	10.05	10.05
Pore Volumes	1.0	2.4	3.9	5.1	6.1	6.5	7.7
pH - RGS measurement	4.46	4.23	4.16	4.19	4.21	3.70	4.02
EC (µS/cm) - RGS record	5,070	1,439	3,450	1,539	2,910	4,410	2,690
Acidity (mg/L)*	123	32	76	34	100	187	18
Alkalinity (mg/L)*	2	<1	<1	<1	<1	<1	<1
Net Alkalinity (mg/L)*	-121	-32	-76	-34	-100	-187	-18
Dissolved elements (mg/L)	Guideline Limits #						
Calcium (Ca)	1,000	284	71	269	75	172	183
Magnesium (Mg)	-	101	21	56	22	52	40
Potassium (K)	-	35	8	19	7	14	11
Sodium (Na)	-	843	191	490	200	354	340
Chloride (Cl)	-	755	216	513	234	425	372
Sulfate (SO ₄)	1,000	1,330	432	1,190	451	1,100	922
Aluminium (Al)	5	5.70	2.10	7.08	2.66	7.53	5.59
Antimony (Sb)	-	0.006	<0.001	0.001	<0.001	0.003	0.003
Arsenic (As)	0.5	0.001	0.001	0.003	0.003	0.006	0.004
Cadmium (Cd)	0.01	0.0260	0.0054	0.0142	0.006	0.012	0.013
Chromium (Cr)	1	0.005	0.002	0.006	0.003	0.007	0.006
Cobalt (Co)	1	1.290	0.320	0.847	0.366	0.729	0.794
Copper (Cu)	1	0.158	0.044	0.11	0.051	0.091	0.086
Iron (Fe)	1#	15.7	<0.05	0.59	<0.05	0.17	<0.05
Lead (Pb)	0.1	<0.001	<0.001	0.003	<0.001	<0.001	0.002
Manganese (Mn)	2#	14.50	3.76	9.55	4.38	9.77	9.60
Molybdenum (Mo)	0.15	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (Ni)	1	2.01	0.521	1.34	0.613	1.310	1.28
Selenium (Se)	0.02	<0.01	<0.01	0.01	<0.01	0.01	0.01
Vanadium (V)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	20	3.34	0.69	1.89	0.87	1.50	1.57
Calculations**							
SO ₄ Release Rate		83	40	111	36	65	56
Cumulative SO ₄ Release		83	122	233	269	334	390
Ca Release Rate		17.7	6.5	25.0	6.0	10.2	5.6
Cumulative Ca Release		17.7	24.2	49.1	55.1	65.3	70.9
Mg Release Rate		6.3	1.9	5.2	1.7	3.1	1.4
Cumulative Mg Release		6.3	8.2	13.4	15.2	18.2	19.6
Residual ANC (%)		74.6	65.9	35.5	27.4	13.6	6.5
Residual Sulfur (%)		98.9	98.4	96.9	96.4	95.6	94.8
SO ₄ /(Ca+Mg) molar ratio		1.23	1.71	1.37	1.69	1.78	2.97

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg CaCO₃/L.

** SO₄, Ca and Mg release rates calculated in mg/kg/flush.

Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.

MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

RGS-KLC # 2A : Yandan Straits Project (Sulfide Tails)

KLC Test Results: Tailings comp (leachate = deionised water)

Weight (kg)	18.763	Total S (%)	0.415	ANC	0.30	NAG pH	4.10
pH (1:5)	4.31	Scr (%)	0.393	NAPP	11.74		
EC (µS/cm)	1,721	MPA	12.04	ANC:MPA	0.02	NAG capacity	0.25 kgH ₂ SO ₄ /t
Date	19-Dec-14	20-Jan-15	19-Feb-15	19-Mar-15	21-Apr-15	26-May-15	16-Jun-15
Week	0	5	9	13	18	23	26
Leach Number	1	2	3	4	5	6	7
ALS Laboratory Number	EB1448978	EB1511069	EB1513237	EB1515129	EB1517151	EB1519626	EB1521030
Volume Added (L)	4.0	2.0	1.9	1.9	1.9	1.9	1.9
Volume Collected (L)	1.025	1.423	1.812	1.673	0.667	0.416	0.193
Cum. Volume (L)	1.03	2.45	4.26	5.93	6.60	7.02	7.21
Solid:Solute Ratio-recovered	18.31	13.19	10.35	11.22	28.13	45.10	97.22
Solid:Solute Ratio-added	4.69	9.38	9.88	9.88	9.88	9.88	9.88
Pore Volumes	0.9	2.1	3.7	5.2	5.7	6.1	6.3
pH - RGS measurement	4.13	3.76	3.68	3.76	3.73	3.76	3.53
EC (µS/cm) - RGS record	3,630	2,341	3,900	2,160	4,070	6,380	5,110
Acidity (mg/L)*	252	196	340	171	418	790	154
Alkalinity (mg/L)*	<1	<1	<1	<1	<1	<1	<1
Net Alkalinity (mg/L)*	-252	-196	-340	-171	-418	-790	-154
Dissolved elements (mg/L)	Guideline Limits #						
Calcium (Ca)	1,000	330	204	378	176	406	722
Magnesium (Mg)	-	73	32	65	29	67	106
Potassium (K)	-	9	4	8	4	6	11
Sodium (Na)	-	466	231	496	214	376	725
Chloride (Cl)	-	426	282	505	252	447	763
Sulfate (SO ₄)	1,000	1,100	954	1,680	806	2,060	3,820
Aluminium (Al)	5	26.80	22.30	46.70	20.20	59.00	93.00
Antimony (Sb)	-	0.057	0.013	0.028	0.017	0.035	0.064
Arsenic (As)	0.5	0.007	0.026	0.05	0.025	0.055	0.093
Cadmium (Cd)	0.01	0.0176	0.0094	0.018	0.0096	0.0176	0.0349
Chromium (Cr)	1	0.021	0.018	0.033	0.015	0.036	0.064
Cobalt (Co)	1	0.868	0.494	0.971	0.496	0.97	1.87
Copper (Cu)	1	0.280	0.168	0.352	0.167	0.317	0.633
Iron (Fe)	1#	1.22	0.13	0.22	0.13	0.23	0.37
Lead (Pb)	0.1	<0.001	0.001	0.005	0.15	0.031	0.026
Manganese (Mn)	2#	8.22	5.52	9.33	5.24	11.10	19.20
Molybdenum (Mo)	0.15	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (Ni)	1	1.390	0.804	1.520	0.796	1.710	2.92
Selenium (Se)	0.02	<0.01	0.01	0.04	0.01	0.04	0.06
Vanadium (V)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	20	5.19	1.46	3.61	1.76	3.00	5.79
Calculations**							
SO ₄ Release Rate		60	72	162	72	73	85
Cumulative SO ₄ Release		60	132	295	367	440	524
Ca Release Rate		18.0	15.5	36.5	15.7	14.4	16.0
Cumulative Ca Release		18.0	33.5	70.0	85.7	100.1	116.1
Mg Release Rate		4.0	2.4	6.3	2.6	2.4	2.4
Cumulative Mg Release		4.0	6.4	12.7	15.3	17.7	20.0
Residual ANC (%)		79.9	64.1	25.8	9.6	0	0
Residual Sulfur (%)		99.5	98.9	97.6	97.1	96.5	95.8
SO ₄ /(Ca+Mg) molar ratio		1.02	1.55	1.44	1.50	1.66	1.78

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg CaCO₃/L.

** SO₄, Ca and Mg release rates calculated in mg/kg/flush.

Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.

MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

RGS-KLC # 3A : Yandan Straits Project (Mixed Tails)

KLC Test Results: Tailings comp (leachate = deionised water)

Weight (kg)		21.745	Total S (%)	0.310	ANC	0.51	NAG pH	4.05
pH (1:5)		4.47	Scr (%)	0.215	NAPP	6.06		
EC (µS/cm)		1,472	MPA	6.57	ANC:MPA	0.08	NAG capacity	22.7 kgH ₂ SO ₄ /t
Date		19-Dec-14	20-Jan-15	19-Feb-15	19-Mar-15	21-Apr-15	19-May-15	16-Jun-15
Week		0	5	9	13	18	22	26
Leach Number		1	2	3	4	5	6	7
ALS Laboratory Number		EB1448978	EB1511069	EB1513237	EB1515129	EB1517151	EB1519626	EB1521030
Volume Added (L)		4.0	2.0	2.3	2.2	2.2	2.2	2.2
Volume Collected (L)		0.989	1.764	2.064	1.969	1.747	1.510	1.848
Cum. Volume (L)		0.99	2.75	4.82	6.79	8.53	10.04	11.89
Solid:Solute Ratio-recovered		21.99	12.33	10.54	11.04	12.45	14.40	11.77
Solid:Solute Ratio-added		5.44	10.87	9.45	9.88	9.88	9.88	9.88
Pore Volumes		0.9	2.4	4.2	5.9	7.4	8.7	10.3
pH - RGS measurement		3.99	4.31	4.39	4.13	4.39	3.89	3.95
EC (µS/cm) - RGS record		2,840	712	710	1,002	490	281	2,373
Acidity (mg/L)*		232	23	33	33	28	137	15
Alkalinity (mg/L)*		<1	<1	<1	<1	<1	<1	<1
Net Alkalinity (mg/L)*		-232	-23	-33	-33	-28	-137	-15
Dissolved elements (mg/L)	Guideline Limits #							
Calcium (Ca)	1,000	195	32	34	49	17	82	132
Magnesium (Mg)	-	67	14	12	21	10	45	56
Potassium (K)	-	12	2	2	3	1	3	5
Sodium (Na)	-	377	80	76	107	41	171	244
Chloride (Cl)	-	397	88	83	132	54	418	311
Sulfate (SO ₄)	1,000	918	185	201	306	139	1,160	674
Aluminium (Al)	5	22.00	1.82	2.41	2.31	0.56	2.99	4.84
Antimony (Sb)	-	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic (As)	0.5	0.005	0.003	0.003	0.004	0.002	0.006	0.011
Cadmium (Cd)	0.01	0.0127	0.0020	0.0021	0.0025	0.0008	0.0032	0.0048
Chromium (Cr)	1	0.016	0.001	<0.001	0.001	<0.001	0.002	0.003
Cobalt (Co)	1	0.599	0.125	0.122	0.171	0.066	0.292	0.412
Copper (Cu)	1	0.176	0.021	0.026	0.028	0.01	0.03	0.046
Iron (Fe)	1 [#]	1.28	<0.05	<0.05	<0.05	<0.05	0.06	<0.05
Lead (Pb)	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Manganese (Mn)	2 [#]	8.28	3.13	2.39	6.64	3.19	17.30	22.20
Molybdenum (Mo)	0.15	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (Ni)	1	0.975	0.174	0.175	0.224	0.087	0.301	0.434
Selenium (Se)	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium (V)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	20	2.19	0.28	0.32	0.34	0.12	0.36	0.56
Calculations**								
SO ₄ Release Rate		42	15	19	28	11	81	57
Cumulative SO ₄ Release		42	57	76	104	115	195	253
Ca Release Rate		8.9	2.6	3.2	4.4	1.4	5.7	11.2
Cumulative Ca Release		8.9	11.5	14.7	19.1	20.5	26.2	37.4
Mg Release Rate		3.0	1.1	1.1	1.9	0.8	3.1	4.8
Cumulative Mg Release		3.0	4.2	5.3	7.2	8.0	11.2	15.9
Residual ANC (%)		93.3	91.2	88.7	85.1	83.8	78.6	69.5
Residual Sulfur (%)		99.6	99.4	99.2	98.9	98.8	97.9	97.3
SO ₄ /(Ca+Mg) molar ratio		1.25	1.40	1.56	1.53	1.73	3.10	1.25

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg CaCO₃/L.

** SO₄, Ca and Mg release rates calculated in mg/kg/flush.

Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.

MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

RGS-KLC # 1B : Yandan Straits Project (Oxide Tails)

KLC Test Results: Tailings comp (leachate = deionised water)

Weight (kg)		1.733	Total S (%)	0.251	ANC	0.27	NAG pH	4.03
pH (1:5)		4.71	Scr (%)	0.079	NAPP	2.14		
EC (µS/cm)		1,324	MPA	2.41	ANC:MPA	0.11	NAG capacity	0.58 kgH ₂ SO ₄ /t
Date		19-Dec-14	20-Jan-15	19-Feb-15	19-Mar-15	21-Apr-15	19-May-15	16-Jun-15
Week		0	5	9	13	18	22	26
Leach Number		1	2	3	4	5	6	7
ALS Laboratory Number		EB1448978	EB1511069	EB1513237	EB1515129	EB1517151	EB1519626	EB1521030
Volume Added (L)		1.0	1.0	0.90	0.87	0.87	0.87	0.87
Volume Collected (L)		0.750	0.644	0.744	0.696	0.682	0.695	0.710
Cum. Volume (L)		0.75	1.39	2.14	2.83	3.52	4.21	4.92
Solid:Solute Ratio-recovered		2.31	2.69	2.33	2.49	2.54	2.49	2.44
Solid:Solute Ratio-added		1.73	1.73	1.93	1.99	1.99	1.99	1.99
Pore Volumes		0.7	1.2	1.9	2.5	3.1	3.7	4.3
pH - RGS measurement		4.03	4.70	4.56	4.52	4.49	4.29	4.48
EC (µS/cm) - RGS record		2,492	124	147	141	110	174	159
Acidity (mg/L)*		159	15	16	9	14	19	2
Alkalinity (mg/L)*		<1	<1	<1	1	<1	<1	<1
Net Alkalinity (mg/L)*		-159	-15	-16	-8	-14	-13	-2
Dissolved elements (mg/L)	Guideline Limits #							
Calcium (Ca)	1,000	192	16	15	12	11	129	8
Magnesium (Mg)	-	36	2	2	1	<1	9	<1
Potassium (K)	-	8	<1	<1	<1	<1	2	<1
Sodium (Na)	-	324	10	13	8	4	<1	6
Chloride (Cl)	-	305	6	11	4	3	7	4
Sulfate (SO ₄)	1,000	709	52	64	50	43	72	50
Aluminium (Al)	5	7.78	0.17	0.20	0.14	0.09	<0.01	0.10
Antimony (Sb)	-	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Arsenic (As)	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001
Cadmium (Cd)	0.01	0.0094	0.0004	0.0006	0.0004	0.0002	<0.0001	0.0002
Chromium (Cr)	1	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (Co)	1	0.512	0.026	0.035	0.022	0.012	0.001	0.016
Copper (Cu)	1	0.22	0.005	0.006	0.006	0.004	<0.001	0.003
Iron (Fe)	1#	10.60	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead (Pb)	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (Mn)	2#	5.31	0.27	0.35	0.24	0.14	0.07	0.17
Molybdenum (Mo)	0.15	<0.001	<0.001	<0.001	<0.001	<0.001	0.056	<0.001
Nickel (Ni)	1	1.060	0.050	0.066	0.042	0.027	0.003	0.03
Selenium (Se)	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Vanadium (V)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	20	1.53	0.07	0.10	0.05	0.03	0.01	0.04
Calculations**								
SO ₄ Release Rate		307	19	27	20	17	29	20
Cumulative SO ₄ Release		307	326	354	374	391	420	440
Ca Release Rate		83.1	5.9	6.4	4.8	4.3	51.7	3.3
Cumulative Ca Release		83.1	89.0	95.5	100.3	104.6	156.4	159.6
Mg Release Rate		15.6	0.7	0.9	0.4	0.2	3.6	0.2
Cumulative Mg Release		15.6	16.3	17.2	17.6	17.8	21.4	21.6
Residual ANC (%)		1.4	0	0	0	0	0	0
Residual Sulfur (%)		95.9	95.7	95.3	95.0	94.8	94.4	94.1
SO ₄ /(Ca+Mg) molar ratio		1.18	1.12	1.46	1.53	1.52	0.21	2.36

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg CaCO₃/L.

** SO₄, Ca and Mg release rates calculated in mg/kg/flush.

Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.

MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

RGS-KLC # 2B : Yandan Straits Project (Sulfide Tails)

KLC Test Results: Tailings comp (leachate = deionised water)

Weight (kg)		2.134	Total S (%)	0.415	ANC	0.30	NAG pH	4.10
pH (1:5)		4.31	Scr (%)	0.393	NAPP	11.74		
EC (µS/cm)		1,721	MPA	12.04	ANC:MPA	0.02	NAG capacity	0.25 kgH ₂ SO ₄ /t
Date		19-Dec-14	20-Jan-15	19-Feb-15	19-Mar-15	21-Apr-15	19-May-15	16-Jun-15
Week		0	5	9	13	18	22	26
Leach Number		1	2	3	4	5	6	7
ALS Laboratory Number		EB1448978	EB1511069	EB1513237	EB1515129	EB1517151	EB1519626	EB1521030
Volume Added (L)		1.00	1.00	1.10	1.07	1.07	1.07	1.07
Volume Collected (L)		0.807	0.834	0.920	0.849	0.773	0.540	0.286
Cum. Volume (L)		0.81	1.64	2.56	3.41	4.18	4.72	5.01
Solid:Solute Ratio-recovered		2.64	2.56	2.32	2.51	2.76	3.95	7.46
Solid:Solute Ratio-added		2.13	2.13	1.94	1.99	1.99	1.99	1.99
Pore Volumes		0.7	1.4	2.2	3.0	3.6	4.1	4.4
pH - RGS measurement		3.84	4.40	4.27	4.23	4.32	3.52	3.52
EC (µS/cm) - RGS record		2,065	126	178	172	132	3,100	3,340
Acidity (mg/L)*		180	31	47	24	33	261	90
Alkalinity (mg/L)*		<1	<1	<1	<1	<1	<1	<1
Net Alkalinity (mg/L)*		-180	-31	-47	-24	-33	-261	-90
Dissolved elements (mg/L)	Guideline Limits #							
Calcium (Ca)	1,000	184	30	31	21	13	356	526
Magnesium (Mg)	-	35	2	4	2	2	30	62
Potassium (K)	-	4	<1	<1	<1	<1	2	4
Sodium (Na)	-	203	8	12	8	5	143	294
Chloride (Cl)	-	212	6	8	6	4	242	309
Sulfate (SO ₄)	1,000	785	91	118	79	60	2,030	2,060
Aluminium (Al)	5	19.50	0.90	1.77	0.89	0.47	18.10	35.10
Antimony (Sb)	-	0.002	<0.001	<0.001	<0.001	<0.001	0.002	0.004
Arsenic (As)	0.5	0.017	0.005	0.007	0.006	0.004	0.048	0.147
Cadmium (Cd)	0.01	0.0083	0.0005	0.0007	0.0005	0.0003	0.0074	0.016
Chromium (Cr)	1	0.02	<0.001	0.001	<0.001	<0.001	0.014	0.027
Cobalt (Co)	1	0.43	0.031	0.055	0.035	0.02	0.429	0.823
Copper (Cu)	1	0.213	0.008	0.014	0.012	0.006	0.107	0.18
Iron (Fe)	1#	0.40	<0.05	<0.05	<0.05	<0.05	0.15	0.56
Lead (Pb)	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Manganese (Mn)	2#	4.58	0.34	0.60	0.42	0.25	5.04	10.20
Molybdenum (Mo)	0.15	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (Ni)	1	0.772	0.053	0.092	0.062	0.038	0.693	1.27
Selenium (Se)	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02
Vanadium (V)	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	20	1.17	0.07	0.12	0.08	0.05	0.99	1.98
Calculations**								
SO ₄ Release Rate		297	36	51	31	22	514	276
Cumulative SO ₄ Release		297	332	383	415	436	950	1226
Ca Release Rate		69.6	11.7	13.4	8.4	4.7	90.1	70.5
Cumulative Ca Release		69.6	81.3	94.7	103.0	107.7	197.8	268.3
Mg Release Rate		13.2	0.8	1.7	0.8	0.7	7.6	8.3
Cumulative Mg Release		13.2	14.0	15.7	16.5	17.3	24.9	33.2
Residual ANC (%)		25.5	14.8	1.6	0	0	0	0
Residual Sulfur (%)		97.6	97.3	96.9	96.7	96.5	92.4	90.1
SO ₄ /(Ca+Mg) molar ratio		1.36	1.14	1.31	1.36	1.54	2.09	1.37

< indicates less than the analytical detection limit. * Acidity and alkalinity data calculated in mg CaCO₃/L.

** SO₄, Ca and Mg release rates calculated in mg/kg/flush.

Total S = Total Sulfur; Scr = Chromium Reducible Sulfur; and ANC = Acid Neutralising Capacity.

MPA = Maximum Potential Acidity, and NAPP = Net Acid Producing Potential.

ANZECC & ARCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, 2000, ANZECC (Australian and New Zealand Environment Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand). Livestock Drinking Water Levels (Irrigation Levels used for Fe and Mn).

ATTACHMENT C

ALS Certificates of Analysis

CERTIFICATE OF ANALYSIS

Work Order	: EB1444979	Page	: 1 of 19
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091	Address	: 2 Byth Street Stafford QLD Australia 4053
	SUNNYBANK SOUTH QLD, AUSTRALIA 4109		
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: Blanket Quote - L2	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 23-Oct-2014 19:30
C-O-C number	: ----	Date Analysis Commenced	: 27-Oct-2014
Sampler	: ALAN ROBERTSON	Issue Date	: 03-Nov-2014 10:47
Site	: ----		
Quote number	: ----	No. of samples received	: 85
		No. of samples analysed	: 85

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.

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.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Andrew Epps	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Satishkumar Trivedi	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils



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.

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	1	2	3	4	5
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-001	EB1444979-002	EB1444979-003	EB1444979-004	EB1444979-005
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		5.8	5.6	5.5	5.2	4.6
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		3.7	4.9	10.4	8.0	12.8
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1060	634	1590	1290	1920
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		6.0	6.6	5.5	10.7	13.6
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.12	0.16	0.34	0.26	0.42



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	6	7	8	9	10
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-006	EB1444979-007	EB1444979-008	EB1444979-009	EB1444979-010
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.9	4.4	4.6	5.0	6.0
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		8.9	12.8	11.3	11.6	4.3
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1410	2220	1700	2580	1260
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	0.6
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		8.2	8.6	10.4	11.3	11.6
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.29	0.42	0.37	0.38	0.16



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	11	12	13	14	15
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-011	EB1444979-012	EB1444979-013	EB1444979-014	EB1444979-015
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		6.6	5.2	6.5	5.2	5.2
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		5.8	5.5	4.6	6.1	5.2
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		2030	1400	1690	1300	1060
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		0.6	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		12.4	15.2	11.6	11.5	13.4
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.21	0.18	0.15	0.20	0.17



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	16	17	18	19	20
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-016	EB1444979-017	EB1444979-018	EB1444979-019	EB1444979-020
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		5.3	5.6	5.3	5.1	4.6
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		3.4	6.4	11.9	9.5	8.3
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		899	1590	2950	2170	1790
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	0.9
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		10.1	11.7	13.4	14.6	8.9
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.11	0.21	0.39	0.31	0.30



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	21	22	23	24	25
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-021	EB1444979-022	EB1444979-023	EB1444979-024	EB1444979-025
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.7	5.2	4.8	5.0	4.7
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		11.0	8.0	9.8	5.8	12.2
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1520	1430	1180	1280	1790
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	0.6	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		9.4	11.6	13.2	9.3	10.7
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.36	0.28	0.32	0.19	0.40



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	26	27	28	29	30
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-026	EB1444979-027	EB1444979-028	EB1444979-029	EB1444979-030
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		5.0	4.3	4.4	4.1	4.7
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		6.1	8.6	7.3	12.8	6.1
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1100	1260	1090	1880	660
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		10.6	18.6	13.6	13.7	9.1
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.20	0.28	0.24	0.42	0.20



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	31	32	33	34	35
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-031	EB1444979-032	EB1444979-033	EB1444979-034	EB1444979-035
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.4	4.4	4.8	4.4	4.7
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		15.6	13.2	6.4	14.1	5.8
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		2290	1570	1100	2000	785
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		14.8	9.6	12.6	14.5	9.9
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.51	0.43	0.21	0.46	0.19



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	36	37	38	39	40
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-036	EB1444979-037	EB1444979-038	EB1444979-039	EB1444979-040
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.4	4.8	4.4	5.0	5.0
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		13.2	6.7	11.3	6.7	6.4
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1870	842	1630	948	1180
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		12.5	8.4	12.7	12.2	7.7
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.43	0.22	0.37	0.22	0.21



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	41	42	43	44	45
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-041	EB1444979-042	EB1444979-043	EB1444979-044	EB1444979-045
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.1	4.8	4.2	4.6	4.4
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		13.5	7.3	14.1	10.4	10.4
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		2390	991	1950	1450	1480
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		17.8	10.6	10.7	9.8	8.5
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.44	0.24	0.46	0.34	0.34



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	46	47	48	49	50
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-046	EB1444979-047	EB1444979-048	EB1444979-049	EB1444979-050
				Result	Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		5.0	4.4	5.0	4.2	5.0
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		6.1	12.2	6.4	14.7	10.1
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		765	1880	1770	618	1780
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		6.3	9.2	12.3	13.7	10.3
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.20	0.40	0.21	0.48	0.33



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	51	52	53	54	55
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-051	EB1444979-052	EB1444979-053	EB1444979-054	EB1444979-055
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.2	4.3	4.3	4.5	4.3
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		8.0	8.0	11.9	7.3	11.9
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1060	1740	2000	926	1680
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		8.2	16.1	18.2	14.1	15.4
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.26	0.26	0.39	0.24	0.39



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	56	57	58	59	60
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-056	EB1444979-057	EB1444979-058	EB1444979-059	EB1444979-060
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.3	4.2	4.4	4.0	4.2
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		9.2	12.8	12.8	14.1	11.0
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1100	1500	1560	2180	1120
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		10.6	9.6	10.2	12.3	7.3
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.30	0.42	0.42	0.46	0.36



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	61	62	63	64 T	65 T
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-061	EB1444979-062	EB1444979-063	EB1444979-064	EB1444979-065
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.0	4.3	4.2	5.5	4.3
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		15.3	11.0	12.8	-2.8	4.4
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		1800	1270	1390	925	1480
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	4.0	0.8
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	0.4	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		11.5	8.6	8.7	5.5	7.5
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.50	0.36	0.42	0.04	0.17



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	66 T	67 T	68 T	69 T	70 T
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-066	EB1444979-067	EB1444979-068	EB1444979-069	EB1444979-070
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.2	4.5	4.6	4.5	6.3
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		16.2	2.8	10.7	12.2	-4.6
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		2450	1550	1360	1400	159
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	1.5	<0.5	<0.5	5.2
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	0.2	<0.1	<0.1	0.5
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		12.0	12.3	11.2	12.0	4.8
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.53	0.14	0.35	0.40	0.02



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	71 T	72 T	73 T	74 T	75 T
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-071	EB1444979-072	EB1444979-073	EB1444979-074	EB1444979-075
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		7.0	6.1	5.8	4.8	6.2
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		-5.7	10.8	3.4	2.1	-2.0
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		268	2210	440	607	225
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		6.9	1.7	<0.5	<0.5	2.6
^ ANC as CaCO3	----	0.1	% CaCO3		0.7	0.2	<0.1	<0.1	0.3
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		7.0	10.4	8.0	14.0	7.6
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.04	0.41	0.11	0.07	0.02



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	76 T - OR	77 T - OR	78 T - OR	79	80
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-076	EB1444979-077	EB1444979-078	EB1444979-079	EB1444979-080
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		5.2	3.9	4.0	4.4	4.4
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		3.1	8.6	13.2	11.9	10.4
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		2000	1940	1560	1920	1160
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		1.8	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		0.2	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		6.9	7.0	10.5	14.0	11.3
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.16	0.28	0.43	0.39	0.34



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	81	82	83	84	85
Client sampling date / time					[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]	[22-Oct-2014]
Compound	CAS Number	LOR	Unit		EB1444979-081	EB1444979-082	EB1444979-083	EB1444979-084	EB1444979-085
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.5	4.1	4.5	4.1	4.4
EA009: Nett Acid Production Potential									
^ Net Acid Production Potential	----	0.5	kg H2SO4/t		7.0	14.1	11.6	12.2	13.5
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		717	1780	1530	1370	1590
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	<0.5	<0.5	<0.5	<0.5
^ ANC as CaCO3	----	0.1	% CaCO3		<0.1	<0.1	<0.1	<0.1	<0.1
Fizz Rating	----	0	Fizz Unit		0	0	0	0	0
EA055: Moisture Content									
^ Moisture Content (dried @ 103°C)	----	1	%		4.7	13.5	5.6	6.3	11.0
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		0.23	0.46	0.38	0.40	0.44



ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1446063	Page	: 1 of 29
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091	Address	: 2 Byth Street Stafford QLD Australia 4053
	SUNNYBANK SOUTH QLD, AUSTRALIA 4109		
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Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 10-Nov-2014 15:29
C-O-C number	: ----	Date Analysis Commenced	: 12-Nov-2014
Sampler	: ----	Issue Date	: 01-Dec-2014 18:45
Site	: ----		
Quote number	: ----	No. of samples received	: 43
		No. of samples analysed	: 43

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.

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.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Greg Vogel	Laboratory Manager	Brisbane Inorganics
Satishkumar Trivedi	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils



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.



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				1	2	3	4	6
				EB1444979001	EB1444979002	EB1444979003	EB1444979004	EB1444979006
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-001	EB1446063-002	EB1446063-003	EB1446063-004	EB1446063-005
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	4.6	4.2	4.4	----	4.6
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	0.2	<0.1	----	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	2.9	2.5	1.7	----	1.4
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	0.007	<0.005	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	1.0	----	----	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	0.4	----	----	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	0.2	----	----	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	0.1	----	----	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	1.8	----	----	----	----
^ Exchangeable Sodium Percent	----	0.1	%	6.2	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	5	----	7	----	<5
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	5	----	7	----	<5
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	----	<5	----	<5
ED038A: Acidity								
Acidity	----	1	mg/kg	60	----	38	----	67
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	980	----	4640	----	2920
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	810	----	260	----	360
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	140	----	1780	----	780
Magnesium	7439-95-4	10	mg/kg	40	----	40	----	100
Sodium	7440-23-5	10	mg/kg	730	----	230	----	550
Potassium	7440-09-7	10	mg/kg	80	----	150	----	70
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	710	----	340	----	710
Potassium	7440-09-7	50	mg/kg	960	----	1440	----	1380
Calcium	7440-70-2	50	mg/kg	390	----	2140	----	1170
Magnesium	7439-95-4	50	mg/kg	170	----	100	----	230
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	----	<1	----	<1



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				1	2	3	4	6
				EB1444979001	EB1444979002	EB1444979003	EB1444979004	EB1444979006
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-001	EB1446063-002	EB1446063-003	EB1446063-004	EB1446063-005
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	<1	----	<1	----	2
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2600	----	2130	----	3370
Antimony	7440-36-0	5	mg/kg	18	----	10	----	16
Arsenic	7440-38-2	5	mg/kg	148	----	129	----	167
Barium	7440-39-3	10	mg/kg	140	----	130	----	150
Beryllium	7440-41-7	1	mg/kg	<1	----	<1	----	1
Boron	7440-42-8	50	mg/kg	<50	----	<50	----	<50
Cadmium	7440-43-9	1	mg/kg	<1	----	<1	----	<1
Chromium	7440-47-3	2	mg/kg	58	----	50	----	56
Cobalt	7440-48-4	2	mg/kg	4	----	<2	----	5
Copper	7440-50-8	5	mg/kg	10	----	10	----	24
Iron	7439-89-6	50	mg/kg	13500	----	8090	----	13400
Lead	7439-92-1	5	mg/kg	7	----	8	----	9
Manganese	7439-96-5	5	mg/kg	37	----	8	----	39
Molybdenum	7439-98-7	2	mg/kg	<2	----	<2	----	<2
Nickel	7440-02-0	2	mg/kg	8	----	3	----	9
Selenium	7782-49-2	5	mg/kg	<5	----	<5	----	<5
Vanadium	7440-62-2	5	mg/kg	8	----	5	----	8
Zinc	7440-66-6	5	mg/kg	16	----	6	----	27
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	<0.01	----	0.03	----	0.02
Selenium	7782-49-2	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Silver	7440-22-4	0.01	mg/kg	<0.01	----	<0.01	----	<0.01
Barium	7440-39-3	0.01	mg/kg	0.11	----	0.07	----	0.03
Beryllium	7440-41-7	0.01	mg/kg	<0.01	----	<0.01	----	0.02
Cadmium	7440-43-9	0.01	mg/kg	<0.01	----	<0.01	----	0.02
Cobalt	7440-48-4	0.01	mg/kg	0.18	----	0.11	----	1.04
Chromium	7440-47-3	0.01	mg/kg	<0.01	----	<0.01	----	<0.01
Thorium	7440-29-1	0.01	mg/kg	<0.01	----	<0.01	----	<0.01
Copper	7440-50-8	0.01	mg/kg	<0.01	----	<0.01	----	0.10
Manganese	7439-96-5	0.01	mg/kg	5.88	----	1.48	----	14.5
Molybdenum	7439-98-7	0.01	mg/kg	<0.01	----	<0.01	----	<0.01
Nickel	7440-02-0	0.01	mg/kg	0.30	----	0.11	----	1.53
Lead	7439-92-1	0.01	mg/kg	<0.01	----	<0.01	----	<0.01



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				1 EB1444979001	2 EB1444979002	3 EB1444979003	4 EB1444979004	6 EB1444979006
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-001	EB1446063-002	EB1446063-003	EB1446063-004	EB1446063-005
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	<0.01	----	0.04	----	0.02
Uranium	7440-61-1	0.01	mg/kg	<0.01	----	<0.01	----	<0.01
Zinc	7440-66-6	0.05	mg/kg	0.52	----	0.11	----	5.64
Vanadium	7440-62-2	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Aluminium	7429-90-5	0.1	mg/kg	<0.1	----	<0.1	----	2.3
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	----	<0.0005	----	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	0.4	----	0.7	----	0.6
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	<1	----	<1	----	<1
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	----	<0.1	----	<0.1



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				10 EB1444979010	11 EB1444979011	12 EB1444979012	13 EB1444979013	14 EB1444979014
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-006	EB1446063-007	EB1446063-008	EB1446063-009	EB1446063-010
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	6.0	6.2	----	----	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	----	----	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	1.2	0.7	----	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.011	0.020	<0.005	0.012	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	1.7	----	----	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	0.3	----	----	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	0.4	----	----	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	----	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	2.5	----	----	----	----
^ Exchangeable Sodium Percent	----	0.1	%	2.8	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	15	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	15	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	----	----	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	29	----	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	3070	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	340	----	----	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	790	----	----	----	----
Magnesium	7439-95-4	10	mg/kg	110	----	----	----	----
Sodium	7440-23-5	10	mg/kg	480	----	----	----	----
Potassium	7440-09-7	10	mg/kg	220	----	----	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	550	----	----	----	----
Potassium	7440-09-7	50	mg/kg	1240	----	----	----	----
Calcium	7440-70-2	50	mg/kg	1230	----	----	----	----
Magnesium	7439-95-4	50	mg/kg	310	----	----	----	----
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				10 EB1444979010	11 EB1444979011	12 EB1444979012	13 EB1444979013	14 EB1444979014
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-006	EB1446063-007	EB1446063-008	EB1446063-009	EB1446063-010
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	<1	----	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2780	----	----	----	----
Antimony	7440-36-0	5	mg/kg	10	----	----	----	----
Arsenic	7440-38-2	5	mg/kg	103	----	----	----	----
Barium	7440-39-3	10	mg/kg	190	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	1	----	----	----	----
Boron	7440-42-8	50	mg/kg	<50	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	----	----	----	----
Chromium	7440-47-3	2	mg/kg	51	----	----	----	----
Cobalt	7440-48-4	2	mg/kg	4	----	----	----	----
Copper	7440-50-8	5	mg/kg	10	----	----	----	----
Iron	7439-89-6	50	mg/kg	10100	----	----	----	----
Lead	7439-92-1	5	mg/kg	9	----	----	----	----
Manganese	7439-96-5	5	mg/kg	52	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	----	----	----	----
Nickel	7440-02-0	2	mg/kg	9	----	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	----	----	----	----
Vanadium	7440-62-2	5	mg/kg	7	----	----	----	----
Zinc	7440-66-6	5	mg/kg	15	----	----	----	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	<0.01	----	----	----	----
Selenium	7782-49-2	0.1	mg/kg	<0.1	----	----	----	----
Silver	7440-22-4	0.01	mg/kg	<0.01	----	----	----	----
Barium	7440-39-3	0.01	mg/kg	0.15	----	----	----	----
Beryllium	7440-41-7	0.01	mg/kg	<0.01	----	----	----	----
Cadmium	7440-43-9	0.01	mg/kg	<0.01	----	----	----	----
Cobalt	7440-48-4	0.01	mg/kg	0.06	----	----	----	----
Chromium	7440-47-3	0.01	mg/kg	<0.01	----	----	----	----
Thorium	7440-29-1	0.01	mg/kg	<0.01	----	----	----	----
Copper	7440-50-8	0.01	mg/kg	<0.01	----	----	----	----
Manganese	7439-96-5	0.01	mg/kg	3.63	----	----	----	----
Molybdenum	7439-98-7	0.01	mg/kg	<0.01	----	----	----	----
Nickel	7440-02-0	0.01	mg/kg	0.20	----	----	----	----
Lead	7439-92-1	0.01	mg/kg	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				10 EB1444979010	11 EB1444979011	12 EB1444979012	13 EB1444979013	14 EB1444979014
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-006	EB1446063-007	EB1446063-008	EB1446063-009	EB1446063-010
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	0.01	----	----	----	----
Uranium	7440-61-1	0.01	mg/kg	<0.01	----	----	----	----
Zinc	7440-66-6	0.05	mg/kg	<0.05	----	----	----	----
Vanadium	7440-62-2	0.1	mg/kg	<0.1	----	----	----	----
Aluminium	7429-90-5	0.1	mg/kg	<0.1	----	----	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	0.4	----	----	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	<1	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				15 EB1444979015	16 EB1444979016	17 EB1444979017	19 EB1444979019	20 EB1444979020
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-011	EB1446063-012	EB1446063-013	EB1446063-014	EB1446063-015
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	----	----	----	----	4.4
NAG (pH 4.5)	----	0.1	kg H2SO4/t	----	----	----	----	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	----	----	----	----	3.2
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	----	----	----	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium Percent	----	0.1	%	----	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	----	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	----	----	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	----	----	----
Magnesium	7439-95-4	10	mg/kg	----	----	----	----	----
Sodium	7440-23-5	10	mg/kg	----	----	----	----	----
Potassium	7440-09-7	10	mg/kg	----	----	----	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	----	----	----	----	----
Potassium	7440-09-7	50	mg/kg	----	----	----	----	----
Calcium	7440-70-2	50	mg/kg	----	----	----	----	----
Magnesium	7439-95-4	50	mg/kg	----	----	----	----	----
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				15 EB1444979015	16 EB1444979016	17 EB1444979017	19 EB1444979019	20 EB1444979020
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-011	EB1446063-012	EB1446063-013	EB1446063-014	EB1446063-015
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	----	----	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	----	----	----
Antimony	7440-36-0	5	mg/kg	----	----	----	----	----
Arsenic	7440-38-2	5	mg/kg	----	----	----	----	----
Barium	7440-39-3	10	mg/kg	----	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	----	----	----	----	----
Boron	7440-42-8	50	mg/kg	----	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	----	----	----	----	----
Chromium	7440-47-3	2	mg/kg	----	----	----	----	----
Cobalt	7440-48-4	2	mg/kg	----	----	----	----	----
Copper	7440-50-8	5	mg/kg	----	----	----	----	----
Iron	7439-89-6	50	mg/kg	----	----	----	----	----
Lead	7439-92-1	5	mg/kg	----	----	----	----	----
Manganese	7439-96-5	5	mg/kg	----	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	----	----	----	----	----
Nickel	7440-02-0	2	mg/kg	----	----	----	----	----
Selenium	7782-49-2	5	mg/kg	----	----	----	----	----
Vanadium	7440-62-2	5	mg/kg	----	----	----	----	----
Zinc	7440-66-6	5	mg/kg	----	----	----	----	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	----	----	----	----	----
Selenium	7782-49-2	0.1	mg/kg	----	----	----	----	----
Silver	7440-22-4	0.01	mg/kg	----	----	----	----	----
Barium	7440-39-3	0.01	mg/kg	----	----	----	----	----
Beryllium	7440-41-7	0.01	mg/kg	----	----	----	----	----
Cadmium	7440-43-9	0.01	mg/kg	----	----	----	----	----
Cobalt	7440-48-4	0.01	mg/kg	----	----	----	----	----
Chromium	7440-47-3	0.01	mg/kg	----	----	----	----	----
Thorium	7440-29-1	0.01	mg/kg	----	----	----	----	----
Copper	7440-50-8	0.01	mg/kg	----	----	----	----	----
Manganese	7439-96-5	0.01	mg/kg	----	----	----	----	----
Molybdenum	7439-98-7	0.01	mg/kg	----	----	----	----	----
Nickel	7440-02-0	0.01	mg/kg	----	----	----	----	----
Lead	7439-92-1	0.01	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				15 EB1444979015	16 EB1444979016	17 EB1444979017	19 EB1444979019	20 EB1444979020
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-011	EB1446063-012	EB1446063-013	EB1446063-014	EB1446063-015
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	----	----	----	----	----
Uranium	7440-61-1	0.01	mg/kg	----	----	----	----	----
Zinc	7440-66-6	0.05	mg/kg	----	----	----	----	----
Vanadium	7440-62-2	0.1	mg/kg	----	----	----	----	----
Aluminium	7429-90-5	0.1	mg/kg	----	----	----	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	----	----	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	----	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				22 EB1444979022	23 EB1444979023	24 EB1444979024	26 EB1444979026	27 EB1444979027
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-016	EB1446063-017	EB1446063-018	EB1446063-019	EB1446063-020
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	----	3.9	----	4.2	4.3
NAG (pH 4.5)	----	0.1	kg H2SO4/t	----	0.4	----	0.6	0.5
NAG (pH 7.0)	----	0.1	kg H2SO4/t	----	1.9	----	3.4	4.0
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	----	----	----	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium Percent	----	0.1	%	----	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	----	----	----	<5
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	----	----	<5
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	----	----	<5
ED038A: Acidity								
Acidity	----	1	mg/kg	----	----	----	----	144
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	----	----	2940
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	----	280
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	----	----	910
Magnesium	7439-95-4	10	mg/kg	----	----	----	----	60
Sodium	7440-23-5	10	mg/kg	----	----	----	----	370
Potassium	7440-09-7	10	mg/kg	----	----	----	----	60
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	----	----	----	----	580
Potassium	7440-09-7	50	mg/kg	----	----	----	----	1440
Calcium	7440-70-2	50	mg/kg	----	----	----	----	1430
Magnesium	7439-95-4	50	mg/kg	----	----	----	----	170
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	----	----	----	----	<1



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				22 EB1444979022	23 EB1444979023	24 EB1444979024	26 EB1444979026	27 EB1444979027
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-016	EB1446063-017	EB1446063-018	EB1446063-019	EB1446063-020
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	----	----	----	----	4
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	----	----	2740
Antimony	7440-36-0	5	mg/kg	----	----	----	----	11
Arsenic	7440-38-2	5	mg/kg	----	----	----	----	170
Barium	7440-39-3	10	mg/kg	----	----	----	----	160
Beryllium	7440-41-7	1	mg/kg	----	----	----	----	<1
Boron	7440-42-8	50	mg/kg	----	----	----	----	<50
Cadmium	7440-43-9	1	mg/kg	----	----	----	----	<1
Chromium	7440-47-3	2	mg/kg	----	----	----	----	40
Cobalt	7440-48-4	2	mg/kg	----	----	----	----	4
Copper	7440-50-8	5	mg/kg	----	----	----	----	15
Iron	7439-89-6	50	mg/kg	----	----	----	----	12400
Lead	7439-92-1	5	mg/kg	----	----	----	----	11
Manganese	7439-96-5	5	mg/kg	----	----	----	----	25
Molybdenum	7439-98-7	2	mg/kg	----	----	----	----	<2
Nickel	7440-02-0	2	mg/kg	----	----	----	----	6
Selenium	7782-49-2	5	mg/kg	----	----	----	----	<5
Vanadium	7440-62-2	5	mg/kg	----	----	----	----	7
Zinc	7440-66-6	5	mg/kg	----	----	----	----	16
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	----	----	----	----	0.06
Selenium	7782-49-2	0.1	mg/kg	----	----	----	----	<0.1
Silver	7440-22-4	0.01	mg/kg	----	----	----	----	<0.01
Barium	7440-39-3	0.01	mg/kg	----	----	----	----	0.04
Beryllium	7440-41-7	0.01	mg/kg	----	----	----	----	0.02
Cadmium	7440-43-9	0.01	mg/kg	----	----	----	----	0.02
Cobalt	7440-48-4	0.01	mg/kg	----	----	----	----	0.86
Chromium	7440-47-3	0.01	mg/kg	----	----	----	----	0.01
Thorium	7440-29-1	0.01	mg/kg	----	----	----	----	<0.01
Copper	7440-50-8	0.01	mg/kg	----	----	----	----	0.13
Manganese	7439-96-5	0.01	mg/kg	----	----	----	----	9.01
Molybdenum	7439-98-7	0.01	mg/kg	----	----	----	----	<0.01
Nickel	7440-02-0	0.01	mg/kg	----	----	----	----	1.38
Lead	7439-92-1	0.01	mg/kg	----	----	----	----	<0.01



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				22 EB1444979022	23 EB1444979023	24 EB1444979024	26 EB1444979026	27 EB1444979027
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-016	EB1446063-017	EB1446063-018	EB1446063-019	EB1446063-020
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	----	----	----	----	0.02
Uranium	7440-61-1	0.01	mg/kg	----	----	----	----	<0.01
Zinc	7440-66-6	0.05	mg/kg	----	----	----	----	2.74
Vanadium	7440-62-2	0.1	mg/kg	----	----	----	----	<0.1
Aluminium	7429-90-5	0.1	mg/kg	----	----	----	----	6.4
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	----	----	----	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	----	----	----	0.7
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	----	----	----	----	<1
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	----	----	----	----	0.1



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				28 EB1444979028	30 EB1444979030	33 EB1444979033	35 EB1444979035	37 EB1444979037
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-021	EB1446063-022	EB1446063-023	EB1446063-024	EB1446063-025
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	3.9	3.9	----	----	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	1.0	0.9	----	----	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	2.7	2.2	----	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	----	----	----	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium Percent	----	0.1	%	----	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	----	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	----	----	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	----	----	----
Magnesium	7439-95-4	10	mg/kg	----	----	----	----	----
Sodium	7440-23-5	10	mg/kg	----	----	----	----	----
Potassium	7440-09-7	10	mg/kg	----	----	----	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	----	----	----	----	----
Potassium	7440-09-7	50	mg/kg	----	----	----	----	----
Calcium	7440-70-2	50	mg/kg	----	----	----	----	----
Magnesium	7439-95-4	50	mg/kg	----	----	----	----	----
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				28 EB1444979028	30 EB1444979030	33 EB1444979033	35 EB1444979035	37 EB1444979037
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-021	EB1446063-022	EB1446063-023	EB1446063-024	EB1446063-025
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	----	----	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	----	----	----
Antimony	7440-36-0	5	mg/kg	----	----	----	----	----
Arsenic	7440-38-2	5	mg/kg	----	----	----	----	----
Barium	7440-39-3	10	mg/kg	----	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	----	----	----	----	----
Boron	7440-42-8	50	mg/kg	----	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	----	----	----	----	----
Chromium	7440-47-3	2	mg/kg	----	----	----	----	----
Cobalt	7440-48-4	2	mg/kg	----	----	----	----	----
Copper	7440-50-8	5	mg/kg	----	----	----	----	----
Iron	7439-89-6	50	mg/kg	----	----	----	----	----
Lead	7439-92-1	5	mg/kg	----	----	----	----	----
Manganese	7439-96-5	5	mg/kg	----	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	----	----	----	----	----
Nickel	7440-02-0	2	mg/kg	----	----	----	----	----
Selenium	7782-49-2	5	mg/kg	----	----	----	----	----
Vanadium	7440-62-2	5	mg/kg	----	----	----	----	----
Zinc	7440-66-6	5	mg/kg	----	----	----	----	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	----	----	----	----	----
Selenium	7782-49-2	0.1	mg/kg	----	----	----	----	----
Silver	7440-22-4	0.01	mg/kg	----	----	----	----	----
Barium	7440-39-3	0.01	mg/kg	----	----	----	----	----
Beryllium	7440-41-7	0.01	mg/kg	----	----	----	----	----
Cadmium	7440-43-9	0.01	mg/kg	----	----	----	----	----
Cobalt	7440-48-4	0.01	mg/kg	----	----	----	----	----
Chromium	7440-47-3	0.01	mg/kg	----	----	----	----	----
Thorium	7440-29-1	0.01	mg/kg	----	----	----	----	----
Copper	7440-50-8	0.01	mg/kg	----	----	----	----	----
Manganese	7439-96-5	0.01	mg/kg	----	----	----	----	----
Molybdenum	7439-98-7	0.01	mg/kg	----	----	----	----	----
Nickel	7440-02-0	0.01	mg/kg	----	----	----	----	----
Lead	7439-92-1	0.01	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				28 EB1444979028	30 EB1444979030	33 EB1444979033	35 EB1444979035	37 EB1444979037
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-021	EB1446063-022	EB1446063-023	EB1446063-024	EB1446063-025
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	----	----	----	----	----
Uranium	7440-61-1	0.01	mg/kg	----	----	----	----	----
Zinc	7440-66-6	0.05	mg/kg	----	----	----	----	----
Vanadium	7440-62-2	0.1	mg/kg	----	----	----	----	----
Aluminium	7429-90-5	0.1	mg/kg	----	----	----	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	----	----	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	----	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				39 EB1444979039	40 EB1444979040	42 EB1444979042	46 EB1444979046	48 EB1444979048
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-026	EB1446063-027	EB1446063-028	EB1446063-029	EB1446063-030
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	4.2	4.2	4.0	----	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	0.5	0.4	0.6	----	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	1.8	1.8	2.2	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	----	----	----	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium Percent	----	0.1	%	----	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	----	----	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	----	----	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	----	----	----	----
Magnesium	7439-95-4	10	mg/kg	----	----	----	----	----
Sodium	7440-23-5	10	mg/kg	----	----	----	----	----
Potassium	7440-09-7	10	mg/kg	----	----	----	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	----	----	----	----	----
Potassium	7440-09-7	50	mg/kg	----	----	----	----	----
Calcium	7440-70-2	50	mg/kg	----	----	----	----	----
Magnesium	7439-95-4	50	mg/kg	----	----	----	----	----
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				39 EB1444979039	40 EB1444979040	42 EB1444979042	46 EB1444979046	48 EB1444979048
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-026	EB1446063-027	EB1446063-028	EB1446063-029	EB1446063-030
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	----	----	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	----	----	----	----
Antimony	7440-36-0	5	mg/kg	----	----	----	----	----
Arsenic	7440-38-2	5	mg/kg	----	----	----	----	----
Barium	7440-39-3	10	mg/kg	----	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	----	----	----	----	----
Boron	7440-42-8	50	mg/kg	----	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	----	----	----	----	----
Chromium	7440-47-3	2	mg/kg	----	----	----	----	----
Cobalt	7440-48-4	2	mg/kg	----	----	----	----	----
Copper	7440-50-8	5	mg/kg	----	----	----	----	----
Iron	7439-89-6	50	mg/kg	----	----	----	----	----
Lead	7439-92-1	5	mg/kg	----	----	----	----	----
Manganese	7439-96-5	5	mg/kg	----	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	----	----	----	----	----
Nickel	7440-02-0	2	mg/kg	----	----	----	----	----
Selenium	7782-49-2	5	mg/kg	----	----	----	----	----
Vanadium	7440-62-2	5	mg/kg	----	----	----	----	----
Zinc	7440-66-6	5	mg/kg	----	----	----	----	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	----	----	----	----	----
Selenium	7782-49-2	0.1	mg/kg	----	----	----	----	----
Silver	7440-22-4	0.01	mg/kg	----	----	----	----	----
Barium	7440-39-3	0.01	mg/kg	----	----	----	----	----
Beryllium	7440-41-7	0.01	mg/kg	----	----	----	----	----
Cadmium	7440-43-9	0.01	mg/kg	----	----	----	----	----
Cobalt	7440-48-4	0.01	mg/kg	----	----	----	----	----
Chromium	7440-47-3	0.01	mg/kg	----	----	----	----	----
Thorium	7440-29-1	0.01	mg/kg	----	----	----	----	----
Copper	7440-50-8	0.01	mg/kg	----	----	----	----	----
Manganese	7439-96-5	0.01	mg/kg	----	----	----	----	----
Molybdenum	7439-98-7	0.01	mg/kg	----	----	----	----	----
Nickel	7440-02-0	0.01	mg/kg	----	----	----	----	----
Lead	7439-92-1	0.01	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				39 EB1444979039	40 EB1444979040	42 EB1444979042	46 EB1444979046	48 EB1444979048
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-026	EB1446063-027	EB1446063-028	EB1446063-029	EB1446063-030
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	----	----	----	----	----
Uranium	7440-61-1	0.01	mg/kg	----	----	----	----	----
Zinc	7440-66-6	0.05	mg/kg	----	----	----	----	----
Vanadium	7440-62-2	0.1	mg/kg	----	----	----	----	----
Aluminium	7429-90-5	0.1	mg/kg	----	----	----	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	----	----	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	----	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	----	----	----	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				50 EB1444979050	51 EB1444979051	52 EB1444979052	54 EB1444979054	56 EB1444979056
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-031	EB1446063-032	EB1446063-033	EB1446063-034	EB1446063-035
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	4.5	3.6	4.1	3.8	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	1.1	0.6	0.8	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	1.4	2.4	2.6	2.3	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	0.040	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	----	----	1.6	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	----	----	0.2	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	----	----	0.2	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	----	----	0.2	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	----	----	2.1	----	----
^ Exchangeable Sodium Percent	----	0.1	%	----	----	5.7	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	<5	<5	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	<5	<5	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	<5	<5	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	----	96	86	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	2380	3610	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	320	660	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	780	900	----	----
Magnesium	7439-95-4	10	mg/kg	----	30	100	----	----
Sodium	7440-23-5	10	mg/kg	----	340	920	----	----
Potassium	7440-09-7	10	mg/kg	----	20	50	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	----	560	980	----	----
Potassium	7440-09-7	50	mg/kg	----	910	1120	----	----
Calcium	7440-70-2	50	mg/kg	----	1040	1260	----	----
Magnesium	7439-95-4	50	mg/kg	----	80	260	----	----
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	----	<1	<1	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				50 EB1444979050	51 EB1444979051	52 EB1444979052	54 EB1444979054	56 EB1444979056
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-031	EB1446063-032	EB1446063-033	EB1446063-034	EB1446063-035
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	----	1	2	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	1650	3110	----	----
Antimony	7440-36-0	5	mg/kg	----	10	19	----	----
Arsenic	7440-38-2	5	mg/kg	----	130	172	----	----
Barium	7440-39-3	10	mg/kg	----	120	150	----	----
Beryllium	7440-41-7	1	mg/kg	----	<1	<1	----	----
Boron	7440-42-8	50	mg/kg	----	<50	<50	----	----
Cadmium	7440-43-9	1	mg/kg	----	<1	<1	----	----
Chromium	7440-47-3	2	mg/kg	----	24	45	----	----
Cobalt	7440-48-4	2	mg/kg	----	<2	6	----	----
Copper	7440-50-8	5	mg/kg	----	10	16	----	----
Iron	7439-89-6	50	mg/kg	----	9960	14800	----	----
Lead	7439-92-1	5	mg/kg	----	7	8	----	----
Manganese	7439-96-5	5	mg/kg	----	16	45	----	----
Molybdenum	7439-98-7	2	mg/kg	----	<2	<2	----	----
Nickel	7440-02-0	2	mg/kg	----	3	9	----	----
Selenium	7782-49-2	5	mg/kg	----	<5	<5	----	----
Vanadium	7440-62-2	5	mg/kg	----	5	9	----	----
Zinc	7440-66-6	5	mg/kg	----	11	21	----	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	----	0.08	<0.01	----	----
Selenium	7782-49-2	0.1	mg/kg	----	<0.1	<0.1	----	----
Silver	7440-22-4	0.01	mg/kg	----	<0.01	<0.01	----	----
Barium	7440-39-3	0.01	mg/kg	----	0.01	0.05	----	----
Beryllium	7440-41-7	0.01	mg/kg	----	0.02	0.02	----	----
Cadmium	7440-43-9	0.01	mg/kg	----	0.01	0.03	----	----
Cobalt	7440-48-4	0.01	mg/kg	----	0.36	1.33	----	----
Chromium	7440-47-3	0.01	mg/kg	----	0.01	<0.01	----	----
Thorium	7440-29-1	0.01	mg/kg	----	<0.01	<0.01	----	----
Copper	7440-50-8	0.01	mg/kg	----	0.11	0.07	----	----
Manganese	7439-96-5	0.01	mg/kg	----	6.75	16.7	----	----
Molybdenum	7439-98-7	0.01	mg/kg	----	<0.01	<0.01	----	----
Nickel	7440-02-0	0.01	mg/kg	----	0.65	1.93	----	----
Lead	7439-92-1	0.01	mg/kg	----	<0.01	<0.01	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				50 EB1444979050	51 EB1444979051	52 EB1444979052	54 EB1444979054	56 EB1444979056
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-031	EB1446063-032	EB1446063-033	EB1446063-034	EB1446063-035
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	----	0.02	<0.01	----	----
Uranium	7440-61-1	0.01	mg/kg	----	<0.01	0.02	----	----
Zinc	7440-66-6	0.05	mg/kg	----	3.26	4.63	----	----
Vanadium	7440-62-2	0.1	mg/kg	----	<0.1	<0.1	----	----
Aluminium	7429-90-5	0.1	mg/kg	----	4.8	2.1	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	<0.0005	<0.0005	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	0.5	0.4	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	----	<1	<1	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	----	<0.1	<0.1	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				65 T EB1444979065	67 T EB1444979067	73 T EB1444979073	76 OR(T) EB1444979076	77 OR(T) EB1444979077
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-036	EB1446063-037	EB1446063-038	EB1446063-039	EB1446063-040
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	5.7	6.2	4.3	6.7	3.3
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	0.2	<0.1	1.0
NAG (pH 7.0)	----	0.1	kg H2SO4/t	1.0	0.7	2.0	0.6	5.7
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	3.0	3.4	----	3.5	1.9
^ Exchangeable Magnesium	----	0.1	meq/100g	0.5	2.2	----	2.1	0.3
^ Exchangeable Potassium	----	0.1	meq/100g	0.4	0.3	----	0.4	0.2
^ Exchangeable Sodium	----	0.1	meq/100g	0.1	0.1	----	0.2	<0.1
^ Cation Exchange Capacity	----	0.1	meq/100g	4.0	5.9	----	6.2	2.5
^ Exchangeable Sodium Percent	----	0.1	%	1.8	1.7	----	2.9	0.9
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	<5	<5	----	7	<5
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	<5	<5	----	7	<5
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	----	<5	<5
ED038A: Acidity								
Acidity	----	1	mg/kg	230	86	----	48	1200
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	3940	3520	----	4840	5520
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	130	640	----	780	360
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	940	610	----	650	1200
Magnesium	7439-95-4	10	mg/kg	140	370	----	460	210
Sodium	7440-23-5	10	mg/kg	420	670	----	1130	540
Potassium	7440-09-7	10	mg/kg	130	70	----	110	70
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	510	750	----	1210	670
Potassium	7440-09-7	50	mg/kg	1750	1460	----	1670	1590
Calcium	7440-70-2	50	mg/kg	1580	1360	----	1350	1510
Magnesium	7439-95-4	50	mg/kg	2710	4140	----	2830	2060
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	----	<1	<1



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				65 T EB1444979065	67 T EB1444979067	73 T EB1444979073	76 OR(T) EB1444979076	77 OR(T) EB1444979077
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-036	EB1446063-037	EB1446063-038	EB1446063-039	EB1446063-040
				Result	Result	Result	Result	Result
EG005S : Soluble Metals by ICPAES - Continued								
Iron	7439-89-6	1	mg/kg	<1	<1	----	<1	<1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	10100	12000	----	10200	10900
Antimony	7440-36-0	5	mg/kg	<5	<5	----	<5	<5
Arsenic	7440-38-2	5	mg/kg	20	11	----	16	14
Barium	7440-39-3	10	mg/kg	160	240	----	160	160
Beryllium	7440-41-7	1	mg/kg	2	2	----	1	3
Boron	7440-42-8	50	mg/kg	<50	<50	----	<50	<50
Cadmium	7440-43-9	1	mg/kg	<1	<1	----	<1	<1
Chromium	7440-47-3	2	mg/kg	50	45	----	53	47
Cobalt	7440-48-4	2	mg/kg	20	22	----	26	18
Copper	7440-50-8	5	mg/kg	23	27	----	25	30
Iron	7439-89-6	50	mg/kg	29700	34000	----	41400	45500
Lead	7439-92-1	5	mg/kg	19	22	----	29	28
Manganese	7439-96-5	5	mg/kg	546	816	----	1370	457
Molybdenum	7439-98-7	2	mg/kg	<2	<2	----	<2	<2
Nickel	7440-02-0	2	mg/kg	31	34	----	45	35
Selenium	7782-49-2	5	mg/kg	<5	<5	----	<5	<5
Vanadium	7440-62-2	5	mg/kg	23	24	----	30	27
Zinc	7440-66-6	5	mg/kg	52	56	----	41	71
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	<0.01	<0.01	----	<0.01	0.01
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	----	<0.1	<0.1
Silver	7440-22-4	0.01	mg/kg	<0.01	<0.01	----	<0.01	<0.01
Barium	7440-39-3	0.01	mg/kg	0.22	0.17	----	0.17	0.24
Beryllium	7440-41-7	0.01	mg/kg	0.04	0.02	----	<0.01	0.23
Cadmium	7440-43-9	0.01	mg/kg	0.03	0.02	----	0.01	0.07
Cobalt	7440-48-4	0.01	mg/kg	2.46	1.09	----	0.50	3.86
Chromium	7440-47-3	0.01	mg/kg	<0.01	<0.01	----	<0.01	0.03
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	----	<0.01	<0.01
Copper	7440-50-8	0.01	mg/kg	0.03	0.03	----	0.02	0.09
Manganese	7439-96-5	0.01	mg/kg	78.9	77.4	----	118	113
Molybdenum	7439-98-7	0.01	mg/kg	<0.01	<0.01	----	<0.01	<0.01
Nickel	7440-02-0	0.01	mg/kg	2.65	1.43	----	2.17	4.41
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	----	<0.01	0.01



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				65 T EB1444979065	67 T EB1444979067	73 T EB1444979073	76 OR(T) EB1444979076	77 OR(T) EB1444979077
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]
Compound	CAS Number	LOR	Unit	EB1446063-036	EB1446063-037	EB1446063-038	EB1446063-039	EB1446063-040
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	<0.01	<0.01	----	<0.01	<0.01
Uranium	7440-61-1	0.01	mg/kg	<0.01	<0.01	----	<0.01	0.02
Zinc	7440-66-6	0.05	mg/kg	2.82	2.70	----	0.55	11.3
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	----	<0.1	<0.1
Aluminium	7429-90-5	0.1	mg/kg	10.5	2.8	----	0.3	131
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	----	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	----	<0.1	<0.1
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	2	<1	----	<1	2
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	<0.1	----	<0.1	<0.1



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				81 EB1444979081	82 EB1444979082	85 EB1444979085	----	----
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	----	----
Compound	CAS Number	LOR	Unit	EB1446063-041	EB1446063-042	EB1446063-043	-----	-----
				Result	Result	Result	Result	Result
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	----	4.2	4.3	----	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	----	0.2	0.2	----	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	----	2.3	1.6	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	0.005	----	----
ED008: Exchangeable Cations								
^ Exchangeable Calcium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Potassium	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium	----	0.1	meq/100g	----	----	----	----	----
^ Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	----
^ Exchangeable Sodium Percent	----	0.1	%	----	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	<5	<5	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	<5	<5	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	<5	<5	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	----	58	173	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	1510	3770	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	120	140	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	420	860	----	----
Magnesium	7439-95-4	10	mg/kg	----	30	120	----	----
Sodium	7440-23-5	10	mg/kg	----	220	700	----	----
Potassium	7440-09-7	10	mg/kg	----	80	90	----	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	----	580	1140	----	----
Potassium	7440-09-7	50	mg/kg	----	1580	1560	----	----
Calcium	7440-70-2	50	mg/kg	----	2520	1080	----	----
Magnesium	7439-95-4	50	mg/kg	----	90	180	----	----
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	----	<1	<1	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				81 EB1444979081	82 EB1444979082	85 EB1444979085	----	----
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	----	----
Compound	CAS Number	LOR	Unit	EB1446063-041	EB1446063-042	EB1446063-043	-----	-----
				Result	Result	Result	Result	Result

EG005S : Soluble Metals by ICPAES - Continued

Iron	7439-89-6	1	mg/kg	----	6	8	----	----
------	-----------	---	-------	------	---	---	------	------

EG005T: Total Metals by ICP-AES

Aluminium	7429-90-5	50	mg/kg	----	2150	2210	----	----
Antimony	7440-36-0	5	mg/kg	----	18	11	----	----
Arsenic	7440-38-2	5	mg/kg	----	209	167	----	----
Barium	7440-39-3	10	mg/kg	----	110	100	----	----
Beryllium	7440-41-7	1	mg/kg	----	<1	<1	----	----
Boron	7440-42-8	50	mg/kg	----	<50	<50	----	----
Cadmium	7440-43-9	1	mg/kg	----	<1	<1	----	----
Chromium	7440-47-3	2	mg/kg	----	45	68	----	----
Cobalt	7440-48-4	2	mg/kg	----	2	5	----	----
Copper	7440-50-8	5	mg/kg	----	8	20	----	----
Iron	7439-89-6	50	mg/kg	----	11100	11500	----	----
Lead	7439-92-1	5	mg/kg	----	19	8	----	----
Manganese	7439-96-5	5	mg/kg	----	8	31	----	----
Molybdenum	7439-98-7	2	mg/kg	----	3	2	----	----
Nickel	7440-02-0	2	mg/kg	----	3	8	----	----
Selenium	7782-49-2	5	mg/kg	----	<5	<5	----	----
Vanadium	7440-62-2	5	mg/kg	----	5	5	----	----
Zinc	7440-66-6	5	mg/kg	----	7	14	----	----

EG020S: Soluble Metals by ICPMS

Arsenic	7440-38-2	0.01	mg/kg	----	0.03	0.11	----	----
Selenium	7782-49-2	0.1	mg/kg	----	<0.1	<0.1	----	----
Silver	7440-22-4	0.01	mg/kg	----	<0.01	<0.01	----	----
Barium	7440-39-3	0.01	mg/kg	----	0.04	0.01	----	----
Beryllium	7440-41-7	0.01	mg/kg	----	<0.01	0.04	----	----
Cadmium	7440-43-9	0.01	mg/kg	----	<0.01	0.04	----	----
Cobalt	7440-48-4	0.01	mg/kg	----	0.30	1.64	----	----
Chromium	7440-47-3	0.01	mg/kg	----	<0.01	0.02	----	----
Thorium	7440-29-1	0.01	mg/kg	----	<0.01	<0.01	----	----
Copper	7440-50-8	0.01	mg/kg	----	0.04	0.07	----	----
Manganese	7439-96-5	0.01	mg/kg	----	6.02	19.5	----	----
Molybdenum	7439-98-7	0.01	mg/kg	----	<0.01	<0.01	----	----
Nickel	7440-02-0	0.01	mg/kg	----	0.48	2.41	----	----
Lead	7439-92-1	0.01	mg/kg	----	<0.01	<0.01	----	----



Analytical Results

Sub-Matrix: PULP
 (Matrix: SOIL)

Client sample ID

				81 EB1444979081	82 EB1444979082	85 EB1444979085	----	----
Client sampling date / time				[23-Oct-2014]	[23-Oct-2014]	[23-Oct-2014]	----	----
Compound	CAS Number	LOR	Unit	EB1446063-041	EB1446063-042	EB1446063-043	-----	-----
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Antimony	7440-36-0	0.01	mg/kg	----	0.02	0.07	----	----
Uranium	7440-61-1	0.01	mg/kg	----	<0.01	0.02	----	----
Zinc	7440-66-6	0.05	mg/kg	----	0.62	4.80	----	----
Vanadium	7440-62-2	0.1	mg/kg	----	<0.1	<0.1	----	----
Aluminium	7429-90-5	0.1	mg/kg	----	1.9	9.4	----	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	<0.0005	<0.0005	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	0.7	0.9	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	----	<1	2	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	----	<0.1	<0.1	----	----

CERTIFICATE OF ANALYSIS

Work Order	: EB1512512	Page	: 1 of 11
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091	Address	: 2 Byth Street Stafford QLD Australia 4053
	SUNNYBANK SOUTH QLD, AUSTRALIA 4109		
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 (Yandan)	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 09-Feb-2015 15:40
C-O-C number	: ----	Date Analysis Commenced	: 11-Feb-2015
Sampler	: ----	Issue Date	: 17-Feb-2015 13:29
Site	: ----		
Quote number	: ----	No. of samples received	: 42
		No. of samples analysed	: 42

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.

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.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils



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.



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				5	7	8	9	18
				EB1444979005	EB1444979007	EB1444979008	EB1444979009	EB1444979018
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-001	EB1512512-002	EB1512512-003	EB1512512-004	EB1512512-005
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				21 EB1444979021	25 EB1444979025	29 EB1444979029	31 EB1444979031	32 EB1444979032
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-006	EB1512512-007	EB1512512-008	EB1512512-009	EB1512512-010
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	0.005	0.005	<0.005



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				34 EB1444979034	36 EB1444979036	38 EB1444979038	41 EB1444979041	43 EB1444979043
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-011	EB1512512-012	EB1512512-013	EB1512512-014	EB1512512-015
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	0.005	<0.005	0.010	<0.005



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				44 EB1444979044	45 EB1444979045	47 EB1444979047	49 EB1444979049	53 EB1444979053
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-016	EB1512512-017	EB1512512-018	EB1512512-019	EB1512512-020
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				55 EB1444979055	57 EB1444979057	58 EB1444979058	59 EB1444979059	60 EB1444979060
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-021	EB1512512-022	EB1512512-023	EB1512512-024	EB1512512-025
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	0.006



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				61 EB1444979061	62 EB1444979062	63 EB1444979063	64 T EB1444979064	66 T EB1444979066
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-026	EB1512512-027	EB1512512-028	EB1512512-029	EB1512512-030
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.009	<0.005	<0.005	<0.005	<0.005



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				68 T EB1444979068	69 T EB1444979069	70 T EB1444979070	71 T EB1444979071	72 T EB1444979072
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-031	EB1512512-032	EB1512512-033	EB1512512-034	EB1512512-035
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				74 T EB1444979074	75 T EB1444979075	78 OR(T) EB1444979078	79 EB1444979079	80 EB1444979080
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]	[22-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1512512-036	EB1512512-037	EB1512512-038	EB1512512-039	EB1512512-040
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	<0.005	<0.005	<0.005	<0.005	<0.005

Page : 11 of 11
 Work Order : EB1512512
 Client : RGS ENVIRONMENTAL PTY LTD
 Project : 201434 (Yandan)



Analytical Results

Sub-Matrix: **SOIL**
 (Matrix: **SOIL**)

Client sample ID

				83 EB1444979083	84 EB1444979084	----	----	----
Client sampling date / time				[22-Dec-2014]	[22-Dec-2014]	----	----	----
Compound	CAS Number	LOR	Unit	EB1512512-041	EB1512512-042	-----	-----	-----
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.006	0.006	----	----	----



Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1448978	Page	: 1 of 5
Amendment	: 1		
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 Yandan Straits	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 19-Dec-2014 17:40
C-O-C number	: ----	Date Analysis Commenced	: 23-Dec-2014
Sampler	: MANDIE MATHESON	Issue Date	: 06-Feb-2015 15:40
Site	: ----		
Quote number	: ----	No. of samples received	: 7
		No. of samples analysed	: 7

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.

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.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Peter Keyte	Newcastle Manager	Newcastle - Inorganics



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.

- **EA150H: Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1 2006 was not requested by the client. Typical sediment SPD values used for calculations and consequently NATA endorsement does not apply to hydrometer results.**



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Client sample ID

				Yandan-1(A/B)-oxide tails	Yandan-2(A/B)-sulfide tails	----	----	----
Client sampling date / time				[19-Dec-2014]	[19-Dec-2014]	----	----	----
Compound	CAS Number	LOR	Unit	EB1448978-006	EB1448978-007	-----	-----	-----
				Result	Result	Result	Result	Result
EA150: Particle Sizing								
+75µm	----	1	%	39	35	----	----	----
+150µm	----	1	%	16	14	----	----	----
+300µm	----	1	%	3	3	----	----	----
+425µm	----	1	%	<1	1	----	----	----
+600µm	----	1	%	<1	<1	----	----	----
+1180µm	----	1	%	<1	<1	----	----	----
+2.36mm	----	1	%	<1	<1	----	----	----
+4.75mm	----	1	%	<1	<1	----	----	----
+9.5mm	----	1	%	<1	<1	----	----	----
+19.0mm	----	1	%	<1	<1	----	----	----
+37.5mm	----	1	%	<1	<1	----	----	----
+75.0mm	----	1	%	<1	<1	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	16	16	----	----	----
Silt (2-60 µm)	----	1	%	40	45	----	----	----
Sand (0.06-2.00 mm)	----	1	%	44	39	----	----	----
Gravel (>2mm)	----	1	%	<1	<1	----	----	----
Cobbles (>6cm)	----	1	%	<1	<1	----	----	----



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Client sample ID

				Yandan-KLC (1A) -oxide	Yandan-KLC (2A) -sulfide	Yandan-KLC (3)-Mixed Tails	Yandan-KLC (1B) -oxide	Yandan-KLC (2B) -sulfide
Client sampling date / time				[18-Dec-2014]	[18-Dec-2014]	[18-Dec-2014]	[18-Dec-2014]	[18-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1448978-001	EB1448978-002	EB1448978-003	EB1448978-004	EB1448978-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	4.64	4.14	4.06	4.00	3.81
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	5280	3740	3040	2510	2100
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L	2	<1	<1	<1	<1
Total Alkalinity as CaCO ₃	----	1	mg/L	2	<1	<1	<1	<1
ED038A: Acidity								
Acidity as CaCO ₃	----	1	mg/L	123	252	232	159	180
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA								
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L	1330	1100	918	709	785
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	755	426	397	305	212
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	284	330	195	192	184
Magnesium	7439-95-4	1	mg/L	101	73	67	36	35
Sodium	7440-23-5	1	mg/L	843	466	377	324	203
Potassium	7440-09-7	1	mg/L	35	9	12	8	4
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	5.70	26.8	22.0	7.78	19.5
Antimony	7440-36-0	0.001	mg/L	0.006	0.057	0.002	<0.001	0.002
Arsenic	7440-38-2	0.001	mg/L	0.001	0.007	0.005	<0.001	0.017
Cadmium	7440-43-9	0.0001	mg/L	0.0260	0.0176	0.0127	0.0094	0.0083
Chromium	7440-47-3	0.001	mg/L	0.005	0.021	0.016	0.008	0.020
Copper	7440-50-8	0.001	mg/L	0.158	0.280	0.176	0.220	0.213
Cobalt	7440-48-4	0.001	mg/L	1.29	0.868	0.599	0.512	0.430
Nickel	7440-02-0	0.001	mg/L	2.01	1.39	0.975	1.06	0.772
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	3.34	5.19	2.19	1.53	1.17
Manganese	7439-96-5	0.001	mg/L	14.5	8.22	8.28	5.31	4.58
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Client sample ID

				Yandan-KLC (1A) -oxide	Yandan-KLC (2A) -sulfide	Yandan-KLC (3)-Mixed Tails	Yandan-KLC (1B) -oxide	Yandan-KLC (2B) -sulfide
Client sampling date / time				[18-Dec-2014]	[18-Dec-2014]	[18-Dec-2014]	[18-Dec-2014]	[18-Dec-2014]
Compound	CAS Number	LOR	Unit	EB1448978-001	EB1448978-002	EB1448978-003	EB1448978-004	EB1448978-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	15.7	1.22	1.28	10.6	0.40

**Environmental****CERTIFICATE OF ANALYSIS**

Work Order	: EB1511069	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091	Address	: 2 Byth Street Stafford QLD Australia 4053
	SUNNYBANK SOUTH QLD, AUSTRALIA 4109		
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 Yandan Straits	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 20-Jan-2015 19:05
C-O-C number	: ----	Date Analysis Commenced	: 21-Jan-2015
Sampler	: MANDIE MATHESON	Issue Date	: 29-Jan-2015 17:09
Site	: ----		
Quote number	: ----	No. of samples received	: 5
		No. of samples analysed	: 5

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

WORLD RECOGNISED
ACCREDITATION

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.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics



General Comments

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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.



Analytical Results

Sub-Matrix: LEACHATE
 (Matrix: WATER)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[20-Jan-2015]	[20-Jan-2015]	[20-Jan-2015]	[20-Jan-2015]	[20-Jan-2015]
Compound	CAS Number	LOR	Unit	EB1511069-001	EB1511069-002	EB1511069-003	EB1511069-004	EB1511069-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	4.23	3.65	4.27	4.75	4.22
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	1450	2340	718	172	244
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L	<1	<1	<1	<1	<1
Total Alkalinity as CaCO ₃	----	1	mg/L	<1	<1	<1	<1	<1
ED038A: Acidity								
Acidity as CaCO ₃	----	1	mg/L	32	196	23	15	31
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA								
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L	432	954	185	52	91
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	216	282	88	6	6
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	71	204	32	16	30
Magnesium	7439-95-4	1	mg/L	21	32	14	2	2
Sodium	7440-23-5	1	mg/L	191	231	80	10	8
Potassium	7440-09-7	1	mg/L	8	4	2	<1	<1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	2.10	22.3	1.82	0.17	0.90
Antimony	7440-36-0	0.001	mg/L	<0.001	0.013	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.001	0.026	0.003	<0.001	0.005
Cadmium	7440-43-9	0.0001	mg/L	0.0054	0.0094	0.0020	0.0004	0.0005
Chromium	7440-47-3	0.001	mg/L	0.002	0.018	0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.044	0.168	0.021	0.005	0.008
Cobalt	7440-48-4	0.001	mg/L	0.320	0.494	0.125	0.026	0.031
Nickel	7440-02-0	0.001	mg/L	0.521	0.804	0.174	0.050	0.053
Lead	7439-92-1	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	0.686	1.46	0.276	0.073	0.071
Manganese	7439-96-5	0.001	mg/L	3.76	5.52	3.13	0.273	0.337
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01



Analytical Results

Sub-Matrix: **LEACHATE**
 (Matrix: **WATER**)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[20-Jan-2015]	[20-Jan-2015]	[20-Jan-2015]	[20-Jan-2015]	[20-Jan-2015]
Compound	CAS Number	LOR	Unit	EB1511069-001	EB1511069-002	EB1511069-003	EB1511069-004	EB1511069-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	<0.05	0.13	<0.05	<0.05	<0.05



Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1513237	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 Yandan Straits	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 19-Feb-2015 20:00
C-O-C number	: ----	Date Analysis Commenced	: 20-Feb-2015
Sampler	: MANDIE MATHESON	Issue Date	: 02-Mar-2015 11:46
Site	: ----		
Quote number	: ----	No. of samples received	: 5
		No. of samples analysed	: 5

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



WORLD RECOGNISED
ACCREDITATION

NATA Accredited Laboratory 825

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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

Kim McCabe

Senior Inorganic Chemist

Brisbane Inorganics



General Comments

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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.



Analytical Results

Sub-Matrix: LEACHATE
 (Matrix: WATER)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[19-Feb-2015]	[19-Feb-2015]	[19-Feb-2015]	[19-Feb-2015]	[19-Feb-2015]
Compound	CAS Number	LOR	Unit	EB1513237-001	EB1513237-002	EB1513237-003	EB1513237-004	EB1513237-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	4.18	3.69	4.39	4.63	4.26
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	3520	4010	706	187	308
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L	<1	<1	<1	<1	<1
Total Alkalinity as CaCO ₃	----	1	mg/L	<1	<1	<1	<1	<1
ED038A: Acidity								
Acidity as CaCO ₃	----	1	mg/L	76	340	33	16	47
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA								
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L	1190	1680	201	64	118
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	513	505	83	11	8
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	269	378	34	15	31
Magnesium	7439-95-4	1	mg/L	56	65	12	2	4
Sodium	7440-23-5	1	mg/L	490	496	76	13	12
Potassium	7440-09-7	1	mg/L	19	8	2	<1	<1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	7.08	46.7	2.41	0.20	1.77
Antimony	7440-36-0	0.001	mg/L	0.001	0.028	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.003	0.050	0.003	<0.001	0.007
Cadmium	7440-43-9	0.0001	mg/L	0.0142	0.0180	0.0021	0.0006	0.0007
Chromium	7440-47-3	0.001	mg/L	0.006	0.033	<0.001	<0.001	0.001
Copper	7440-50-8	0.001	mg/L	0.110	0.352	0.026	0.006	0.014
Cobalt	7440-48-4	0.001	mg/L	0.847	0.971	0.122	0.035	0.055
Nickel	7440-02-0	0.001	mg/L	1.34	1.52	0.175	0.066	0.092
Lead	7439-92-1	0.001	mg/L	0.003	0.005	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	1.89	3.61	0.323	0.097	0.120
Manganese	7439-96-5	0.001	mg/L	9.55	9.33	2.39	0.352	0.596
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	0.01	0.04	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01

Page : 4 of 4
 Work Order : EB1513237
 Client : RGS ENVIRONMENTAL PTY LTD
 Project : 201434 Yandan Straits



Analytical Results

Sub-Matrix: **LEACHATE**
 (Matrix: **WATER**)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[19-Feb-2015]	[19-Feb-2015]	[19-Feb-2015]	[19-Feb-2015]	[19-Feb-2015]
Compound	CAS Number	LOR	Unit	EB1513237-001	EB1513237-002	EB1513237-003	EB1513237-004	EB1513237-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	0.59	0.22	<0.05	<0.05	<0.05



Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1515129	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 Yandan Straits	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 19-Mar-2015 18:45
C-O-C number	: ----	Date Analysis Commenced	: 20-Mar-2015
Sampler	: MANDIE MATHESON	Issue Date	: 25-Mar-2015 13:29
Site	: ----		
Quote number	: ----	No. of samples received	: 5
		No. of samples analysed	: 5

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



WORLD RECOGNISED
ACCREDITATION

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
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics



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.



Analytical Results

Sub-Matrix: LEACHATE
 (Matrix: WATER)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[19-Mar-2015]	[19-Mar-2015]	[19-Mar-2015]	[19-Mar-2015]	[19-Mar-2015]
Compound	CAS Number	LOR	Unit	EB1515129-001	EB1515129-002	EB1515129-003	EB1515129-004	EB1515129-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	4.26	3.80	4.29	4.83	4.43
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	1620	2240	1060	144	215
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L	<1	<1	<1	1	<1
Total Alkalinity as CaCO ₃	----	1	mg/L	<1	<1	<1	1	<1
ED038A: Acidity								
Acidity as CaCO ₃	----	1	mg/L	34	171	33	9	24
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA								
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L	451	806	306	50	79
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	234	252	132	4	6
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	75	176	49	12	21
Magnesium	7439-95-4	1	mg/L	22	29	21	1	2
Sodium	7440-23-5	1	mg/L	200	214	107	8	8
Potassium	7440-09-7	1	mg/L	7	4	3	<1	<1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	2.66	20.2	2.31	0.14	0.89
Antimony	7440-36-0	0.001	mg/L	<0.001	0.017	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.003	0.025	0.004	<0.001	0.006
Cadmium	7440-43-9	0.0001	mg/L	0.0060	0.0096	0.0025	0.0004	0.0005
Chromium	7440-47-3	0.001	mg/L	0.003	0.015	0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.051	0.167	0.028	0.006	0.012
Cobalt	7440-48-4	0.001	mg/L	0.366	0.496	0.171	0.022	0.035
Nickel	7440-02-0	0.001	mg/L	0.613	0.796	0.224	0.042	0.062
Lead	7439-92-1	0.001	mg/L	<0.001	0.150	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	0.869	1.76	0.335	0.054	0.077
Manganese	7439-96-5	0.001	mg/L	4.38	5.24	6.64	0.235	0.418
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	<0.01	0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01



Analytical Results

Sub-Matrix: **LEACHATE**
 (Matrix: **WATER**)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[19-Mar-2015]	[19-Mar-2015]	[19-Mar-2015]	[19-Mar-2015]	[19-Mar-2015]
Compound	CAS Number	LOR	Unit	EB1515129-001	EB1515129-002	EB1515129-003	EB1515129-004	EB1515129-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	<0.05	0.13	<0.05	<0.05	<0.05



ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1517151	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Carsten Emrich
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: carsten.emrich@alsenviro.com
Telephone	: +61 07 3344 1222	Telephone	: +61 7 3243 7123
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 Yandan Straits	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 21-Apr-2015 16:30
C-O-C number	: ----	Date Analysis Commenced	: 22-Apr-2015
Sampler	: MANDIE MATHESON	Issue Date	: 27-Apr-2015 14:46
Site	: ----		
Quote number	: ----	No. of samples received	: 5
		No. of samples analysed	: 5

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



WORLD RECOGNISED
ACCREDITATION

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

Kim McCabe

Senior Inorganic Chemist

Brisbane Inorganics



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.



Analytical Results

Sub-Matrix: LEACHATE
 (Matrix: WATER)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[21-Apr-2015]	[21-Apr-2015]	[21-Apr-2015]	[21-Apr-2015]	[21-Apr-2015]
Compound	CAS Number	LOR	Unit	EB1517151-001	EB1517151-002	EB1517151-003	EB1517151-004	EB1517151-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	4.30	3.75	4.56	4.74	4.45
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	3040	4200	504	121	166
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L	<1	<1	<1	<1	<1
Total Alkalinity as CaCO ₃	----	1	mg/L	<1	<1	<1	<1	<1
ED038A: Acidity								
Acidity as CaCO ₃	----	1	mg/L	100	418	28	14	33
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA								
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L	1100	2060	139	43	60
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	425	447	54	3	4
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	172	406	17	11	13
Magnesium	7439-95-4	1	mg/L	52	67	10	<1	2
Sodium	7440-23-5	1	mg/L	354	376	41	4	5
Potassium	7440-09-7	1	mg/L	14	6	1	<1	<1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	7.53	59.0	0.56	0.09	0.47
Antimony	7440-36-0	0.001	mg/L	0.003	0.035	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.006	0.055	0.002	<0.001	0.004
Cadmium	7440-43-9	0.0001	mg/L	0.0120	0.0176	0.0008	0.0002	0.0003
Chromium	7440-47-3	0.001	mg/L	0.007	0.036	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.091	0.317	0.010	0.004	0.006
Cobalt	7440-48-4	0.001	mg/L	0.729	0.970	0.066	0.012	0.020
Nickel	7440-02-0	0.001	mg/L	1.31	1.71	0.087	0.027	0.038
Lead	7439-92-1	0.001	mg/L	<0.001	0.031	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	1.50	3.00	0.116	0.032	0.047
Manganese	7439-96-5	0.001	mg/L	9.77	11.1	3.19	0.135	0.250
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L	0.01	0.04	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01



Analytical Results

Sub-Matrix: **LEACHATE**
 (Matrix: **WATER**)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[21-Apr-2015]	[21-Apr-2015]	[21-Apr-2015]	[21-Apr-2015]	[21-Apr-2015]
Compound	CAS Number	LOR	Unit	EB1517151-001	EB1517151-002	EB1517151-003	EB1517151-004	EB1517151-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	0.17	0.23	<0.05	<0.05	<0.05



Environmental

CERTIFICATE OF ANALYSIS

Work Order	: EB1519626	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Carsten Emrich
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: carsten.emrich@alsenviro.com
Telephone	: +61 07 3344 1222	Telephone	: +61 7 3243 7123
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 Yandan Straits	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 26-May-2015 14:45
C-O-C number	: ----	Date Analysis Commenced	: 27-May-2015
Sampler	: VERONICA CANALES	Issue Date	: 01-Jun-2015 14:39
Site	: ----		
Quote number	: ----	No. of samples received	: 5
		No. of samples analysed	: 5

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



WORLD RECOGNISED
ACCREDITATION

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

Kim McCabe

Senior Inorganic Chemist

Brisbane Inorganics



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.



Analytical Results

Sub-Matrix: LEACHATE
 (Matrix: WATER)

Client sample ID

Client sampling date / time				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
[19-May-2015]				[19-May-2015]	[26-May-2015]	[19-May-2015]	[19-May-2015]	[19-May-2015]
Compound	CAS Number	LOR	Unit	EB1519626-001	EB1519626-002	EB1519626-003	EB1519626-004	EB1519626-005
Result				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	4.13	3.67	4.09	4.72	3.67
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	4530	6840	2900	184	3340
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L	<1	<1	<1	<1	<1
Total Alkalinity as CaCO ₃	----	1	mg/L	<1	<1	<1	<1	<1
ED038A: Acidity								
Acidity as CaCO ₃	----	1	mg/L	187	790	137	19	261
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA								
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L	1880	3820	1160	72	2030
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	642	763	418	7	242
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	188	722	82	129	356
Magnesium	7439-95-4	1	mg/L	46	106	45	9	30
Sodium	7440-23-5	1	mg/L	368	725	171	<1	143
Potassium	7440-09-7	1	mg/L	11	11	3	2	2
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	7.06	93.0	2.99	<0.01	18.1
Antimony	7440-36-0	0.001	mg/L	0.003	0.064	<0.001	0.001	0.002
Arsenic	7440-38-2	0.001	mg/L	0.004	0.093	0.006	0.005	0.048
Cadmium	7440-43-9	0.0001	mg/L	0.0130	0.0349	0.0032	<0.0001	0.0074
Chromium	7440-47-3	0.001	mg/L	0.006	0.064	0.002	<0.001	0.014
Copper	7440-50-8	0.001	mg/L	0.086	0.633	0.030	<0.001	0.107
Cobalt	7440-48-4	0.001	mg/L	0.794	1.87	0.292	0.001	0.429
Nickel	7440-02-0	0.001	mg/L	1.28	2.92	0.301	0.003	0.693
Lead	7439-92-1	0.001	mg/L	0.002	0.026	0.002	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	1.57	5.79	0.355	0.006	0.993
Manganese	7439-96-5	0.001	mg/L	9.60	19.2	17.3	0.069	5.04
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	0.056	<0.001
Selenium	7782-49-2	0.01	mg/L	0.01	0.06	<0.01	0.01	0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01



Analytical Results

Sub-Matrix: **LEACHATE**
 (Matrix: **WATER**)

Client sample ID

				Yandan - KLC (1A) - oxide	Yandan - KLC (2A) - sulfide	Yandan - KLC (3A) - mixed tails	Yandan - KLC (1B) - oxide	Yandan - KLC (2B) - sulfide
Client sampling date / time				[19-May-2015]	[26-May-2015]	[19-May-2015]	[19-May-2015]	[19-May-2015]
Compound	CAS Number	LOR	Unit	EB1519626-001	EB1519626-002	EB1519626-003	EB1519626-004	EB1519626-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	<0.05	0.37	0.06	<0.05	0.15

CERTIFICATE OF ANALYSIS

Work Order	: EB1521030	Page	: 1 of 4
Client	: RGS ENVIRONMENTAL PTY LTD	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Carsten Emrich
Address	: PO Box 3091	Address	: 2 Byth Street Stafford QLD Australia 4053
	SUNNYBANK SOUTH QLD, AUSTRALIA 4109		
E-mail	: alan@rgsenv.com	E-mail	: carsten.emrich@alsenviro.com
Telephone	: +61 07 3344 1222	Telephone	: +61 7 3243 7123
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201434 Yandan Straits	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 16-Jun-2015 15:40
C-O-C number	: ----	Date Analysis Commenced	: 17-Jun-2015
Sampler	: VERONICA CANALES	Issue Date	: 23-Jun-2015 14:11
Site	: ----		
Quote number	: ----	No. of samples received	: 5
		No. of samples analysed	: 5

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.

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.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics



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.



Analytical Results

Sub-Matrix: LEACHATE (Matrix: WATER)				Client sample ID	KLC 1A	KLC 2A	KLC 3A	KLC 1B	KLC 2B
Client sampling date / time					[16-Jun-2015]	[16-Jun-2015]	[16-Jun-2015]	[16-Jun-2015]	[16-Jun-2015]
Compound	CAS Number	LOR	Unit		EB1521030-001	EB1521030-002	EB1521030-003	EB1521030-004	EB1521030-005
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		4.15	3.60	4.10	4.76	3.59
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		2900	5350	2400	144	3980
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO ₃	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/L		<1	<1	<1	<1	<1
Total Alkalinity as CaCO ₃	----	1	mg/L		<1	<1	<1	<1	<1
ED038A: Acidity									
Acidity as CaCO ₃	----	1	mg/L		18	154	15	2	90
ED041G: Sulfate (Turbidimetric) as SO₄ 2- by DA									
Sulfate as SO ₄ - Turbidimetric	14808-79-8	1	mg/L		922	2500	674	50	2060
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		372	519	311	4	309
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		183	520	132	8	526
Magnesium	7439-95-4	1	mg/L		40	78	56	<1	62
Sodium	7440-23-5	1	mg/L		340	528	244	6	294
Potassium	7440-09-7	1	mg/L		11	8	5	<1	4
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		5.59	69.4	4.84	0.10	35.1
Antimony	7440-36-0	0.001	mg/L		0.002	0.037	<0.001	<0.001	0.004
Arsenic	7440-38-2	0.001	mg/L		0.006	0.087	0.011	<0.001	0.147
Cadmium	7440-43-9	0.0001	mg/L		0.0116	0.0266	0.0048	0.0002	0.0160
Chromium	7440-47-3	0.001	mg/L		0.005	0.047	0.003	<0.001	0.027
Copper	7440-50-8	0.001	mg/L		0.064	0.453	0.046	0.003	0.180
Cobalt	7440-48-4	0.001	mg/L		0.691	1.36	0.412	0.016	0.823
Nickel	7440-02-0	0.001	mg/L		1.10	2.08	0.434	0.030	1.27
Lead	7439-92-1	0.001	mg/L		<0.001	0.006	<0.001	<0.001	0.003
Zinc	7440-66-6	0.005	mg/L		1.35	3.90	0.558	0.040	1.98
Manganese	7439-96-5	0.001	mg/L		8.19	14.0	22.2	0.165	10.2
Molybdenum	7439-98-7	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L		<0.01	0.05	<0.01	<0.01	0.02
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01



Analytical Results

Sub-Matrix: **LEACHATE**
 (Matrix: **WATER**)

Client sample ID

				KLC 1A	KLC 2A	KLC 3A	KLC 1B	KLC 2B
Client sampling date / time				[16-Jun-2015]	[16-Jun-2015]	[16-Jun-2015]	[16-Jun-2015]	[16-Jun-2015]
Compound	CAS Number	LOR	Unit	EB1521030-001	EB1521030-002	EB1521030-003	EB1521030-004	EB1521030-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	<0.05	0.30	<0.05	<0.05	0.56



**LEADERS IN MINING
GEOCHEMISTRY**

01 August 2021
Project Number 2021068

From: RGS Environmental Consultants Pty Ltd
To: AARC Environmental Solutions Pty Ltd
Attention: Kate Jeffrey – Environmental Scientist
Content: Yandan Tailings Storage Facility: Technical Memorandum

1.0 Introduction

RGS Environmental Consultants Pty Ltd (RGS) has been requested by AARC Environmental Solutions Pty Ltd (AARC) on behalf of GBM Resources Limited (GBM) to provide a response to specific information gaps cited by the Regulator regarding the 'risk level' associated with Cell B of the Tailings Storage Facility (TSF) at Yandan Gold Mine. It is understood that GBM has applied to the Department of Environment and Science (DES) for an Estimated Rehabilitation Cost (ERC) decision for the environmental authority (EA EPML00771913 – Yandan Gold Mine and that DES has subsequently completed an initial assessment and determined the application is invalid¹.

RGS has previously completed a geochemical assessment of oxide and sulfide tailing materials stored at TSF Cell B and in order to provide a qualified response, has relied upon information and findings associated with the RGS technical report² as well as the findings of an independent review of the risk level and appropriate capping strategy for TSF Cell B³.

This technical memorandum provides a response to specific information gaps cited by DES regarding the 'risk level' associated with the Tailings Storage Facility (TSF) at Yandan Gold Mine shown in **Figure 1**.

2.0 Information Gaps

The specific information gaps cited by DES which RGS has been requested to address are:

1. *The combined volume of waste material was provided for both TSF Cell A and B, however individual volumes are required to assist in consideration of whether representative sampling was undertaken in accordance with the recognised guideline Queensland Department of Mines and Energy (1995) Assessment and management of acid drainage - Technical guidelines for the environmental management of exploration and mining in Queensland (DME 1995 Guideline).*
2. *The supporting document indicates that the proposal for a low-risk capping methodology is supported by a report prepared by RGS Environmental Pty Ltd (RGS Report), which provides a geochemical assessment of the tailings based off 85 samples collected to a maximum depth of 600mm in Cell B. The embankments are known to be 4.5m on the Eastern Perimeter wall and 1.0m at the Northern Perimeter Embankment, indicating that the 600mm samples were unlikely to intercept the deepest area of the TSF. the department considers that the sampling effort (a total of 85 samples on Cell B) is not considered to have been undertaken in accordance with the recognised DME 1995 Guideline and therefore the assumptions made by the applicant cannot be relied upon.*
3. *The RGS Report provides several recommendations for TSF Cell B in Section 9.0 of the document, notably the advice to the EA holder to verify the depth of oxidation in the tailings profile by undertaking in-situ core sampling of the tailings through the tailings profile in the deepest area of the TSF. Please provide an assessment and demonstrate consideration and implementation of the recommendations in Section 9 of the RGS Report.*

¹ DES (2021). Invalid Application Notice. Department of Environment and Science. 23 June.

² RGS (2015). Yandan Oxide and Sulfide Tailings Assessment. Report prepared by RGS Environmental Pty Ltd for Straits Gold Pty Ltd. 31 July.

³ Williams (2021). Independent Desktop Review of Risk Level and Appropriate Capping Strategy for TSF Cell B at Yandan Gold Mine. 2 June.



Figure 1: Yandan TSF (Source: Williams, 2021)

3.0 RGS Responses

The RGS responses to specific information gaps detailed in Section 2.0 are as follows:

1. The combined amount of tailings materials stored at Cell A and Cell B at the TSF was described (at closure) in the 2005 Plan of Operations⁴ as 7,500,000 tonnes (t). The original Environmental Management Overview Strategy (EMOS⁵) predicted that 2,111,850 t of tailings would report to Cell A. Given an *in situ* bulk density of 1.38 t/m³, this equates to approximately 2,900,000 t of tailings in Cell A and approximately 4,600,000 t of tailings in Cell B.

The Draft Technical Guidelines for Assessment and Management of Acid Drainage in Queensland (DME 1995 Guidelines)⁶, whilst useful, is currently not a discoverable document on the DES website. Notwithstanding, the DME 1995 Guidelines provide a sampling rate of 80 samples per 10,000,000 t of waste material. Given that the number of tailings samples from Cell B provided to RGS for geochemical assay was 85 and the amount of tailings materials in Cell B is approximately 4,600,000 t the number of samples is greater than required by the cited guidelines. The relevant sampling locations are provided in **Figure 2**.

⁴ Straits (2005). *Plan of Operations Yandan Gold Mine*. Straits Exploration (Australia) Pty Ltd. 1 November

⁵ Ross Mining N.I. (1992). *Yandan Gold Deposit Environmental Overview Strategy*. December.

⁶ DME 1995. *Draft Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*. Assessment and Management of Acid Drainage. Department of Minerals and Energy, Brisbane, Queensland.

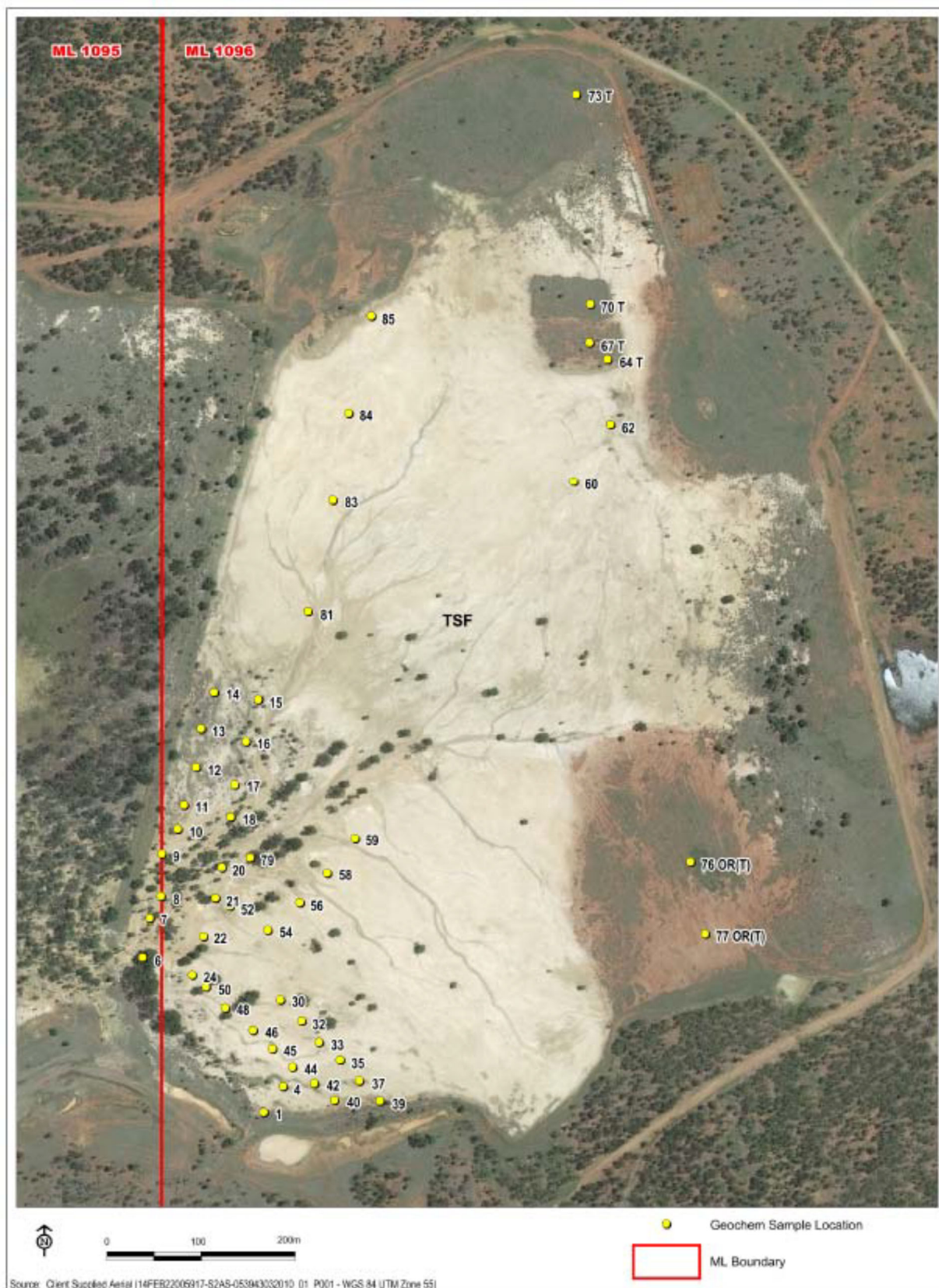


Figure 2: Sampling Locations at TSF Cell B (Source: RGS, 2015)

2. The low risk capping methodology for TSF Cell B is supported by RGS on the basis of the findings of the geochemistry assessment² and the independent review of the risk level and appropriate capping strategy³. The geochemistry assessment found that since placement, the sulfide minerals (e.g., pyrite) in the tailings, to at least 600 mm depth, have oxidized and that no residual sulfide minerals remain. Secondary sulfide minerals (e.g., jarosite) are likely to be controlling solute chemistry and capillary rise of solutes (e.g., acidity, salts and metals) into the trial soil cover is not apparent.

The original EMOS⁵ estimated that sulfide ore is was likely to represent less than 15 % of the total mined ore on site. Tailings from the oxide and sulfide ore were generally placed within 'layers', with sulfide ore only mined in the latter stages of the pit. As such deposition of sulfide ore is limited to the upper portion of TSF Cell B, with this underlain in most areas by oxide tailings.

On the basis of the geochemical nature of the tailings materials, RGS suggested that the cover design objectives at TSF Cell B should be to stop wind blown movement of tailings, provide a growth medium that is capable of supporting vegetation and provide a stable soil surface that may include coarse rock mulch to retain moisture from small rain events and protect the surface from erosion during large rainfall events. The use of a capillary break in the cover system is not required and is fundamentally questionable due to the potential for long term failure through differential settlement into the tailings mass and also migration of fines from the cover system into the capillary layer.

RGS advocated mild grading of the tailings surface to encourage rainwater to flow in a controlled direction, compaction of the tailings surface to further decrease permeability and placement of a 0.5 to 1.0 m deep spoil cover over the tailings with a nominal 0.5 m depth in drier areas and a 1.0 m depth in wetter areas.

RGS went on to recommend that a forward test work program be completed on the Cell B tailings materials including field permeability measurements; specific gravity, bulk density, porosity and initial soil moisture on collected samples; in situ push tube core tailings sampling and geochemical testing through the tailings profile in the deepest area of the TSF; event based water volume/quality monitoring; and investigation of the effect of addition of alkaline material.

3. The RGS 2015 report and recommendations acknowledge the fact that the tailings samples provided to RGS for geochemical assay down to 600 mm depth do not intercept the deepest area of the TSF. **Figure 3** shows the depth of tailings within TSF Cell B and illustrates that the tailings depths across the facility range from approximately 1 to 10 m.

Whilst the deeper tailings may contain some residual sulfide minerals, it is unlikely that the sulfide minerals content would be more variable and/or significantly higher than that of the total sulfur values found for the tailings samples collected from up to 600 mm depth (up to 0.53 %S). In addition, interaction of rainwater and runoff with these materials is unlikely given the low permeability of the near-surface tailings and is even less likely when a cover system has been placed due to its "store and release" function. It is noted that the water quality monitoring data from the TSF return water dam provided in the RGS 2015 report showed that this is likely to be the case as in 2013/2014 water quality met applied livestock drinking water quality guidelines and generally met applied freshwater aquatic ecosystem guidelines⁷.

Notwithstanding, it is understood that GBM will consider the recommendations in the RGS 2015 report with respect to additional sampling and testing and implement these, where appropriate.

⁷ ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines. (Superseed ANZECC and ARM CANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000).

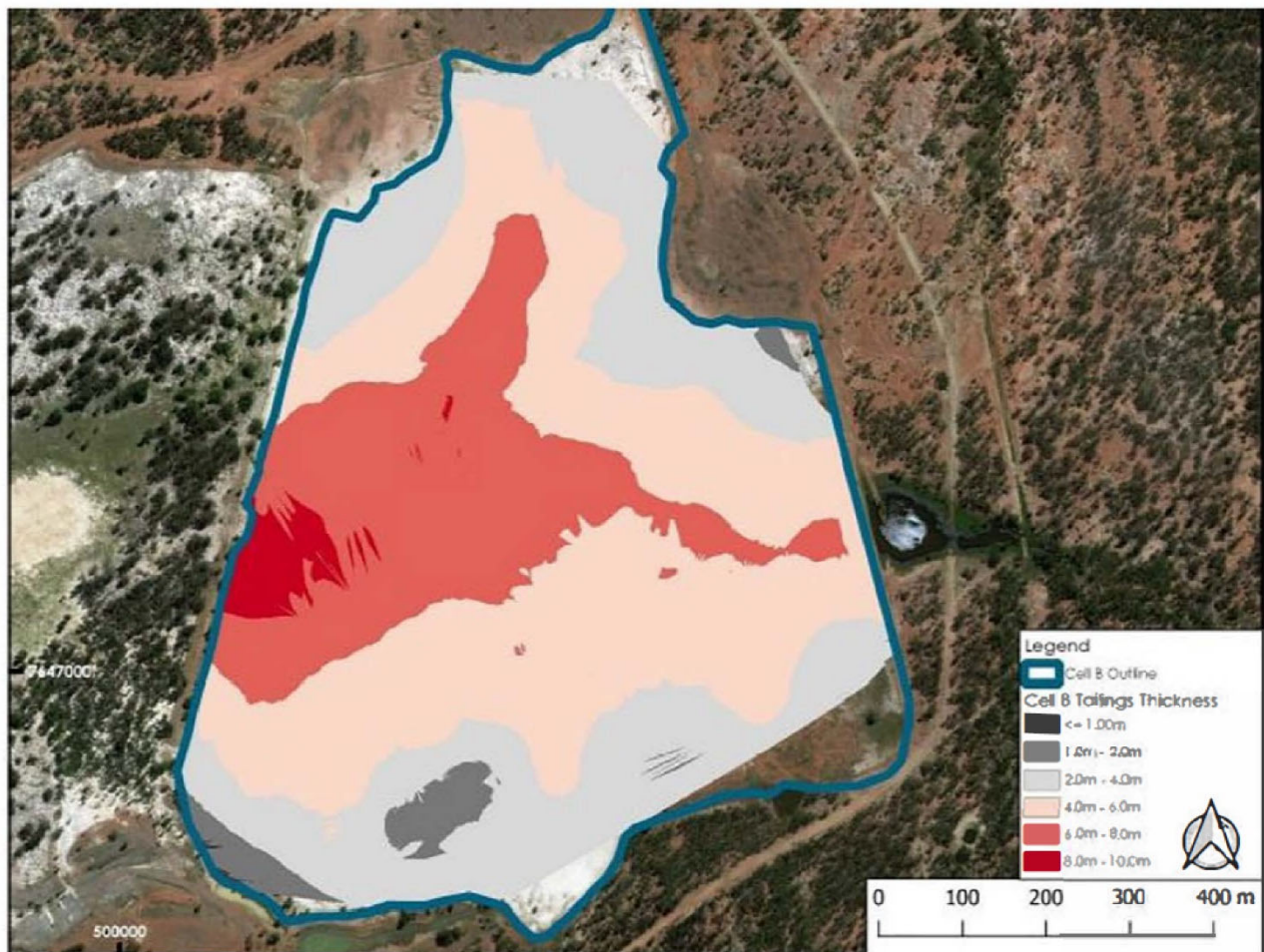


Figure 3: Depth of Tailings within TSF Cell B (Source: AARC, 2021)

4.0 Independent Review

The independent review of the risk level and appropriate capping strategy for TSF Cell B³ (Williams 2021) found that based on the available information, TSF Cell B satisfies Table 6-1 of the ERC Users Guide (2009) for a Low Risk Category and recommended a grass covered 400 to 600 mm gravelly topsoil cover system. These findings were based on the RGS 2015 Geochemistry Report results in that the sulfide minerals in TSF Cell B have completely oxidised to at least 600 mm depth, and revegetation of the trial 400 to 600 mm of gravelly topsoil placed on Cell B tailings is achieving similar success to reference sites, with similar minor erosion over a seven year period. The available information therefore does not support a High Risk Category as considered by DES.

In line with RGS, Williams (2021) went on to recommend consideration of compaction of the surface tailings to form a low permeability layer to enhance the “store and release” function of a revegetated gravelly topsoil layer on TSF Cell B. This would better hold-up moisture to be available to support revegetation, limit net percolation and seepage, and limit potential salt uptake into the cover.

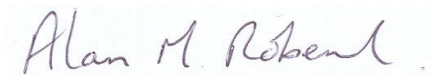
A capillary break coupled to a thicker cover system was not advocated by the author and was expected to be counter productive in that net percolation into underlying tailings could actually increase with deep drainage passing beyond the rooting zone of the proposed grass cover.

5.0 Closing

Please contact Alan Robertson on 07 3344 1222 (office) or 0431 620 623 (mobile) if you require further information.

Yours sincerely,

RGS ENVIRONMENTAL CONSULTANTS PTY LTD

A handwritten signature in blue ink that reads 'Alan M. Robertson'.

Dr. Alan M. Robertson
Principal Geochemist/Director

RGGS



MINE WASTE AND
WATER MANAGEMENT

Date issued: 28 July 2022
Document Number: 01
Project Number 2022017
Revision Number: Revision 1

From: RGS Environmental Consultants Pty Ltd
 3/30 Lensworth Street,
 Coopers Plains QLD 4108

To: GBM Resources Ltd; Straits Gold Pty Ltd

Project Name: Yandan Tailings Technical Memorandum

Attention: Tom Cooney; GBM Resources Ltd

Content: Discussion of tailings assessment results

1 Introduction

RGS Environmental Consultants Pty Ltd (RGS) was commissioned by GBM Resources Ltd (GBM) to complete a tailings assessment at the non-operational Yandan Gold Project (the Project). The assessment was in response to an information request GBM received from the Department of Environment and Science (DES). This technical memorandum presents the results of in-situ, geochemical, and physical analyses undertaken.

1.1 Background

GBM has applied to DES for an Estimated Rehabilitation Cost (ERC) decision for the Environmental Authority (EA EPML00771913) for the Project. The current holder of Environmental Authority is Straits Gold Pty Ltd.

In August 2021, RGS completed a Technical Memorandum¹ which responded to information gaps cited by DES regarding the 'risk level' associated with the Project's TSF, based on the Tailings Assessment Report². Both RGS documents contained recommendations for a forward works program of field trials and additional geochemical analysis of tailings materials within the Project TSF.

DES has requested that the forward works previously recommended be actioned as follows:

"A number of recommendations within the RGS Environmental Pty Ltd (RGS) 2015 are made; however these points do not appear to have been actioned. Please provide supporting information relating to how the recommendations made have been considered and actioned, and the results to each relevant point (refer to Page 34 of the RGS) 2015). It is noted that information is not required on the recommendation regarding geochemical characterisation below 600mm of the Tailings Storage Facility (TSF) Cell B."

This Technical Memorandum details the outcomes of the actioned RGS recommendations.

1.2 Project location and layout

The Project is located in the Drummond Basin, Queensland, approximately 230 kms west of Mackay, 230 kms south of Townsville, and 40 km west of Mount Coolon (**Figure 1-1**). The Project comprises a mine area; two open pits (the first comprising a pit lake, with minimal water in the second pit), one backfilled mine pit, a non-operational heap leach stockpile, an infrastructure area and a tailings storage facility (TSF) divided into two cells (Cell A and Cell B). The TSF has an area of approximately 109.8 ha, with Cell A covering 41.6 ha and Cell B covering 68.3 ha.

¹ RGS Environmental Consultants Pty Ltd (2021). Yandan Tailings Storage Facility: Technical Memorandum.

² RGS Environmental Pty Ltd (2015). Yandan Oxide and Sulfide Tailings Assessment. Technical Memorandum.

In order to minimise the potential drying time and maximise the rate of cyanide degradation, tailings were deposited sub-aerially into the cells from the perimeter of the TSF³. Once a beach was established adjacent to the central wall of the TSF deposition was moved into the other cell of the TSF. Tailings deposition was alternated between the two cells until approximately 4.0 Mm³ of tailings were deposited in Cell A and 6.3 Mm³ of tailings were deposited in Cell B⁴.

Cell A was rehabilitated between 1999-2000, with a selection of grass and tree species directly planted into the tailings surface following the results from a number of rehabilitation trials. Cell B has not been rehabilitated, although a number of cover system trials have been established on the surface of Cell B to inform the closure strategy for the facility.

Vegetation cover is more developed on TSF Cell A relative to Cell B, with a larger number of trees and more grass cover established on Cell A (**Figure 1-2**). Trees are well established (larger than saplings) on both TSF Cell A and Cell B.

The TSF has been fenced off from the surrounding area which is currently grazed by livestock. Vegetation outside of the TSF varies from wooded scrub south-east of the TSF to open grassland comprising low to knee-high tussocks of grass and isolated trees and shrubs (**Figure 1-3**).

1.3 Objectives

The objective of the scope of work was to undertake the works previously recommended by RGS and subsequently requested by DES. The recommendations included permeability measurements at nine locations within TSF Cell B, three locations within TSF Cell A, and three locations outside of the TSF, geochemical analyses, and physical analyses.

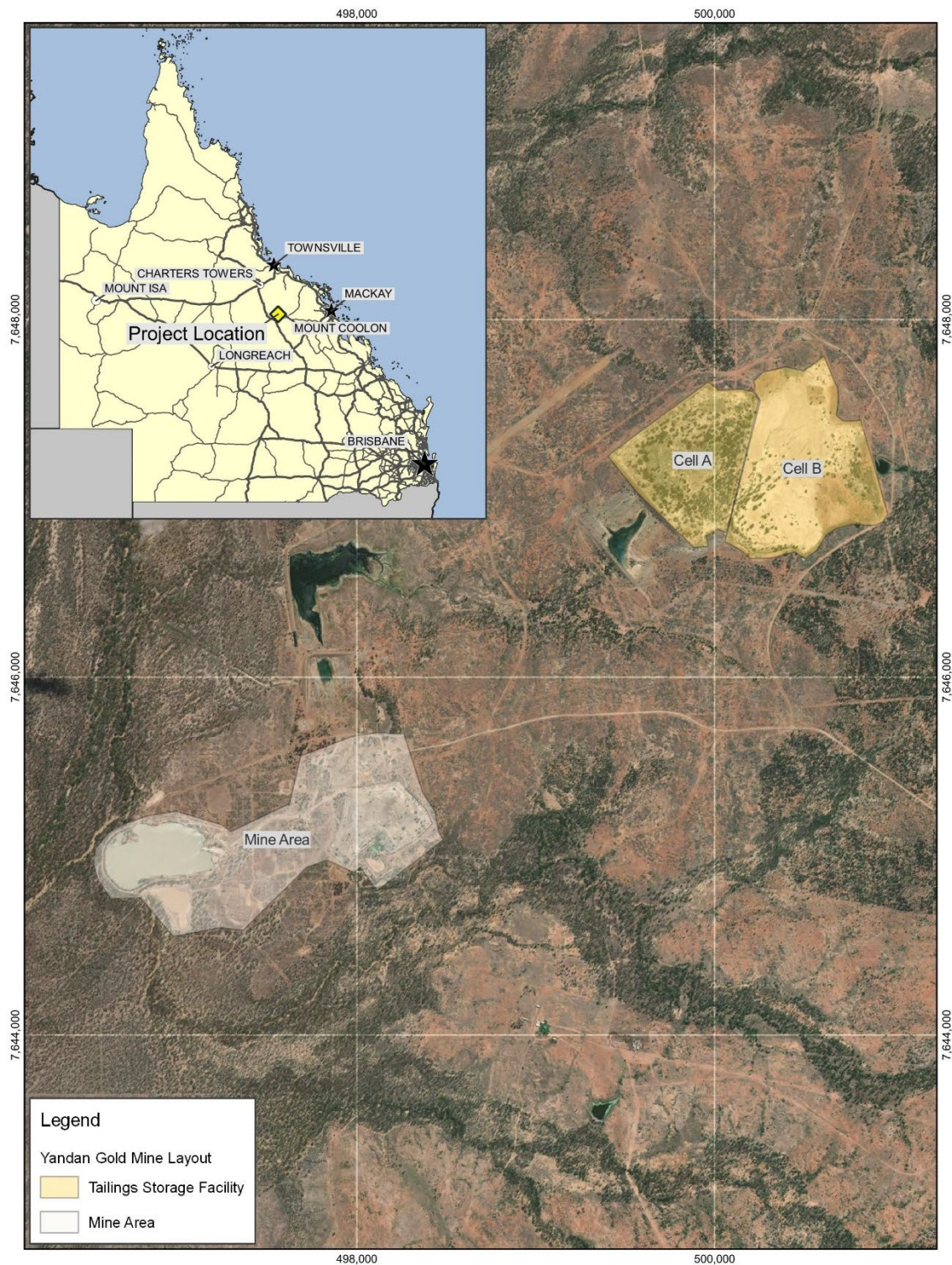
1.4 Scope of work

The following scope of work was developed to address the above objective and recommendations:

- A site visit to undertake in-situ permeability measurements and collect surface material samples,
- A geochemical analysis program comprising static and kinetic testing on selected individual and/or composite surface material samples, and
- A physical analysis program comprising specific gravity, soil moisture, bulk density, and porosity on surface material samples.

³ Ross Mining N.E. (1992). Yandan Gold Deposit Environmental Overview Strategy. December.

⁴ Straits (2005). Plan of Operations Yandan Gold Mine. Straits Exploration (Australia) Pty Ltd. 1 November.



Source: ESRI Satellite

	Scale 1:30,000 Datum: GDA94 / MGA zone 55	Yandan Tailings Technical Memorandum		400 0 400 800 m 	
	TSF Sample Points Updated.qgz; Project Location	Project location and layout		Figure: 1-1	
				Job Number: 2022017 27/07/2022	

Figure 1-1: Project location and layout

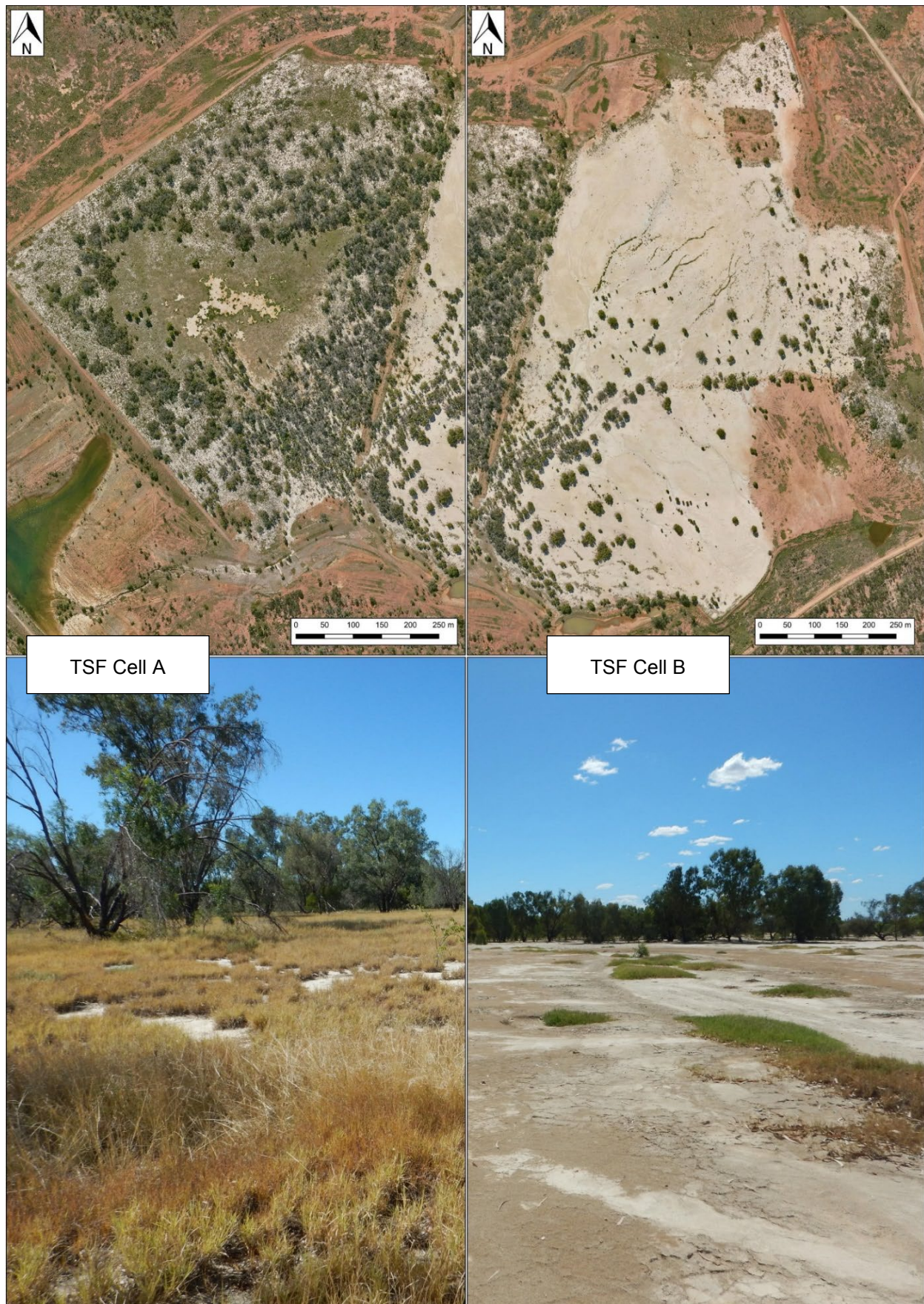


Figure 1-2: Examples of the vegetation cover on the Project TSF



Figure 1-3: Vegetation in the areas surrounding the Project's TSF

2 Review of existing information

2.1 RGS (2015)² – Yandan Oxide and Sulfide Tailings Assessment

RGS was commissioned by Straits Gold Pty Ltd to complete a geochemical assessment of tailings from Cell B of the Project's TSF. The purpose of the testing program was to undertake static and kinetic testing on oxide and sulfide tailings samples to quantify the rate of acid production/consumption and the rate that major, minor and trace elements may be leached from free draining samples under laboratory conditions.

The RGS scope of work comprised:

- Coordination of static geochemical characterisation tests for 85 tailings samples.
- Completion of kinetic leach column geochemical testing on both oxide and sulfide tailings.
- Tabulation and interpretation of static and kinetic geochemical test data.
- Provision of a letter report, which provides the geochemical test results and the RGS interpretation of the results; and
- Provision of recommendations for the management of mine materials with respect to potential AMD.

The report concluded that:

- In the tailings, to at least 0.6 m depth, essentially no residual sulfide minerals are present;
 - Metal/metalloid concentrations in solids are relatively low and/or are sparingly soluble under expected field conditions;
 - The measured acidity in leachate from tailings is dominated by acidity from metals ions as opposed to H^+ in sulfuric acid from sulfide oxidation;
 - Secondary sulfide minerals (e.g., jarosite) are likely to be controlling solute chemistry; and
- The soil has not been adversely impacted by the accumulation of tailings through wind borne erosion processes, nor has there been an accumulation of soluble elements from the tailings into the trial soil cover through capillary action.

The RGS report made the following recommendations:

- Field permeability measurements be undertaken;
- Event based water monitoring be undertaken; and
- Addition of fine agricultural limestone ('Aglime') ($CaCO_3$) to the surface of the oxide and sulfide tailings samples to ascertain if:
 - the addition of alkalinity to the mildly acidic tailings changes the rate that metals (e.g. Mn) or metalloids (e.g. As) are released from the tailings; and
 - leachate chemistry is in fact dominated by secondary minerals such as jarosite that sorb metals and acid below pH 4 but can also release them if the pH increases.

2.2 RGS (2021) – Yandan Tailings Storage Facility: Technical Memorandum

RGS was requested by AARC Environmental Solutions Pty Ltd (AARC) on behalf of GBM to provide a response to specific information gaps cited by DES regarding the 'risk level' associated with Cell B of the TSF at the Project. This technical memorandum provided a response to the information gaps cited by DES regarding the 'risk level' associated with the TSF at the Project.

The information gaps are summarised as:

- The individual volumes of tailings contained in TSF Cells A and B were not stated;
- The depth of collection of tailings samples did not sufficiently meet relevant guidelines to be considered representative; and
- Recommendations made previously by RGS were not considered for implementation.

In response RGS provided:

- Calculated tailings volumes for each TSF Cell;

- A justification of the number of samples collected based on the volume of TSF Cell B;
- A description of the basis for recommending a low-risk, non-capillary break cover type; and
- A justification of the sampling depths used based on the range of depths of the TSF Cell B, the homogeneity of the tailings, the observed permeability of the samples, and the water quality monitoring data from the TSF return water dam for 2013/2014.

The 2021 RGS technical memorandum also described the findings and recommendations of an independent review of a previously proposed capillary break type cover system for TSF Cell B⁵.

2.3 Williams (2021) – Independent Desktop Review of Risk Level and Appropriate Capping Strategy for TSF Cell B

The independent review of the risk level and appropriate capping strategy for TSF Cell B⁶ found that based on the available information, TSF Cell B satisfied Table 6-1 of the ERC Users Guide (2019)⁶ for a Low Risk Category and recommended a grass covered 400 to 600 mm gravelly topsoil cover system. Table 6-1 and Table 6-2 of the ERC User's Guide (2019) are reproduced at **Attachment E** of the current RGS Technical Memorandum (i.e., herein).

The findings by Williams⁶ were based on a review of available information including:

- Monitoring of ongoing capping trials on Cell B from 2014 to 2021, including an AARC Yandan Gold Mine Rehabilitation Monitoring Report, dated 22 January 2021;
- Report by O'Kane Consultants Pty Ltd (O'Kane) on Yandan Gold Mine TSF Cell B Conceptual Cover System Design Update, dated 1 December 2019; and
- the RGS 2015 Oxide and Sulfide Tailings Geochemistry Report.

The Williams independent review relied upon the RGS 2015 tailings geochemistry results which found that the sulfide minerals in TSF Cell B have completely oxidised to a depth of at least 600 mm depth, and the fact that revegetation of the trial 400 to 600 mm of gravelly topsoil placed on Cell B tailings is achieving similar success to reference sites, with similar minor erosion over a seven year period. The author concluded that the available information therefore does not support a High Risk Category as considered by DES.

In line with a previous 2015 RGS recommendation, Williams (2021) went on to recommend consideration of compaction of the surface tailings to form a low permeability layer to enhance the "store and release" function of a revegetated gravelly topsoil layer on TSF Cell B. This was predicted to better hold-up moisture to then be available to support revegetation, limit net percolation and seepage, and limit potential salt uptake into the cover system.

A capillary break coupled to a thicker cover system was not advocated by the author and was expected to be counter-productive in that net percolation into underlying tailings could actually increase with deep drainage passing beyond the rooting zone of the proposed grass cover and interacting with underlying tailings.

⁵ Williams (2021). *Independent Desktop Review of Risk Level and Appropriate Capping Strategy for TSF Cell B at Yandan Gold Mine*. 2 June.

⁶ DES. (2019). User Guide for Estimated Rehabilitation Cost Calculator for Mining. Operational Support, Department of Environment and Science, State of Queensland. (https://environment.des.qld.gov.au/data/assets/pdf_file/0029/89615/rs-gl-user-guide-erc-calculator-mining.pdf).

3 Sampling and Testing Methodology

The site visit was completed by Peter Long and Alexandra Kiss of RGS from 28 to 31 March 2022. During the site visit, in-situ saturated hydraulic conductivity measurements were completed and 15 surface samples were collected by RGS staff for subsequent laboratory analysis (**Table 3-1**). The samples were initially sent to the RGS in-house laboratory for registration before being sub-sampled and dispatched to the National Association of Testing Authorities (NATA) accredited ALS Environmental Laboratory (ALS) and Trilab Pty Ltd (Trilab) for further analyses.

The 15 samples collected during the site visit are described in **Table 3-1** and comprised 3 soil and 12 tailing samples.

Table 3-1: Surface samples collected for analysis from the Project

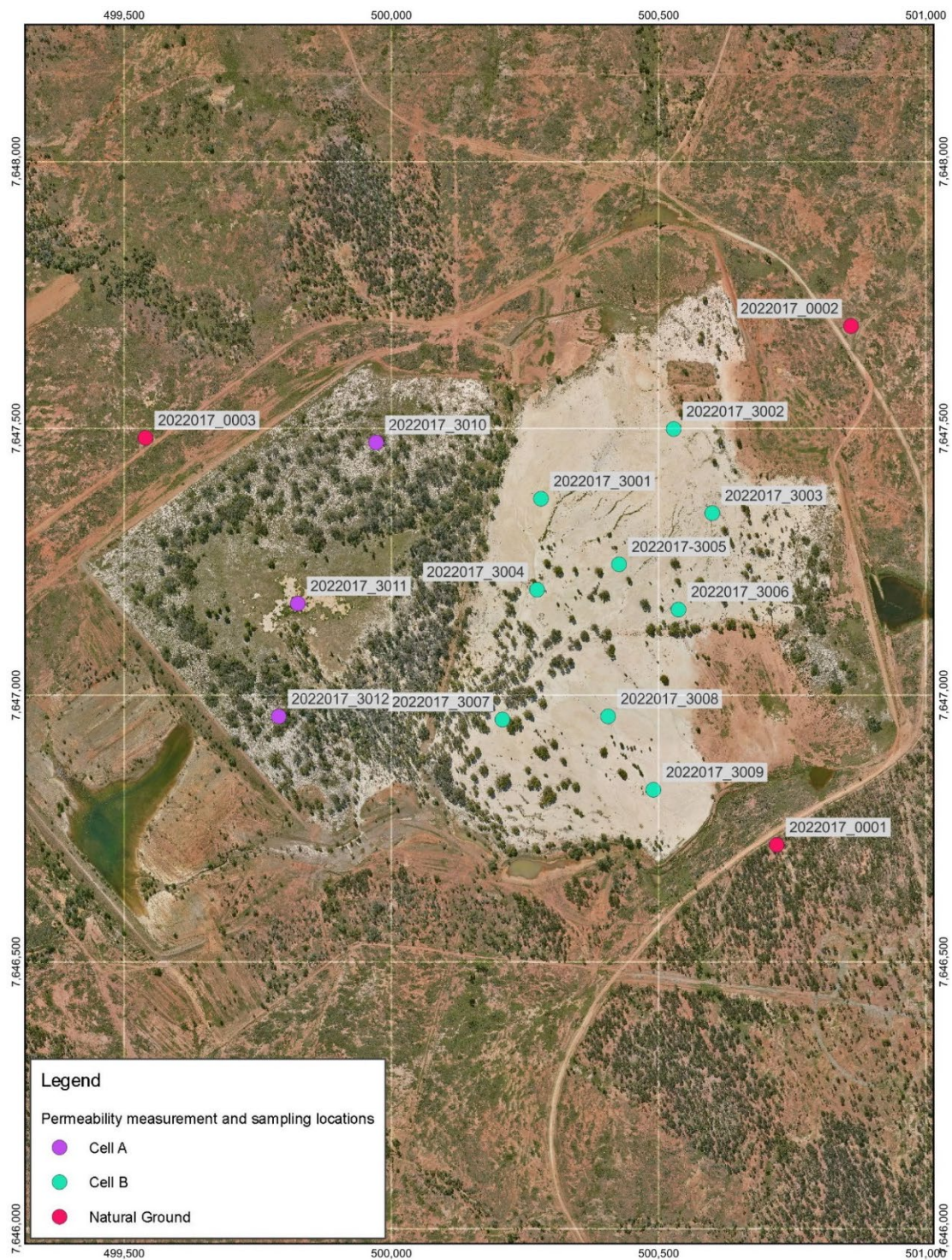
Sample Number	RGS Sample ID	Sample Material	Sample Location
Sample 1	2022017_0001	Soil	Natural Ground
Sample 2	2022017_0002	Soil	Natural Ground
Sample 3	2022017_0003	Soil	Natural Ground
Sample 4	2022017_3001	Tailings	TSF Cell B
Sample 5	2022017_3002	Tailings	TSF Cell B
Sample 6	2022017_3003	Tailings	TSF Cell B
Sample 7	2022017_3004	Tailings	TSF Cell B
Sample 8	2022017_3005	Tailings	TSF Cell B
Sample 9	2022017_3006	Tailings	TSF Cell B
Sample 10	2022017_3007	Tailings	TSF Cell B
Sample 11	2022017_3008	Tailings	TSF Cell B
Sample 12	2022017_3009	Tailings	TSF Cell B
Sample 13	2022017_3010	Tailings	TSF Cell A
Sample 14	2022017_3011	Tailings	TSF Cell A
Sample 15	2022017_3012	Tailings	TSF Cell A

3.1 In-situ saturated hydraulic conductivity measurement

In-situ saturated hydraulic conductivity (permeability) measurements were recorded at 15 locations on and around the Project TSF. The measurements were taken using a Guelph Permeameter at nine locations in TSF Cell B, three locations in TSF Cell A, and three locations outside the TSF (**Figure 3-1**).

The Guelph Permeameter is used to measure the steady-state rate of water recharge into a hole of known dimensions in unsaturated soil under a constant head of water. Once a constant rate of flow into the hole is established, the rate of flow, the diameter of the hole, and the height of the head on the water can be used to calculate the saturated hydraulic conductivity (K_{fs}) of the surface materials.

Raw results from the Guelph Permeameter are provided at **Attachment B**.



Source: GBM Resources Ltd

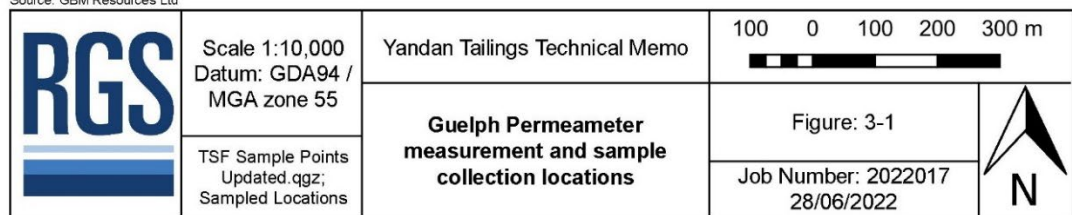


Figure 3-1: Guelph Permeameter measurement and sample collection locations

3.2 Static geochemical analysis

A series of static geochemical tests were completed by ALS on the 15 surface samples. The geochemical test program was designed to assess the degree of risk from the presence and potential oxidation of sulfides, acid generation and the presence/leaching of soluble metals/metalloids and salts.

A summary of the parameters involved in geochemical assessment of mining waste materials is provided in **Attachment A**.

An Acid Base Account test program was used to determine the acid-neutralising and acid-generating characteristics of the 15 surface sample materials. The test program included static geochemical tests for the following parameters:

- pH (1:5 weight:volume (w:v));
- Electrical Conductivity (EC) (1:5 w:v, electrometric);
- Total Sulfur (TS) (LECO Analyser); and
- Acid Neutralising Capacity (ANC) (Sobek Method).

Eleven (11) of the 15 surface samples with total sulfur content ≥ 0.1 percent sulfur (%S) were also analysed for Chromium Reducible Sulfur (Scr) (Australian Standard AS 4969.7, 2008 method).

From the total sulfur and ANC results, Maximum Potential Acidity (MPA) and Net Acid Producing Potential (NAPP) values were calculated. The sample MPA was calculated using the total sulfur or sulfide (Scr) data. The Scr test provides a more accurate representation of the MPA that could be generated from a sample material, as acid generation primarily forms from any reactive sulfide content measured by this method. NAPP values were calculated using the MPA value balanced against the ANC.

Following the Acid Base Account tests the 15 surface samples were also analysed for:

- Total major cations (Ca, Mg, Na, K, Al, Fe) (2-acid digest, ICP- AES);
- Metals/metalloids in solids (As, B, Ba, Be, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, U, V, and Zn) (2-acid digest, ICP-MS/AES);
- Titratable alkalinity and acidity (automatic titrator measured as CaCO_3 equivalent);
- Soluble major ions (Ca, Mg, Na, K, Cl, SO_4 , F) (1:5 w:v water extracts by ICP-MS/AES and PC Titrator); and
- Soluble metals/metalloids (Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, U, V, and Zn) (1:5 w:v water extracts by ICP-MS/AES).

Nine (9) of the 15 surface samples were also analysed for:

- Exchangeable cations; and
- Soil nutrients (P, N, NO_2 , NO_3 , NH_3 , and NO_x).

3.3 Physical analysis

The samples underwent the following physical analyses:

- In-situ bulk density;
- Dried bulk density; and
- Soil particle density.

The total porosity and moisture content of the samples were calculated based on the results of the above tests.

3.4 Kinetic geochemical analysis

Following the receipt and interpretation of the results of the static geochemical analyses, selected samples were combined into two representative composite samples for short term kinetic leach column (KLC) geochemical analysis (**Table 3-2**). Essentially the nine TSF Cell B tailings samples were combined into a single composite sample and the three Cell A samples were combined into a single tailings sample for KLC analysis. The two composite samples were subjected to dynamic leaching tests using deionised water as the leaching fluid at the RGS in-house laboratory and were operated under free-leaching (i.e., wetting and drying) conditions.

A total of six KLC tests were established with sample compositions shown in **Table 3-3**. Essentially the two composite tailings samples were used as 'control' samples (KLC 3 and KLC 6) with varying amounts of crushed limestone mixed with the composite samples to create the samples used in KLC 1, KLC 2; KLC 4 and KLC 5.

The composite samples have undergone KLC analysis, with four weekly leaching events conducted over four weeks. The results from these tests have been used to predict the ongoing geochemical characteristics and likely quality of pore water in the TSF surface materials and to assess the effectiveness of the addition of crushed limestone ('Aglime') to neutralise any existing acidity.

Leachate collected from the KLC test program was analysed for:

- pH and EC;
- Acidity and alkalinity [PC Titrator];
- Dissolved metals/metalloids (Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, U, V, and Zn) [ICP-AES/MS];
 - Dissolved major cations (Ca, Mg, Na and K) [ICP-AES/MS]; and
 - Dissolved major anions (Cl, F, and SO₄) [ICP-AES/MS].

Summary KLC results tables are provided in **Attachment C** and discussed in **Section 0**. The raw ALS test results for the kinetic geochemical test program are provided in **Attachment D**.

Table 3-2: Surface tailings sample composites used for KLC analysis

Composite ID	RGS Sample ID	Sample Lithology	Sample Location
TSF Cell B	2022017_3001	Tailings	TSF Cell B
TSF Cell B	2022017_3002	Tailings	TSF Cell B
TSF Cell B	2022017_3003	Tailings	TSF Cell B
TSF Cell B	2022017_3004	Tailings	TSF Cell B
TSF Cell B	2022017_3005	Tailings	TSF Cell B
TSF Cell B	2022017_3006	Tailings	TSF Cell B
TSF Cell B	2022017_3007	Tailings	TSF Cell B
TSF Cell B	2022017_3008	Tailings	TSF Cell B
TSF Cell B	2022017_3009	Tailings	TSF Cell B
TSF Cell A	2022017_3010	Tailings	TSF Cell A
TSF Cell A	2022017_3011	Tailings	TSF Cell A
TSF Cell A	2022017_3012	Tailings	TSF Cell A

Table 3-3: KLC compositions

Column	Tailings Composite	Crushed Limestone Added
KLC 1	TSF Cell B	4 g limestone/kg of sample
KLC 2	TSF Cell B	2 g limestone/kg of sample
KLC 3	TSF Cell B	No limestone added
KLC 4	TSF Cell A	4 g limestone/kg of sample
KLC 5	TSF Cell A	2 g limestone/kg of sample
KLC 6	TSF Cell A	No limestone added

4 Results

4.1 In-situ saturated hydraulic conductivity

The in-situ saturated hydraulic conductivity (K_{fs}) results for the 15 sample locations at the Project obtained using the Guelph Permeameter are provided in **Table B1 (Attachment B)**. In-situ K_{fs} results range from 0.00003 to 0.02671 cm/min (**Figure 4-1**). Soil outside the TSF has a higher rate of K_{fs} than the tailings; and tailings in TSF Cell A generally have lower rates of K_{fs} than tailings in TSF Cell B.

Overall these results indicate that the surface tailing materials in TSF Cell B are more compact than surface soils, but are generally not as compact as the surface tailings in Cell A.

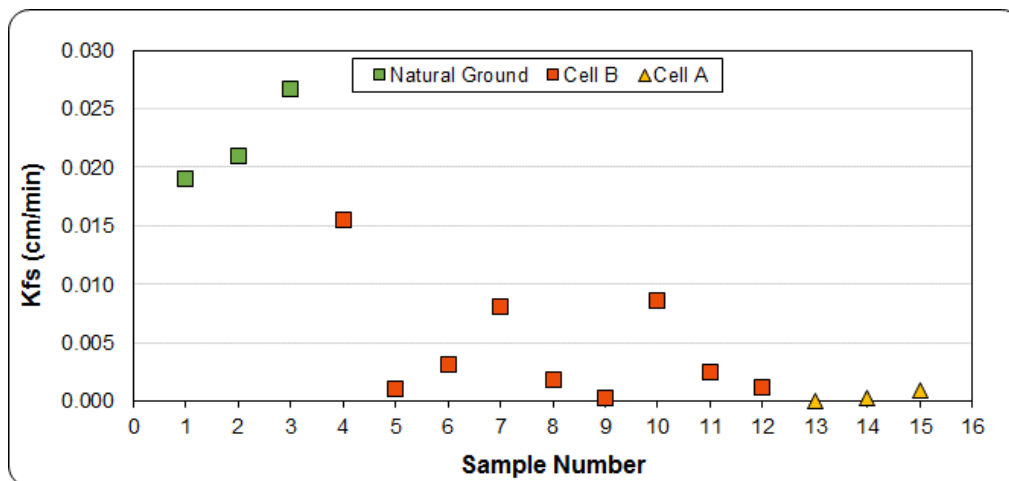


Figure 4-1: In situ saturated hydraulic conductivity results for soil and tailing

4.2 Acid Base Account

The Acid Base Account test results for the 15 surface samples from the Project are provided in **Table C1 (Attachment C)**. An explanation of the methodology used in this section, including a description of the Acid Base Account, is provided at **Section 0** and **Attachment A**. The data trends discussed in this section are presented in **Figure 4-2** to **Figure 4-7**.

4.2.1 $pH_{(1:5)}$

The $pH_{(1:5)}$ results for the 15 samples range from 3.7 to 8.5 (**Figure 4-2**) and are consistently about pH 4 for the Cell B tailings, which is most likely indicative of the presence of jarosite or alunite, for example.

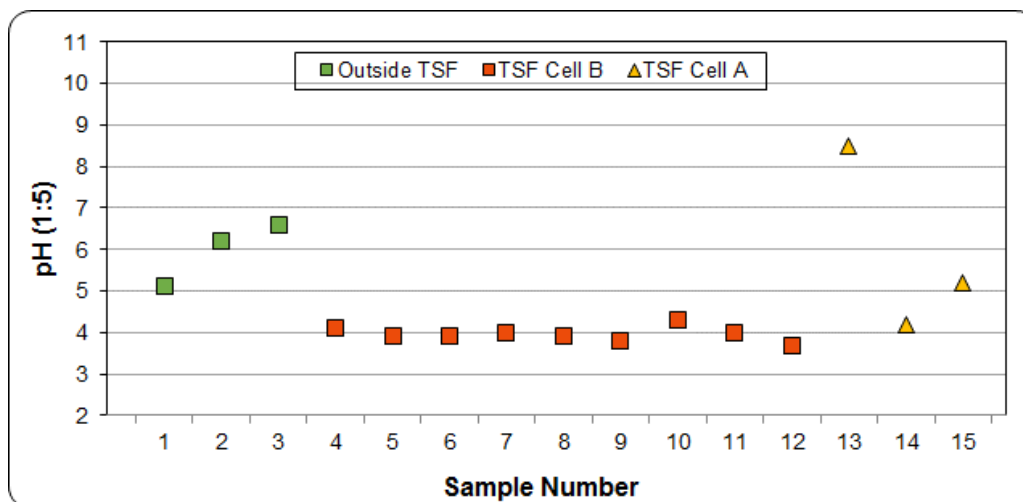


Figure 4-2: $pH_{(1:5)}$ values for soil and tailing samples

4.2.2 $EC_{(1:5)}$

The $EC_{(1:5)}$ results for the 15 samples range from 28 to 4,010 $\mu S/cm$ (**Figure 4-3**). The $EC_{(1:5)}$ value for the surface soil samples outside of the TSF is much lower than the $EC_{(1:5)}$ value for the surface tailing samples obtained from the TSF.

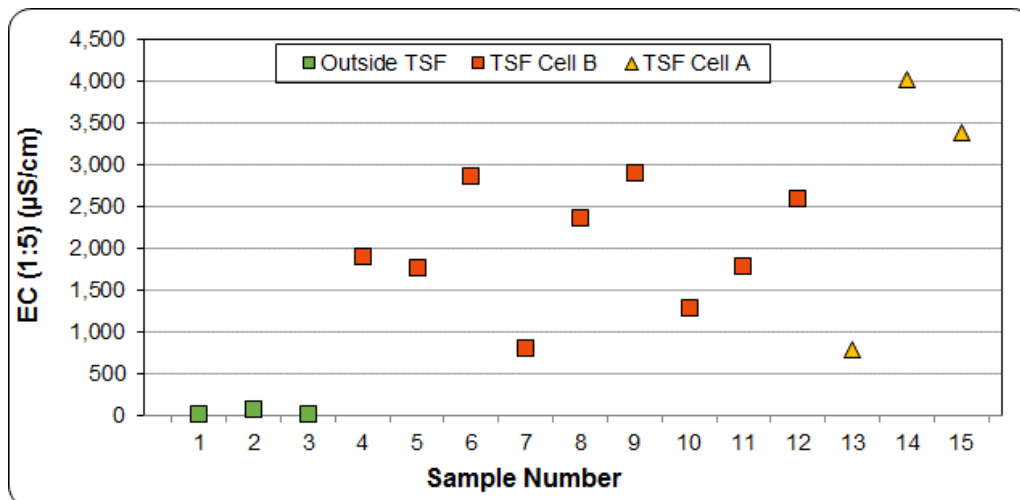


Figure 4-3: $EC_{(1:5)}$ values for soil and tailing samples

4.2.3 Total Sulfur

The total sulfur concentration for the 15 samples ranges from 0.01 to 1.33 percent sulfur (%S) (**Figure 4-4**). The three soil samples from outside the TSF have a very low total sulfur concentration of 0.01 %S compared to the total sulfur content of the tailings in the TSF. The mean total sulfur concentration for the tailings samples from TSF Cell B and TSF Cell A samples is 0.44 %S and 0.57 %S, respectively. For reference, the median crustal abundance of sulfur in unmineralised soils is 0.07%^{7, 8}.

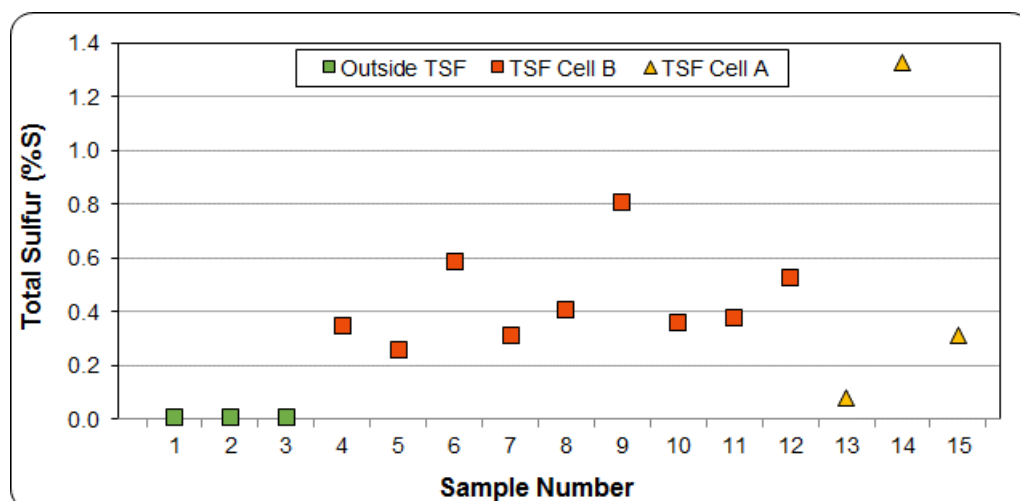


Figure 4-4: Total sulfur concentrations for soil and tailing samples

⁷ Bowen H. J. M. (1979). Environmental Chemistry of the Elements. Academic Press. New York.

⁸ INAP (2022). Global Acid Rock Drainage Guide (GARD Guide). Document prepared by Golder Associates on behalf of the International Network on Acid Prevention (INAP). July. (<https://www.inap.com.au/>).

4.2.4 Chromium Reducible Sulfur (Scr)

Scr is the concentration of sulfur present in a sample material as sulfide, a reduced form of sulfur. Oxidation of sulfide minerals, particularly the iron-sulfide pyrite, may generate acidic drainage.

Samples with a total sulfur concentration greater than 0.1% sulfur (the median crustal abundance of sulfur in unmineralised soils rounded to one decimal place^{8,9}) were analysed for Scr to assess the concentration of sulfur present in the samples as sulfide. The Scr concentration of the eleven samples tested (two samples from TSF Cell A and nine samples from TSF Cell B) were all below 0.1%S (**Figure 4-5**). The proportion of total sulfur present as Scr ranged from 2.0 % to 9.0 % (mean 5.1 %).

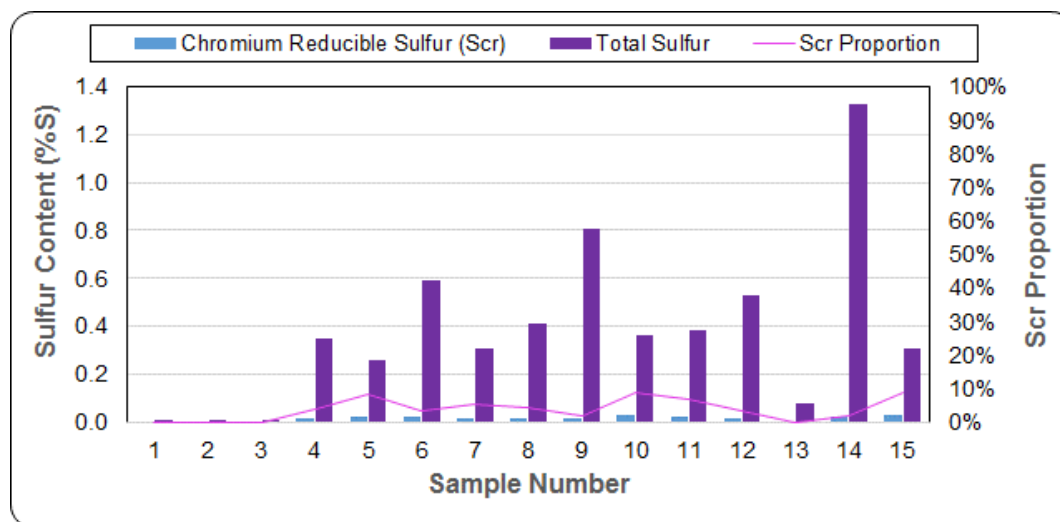


Figure 4-5: Comparison of Scr and TS for soil and tailing samples from the Project

These results confirm the results in the RGS 2015² report for 85 samples of tailing and soil materials from TSF Cell B, which found that the near surface tailing materials have already weathered/oxidised.

4.2.5 Maximum Potential Acidity (MPA)

The MPA of the samples is calculated by multiplying the total sulfur (or Scr, where available) concentration of a sample by a stoichiometric factor based on the production of H_2SO_4 from FeS_2 , where a sulfide concentration of 1 %S produces 30.625 kg H_2SO_4 /tonne of sample.

The MPA results for the samples are low and range from 0.31 to 2.45 kg H_2SO_4 /tonne. The mean MPA results for the samples are 0.31, 0.61, and 1.33 kg H_2SO_4 /tonne for the soil, TSF Cell B and TSF Cell A samples, respectively.

4.2.6 Acid Neutralising Capacity (ANC)

The ANC of the samples provides an indication of the ability of the samples to neutralise acid generated by the samples. The ANC results for the samples are low and range from 0.3 to 10.3 kg H_2SO_4 /tonne. The Mean ANC results for the soil, TSF Cell B, and TSF Cell A samples are 5.1, 2.2 and 4.9 kg H_2SO_4 /tonne, respectively.

4.2.7 ANC:MPA ratio

The ANC:MPA ratio of a sample provides an indication of the potential risk of a sample generating additional acidity through sulfide oxidation. An ANC:MPA ratio of greater than 2 is associated with a negligible to low risk profile whereas an ANC:MPA ratio of less than 1 is associated with increased risk profile.

Figure 4-6 shows that while some samples from TSF Cell B and a sample from TSF Cell A have ratios of ANC:MPA of less than 2, all of the samples have sufficiently low concentrations of sulfide sulfur to be considered essentially barren of sulfide^{8,9}.

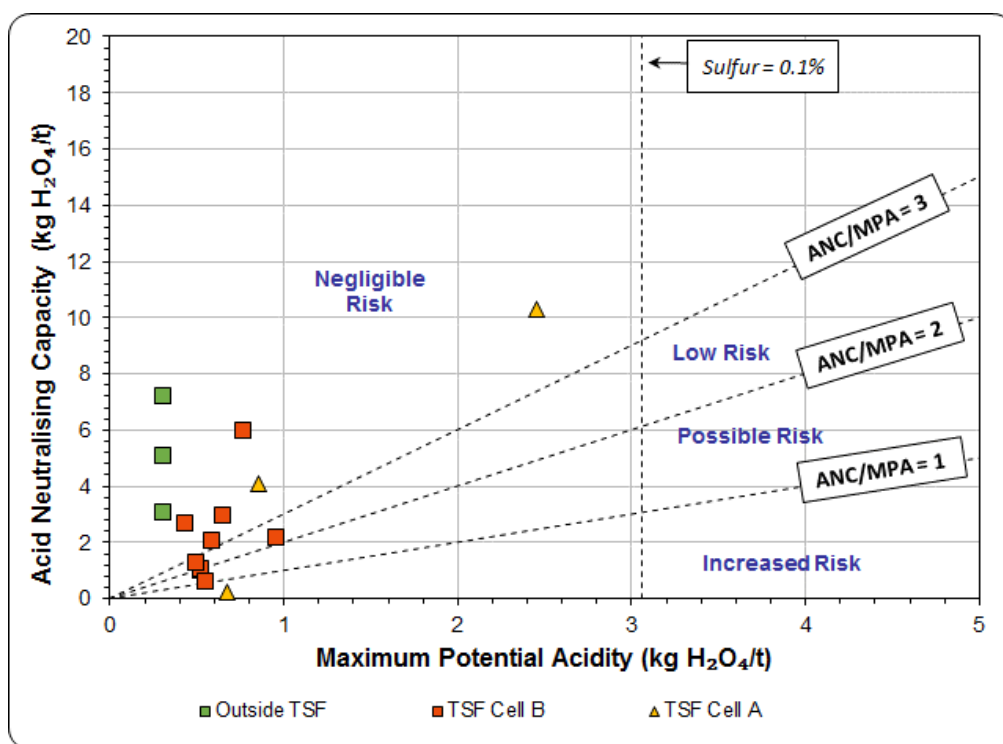


Figure 4-6: ANC vs MPA for soil and tailing samples

4.2.8 Net acid production potential (NAPP)

The NAPP of a sample describes the balance of the MPA and ANC of the sample material. A negative NAPP value indicates that the sample is unlikely to generate acidic drainage, while a positive NAPP value suggests the sample may have the potential to generate acidic drainage.

The NAPP values for samples from the Project range from -7.9 to 0.4 kg H₂SO₄/tonne. The mean NAPP values for the soil, TSF Cell B, and TSF Cell A samples are -4.8, -1.6, and -3.6 kg H₂SO₄/tonne respectively.

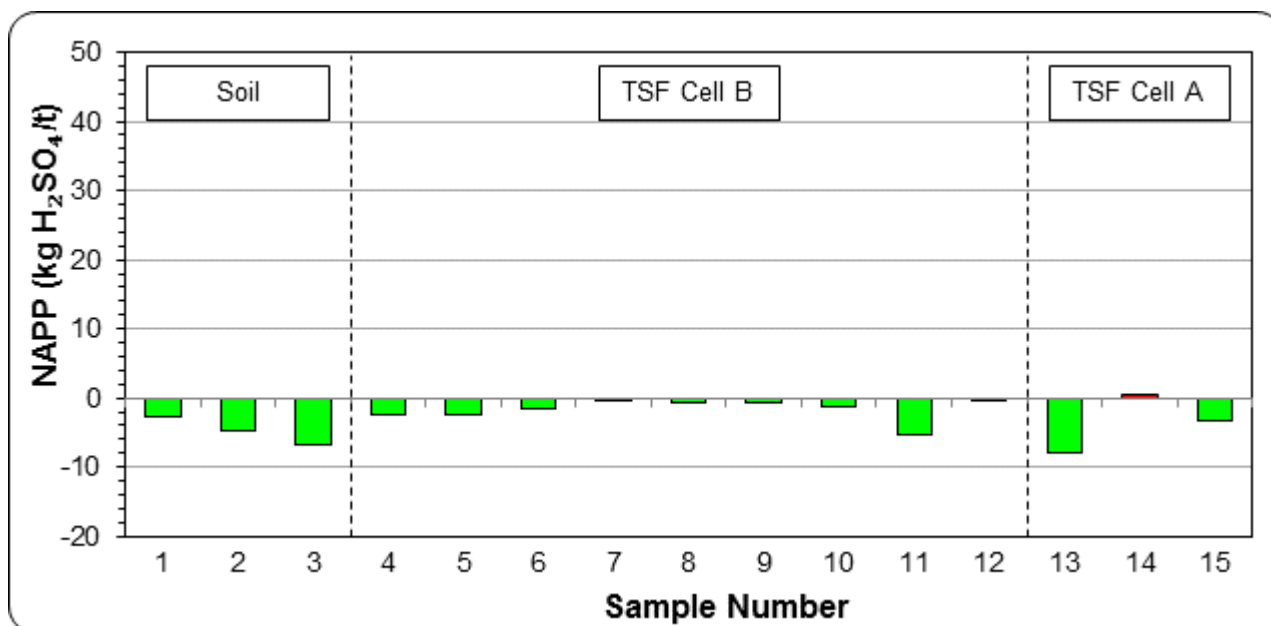


Figure 4-7: NAPP results for soil and tailing samples

4.2.9 Geochemical classification

Table 4-1 illustrates the sample classification methodology used by RGS to classify the acid forming nature of the 15 surface samples, with the number of samples in each specific classification category provided⁹. The results demonstrate that all of the samples are classified as Non-Acid Forming (Barren), have a sufficiently low concentration of sulfur to be considered barren of sulfides, and have a high factor of safety with respect to potential to generate any additional acidity through sulfide oxidation.

Table 4-1: Geochemical classification of soil and tailings samples from the Project

Classification	Total Sulfur or Scr (%)	NAPP (kg H ₂ SO ₄ /t)	Number of samples
Non-Acid Forming (Barren)	≤ 0.1	-	15
Non-Acid Forming (NAF)	> 0.1	≤ -5	0
Uncertain	> 0.1	> -5 to ≤ +5	0
Potentially Acid Forming (PAF)	> 0.1	> +5	0

Whilst the above Acid Base Account material classification scheme is useful for the classification of fresh mine waste materials it does not take into account the fact that if mine waste materials have been exposed to oxidising conditions they may have already weathered/oxidised to generate acidity and/or secondary minerals, such as jarosite. In instances where mine waste materials have already weathered/oxidised, and the inherent ANC has been essentially consumed through neutralisation processes, some of these materials may have already generated products such as acidity, sulfate salts and secondary minerals. These products of sulfide oxidation may have already leached from the mine waste materials or could still be temporarily stored within the material matrix and/or within secondary minerals.

The strength of acidity is a function of the soluble concentrations of H⁺ (measured by the pH) and the acidity from the H⁺ ion and dissolved metals such as Al, Cu, Fe, Mn and Zn can be measured as titratable acidity. The Acid Base Account results for the 15 soil and tailing samples described in this section and summarised in **Table C1 (Attachment C)** demonstrate that most of the tailings samples have reduced pH values and very low sulfide sulfur and ANC values.

Due to the fact that all of the soil and TSF tailing samples have already weathered/oxidised *in situ*, pH criteria have been used by RGS to describe the samples in terms of their existing acidity (**Table 4-2**). The classification used in this report ranges from Inert (where the pH greater than 6) to Mild Acid Forming Potential (MAFP) where the pH is less than 4. While five of the nine TSF Cell B tailing samples have a pH value less than 4, the nine TSF Cell B samples cover a narrow pH range of pH 3.7 to 4.3.

Table 4-2: Geochemical classification of soil and tailings samples from the Project

Existing Acid Forming Potential (AFP) (Sulfide minerals have oxidised and ANC is consumed)		AFP Criteria	Number of samples (n=15)
No Acid Forming Potential	Inert	pH > 6	3
Low Acid Forming Potential	LAFP	pH 4 to 6	7
Mild Acid Forming Potential	MAFP	pH < 4	5

It should be noted that RGS previously completed a more comprehensive study on a larger number (85) of near-surface (up to 600 mm depth) tailing and soil samples from Cell B in 2015², which found that only one of the 85 samples was classified as MAFP.

⁹ AMIRA (2002). ARD Test Handbook: Project 387A Prediction and Kinetic Control of Acid Mine Drainage, Australian Minerals Industry Research Association, Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd, May.

4.3 Multi-elements in solids

Multi-element analyses were completed on the 15 surface samples to assess the concentration of metals/metalloids in the soil and tailing materials that may be of environmental concern with respect to material storage, rehabilitation and water quality. The results from the multi-element testing are presented in **Sections 4.4 and 4.5**.

The results from multi-element testing (metals/metalloids in solids using a 2-acid digestion method) are presented in **Table C2 (Attachment C)**. To provide relevant context, RGS has compared the metal/metalloid concentration in samples to National Environmental Protection Council (NEPC) Health-based Investigation Levels (HIL-C) for soils in public open spaces¹⁰.

The multi-element data for the 15 samples show that none of the measured elements exceed the applied health based criteria for soils in public open spaces. This finding is similar to that reported by RGS in 2015² for 13 individual and composite samples of soil and tailing materials from TSF Cell B.

4.4 Assessment of enrichment in solids

To provide additional context and in line with mining industry technical guidelines, the multi-element results described in the previous section were also compared to the typical background concentrations (median crustal abundance) of those elements (metal/metalloids) in un-mineralised soils^{8,9,11}.

The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration in a sample with the median crustal abundance on a log₁₀ scale. The GAI is expressed in integer increments from 0 to 6, where a GAI value of 0 indicates that the element is present at a concentration less than, or similar to, the median crustal abundance; and a GAI value of 6 indicates approximately a 100-fold enrichment above median crustal abundance (**Table 4-3**).

Table 4-3: GAI Values and Enrichment Factors

GAI	Enrichment Factor	GAI	Enrichment Factor
0	Less than 3-fold enrichment	4	24- to 48-fold enrichment
1	3- to 6-fold enrichment	5	48- to 96-fold enrichment
2	6- to 12-fold enrichment	6	Greater than 96-fold enrichment
3	12- to 24-fold enrichment		

As a general rule, a GAI of 3.0 or greater signifies enrichment that may warrant further examination. This is particularly the case with some environmentally important 'trace' elements, such as As, Cr, Cd, Cu, Pb, Ni and Zn, generally more so than with major rock-forming elements, such as Al, Ca, Fe, Mg and Na.

Elements identified as enriched using the GAI may not necessarily be a concern for revegetation, drainage water quality or public health and the following points should also be noted:

- The median crustal abundance varies between different literature sources, therefore affecting the calculated GAI values.
- If a sample is enriched relative to the median crustal abundance, there is no direct correlation that the sample will also leach metals/metalloids at elevated concentrations. The mobility of metals/metalloids is dependent on mineralogy, adsorption/desorption, and the environment in which it occurs.
- Whilst some element concentrations can be elevated relative to the median crustal abundance, the nature of a deposit means the background levels of some elements are generally expected to be elevated.

¹⁰ NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version.

¹¹ COA (2016). Leading Practice Sustainable Development Program for the Mining Industry. Prevention and Acid and Metalliferous Drainage. Commonwealth of Australia, Canberra ACT. September.

Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (e.g. low pH) the solubility of common environmentally important elements such as Al, Cu, Cd, Fe, Ni and Zn can increase significantly.

Table C2 (Attachment B) provides metal/metalloid concentrations in solids for the 15 soil and tailing samples. The relative enrichment of metals/metalloids in these samples compared to median crustal abundance (the GAI) in un-mineralised soils is presented in **Table C3 (Attachment C)**.

The GAI results show that there are all elements tested in soils have a GAI value less than 3.0 and therefore there are no element significantly enrichments in soils compared to median crustal abundance in un-mineralised soils. Similarly, most elements tested in tailing samples have a GAI value less than 3.0 and are not significantly enriched compared to median crustal abundance in un-mineralised soils. The main exception is Arsenic (As) which has a GAI value ranging from 3.2 or 4.1 in all nine samples collected from TSF Cell B and a GAI value of 4.4 in one of the three tailing samples collected from TSF Cell A. Antimony had a GAI value of 3.1 in one of the nine tailing samples from TSF Cell B.

4.5 Multi-elements in water extracts

The potential solubility and mobility of the metals/metalloids contained in the 15 surface soil and tailing samples was investigated further using water extract tests. Using sample pulps (ground to passing 75 µm) in these tests provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. As such, the results of the water extract solutions are assumed to represent a 'worst case' scenario for pore water in sample materials.

RGS has compared the multi-element test results for water extracts from the 15 samples with applied ANZG (2018) water quality guideline values¹². These guidelines are provided for context only and are not intended to be interpreted as "maximum permissible levels" for site water storage or discharge.

It should also be recognised that direct comparison of geochemical data with guideline values can be misleading. For the purposes of this study, guideline values are only provided for broad context and should not be interpreted as arbitrary 'maximum' values or 'trigger' values. Whilst arbitrary comparisons against guideline concentrations can be useful in some situations and help to provide relevant context, such comparisons cannot be directly extrapolated to the field situation and numerical modelling with a wider range of material balance, water balance and water quality inputs would also typically be required.

The results from multi-element testing of water extracts (1:5 solid:water) from the 15 surface material samples are presented in **Table C4 (Attachment C)**.

4.5.1 pH and acidity

The pH of the 1:5_(w:v) water extracts from the soil and tailing samples has already been described in some detail in **Section 4.2**. Essentially, the soils are pH neutral to slightly acidic and the tailings are typically mildly acidic and below the applied guideline pH range for freshwater aquatic ecosystems (pH 6 to 9).

The measured acidity in the soils ranges from 31 to 162 mg/L (as CaCO₃) and ranges from 116 to 346 mg/L and 2 to 544 mg/L in the TSF Cell B and TSF Cell A tailing samples, respectively.

The measured alkalinity in the soil samples ranges from 9 to 64 mg/L and is <0.2 mg/L and ranges from <0.2 to 128 mg/L in the TSF Cell B and TSF Cell A tailing samples, respectively.

4.5.2 Salinity

The EC of the 1:5_(w:v) water extracts from the 15 soil and tailing samples has already been described in some detail in **Section 4.2**. Essentially, the EC value of surface soil samples outside of the TSF is lower than the EC value for the surface tailing samples obtained from the TSF.

According to Hazelton and Murphy (2007)¹³, soils with an EC of < 2,000 µS/cm are defined as having negligible effects on agronomic plants, but that at EC values of 2,000 to 4,000 µS/cm, yields of sensitive crops can be affected.

¹² ANZG (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

¹³ Hazelton, P.A. and Murphy, B.W. (eds). (2007). *Interpreting Soil Test Results: What do all the numbers mean?* [2nd edn.] CSIRO Publishing, Collingwood, Victoria.

The Authors state that water extracts with an EC of:

- < 700 $\mu\text{S/cm}$ are considered suitable for irrigation and drinking water (3 soil samples)
- 700 to 2,000 $\mu\text{S/cm}$ are considered suitable for irrigation water (6 tailing samples)
- < 3,000 $\mu\text{S/cm}$ are considered to have slight to moderate salinity (4 tailing samples)

Only two of the 15 samples (both from TSF Cell A) have an EC value greater than 3,000 $\mu\text{S/cm}$ as shown in **Figure 4-3** and **Table C3 (Attachment C)** and could therefore be described as moderately saline. It should be noted that the focus of this assessment was Cell B tailing materials and only three tailing samples were collected from Cell A.

The dominant major ion in most of the water extracts from the 15 samples is sulfate (SO_4^{2-}) (**Table C3, Attachment C**) and there is a relationship between EC and total sulfur as shown in **Figure 4-8**.

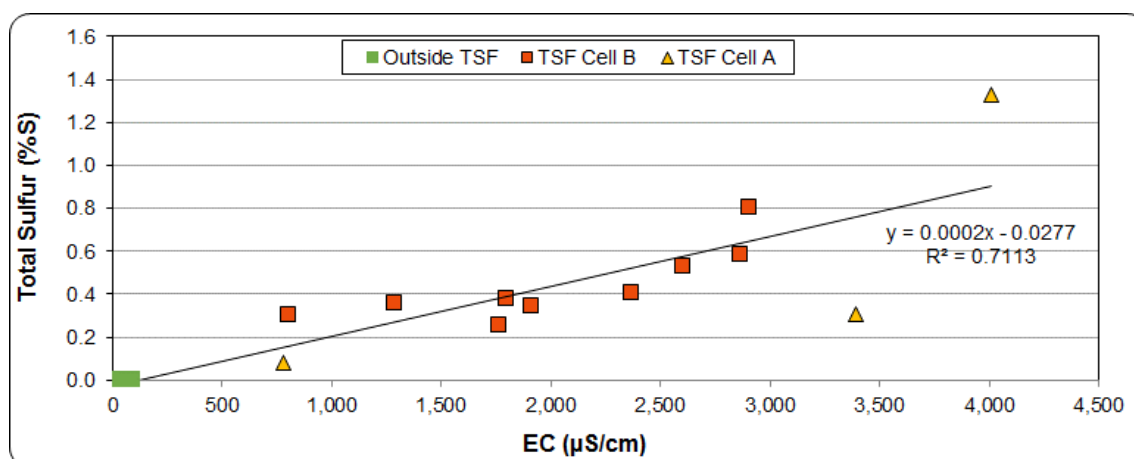


Figure 4-8: Correlation between total sulfur and EC for soil and tailing samples

These results tend to confirm that the surface tailing samples have weathered/oxidised at the TSF and have generated sulfate, which generally remains temporarily in the sample matrix and/or secondary minerals.

4.5.3 Major ions and trace metals/metalloids

The concentration of dissolved major ions in the water extracts from the soil samples are low in comparison to the tailing samples (**Table C3, Attachment C**). For the tailing samples, the dissolved major ions in the water extracts are generally dominated by calcium, sulfate and to a lesser extent sodium and chloride.

The calcium concentrations in all water extracts are below the applied livestock drinking water guideline value for this cation (1,000 mg/L). Tailing Samples 6, 8, 9, 12, 14, and 15 have sulfate concentrations that are greater than the applied livestock drinking water guideline value for this anion (1,000 mg/L).

The concentration of dissolved trace metal/metalloid concentrations in water extracts from the 15 surface material samples are variable. The three soil samples have dissolved concentrations that are generally below the laboratory limit of reporting (LoR) and applied water quality guideline values, except from dissolved aluminium, which is greater the applied freshwater aquatic ecosystem guideline value¹². Given the range of pH values of the soil samples (pH 5.1 to 6.6), the dissolved aluminium concentration is more likely to be an artefact of the laboratory filtration process and fine particle size whereby a portion of the fine colloidal material can pass through the sample filtration (0.45 μm filter) stage and report to the filterable (dissolved) fraction. This is often found for aluminium and iron as shown in **Table C4, (Attachment C)**.

In comparison, the water extracts obtained from the 12 tailing samples generally have higher dissolved metal/metalloid concentrations than the water extracts from soils. While some metal/metalloid concentrations are below the laboratory LoR and applied water quality guideline values, the concentrations of aluminium (11 samples), arsenic (2 samples), cadmium (8 samples), chromium (8 samples), copper (12 samples), manganese (8 samples), nickel (11 samples) and zinc (11 samples) are greater than the applied water quality guideline for freshwater aquatic ecosystem (95 % species protection)¹². The concentrations of aluminium

(5 samples), cadmium (2 samples) and nickel (2 samples) can also be greater than the applied livestock drinking water guideline values¹².

It should also be noted that during sample collection and laboratory preparation, the physical agitation and mixing of the samples can affect the physical stability of minerals and increase their solubility in a “first flush” leaching event, such as a static water extract test, which may not reflect the field situation where, in particular, tailings have compacted over time, and rainfall/hydrological interaction with these materials is limited.

The most recent review of water quality data associated with rainfall interaction with the tailings at the TSF as monitored at the Tailings Water Return Dam (TWRD) from 2011 to 2022¹⁴ found that since 2011, the pH of water at the TWRD has typically been in the pH neutral range (6 to 9) with occasional pH values between pH 5.5 and 6.0. The salinity as measured by EC is dominated by sulfate however sulfate concentrations in groundwater are stable and can increase in the TWRD following rainfall. The author considered that sulfate peaks appear to be occurring through limited infiltration with surface tailings or loss of dilution over the dry season.

Dissolved metal/metalloid concentrations measured at the TWRD from 2013 to 2022 are typically low and well below relevant contaminant limits set out in the Environmental Authority (EA)¹⁵. While some low and infrequent peaks in the concentration of dissolved metals (cadmium, copper, nickel and zinc) at the TWRD are apparent in the available dataset, these also appear to be associated with limited infiltration with surface tailings or loss of dilution over the dry season. The relatively low concentrations of metals/metalloids in the TWRD tends to confirm limited infiltration of rainfall/surface runoff into tailing materials at the TSF and confirms that these materials are naturally fine grained and well compacted.

The 2022 report¹⁵ indicates that further work has been identified to better understand the mechanisms associated with the peaks in the metals and sulfate occurring within the TWRD. It is noted that downgradient groundwater monitoring bores demonstrate that containment of potential water quality impacts is effective, and that the TWRD is effectively capturing surface runoff from the TSF.

The water quality results at the TWRD over the past decade are in direct contrast to the water extract results for 12 tailing samples from the TSF described in this RGS report (herein). In particular, the disturbance of the tailing materials as sampling and physical agitation during laboratory preparation has increased the solubility of metals, for example, and therefore physical disturbance of surface tailings in the field should be avoided. Indeed additional compaction of surface tailings prior to placement of a soil cover system (as previously advocated by RGS² and Williams⁶) prior to rehabilitation would appear to be warranted to minimise water infiltration and to form a low permeability layer to enhance the “store and release” function of a revegetated gravelly topsoil layer on TSF Cell B. As described in **Section 2.4**, this approach was predicted by Williams to better hold-up moisture to then be available to support revegetation, limit net percolation and seepage, and limit potential salt uptake into the cover system.

4.6 Nutrient and physical analysis

4.6.1 Cation exchange capacity

Nine (9) soil and tailing surface samples with a total sulfur concentration less than 0.1 %S were analysed for exchangeable cations. The individual exchangeable cation values and total effective cation exchange capacity (effective CEC) for the nine samples (three soil samples, three TSF Cell B samples, and three TSF Cell A samples) is presented in **Table C5 (Attachment C)**. In general, the effective CEC results indicate the effective capacity of a soil to hold and exchange cations, which provides a buffering effect to changes in pH and available nutrient levels¹⁶.

The results show that the effective CEC of the samples ranges from 2.7 to 10.0 meq/100g (**Table 4-3**) which corresponds to an effective CEC value in the ‘very low’ to ‘low’ range. The CEC rating indicates these materials will have little resistance to any changes in soil chemistry such as pH and available nutrients¹⁷.

¹⁴ See Built Earth (2022). Water performance of Yandan Mine landscape at closure. Report prepared for GBM Resources Limited, March.

¹⁵ (DERM, 2012). Environmental Authority No. MIN100902609. Issued to Straits Gold Pty Ltd for ML1095 (Yandan). 20 January

¹⁶ Hazelton and Murphy (2007). Interpreting Soil Test Results. What do all the numbers mean? CSIRO Publishing, Victoria.

Table 4-4: Summary of exchangeable cation results

Sample Number	Sample description	Effective CEC (meq/100g)	Effective CEC Rating*
1	Soil	5.8	Very Low
2	Soil	5.0	Very Low
3	Soil	2.9	Very Low
5	TSF Cell B Tailings	3.5	Very Low
8	TSF Cell B Tailings	5.3	Very Low
11	TSF Cell B Tailings	2.7	Very Low
13	TSF Cell A Tailings	3.0	Very Low
14	TSF Cell A Tailings	10.0	Low
15	TSF Cell A Tailings	6.3	Low

* Ratings based on Hazelton and Murphy (2007)¹⁶

The results for the individual exchangeable cation values show that the soil samples are very low to low in exchangeable calcium, and exchangeable sodium and low to moderate in exchangeable magnesium and exchangeable potassium (**Table 4-4**). TSF Cell B tailings samples are low in exchangeable calcium, very low in exchangeable magnesium and exchangeable potassium, and very low to low in exchangeable sodium. Samples of TSF Cell A tailings have low to moderate exchangeable calcium, very low to low exchangeable magnesium, and low to high exchangeable potassium and exchangeable sodium.

Table 4-5: Exchangeable cation levels in sample materials from the Project

Sample No.	Sample Type	Exchangeable Calcium Level*	Exchangeable Magnesium Level*	Exchangeable Potassium Level*	Exchangeable Sodium Level*
1	Soil	Very Low	Moderate	Low	Low
2	Soil	Low	Moderate	Moderate	Very Low
3	Soil	Low	Moderate	Moderate	Very Low
5	TSF Cell B Tailings	Low	Very Low	Very Low	Low
8	TSF Cell B Tailings	Low	Very Low	Very Low	Very Low
11	TSF Cell B Tailings	Low	Very Low	Very Low	Very Low
13	TSF Cell A Tailings	Low	Very Low	Moderate	Moderate
14	TSF Cell A Tailings	Moderate	Low	High	High
15	TSF Cell A Tailings	Moderate	Low	Low	Low

* Levels derived from Metson (1961)¹⁷

4.6.2 Sodicity

Sodicity occurs when exchangeable sodium on the cation-exchange complex leads to clay dispersion in the soil¹⁷. Generally, samples with exchangeable sodium percentage (ESP) values less than 6 % are considered non-sodic, greater than 6 % are considered moderately sodic, and greater than 14 % are considered strongly sodic and may be susceptible to dispersion and erosion^{18, 19}. Sodidity is of interest as it can result in surface crusting and low levels of infiltration and hydraulic conductivity within affected soils.

The ESP of the nine surface material samples is presented in **Table C5 (Attachment C)** and ranges from less than 0.1 % to 13.3 %. The soil and TSF Cell B samples can be considered non-sodic (i.e. ESP less than 6 %), while samples from TSF Cell A were found to be moderately sodic (ESP between 6% and 14%).

¹⁷ Metson, A. J. (1961). Methods of chemical analysis for soil survey samples. Soil Bureau Bulletin No. 12, New Zealand Department of Scientific and Industrial Research, pp. 168–175. (Government Printer: Wellington, New Zealand.)

¹⁸ Isbell, R.F. (2002). The Australian Soil Classification (revised edition). CSIRO, Victoria.

¹⁹ Northcote, K.H., Skene, J.K.M. (1972). Australian Soils with Saline and Sodic properties. Soil Publication No. 27. CSIRO, Canberra

4.6.3 Sample nutrients

Nine (9) soil and tailing surface samples with a total sulfur concentration less than 0.1 %S were analysed for nutrients.

The total nitrogen concentrations of the surface samples are provided in **Table C5 (Attachment C)** and range from 110 to 730 mg/kg. The soil samples contain a higher concentrations of total nitrogen relative to the tailing samples (**Figure 4-9**).

Plant available nitrogen is primarily present as nitrate (range 0.1 to 47.6 mg/kg, median 7.4 mg/kg), with ammonia concentrations below the laboratory LoR (20 mg/kg).

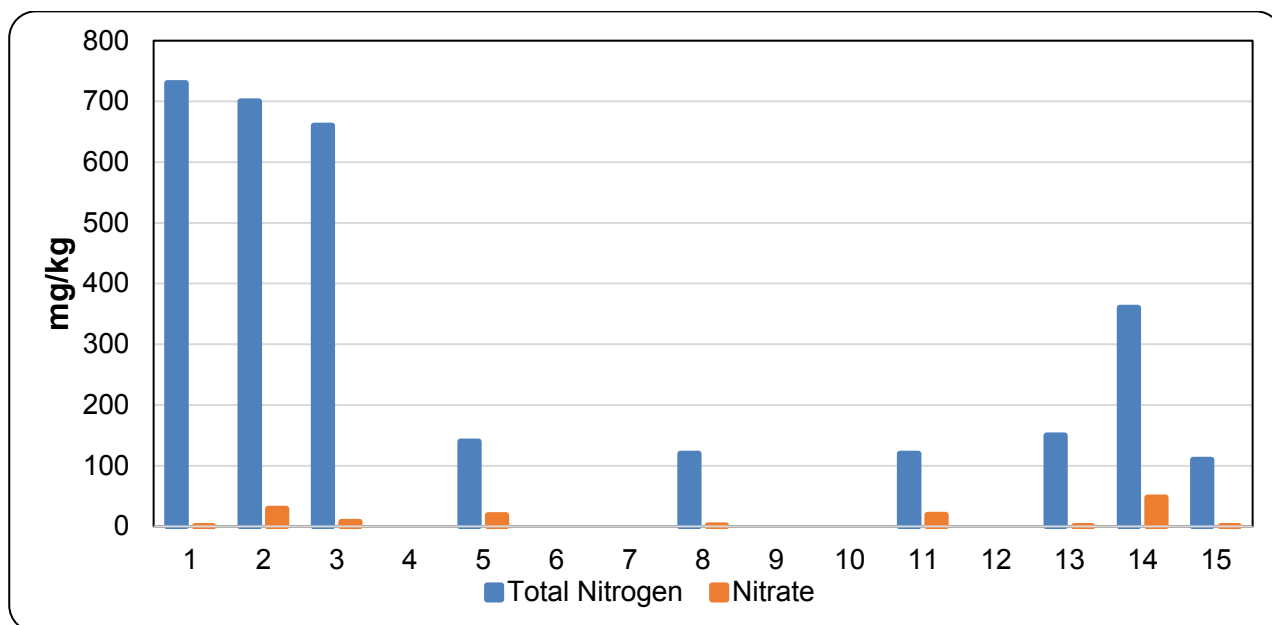


Figure 4-9: Total nitrogen and nitrate concentrations for soil and tailing samples

4.7 Sample density, porosity, and moisture

Density, porosity, and moisture results for the 15 surface soil and tailing samples are presented in **Table C5 (Attachment C)**. Dry bulk density of the samples ranges from 1.08 to 1.62 g/cm³, median dry bulk densities are 1.50, 1.29, and 1.25 g/cm³ for the soil, TSF Cell B, and TSF Cell A samples, respectively. The soil particle density of the samples ranges from 2.31 to 2.62 tonnes/m³, the median soil particle densities are 2.58, 2.52, and 2.58 for the soil, TSF Cell B, and TSF Cell A samples respectively.

The total porosity of the samples has been calculated using the sample dry bulk density and soil particle density. The total porosity of the samples ranges from 37 % to 59 % (**Figure 4-10**). The tailing samples have a smaller range of porosity values than the soil samples but higher median values (49 % and 51 % for TSF Cells B and A respectively compared to 42% for the soil samples).

Sample moisture ranges from 1 % to 14 %, with soil samples holding little moisture relative to the tailings samples (**Figure 4-11**).

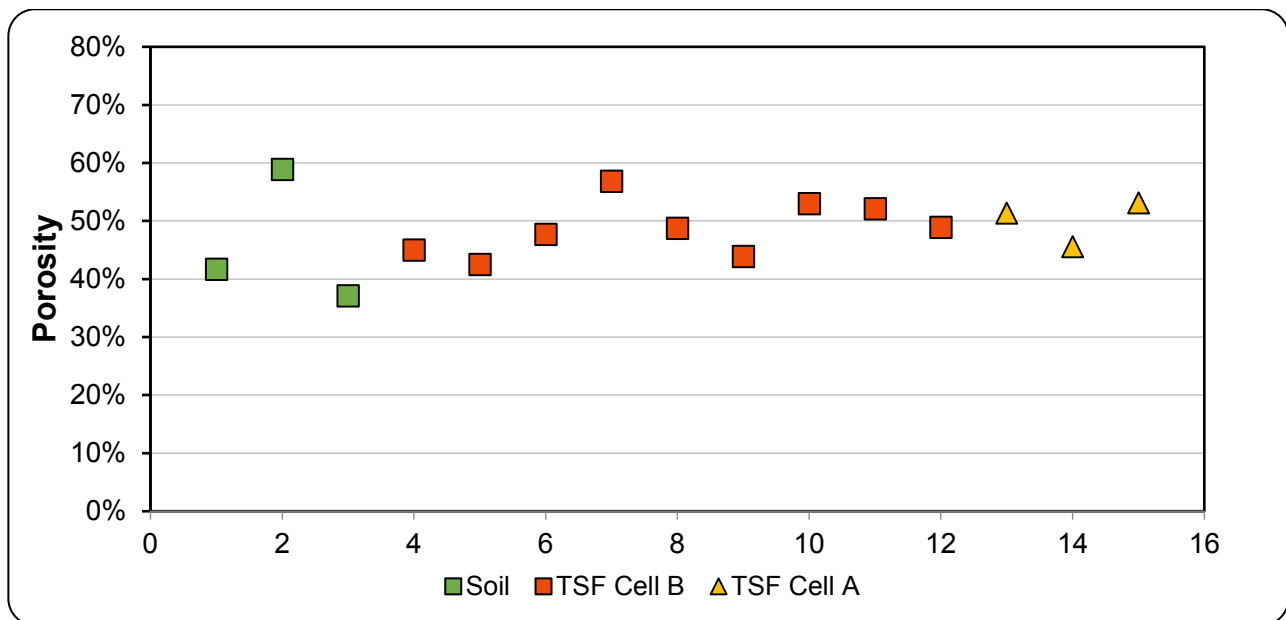


Figure 4-10: Total porosity results for soil and tailing samples

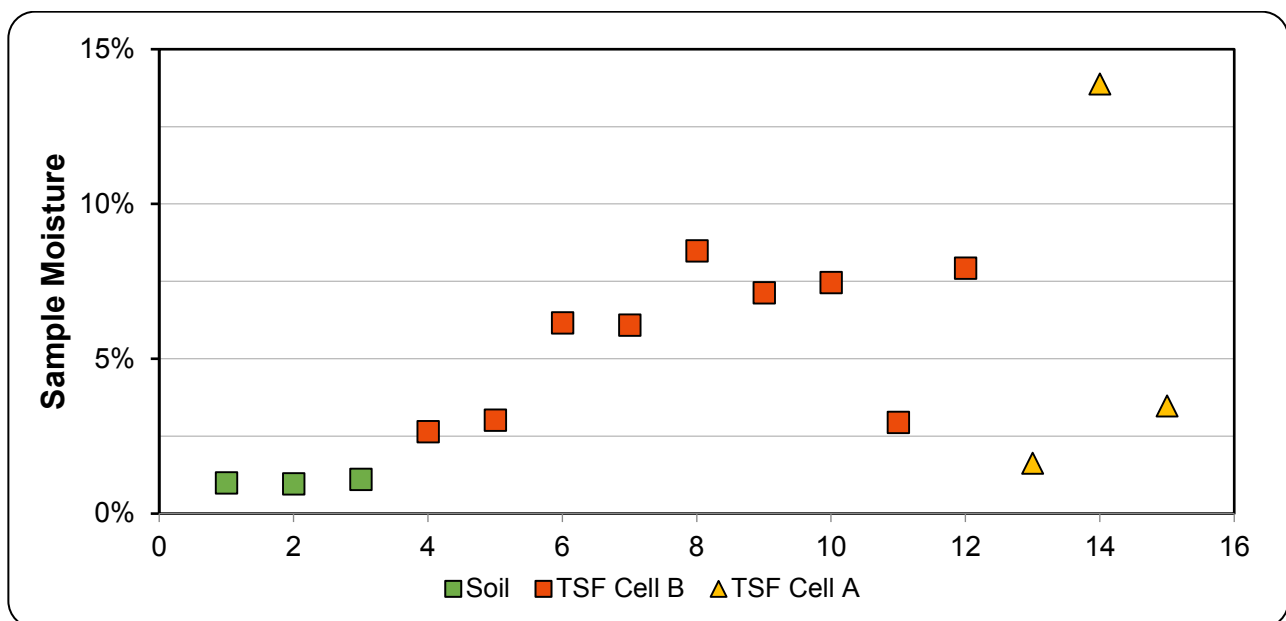


Figure 4-11: Soil moisture results for soil and tailing samples

4.8 KLC test program

A KLC test program was completed on two composite tailing samples (TSF Cell A and TSF Cell B composites) using the methodology described in **Section 0** and **Attachment A**. A total of six KLC tests were established (**Table 3-3**) and were initially leached on a weekly basis for four weeks. KLC test results for collected leachate were found to be relatively similar for the TSF cell composites with 4 g/kg CaCO₃ and 2 g/kg CaCO₃ “Aglime” mixed, such that leaching was discontinued on the KLCs with 4 g/kg CaCO₃ (KLC 1 and KLC 4) after Week 4. The remaining KLC tests (KLC 2, KLC 3, KLC 5 and KLC 6) continued for a further two weeks.

The results from the KLC tests have been used to predict the ongoing geochemical characteristics and likely quality of pore water in the TSF surface materials if these are disturbed and to assess the effectiveness of the addition of crushed limestone (‘Aglime’) to neutralise any existing acidity.

The KLC leach test results are presented in **Attachment D** with leachate results from the KLC test program presented alongside Australian water quality guideline values for livestock drinking water quality¹². These guidelines are provided for context only and are not intended to be interpreted as “maximum permissible levels” for site water storage or discharge. The ratio of sample to water in the KLC tests is currently approximately 3:1 for the tailing samples (i.e., concentrated), whereas the ratio of sample to water generally used in tests where results can (arbitrarily) be compared against guideline concentrations to provide relevant context is typically more than an order of magnitude more dilute at 1:5 (w/v). Whilst arbitrary comparisons against guideline concentrations can be helpful in some situations to provide relevant context, such comparisons cannot be directly extrapolated to the field situation at the Project and numerical modelling with a wider range of material balance, water balance and water quality inputs would also typically be required.

Results from the KLC leach events to date show the following:

4.8.1 pH, acidity and alkalinity

- Leachate from the TSF Cell B composite tailing sample control test (i.e., that does not contain ‘Aglime’ (KLC 3)) has an acidic pH value ranging from 3.67 to 4.28. Leachate from the same TSF Cell B composite tailing sample with “Aglime” added/mixed has a neutral pH value in the range 6.87 to 7.76.
- Leachate from the TSF Cell A composite tailing sample control test (i.e., that does not contain ‘Aglime’ (KLC 6)) initially has a neutral pH value (7.02) that tends to decrease over time (4.88). Leachate from the same TSF Cell A composite tailing sample with “Aglime” added/mixed also has an initial neutral pH value that tends to decrease over time (to 5.82).
- Leachate from TSF Cell B composite tailing sample control test (KLC3) has an elevated acidity value that ranges from 657 to 101 mg/L (as CaCO₃ equivalent), negligible alkalinity, a negative net alkalinity, and shows a decreasing acidity trend over time. The acidity of the same TSF Cell B sample with “Aglime” added/mixed has a lower acidity value (8 to 43 mg/L (as CaCO₃ equivalent)), a higher alkalinity value (73 to 224 mg/L (as CaCO₃)) and a positive net alkalinity value.

4.8.2 Salinity and major ions

- The salinity of leachate from TSF Cell B composite tailing sample control test (KLC 3) is initially elevated (up to 10,000 µS/cm) but shows a decreasing trend over the test period. Leachate from the same TSF Cell B composite tailing sample with “Aglime” added/mixed is also initially elevated and shows a decreasing trend over time.
- The salinity of leachate from TSF Cell A composite tailing sample control test (KLC 6) is initially elevated (up to 39,300 µS/cm) but shows a decreasing trend over the test period. Leachate from the same TSF Cell A composite tailing sample with “Aglime” added/mixed is also initially elevated and shows a decreasing trend over time.
- The dominant major ions in leachate from all KLC tests are calcium, magnesium, sodium, chloride and sulfate although the concentrations of these ions in leachate tends to decrease over time.
- The sulfate concentration in the KLC leachates is elevated and makes a significant contribution to the overall salinity value and despite showing a decreasing trend over time, remains greater than the applied livestock drinking water guideline value (1,000 mg/L)¹².

4.8.3 Trace metals/metalloids

- Leachate from the TSF Cell B composite tailing sample control test (KLC 3) has elevated dissolved concentrations of aluminium, arsenic, cadmium, cobalt, chromium, copper, manganese, nickel, selenium and zinc compared to the applied freshwater aquatic ecosystem (95 % species protection) values. Some of these metals/metalloids have dissolved concentrations in leachate (aluminium, arsenic, cadmium, cobalt, nickel and selenium) greater than the applied livestock drinking water criteria¹². In contrast, leachate from the same TSF Cell B composite tailing sample with ‘Aglime’ added/mixed has lower concentrations of these dissolved metals/metalloids whereby only cadmium, cobalt, nickel are greater than livestock drinking water guideline values in initial leachates and show a decreasing trend over time.
- Leachate from the TSF Cell A composite tailing sample control test (KLC 6) has elevated dissolved concentrations of arsenic, cadmium, cobalt, chromium, copper, lead, manganese, nickel, and zinc compared to the applied freshwater aquatic ecosystem (95 % species protection) values. Some of these metals/metalloids have dissolved concentrations in leachate (arsenic, cadmium, cobalt, nickel and selenium) greater than the applied livestock drinking water criteria¹². Leachate from the same TSF Cell A composite tailing sample with ‘Aglime’ added/mixed generally has lower concentrations of these dissolved metals/metalloids although cobalt remains greater than livestock drinking water guideline value in one of the initial leachates but shows a decreasing trend over time.

5 Conclusions and recommendations

5.1 Conclusions

The results of this study generally align with the findings of the previous RGS 2015 report². Based on the results of the in-situ hydraulic conductivity, static and kinetic geochemical, and physical testing undertaken the following conclusions are drawn:

- Tailings contained in TSF Cells A and B were confirmed to have lower hydraulic conductivity than surrounding soil, with TSF Cell A having lower hydraulic conductivity than TSF Cell B. These findings support the RGS 2015² finding that the Cell B tailings are low permeability;
- The very low sulfide sulfur concentrations for all tailings samples confirm that the near surface tailing materials in both TSF Cells have already weathered/oxidised, are classified as NAF (Barren), and will not generate any additional acidity through sulfide oxidation;
- The elevated total sulfur concentrations relative to the sulfide sulfur concentrations confirm that the residual acidity observed in the tailings is likely due to sulfate hosted in secondary mineral such as jarosite and/or alunite as previously found by RGS in 2015²;
- Most metals/metalloids are not enriched in tailing materials compared to un-mineralised soils. Arsenic and antimony can be slightly enriched in some tailings samples compared to un-mineralised soils.
- If surface tailing materials are physically disturbed, this is likely to increase the risk of sulfate and some dissolved metals/metalloids to be mobilised by contact water such as rainfall and surface runoff.
- The most recent review water quality data associated with rainfall and surface runoff interaction with the tailings at the TSF as monitored at the TWRD ¹⁵ has found that since 2011, the pH of water at the TWRD has typically been in the pH neutral range (6 to 9) with occasional pH values between pH 5.5 and 6.0. The salinity is dominated by sulfate however sulfate concentrations in groundwater are stable and can increase in the TWRD following rainfall. The author considered that sulfate peaks appear to be occurring through limited infiltration with surface tailings or loss of dilution over the dry season.
- Dissolved metal/metalloid concentrations measured at the TWRD are typically low and well below relevant contaminant limits set out in the Environmental Authority (EA)¹⁵. While some low and infrequent peaks in the concentration of dissolved metals (cadmium, copper, nickel and zinc) at the TWRD are apparent in the available dataset, these also appear to be associated with limited infiltration with surface tailings or loss of dilution over the dry season. The relatively low concentrations of metals/metalloids in the TWRD confirms the limited infiltration of rainfall/surface runoff into tailing materials at the TSF as these materials are naturally fine grained and well compacted and therefore low mobility of potential solutes from tailing materials under field conditions. Hence, disturbance of these tailings during rehabilitation activities should be avoided.
- Further work has been identified to better understand the mechanisms associated with the peaks in the metals and sulfate occurring within the TWRD. It is noted that downgradient groundwater monitoring bores demonstrate that containment of potential water quality impacts is effective, and that the TWRD is effectively capturing surface runoff from the TSF¹⁵.
- The water quality results at the TWRD over the past decade are in direct contrast to the water extract results for 12 tailing samples from the TSF described in this RGS report (herein). In particular, the disturbance of the tailing materials as sampling and physical agitation during laboratory preparation has increased the solubility of metals, for example, and therefore physical disturbance of surface tailings in the field should be avoided. Indeed additional compaction of surface tailings prior to placement of a soil cover system (as previously advocated by RGS² and Williams⁶) would appear to be warranted to minimise water infiltration and to form a low permeability layer to enhance the “store and release” function of a revegetated gravelly topsoil layer on TSF Cell B. As described in **Section 2.4**, this approach was predicted by Williams to better hold-up moisture to then be available to support revegetation, limit net percolation and seepage, and limit potential salt uptake into the cover system.

- The tailing materials have low to moderate sodicity and low cation exchange capacities and so are likely to be non-dispersive, but susceptible to changes in pH, nutrient availability, and calcium levels.
- Addition of 'Aglime' to the surface materials in TSF Cell B as part of cover placement is likely to increase the pH and alkalinity and reduce the acidity and concentrations of some metals/metalloids that could potentially be present in tailings pore water and periodically report as seepage to the TWRD.
- The benefits of 'Aglime' addition to tailing materials at TSF Cell A are less pronounced than for tailing materials at Cell B and 'Aglime' addition to Cell A tailings may not be warranted as part of final rehabilitation activities.

5.2 Recommendations

Based on the outcomes of the geochemical assessment, RGS recommends that:

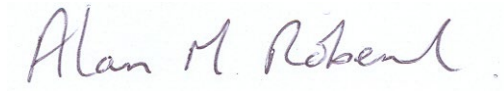
- The near surface tailing materials at TSF Cell B be traffic compacted as part of cover and rehabilitation activities advocated by Williams⁶.
- Physical disturbance of near-surface tailing materials at the TSF should be avoided.
- GBM consider addition of 'Aglime' to the tailings surface and/or to the lower part of the cover system as part of rehabilitation activities at TSF Cell B advocated by Williams⁶.

6 Closing

Please contact Alan Robertson on 07 3344 1222 (office) or 0431 620 623 (mobile) if you require further information.

Yours sincerely,

RGS ENVIRONMENTAL CONSULTANTS PTY LTD

A handwritten signature in purple ink that reads 'Alan M. Robertson'.

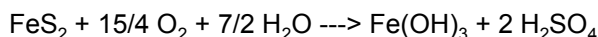
Dr. Alan M. Robertson
Managing Director/Principal Geochemist

Attachments

Attachment A: Geochemical Assessment of Mining Waste Materials

ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the maximum amount of acid that could be generated by a material based on either direct measurement of the pyritic sulfur content, or assuming that all sulfur, not present as sulfate, occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:



According to this reaction, the maximum potential acidity (MPA) of a sample containing 1%S as pyrite would be 30.6 kg H_2SO_4 /t. The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralization, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

NAPP

The NAPP is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulfide sulfur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4 /t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests that include:

Determination of pH and EC

pH and EC measured on 1:5 w:v water extract. This gives an indication of the inherent acidity and salinity of the mining waste material when initially exposed in an emplacement area.

TS content and MPA

Total sulfur content is determined by the Leco high temperature combustion method. The total sulfur content is then used to calculate the MPA, which assumes that the entire sulfur content is present as reactive pyrite. Direct determination of the pyritic sulfur content can provide a more accurate estimate of the MPA.

ANC

The ANC is determined by addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acid titration to a set end point in the Acid Buffering Characteristic Curve (ABCC) test through calculation of the amount of acid consumed during the reaction process.

NAG

The net acid generation (NAG) test involves the addition of hydrogen peroxide to a sample of mine rock or process residue to oxidise reactive sulfide, then measurement of pH and titration of any net acidity produced by the acid generation and neutralisation reactions occurring in the sample. A significant NAG result (*i.e.*, final $\text{NAG}_{\text{pH}} < 4.5$) indicates that the sample is potentially acid forming (PAF) and the test provides a direct measure of the net amount of acid remaining in the sample after all acid generating and acid neutralising reactions have taken place. A $\text{NAG}_{\text{pH}} > 4.5$ indicates that the sample is non-acid forming (NAF). The NAG test can provide a direct assessment of the potential for a material to produce acid after a period of exposure and weathering and is used to refine the results of the theoretical NAPP predictions. The NAG test can be used as a stand-alone test but is recommended that this only be considered after site specific calibration work is carried out.

ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material (or readily leachable from a material) at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health. The samples are generally analysed for major elements (i.e. Al, Ca, Fe, K, Mg, Na and S) and a range of minor elements.

The concentration of these elements in samples can be directly compared with the median concentration in un-mineralised soils to determine the Geochemical Abundance Index (GAI) and level of significance (INAP, 2009; Bowen, 1979). Water extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. The following tests are normally carried out:

Multi-element composition of solids

Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-atomic emission spectroscopy (AES), and atomic absorption spectrometry (AAS).

Multi-element composition of water extracts

Multi-element composition of 1:5 (w:v [deionised water]) water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-atomic emission spectroscopy (AES), and atomic absorption spectrometry (AAS).

Under some conditions (e.g. low pH) the solubility and mobility of common environmentally important elements can increase significantly. If element mobility under initial pH conditions is deemed likely and/or subsequent low pH conditions may occur, kinetic leach column test work may be completed on representative samples.

KINETIC LEACH COLUMN TESTS

Kinetic leach column (KLC) tests can be used to provide information on the reaction kinetics of mine waste materials. The major objectives of kinetics tests are to:

- Provide time-dependent data on the kinetics and rate of acid generation and acid neutralising reactions under laboratory controlled (or onsite conditions);
- Investigate metal(loid) release and drainage/seepage quality; and
- Assess treatment options such as addition of alkaline materials.

The KLC tests simulate the weathering process that leads to acid and base generation and reaction under laboratory controlled or site conditions. The kinetic tests allow an assessment of the acid forming or acid consuming characteristics and indicate the rate of acid generation/consumption, over what period it will occur, and what management controls may be required.

In the free draining KLC test used in this project, deionised water was added to the samples to simulate rainfall. The mixture was then allowed to leach products and by-products of any acid producing and consuming reactions. Samples of leachate were collected and analysed monthly.

In the saturated KLC tests, a head of water was maintained above the sample material. These tests provide real-time information and generally continue for months up to about a year or more. Monitoring includes trends in pH, sulfate, acidity or alkalinity, and dissolved metals/metalloids, for example. The pH of the collected leachate simulates the acid drainage/consumption process, acidity or alkalinity levels indicate the rate of acid production and acid neutralisation, and sulfate production can be related to the rate of sulfide oxidation. Metal/metalloid concentration data provides an indication of metal/metalloid solubility and potential mobility.

Attachment B: Guelph Permeameter Results

Attachment B - Guelph Permeameter - Raw Results
Yandan Gold Mine Tailings Storage Facility (TSF), March 2022
GBM Resources

For natural ground, Kfs assumes mostly structured soils from clays through loams; also includes unstructured medium and fine sands. This category is most applicable to agricultural soils.
Kfs is calculated using the Soil Moisture® Single Head Method.

Natural Ground

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
30/03/2022	7:30 AM	2022017_0001	14	10	1	0	8.5	-	-	-	Combined reservoir used
					2	2	11	2.5	1.25	0.021	
					3	4	12.6	1.6	0.80	0.013	
					4	6	14.1	1.5	0.75	0.013	
Combined Reservoir (cm2):			35.22		5	8	15.4	1.3	0.65	0.011	
Inner Reservoir (cm2):			2.16		6	10	16.5	1.1	0.55	0.009	
Kfs (cm/min) (Ksat calculator):			0.019081		7	12	17.7	1.2	0.60	0.010	
					8	14	18.7	1.0	0.50	0.008	
					9	16	19.8	1.1	0.55	0.009	
					10	18	20.8	1.0	0.50	0.008	
					11	20	21.8	1.0	0.50	0.008	
					12	22	22.8	1.0	0.50	0.008	

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
30/03/2022	8:00 AM	2022017_0002	15	10	1	0	11	-	-	-	Combined reservoir used
					2	2	14	3.0	1.50	0.025	
					3	4	15.5	1.5	0.75	0.013	
					4	6	17	1.5	0.75	0.013	
Combined Reservoir (cm2):			35.22		5	8	18.2	1.2	0.60	0.010	
Inner Reservoir (cm2):			2.16		6	10	19.3	1.1	0.55	0.009	
Kfs (cm/min) (Ksat calculator):			0.020989		7	12	20.3	1.0	0.50	0.008	
					8	14	21.4	1.1	0.55	0.009	

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
30/03/2022	9:00 AM	2022017_0003	14	10	1	0	32.6	-	-	-	Combined reservoir used
					2	2	34.8	2.2	1.10	0.018	
					3	4	36.6	1.8	0.90	0.015	
					4	6	38.2	1.6	0.80	0.013	
Combined Reservoir (cm2):			35.22		5	8	40	1.8	0.90	0.015	
Inner Reservoir (cm2):			2.16		6	10	41.4	1.4	0.70	0.012	
Kfs (cm/min) (Ksat calculator):			0.026713		7	12	42.8	1.4	0.70	0.012	
					8	14	43.9	1.1	0.55	0.009	
					9	16	45.3	1.4	0.70	0.012	
					10	18	46.6	1.3	0.65	0.011	
					11	20	48	1.4	0.70	0.012	

Attachment B - Guelph Permeameter - Raw Results
Yandan Gold Mine Tailings Storage Facility (TSF), March 2022
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For TSF Cell A, Kfs assumes compacted, structure-less, clayey or silty materials such as landfill capsand liners, lacustrine or marine sediments.
Kfs is calculated using the Soil Moisture® Single Head Method.

TSF Cell A

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
30/03/2022	10:00am	2022017_3010	15	10	1	0	7.5	-	-	-	Combined reservoir used
					2	2	7.9	0.4	0.20	0.003	
					3	4	8.3	0.4	0.20	0.003	
					4	6	8.7	0.4	0.20	0.003	
Combined Reservoir (cm2):		35.22			5	8	9	0.3	0.15	0.003	
Inner Reservoir (cm2):		2.16			6	10	9.1	0.1	0.05	0.001	
Kfs (cm/min) (Ksat calculator):		0.000031			7	12	9.2	0.1	0.05	0.001	
					8	14	9.4	0.2	0.10	0.002	
					9	16	9.5	0.1	0.05	0.001	
					10	18	9.7	0.2	0.10	0.002	
					11	20	9.9	0.2	0.10	0.002	
					12	22	10	0.1	0.05	0.001	
					13	24	10.2	0.2	0.10	0.002	
					14	26	10.4	0.2	0.10	0.002	
					15	28	10.5	0.1	0.05	0.001	
					16	30	10.6	0.1	0.05	0.001	
					17	32	10.7	0.1	0.05	0.001	
Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
30/03/2022	12:00 PM	2022017_3011	15	10	1	0	31.4	-	-	-	Inner reservoir used
					2	5	31.4	0.0	0.00	0.000	
					3	10	32.5	1.1	0.22	0.009	
					4	15	34.7	2.2	0.44	0.018	
Combined Reservoir (cm2):		35.22			5	20	37.5	2.8	0.56	0.023	
Inner Reservoir (cm2):		2.16			6	22	41.7	4.2	2.10	0.035	
Kfs (cm/min) (Ksat calculator):		0.000284			7	24	41.9	0.2	0.10	0.002	
					8	26	43.1	1.2	0.60	0.010	
					9	28	44.6	1.5	0.75	0.013	
					10	30	46	1.4	0.70	0.012	
					11	32	47.5	1.5	0.75	0.013	
Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
30/03/2022	1:00 PM	2022017_3012	14	10	1	0	34.1	-	-	-	Combined reservoir used
					2	2	34.4	0.3	0.15	0.002	
					3	4	34.9	0.5	0.25	0.004	
					4	6	35.2	0.3	0.15	0.003	
Combined Reservoir (cm2):		35.22			5	8	35.7	0.5	0.25	0.004	
Inner Reservoir (cm2):		2.16			6	10	35.9	0.2	0.10	0.002	
Kfs (cm/min) (Ksat calculator):		0.000927			7	12	36.2	0.3	0.15	0.003	
					8	14	36.6	0.4	0.20	0.003	
					9	16	36.9	0.3	0.15	0.002	
					10	18	37.2	0.3	0.15		

Attachment B - Guelph Permeameter - Raw Results
Yandan Gold Mine Tailings Storage Facility (TSF), March 2022
GBM Resources

For TSF Cell B, Kfs assumes mostly structured soils from clays through loams; also includes unstructured medium and fine sands. This category is most applicable to agricultural soils.
Kfs is calculated using the Soil Moisture® Single Head Method.

TSF Cell B

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	8:00 AM	2022017_3001	12	10	1	0	33.5	-	-	-	Combined reservoir used
					2	2	49.5	16.0	8.00	0.133	
					3	4	61.5	12.0	6.00	0.100	
					4	6	71	9.5	4.75	0.079	
Combined Reservoir (cm2):			35.22		5	8	1.5	-	-	-	Guelph re-filled
Inner Reservoir (cm2):			2.16		6	10	2.2	0.7	0.35	0.006	
Kfs (cm/min) (Ksat calculator):			0.015446		7	12	3	0.8	0.40	0.007	
					8	14	6	3.0	1.50	0.025	
					9	16	15	9.0	4.50	0.075	
					10	18	21.5	6.5	3.25	0.054	
					11	20	29	7.5	3.75	0.063	
					12	22	34.8	5.8	2.90	0.048	
					13	24	40.5	5.7	2.85	0.048	
					14	26	45.5	5.0	2.50	0.042	

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	9:00 AM	2022017_3002	12	10	1	0	0	-	-	-	Inner reservoir used
					2	2	0	0.0	0.00	0.000	
					3	4	0	0.0	0.00	0.000	
					4	6	3.7	3.7	1.85	0.031	
Combined Reservoir (cm2):			35.22		5	8	9.7	6.0	3.00	0.050	
Inner Reservoir (cm2):			2.16		6	10	15.4	5.7	2.85	0.048	
Kfs (cm/min) (Ksat calculator):			0.001023		7	12	20.7	5.3	2.65	0.044	
					8	14	26.6	5.9	2.95	0.049	
					9	16	31.8	5.2	2.60	0.043	
					10	18	37.4	5.6	2.80	0.047	
					11	20	42.8	5.4	2.70	0.045	

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	10:00 AM	2022017_3003	12	10	1	0	4.1	-	-	-	Combined reservoir used
					2	2	19	14.9	7.45	0.124	
					3	4	20.5	1.5	0.75	0.013	
					4	6	22	1.5	0.75	0.013	
Combined Reservoir (cm2):			35.22		5	8	23.2	1.2	0.60	0.010	
Inner Reservoir (cm2):			2.16		6	10	24.5	1.3	0.65	0.011	
Kfs (cm/min) (Ksat calculator):			0.003089		7	12	25.6	1.1	0.55	0.009	
					8	14	27	1.4	0.70	0.012	
					9	16	28	1.0	0.50	0.008	

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Yandan Gold Mine Tailings Storage Facility (TSF), March 2022
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Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	12:00 PM	2022017_3004	14	10	1	0	0	-	-	-	Combined reservoir used
					2	2	22.6	22.6	11.30	0.188	
					3	4	27.1	4.5	2.25	0.038	
					4	6	30.8	3.7	1.85	0.031	
Combined Reservoir (cm2):		35.22			5	8	33.8	3	1.50	0.025	
Inner Reservoir (cm2):		2.16			6	10	36.8	3	1.50	0.025	
Kfs (cm/min) (Ksat calculator):		0.008032			7	12	39.7	2.9	1.45	0.024	
					8	14	42.4	2.7	1.35	0.023	
					9	16	44.9	2.5	1.25	0.021	
					10	18	47.4	2.5	1.25	0.021	
					11	20	50	2.6	1.30	0.022	
Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	11:00 AM	2022017_3005	14	10	1	0	6	-	-	-	Combined reservoir used
					2	2	7.9	1.9	0.95	0.016	
					3	4	7.9	0.0	0.00	0.000	
					4	6	9.9	2.0	1.00	0.017	
Combined Reservoir (cm2):		35.22			5	8	10.8	0.9	0.45	0.008	
Inner Reservoir (cm2):		2.16			6	10	11.7	0.9	0.45	0.007	
Kfs (cm/min) (Ksat calculator):		0.001853			7	12	12.2	0.5	0.25	0.004	
					8	14	13.1	0.9	0.45	0.008	
					9	16	13.6	0.5	0.25	0.004	
					10	18	14.3	0.7	0.35	0.006	
					11	22	15	0.7	0.35	0.006	
					12	24	15.6	0.6	0.30	0.005	
Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	10:30 AM	2022017_3006	14	10	1	0	46	-	-	-	Internal reservoir used
					2	2	56.7	10.7	5.35	0.089	
					3	4	66	9.3	4.65	0.078	
					4	6	75	9.0	4.50	0.075	
Combined Reservoir (cm2):		35.22			5	8	42	-	-	-	Guelph re-filled
Inner Reservoir (cm2):		2.16			6	10	42.6	0.6	0.30	0.005	
Kfs (cm/min) (Ksat calculator):		0.000341			7	12	43.3	0.7	0.35	0.006	
					8	14	43.8	0.5	0.25	0.004	
					9	16	44.6	0.8	0.40	0.007	
					10	18	45.6	1.0	0.50	0.008	
					11	20	47.2	1.6	0.80	0.013	
					12	22	49	1.8	0.90	0.015	

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Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	1:00 PM	2022017_3007	15	10	1	0	28.4	-	-	-	Combined reservoir used
					2	2	39.5	11.1	5.55	0.093	
					3	4	49	9.5	4.75	0.079	
					4	6	57.6	8.6	4.30	0.072	
Combined Reservoir (cm2):		35.22			5	8	66.3	8.7	4.35	0.073	
Inner Reservoir (cm2):		2.16			6	10	73.8	7.5	3.75	0.063	
Kfs (cm/min) (Ksat calculator):		0.008650			7	12	0	-	-	-	Guelph re-filled
					8	14	7.4	7.4	3.70	0.062	
					9	16	10.4	3.0	1.50	0.025	
					10	18	13.6	3.2	1.60	0.027	
					11	20	16.7	3.1	1.55	0.026	
					12	22	19.5	2.8	1.40	0.023	
					13	24	22.2	2.7	1.35	0.023	
					14	26	24.9	2.7	1.35	0.023	
					15	28	27.7	2.8	1.40	0.023	

Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	2:00 PM	2022017_3008	14	10	1	0	8.1	-	-	-	Combined reservoir used
					2	2	10.01	1.9	0.96	0.016	
					3	4	11.3	1.3	0.65	0.011	
					4	6	12.5	1.2	0.60	0.010	
Combined Reservoir (cm2):		35.22			5	8	13.6	1.1	0.55	0.009	
Inner Reservoir (cm2):		2.16			6	10	14.5	0.9	0.45	0.008	
Kfs (cm/min) (Ksat calculator):		0.002471			7	12	15.5	1.0	0.50	0.008	
					8	14	16.5	1.0	0.50	0.008	
					9	16	17.4	0.9	0.45	0.007	
					10	18	18.2	0.8	0.40	0.007	
					11	20	19.1	0.9	0.45	0.008	
					12	22	20	0.9	0.45	0.007	
					13	24	20.5	0.5	0.25	0.004	
					14	26	21.3	0.8	0.40	0.007	
					15	28	22.2	0.9	0.45	0.007	
					16	30	23	0.8	0.40	0.007	

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Yandan Gold Mine Tailings Storage Facility (TSF), March 2022
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Date	Time	Location	Depth of hole (cm)	Height of water in well (cm)	Reading No.	Time Interval (min)	Water Level in Reservoir (cm)	Water Level Change (cm)	Rate of Water Level Change (cm/min)	Rate of Water Level Change (cm/sec)	Comments
29/03/2022	3:00 PM	2022017_3009	15	10	1	0	7	-	-	-	Combined reservoir used
					2	2	8.2	1.2	0.60	0.010	
					3	4	9.2	1.0	0.50	0.008	
					4	6	10	0.8	0.40	0.007	
Combined Reservoir (cm2):		35.22			5	8	10.6	0.6	0.30	0.005	
Inner Reservoir (cm2):		2.16			6	10	11	0.4	0.20	0.003	Change to inner reservoir
Kfs (cm/min) (Ksat calculator):		0.001175			7	12	21.2	10.2	5.10	0.085	
					8	14	28.6	7.4	3.70	0.062	
					9	16	37.8	9.2	4.60	0.077	
					10	18	46.5	8.7	4.35	0.073	
					11	20	54.3	7.8	3.90	0.065	
					12	22	62.6	8.3	4.15	0.069	
					13	24	69.6	7.0	3.50	0.058	
					14	26	17.9	-	-	-	Guelph re-filled
					15	28	24.1	6.2	3.10	0.052	
					16	30	32.6	8.5	4.25	0.071	
					17	32	38.6	6.0	3.00	0.050	
					18	34	46.1	7.5	3.75	0.063	
					19	36	53	6.9	3.45	0.058	
					20	38	59.3	6.3	3.15	0.053	
					21	40	66.7	7.4	3.70	0.062	
					22	42	72.9	6.2	3.10	0.052	

Attachment C: Static Geochemical Analysis Results

Table C1: Acid Base Account Results for Soil and Tailing Samples

Sample No.	RGS Sample ID	ALS Lab ID	Sample Material	Sample Location	Easting	Northing	pH _(1:5) ¹	EC _(1:5) ¹ (µS/cm)	pH based Acid Forming Potential	Total S (%)	Scr ² (%)	MPA ² (kg H ₂ SO ₄ /t)	ANC ² (kg H ₂ SO ₄ /t)	NAPP ² (kg H ₂ SO ₄ /t)	ANC: MPA Ratio	Geochemical Classification ³
1	2022017_0001	EB2210698001	Soil	Outside TSF	500,759	7,646,672	5.1	29	LAFP	0.01		0.31	3.1	-2.79	10.12	Non-Acid Forming (Barren)
2	2022017_0002	EB2210698002	Soil	Outside TSF	500,904	7,647,693	6.2	87	Inert	0.01		0.31	5.1	-4.79	16.65	Non-Acid Forming (Barren)
3	2022017_0003	EB2210698003	Soil	Outside TSF	499,625	7,647,575	6.6	28	Inert	0.01		0.31	7.2	-6.89	23.51	Non-Acid Forming (Barren)
4	2022017_3001	EB2210698004	Tailings	TSF Cell B	500,342	7,647,447	4.1	1910	LAFP	0.35	0.014	0.43	2.7	-2.27	6.30	Non-Acid Forming (Barren)
5	2022017_3002	EB2210698005	Tailings	TSF Cell B	500,498	7,647,477	3.9	1760	MAFP	0.26	0.021	0.64	3.0	-2.36	4.66	Non-Acid Forming (Barren)
6	2022017_3003	EB2210698006	Tailings	TSF Cell B	500,605	7,647,353	3.9	2860	MAFP	0.59	0.019	0.58	2.1	-1.52	3.61	Non-Acid Forming (Barren)
7	2022017_3004	EB2210698007	Tailings	TSF Cell B	500,262	7,647,227	4.0	800	LAFP	0.31	0.017	0.52	1.0	-0.48	1.92	Non-Acid Forming (Barren)
8	2022017_3005	EB2210698008	Tailings	TSF Cell B	500,434	7,647,242	3.9	2360	MAFP	0.41	0.017	0.52	1.1	-0.58	2.11	Non-Acid Forming (Barren)
9	2022017_3006	EB2210698009	Tailings	TSF Cell B	500,540	7,647,146	3.8	2900	MAFP	0.81	0.016	0.49	1.3	-0.81	2.65	Non-Acid Forming (Barren)
10	2022017_3007	EB2210698010	Tailings	TSF Cell B	500,226	7,646,940	4.3	1280	LAFP	0.36	0.031	0.95	2.2	-1.25	2.32	Non-Acid Forming (Barren)
11	2022017_3008	EB2210698011	Tailings	TSF Cell B	500,380	7,646,930	4.0	1790	LAFP	0.38	0.025	0.77	6.0	-5.23	7.84	Non-Acid Forming (Barren)
12	2022017_3009	EB2210698012	Tailings	TSF Cell B	500,487	7,646,819	3.7	2600	MAFP	0.53	0.018	0.55	0.6	-0.05	1.09	Non-Acid Forming (Barren)
13	2022017_3010	EB2210698013	Tailings	TSF Cell A	499,874	7,647,368	8.5	780	Inert	0.08		2.45	10.3	-7.85	4.20	Non-Acid Forming (Barren)
14	2022017_3011	EB2210698014	Tailings	TSF Cell A	499,842	7,647,167	4.2	4010	LAFP	1.33	0.022	0.67	0.3	0.42	0.37	Non-Acid Forming (Barren)
15	2022017_3012	EB2210698015	Tailings	TSF Cell A	499,853	7,646,938	5.2	3390	LAFP	0.31	0.028	0.86	4.1	-3.24	4.78	Non-Acid Forming (Barren)

Notes:

1. pH and EC for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; NAPP = Net Acid Production Potential.
3. Sample classification criteria detail provided in report text. LAFP = Low acid forming Potential. MAFP = Mild Acid Forming Potential.

Table C2: Multi-Element Results for Soil and Tailing Samples

	RGS Sample Number →		2022017_0001	2022017_0002	2022017_0003	2022017_3001	2022017_3002
	Sampling Date →		3/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
	ALS Laboratory ID →		EB2212717001	EB2212717002	EB2212717003	EB2212717004	EB2212717005
Parameters	Limit of Reporting	NEPC ¹ Health-Based Investigation Level (HILs)-C	Sample 1 Soil Outside TSF	Sample 2 Soil Outside TSF	Sample 3 Soil Outside TSF	Sample 4 TSF Cell B	Sample 5 TSF Cell B
Major Cations		-	All units mg/kg				
Calcium (Ca)	50	-	120	690	1,130	4,770	1,090
Magnesium (Mg)	50	-	1,460	1,530	1,310	120	90
Potassium (K)	50	-	460	1,140	1,410	710	480
Sodium (Na)	50	-	50	<50	<50	980	1,110
Aluminium (Al)	50	-	5,120	4,760	5,100	1,200	510
Iron (Fe)	50	-	22,100	24,900	33,800	8,530	6,140
Minor and Trace Elements		-	All units mg/kg				
Arsenic (As)	0.1	300	4.3	3.5	5.0	88.6	96.6
Boron (B)	50	20,000	<50	<50	<50	<50	<50
Barium (Ba)	0.1	-	37.2	190.0	117.0	85.1	52.0
Beryllium (Be)	0.1	90	0.4	0.6	0.6	0.4	0.2
Cadmium (Cd)	0.1	90	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt (Co)	0.1	300	5.2	9.3	9.2	2.1	1.6
Chromium (Cr)	0.1	-	15.5	22.8	55.4	21.4	6.9
Copper (Cu)	0.1	17,000	7.4	6.5	12.6	10.4	6.5
Mercury (Hg)	0.1	80	<0.1	<0.1	<0.1	0.3	0.4
Manganese (Mn)	0.1	19,000	114.0	392.0	559.0	20.9	15.4
Molybdenum (Mo)	0.1	-	0.2	0.2	0.2	1.4	1.2
Nickel (Ni)	0.1	1,200	12.7	9.7	22.4	3.6	2.8
Lead (Pb)	0.1	600	13.0	27.5	19.4	3.9	2.7
Antimony (Sb)	0.1	-	0.2	0.2	0.3	8.7	6.1
Selenium (Se)	1	700	<1	<1	<1	<1	<1
Thorium (Th)	0.1	-	1.0	3.3	3.8	1.4	0.9
Uranium (U)	0.1	-	0.6	0.4	0.4	1.5	0.5
Vanadium (V)	1	-	14	16	24	4	2
Zinc (Zn)	0.5	30,000	19.2	15.1	26.5	9.4	6.9

Notes:

< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit. ** Guideline level for Cr(VI) = 300 mg/kg.

1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table C2: Multi-Element Results for Soil and Tailing Samples

	RGS Sample Number →		2022017_3003	2022017_3004	2022017_3005	2022017_3006	2022017_3007
	Sampling Date →		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
	ALS Laboratory ID →		EB2212717006	EB2212717007	EB2212717008	EB2212717009	EB2212717010
Parameters	Limit of Reporting	NEPC ¹ Health-Based Investigation Level (HILs)-C	Sample 6 TSF Cell B	Sample 7 TSF Cell B	Sample 8 TSF Cell B	Sample 9 TSF Cell B	Sample 10 TSF Cell B
Major Cations		-	All units mg/kg				
Calcium (Ca)	50	-	2,840	470	1,060	7,620	830
Magnesium (Mg)	50	-	150	90	140	240	150
Potassium (K)	50	-	790	880	1,000	970	1,160
Sodium (Na)	50	-	1,370	910	930	1,670	1,420
Aluminium (Al)	50	-	750	2,930	1,350	2,440	3,780
Iron (Fe)	50	-	9,150	6,480	10,800	10,600	6,880
Minor and Trace Elements		-	All units mg/kg				
Arsenic (As)	0.1	300	106.0	84.4	146.0	128.0	80.8
Boron (B)	50	20,000	<50	<50	<50	<50	<50
Barium (Ba)	0.1	-	47.3	66.7	78.9	81.2	74.2
Beryllium (Be)	0.1	90	0.4	0.4	0.3	0.5	0.8
Cadmium (Cd)	0.1	90	<0.1	<0.1	<0.1	0.1	<0.1
Cobalt (Co)	0.1	300	3.5	2.6	2.9	6.2	4.6
Chromium (Cr)	0.1	-	10.5	15.6	17.4	29.5	22.1
Copper (Cu)	0.1	17,000	7.4	17.1	10.1	16.7	19.0
Mercury (Hg)	0.1	80	0.4	0.1	0.4	0.4	0.2
Manganese (Mn)	0.1	19,000	30.0	21.0	23.5	40.4	31.9
Molybdenum (Mo)	0.1	-	1.3	1.0	1.3	1.8	1.2
Nickel (Ni)	0.1	1,200	5.6	3.8	4.4	8.2	5.7
Lead (Pb)	0.1	600	4.3	4.6	7.5	8.0	3.2
Antimony (Sb)	0.1	-	8.7	7.8	9.6	10.7	9.3
Selenium (Se)	1	700	<1	<1	<1	<1	<1
Thorium (Th)	0.1	-	1.0	1.1	1.4	1.6	1.2
Uranium (U)	0.1	-	0.6	1.0	1.2	1.5	1.3
Vanadium (V)	1	-	2	3	3	4	3
Zinc (Zn)	0.5	30,000	9.6	7.6	10.0	18.5	14.9

Notes:

< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit. ** Guideline level for Cr(VI) = 300 mg/kg.

1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table C2: Multi-Element Results for Soil and Tailing Samples

	RGS Sample Number →		2022017_3008	2022017_3009	2022017_3010	2022017_3011	2022017_3012
	Sampling Date →		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
	ALS Laboratory ID →		EB2212717011	EB2212717012	EB2212717013	EB2212717014	EB2212717015
Parameters	Limit of Reporting	NEPC ¹ Health-Based Investigation Level (HILs)-C	Sample 11 TSF Cell B	Sample 12 TSF Cell B	Sample 13 TSF Cell A	Sample 14 TSF Cell A	Sample 15 TSF Cell A
Major Cations		-	All units mg/kg				
Calcium (Ca)	50	-	1,150	4,240	1,190	1,970	1,480
Magnesium (Mg)	50	-	90	160	450	480	570
Potassium (K)	50	-	990	1,130	520	3,390	920
Sodium (Na)	50	-	920	1,010	410	4,870	2,150
Aluminium (Al)	50	-	540	860	1,250	9,570	1,230
Iron (Fe)	50	-	9,110	9,440	5,250	17,600	6,410
Minor and Trace Elements		-	All units mg/kg				
Arsenic (As)	0.1	300	143.0	156.0	33.8	194.0	54.8
Boron (B)	50	20,000	<50	<50	<50	<50	<50
Barium (Ba)	0.1	-	67.6	59.0	118.0	162.0	118.0
Beryllium (Be)	0.1	90	<0.1	0.3	0.3	1.4	0.2
Cadmium (Cd)	0.1	90	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt (Co)	0.1	300	1.2	3.8	1.9	5.1	1.4
Chromium (Cr)	0.1	-	7.7	7.8	12.7	94.7	7.3
Copper (Cu)	0.1	17,000	9.1	6.5	7.4	43.2	8.4
Mercury (Hg)	0.1	80	0.4	0.3	0.2	0.2	0.1
Manganese (Mn)	0.1	19,000	10.4	27.8	60.7	30.9	47.9
Molybdenum (Mo)	0.1	-	1.4	3.0	0.7	2.2	1.5
Nickel (Ni)	0.1	1,200	2.0	5.8	4.0	5.8	1.8
Lead (Pb)	0.1	600	5.3	12.8	3.2	11.3	4.8
Antimony (Sb)	0.1	-	8.2	12.8	3.5	8.6	3.0
Selenium (Se)	1	700	<1	<1	<1	1	<1
Thorium (Th)	0.1	-	1.3	1.8	1.0	2.4	1.3
Uranium (U)	0.1	-	0.5	1.2	0.4	3.3	0.5
Vanadium (V)	1	-	3	2	4	6	4
Zinc (Zn)	0.5	30,000	6.9	10.8	6.4	17.7	7.4

Notes:

< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit. ** Guideline level for Cr(VI) = 300 mg/kg.

1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table C3: Geochemical Abundance Index Results for Soil and Tailing Samples

	RGS Sample Number →		2022017_0001	2022017_0002	2022017_0003	2022017_3001	2022017_3002
	Sampling Date →		3/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
	ALS Laboratory ID →		EB2212717001	EB2212717002	EB2212717003	EB2212717004	EB2212717005
Parameters	Limit of Reporting	Median Crustal Abundance ^{1,2,3}	Sample 1 Soil Outside TSF	Sample 2 Soil Outside TSF	Sample 3 Soil Outside TSF	Sample 4 TSF Cell B	Sample 5 TSF Cell B
Major Cations			Geochemical Abundance Index				
	(All units in mg/kg)						
Calcium (Ca)	50	15,000	0.0	0.0	0.0	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0	0.0	0.0
Minor and Trace Elements			Geochemical Abundance Index				
	(All units in mg/kg)						
Arsenic (As)	0.1	6	0.0	0.0	0.0	3.3	3.4
Boron (B)	50	20	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	0.0	0.4	0.4	0.0	0.0
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.0	0.0	0.0	0.0	0.0
Mercury (Hg)	0.1	0.06	0.0	0.0	0.0	1.7	2.2
Manganese (Mn)	0.1	1000	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0.1	1	0.0	0.0	0.0	2.5	2.0
Selenium (Se)	1	0.4	0.0	0.0	0.0	0.0	0.0
Thorium (Th)	0.1	9	0.0	0.0	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0	0.0	0.0

Notes:

GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table C3: Geochemical Abundance Index Results for Soil and Tailing Samples

	RGS Sample Number →		2022017_3003	2022017_3004	2022017_3005	2022017_3006	2022017_3007
	Sampling Date →		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
	ALS Laboratory ID →		EB2212717006	EB2212717007	EB2212717008	EB2212717009	EB2212717010
Parameters	Limit of Reporting	Median Crustal Abundance ^{1,2,3}	Sample 6 TSF Cell B	Sample 7 TSF Cell B	Sample 8 TSF Cell B	Sample 9 TSF Cell B	Sample 10 TSF Cell B
Major Cations			Geochemical Abundance Index				
	(All units in mg/kg)						
Calcium (Ca)	50	15,000	0.0	0.0	0.0	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0	0.0	0.0
Minor and Trace Elements			Geochemical Abundance Index				
	(All units in mg/kg)						
Arsenic (As)	0.1	6	3.6	3.2	4.0	3.8	3.2
Boron (B)	50	20	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	0.0	0.0	0.0	0.2	0.8
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.0	0.0	0.0	0.0	0.0
Mercury (Hg)	0.1	0.06	2.2	0.2	2.2	2.2	1.2
Manganese (Mn)	0.1	1000	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0.1	1	2.5	2.4	2.7	2.8	2.6
Selenium (Se)	1	0.4	0.0	0.0	0.0	0.0	0.0
Thorium (Th)	0.1	9	0.0	0.0	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0	0.0	0.0

Notes:

GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table C3: Geochemical Abundance Index Results for Soil and Tailing Samples

	RGS Sample Number →		2022017_3008	2022017_3009	2022017_3010	2022017_3011	2022017_3012
	Sampling Date →		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
	ALS Laboratory ID →		EB2212717011	EB2212717012	EB2212717013	EB2212717014	EB2212717015
Parameters	Limit of Reporting	Median Crustal Abundance ^{1,2,3}	Sample 11 TSF Cell B	Sample 12 TSF Cell B	Sample 13 TSF Cell A	Sample 14 TSF Cell A	Sample 15 TSF Cell A
Major Cations			Geochemical Abundance Index				
	(All units in mg/kg)						
Calcium (Ca)	50	15,000	0.0	0.0	0.0	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0	0.0	0.0
Minor and Trace Elements			Geochemical Abundance Index				
	(All units in mg/kg)						
Arsenic (As)	0.1	6	4.0	4.1	1.9	4.4	2.6
Boron (B)	50	20	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	0.0	0.0	0.0	1.6	0.0
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.0	0.0	0.0	0.0	0.0
Mercury (Hg)	0.1	0.06	2.2	1.7	1.2	1.2	0.2
Manganese (Mn)	0.1	1000	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.7	0.0	0.3	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0.1	1	2.5	3.1	1.2	2.5	1.0
Selenium (Se)	1	0.4	0.0	0.0	0.0	0.7	0.0
Thorium (Th)	0.1	9	0.0	0.0	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0	0.1	0.0
Vanadium (V)	1	90	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0	0.0	0.0

Notes:

GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table C4: Multi-Element Test Results for Water Extracts from Soil and Tailing Samples

		RGS Sample Number →		2022017_0001	2022017_0002	2022017_0003	2022017_3001	2022017_3002
		Sample Date →		3/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
		ALS Laboratory ID →		EB2212717001	EB2212717002	EB2212717003	EB2212717004	EB2212717005
Parameters	Limit of Reporting	Aquatic Ecosystems (freshwater) ¹	Livestock Drinking Water ²	Sample 1 Soil Outside TSF	Sample 2 Soil Outside TSF	Sample 3 Soil Outside TSF	Sample 4 TSF Cell B	Sample 5 TSF Cell B
pH	0.01 pH unit	6 to 9	-	5.1	6.6	5.9	4.1	4.0
Electrical Conductivity (µS/cm)	1 µS/cm	<1,000 [#]	3,580 [^]	25	27	65	1,910	1,600
Carbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2
Bicarbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	9	49	64	<0.2	<0.2
Total Alkalinity (mg CaCO ₃ /L)	0.2	-	-	9	49	64	<0.2	<0.2
Acidity (mg CaCO ₃ /L)	0.2	-	-	162	50	31	178	116
Net Alkalinity (mg CaCO ₃ /L)	0.2	-	-	-153	-2	33	-177	-115
Major Ions		All units mg/L						
Calcium (Ca)	2	-	1,000	<2	2	2	336	142
Magnesium (Mg)	2	-	-	<2	2	2	18	18
Potassium (K)	2	-	-	<2	8	8	<2	2
Sodium (Na)	2	-	-	6	<2	<2	136	180
Chloride (Cl)	2	-	-	4	2	<2	152	136
Fluoride (F)	0.4	-	2	<0.4	<0.4	<0.4	0.4	0.4
Sulfate (SO ₄ ²⁻)	2	-	1,000	8	6	4	992	658
Trace Metals/Metalloids		All units mg/L						
Aluminium (Al)	0.02	0.055	5	0.82	0.32	0.96	3.98	4.82
Arsenic (As)	0.002	0.024 ^{**}	0.5	<0.002	<0.002	<0.002	0.004	0.022
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	0.008	0.068	0.016	<0.002	0.002
Beryllium (Be)	0.002	-	-	<0.002	<0.002	<0.002	0.012	0.016
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	<0.002	<0.002	0.004	0.004
Cobalt (Co)	0.002	-	1	<0.002	<0.002	<0.002	0.184	0.268
Chromium (Cr)	0.002	0.001 ^{(hex)*}	1 ^(total)	<0.002	<0.002	<0.002	0.004	0.004
Copper (Cu)	0.002	0.0014	1	<0.002	<0.002	<0.002	0.062	0.062
Iron (Fe)	0.2	-	-	1.2	0.4	16.2	0.4	0.6
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	0.068	0.106	0.010	2.360	2.060
Molybdenum (Mo)	0.002	-	0.15	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	<0.002	<0.002	0.002	0.264	0.350
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	<0.002
Antimony (Sb)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	<0.002	0.006	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01	0.74	0.89

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values.

* Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Table C4: Multi-Element Test Results for Water Extracts from Soil and Tailing Samples

		RGS Sample Number →		2022017_3003	2022017_3004	2022017_3005	2022017_3006	2022017_3007
		Sample Date →		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
		ALS Laboratory ID →		EB2212717006	EB2212717007	EB2212717008	EB2212717009	EB2212717010
Parameters	Limit of Reporting	Aquatic Ecosystems (freshwater) ¹	Livestock Drinking Water ²	Sample 6 TSF Cell B	Sample 7 TSF Cell B	Sample 8 TSF Cell B	Sample 9 TSF Cell B	Sample 10 TSF Cell B
pH	0.01 pH unit	6 to 9	-	3.9	4.0	3.9	3.8	4.3
Electrical Conductivity (µS/cm)	1 µS/cm	<1,000 [#]	3,580 [^]	2,860	800	2,040	2,900	1,280
Carbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2
Bicarbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2
Total Alkalinity (mg CaCO ₃ /L)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2
Acidity (mg CaCO ₃ /L)	0.2	-	-	214	182	248	346	198
Net Alkalinity (mg CaCO ₃ /L)	0.2	-	-	-213	-181	-247	-345	-197
Major Ions		All units mg/L						
Calcium (Ca)	2	-	1,000	526	98	508	618	104
Magnesium (Mg)	2	-	-	32	14	20	36	22
Potassium (K)	2	-	-	<2	<2	<2	<2	<2
Sodium (Na)	2	-	-	204	82	96	222	180
Chloride (Cl)	2	-	-	52	46	10	80	148
Fluoride (F)	0.4	-	2	0.6	0.6	0.8	0.8	0.2
Sulfate (SO ₄ ²⁻)	2	-	1,000	1,820	438	1,552	2,040	544
Trace Metals/Metalloids		All units mg/L						
Aluminium (Al)	0.02	0.055	5	17.22	6.28	17.22	16.48	0.84
Arsenic (As)	0.002	0.024 ^{**}	0.5	0.018	0.004	0.018	0.006	<0.002
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Beryllium (Be)	0.002	-	-	0.034	0.016	0.018	0.044	0.008
Cadmium (Cd)	0.002	0.0002	0.01	0.012	0.004	0.008	0.018	0.006
Cobalt (Co)	0.002	-	1	0.652	0.270	0.478	0.824	0.404
Chromium (Cr)	0.002	0.001 ^{(hex)*}	1 ^(total)	0.008	0.004	0.008	0.012	<0.002
Copper (Cu)	0.002	0.0014	1	0.134	0.074	0.140	0.204	0.020
Iron (Fe)	0.2	-	-	<0.2	<0.2	0.2	<0.2	0.4
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	4.980	1.920	2.700	5.300	3.020
Molybdenum (Mo)	0.002	-	0.15	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	0.944	0.360	0.640	1.134	0.524
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	<0.002
Antimony (Sb)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	0.010	0.006	0.012	0.030	0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	1.39	0.55	1.10	2.06	0.88

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values.

* Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Table C4: Multi-Element Test Results for Water Extracts from Soil and Tailing Samples

		RGS Sample Number →		2022017_3008	2022017_3009	2022017_3010	2022017_3011	2022017_3012
		Sample Date →		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
		ALS Laboratory ID →		EB2212717011	EB2212717012	EB2212717013	EB2212717014	EB2212717015
Parameters	Limit of Reporting	Aquatic Ecosystems (freshwater) ¹	Livestock Drinking Water ²	Sample 11 TSF Cell B	Sample 12 TSF Cell B	Sample 13 TSF Cell A	Sample 14 TSF Cell A	Sample 15 TSF Cell A
pH	0.01 pH unit	6 to 9	-	4.1	3.7	8.6	4.2	5.4
Electrical Conductivity (µS/cm)	1 µS/cm	<1,000 [#]	3,580 [^]	1,760	2,600	738	3,810	3,130
Carbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2
Bicarbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	<0.2	<0.2	128	<0.2	12
Total Alkalinity (mg CaCO ₃ /L)	0.2	-	-	<0.2	<0.2	128	<0.2	12
Acidity (mg CaCO ₃ /L)	0.2	-	-	140	330	2	544	50
Net Alkalinity (mg CaCO ₃ /L)	0.2	-	-	-139	-329	127	-543	-37
Major Ions		All units mg/L						
Calcium (Ca)	2	-	1,000	302	444	70	358	312
Magnesium (Mg)	2	-	-	14	36	8	70	52
Potassium (K)	2	-	-	10	<2	20	20	50
Sodium (Na)	2	-	-	130	176	68	752	452
Chloride (Cl)	2	-	-	168	68	64	700	480
Fluoride (F)	0.4	-	2	<0.4	1.6	0.4	0.2	<0.4
Sulfate (SO ₄ ²⁻)	2	-	1,000	846	1,628	274	1,776	1,318
Trace Metals/Metalloids		All units mg/L						
Aluminium (Al)	0.02	0.055	5	1.46	33.80	0.04	2.30	0.04
Arsenic (As)	0.002	0.024 ^{**}	0.5	0.032	0.06	0.014	0.014	0.004
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	0.004	0.004	0.044	<0.002	0.012
Beryllium (Be)	0.002	-	-	<0.002	0.018	<0.002	0.010	<0.002
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	0.008	<0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	1	0.098	0.690	0.008	0.108	0.052
Chromium (Cr)	0.002	0.001 ^{(hex)*}	1 ^(total)	<0.002	0.016	<0.002	0.002	<0.002
Copper (Cu)	0.002	0.0014	1	0.038	0.146	0.006	0.028	0.004
Iron (Fe)	0.2	-	-	0.4	<0.2	<0.2	<0.2	<0.2
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	1.008	5.440	0.018	0.810	1.624
Molybdenum (Mo)	0.002	-	0.15	<0.002	<0.002	0.004	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	0.132	1.048	<0.002	0.128	0.014
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	<0.002
Antimony (Sb)	0.002	-	-	<0.002	0.002	<0.002	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	0.006	<0.002	0.004	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	0.65	1.62	<0.01	0.48	0.05

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values.

* Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Table C5: Physical and Nutrient Test Results for Soils and Tailings from the Yandan Project

	RGS Sample Number →		2022017_0001	2022017_0002	2022017_0003	2022017_3001	2022017_3002
	Sampling Date →		3/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
	ALS Laboratory ID →		EB2212717001	EB2212717002	EB2212717003	EB2212717004	EB2212717005
Exchangeable Cations	Laboratory Limit of Reporting	Units	Sample 1 Soil Outside TSF	Sample 2 Soil Outside TSF	Sample 3 Soil Outside TSF	Sample 4 TSF Cell B	Sample 5 TSF Cell B
Exchangeable Calcium	0.1	meq/100g	0.5	3	4.8	----	2.5
Exchangeable Magnesium	0.1	meq/100g	1	2.9	1.5	----	<0.1
Exchangeable Potassium	0.1	meq/100g	0.2	0.6	0.5	----	<0.1
Exchangeable Sodium	0.1	meq/100g	0.2	<0.1	<0.1	----	0.1
Cation Exchange Capacity	0.1	meq/100g	4.4	6.6	6.9	----	4.8
Exchangeable Sodium Percent	0.1	%	4.5%	<0.02%	<0.01%	----	2.1%
Calcium/Magnesium Ratio	0.1	-	0.5	1.0	3.2	----	----
Magnesium/Potassium Ratio	0.1	-	0.5	1	3.2	----	----
Cation Exchange Capacity	-	-	5.8	5.0	2.9	----	3.5
Soil Nutrients	Laboratory Limit of Reporting	Units					
Total Nitrogen	20	mg/kg	730	700	660	----	140
Nitrite	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1
Nitrate	0.1	mg/kg	0.2	29	7.4	----	18.5
Ammonia	20	mg/kg	<20	<20	<20	----	<20
Total Phosphorus	2	mg/kg	158	154	167	----	468
Reactive Phosphorus	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Soil Porosity		Units					
Soil Particle Density		tonnes/m ³	2.58	2.62	2.58	2.54	2.52
Dry Bulk Density		g/cm ³	1.50	1.08	1.62	1.40	1.45
In-situ Bulk Density		g/cm ³	1.52	1.09	1.64	1.43	1.49
Total Porosity		%	42%	59%	37%	45%	43%
Sample Moisture		%	1%	1%	1%	3%	3%

Table C5: Physical and Nutrient Test Results for Soils and Tailings from the Yandan Project

		RGS Sample Number →	2022017_3003	2022017_3004	2022017_3005	2022017_3006	2022017_3007
		Sampling Date →	03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
		ALS Laboratory ID →	EB2212717006	EB2212717007	EB2212717008	EB2212717009	EB2212717010
Exchangeable Cations	Laboratory Limit of Reporting	Units	Sample 6 TSF Cell B	Sample 7 TSF Cell B	Sample 8 TSF Cell B	Sample 9 TSF Cell B	Sample 10 TSF Cell B
Exchangeable Calcium	0.1	meq/100g	----	----	4.3	----	----
Exchangeable Magnesium	0.1	meq/100g	----	----	<0.1	----	----
Exchangeable Potassium	0.1	meq/100g	----	----	<0.1	----	----
Exchangeable Sodium	0.1	meq/100g	----	----	<0.1	----	----
Cation Exchange Capacity	0.1	meq/100g	----	----	1.9	----	----
Exchangeable Sodium Percent	0.1	%	----	----	<0.05%	----	----
Calcium/Magnesium Ratio	0.1	-	----	----	----	----	----
Magnesium/Potassium Ratio	0.1	-	----	----	----	----	----
Cation Exchange Capacity	-	-	----	----	5.3	----	----
Soil Nutrients	Laboratory Limit of Reporting	Units					
Total Nitrogen	20	mg/kg	----	----	120	----	----
Nitrite	0.1	mg/kg	----	----	<0.1	----	----
Nitrate	0.1	mg/kg	----	----	1.7	----	----
Ammonia	20	mg/kg	----	----	<20	----	----
Total Phosphorus	2	mg/kg	----	----	519	----	----
Reactive Phosphorus	0.1	mg/kg	<0.1	<0.1	0.1	<0.1	<0.1
Soil Porosity		Units					
Soil Particle Density		tonnes/m ³	2.53	2.58	2.52	2.39	2.58
Dry Bulk Density		g/cm ³	1.32	1.11	1.29	1.34	1.21
In-situ Bulk Density		g/cm ³	1.41	1.18	1.41	1.44	1.31
Total Porosity		%	48%	57%	49%	44%	53%
Sample Moisture		%	6%	6%	8%	7%	7%

Table C5: Physical and Nutrient Test Results for Soils and Tailings from the Yandan Project

		RGS Sample Number →	2022017_3008	2022017_3009	2022017_3010	2022017_3011	2022017_3012
		Sampling Date →	03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022
		ALS Laboratory ID →	EB2212717011	EB2212717012	EB2212717013	EB2212717014	EB2212717015
Exchangeable Cations	Laboratory Limit of Reporting	Units	Sample 11 TSF Cell B	Sample 12 TSF Cell B	Sample 13 TSF Cell A	Sample 14 TSF Cell A	Sample 15 TSF Cell A
Exchangeable Calcium	0.1	meq/100g	2	----	2.2	7	5.4
Exchangeable Magnesium	0.1	meq/100g	<0.1	----	<0.2	0.4	0.4
Exchangeable Potassium	0.1	meq/100g	0.1	----	0.4	0.9	0.2
Exchangeable Sodium	0.1	meq/100g	<0.1	----	0.4	1	0.2
Cation Exchange Capacity	0.1	meq/100g	3.2	----	3	10.5	2.5
Exchangeable Sodium Percent	0.1	%	<0.03%	----	13.3%	9.5%	8.0%
Calcium/Magnesium Ratio	0.1	-	----	----	----	17.5	13.5
Magnesium/Potassium Ratio	0.1	-	<0.1	----	<0.2	0.4	1.5
Cation Exchange Capacity	-	-	2.7	----	3.0	10.0	6.3
Soil Nutrients	Laboratory Limit of Reporting	Units					
Total Nitrogen	20	mg/kg	120	----	150	360	110
Nitrite	0.1	mg/kg	<0.1	----	<0.1	0.2	<0.1
Nitrate	0.1	mg/kg	19	----	0.1	47.6	0.4
Ammonia	20	mg/kg	<20	----	<20	<20	<20
Total Phosphorus	2	mg/kg	414	----	516	880	466
Reactive Phosphorus	0.1	mg/kg	0.1	1.3	<0.1	<0.1	<0.1
Soil Porosity		Units					
Soil Particle Density		tonnes/m ³	2.57	2.54	2.58	2.31	2.60
Dry Bulk Density		g/cm ³	1.23	1.30	1.25	1.26	1.22
In-situ Bulk Density		g/cm ³	1.27	1.41	1.28	1.46	1.26
Total Porosity		%	52%	49%	51%	46%	53%
Sample Moisture		%	3%	8%	2%	14%	3%

Attachment D: Kinetic Geochemical Analysis Results

KLC 1
Cell B Tailings + 4 g/kg CaCO₃

			Weight (kg)		4.00	Total S (%)	0.440	ANC		6.3		
			pH (1:5)		7.20	Scr (%)	0.020	NAPP		-5.7		
			EC (µS/cm)		9,020	MPA	0.61	ANC:MPA		10.3		
Date					09-Jun-22	15-Jun-22	24-Jun-22	30-Jun-22				
Number of Weeks					1	2	3	4				
Leach Number					1	2	3	4				
ALS Laboratory Number					EB2216488004	EB2217195001	EB2218381001	EB2218962001				
Volume On (L)					1.4	1.4	1.4	1.4				
Volume Off (L)					0.444	1.125	1.074	1.059				
Cum. Volume (L)					0.4	1.569	2.643	3.702				
Pore Volumes			Water Quality Guidelines		0.329	1.162	1.958	2.742				
pH (RGS Measurement)			6 to 9	-	6.70	6.48	6.61	6.53				
pH (ALS Measurement)					7.20	7.55	7.44	6.87				
pH (deionised water used in test)					5.99	6.08	6.75	5.98				
EC (RGS Measurement) (µS/cm)			<1,000 #	3,580^	11,010	8,650	3,250	2,460				
EC (ALS Measurement) (µS/cm)					9,020	8,610	3,590	2,540				
Acidity (mg/L as CaCO ₃)*			-	-	21	43	34	11				
Alkalinity (mg/L as CaCO ₃)*			-	-	73	220	162	129				
Net Alkalinity (mg/L as CaCO ₃)*					52	177	128	118				
Major Ions (mg/L)					Elements		LoR		Aquatic Ecosystems (Freshwater) ¹		Livestock Drinking Water ²	
Calcium					Ca		1		-		1,000	
Potassium					K		1		-		-	
Magnesium					Mg		1		-		-	
Sodium					Na		1		-		-	
Chloride					Cl		1		-		-	
Fluoride					F ⁴		0.1		-		2	
Sulfate					SO		1		-		1,000	
Trace metals/ metalloids (mg/L)					Elements		LoR		Aquatic Ecosystems (Freshwater) ¹		Livestock Drinking Water ²	
Aluminium					Al		0.01		0.055		5	
Antimony					Sb		0.001		-		-	
Arsenic					As		0.001		0.024		0.5	
Beryllium					Be		0.001		-		-	
Barium					Ba		0.001		-		-	
Cadmium					Cd		1E-04		0.0002		0.01	
Chromium					Cr		0.0010		0.001		1	
Cobalt					Co		0.001		-		1	
Copper					Cu		0.001		0.0014		1	
Lead					Pb		0.001		0.0034		0.1	
Manganese					Mn		0.001		1.9		-	
Molybdenum					Mo		0.001		-		0.15	
Nickel					Ni		0.001		0.011		1	
Selenium					Se		0.01		0.011		0.02	
Thorium					Th		0.001		-		-	
Uranium					U		0.001		-		-	
Vanadium					V		0.01		-		-	
Zinc					Zn		0.005		0.008		-	
Boron					B		0.05		0.37		5	
Iron					Fe		0.05		-		-	
Mercury					Hg		1E-04		0.0006		0.002	

Notes:

ANZG 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

1. Trigger values for freshwater aquatic ecosystems (95% species protection level).

2. Recommended guideline limits for Livestock Drinking Water.

< indicates less than the analytical detection limit. ³

* Acidity and alkalinity data calculated in mg CaCO₃ /L.

Shaded cells exceed applied guideline values.

(tri)* 0.024 mg/L for trivalent Arsenic (III). 0.013 mg/L for pentavalent Arsenic (V)
(hex)* Cr (VI) = hexavalent.

for still water bodies only, moving rivers at low flow rates should not exceed 2,200 µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

KLC 2
Cell B Tailings + 2 g/kg CaCO₃

			Weight (kg)		4.00	Total S (%)	0.440	ANC		4.2
			pH (1:5)		7.56	Scr (%)	0.020	NAPP		-3.6
			EC (µS/cm)		10,900	MPA	0.61	ANC:MPA		6.9
Date					09-Jun-22	15-Jun-22	24-Jun-22	30-Jun-22	07-Jul-22	14-Jul-22
Number of Weeks					1	2	3	4	5	6
Leach Number					1	2	3	4	5	6
ALS Laboratory Number					EB2216488001	EB2217195002	EB2218381002	EB2218962002	EB2219972001	EB2220545001
Volume On (L)					1.9	1.4	1.4	1.4	1.4	1.4
Volume Off (L)					0.638	1.206	1.080	1.124	1.165	1.083
Cum. Volume (L)					0.6	1.844	2.924	4.048	5.213	6.296
Pore Volumes					Water Quality Guidelines		0.473	1.366	2.166	2.999
pH (RGS Measurement)			6 to 9	-	7.01	6.83	6.99	6.98	6.89	6.83
pH (ALS Measurement)					7.56	7.76	7.74	7.37	7.72	7.51
pH (deionised water used in test)					5.99	6.08	6.75	5.98	5.68	6.20
EC (RGS Measurement) (µS/cm)			<1,000 #	3,580^	17,710	4,950	2,530	2,350	2,274	2,331
EC (ALS Measurement) (µS/cm)					10,900	5,060	2,790	2,400	2,300	2,280
Acidity (mg/L as CaCO ₃)*					-	-	15	26	20	8
Alkalinity (mg/L as CaCO ₃)*			-	-	194	224	164	147	138	118
Net Alkalinity (mg/L as CaCO ₃)*					179	198	144	139	126	110
Major Ions (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Calcium	Ca	1	-	1,000	429	502	644	590	594	574
Potassium	K	1	-	-	9	2	1	<1	<1	<1
Magnesium	Mg	1	-	-	379	105	40	16	6	2
Sodium	Na	1	-	-	3480	584	102	29	14	8
Chloride	Cl	1	-	-	1850	321	10	3	2	1
Fluoride	F ⁴	0.1	-	2	0.3	0.3	0.2	0.3	0.3	0.2
Sulfate	SO	1	-	1,000	5,650	2,390	1,510	1,490	1,370	1370
Trace metals/ metalloids (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Aluminium	Al	0.01	0.055	5	0.02	0.08	<0.01	<0.01	<0.01	<0.01
Antimony	Sb	0.001	-	-	0.024	0.027	0.022	0.030	0.027	0.032
Arsenic	As	0.001	0.024	0.5	0.012	0.025	0.031	0.069	0.044	0.044
Beryllium	Be	0.001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	Ba	0.001	-	-	0.031	0.002	0.001	0.001	0.001	0.001
Cadmium	Cd	1E-04	0.0002	0.01	0.016	0.0026	0.0015	0.0012	0.0009	0.0008
Chromium	Cr	0.0010	0.001	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	Co	0.001	-	1	1.68	0.513	0.481	0.328	0.184	0.134
Copper	Cu	0.001	0.0014	1	0.013	0.005	0.006	0.004	0.006	0.006
Lead	Pb	0.001	0.0034	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	Mn	0.001	1.9	-	32.8	8.7	5.1	3.7	2.3	1.63
Molybdenum	Mo	0.001	-	0.15	0.003	0.003	0.003	0.002	0.004	0.004
Nickel	Ni	0.001	0.011	1	1.51	0.287	0.167	0.113	0.077	0.06
Selenium	Se	0.01	0.011	0.02	0.10	0.01	<0.01	<0.01	<0.01	<0.01
Thorium	Th	0.001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	U	0.001	-	-	0.015	0.071	0.055	0.041	0.037	0.025
Vanadium	V	0.01	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	Zn	0.005	0.008	-	0.738	0.087	0.045	0.035	0.024	0.016
Boron	B	0.05	0.37	5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	Fe	0.05	-	-	0.09	<0.05	0.21	<0.05	<0.05	<0.05
Mercury	Hg	1E-04	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Notes:

ANZG 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

1. Trigger values for freshwater aquatic ecosystems (95% species protection level).

2. Recommended guideline limits for Livestock Drinking Water.

< indicates less than the analytical detection limit.

* Acidity and alkalinity data calculated in mg CaCO₃ /L.

Shaded cells exceed applied guideline values.

(tri)* 0.024 mg/L for trivalent Arsenic (III), 0.013 mg/L for pentavalent Arsenic (V)

(hex)* Cr (VI) = hexavalent.

for still water bodies only, moving rivers at low flow rates should not exceed 2,200 µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

KLC 3
Cell B Tailings

			Weight (kg)		4.00	Total S (%)	0.440	ANC		2.2
			pH (1:5)		3.91	Scr (%)	0.020	NAPP		-1.6
			EC (µS/cm)		7,330	MPA	0.61	ANC:MPA		3.6
Date					09-Jun-22	15-Jun-22	24-Jun-22	30-Jun-22	07-Jul-22	14-Jul-22
Number of Weeks					1	2	3	4	5	6
Leach Number					1	2	3	4	5	6
ALS Laboratory Number					EB2216488002	EB2217195003	EB2218381003	EB2218962003	EB2219972002	EB2220545002
Volume On (L)					1.4	1.4	1.4	1.4	1.4	1.4
Volume Off (L)					0.412	1.191	1.159	1.132	1.157	1.081
Cum. Volume (L)					0.4	1.603	2.762	3.894	5.051	6.132
Pore Volumes	Water Quality Guidelines		0.305	1.187	2.046	2.884	3.741	4.542		
pH (RGS Measurement)	6 to 9	-	3.93	3.58	4.10	3.98	3.87	4.08		
pH (ALS Measurement)			3.91	3.67	4.27	4.05	4.09	4.28		
pH (deionised water used in test)			5.99	6.08	6.75	5.98	5.68	6.20		
EC (RGS Measurement) (µS/cm)	<1,000 #	3,580^	8,820	10,420	3,280	2,380	1,903	1,622		
EC (ALS Measurement) (µS/cm)			7,330	10,000	3,810	2,440	969	1,610		
Acidity (mg/L as CaCO ₃)*	-	-	469	657	290	172	109	101		
Alkalinity (mg/L as CaCO)*	-	-	<1	<1	<1	<1	<1	<1		
Net Alkalinity (mg/L as CaCO)*			-469	-657	-290	-172	-109	-101		
Major Ions (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Calcium	Ca	1	-	1,000	353	429	537	527	428	340
Potassium	K	1	-	-	6	5	2	<1	<1	<1
Magnesium	Mg	1	-	-	166	213	53	12	2	<1
Sodium	Na	1	-	-	1330	1570	258	54	16	8
Chloride	Cl	1	-	-	904	1030	135	11	3	1
Fluoride	F ⁴	0.1	-	2	0.2	0.2	1.6	0.4	0.6	0.5
Sulfate	SO	1	-	1,000	3,870	4,760	2,110	1,590	1,120	867
Trace metals/ metalloids (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Aluminium	Al	0.01	0.055	5	63.0	99.5	19.6	14.2	10.1	4.88
Antimony	Sb	0.001	-	-	0.004	0.004	0.006	0.005	0.005	0.007
Arsenic	As	0.001	0.024	0.5	0.046	0.134	0.667	0.629	0.163	0.818
Beryllium	Be	0.001	-	-	0.163	0.238	0.082	0.038	0.029	0.017
Barium	Ba	0.001	-	-	0.007	0.005	0.002	0.001	0.001	0.002
Cadmium	Cd	1E-04	0.0002	0.01	0.0662	0.0806	0.0163	0.006	0.0022	0.001
Chromium	Cr	0.0010	0.001	1	0.052	0.062	0.039	0.018	0.010	0.008
Cobalt	Co	0.001	-	1	3.33	3.67	0.941	0.326	0.115	0.081
Copper	Cu	0.001	0.0014	1	0.628	0.83	0.014	0.072	0.034	0.008
Lead	Pb	0.001	0.0034	0.1	0.001	0.002	0.002	0.003	0.002	0.002
Manganese	Mn	0.001	1.9	-	25.7	31.0	7.2	1.9	0.4	0.212
Molybdenum	Mo	0.001	-	0.15	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	Ni	0.001	0.011	1	4.40	5.01	1.39	0.524	0.179	0.107
Selenium	Se	0.01	0.011	0.02	0.07	0.05	0.01	<0.01	<0.01	<0.01
Thorium	Th	0.001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	U	0.001	-	-	0.074	0.13	0.017	0.014	0.010	0.004
Vanadium	V	0.01	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	Zn	0.005	0.008	-	8.050	8.710	2.460	0.985	0.320	0.182
Boron	B	0.05	0.37	5	0.06	0.08	<0.05	<0.05	<0.05	<0.05
Iron	Fe	0.05	-	-	1.1	1.1	46.0	30.5	15.6	27.8
Mercury	Hg	1E-04	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Notes:

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1. Trigger values for freshwater aquatic ecosystems (95% species protection level).

2. Recommended guideline limits for Livestock Drinking Water.

< indicates less than the analytical detection limit.

* Acidity and alkalinity data calculated in mg CaCO₃ /L.

Shaded cells exceed applied guideline values.

(tri)* 0.024 mg/L for trivalent Arsenic (III), 0.013 mg/L for pentavalent Arsenic (V)

(hex)* Cr (VI) = hexavalent.

for still water bodies only, moving rivers at low flow rates should not exceed 2,200 µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

KLC 4
Cell A Tailings + 4 g/kg CaCO₃

			Weight (kg)		4.00	Total S (%)	0.570	ANC		9.0
			pH (1:5)		7.35	Scr (%)	0.043	NAPP		-7.7
			EC (µS/cm)		22,400	MPA	1.32	ANC:MPA		6.8
Date					09-Jun-22	15-Jun-22	24-Jun-22	30-Jun-22		
Number of Weeks					1	2	3	4		
Leach Number					1	2	3	4		
ALS Laboratory Number					EB2216488003	EB2217195004	EB2218381004	EB2218962004		
Volume On (L)					1.9	1.4	1.4	1.4		
Volume Off (L)					0.256	0.258	0.529	0.271		
Cum. Volume (L)					0.3	0.514	1.043	1.314		
Pore Volumes			Water Quality Guidelines		0.190	0.381	0.773	0.973		
pH (RGS Measurement)			6 to 9	-	7.34	7.32	6.78	6.38		
pH (ALS Measurement)					7.35	7.80	7.11	5.96		
pH (deionised water used in test)			<1,000 #	-	5.99	6.08	6.75	5.98		
EC (RGS Measurement) (µS/cm)					27,000	31,700	11,760	4,130		
EC (ALS Measurement) (µS/cm)					22,400	39,600	12,700	4,000		
Acidity (mg/L as CaCO ₃)*			-	-	22	25	30	60		
Alkalinity (mg/L as CaCO ₃)*			-	-	102	272	143	8		
Net Alkalinity (mg/L as CaCO ₃)*					80	247	113	-52		
Major Ions (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Calcium	Ca	1	-	1,000	507	579	489	487		
Potassium	K	1	-	-	277	414	142	88		
Magnesium	Mg	1	-	-	683	1160	306	118		
Sodium	Na	1	-	-	6560	10000	2180	323		
Chloride	Cl	1	-	-	7600	10500	1550	127		
Fluoride	F ⁴	0.1	-	2	0.2	0.3	0.2	0.2		
Sulfate	SO	1	-	1,000	7,610	9,720	5,020	2,600		
Trace metals/ metalloids (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Aluminium	Al	0.01	0.055	5	<0.05	<0.05	0.02	<0.01		
Antimony	Sb	0.001	-	-	0.008	0.013	0.002	<0.001		
Arsenic	As	0.001	0.024	0.5	0.036	0.054	0.058	0.031		
Beryllium	Be	0.001	-	-	<0.005	<0.005	<0.001	<0.001		
Barium	Ba	0.001	-	-	0.03	0.016	0.011	0.01		
Cadmium	Cd	1E-04	0.0002	0.01	0.0023	0.0029	<0.0001	0.0002		
Chromium	Cr	0.0010	0.001	1	<0.005	<0.005	<0.001	<0.001		
Cobalt	Co	0.001	-	1	0.717	1.38	0.409	0.154		
Copper	Cu	0.001	0.0014	1	0.03	0.074	0.001	0.001		
Lead	Pb	0.001	0.0034	0.1	<0.005	<0.005	<0.001	<0.001		
Manganese	Mn	0.001	1.9	-	9.8	17.1	11.8	10.3		
Molybdenum	Mo	0.001	-	0.15	<0.005	<0.005	0.007	0.002		
Nickel	Ni	0.001	0.011	1	0.040	0.048	0.046	0.024		
Selenium	Se	0.01	0.011	0.02	<0.05	<0.05	<0.01	<0.01		
Thorium	Th	0.001	-	-	<0.005	<0.005	<0.001	<0.001		
Uranium	U	0.001	-	-	<0.005	0.057	0.02	0.002		
Vanadium	V	0.01	-	-	<0.05	<0.05	<0.01	<0.01		
Zinc	Zn	0.005	0.008	-	0.128	0.087	0.005	0.043		
Boron	B	0.05	0.37	5	0.14	0.2	0.07	0.08		
Iron	Fe	0.05	-	-	0.2	0.7	15.3	40.2		
Mercury	Hg	1E-04	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001		

Notes:

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1. Trigger values for freshwater aquatic ecosystems (95% species protection level).

2. Recommended guideline limits for Livestock Drinking Water.

< indicates less than the analytical detection limit. ³

* Acidity and alkalinity data calculated in mg CaCO₃ /L.

Shaded cells exceed applied guideline values.

(tri)* 0.024 mg/L for trivalent Arsenic (III). 0.013 mg/L for pentavalent Arsenic (V)

(hex)* Cr (VI) = hexavalent.

for still water bodies only, moving rivers at low flow rates should not exceed 2,200 µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

KLC 5
Cell A Tailings + 2 g/kg CaCO₃

			Weight (kg)	4.00	Total S (%)	0.570	ANC	6.9		
			pH (1:5)	7.64	Scr (%)	0.043	NAPP	-5.6		
			EC (µS/cm)	19,800	MPA	1.32	ANC:MPA	5.3		
Date				09-Jun-22	15-Jun-22	24-Jun-22	30-Jun-22	08-Jul-22	15-Jul-22	
Number of Weeks				1	2	3	4	5	6	
Leach Number				1	2	3	4	5	6	
ALS Laboratory Number				EB2216488005	EB2217195005	EB2218381005	EB2218962005	EB2219972003	EB2220545003	
Volume On (L)				1.9	1.4	1.4	1.4	1.4	1.4	
Volume Off (L)				0.322	0.333	0.599	0.280	0.491	0.278	
Cum. Volume (L)				0.3	0.655	1.254	1.534	2.025	2.303	
Pore Volumes	Water Quality Guidelines			0.239	0.485	0.929	1.136	1.500	1.706	
pH (RGS Measurement)	6 to 9	-		7.49	7.43	7.04	6.54	5.99	5.89	
pH (ALS Measurement)				7.64	7.95	7.56	6.60	6.22	5.82	
pH (deionised water used in test)				5.99	6.08	6.75	5.98	5.68	6.20	
EC (RGS Measurement) (µS/cm)	<1,000 #	3,580^		21,500	36,100	6,440	3,450	2,620	2,560	
EC (ALS Measurement) (µS/cm)				19,800	37,900	7,300	3,410	1,130	2,580	
Acidity (mg/L as CaCO ₃)*	-	-		12	27	17	12	65	72	
Alkalinity (mg/L as CaCO ₃)*	-	-		143	313	153	34	8	4	
Net Alkalinity (mg/L as CaCO ₃)*				131	286	136	22	-57	-68	
Major Ions (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Calcium	Ca	1	-	1,000	516	580	497	470	531	534
Potassium	K	1	-	-	208	353	88	57	59	55
Magnesium	Mg	1	-	-	494	1060	194	97	49	22
Sodium	Na	1	-	-	5060	9480	952	166	44	28
Chloride	Cl	1	-	-	6190	10100	526	68	7	5
Fluoride	F ⁴	0.1	-	2	0.2	0.2	0.2	0.3	0.3	0.2
Sulfate	SO	1	-	1,000	6,480	9,920	3,490	2,200	1,700	1640
Trace metals/ metalloids (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Aluminium	Al	0.01	0.055	5	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01
Antimony	Sb	0.001	-	-	0.006	0.013	0.002	<0.001	<0.001	<0.001
Arsenic	As	0.001	0.024	0.5	0.039	0.064	0.053	0.029	0.020	0.018
Beryllium	Be	0.001	-	-	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Barium	Ba	0.001	-	-	0.02	0.015	0.005	0.007	0.007	0.008
Cadmium	Cd	1E-04	0.0002	0.01	0.001	0.002	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	Cr	0.0010	0.001	1	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Cobalt	Co	0.001	-	1	0.567	1.28	0.333	0.131	0.067	0.058
Copper	Cu	0.001	0.0014	1	0.024	0.047	<0.001	0.002	<0.001	0.001
Lead	Pb	0.001	0.0034	0.1	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Manganese	Mn	0.001	1.9	-	5.2	11.8	7.8	7.8	7.9	7.37
Molybdenum	Mo	0.001	-	0.15	<0.005	<0.005	0.006	0.003	<0.001	<0.001
Nickel	Ni	0.001	0.011	1	0.019	0.034	0.027	0.018	0.012	0.009
Selenium	Se	0.01	0.011	0.02	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01
Thorium	Th	0.001	-	-	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Uranium	U	0.001	-	-	0.013	0.118	0.016	0.008	0.002	0.001
Vanadium	V	0.01	-	-	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01
Zinc	Zn	0.005	0.008	-	0.050	0.048	0.008	0.012	0.010	0.013
Boron	B	0.05	0.37	5	0.09	0.12	0.06	0.06	0.06	0.06
Iron	Fe	0.05	-	-	0.2	0.6	3.6	17.0	29.7	33.4
Mercury	Hg	1E-04	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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* Acidity and alkalinity data calculated in mg CaCO₃ /L.

Shaded cells exceed applied guideline values.

(tri)* 0.024 mg/L for trivalent Arsenic (III), 0.013 mg/L for pentavalent Arsenic (V)

(hex)* Cr (VI) = hexavalent.

for still water bodies only, moving rivers at low flow rates should not exceed 2,200 µS/cm.

^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

KLC 6
Cell A Tailings

			Weight (kg)	4.00	Total S (%)	0.570	ANC	4.9		
			pH (1:5)	7.02	Scr (%)	0.043	NAPP	-3.6		
			EC (µS/cm)	23,200	MPA	1.32	ANC:MPA	3.7		
Date				09-Jun-22	15-Jun-22	24-Jun-22	30-Jun-22	07-Jul-22	15-Jul-22	
Number of Weeks				1	2	3	4	5	6	
Leach Number				1	2	3	4	5	6	
ALS Laboratory Number				EB2216488006	EB2217195006	EB2218381006	EB2218962006	EB2219972004	EB2220545004	
Volume On (L)				1.4	1.4	1.4	1.0	1.4	0.9	
Volume Off (L)				0.434	0.224	0.296	0.259	0.232	0.794	
Cum. Volume (L)				0.4	0.658	0.954	1.213	1.445	2.239	
Pore Volumes	Water Quality Guidelines			0.321	0.487	0.707	0.899	1.070	1.659	
pH (RGS Measurement)	6 to 9	-		6.63	6.70	6.20	5.97	5.36	5.24	
pH (ALS Measurement)				7.02	7.54	6.01	5.24	4.91	4.88	
pH (deionised water used in test)				5.99	6.08	6.75	5.98	5.68	6.20	
EC (RGS Measurement) (µS/cm)	<1,000 #	3,580^		29,600	37,900	20,500	5,810	3,420	2,960	
EC (ALS Measurement) (µS/cm)				23,200	39,300	20,900	5,450	3,530	3,060	
Acidity (mg/L as CaCO ₃)*	-	-		13	15	133	206	253	299	
Alkalinity (mg/L as CaCO ₃)*	-	-		50	74	8	<1	<1	<1	
Net Alkalinity (mg/L as CaCO ₃)*				37	59	-125	-206	-253	-299	
Major Ions (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Calcium	Ca	1	-	1,000	498	569	498	447	481	492
Potassium	K	1	-	-	322	424	202	87	70	60
Magnesium	Mg	1	-	-	815	1230	549	147	90	47
Sodium	Na	1	-	-	7310	9850	4430	684	180	64
Chloride	Cl	1	-	-	8140	10400	3780	376	46	37
Fluoride	F ⁴	0.1	-	2	0.1	<0.1	0.1	0.1	<0.1	0.1
Sulfate	SO	1	-	1,000	8,620	11,000	7,340	3,290	2,310	1930
Trace metals/ metalloids (mg/L)	Elements	LoR	Aquatic Ecosystems (Freshwater) ¹	Livestock Drinking Water ²						
Aluminium	Al	0.01	0.055	5	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01
Antimony	Sb	0.001	-	-	0.006	0.008	0.002	<0.001	<0.001	<0.001
Arsenic	As	0.001	0.024	0.5	0.036	0.028	0.032	0.028	0.018	0.022
Beryllium	Be	0.001	-	-	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Barium	Ba	0.001	-	-	0.036	0.02	0.01	0.009	0.010	0.01
Cadmium	Cd	1E-04	0.0002	0.01	0.0052	0.0063	0.0014	0.0003	0.0002	<0.0001
Chromium	Cr	0.0010	0.001	1	<0.005	<0.005	0.001	<0.001	<0.001	<0.001
Cobalt	Co	0.001	-	1	0.917	1.37	0.732	0.233	0.182	0.122
Copper	Cu	0.001	0.0014	1	0.028	0.029	0.007	0.002	0.002	0.002
Lead	Pb	0.001	0.0034	0.1	0.024	0.015	<0.001	<0.001	<0.001	<0.001
Manganese	Mn	0.001	1.9	-	16.2	25.6	20.4	10.5	8.8	7.46
Molybdenum	Mo	0.001	-	0.15	<0.005	<0.005	0.002	<0.001	<0.001	<0.001
Nickel	Ni	0.001	0.011	1	0.079	0.105	0.147	0.043	0.068	0.023
Selenium	Se	0.01	0.011	0.02	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01
Thorium	Th	0.001	-	-	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Uranium	U	0.001	-	-	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Vanadium	V	0.01	-	-	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01
Zinc	Zn	0.005	0.008	-	0.354	0.377	0.112	0.089	0.137	0.08
Boron	B	0.05	0.37	5	0.22	0.26	0.13	0.07	0.06	0.06
Iron	Fe	0.05	-	-	0.25	0.54	49.2	95.9	111.0	149
Mercury	Hg	1E-04	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Notes:

ANZG 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

1. Trigger values for freshwater aquatic ecosystems (95% species protection level).

2. Recommended guideline limits for Livestock Drinking Water.

< indicates less than the analytical detection limit. ^a

* Acidity and alkalinity data calculated in mg CaCO₃ /L.

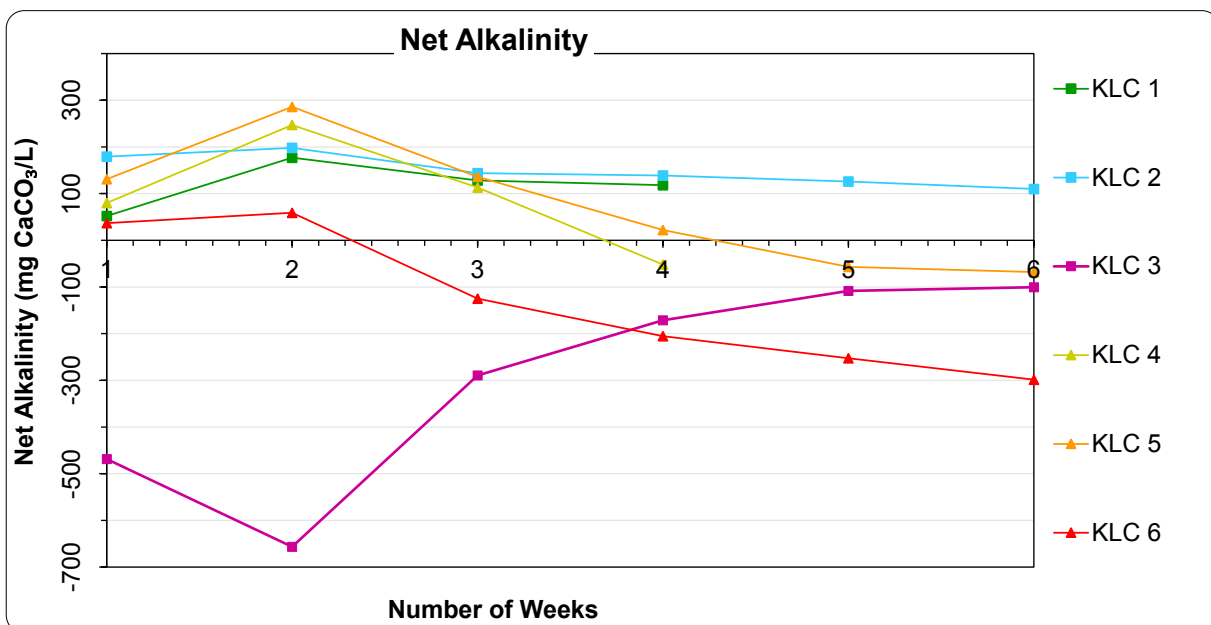
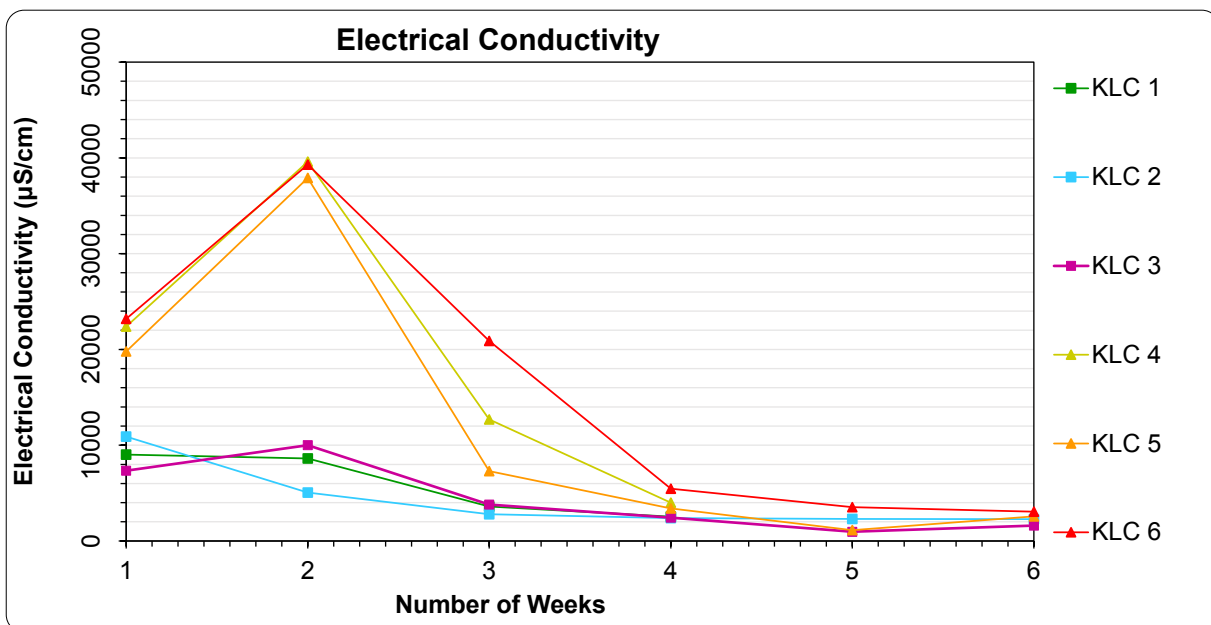
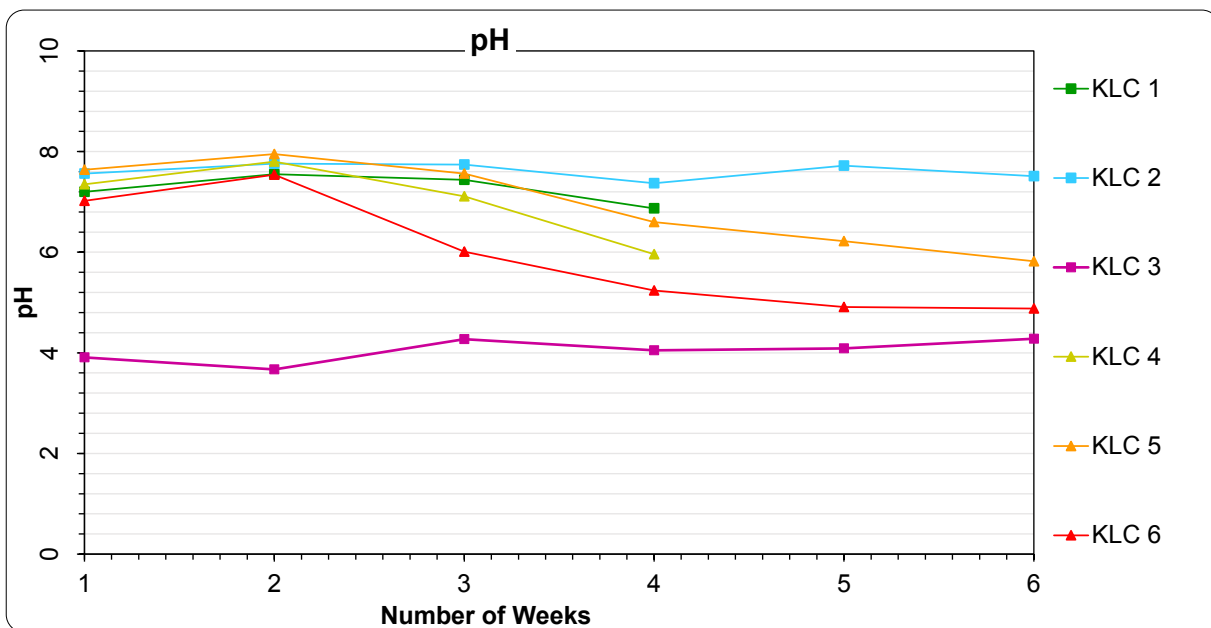
Shaded cells exceed applied guideline values.

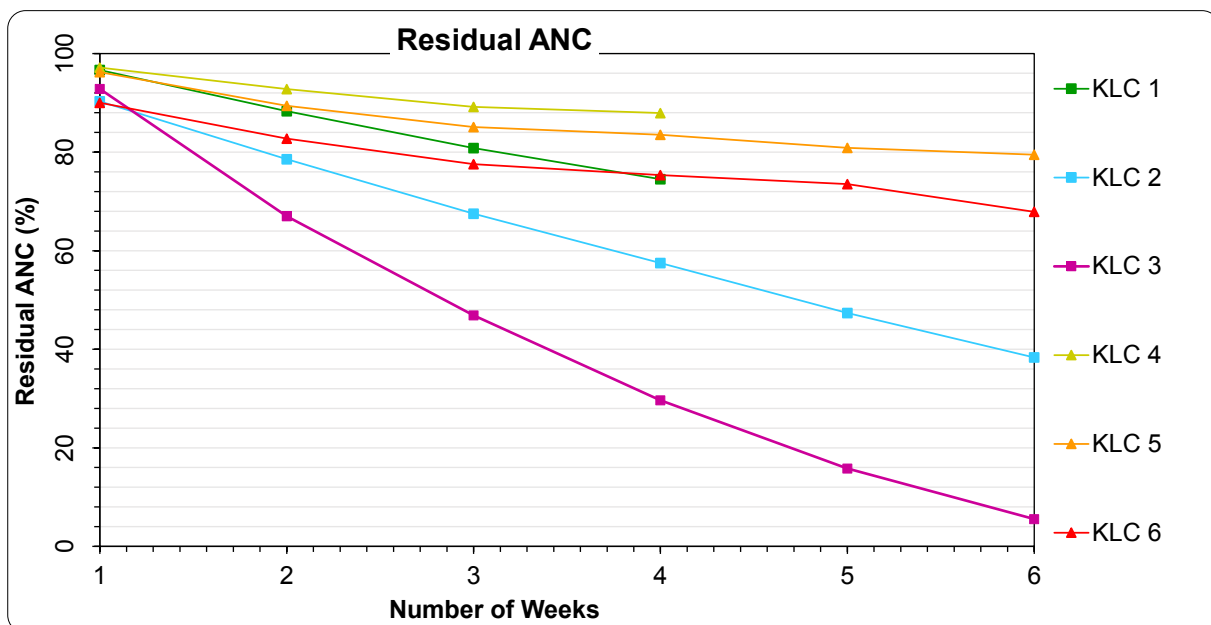
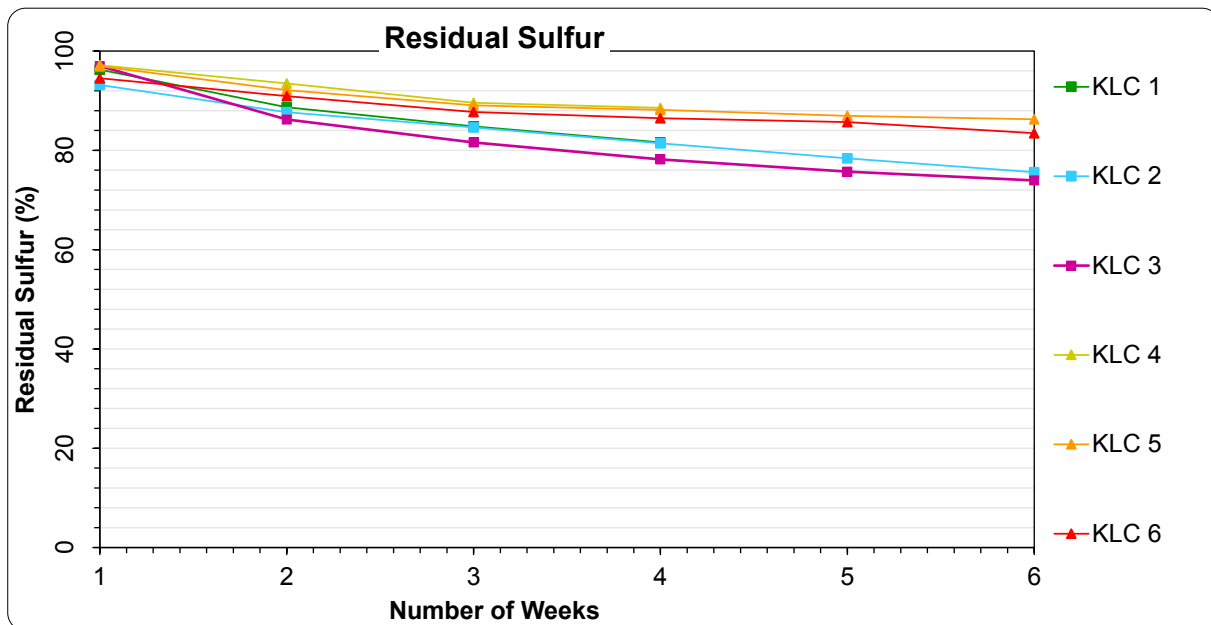
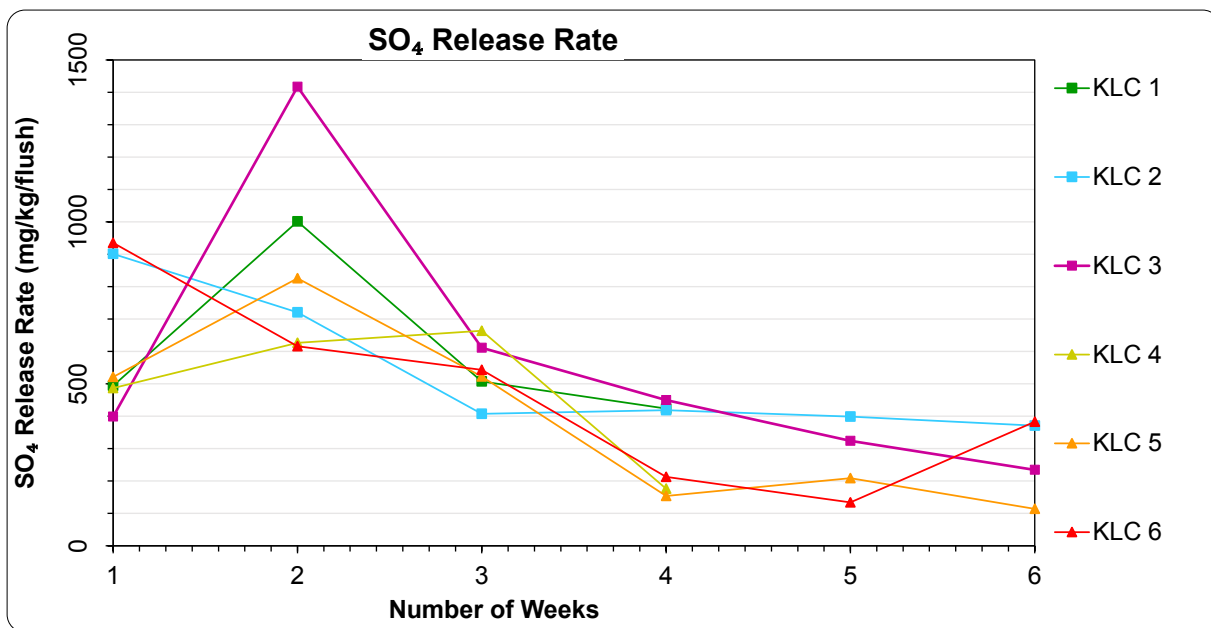
(tri)* 0.024 mg/L for trivalent Arsenic (III), 0.013 mg/L for pentavalent Arsenic (V)

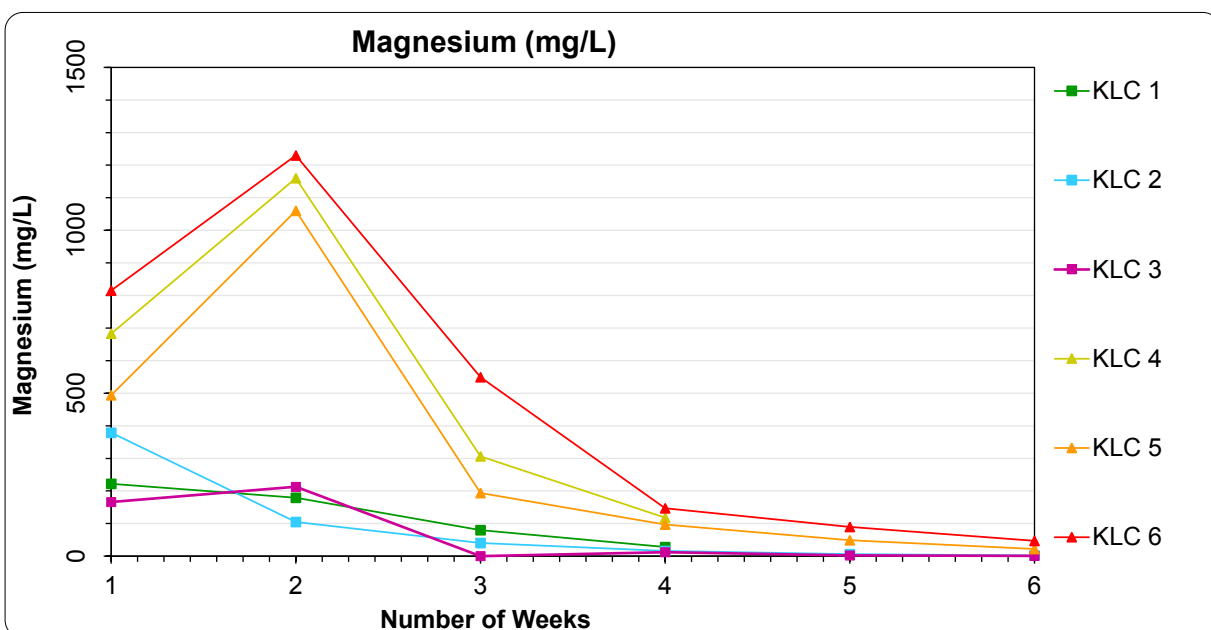
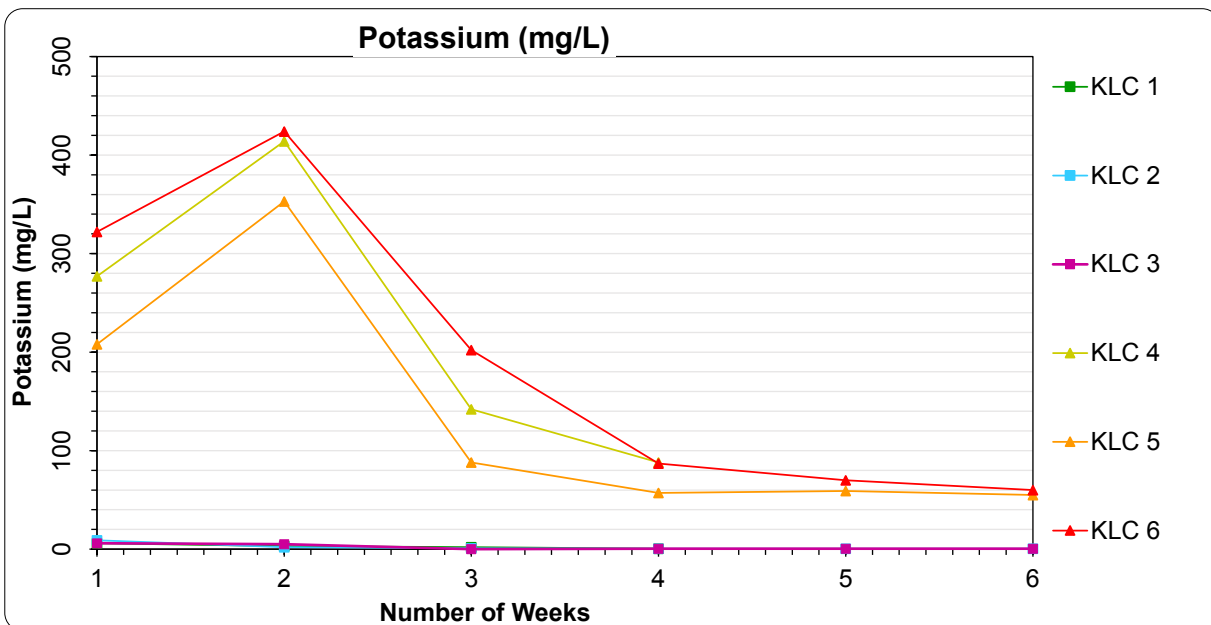
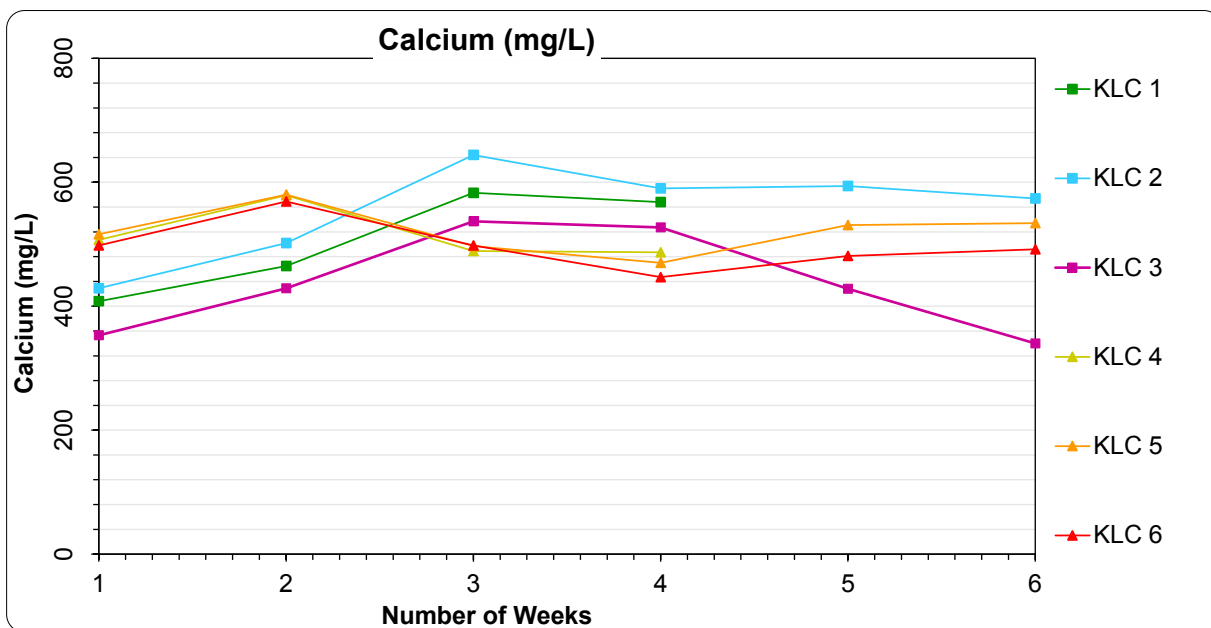
(hex)* Cr (VI) = hexavalent.

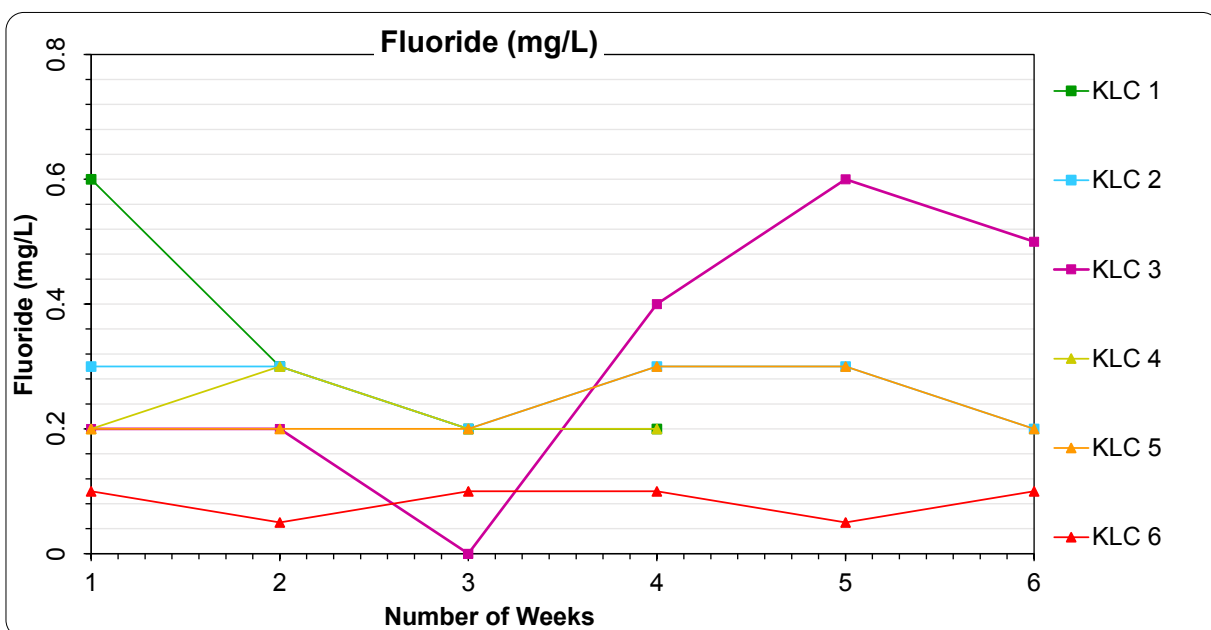
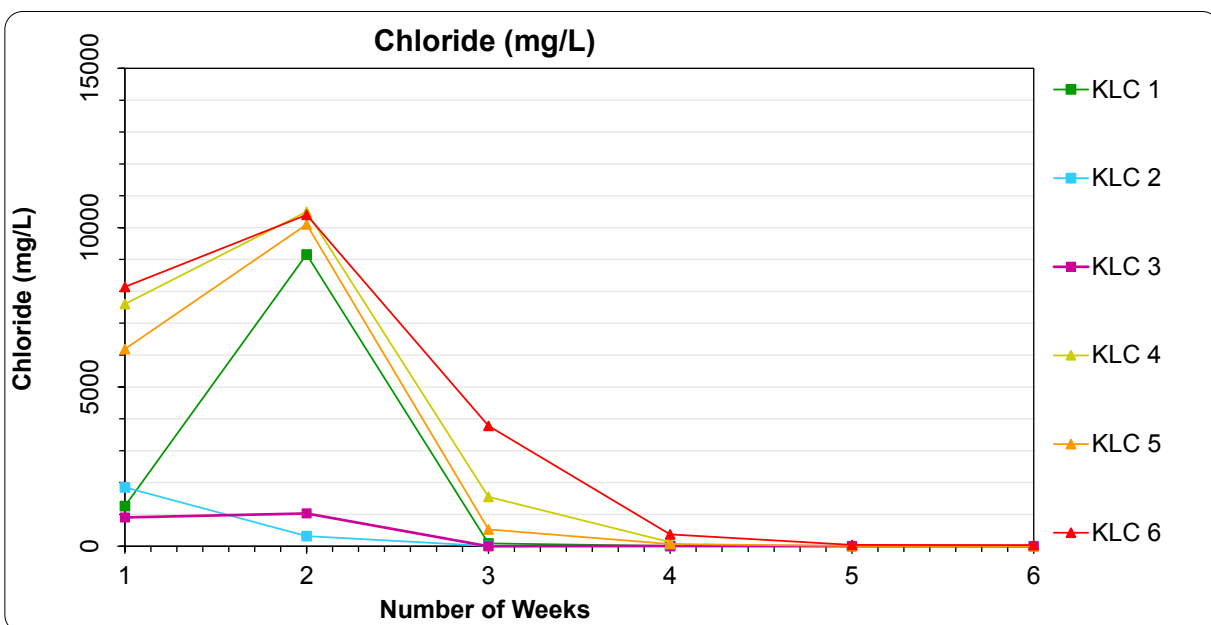
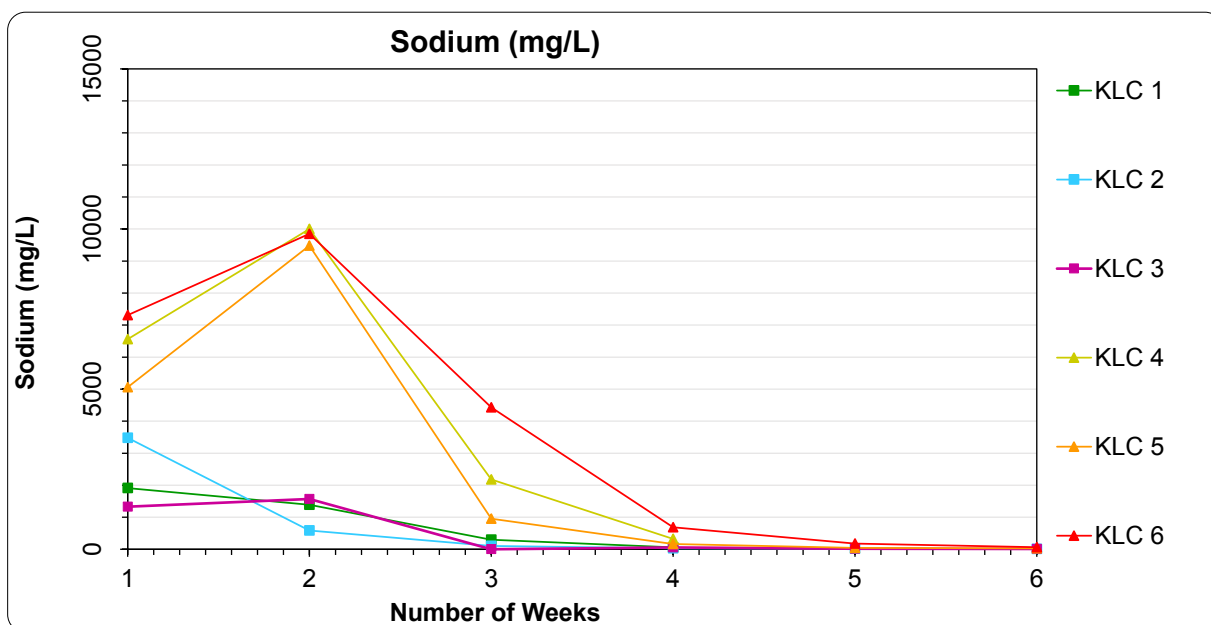
for still water bodies only, moving rivers at low flow rates should not exceed 2,200 µS/cm.

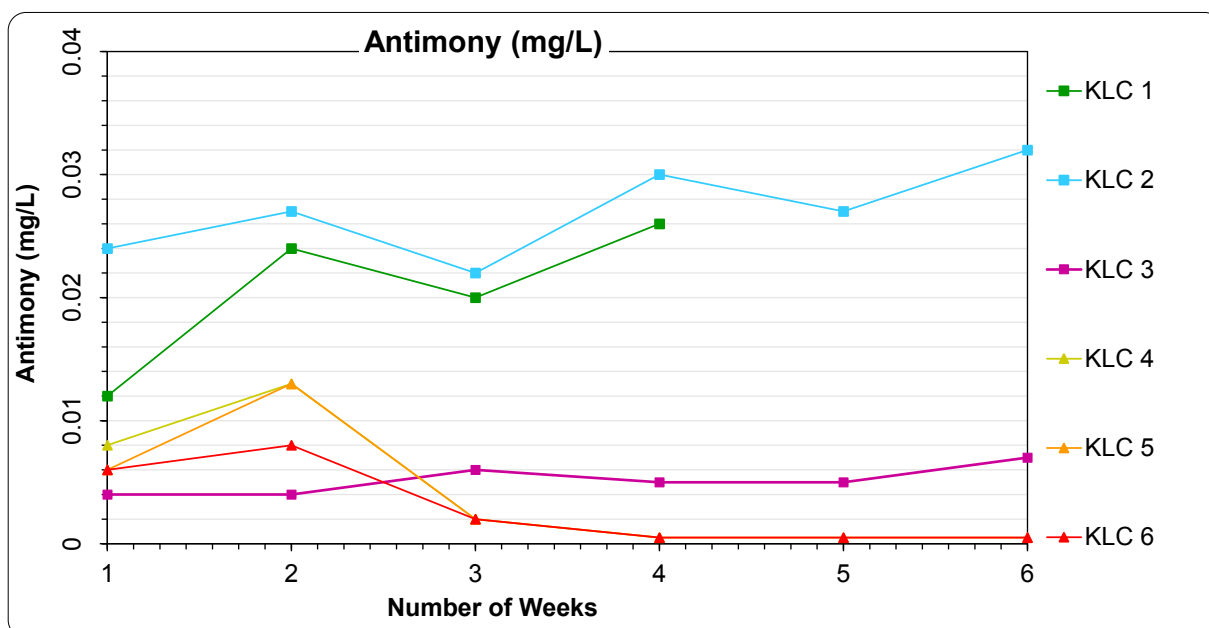
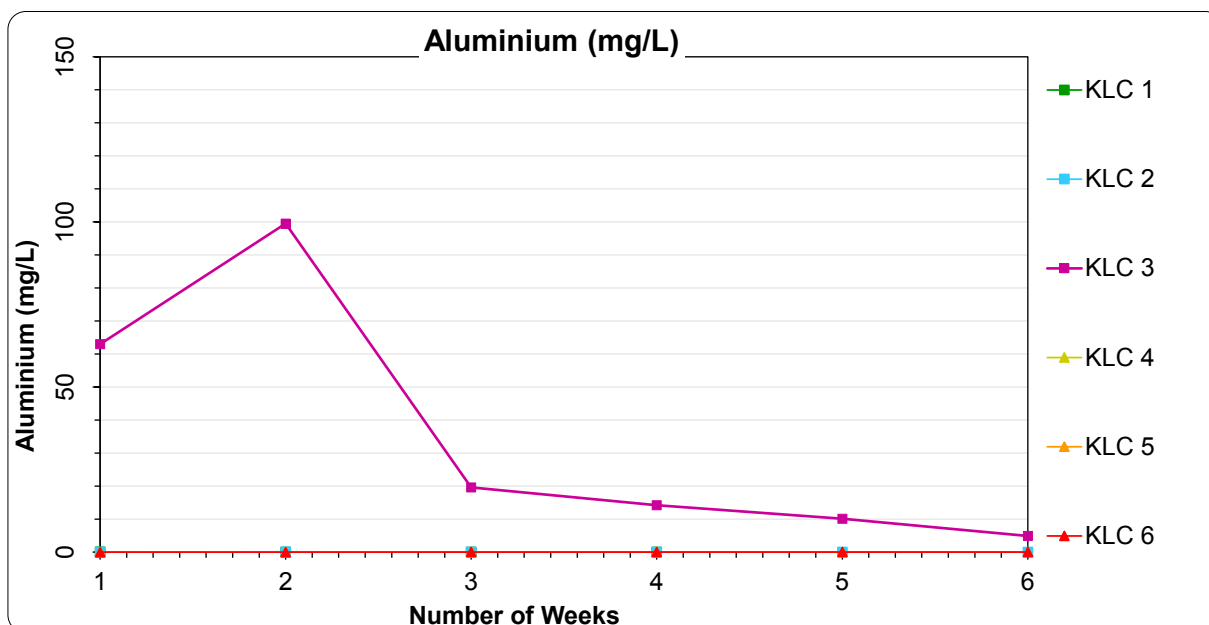
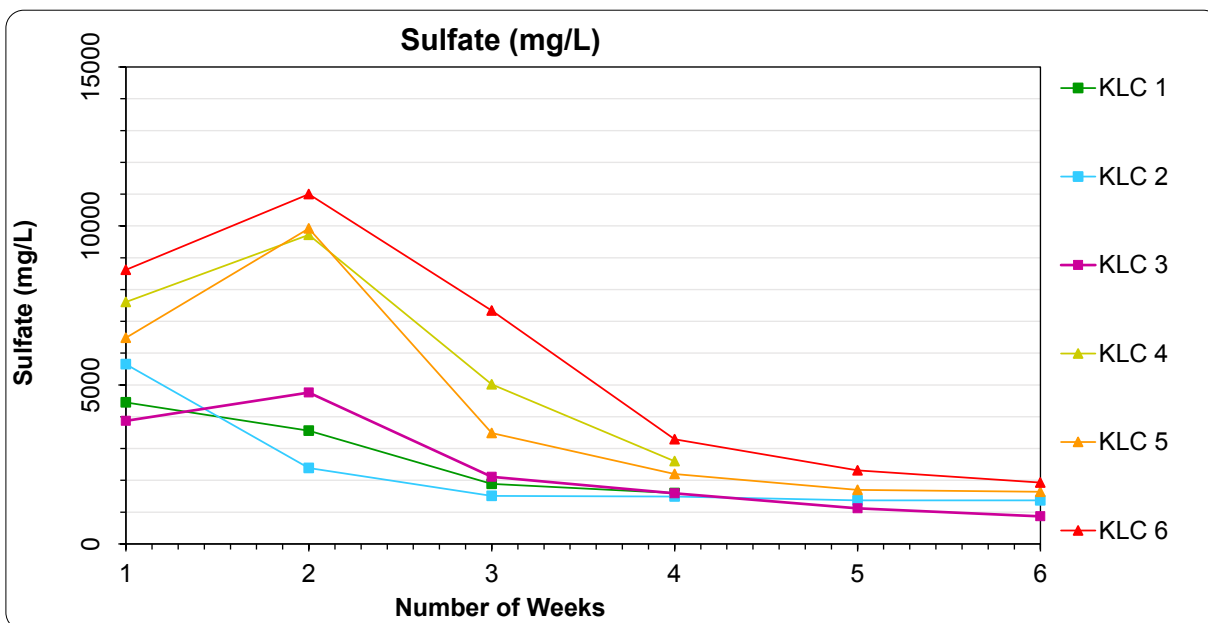
^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

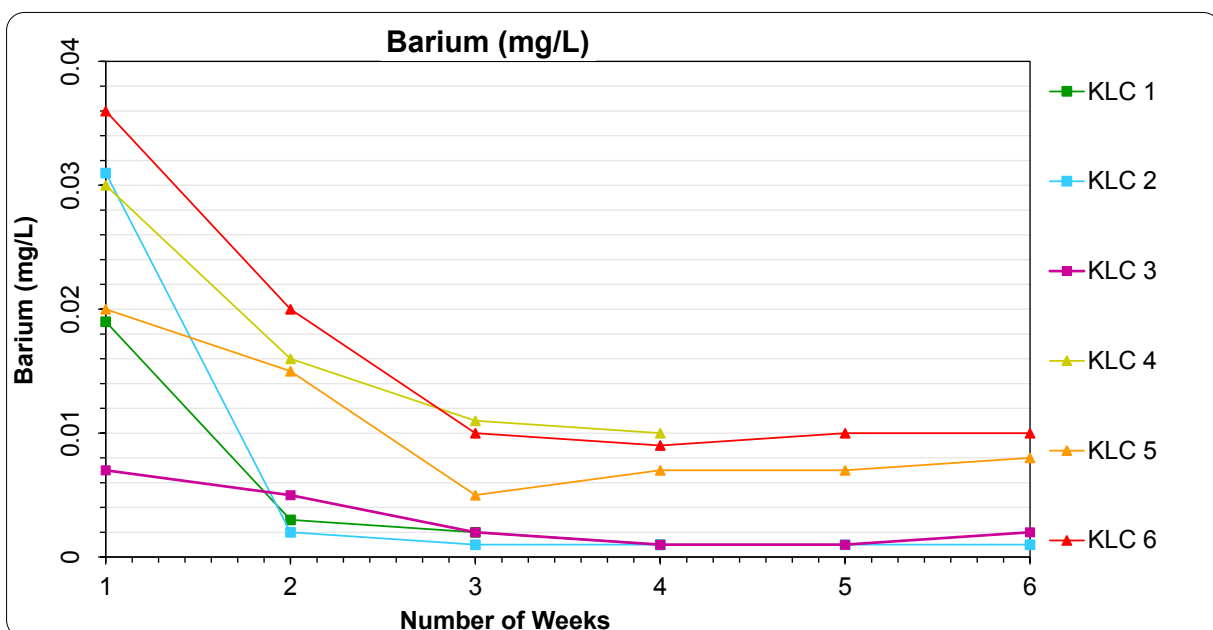
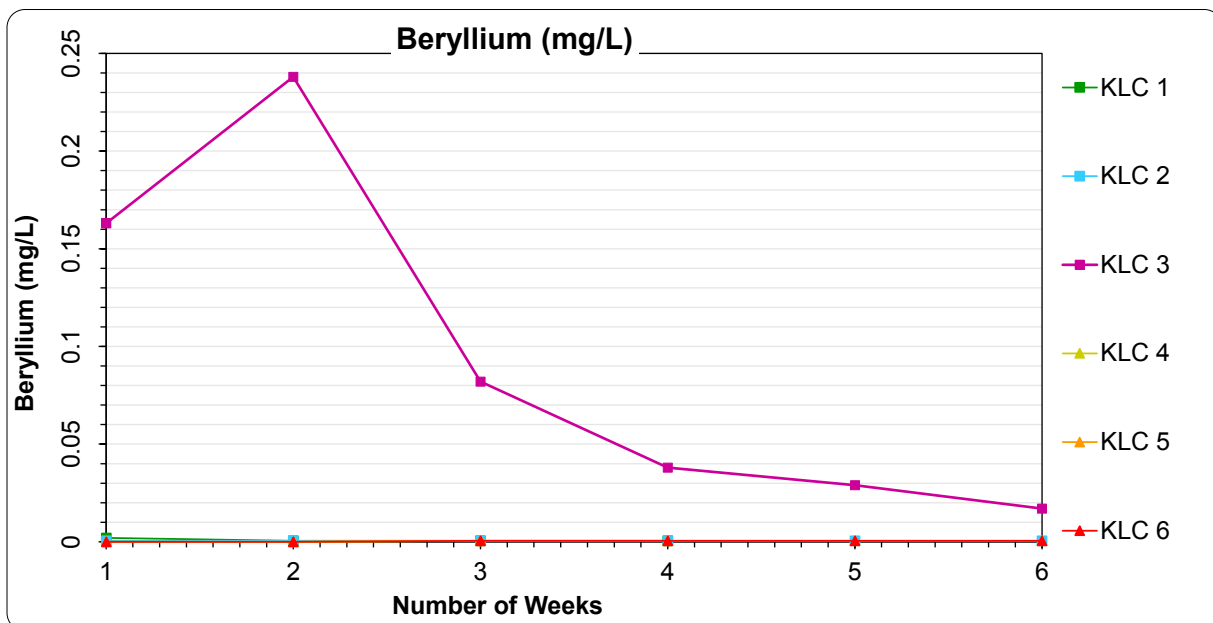
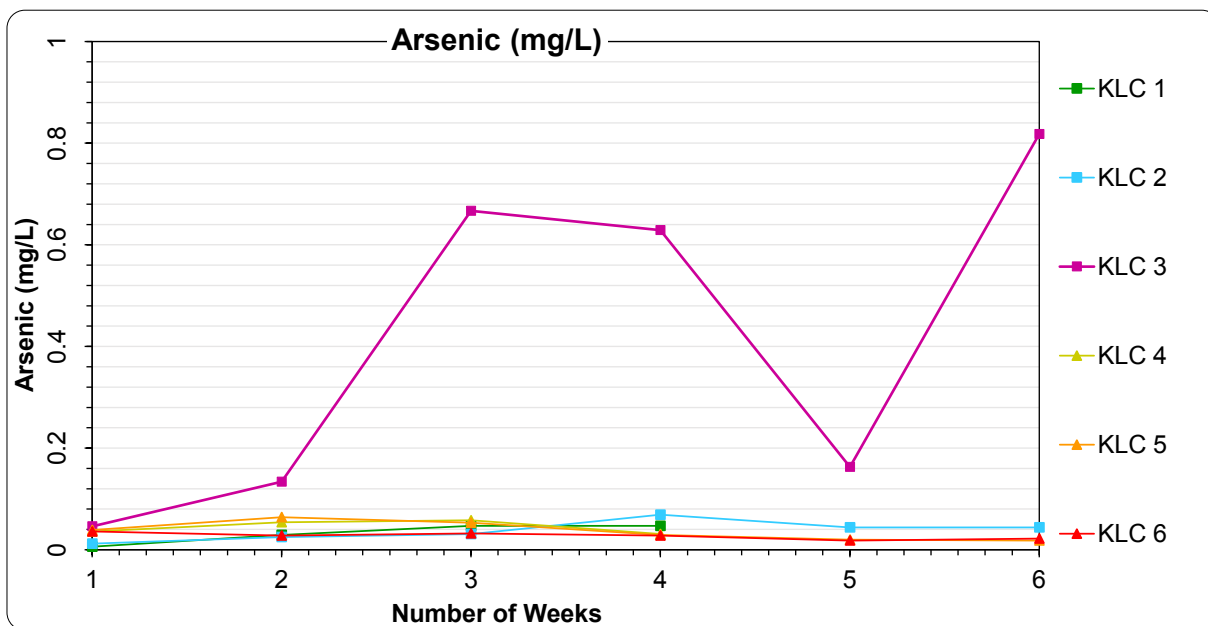


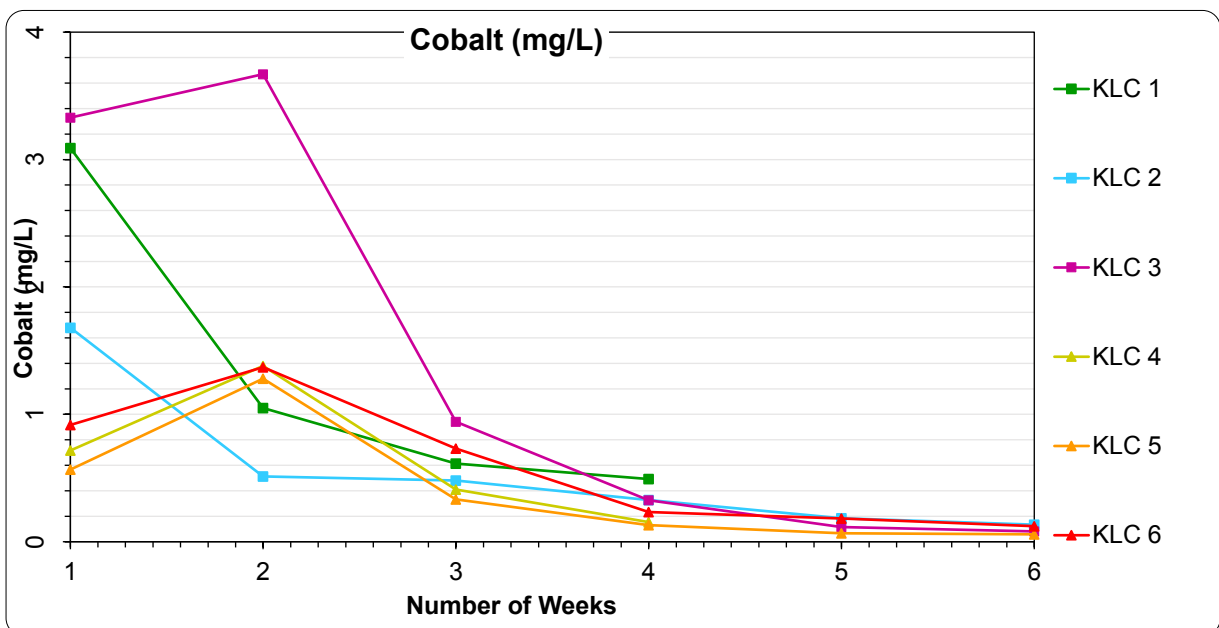
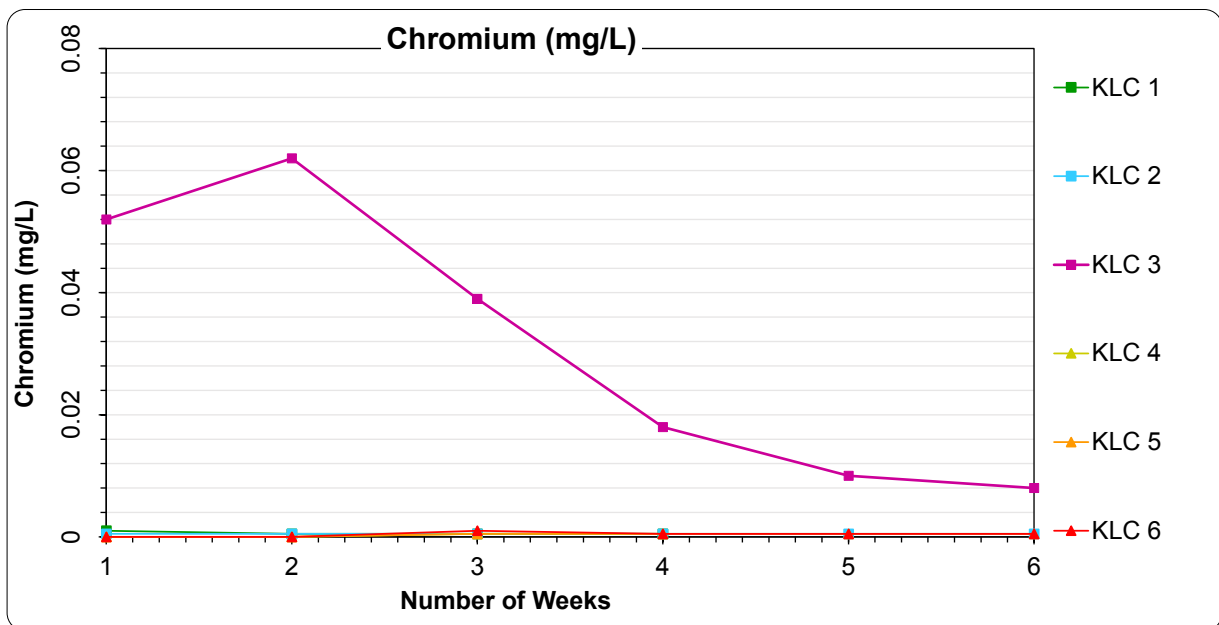
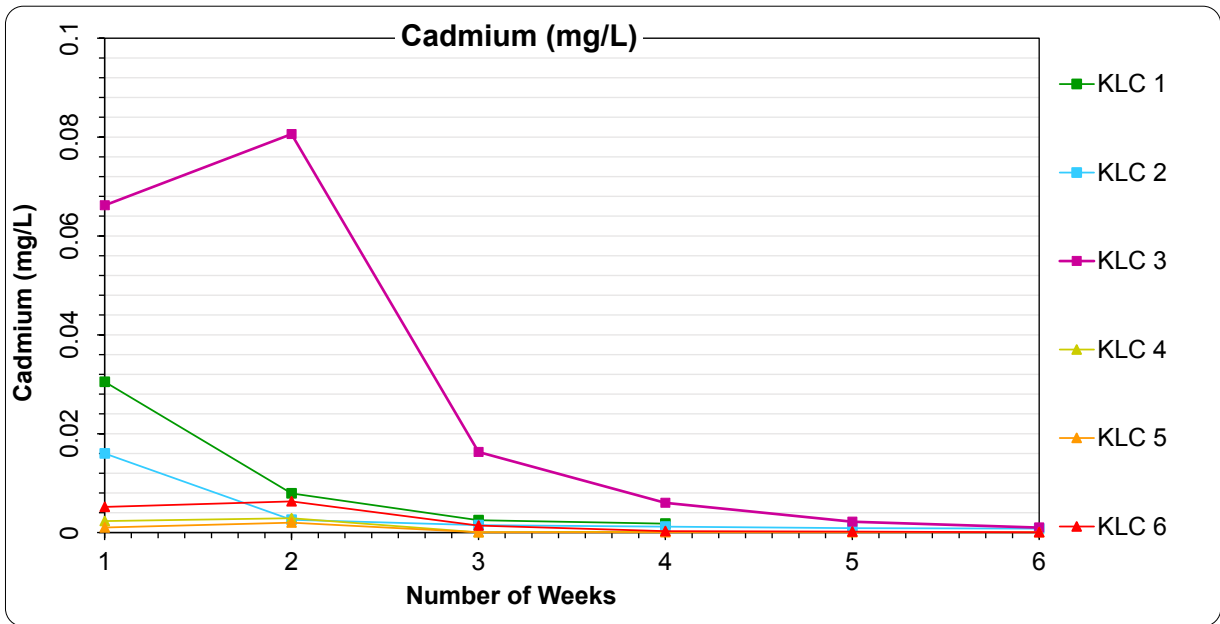


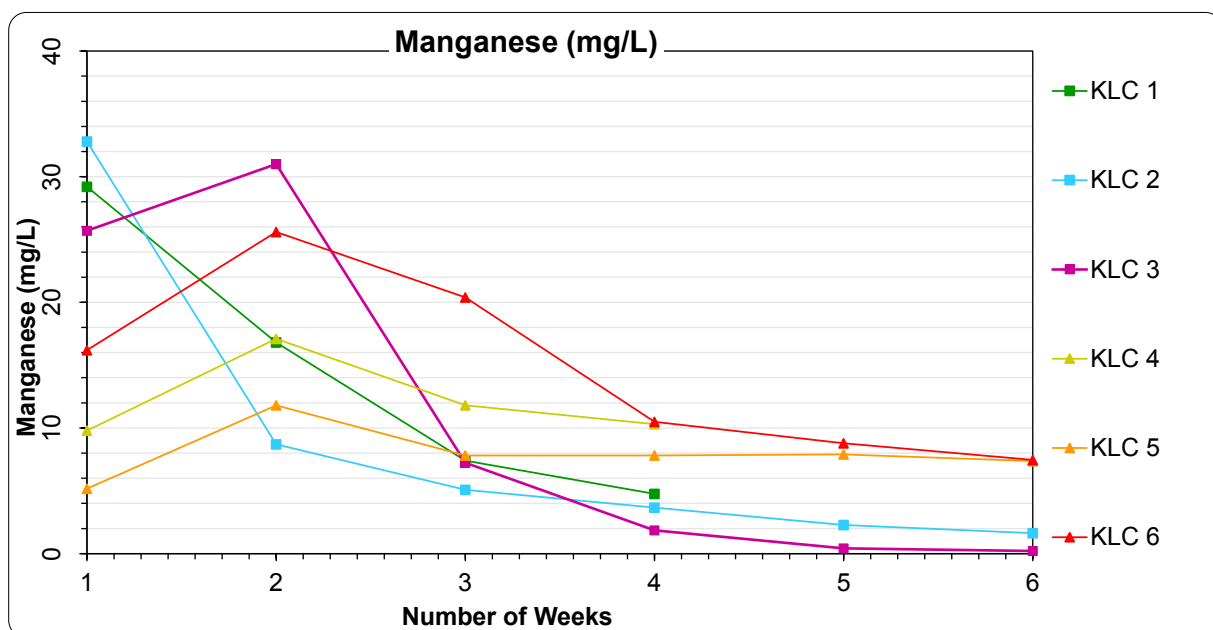
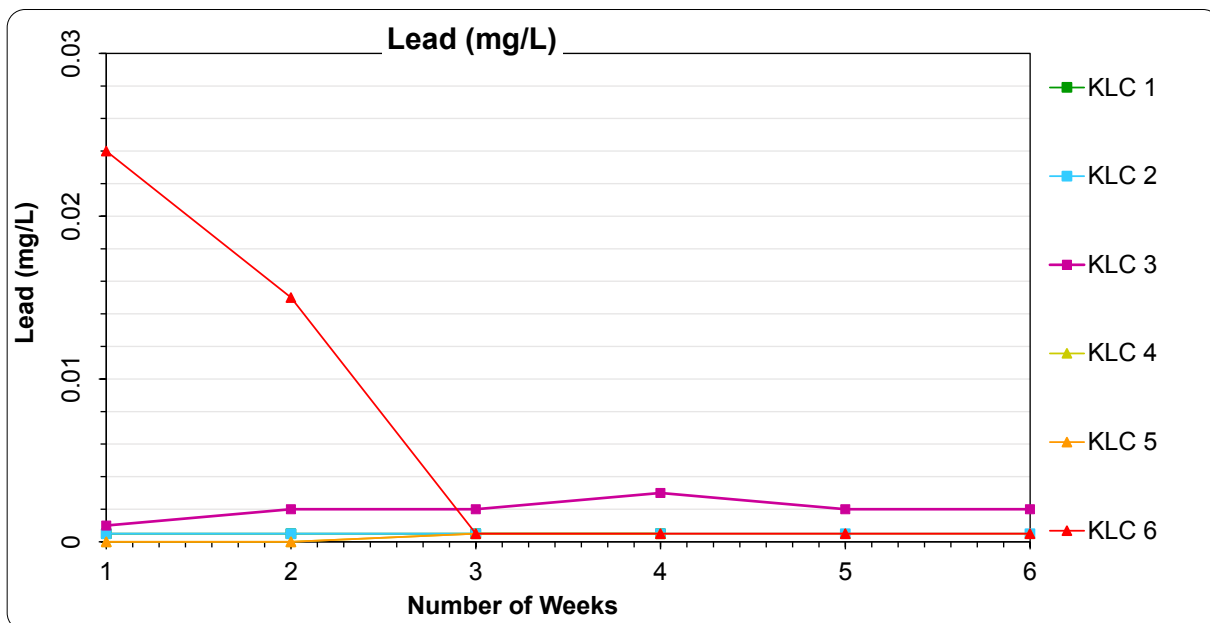
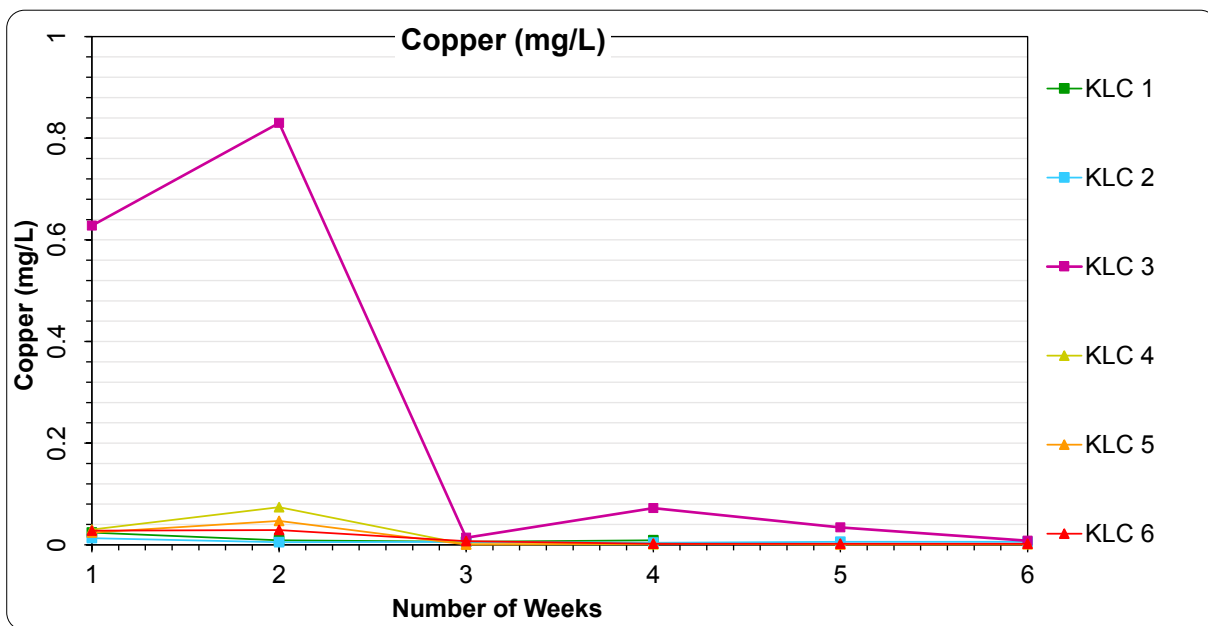


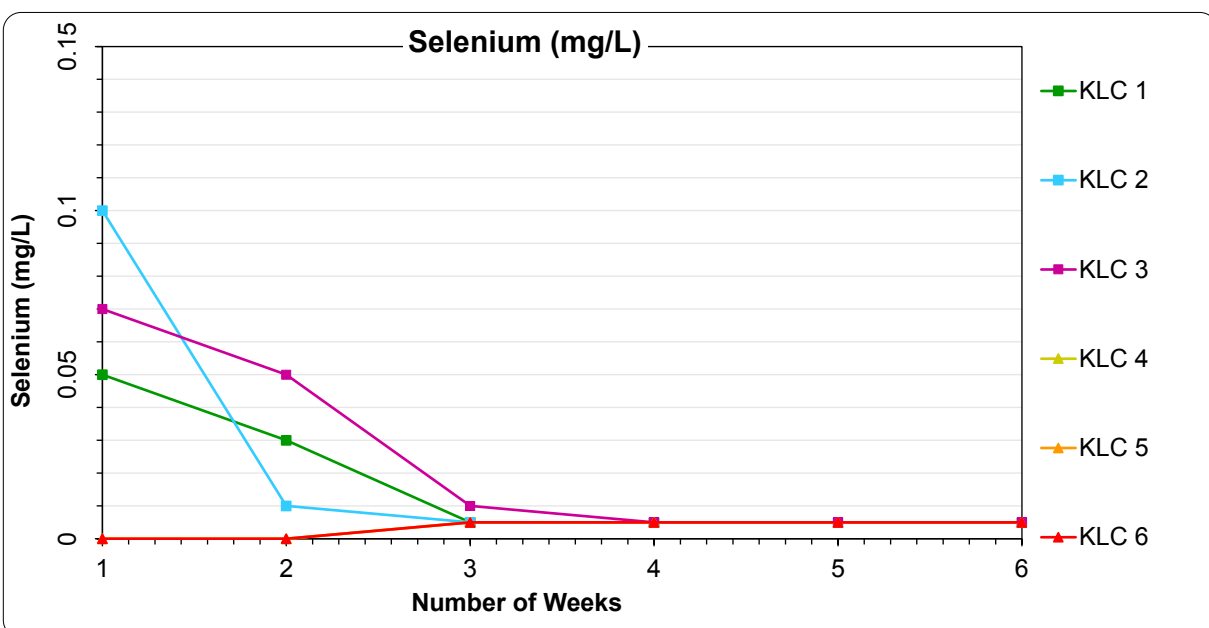
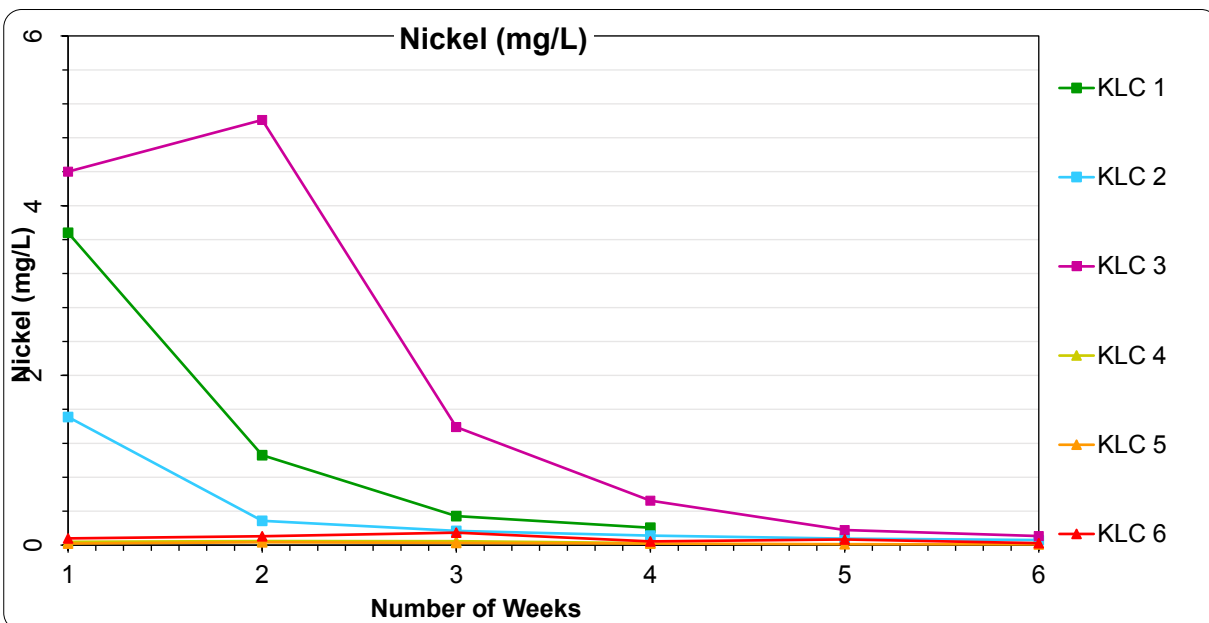
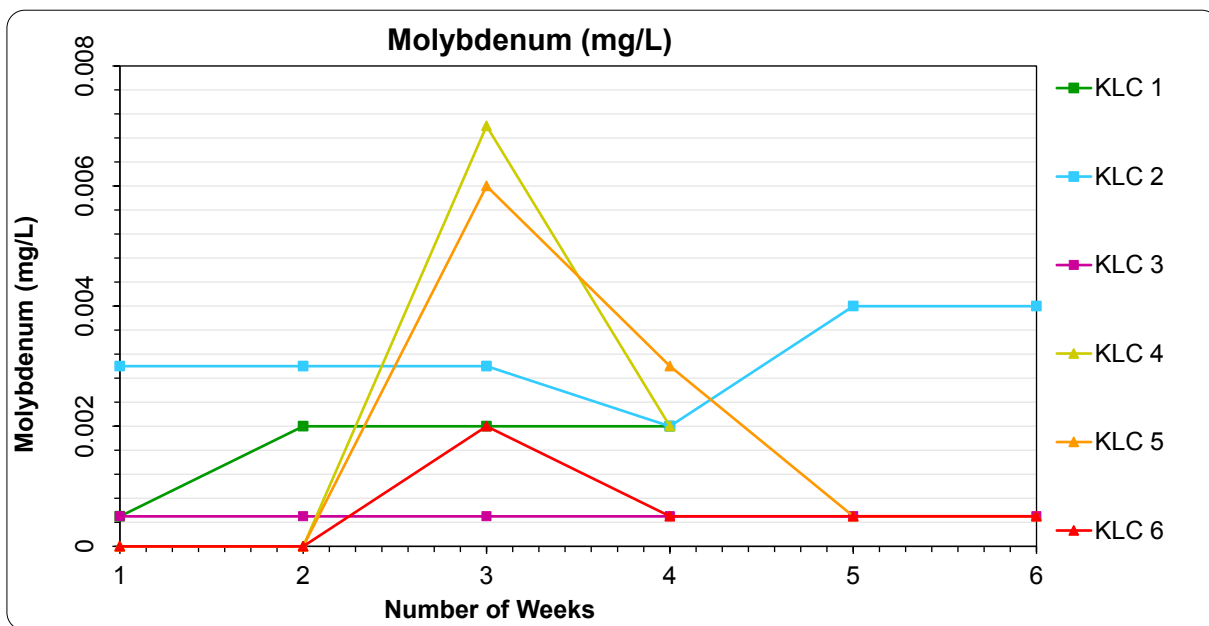


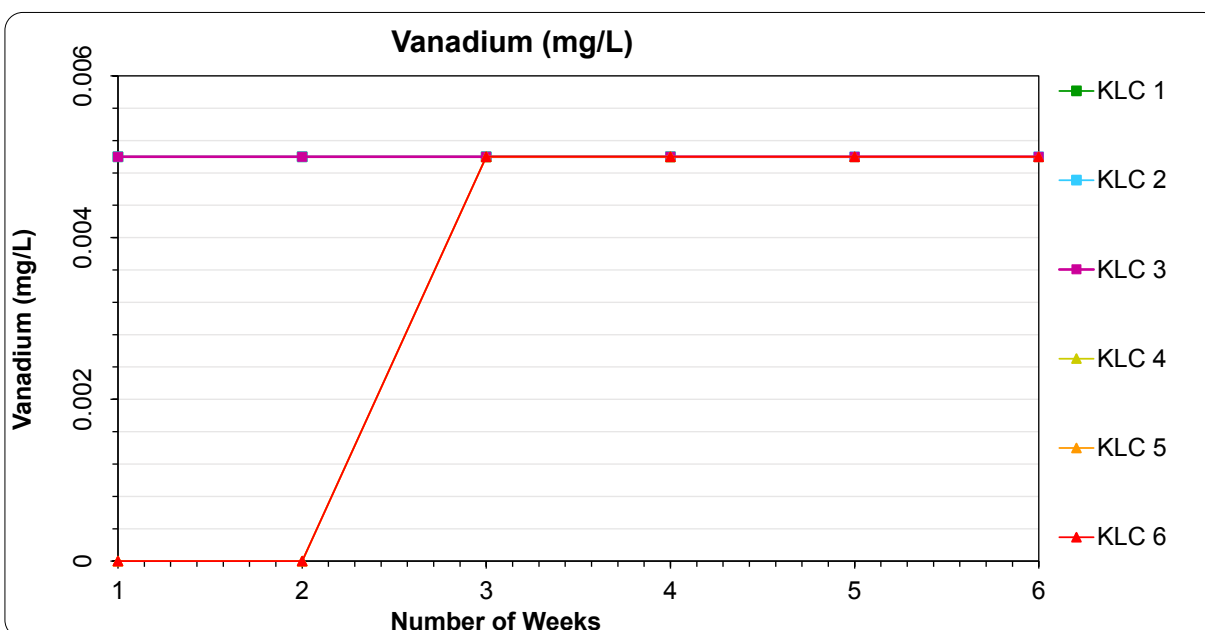
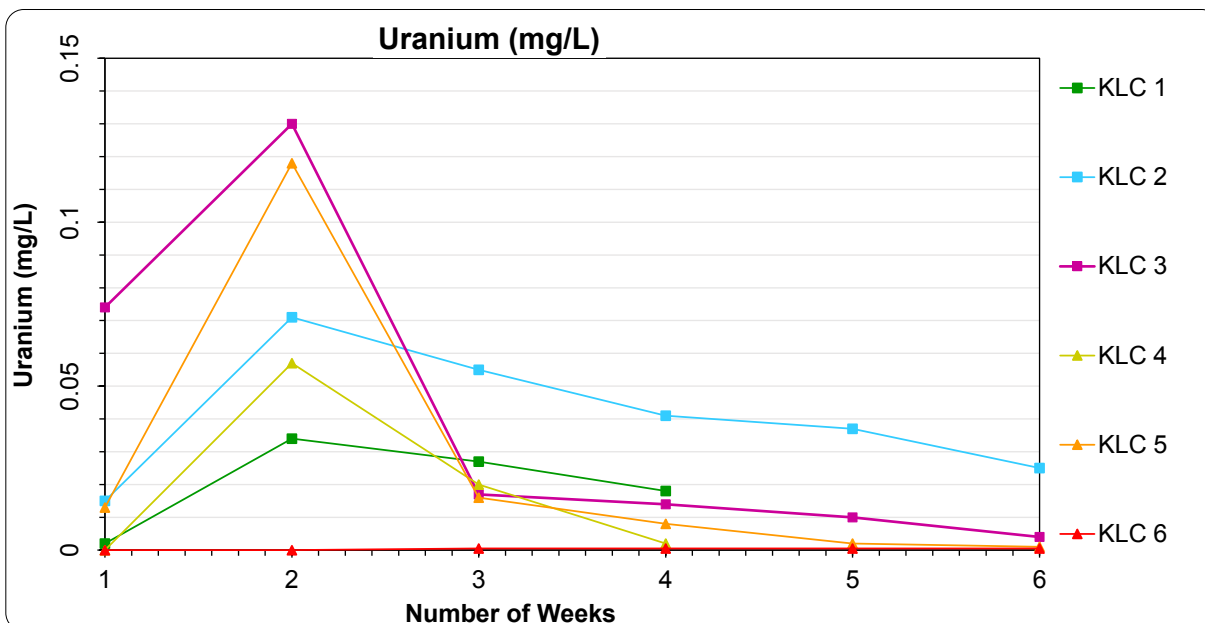
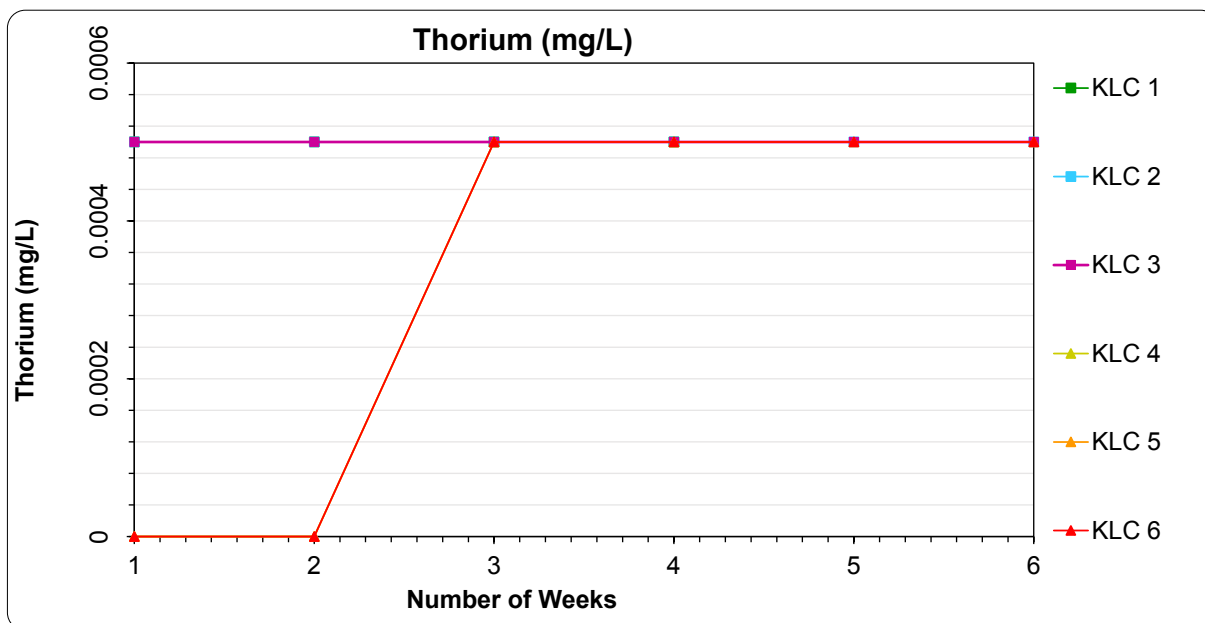


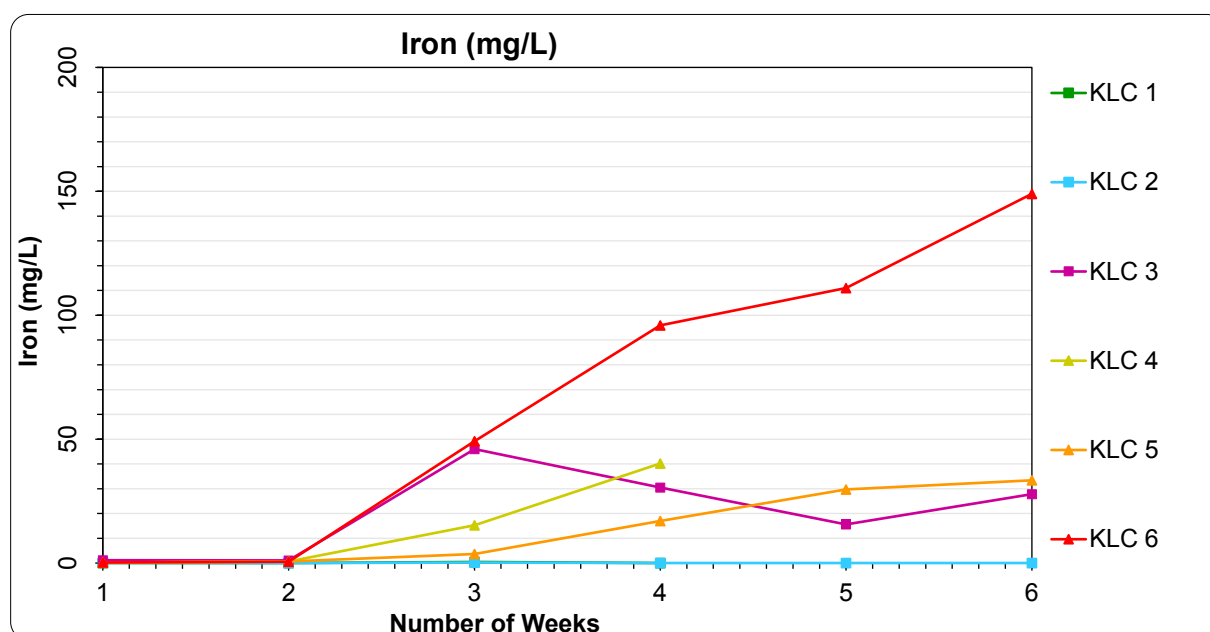
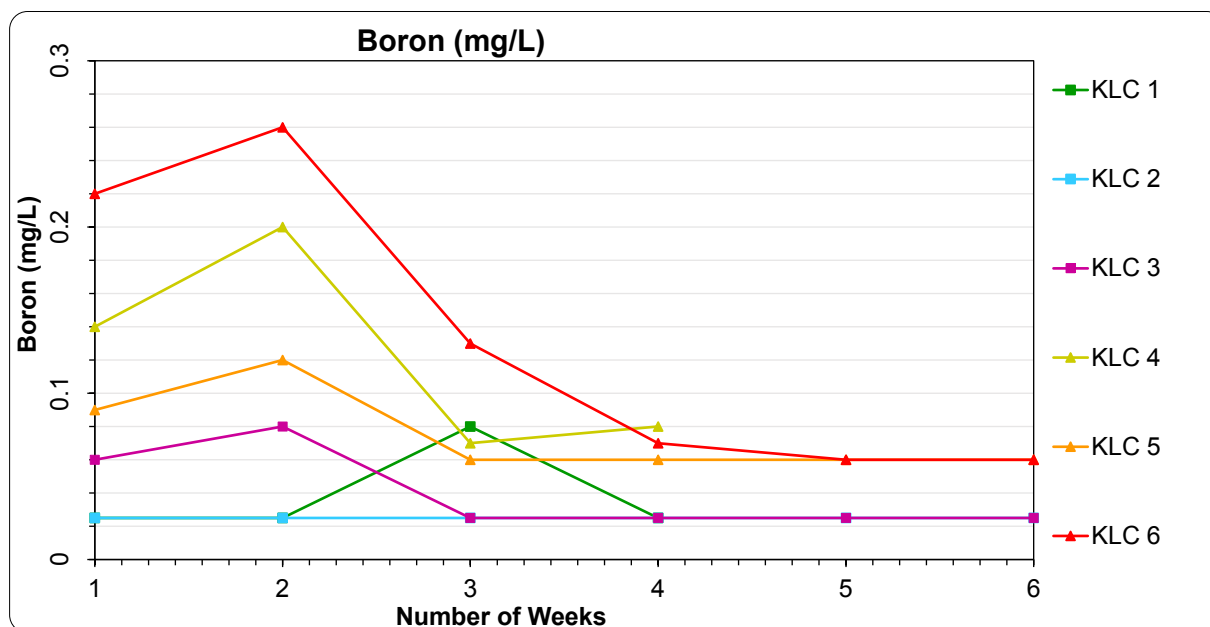
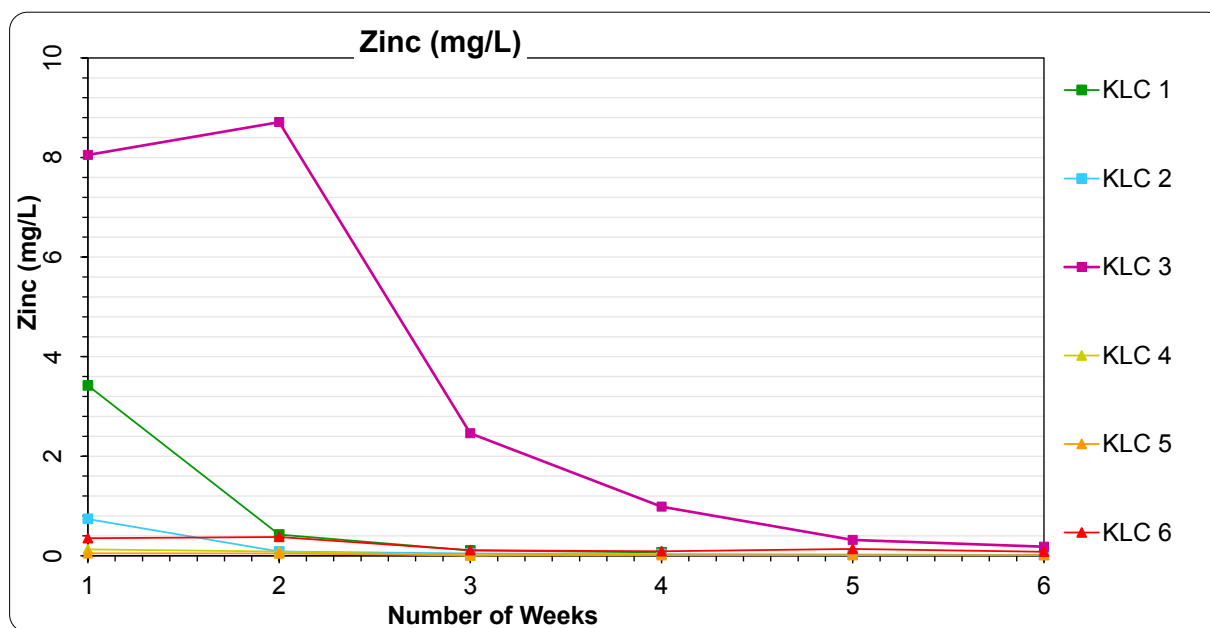


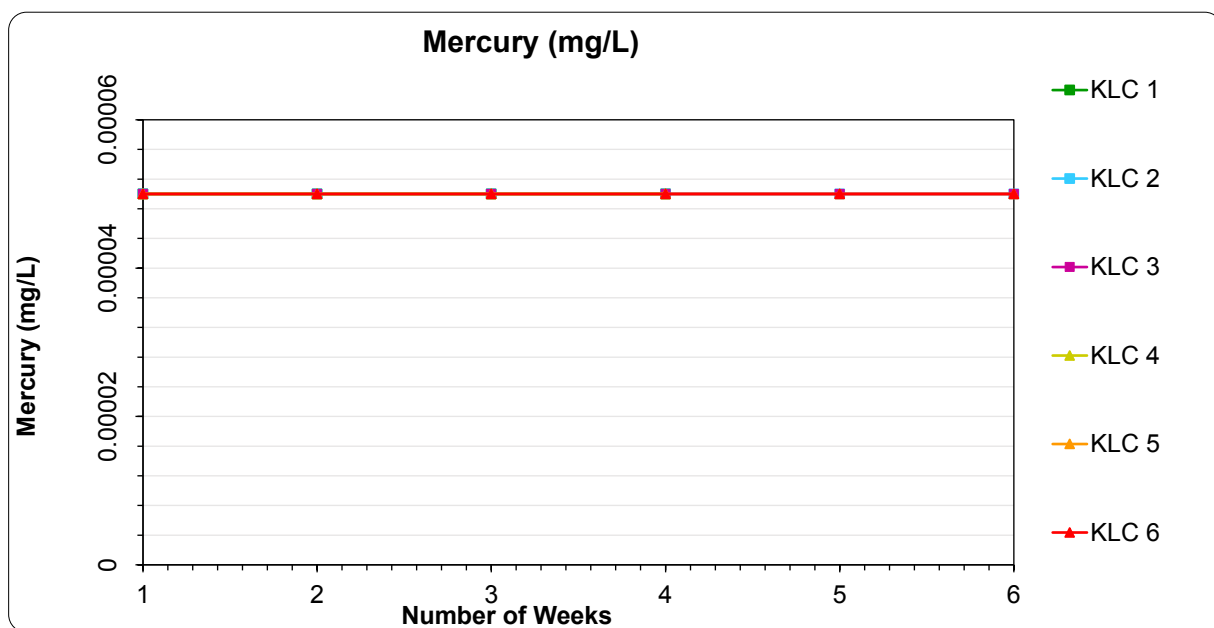












Attachment E: Laboratory Certificates of Analysis

CERTIFICATE OF ANALYSIS

Work Order : **EB2210698**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALEXANDRA KISS
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4107
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : ALEXANDRA KISS
Site : ----
Quote number : EN/222
No. of samples received : 16
No. of samples analysed : 16

Page : 1 of 6
Laboratory : Environmental Division Brisbane
Contact : Customer Services EB
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61-7-3243 7222
Date Samples Received : 13-Apr-2022 12:38
Date Analysis Commenced : 21-Apr-2022
Issue Date : 03-May-2022 13:05



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_0001 Surface Sample	2022017_0002 Surface Sample	2022017_0003 Surface Sample	2022017_3001 Surface Sample	2022017_3002 Surface Sample
Sampling date / time				12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00
Compound	CAS Number	LOR	Unit	EB2210698-001	EB2210698-002	EB2210698-003	EB2210698-004	EB2210698-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.1	6.2	6.6	4.1	3.9
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-2.8	-4.8	-6.9	8.0	5.0
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	29	87	28	1910	1760
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	3.1	5.1	7.2	2.7	3.0
ANC as CaCO3	----	0.1	% CaCO3	0.3	0.5	0.7	0.3	0.3
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.01	0.01	0.35	0.26



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_3003 Surface Sample	2022017_3004 Surface Sample	2022017_3005 Surface Sample	2022017_3006 Surface Sample	2022017_3007 Surface Sample
Sampling date / time				12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00
Compound	CAS Number	LOR	Unit	EB2210698-006	EB2210698-007	EB2210698-008	EB2210698-009	EB2210698-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	3.9	4.0	3.9	3.8	4.3
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	16.0	8.5	11.4	23.5	8.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	2860	800	2360	2900	1280
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	2.1	1.0	1.1	1.3	2.2
ANC as CaCO3	----	0.1	% CaCO3	0.2	0.1	0.1	0.1	0.2
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.59	0.31	0.41	0.81	0.36



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_3008 Surface Sample	2022017_3009 Surface Sample	2022017_3010 Surface Sample	2022017_3011 Surface Sample	2022017_3012 Surface Sample
Sampling date / time				12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00	12-Apr-2022 00:00
Compound	CAS Number	LOR	Unit	EB2210698-011	EB2210698-012	EB2210698-013	EB2210698-014	EB2210698-015
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	4.0	3.7	8.5	4.2	5.2
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	5.6	15.6	-7.8	40.7	5.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1790	2600	780	4010	3390
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	6.0	0.6	10.3	<0.5	4.1
ANC as CaCO3	----	0.1	% CaCO3	0.6	<0.1	1.0	<0.1	0.4
Fizz Rating	----	0	Fizz Unit	1	0	1	0	0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.38	0.53	0.08	1.33	0.31



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	pH and EC of DI water	----	----	----	----
				Sampling date / time	12-Apr-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB2210698-016	-----	-----	-----	-----
					Result	----	----	----	----
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		5.8	----	----	----	----
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		<1	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order : **EB2212717**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALEXANDRA KISS
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4107
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : ALEXANDRA KISS
Site : ----
Quote number : EN/222
No. of samples received : 15
No. of samples analysed : 15

Page : 1 of 14
Laboratory : Environmental Division Brisbane
Contact : Customer Services EB
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61-7-3243 7222
Date Samples Received : 03-May-2022 17:00
Date Analysis Commenced : 10-May-2022
Issue Date : 23-May-2022 12:50



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-T (Total Metals by ICP-MS): Sample 2022017_0002 (EB2212717-002) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.
- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- EK040S (Fluoride - Soluble) - Particular samples required dilution prior to analysis due to matrix interferences. LOR values have been adjusted accordingly.
- EG005T (Total Metals by ICP-AES): 2022017_0003 (EB2212717-003) shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- EG020T (Total Metals by ICP-MS): 2022017_0001 (EB2212717-001) shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- ED040S (Soluble Major Anions by ICP-AES): 2022017_0001 (EB2212717-001) shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- It is recognised that ED093T (Total Major Cations by ICP) is less than ED093S (Soluble Major Cations by ICP) for some samples. However, the difference is within experimental variation of the methods.
- EG020X-S - Soluble Metals: Sample 2022017_0001 (EB2212717-001) shows poor duplicate results due to sample heterogeneity. Confirmed by Visual Examination.
- It is recognised that ED093T (Total Major Cations by ICP) is less than ED093S (Soluble Major Cations by ICP) for 2022017_3005 (EB2212717-008). This was confirmed by re-extraction and re-analysis.
- It is recognised that ED093T (Total Major Cations by ICP) is less than ED093S (Soluble Major Cations by ICP) for 2022017_3008 (EB2212717-011). This was confirmed by re-extraction and re-analysis.
- ED006 (Exchangeable Cations on Alkaline Soils): Unable to calculate Calcium/Magnesium Ratio results for some samples as required Calcium & Magnesium results are less than the limit of reporting.
- ED008 (Exchangeable Cations with pre-treatment): Unable to calculate Magnesium/Potassium Ratio results for some samples as required Exchangeable Potassium results are less than the limit of reporting.
- ED008 (Exchangeable Cations with pre-treatment): Unable to calculate Calcium/Magnesium Ratio results for some samples as required Calcium & Magnesium results are less than the limit of reporting.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H^+ + Al^{3+}).



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_0001 Surface Sample	2022017_0002 Surface Sample	2022017_0003 Surface Sample	2022017_3001 Surface Sample	2022017_3002 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-001	EB2212717-002	EB2212717-003	EB2212717-004	EB2212717-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.1	6.6	5.9	----	4.0
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	25	27	65	----	1600
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	----	----	0.014	0.021
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	1.5	1.3	2.1	3.3	1.0
ED005: Exchange Acidity								
∅ Exchange Acidity	----	0.1	meq/100g	2.5	----	<0.1	----	0.7
∅ Exchangeable Aluminium	----	0.1	meq/100g	2.0	----	<0.1	----	0.4
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	0.5	3.0	4.8	----	----
Exchangeable Magnesium	----	0.1	meq/100g	1.0	2.9	1.5	----	----
Exchangeable Potassium	----	0.1	meq/100g	0.2	0.6	0.5	----	----
Exchangeable Sodium	----	0.1	meq/100g	0.2	<0.1	<0.1	----	----
Cation Exchange Capacity	----	0.1	meq/100g	4.4	----	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	----	6.6	6.9	----	----
Exchangeable Sodium Percent	----	0.1	%	10.3	0.8	0.6	----	----
Calcium/Magnesium Ratio	----	0.1	-	0.5	1.0	3.2	----	----
Magnesium/Potassium Ratio	----	0.1	-	5.8	5.0	2.9	----	----
ED008: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	----	2.5
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	----	<0.1
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	----	<0.1
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	----	0.1
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	3.5
Exchangeable Sodium Percent	----	0.1	%	----	----	----	----	4.8
ED037: Alkalinity								
∅ Total Alkalinity as CaCO ₃	----	1	mg/kg	43	243	321	<5	<5
∅ Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/kg	43	243	321	<5	<5
∅ Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/kg	<5	<5	<5	<5	<5
ED038A: Acidity								
Acidity	----	1	mg/kg	808	252	156	888	578



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_0001 Surface Sample	2022017_0002 Surface Sample	2022017_0003 Surface Sample	2022017_3001 Surface Sample	2022017_3002 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-001	EB2212717-002	EB2212717-003	EB2212717-004	EB2212717-005
				Result	Result	Result	Result	Result
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	40	30	20	4960	3290
Silica	7631-86-9	1	mg/kg	55	36	449	18	19
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	10	<10	760	680
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	10	10	1680	710
Magnesium	7439-95-4	10	mg/kg	<10	10	10	90	90
Sodium	7440-23-5	10	mg/kg	30	<10	<10	680	900
Potassium	7440-09-7	10	mg/kg	<10	40	40	<10	10
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	50	<50	<50	980	1110
Potassium	7440-09-7	50	mg/kg	460	1140	1410	710	480
Calcium	7440-70-2	50	mg/kg	120	690	1130	4770	1090
Magnesium	7439-95-4	50	mg/kg	1460	1530	1310	120	90
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Iron	7439-89-6	1	mg/kg	6	2	81	2	3
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	5120	4760	5100	1200	510
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	22100	24900	33800	8530	6140
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	<0.01	<0.01	<0.01	0.02	0.11
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	7440-39-3	0.01	mg/kg	0.04	0.34	0.08	<0.01	0.01
Beryllium	7440-41-7	0.01	mg/kg	<0.01	<0.01	<0.01	0.06	0.08
Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	<0.01	0.02	0.02
Cobalt	7440-48-4	0.01	mg/kg	<0.01	<0.01	<0.01	0.92	1.34
Chromium	7440-47-3	0.01	mg/kg	<0.01	<0.01	<0.01	0.02	0.02
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	7440-50-8	0.01	mg/kg	<0.01	<0.01	<0.01	0.31	0.31
Manganese	7439-96-5	0.01	mg/kg	0.34	0.53	0.05	11.8	10.3
Molybdenum	7439-98-7	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	7440-02-0	0.01	mg/kg	<0.01	<0.01	0.01	1.32	1.75



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_0001 Surface Sample	2022017_0002 Surface Sample	2022017_0003 Surface Sample	2022017_3001 Surface Sample	2022017_3002 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-001	EB2212717-002	EB2212717-003	EB2212717-004	EB2212717-005
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	7440-36-0	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.01	mg/kg	<0.01	<0.01	<0.01	0.03	<0.01
Zinc	7440-66-6	0.05	mg/kg	<0.05	<0.05	<0.05	3.69	4.47
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Aluminium	7429-90-5	0.1	mg/kg	4.1	1.6	4.8	19.9	24.1
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	4.3	3.5	5.0	88.6	96.6
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	<1	<1
Barium	7440-39-3	0.1	mg/kg	37.2	190	117	85.1	52.0
Beryllium	7440-41-7	0.1	mg/kg	0.4	0.6	0.6	0.4	0.2
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	5.2	9.3	9.2	2.1	1.6
Chromium	7440-47-3	0.1	mg/kg	15.5	22.8	55.4	21.4	6.9
Copper	7440-50-8	0.1	mg/kg	7.4	6.5	12.6	10.4	6.5
Thorium	7440-29-1	0.1	mg/kg	1.0	3.3	3.8	1.4	0.9
Manganese	7439-96-5	0.1	mg/kg	114	392	559	20.9	15.4
Molybdenum	7439-98-7	0.1	mg/kg	0.2	0.2	0.2	1.4	1.2
Nickel	7440-02-0	0.1	mg/kg	12.7	9.7	22.4	3.6	2.8
Lead	7439-92-1	0.1	mg/kg	13.0	27.5	19.4	3.9	2.7
Antimony	7440-36-0	0.1	mg/kg	0.2	0.2	0.3	8.7	6.1
Uranium	7440-61-1	0.1	mg/kg	0.6	0.4	0.4	1.5	0.5
Zinc	7440-66-6	0.5	mg/kg	19.2	15.1	26.5	9.4	6.9
Vanadium	7440-62-2	1	mg/kg	14	16	24	4	2
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	0.3	0.4
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	<2	<2	<2	2	2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	----	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	<0.1



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022017_0001 Surface Sample	2022017_0002 Surface Sample	2022017_0003 Surface Sample	2022017_3001 Surface Sample	2022017_3002 Surface Sample
Sampling date / time					03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-001	EB2212717-002	EB2212717-003	EB2212717-004	EB2212717-005	
Result				Result	Result	Result	Result	Result	
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	0.2	29.0	7.4	----	18.5	
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	0.2	29.0	7.4	----	18.5	
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg	730	670	650	----	120	
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg	730	700	660	----	140	
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg	158	154	167	----	468	
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022017_3003 Surface Sample	2022017_3004 Surface Sample	2022017_3005 Surface Sample	2022017_3006 Surface Sample	2022017_3007 Surface Sample
Sampling date / time					03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit		EB2212717-006	EB2212717-007	EB2212717-008	EB2212717-009	EB2212717-010
				Result	Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit	----	----	----	3.9	----	----
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm	----	----	----	2040	----	----
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%	0.019	0.017	0.017	0.017	0.016	0.031
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%	3.5	6.6	12.0	9.9	4.9	
ED005: Exchange Acidity									
∅ Exchange Acidity	----	0.1	meq/100g	----	----	0.7	----	----	----
∅ Exchangeable Aluminium	----	0.1	meq/100g	----	----	0.4	----	----	----
ED008: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g	----	----	4.3	----	----	----
Exchangeable Magnesium	----	0.1	meq/100g	----	----	<0.1	----	----	----
Exchangeable Potassium	----	0.1	meq/100g	----	----	<0.1	----	----	----
Exchangeable Sodium	----	0.1	meq/100g	----	----	<0.1	----	----	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	5.3	----	----	----
Exchangeable Sodium Percent	----	0.1	%	----	----	1.9	----	----	----
ED037: Alkalinity									
∅ Total Alkalinity as CaCO ₃	----	1	mg/kg	<5	<5	<5	<5	<5	<5
∅ Bicarbonate Alkalinity as CaCO ₃	71-52-3	1	mg/kg	<5	<5	<5	<5	<5	<5
∅ Carbonate Alkalinity as CaCO ₃	3812-32-6	1	mg/kg	<5	<5	<5	<5	<5	<5
ED038A: Acidity									
Acidity	----	1	mg/kg	1070	908	1240	1730	990	
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO ₄ 2-	14808-79-8	10	mg/kg	9100	2190	7760	10200	2720	
Silica	7631-86-9	1	mg/kg	23	26	32	37	19	
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg	260	230	50	400	740	
ED093S: Soluble Major Cations									
Calcium	7440-70-2	10	mg/kg	2630	490	2540	3090	520	
Magnesium	7439-95-4	10	mg/kg	160	70	100	180	110	
Sodium	7440-23-5	10	mg/kg	1020	410	480	1110	900	
Potassium	7440-09-7	10	mg/kg	<10	<10	<10	<10	<10	



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_3003 Surface Sample	2022017_3004 Surface Sample	2022017_3005 Surface Sample	2022017_3006 Surface Sample	2022017_3007 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-006	EB2212717-007	EB2212717-008	EB2212717-009	EB2212717-010
				Result	Result	Result	Result	Result
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	1370	910	930	1670	1420
Potassium	7440-09-7	50	mg/kg	790	880	1000	970	1160
Calcium	7440-70-2	50	mg/kg	2840	470	1060	7620	830
Magnesium	7439-95-4	50	mg/kg	150	90	140	240	150
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Iron	7439-89-6	1	mg/kg	<1	<1	1	<1	2
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	750	2930	1350	2440	3780
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	9150	6480	10800	10600	6880
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	0.09	0.02	0.09	0.03	<0.01
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	7440-39-3	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Beryllium	7440-41-7	0.01	mg/kg	0.17	0.08	0.09	0.22	0.04
Cadmium	7440-43-9	0.01	mg/kg	0.06	0.02	0.04	0.09	0.03
Cobalt	7440-48-4	0.01	mg/kg	3.26	1.35	2.39	4.12	2.02
Chromium	7440-47-3	0.01	mg/kg	0.04	0.02	0.04	0.06	<0.01
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	7440-50-8	0.01	mg/kg	0.67	0.37	0.70	1.02	0.10
Manganese	7439-96-5	0.01	mg/kg	24.9	9.60	13.5	26.5	15.1
Molybdenum	7439-98-7	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	7440-02-0	0.01	mg/kg	4.72	1.80	3.20	5.67	2.62
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	7440-36-0	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.01	mg/kg	0.05	0.03	0.06	0.15	0.01
Zinc	7440-66-6	0.05	mg/kg	6.95	2.76	5.52	10.3	4.42
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Aluminium	7429-90-5	0.1	mg/kg	86.1	31.4	86.1	82.4	4.2
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	106	84.4	146	128	80.8
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	<1	<1
Barium	7440-39-3	0.1	mg/kg	47.3	66.7	78.9	81.2	74.2

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022017_3003 Surface Sample	2022017_3004 Surface Sample	2022017_3005 Surface Sample	2022017_3006 Surface Sample	2022017_3007 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	
Compound	CAS Number	LOR	Unit	EB2212717-006	EB2212717-007	EB2212717-008	EB2212717-009	EB2212717-010	
				Result	Result	Result	Result	Result	
EG020T: Total Metals by ICP-MS - Continued									
Beryllium	7440-41-7	0.1	mg/kg	0.4	0.4	0.3	0.5	0.8	
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	0.1	<0.1	
Cobalt	7440-48-4	0.1	mg/kg	3.5	2.6	2.9	6.2	4.6	
Chromium	7440-47-3	0.1	mg/kg	10.5	15.6	17.4	29.5	22.1	
Copper	7440-50-8	0.1	mg/kg	7.4	17.1	10.1	16.7	19.0	
Thorium	7440-29-1	0.1	mg/kg	1.0	1.1	1.4	1.6	1.2	
Manganese	7439-96-5	0.1	mg/kg	30.0	21.0	23.5	40.4	31.9	
Molybdenum	7439-98-7	0.1	mg/kg	1.3	1.0	1.3	1.8	1.2	
Nickel	7440-02-0	0.1	mg/kg	5.6	3.8	4.4	8.2	5.7	
Lead	7439-92-1	0.1	mg/kg	4.3	4.6	7.5	8.0	3.2	
Antimony	7440-36-0	0.1	mg/kg	8.7	7.8	9.6	10.7	9.3	
Uranium	7440-61-1	0.1	mg/kg	0.6	1.0	1.2	1.5	1.3	
Zinc	7440-66-6	0.5	mg/kg	9.6	7.6	10.0	18.5	14.9	
Vanadium	7440-62-2	1	mg/kg	2	3	3	4	3	
EG035S: Soluble Mercury by FIMS									
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg	0.4	0.1	0.4	0.4	0.2	
EK040S: Fluoride Soluble									
Fluoride	16984-48-8	1	mg/kg	3	3	4	4	1	
EK055: Ammonia as N									
Ammonia as N	7664-41-7	20	mg/kg	----	----	<20	----	----	
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	----	----	<0.1	----	----	
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	----	----	1.7	----	----	
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	----	----	1.7	----	----	
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg	----	----	120	----	----	
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg	----	----	120	----	----	
EK067G: Total Phosphorus as P by Discrete Analyser									



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_3003 Surface Sample	2022017_3004 Surface Sample	2022017_3005 Surface Sample	2022017_3006 Surface Sample	2022017_3007 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-006	EB2212717-007	EB2212717-008	EB2212717-009	EB2212717-010
				Result	Result	Result	Result	Result
EK067G: Total Phosphorus as P by Discrete Analyser - Continued								
Total Phosphorus as P	----	2	mg/kg	----	----	519	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	<0.1	0.1	<0.1	<0.1

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022017_3008 Surface Sample	2022017_3009 Surface Sample	2022017_3010 Surface Sample	2022017_3011 Surface Sample	2022017_3012 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	
Compound	CAS Number	LOR	Unit	EB2212717-011	EB2212717-012	EB2212717-013	EB2212717-014	EB2212717-015	
				Result	Result	Result	Result	Result	
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit	4.1	----	8.6	4.2	5.4	
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm	1760	----	738	3810	3130	
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%	0.025	0.018	----	0.022	0.028	
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%	4.1	9.0	<1.0	11.1	3.3	
ED005: Exchange Acidity									
∅ Exchange Acidity	----	0.1	meq/100g	0.3	----	----	0.5	<0.1	
∅ Exchangeable Aluminium	----	0.1	meq/100g	0.1	----	----	0.2	<0.1	
ED006: Exchangeable Cations on Alkaline Soils									
∅ Exchangeable Calcium	----	0.2	meq/100g	----	----	2.2	----	----	
∅ Exchangeable Magnesium	----	0.2	meq/100g	----	----	<0.2	----	----	
∅ Exchangeable Potassium	----	0.2	meq/100g	----	----	0.4	----	----	
∅ Exchangeable Sodium	----	0.2	meq/100g	----	----	0.4	----	----	
∅ Cation Exchange Capacity	----	0.2	meq/100g	----	----	3.0	----	----	
∅ Exchangeable Sodium Percent	----	0.2	%	----	----	14.2	----	----	
∅ Magnesium/Potassium Ratio	----	0.2	-	----	----	<0.2	----	----	
ED008: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g	2.0	----	----	7.0	5.4	
Exchangeable Magnesium	----	0.1	meq/100g	<0.1	----	----	0.4	0.4	
Exchangeable Potassium	----	0.1	meq/100g	0.1	----	----	0.9	0.2	
Exchangeable Sodium	----	0.1	meq/100g	<0.1	----	----	1.0	0.2	
Cation Exchange Capacity	----	0.1	meq/100g	2.7	----	----	10.0	----	
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	----	6.3	
Exchangeable Sodium Percent	----	0.1	%	3.2	----	----	10.5	2.5	
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	17.5	13.5	
Magnesium/Potassium Ratio	----	0.1	-	<0.1	----	----	0.4	1.5	
ED037: Alkalinity									
∅ Total Alkalinity as CaCO3	----	1	mg/kg	<5	<5	641	<5	61	
∅ Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	<5	<5	641	<5	61	
∅ Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	<5	<5	
ED038A: Acidity									



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_3008 Surface Sample	2022017_3009 Surface Sample	2022017_3010 Surface Sample	2022017_3011 Surface Sample	2022017_3012 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-011	EB2212717-012	EB2212717-013	EB2212717-014	EB2212717-015
				Result	Result	Result	Result	Result
ED038A: Acidity - Continued								
Acidity	----	1	mg/kg	702	1650	8	2720	248
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	4230	8140	1370	8880	6590
Silica	7631-86-9	1	mg/kg	24	31	31	42	22
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	840	340	320	3500	2400
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	1510	2220	350	1790	1560
Magnesium	7439-95-4	10	mg/kg	70	180	40	350	260
Sodium	7440-23-5	10	mg/kg	650	880	340	3760	2260
Potassium	7440-09-7	10	mg/kg	50	<10	100	100	250
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	920	1010	410	4870	2150
Potassium	7440-09-7	50	mg/kg	990	1130	520	3390	920
Calcium	7440-70-2	50	mg/kg	1150	4240	1190	1970	1480
Magnesium	7439-95-4	50	mg/kg	90	160	450	480	570
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Iron	7439-89-6	1	mg/kg	2	<1	<1	<1	<1
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	540	860	1250	9570	1230
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	9110	9440	5250	17600	6410
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	0.16	0.30	0.07	0.07	0.02
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	7440-39-3	0.01	mg/kg	0.02	0.02	0.22	<0.01	0.06
Beryllium	7440-41-7	0.01	mg/kg	<0.01	0.09	<0.01	0.05	<0.01
Cadmium	7440-43-9	0.01	mg/kg	<0.01	0.04	<0.01	<0.01	<0.01
Cobalt	7440-48-4	0.01	mg/kg	0.49	3.45	0.04	0.54	0.26
Chromium	7440-47-3	0.01	mg/kg	<0.01	0.08	<0.01	0.01	<0.01
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	7440-50-8	0.01	mg/kg	0.19	0.73	0.03	0.14	0.02
Manganese	7439-96-5	0.01	mg/kg	5.04	27.2	0.09	4.05	8.12



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_3008 Surface Sample	2022017_3009 Surface Sample	2022017_3010 Surface Sample	2022017_3011 Surface Sample	2022017_3012 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-011	EB2212717-012	EB2212717-013	EB2212717-014	EB2212717-015
				Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued								
Molybdenum	7439-98-7	0.01	mg/kg	<0.01	<0.01	0.02	<0.01	<0.01
Nickel	7440-02-0	0.01	mg/kg	0.66	5.24	<0.01	0.64	0.07
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	7440-36-0	0.01	mg/kg	<0.01	0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.01	mg/kg	<0.01	0.03	<0.01	0.02	<0.01
Zinc	7440-66-6	0.05	mg/kg	3.24	8.10	<0.05	2.39	0.24
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Aluminium	7429-90-5	0.1	mg/kg	7.3	169	0.2	11.5	0.2
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	143	156	33.8	194	54.8
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	1	<1
Barium	7440-39-3	0.1	mg/kg	67.6	59.0	118	162	118
Beryllium	7440-41-7	0.1	mg/kg	<0.1	0.3	0.3	1.4	0.2
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg	1.2	3.8	1.9	5.1	1.4
Chromium	7440-47-3	0.1	mg/kg	7.7	7.8	12.7	94.7	7.3
Copper	7440-50-8	0.1	mg/kg	9.1	6.5	7.4	43.2	8.4
Thorium	7440-29-1	0.1	mg/kg	1.3	1.8	1.0	2.4	1.3
Manganese	7439-96-5	0.1	mg/kg	10.4	27.8	60.7	30.9	47.9
Molybdenum	7439-98-7	0.1	mg/kg	1.4	3.0	0.7	2.2	1.5
Nickel	7440-02-0	0.1	mg/kg	2.0	5.8	4.0	5.8	1.8
Lead	7439-92-1	0.1	mg/kg	5.3	12.8	3.2	11.3	4.8
Antimony	7440-36-0	0.1	mg/kg	8.2	12.8	3.5	8.6	3.0
Uranium	7440-61-1	0.1	mg/kg	0.5	1.2	0.4	3.3	0.5
Zinc	7440-66-6	0.5	mg/kg	6.9	10.8	6.4	17.7	7.4
Vanadium	7440-62-2	1	mg/kg	3	2	4	6	4
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	0.4	0.3	0.2	0.2	0.1
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	<1	8	2	1	<1
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	----	<20	<20	<20



Analytical Results

Sub-Matrix: SOIL
 (Matrix: SOIL)

Sample ID

				2022017_3008 Surface Sample	2022017_3009 Surface Sample	2022017_3010 Surface Sample	2022017_3011 Surface Sample	2022017_3012 Surface Sample
Sampling date / time				03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00	03-May-2022 00:00
Compound	CAS Number	LOR	Unit	EB2212717-011	EB2212717-012	EB2212717-013	EB2212717-014	EB2212717-015
				Result	Result	Result	Result	Result
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	----	<0.1	0.2	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	19.0	----	0.1	47.6	0.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	19.0	----	0.1	47.8	0.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	100	----	150	310	110
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	120	----	150	360	110
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	414	----	516	880	466
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	0.1	1.3	<0.1	<0.1	<0.1

SOIL PARTICLE DENSITY TEST REPORT

Test Method: AS 1289 3.5.1

Client	RGS Environmental Pty Ltd	Report No.	22050524-SG
Address	PO Box 3091, Sunnybank South QLD 4109	Workorder No.	0009793
		Report Date	24/05/2022

Project 2022017 Yandan Tailings Assessment

Sample No.	22050524	22050525	22050526	22050527	22050528	22050529	22050530
Test Date	23/05/2022	23/05/2022	23/05/2022	23/05/2022	23/05/2022	23/05/2022	23/05/2022
Client ID	2022017_000 1	2022017_000 2	2022017_000 3	2022017_30 01	2022017_300 2	2022017_30 03	2022017_300 4
Depth (m)	Surface Sample	Surface Sample	Surface Sample	Surface Sample	Surface Sample	Surface Sample	Surface Sample
Soil Particle Density (t/m³) (-2.36mm)	2.58	2.62	2.58	2.54	2.52	2.53	2.58

Sample No.	22050531	22050532	22050533	22050534	22050535	22050536	22050537
Test Date	23/05/2022	23/05/2022	23/05/2022	23/05/2022	23/05/2022	23/05/2022	23/05/2022
Client ID	2022017_300 5	2022017_300 6	2022017_300 7	2022017_30 08	2022017_300 9	2022017_30 10	2022017_301 1
Depth (m)	Surface Sample	Surface Sample	Surface Sample	Surface Sample	Surface Sample	Surface Sample	Surface Sample
Soil Particle Density (t/m³) (-2.36mm)	2.52	2.39	2.58	2.57	2.54	2.58	2.31

NOTES/REMARKS:

Sample/s supplied by the client

Page 1 of 1 REP04603

Accredited for compliance with ISO/IEC 17025 - Testing.
 The results of the tests, calibrations, and/or measurements included in this document are traceable to the International System of Units (SI). References are traceable to National Measurement Institutes or laboratories accredited to ISO/IEC 17025 by a signatory to the ILAC MRA.

Tested at Trilab Brisbane Laboratory

Authorised Signatory



Joshua Hawley



Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
 Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.

Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

SOIL PARTICLE DENSITY TEST REPORT

Test Method: AS 1289 3.5.1

Client	RGS Environmental Pty Ltd	Report No.	22050538-SG
Address	PO Box 3091, Sunnybank South QLD 4109	Workorder No.	0009793
		Report Date	24/05/2022

Project 2022017 Yandan Tailings Assessment

Sample No.	22050538						
Test Date	23/05/2022						
Client ID	2022017_301 2	-	-	-	-	-	-
Depth (m)	Surface Sample	-	-	-	-	-	-
Soil Particle Density (t/m³) (-2.36mm)	2.60						

Sample No.							
Test Date							
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Soil Particle Density (t/m³) (-2.36mm)							

NOTES/REMARKS:

Sample/s supplied by the client

Page 1 of 1 REP04603

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to the International System of Units (SI). References are traceable to National Measurement Institutes or laboratories accredited to ISO/IEC 17025 by a signatory to the ILAC MRA.

Tested at Trilab Brisbane Laboratory

Authorised Signatory



Joshua Hawley



Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.

Trilab Pty Ltd ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

CERTIFICATE OF ANALYSIS

Work Order : **EB2217195**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALEXANDRA KISS
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4107
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : ASITHA JAJASINGHE
Site :
Quote number : BN/1234/19
No. of samples received : 6
No. of samples analysed : 6

Page : 1 of 6
Laboratory : Environmental Division Brisbane
Contact : Carsten Emrich
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61 7 3552 8616
Date Samples Received : 15-Jun-2022 15:21
Date Analysis Commenced : 17-Jun-2022
Issue Date : 23-Jun-2022 16:15



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- EG020-F (Dissolved Metals by ICP-MS): Limit of reporting raised for some samples due to matrix interference.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Sample ID

				WKLC1 Treated tailings Cell B 4g/kg CaCO3	WKLC2 Treated tailings Cell B 42/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated tailings Cell A 4g/kg CaCO3	WKLC5 Treated tailings Cell A 2g/kg CaCO3
Sampling date / time				15-Jun-2022 00:00	15-Jun-2022 00:00	15-Jun-2022 00:00	15-Jun-2022 00:00	15-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2217195-001	EB2217195-002	EB2217195-003	EB2217195-004	EB2217195-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.55	7.76	3.67	7.80	7.95
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	8610	5060	10000	39600	37900
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	220	224	<1	272	313
Total Alkalinity as CaCO3	----	1	mg/L	220	224	<1	272	313
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	43	26	657	25	27
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	3560	2340	4760	9720	9920
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	916	321	1030	10500	10100
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	465	502	429	579	580
Magnesium	7439-95-4	1	mg/L	179	105	213	1160	1060
Sodium	7440-23-5	1	mg/L	1390	584	1570	10000	9480
Potassium	7440-09-7	1	mg/L	3	2	5	414	353
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.02	0.08	99.5	<0.05	<0.05
Antimony	7440-36-0	0.001	mg/L	0.024	0.027	0.004	0.013	0.013
Arsenic	7440-38-2	0.001	mg/L	0.029	0.025	0.134	0.054	0.064
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.238	<0.005	<0.005
Barium	7440-39-3	0.001	mg/L	0.003	0.002	0.005	0.016	0.015
Cadmium	7440-43-9	0.0001	mg/L	0.0079	0.0026	0.0806	0.0029	0.0020
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.062	<0.005	<0.005
Cobalt	7440-48-4	0.001	mg/L	1.05	0.513	3.67	1.38	1.28
Copper	7440-50-8	0.001	mg/L	0.009	0.005	0.830	0.074	0.047
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.002	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	16.8	8.70	31.0	17.1	11.8
Molybdenum	7439-98-7	0.001	mg/L	0.002	0.003	<0.001	<0.005	<0.005
Nickel	7440-02-0	0.001	mg/L	1.06	0.287	5.01	0.048	0.034



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC1 Treated tailings Cell B 4g/kg CaCO3	WKLC2 Treated tailings Cell B 42/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated tailings Cell A 4g/kg CaCO3	WKLC5 Treated tailings Cell A 2g/kg CaCO3
Sampling date / time				15-Jun-2022 00:00	15-Jun-2022 00:00	15-Jun-2022 00:00	15-Jun-2022 00:00	15-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2217195-001	EB2217195-002	EB2217195-003	EB2217195-004	EB2217195-005
Result				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	0.03	0.01	0.05	<0.05	<0.05
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005
Uranium	7440-61-1	0.001	mg/L	0.034	0.071	0.130	0.057	0.118
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.05	<0.05
Zinc	7440-66-6	0.005	mg/L	0.427	0.087	8.71	0.087	0.048
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.08	0.20	0.12
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	1.08	0.68	0.60
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.3	0.3	9.2	0.3	0.2
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	104	62.2	128	504	498
∅ Total Cations	----	0.01	meq/L	98.5	59.1	107	570	538
∅ Ionic Balance	----	0.01	%	2.90	2.56	8.83	6.14	3.85



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC6	----	----	----	----
				Control Cell A	----	----	----	----
Sampling date / time				15-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2217195-006	-----	-----	-----	-----
Result				----	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.54	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	39300	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	74	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	74	----	----	----	----
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	15	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	11000	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	10400	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	569	----	----	----	----
Magnesium	7439-95-4	1	mg/L	1230	----	----	----	----
Sodium	7440-23-5	1	mg/L	9850	----	----	----	----
Potassium	7440-09-7	1	mg/L	424	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.05	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	0.008	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.028	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.005	----	----	----	----
Barium	7440-39-3	0.001	mg/L	0.020	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0063	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.005	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	1.37	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.029	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.015	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	25.6	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.005	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.105	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.05	----	----	----	----



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC6	----	----	----	----
				Control Cell A				
Sampling date / time				15-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2217195-006	-----	-----	-----	-----
Result					----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Thorium	7440-29-1	0.001	mg/L	<0.005	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.005	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.05	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.377	----	----	----	----
Boron	7440-42-8	0.05	mg/L	0.26	----	----	----	----
Iron	7439-89-6	0.05	mg/L	0.54	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	524	----	----	----	----
∅ Total Cations	----	0.01	meq/L	569	----	----	----	----
∅ Ionic Balance	----	0.01	%	4.12	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order : **EB2216488**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALAN ROBERTSON
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4107
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : LE XI NG
Site :
Quote number : BN/1234/19
No. of samples received : 6
No. of samples analysed : 6

Page : 1 of 6
Laboratory : Environmental Division Brisbane
Contact : Carsten Emrich
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61 7 3552 8616
Date Samples Received : 09-Jun-2022 16:33
Date Analysis Commenced : 13-Jun-2022
Issue Date : 20-Jun-2022 11:14



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- EG020-F (Dissolved Metals by ICP-MS): Limit of reporting raised for some samples due to matrix interference.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Sample ID

				WKLC2 Treated Tailing Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated Tailing Cell A 4g/kg CaCO3	WKLC1 Treated Tailing Cell B 4g/kg CaCO3	WKLC5 Treated Tailing Cell A 2g/kg CaCO3
Sampling date / time				09-Jun-2022 00:00	09-Jun-2022 00:00	09-Jun-2022 00:00	09-Jun-2022 00:00	09-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2216488-001	EB2216488-002	EB2216488-003	EB2216488-004	EB2216488-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.56	3.91	7.35	7.20	7.64
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	10900	7330	22400	9020	18900
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	194	<1	102	73	143
Total Alkalinity as CaCO3	----	1	mg/L	194	<1	102	73	143
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	15	469	22	21	12
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	5650	3870	7610	4450	6480
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	1850	904	7600	1260	6190
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	429	353	507	408	516
Magnesium	7439-95-4	1	mg/L	379	166	683	222	494
Sodium	7440-23-5	1	mg/L	3480	1330	6560	1910	5060
Potassium	7440-09-7	1	mg/L	9	6	277	6	208
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.02	63.0	<0.05	0.07	<0.05
Antimony	7440-36-0	0.001	mg/L	0.024	0.004	0.008	0.012	0.006
Arsenic	7440-38-2	0.001	mg/L	0.012	0.046	0.036	0.006	0.039
Beryllium	7440-41-7	0.001	mg/L	<0.001	0.163	<0.005	0.002	<0.005
Barium	7440-39-3	0.001	mg/L	0.031	0.007	0.030	0.019	0.020
Cadmium	7440-43-9	0.0001	mg/L	0.0160	0.0662	0.0023	0.0305	0.0010
Chromium	7440-47-3	0.001	mg/L	<0.001	0.052	<0.005	0.001	<0.005
Cobalt	7440-48-4	0.001	mg/L	1.68	3.33	0.717	3.09	0.567
Copper	7440-50-8	0.001	mg/L	0.013	0.628	0.030	0.024	0.024
Lead	7439-92-1	0.001	mg/L	<0.001	0.001	<0.005	<0.001	<0.005
Manganese	7439-96-5	0.001	mg/L	32.8	25.7	9.79	29.2	5.17
Molybdenum	7439-98-7	0.001	mg/L	0.003	<0.001	<0.005	<0.001	<0.005
Nickel	7440-02-0	0.001	mg/L	1.51	4.40	0.040	3.68	0.019



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC2 Treated Tailing Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated Tailing Cell A 4g/kg CaCO3	WKLC1 Treated Tailing Cell B 4g/kg CaCO3	WKLC5 Treated Tailing Cell A 2g/kg CaCO3
Sampling date / time				09-Jun-2022 00:00	09-Jun-2022 00:00	09-Jun-2022 00:00	09-Jun-2022 00:00	09-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2216488-001	EB2216488-002	EB2216488-003	EB2216488-004	EB2216488-005
Result				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	0.10	0.07	<0.05	0.05	<0.05
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.005	<0.001	<0.005
Uranium	7440-61-1	0.001	mg/L	0.015	0.074	<0.005	0.002	0.013
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.05	<0.01	<0.05
Zinc	7440-66-6	0.005	mg/L	0.738	8.05	0.128	3.42	0.050
Boron	7440-42-8	0.05	mg/L	<0.05	0.06	0.14	<0.05	0.09
Iron	7439-89-6	0.05	mg/L	0.09	1.14	0.21	<0.05	0.20
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.3	0.2	0.2	0.6	0.2
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	174	106	375	130	312
∅ Total Cations	----	0.01	meq/L	204	89.3	374	122	292
∅ Ionic Balance	----	0.01	%	8.07	8.60	0.12	3.10	3.40



Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	WKLC6 Control Cell A	----	----	----	----
Sampling date / time				09-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2216488-006	-----	-----	-----	-----
Result				----	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.02	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	23200	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	50	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	50	----	----	----	----
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	13	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	8620	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	8140	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	498	----	----	----	----
Magnesium	7439-95-4	1	mg/L	815	----	----	----	----
Sodium	7440-23-5	1	mg/L	7310	----	----	----	----
Potassium	7440-09-7	1	mg/L	322	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.05	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	0.006	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.036	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.005	----	----	----	----
Barium	7440-39-3	0.001	mg/L	0.036	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0052	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.005	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.917	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.028	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.024	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	16.2	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.005	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.079	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.05	----	----	----	----



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC6	----	----	----	----
				Control Cell A				
Sampling date / time				09-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2216488-006	-----	-----	-----	-----
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Thorium	7440-29-1	0.001	mg/L	<0.005	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.005	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.05	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.354	----	----	----	----
Boron	7440-42-8	0.05	mg/L	0.22	----	----	----	----
Iron	7439-89-6	0.05	mg/L	0.25	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.1	----	----	----	----
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	410	----	----	----	----
∅ Total Cations	----	0.01	meq/L	418	----	----	----	----
∅ Ionic Balance	----	0.01	%	0.97	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order : **EB2218381**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALEXANDRA KISS
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4107
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : ASITHA JAJASINGHE
Site : ----
Quote number : BN/1234/19
No. of samples received : 6
No. of samples analysed : 6

Page : 1 of 6
Laboratory : Environmental Division Brisbane
Contact : Carsten Emrich
Address : 2 Byth Street Stafford QLD Australia 4053

Telephone : +61 7 3552 8616
Date Samples Received : 24-Jun-2022 15:45
Date Analysis Commenced : 28-Jun-2022
Issue Date : 06-Jul-2022 08:31



Accreditation No. 825
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 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Sample ID

				WKLC1 Treated tailings Cell B 4g/kg CaCO3	WKLC2 Treated tailings Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated tailings Cell A 4g/kg CaCO3	WKLC5 Treated tailings Cell A 2g/kg CaCO3
Sampling date / time				24-Jun-2022 00:00	24-Jun-2022 00:00	24-Jun-2022 00:00	24-Jun-2022 00:00	24-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2218381-001	EB2218381-002	EB2218381-003	EB2218381-004	EB2218381-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.44	7.74	4.27	7.11	7.56
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	3590	2790	3810	12700	7300
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	162	164	<1	143	153
Total Alkalinity as CaCO3	----	1	mg/L	162	164	<1	143	153
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	34	20	290	30	17
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1890	1510	2110	5020	3490
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	88	10	135	1550	526
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	583	644	537	489	497
Magnesium	7439-95-4	1	mg/L	80	40	53	306	194
Sodium	7440-23-5	1	mg/L	300	102	258	2180	952
Potassium	7440-09-7	1	mg/L	2	1	2	142	88
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.01	<0.01	19.6	0.02	<0.01
Antimony	7440-36-0	0.001	mg/L	0.020	0.022	0.006	0.002	0.002
Arsenic	7440-38-2	0.001	mg/L	0.047	0.031	0.667	0.058	0.053
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.082	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	0.002	0.001	0.002	0.011	0.005
Cadmium	7440-43-9	0.0001	mg/L	0.0025	0.0015	0.0163	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.039	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	0.613	0.481	0.941	0.409	0.333
Copper	7440-50-8	0.001	mg/L	0.006	0.006	0.014	0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.002	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	7.40	5.08	7.23	11.8	7.81
Molybdenum	7439-98-7	0.001	mg/L	0.002	0.003	<0.001	0.007	0.006
Nickel	7440-02-0	0.001	mg/L	0.343	0.167	1.39	0.046	0.027



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC1 Treated tailings Cell B 4g/kg CaCO3	WKLC2 Treated tailings Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated tailings Cell A 4g/kg CaCO3	WKLC5 Treated tailings Cell A 2g/kg CaCO3
Sampling date / time				24-Jun-2022 00:00	24-Jun-2022 00:00	24-Jun-2022 00:00	24-Jun-2022 00:00	24-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2218381-001	EB2218381-002	EB2218381-003	EB2218381-004	EB2218381-005
Result				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.01	<0.01	<0.01
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L	0.027	0.055	0.017	0.020	0.016
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	0.108	0.045	2.46	0.005	0.008
Boron	7440-42-8	0.05	mg/L	0.08	<0.05	<0.05	0.07	0.06
Iron	7439-89-6	0.05	mg/L	0.45	0.21	46.0	15.3	3.63
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.2	0.2	1.6	0.2	0.2
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	45.1	35.0	47.7	151	90.6
∅ Total Cations	----	0.01	meq/L	48.8	39.9	42.4	148	84.4
∅ Ionic Balance	----	0.01	%	3.95	6.53	5.88	1.02	3.50



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC6	----	----	----	----
				Control Cell A				
Sampling date / time				24-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2218381-006	-----	-----	-----	-----
Result					----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.01	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	20900	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	8	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	8	----	----	----	----
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	133	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	7340	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	3780	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	498	----	----	----	----
Magnesium	7439-95-4	1	mg/L	549	----	----	----	----
Sodium	7440-23-5	1	mg/L	4430	----	----	----	----
Potassium	7440-09-7	1	mg/L	202	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	0.002	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.032	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L	0.010	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0014	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.732	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.007	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	20.4	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	0.002	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.147	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC6	----	----	----	----
				Control Cell A				
Sampling date / time				24-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2218381-006	-----	-----	-----	-----
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Thorium	7440-29-1	0.001	mg/L	<0.001	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.112	----	----	----	----
Boron	7440-42-8	0.05	mg/L	0.13	----	----	----	----
Iron	7439-89-6	0.05	mg/L	49.2	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.1	----	----	----	----
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	260	----	----	----	----
∅ Total Cations	----	0.01	meq/L	268	----	----	----	----
∅ Ionic Balance	----	0.01	%	1.57	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order : **EB2218962**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALEXANDRA KISS
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4108
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : ASITHA JAYASINGHE
Site :
Quote number : BN/1234/19
No. of samples received : 6
No. of samples analysed : 6

Page : 1 of 6
Laboratory : Environmental Division Brisbane
Contact : Carsten Emrich
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61 7 3552 8616
Date Samples Received : 30-Jun-2022 15:05
Date Analysis Commenced : 01-Jul-2022
Issue Date : 11-Jul-2022 18:05



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Mark Hallas	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Sample ID

				WKLC1 Treated tailings Cell B 4g/kg CaCO3	WKLC2 Treated tailings Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated tailings Cell A 4g/kg CaCO3	WKLC5 Treated tailings Cell A 2g/kg CaCO3
Sampling date / time				30-Jun-2022 00:00	30-Jun-2022 00:00	30-Jun-2022 00:00	30-Jun-2022 00:00	30-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2218962-001	EB2218962-002	EB2218962-003	EB2218962-004	EB2218962-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.87	7.37	4.05	5.96	6.60
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	2540	2400	2440	4000	3410
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	129	147	<1	8	34
Total Alkalinity as CaCO3	----	1	mg/L	129	147	<1	8	34
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	11	8	172	60	12
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1600	1490	1590	2600	2200
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	8	3	11	127	68
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	568	590	527	487	470
Magnesium	7439-95-4	1	mg/L	28	16	12	118	97
Sodium	7440-23-5	1	mg/L	60	29	54	323	166
Potassium	7440-09-7	1	mg/L	<1	<1	<1	88	57
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	14.2	<0.01	<0.01
Antimony	7440-36-0	0.001	mg/L	0.026	0.030	0.005	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.047	0.069	0.629	0.031	0.029
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.038	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	0.001	0.001	0.001	0.010	0.007
Cadmium	7440-43-9	0.0001	mg/L	0.0018	0.0012	0.0060	0.0002	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.018	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	0.492	0.328	0.326	0.154	0.131
Copper	7440-50-8	0.001	mg/L	0.009	0.004	0.072	0.001	0.002
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.003	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	4.76	3.66	1.86	10.3	7.82
Molybdenum	7439-98-7	0.001	mg/L	0.002	0.002	<0.001	0.002	0.003
Nickel	7440-02-0	0.001	mg/L	0.205	0.113	0.524	0.024	0.018



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC1 Treated tailings Cell B 4g/kg CaCO3	WKLC2 Treated tailings Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC4 Treated tailings Cell A 4g/kg CaCO3	WKLC5 Treated tailings Cell A 2g/kg CaCO3
Sampling date / time				30-Jun-2022 00:00	30-Jun-2022 00:00	30-Jun-2022 00:00	30-Jun-2022 00:00	30-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2218962-001	EB2218962-002	EB2218962-003	EB2218962-004	EB2218962-005
Result				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L	0.018	0.041	0.014	0.002	0.008
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	0.068	0.035	0.985	0.043	0.012
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	0.08	0.06
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	30.5	40.2	17.0
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.2	0.3	0.4	0.2	0.3
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	36.1	34.0	33.4	57.9	48.4
∅ Total Cations	----	0.01	meq/L	33.2	32.0	29.6	50.3	40.1
∅ Ionic Balance	----	0.01	%	4.12	3.06	6.00	6.99	9.36



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC6	----	----	----	----
				Control Cell A	----	----	----	----
Sampling date / time				30-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2218962-006	-----	-----	-----	-----
Result				----	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	5.24	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	5450	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	<1	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	<1	----	----	----	----
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	206	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	3290	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	376	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	447	----	----	----	----
Magnesium	7439-95-4	1	mg/L	147	----	----	----	----
Sodium	7440-23-5	1	mg/L	684	----	----	----	----
Potassium	7440-09-7	1	mg/L	87	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.028	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L	0.009	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0003	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.233	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.002	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	10.5	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.043	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC6	----	----	----	----
				Control Cell A				
Sampling date / time				30-Jun-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2218962-006	-----	-----	-----	-----
Result					----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Thorium	7440-29-1	0.001	mg/L	<0.001	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.089	----	----	----	----
Boron	7440-42-8	0.05	mg/L	0.07	----	----	----	----
Iron	7439-89-6	0.05	mg/L	95.9	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.1	----	----	----	----
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	79.1	----	----	----	----
∅ Total Cations	----	0.01	meq/L	66.4	----	----	----	----
∅ Ionic Balance	----	0.01	%	8.74	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order : **EB2219972**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALEXANDRA KISS
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4108
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : ASITHA JAYASINGHE
Site : ----
Quote number : BN/1234/19
No. of samples received : 4
No. of samples analysed : 4

Page : 1 of 4
Laboratory : Environmental Division Brisbane
Contact : Carsten Emrich
Address : 2 Byth Street Stafford QLD Australia 4053

Telephone : +61 7 3552 8616
Date Samples Received : 08-Jul-2022 16:47
Date Analysis Commenced : 11-Jul-2022
Issue Date : 18-Jul-2022 15:20



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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 Contract 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

ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Sample ID

				WKLC2 Treated tailings Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC5 Treated tailings Cell A 2g/kg CaCO3	WKLC6 Control Cell A	----
Sampling date / time				08-Jul-2022 00:00	08-Jul-2022 00:00	08-Jul-2022 00:00	08-Jul-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2219972-001	EB2219972-002	EB2219972-003	EB2219972-004	-----
				Result	Result	Result	Result	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.72	4.09	6.22	4.91	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	2300	969	1130	3530	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	138	<1	8	<1	----
Total Alkalinity as CaCO3	----	1	mg/L	138	<1	8	<1	----
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	12	109	65	253	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1370	1120	1700	2310	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	2	3	7	46	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	594	428	531	481	----
Magnesium	7439-95-4	1	mg/L	6	2	49	90	----
Sodium	7440-23-5	1	mg/L	14	16	44	180	----
Potassium	7440-09-7	1	mg/L	<1	<1	59	70	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	10.1	<0.01	<0.01	----
Antimony	7440-36-0	0.001	mg/L	0.027	0.005	<0.001	<0.001	----
Arsenic	7440-38-2	0.001	mg/L	0.044	0.163	0.020	0.018	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	0.029	<0.001	<0.001	----
Barium	7440-39-3	0.001	mg/L	0.001	0.001	0.007	0.010	----
Cadmium	7440-43-9	0.0001	mg/L	0.0009	0.0022	<0.0001	0.0002	----
Chromium	7440-47-3	0.001	mg/L	<0.001	0.010	<0.001	<0.001	----
Cobalt	7440-48-4	0.001	mg/L	0.184	0.115	0.067	0.182	----
Copper	7440-50-8	0.001	mg/L	0.006	0.034	<0.001	0.002	----
Lead	7439-92-1	0.001	mg/L	<0.001	0.002	<0.001	<0.001	----
Manganese	7439-96-5	0.001	mg/L	2.29	0.424	7.91	8.78	----
Molybdenum	7439-98-7	0.001	mg/L	0.004	<0.001	<0.001	<0.001	----
Nickel	7440-02-0	0.001	mg/L	0.077	0.179	0.012	0.068	----



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC2 Treated tailings Cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC5 Treated tailings Cell A 2g/kg CaCO3	WKLC6 Control Cell A	----
Sampling date / time				08-Jul-2022 00:00	08-Jul-2022 00:00	08-Jul-2022 00:00	08-Jul-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2219972-001	EB2219972-002	EB2219972-003	EB2219972-004	-----
				Result	Result	Result	Result	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Uranium	7440-61-1	0.001	mg/L	0.037	0.010	0.002	<0.001	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Zinc	7440-66-6	0.005	mg/L	0.024	0.320	0.010	0.137	----
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.06	0.06	----
Iron	7439-89-6	0.05	mg/L	<0.05	15.6	29.7	111	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.3	0.6	0.3	<0.1	----
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	31.3	23.4	35.8	49.4	----
∅ Total Cations	----	0.01	meq/L	30.7	22.2	34.0	41.0	----
∅ Ionic Balance	----	0.01	%	0.96	2.60	2.58	9.25	----

CERTIFICATE OF ANALYSIS

Work Order : **EB2220545**
Client : **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**
Contact : ALEXANDRA KISS
Address : 3/30 LENSWORTH STREET
 COOPERS PLAINS 4108
Telephone : 07 3344 1222
Project : 2022017 Yandan Tailings Assessment
Order number : ----
C-O-C number : ----
Sampler : LE XI K NG
Site :
Quote number : BN/1234/19
No. of samples received : 4
No. of samples analysed : 4

Page : 1 of 4
Laboratory : Environmental Division Brisbane
Contact : Carsten Emrich
Address : 2 Byth Street Stafford QLD Australia 4053
Telephone : +61 7 3552 8616
Date Samples Received : 14-Jul-2022 17:22
Date Analysis Commenced : 15-Jul-2022
Issue Date : 19-Jul-2022 17:27



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Signatories	Position	Accreditation Category
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD



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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 Contract 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

Ø = ALS is not NATA accredited for these tests.

~ = Indicates an estimated value.

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.



Analytical Results

Sub-Matrix: WATER
 (Matrix: WATER)

Sample ID

				WKLC2 Treated tailings cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC5 Treated tailings cell A 2g/kg CaCO3	WKLC6 Control Cell A	----
Sampling date / time				14-Jul-2022 00:00	14-Jul-2022 00:00	14-Jul-2022 00:00	14-Jul-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2220545-001	EB2220545-002	EB2220545-003	EB2220545-004	-----
				Result	Result	Result	Result	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.51	4.28	5.82	4.88	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	2280	1610	2580	3060	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	118	<1	4	<1	----
Total Alkalinity as CaCO3	----	1	mg/L	118	<1	4	<1	----
ED038: Acidity								
Acidity as CaCO3	----	1	mg/L	8	101	72	299	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1370	867	1640	1930	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	1	1	5	37	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	574	340	534	492	----
Magnesium	7439-95-4	1	mg/L	2	<1	22	47	----
Sodium	7440-23-5	1	mg/L	8	8	28	64	----
Potassium	7440-09-7	1	mg/L	<1	<1	55	60	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	4.88	<0.01	<0.01	----
Antimony	7440-36-0	0.001	mg/L	0.032	0.007	<0.001	<0.001	----
Arsenic	7440-38-2	0.001	mg/L	0.044	0.818	0.018	0.022	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	0.017	<0.001	<0.001	----
Barium	7440-39-3	0.001	mg/L	0.001	0.002	0.008	0.010	----
Cadmium	7440-43-9	0.0001	mg/L	0.0008	0.0010	<0.0001	<0.0001	----
Chromium	7440-47-3	0.001	mg/L	<0.001	0.008	<0.001	<0.001	----
Cobalt	7440-48-4	0.001	mg/L	0.134	0.081	0.058	0.122	----
Copper	7440-50-8	0.001	mg/L	0.006	0.008	0.001	0.002	----
Lead	7439-92-1	0.001	mg/L	<0.001	0.002	<0.001	<0.001	----
Manganese	7439-96-5	0.001	mg/L	1.63	0.212	7.37	7.46	----
Molybdenum	7439-98-7	0.001	mg/L	0.004	<0.001	<0.001	<0.001	----
Nickel	7440-02-0	0.001	mg/L	0.060	0.107	0.009	0.023	----



Analytical Results

Sub-Matrix: **WATER**
 (Matrix: **WATER**)

Sample ID

				WKLC2 Treated tailings cell B 2g/kg CaCO3	WKLC3 Control Cell B	WKLC5 Treated tailings cell A 2g/kg CaCO3	WKLC6 Control Cell A	----
Sampling date / time				14-Jul-2022 00:00	14-Jul-2022 00:00	14-Jul-2022 00:00	14-Jul-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2220545-001	EB2220545-002	EB2220545-003	EB2220545-004	-----
				Result	Result	Result	Result	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Uranium	7440-61-1	0.001	mg/L	0.025	0.004	0.001	<0.001	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
Zinc	7440-66-6	0.005	mg/L	0.016	0.182	0.013	0.080	----
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.06	0.06	----
Iron	7439-89-6	0.05	mg/L	<0.05	27.8	33.4	149	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	0.2	0.5	0.2	0.1	----
EN055: Ionic Balance								
∅ Total Anions	----	0.01	meq/L	30.9	18.1	34.4	41.2	----
∅ Total Cations	----	0.01	meq/L	----	----	----	40.7	----
∅ Total Cations	----	0.01	meq/L	29.2	17.3	31.1	----	----
∅ Ionic Balance	----	0.01	%	----	----	----	0.61	----
∅ Ionic Balance	----	0.01	%	2.92	2.16	5.02	----	----

Attachment F:Table 6-1 and 6-2 of the ERC Users Guide (2019)⁷

User Guide for Estimated Rehabilitation Cost Calculator for Mining

Table 6-1 Risk Category Characteristics

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High Select this category if the waste structure has one or more of the following characteristics:	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm.	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tails materials Requiring composite liners (e.g. HDPE) Embankments > 30 metres high Observed contaminated seepage capable of causing environmental harm.
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end Low strength consolidated tailings land use objectives for the facility Embankments 15 to 30 m high
Low	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD) Moderate to low salinity Moderate strength consolidated tailings Embankments less than 15 m high
Very Low	Benign materials	Benign materials	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments less than 15 m high

An allowance for engineering and design of Waste Rock Dumps, Heap Leach Pads and Tailings Storage Facilities is included in the Default and User-Defined rates.

The engineering costs and default minimum thicknesses of each cap item are shown in **Table 6-2**.

Table 6-2 Capping Engineering Cost and Default Minimum Thicknesses

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High	Engineering \$2,000/ha Working layer 0 m Capillary break 0.6 m Low permeability layer 0.5 m Top Rock Layer 1.5 m	Engineering \$2,000/ha Working layer 0 m Capillary break 0.6 m Low permeability layer 0.5 m Top Rock Layer 1.5 m	Engineering \$2,000/ha Working layer 0.5 m Capillary break 0.6 m Low permeability layer 0.5 m Top Rock Layer 1.5 m
Medium	Engineering \$2,000/ha Working layer 0 m Capillary break 0.3 m Low permeability layer 0 m Top Rock Layer 1.0 m	Engineering \$2,000/ha Working layer 0 m Capillary break 0.3 m Low permeability layer 0 m Top Rock Layer 1.0 m	Engineering \$2,000/ha Working layer 0.5 m Capillary break 0.3 m Low permeability layer 0 m Top Rock Layer 1.0 m
Low	Engineering \$1,500/ha Working layer 0 m Capillary break 0 m Low permeability layer 0 m Top Rock Layer 0.5 m	Engineering \$1,500/ha Working layer 0 m Capillary break 0 m Low permeability layer 0 m Top Rock Layer 0.5 m	Engineering \$1,500/ha Working layer 0 m Capillary break 0 m Low permeability layer 0 m Top Rock Layer 1 m
Very Low	Engineering \$500/ha Working layer 0 m Capillary break 0 m Low permeability layer 0 m Top Rock Layer 0 m	Engineering \$500/ha Working layer 0 m Capillary break 0 m Low permeability layer 0 m Top Rock Layer 0 m	Engineering \$500/ha Working layer 0 m Capillary break 0 m Low permeability layer 0 m Top Rock Layer 0 m

The default thickness for growth media is 0.15 m for all cases.

A worked example illustrating how to calculate the cost of capping of a Waste Rock Dump using the Default and User Defined options is shown in Section 7.

For High Risk Waste Rock Dumps, Heap Leach Pads and Tailings Storage Facilities, the default minimum top rock, capillary break and low-permeability layer thicknesses are locked. This means if the User enters a value below the minimum, it will not be accepted, and the Calculation will default to the minimum. If the User enters a thickness greater than the default minimum, the Calculator uses the User-entered value. The default thickness is not fixed for elements of Medium, Low and Very Low Risk Category. See the worked example in Section 7.4.

6.2 Pasture and Native Seed

Most activities require re-vegetation of the land surface and the Calculator allows for native or pasture type seed. The Calculator typically includes a drop-down menu to allow the selection of native or pasture seed. The Calculator applies the appropriate rate to area required to be seeded. If an area covers both native and pasture land, the User must input separate lines (

Figure 6-2).

RGS



MINE WASTE AND
WATER MANAGEMENT



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RL/rl: (Yandan Groundwater Data Review)
Project No. 284
July 2019

GROUNDWATER DATA REVIEW

YANDAN PROJECT

AERIS RESOURCES PTY LTD

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1.0 INTRODUCTION

Aeris Resources Pty Ltd requested Rob Lait and Associates Pty Ltd to review historical groundwater data collected at the Yandan Mine Project to assess its veracity.

2.0 SCOPE OF WORK

The scope of the work undertaken included:

- Review of the groundwater aspects of the current Environmental Authority (EA) that pertains to Yandan;
- Detailed assessment of the groundwater level and groundwater quality data collected since 2013 and comment on compliance of the groundwater with the EA; and
- Assessment of the groundwater monitoring bore network and recommendation for additional or replacement groundwater monitoring bores.

3.0 ENVIRONMENTAL AUTHORITY GROUNDWATER ASPECTS

Aeris Resources provided a document entitled Yandan EA draft for final distribution to RLA for the purposes of this review. From that document Environmental Authority No. MIN100390005 contains the following groundwater conditions:

- (C7-1) Within 12 months of the date of approval of this licence, the holder of the environmental authority must establish suitable reference bores for the establishment of background groundwater quality. Reference sites must:*
- (a) be selected in accordance with the ANZECC & ARMCANZ 2000 methodology*
 - (b) be from the same bio-geographic and climatic region; and*
 - (c) have similar geology, soil types and topography; and*
 - (d) not be so close to the test sites that any disturbance at the test site also results in a change at the reference site.*
- (C7-2) Groundwater quality and level must be monitored at the locations and frequencies defined in Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency) & Schedule J – Figure 3 for quality characteristics identified in Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits).*
- (C7-3) If quality characteristics of groundwater from compliance bores identified in Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency) exceed any of the trigger levels stated in Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits), the holder of this environmental authority must compare the compliance monitoring bore results to the reference bore results and:*
- (a) if the level of contaminants at the compliance monitoring bore does not exceed the reference bore results, then no action is to be taken; and*
 - (b) if the level of contaminants at the compliance monitoring bore is greater than the reference bore results, complete an investigation in accordance with the ANZECC & ARMCANZ 2000, into the potential for environmental harm and provide a written report to the administering authority within 3 months, outlining:*
 - (i) details of the investigations carried out; and*
 - (ii) actions taken to prevent environmental harm.*

Note: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with this condition, no further reporting is required for subsequent trigger events for that quality characteristic within the three month investigation period.

- (C7-4) *Monitoring of groundwater from compliance bores identified in Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency), must not exceed any of the limits defined in Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits).*
- (C7-5) *Groundwater monitoring bores must be constructed and operated in accordance with methods prescribed in the latest edition of the Agriculture and Resource Management Council of Australia and New Zealand manual titled Minimum Construction Requirements for Water Bores in Australia.*
- (C7-6) *Annual groundwater monitoring reports analysing groundwater chemistry and hydro-geological status of all groundwater bores and groundwater conditions must be prepared and submitted to the administering authority with each annual return.*

Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency)

Monitoring Point	Easting MGA (GDA94)	Northing MGA (GDA94)	Surface RL¹ (m)	Monitoring Frequency
Compliance Bores				
Yandan – Tailings Dam (TD) South Bore 3	7646587	499183	To be advised ³	Quarterly
Yandan – TD West Bore 4	7647252	49950	To be advised ³	Quarterly
Yandan – TD North Bore 5	7647729	500433	To be advised ³	Quarterly
Yandan – TD East Bore 6	7646928	500831	To be advised ³	Quarterly
Yandan – TD South Bore 7	7646361	499319	To be advised ³	Quarterly
Yandan – South Hill pit bore 2	7644368	497233	To be advised ³	Quarterly
Yandan – Heap Leach west bore 1	7644683	497984	To be advised ³	Quarterly
Yandan – Heap Leach west bore 3	7644653	498172	To be advised ³	Quarterly
Yandan – Heap Leach west bore 4	7644787	497803	To be advised ³	Quarterly
Yandan – Heap Leach east bore 5	7644888	498195	To be advised ³	Quarterly
Yandan – Heap Leach north bore 6	7645166	498198	To be advised ³	Quarterly

Monitoring Point	Easting MGA (GDA94)	Northing MGA (GDA94)	Surface RL¹ (m)	Monitoring Frequency
Yandan – Heap Leach north bore 7	7645249	498034	To be advised ³	Quarterly
Reference Bores²				
To be determined within 12 months of the date of approval of this licence, in accordance with condition C7-1				

¹ RL measurement to be taken from top of bore casing and measured to nearest 0.05m

² Reference sites must:

- (a) be from the same bio-geographic and climatic region; and
- (b) have similar geology, soil types and topography; and
- (c) not be so close to the test sites that any disturbance at the test site also results in a change at the reference site

³ within three months of the date of approval of this environmental authority

Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits)

Parameter	Units	Limit type	Contaminant limit	Trigger Level
pH		Range	6 – 8.5 ³	6.0 – 7.5
Sulfate	mg/L	Maximum	1000 ⁵	The 80% percentile of the background reference
Arsenic	mg/L	Maximum	0.5 ¹	0.013 ^{2,4} or the 80% percentile of the background reference
Cadmium	mg/L	Maximum	0.01 ¹	0.0002 ⁴ or the 80% percentile of the background reference
Copper	mg/L	Maximum	0.5 ¹	0.0014 ⁴ or the 80% percentile of the background reference
Lead	mg/L	Maximum	0.1 ¹	0.0034 ⁴ or the 80% percentile of the background reference
Mercury	mg/L	Maximum	0.002 ¹	0.0006 ⁴ or the 80% percentile of the background reference
Molybdenum	mg/L	Maximum	0.05 ¹	The 80% percentile of the background reference
Selenium	mg/L	Maximum	0.02 ¹	0.011 ⁴ or the 80% percentile of the background reference
Zinc	mg/L	Maximum	20 ¹	0.008 ⁴ or the 80% percentile of the background reference
WAD Cyanide	mg/L	Maximum	0.2	0.007 ⁴ or the 80% percentile of the background reference

1. All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered).

2. If arsenic (soluble) exceeds 13ug/L then speciation to As(III) and As(V) must be conducted. The As(III) and As(V) levels must not exceed the 80th percentile of reference site samples or the respective trigger level: As(III) – 24ug/L; As(V) – 13ug/L.

3. Based on ANZECC (2000) primary industries guidelines

4. Default trigger values from ANZECC 2000 for aquatic ecosystems

5. Based on ANZECC (2000) Livestock Drinking Water Guidelines

The EA requires that groundwater monitoring should occur quarterly. This is not the case as groundwater monitoring is being carried out six-monthly. It is recommended that Aeris Resources increases groundwater monitoring to quarterly to comply with the EA.

There is no evidence that any reference bore or bores has/have been established to date. It is recommended that two reference bores be installed as soon as possible to comply with the EA. The locations and depths of these two bores will be discussed later in this review report.

4.0 ACTUAL GROUNDWATER MONITORING BORE LOCATIONS

The groundwater monitoring bores specified within the EA are monitored by Northern Groundwater Solutions Pty Ltd (NGS) on a six-monthly basis.

The actual locations of the groundwater monitoring bores have been ground-truthed by NGS and the coordinates of those bores differ from those recorded in the EA.

Table 1 shows the actual locations of the Yandan groundwater monitoring bore suite.

TABLE 1: ACTUAL GROUNDWATER MONITORING BORE LOCATIONS		
Bore	Easting MGA94	Northing MGA94
HL1	7644870	498094
HL3	7644837	498284
HL4	7644964	497913
HL5	7645103	498358
HL6	7645358	498321
HL7	7645427	498144
SH3	7644570	497420
TD3	7646724	499333
TD5	7647882	500548
TD6	7647110	500941
TD7	7646580	499440

As at 9th June 2019, TD6 has been destroyed and TD7 is blocked at 0.92m below the measuring point.

It is recommended that bore TD6 should be replaced as soon as possible and that bore TD7 be rehabilitated.

5.0 PHYSICAL SETTING AND WATER MONITORING SITES

The Yandan Mine Project (henceforth referred to as Yandan) is located some 39km to the west north west of the town of Mount Coolon.

The Yandan site is essentially flat lying with gentle slopes towards the west. The main drainage feature is the Suttor River located to the west of the site. Unnamed tributaries of the Suttor River flow more or less east to west to join the river.

The project's water supply dam is located on one of these tributaries. A surface water monitoring site (WS1) is located on the impoundment wall of the water supply dam.

Yandan consists of three main segments of infrastructure:

- The South Hill Pit (groundwater monitoring bores here are designated by the prefix SH);
- The tailings dam (groundwater monitoring bores here are designated by the prefix TD); and
- The heap leach processing area (groundwater monitoring bores here are designated by the prefix HL).

A Google Earth image of the Yandan site, that also shows the locations of the EA groundwater monitoring bores and WS1, is shown as Figure 1.

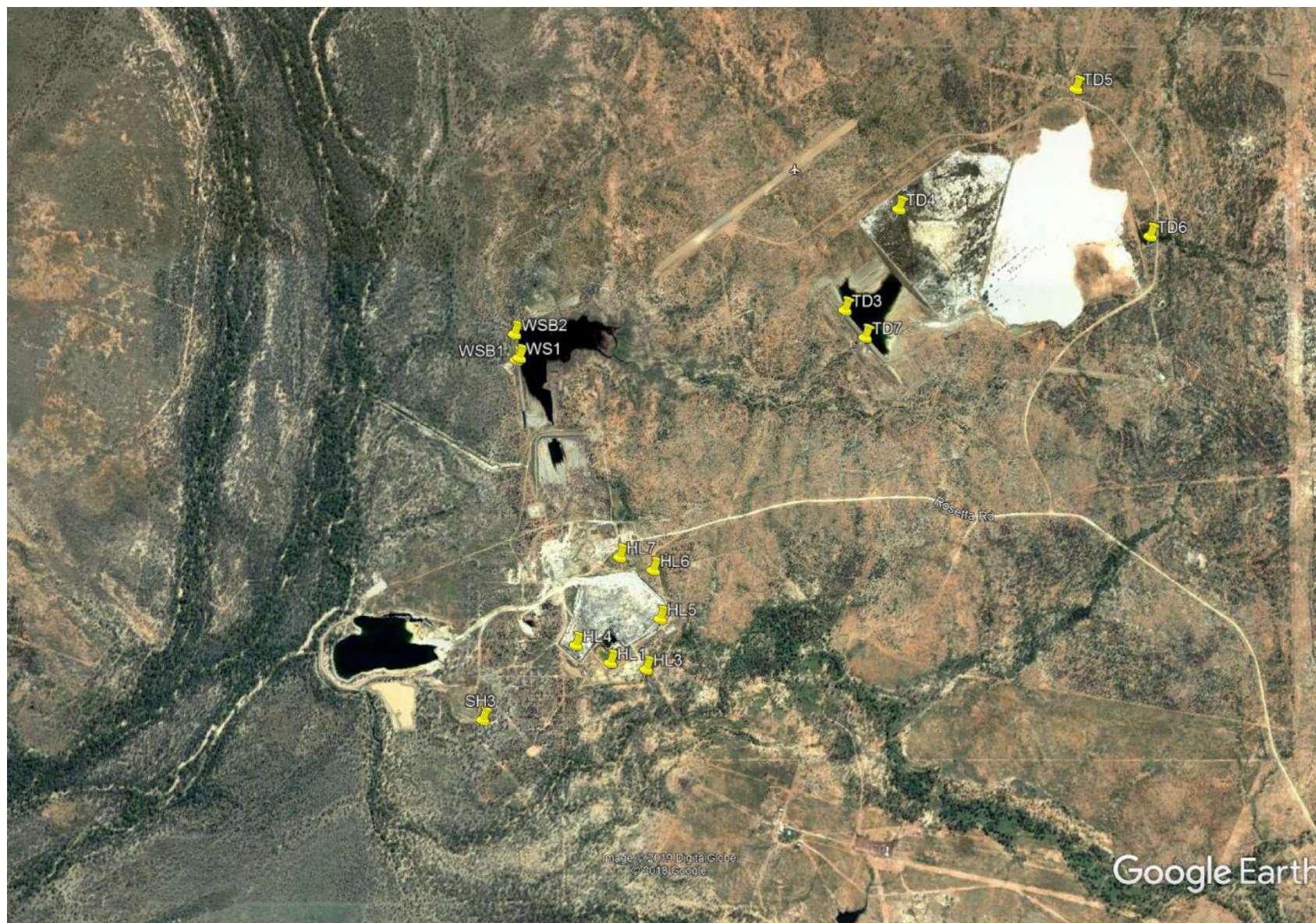


Figure 1: Water Monitoring Sites at Yandan

6.0 HYDROGEOLOGY

No drilling and construction log records are available for the Yandan suite of monitoring bores.

The lack of information available on the construction of the groundwater monitoring bores is an impediment to the understanding of the hydrogeological regime of the site i.e. the strata sequence, aquifer occurrence and thickness, airlift yields from the water-bearing intervals and aquifer permeability.

7.0 GROUNDWATER LEVEL BEHAVIOUR

Groundwater levels have been measured by NGS since 2012. Figure 2 is a chart of the groundwater level behaviour in all the Yandan EA groundwater monitoring bores in the period 2012 to 2019. Groundwater levels have been compared to rainfall received at Mt Douglas, some 30km to the southwest of the Yandan site.

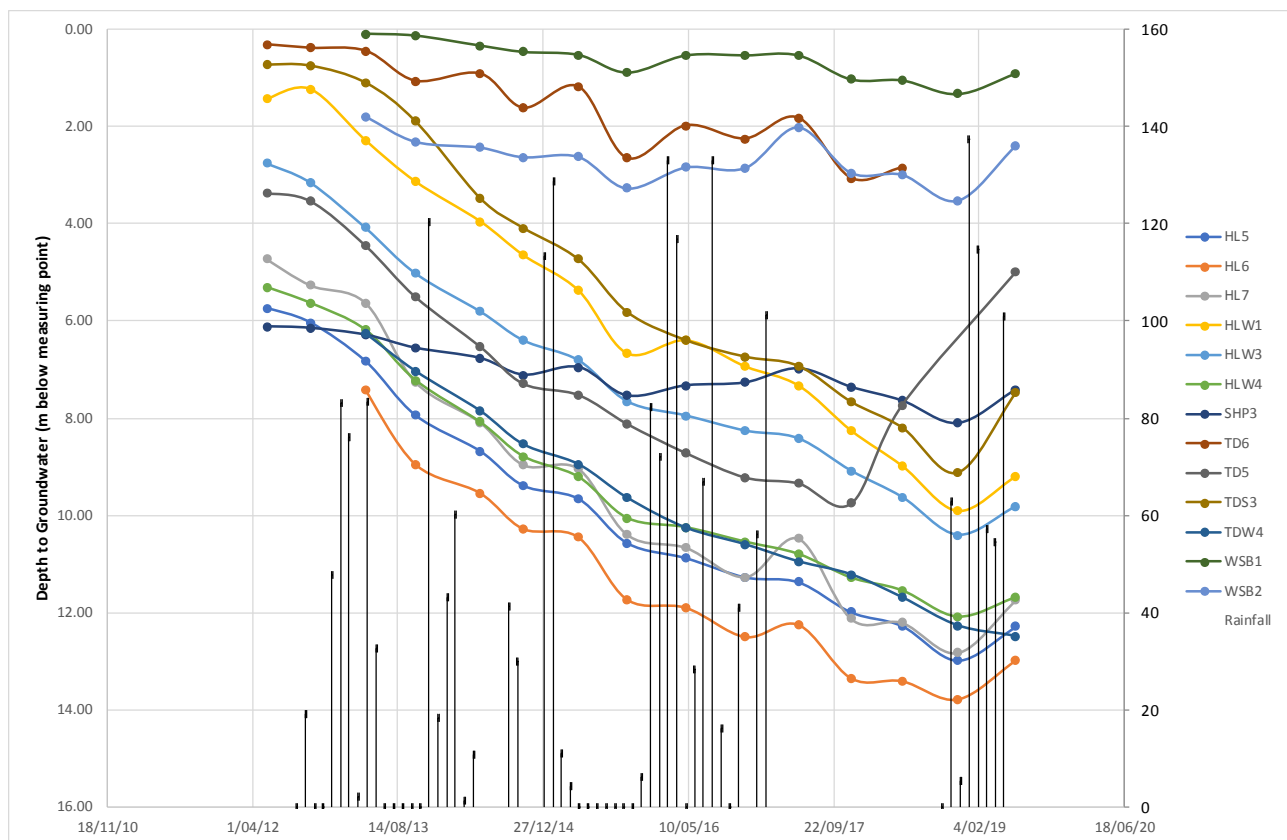


Figure 2: Groundwater Levels in Yandan EA monitoring bores compared to Monthly Rainfall

It can be seen from Figure 2 that groundwater levels have been steadily declining in all the EA groundwater monitoring bores over the period of record. The sudden rise in groundwater level in TD5 since October 2017 is uncharacteristic and no explanation for this observation is evident.

Groundwater levels generally show a muted but delayed response to incident rainfall indicating that the aquifers beneath Yandan are of low permeability as it takes up to three months for groundwater levels to rise following peak rainfall periods.

Two water supply bores located immediately below the water supply dam (WSB1 and WSB2) have also been measured by NGS. Figure 3 shows the groundwater level behaviour in those bores.

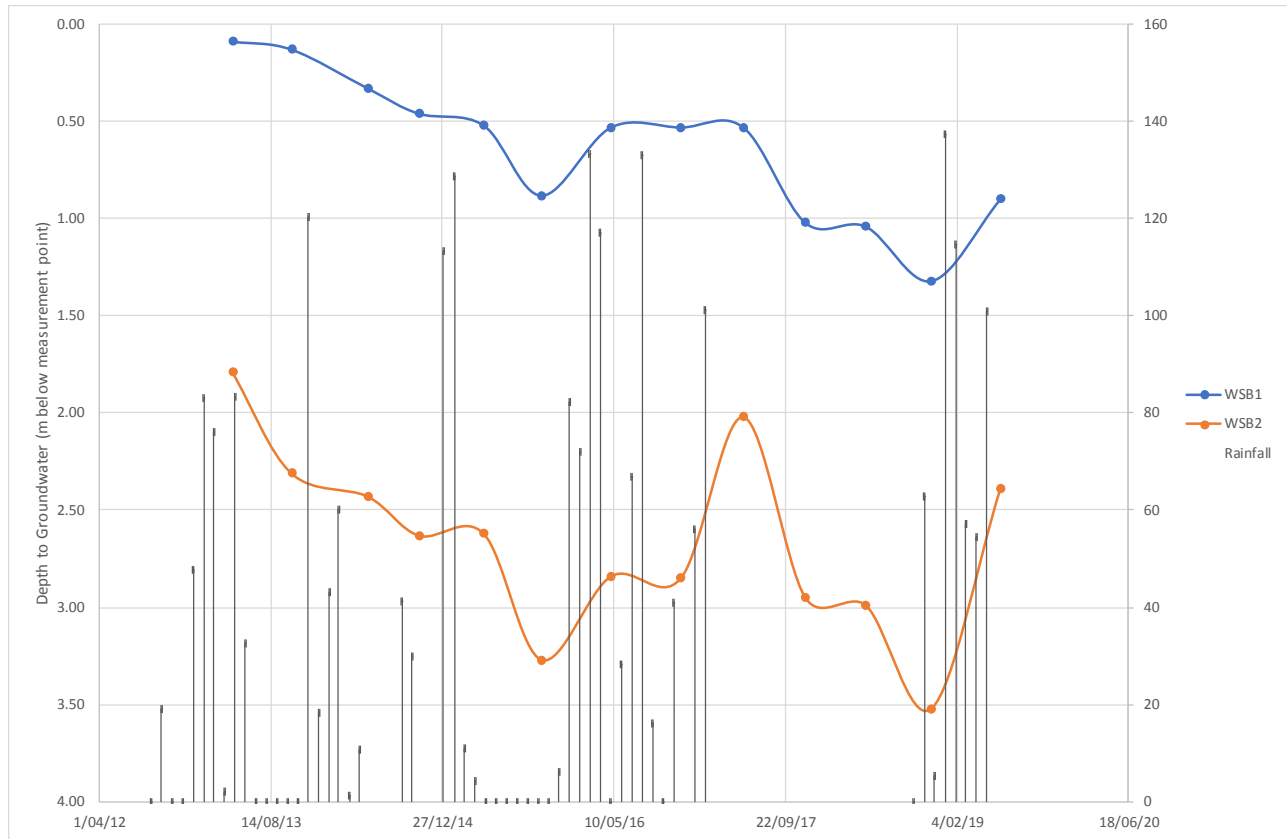


Figure 3: Groundwater Levels in Yandan EA monitoring bores compared to Monthly Rainfall

WSB1 and WSB2 demonstrate very similar groundwater level behaviour to the majority of the EA monitoring bores. It is interpreted that they are not impacted by the water level in the water supply dam.

Either WSB1 or WSB2 may be a reasonable choice for a reference bore.

8.0 GROUNDWATER CHEMISTRY

The groundwater chemistry data from the bi-annual groundwater monitoring undertaken by NGS since 2013 were sorted and assessed according to the contaminant limits (CL) and trigger limits (TL) specified for each analyte in the EA.

The physico-chemical parameters electrical conductivity and pH, as well as sulphate, were analysed graphically and all other analytes were tabulated for comparison with the CL and TL specified in the EA.

8.1 Electrical Conductivity

Figure 4 shows electrical conductivity behaviour of the tailings storage dam bores. For comparison monthly rainfall is also plotted.

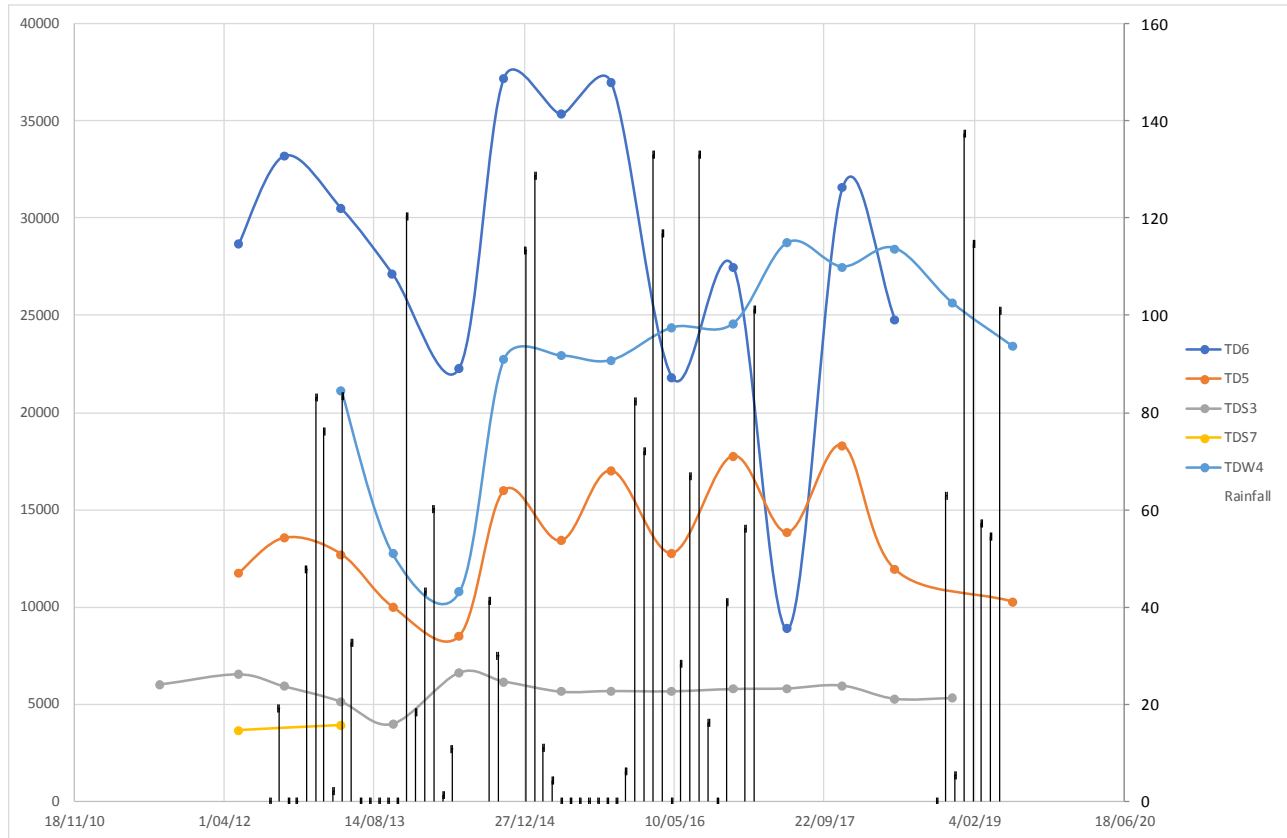


Figure 4: Electrical conductivity in tailings storage dam bores versus rainfall

Left hand vertical axis is electrical conductivity in $\mu\text{S}/\text{cm}$

Right hand vertical axis is monthly rainfall in mm

Figure 5 shows electrical conductivity behaviour of the heap leach processing area bores. For comparison monthly rainfall is also plotted.

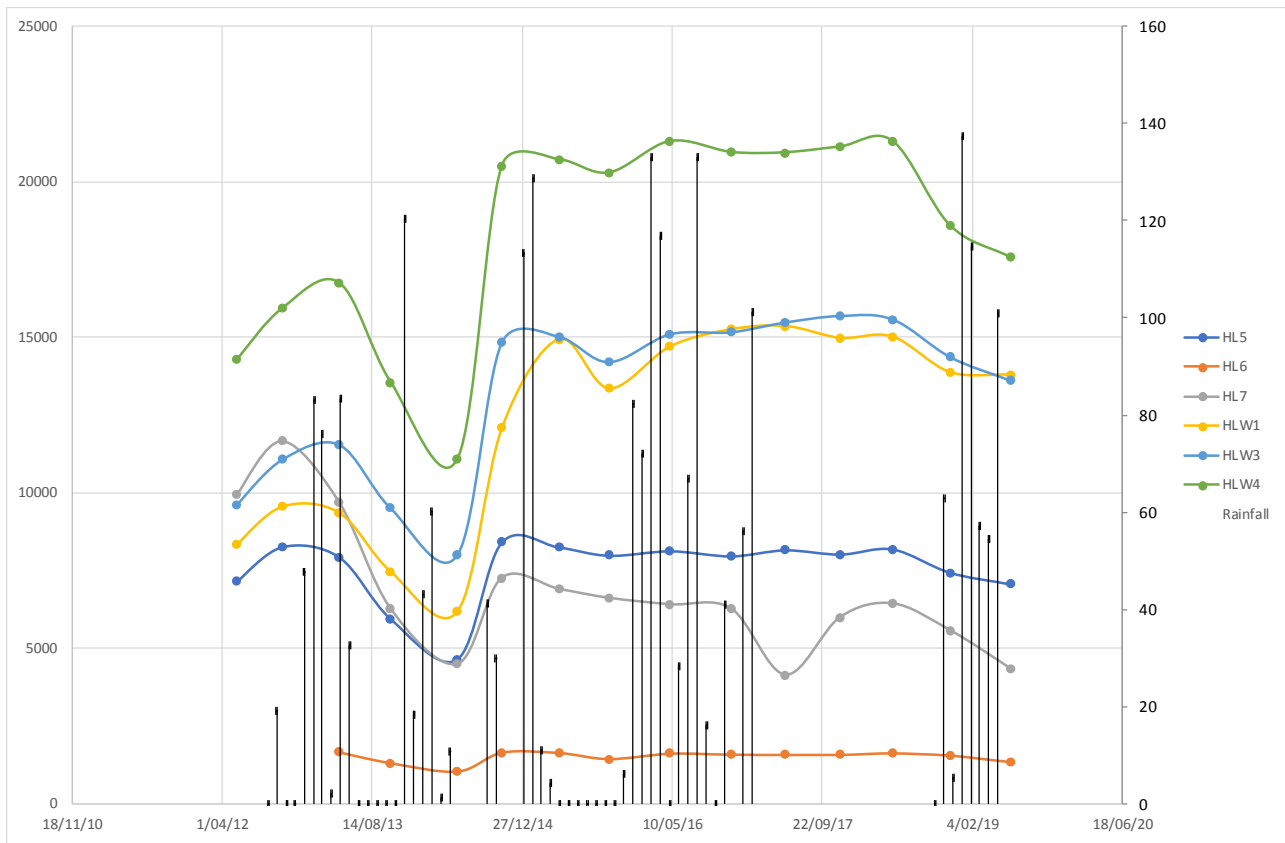


Figure 5: Electrical conductivity in heap leach processing area bores versus rainfall
Left hand vertical axis is electrical conductivity in $\mu\text{S/cm}$
Right hand vertical axis is monthly rainfall in mm

Figure 6 shows electrical conductivity behaviour of the South Hill pit area bore. For comparison monthly rainfall is also plotted.

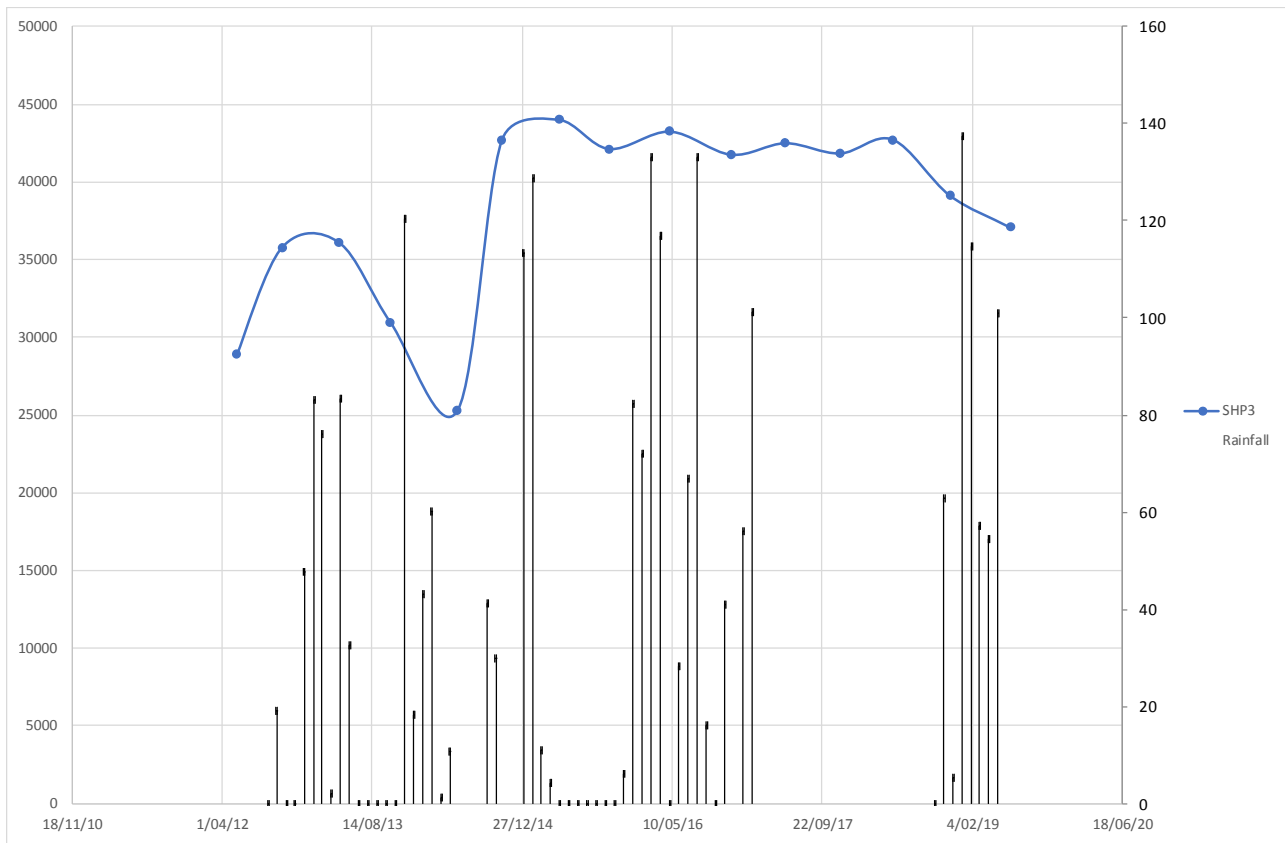


Figure 6: Electrical conductivity in South Hill Pit area bore versus rainfall

Left hand vertical axis is electrical conductivity in $\mu\text{S/cm}$
Right hand vertical axis is monthly rainfall in mm

No electrical conductivity limit is specified in the EA, however the electrical conductivity of the groundwater from all the EA monitoring bores is very high.

Historical reporting on the groundwater at Yandan from 2010¹ stated the following:

TDS values have been continuously high in the bores since monitoring commenced and as documented in the Groundwater Report April 2008 TDS in the alluvial sediments often exceeds 6,000 mg/L and groundwater is generally of poor quality. For background context, in September and December 2008 three regional bores (MW1, WS1 and WS2) were sampled. TDS in these bores, which are located well away from the area of mining disturbance, also exceeded 6,000 mg/L, ranging up to 22,500 mg/L.

As total dissolved solids (TDS) concentrations are directly proportional to electrical conductivity it is evident that the high electrical conductivity values shown in Figures 4, 5 and 6 are not new occurrences.

A chart of electrical conductivity in WSB1 and WSB2, as well as the electrical conductivity of surface water from WS1 (the water supply dam) is presented in Figure 7.

¹ Straits Gold Pty Ltd Report for Yandan Mine Site Queensland Environmental Monitoring Annual Report October 2010

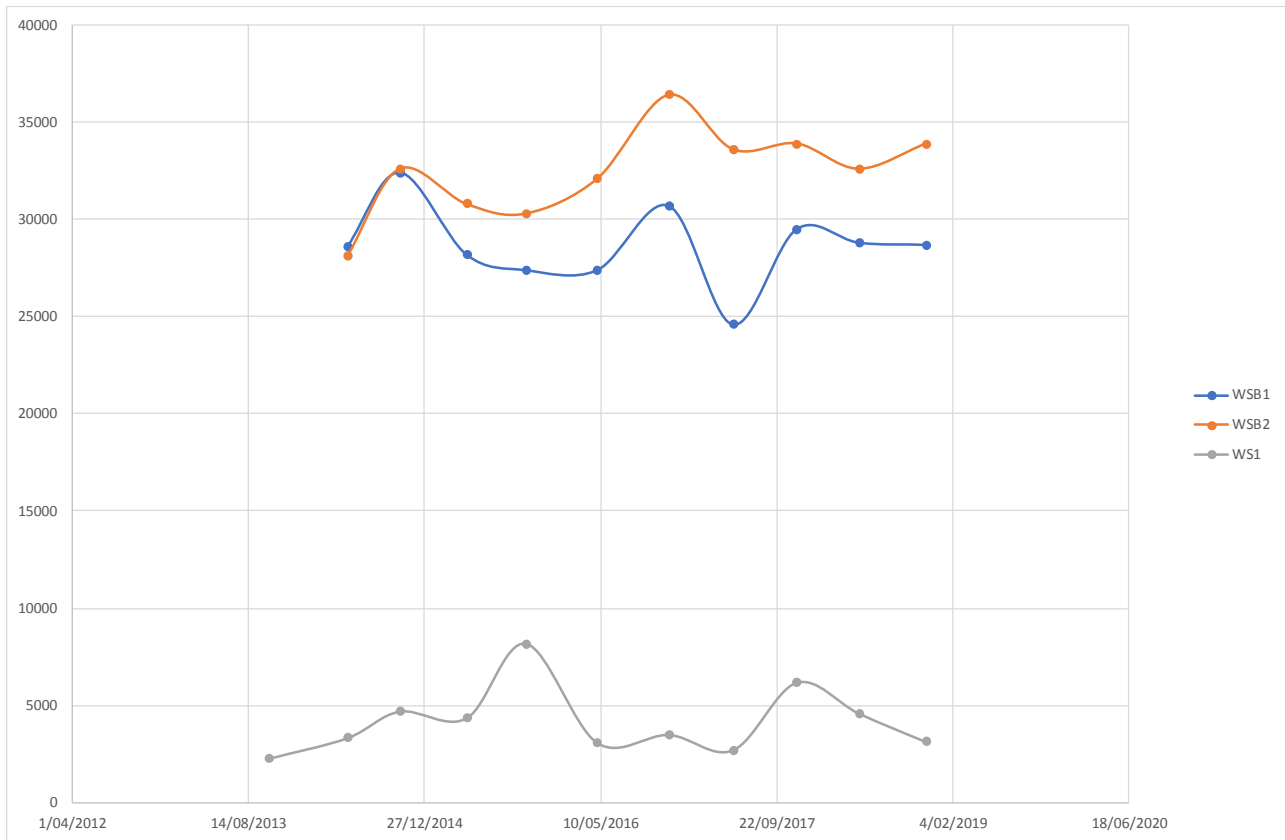


Figure 7: Electrical conductivity in Water Supply bores and SW1
Left hand vertical axis is electrical conductivity in $\mu\text{S/cm}$

It is clear from Figure 7 that the electrical conductivity of the water in the water supply dam is an order of magnitude lower than the groundwater in the two bores immediately below the dam. This chart provides further evidence that they are not impacted by the water in the water supply dam.

8.2 Groundwater pH

Figure 8 shows groundwater pH behaviour of the Yandan EA monitoring bores.

In general, the groundwater at Yandan remains within the EA contaminant limits of 6.5 to 8.5.

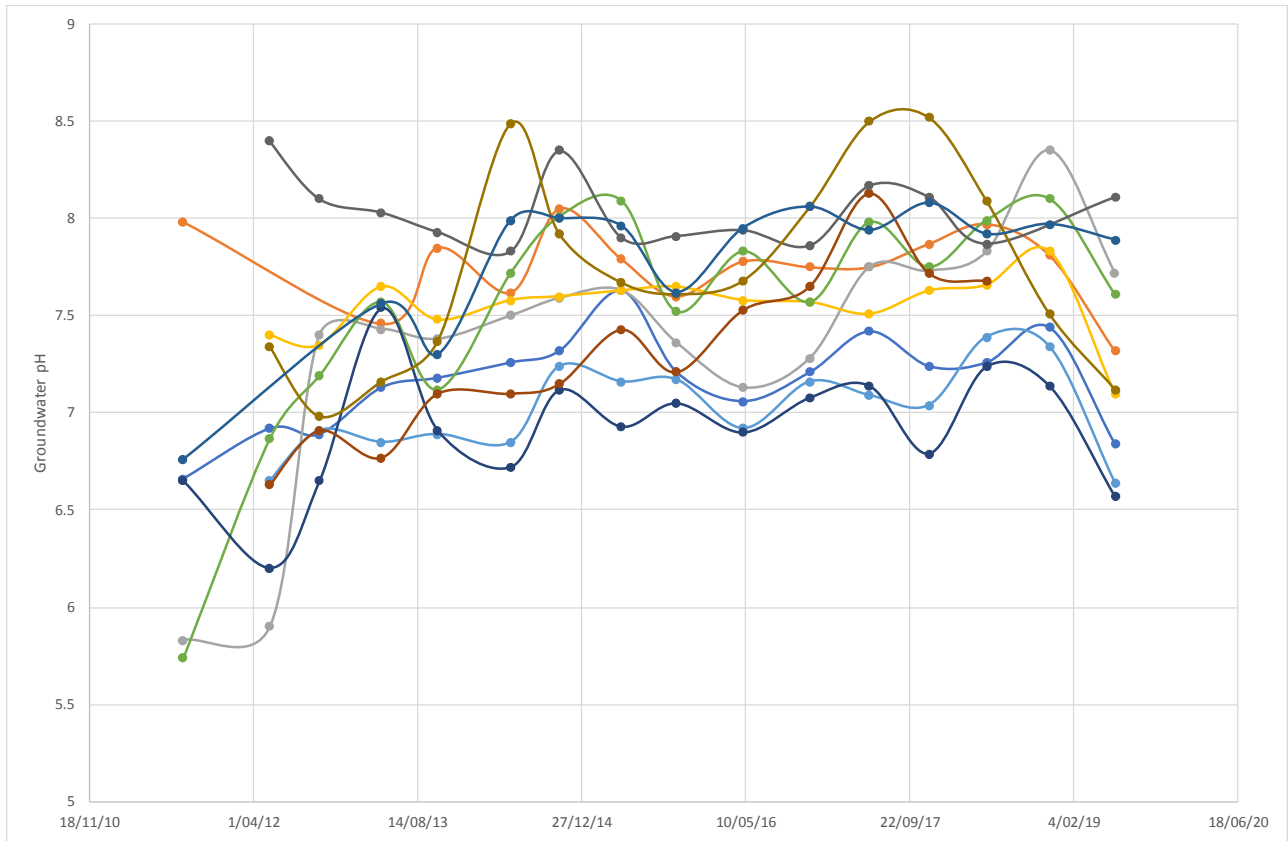


Figure 8: Groundwater pH in Yandan EA groundwater monitoring bores

8.3 Sulphate

Figure 9 shows sulphate concentration behaviour of the tailings storage dam bores.

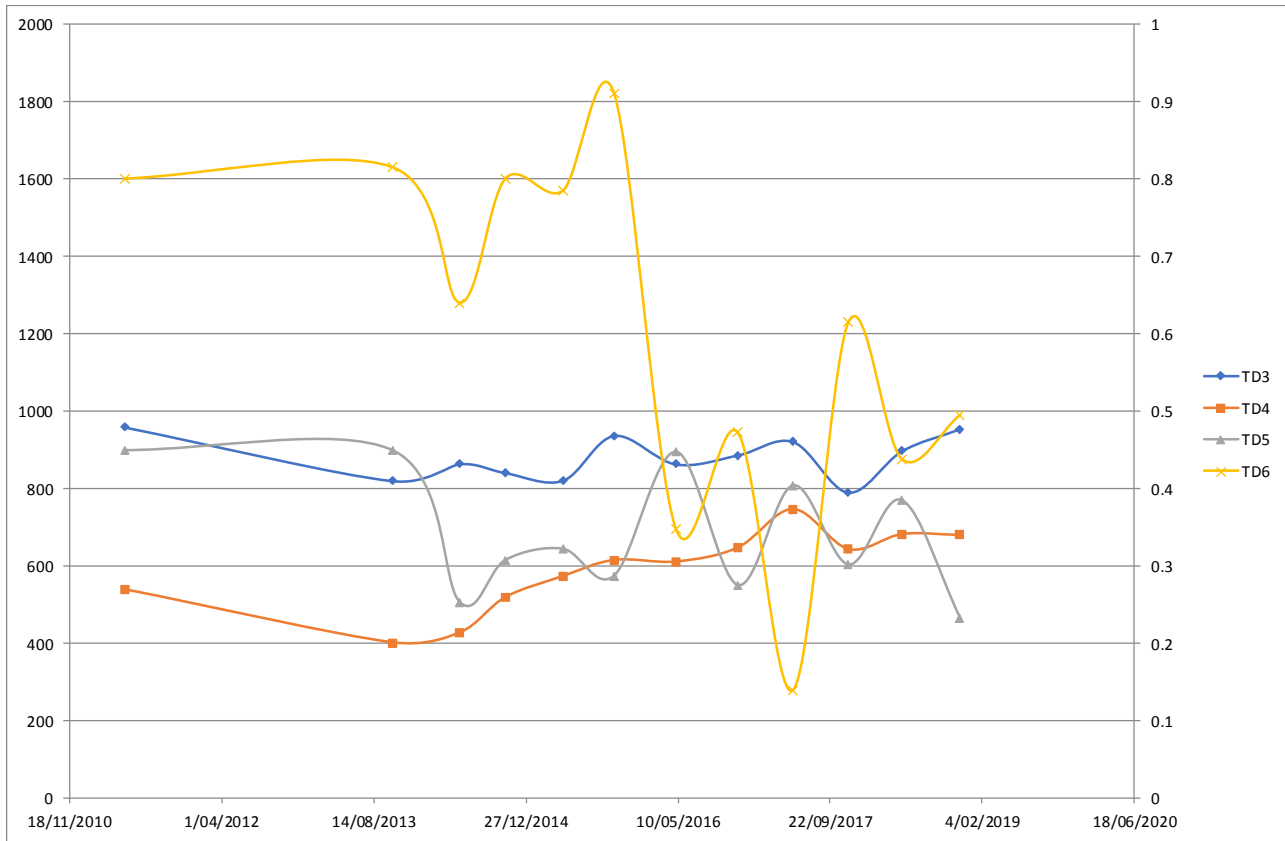


Figure 9: Sulphate Concentration in tailings storage dam bores
Left hand vertical axis is sulphate concentration in mg/L

Figure 10 shows sulphate concentration behaviour of the heap leach processing area bores.

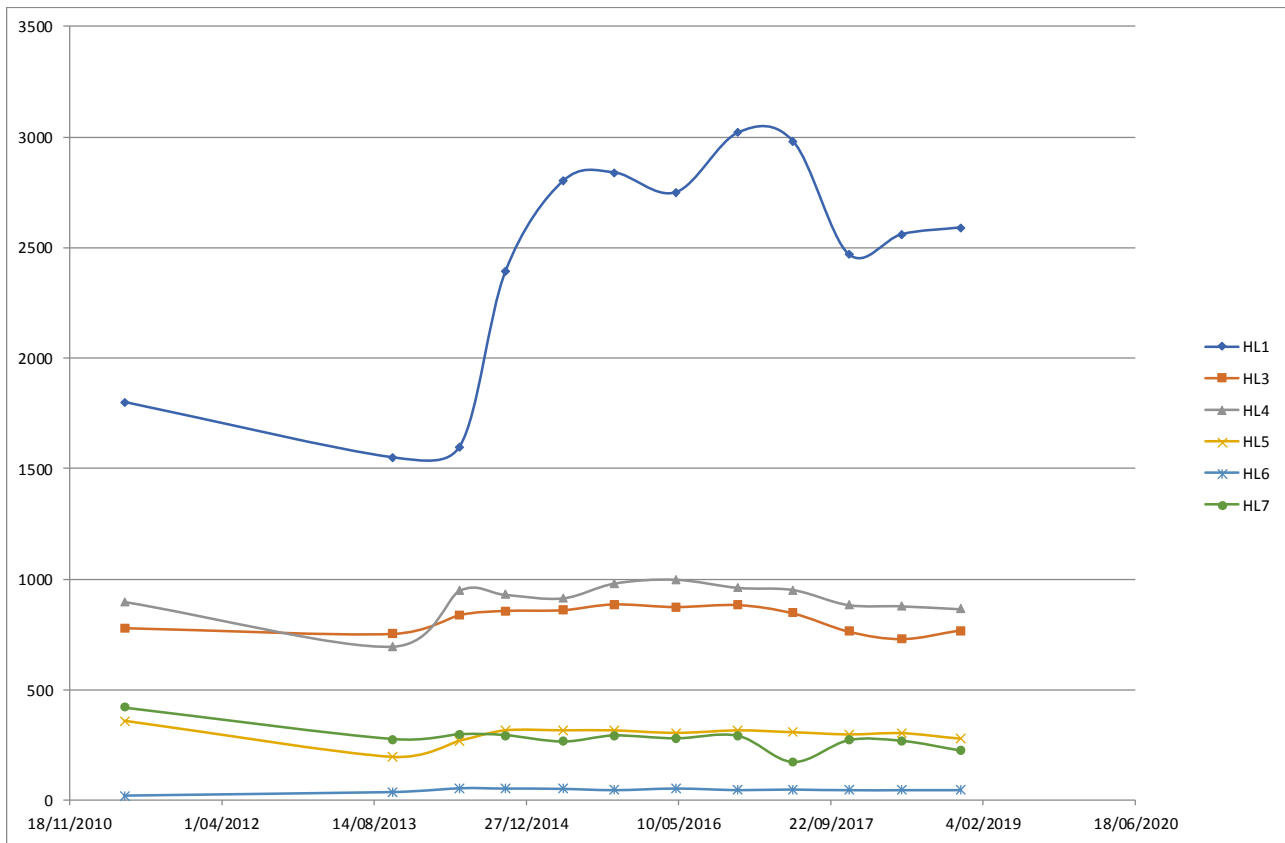


Figure 10: Sulphate Concentration in heap leach processing area bores
Left hand vertical axis is sulphate concentration in mg/L

Figure 11 shows sulphate concentration behaviour of the South Hill pit area bore.

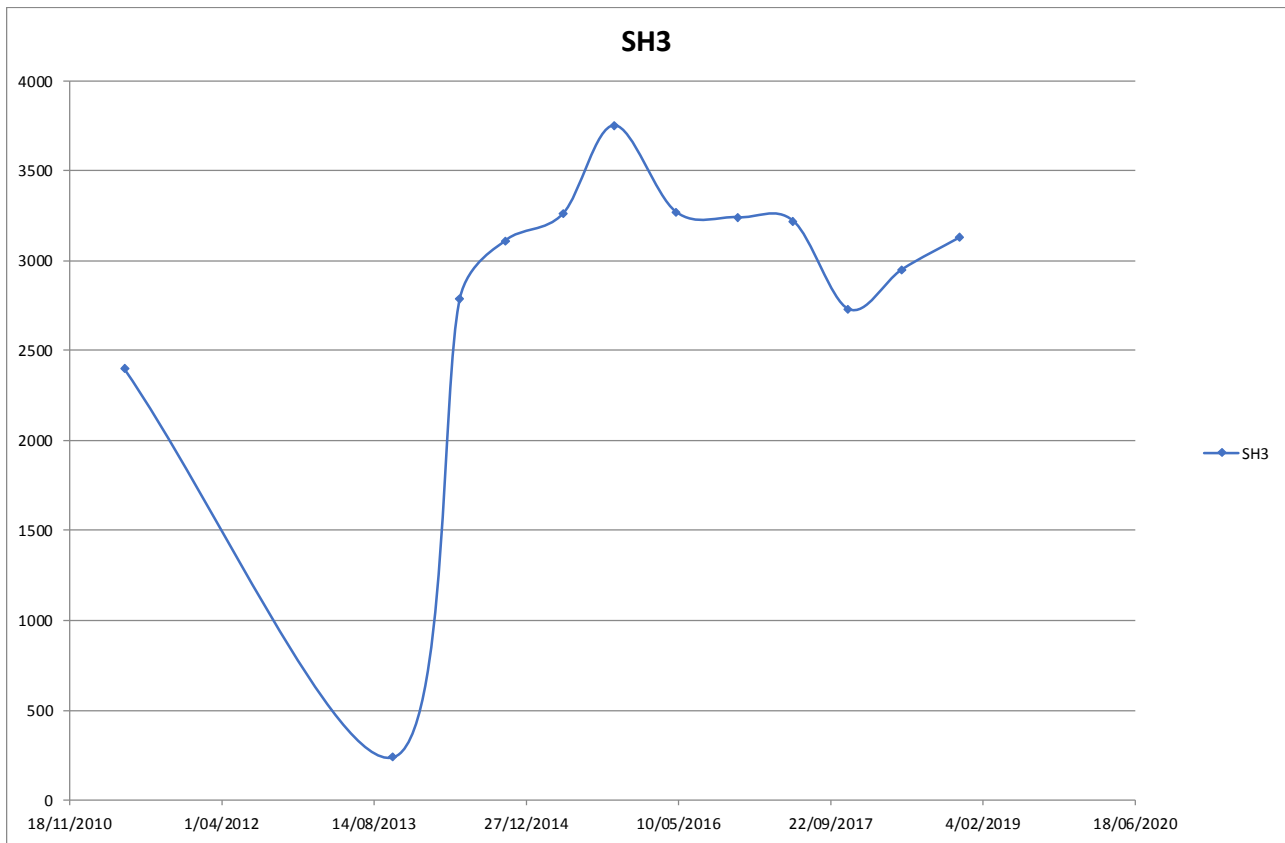


Figure 11: Sulphate Concentration in South Hill Pit bore
Left hand vertical axis is sulphate concentration in mg/L

The sulphate concentration in the groundwater from TD6, HL1 and SH3 exceed the EA contaminant limit for sulphate almost all the time. The groundwater from the other EA groundwater monitoring bores complies with the EA contaminant limit.

Historical reporting on the groundwater at Yandan from 2010 stated the following:

“sulfate background values often exceed 1,000 mg/L and are associated with the oxidation of the sulphide minerals in the fractured Drummond units that host the mineralisation. In September and December 2008 three regional bores (MW1, WS1 and WS2) were sampled. Sulphate in these bores also exceeded 1,000 mg/L with 3,610 mg/L sulfate recorded in WS1”.

8.4 Arsenic

Table 2 shows groundwater arsenic concentrations in the Yandan EA monitoring bores assessed against the contaminant limit (CL) and trigger limit (TL) specified in the EA.

TABLE 2: ARSENIC COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Diss As	CL	TL		Tot As	CL	TL
14/10/2013	HL1	0.001				<0.0001		
24/05/2014	HL1	0.001				<0.0001		
20/10/2014	HL1	0.001				<0.001		
27/04/2015	HL1	<0.001				<0.0001		
12/10/2015	HL1	<0.001				0.001		
02/05/2016	HL1	<0.001				<0.001		
21/11/2016	HL1	<0.001				<0.001		
22/05/2017	HL1	<0.001				<0.001		
20/11/2017	HL1	<0.001				<0.001		
14/05/2018	HL1	<0.001				0.001		
21/11/2018	HL1	<0.001				<0.001		
14/10/2013	HL3	0.001				<0.0001		
24/05/2014	HL3	0.002				<0.0001		
20/10/2014	HL3	0.001				0.001		
27/04/2015	HL3	0.001				<0.0001		
12/10/2015	HL3	0.002				0.002		
02/05/2016	HL3	0.001				0.001		
21/11/2016	HL3	0.001				0.001		
22/05/2017	HL3	0.001				0.002		
20/11/2017	HL3	0.001				0.001		
14/05/2018	HL3	0.002				0.002		
21/11/2018	HL3	0.001				0.001		
14/10/2013	HL4	0.006				<0.0001		
24/05/2014	HL4	0.005				0.0001		
20/10/2014	HL4	0.014	exceeded	exceeded		0.016	exceeded	exceeded
27/04/2015	HL4	0.012	exceeded			<0.0001		
12/10/2015	HL4	0.007				0.013	exceeded	
02/05/2016	HL4	0.008				0.007		
21/11/2016	HL4	0.005				0.006		
22/05/2017	HL4	0.007				0.019	exceeded	exceeded
20/11/2017	HL4	0.008				0.009		
14/05/2018	HL4	0.009				0.009		
21/11/2018	HL4	0.008				0.009		
14/10/2013	HL5	0.004				<0.0001		

Date	Bore	Diss As	CL	TL		Tot As	CL	TL
24/05/2014	HL5	0.005				<0.0001		
20/10/2014	HL5	0.004				0.004		
27/04/2015	HL5	0.004				<0.0001		
12/10/2015	HL5	0.002				0.006		
02/05/2016	HL5	0.002				0.002		
21/11/2016	HL5	0.002				0.003		
22/05/2017	HL5	0.002				0.004		
20/11/2017	HL5	0.002				0.002		
14/05/2018	HL5	0.003				0.004		
21/11/2018	HL5	0.003				0.003		
14/10/2013	HL6	0.04	exceeded	exceeded		<0.0001		
24/05/2014	HL6	0.044	exceeded	exceeded		<0.0001		
20/10/2014	HL6	0.029	exceeded	exceeded		0.031	exceeded	exceeded
27/04/2015	HL6	0.036	exceeded	exceeded		<0.0001		
12/10/2015	HL6	0.028	exceeded	exceeded		0.029	exceeded	exceeded
02/05/2016	HL6	0.046	exceeded	exceeded		0.04	exceeded	exceeded
21/11/2016	HL6	0.034	exceeded	exceeded		0.038	exceeded	exceeded
22/05/2017	HL6	0.035	exceeded	exceeded		0.039	exceeded	exceeded
20/11/2017	HL6	0.03	exceeded	exceeded		0.034	exceeded	exceeded
14/05/2018	HL6	0.031	exceeded	exceeded		0.031	exceeded	exceeded
21/11/2018	HL6	0.036	exceeded	exceeded		0.038	exceeded	exceeded
14/10/2013	HL7	0.001				<0.0001		
24/05/2014	HL7	0.001				<0.0001		
20/10/2014	HL7	0.001				0.001		
27/04/2015	HL7	0.001				<0.0001		
12/10/2015	HL7	0.001				0.002		
02/05/2016	HL7	<0.001				<0.001		
21/11/2016	HL7	0.002				0.002		
22/05/2017	HL7	0.002				0.003		
20/11/2017	HL7	0.002				0.002		
14/05/2018	HL7	0.002				0.003		
21/11/2018	HL7	0.005				0.006		
14/10/2013	SH3	0.026	exceeded	exceeded		0.0001		
24/05/2014	SH3	0.031	exceeded	exceeded		0.0003		
27/04/2015	SH3	0.034	exceeded	exceeded		0.0002		
12/10/2015	SH3	0.012	exceeded			0.015	exceeded	exceeded
02/05/2016	SH3	0.006				0.009		
21/11/2016	SH3	0.013	exceeded			0.016	exceeded	exceeded
22/05/2017	SH3	<0.005				0.008		
19/11/2017	SH3	0.008				0.011	exceeded	
14/05/2018	SH3	0.006				0.007		
21/11/2018	SH3	<0.005				<0.005		
14/10/2013	TD3	0.01				<0.0001		

Date	Bore	Diss As	CL	TL		Tot As	CL	TL
24/05/2014	TD3	0.018	exceeded	exceeded		<0.0001		
20/10/2014	TD3	0.004				0.004		
27/04/2015	TD3	0.004				<0.0001		
12/10/2015	TD3	0.004				0.004		
02/05/2016	TD3	0.004				0.005		
21/11/2016	TD3	0.004				0.004		
22/05/2017	TD3	0.007				0.008		
20/11/2017	TD3	0.007				0.007		
14/05/2018	TD3	0.004				0.006		
21/11/2018	TD3	0.002				0.002		
14/10/2013	TD4	0.009				<0.0001		
24/05/2014	TD4	0.01				<0.0001		
20/10/2014	TD4	0.013	exceeded			0.015	exceeded	exceeded
27/04/2015	TD4	0.018	exceeded	exceeded		<0.0001		
12/10/2015	TD4	0.012	exceeded			0.012	exceeded	
02/05/2016	TD4	0.012	exceeded			0.012	exceeded	
21/11/2016	TD4	0.011	exceeded			0.012	exceeded	
22/05/2017	TD4	0.011	exceeded			0.018	exceeded	exceeded
20/11/2017	TD4	0.011	exceeded			0.011	exceeded	
14/05/2018	TD4	0.014	exceeded	exceeded		0.015	exceeded	exceeded
21/11/2018	TD4	0.012	exceeded			0.013	exceeded	
14/10/2013	TD5	0.001				<0.0001		
24/05/2014	TD5	0.002				0.0001		
20/10/2014	TD5	0.002				0.002		
27/04/2015	TD5	0.001				<0.0001		
12/10/2015	TD5	0.002				0.002		
02/05/2016	TD5	0.002				0.002		
21/11/2016	TD5	0.001				0.001		
22/05/2017	TD5	0.001				0.002		
20/11/2017	TD5	0.001				0.001		
14/05/2018	TD5	0.001				0.002		
14/10/2013	TD6	<0.005				0.0001		
24/05/2014	TD6	0.002				0.0001		
27/04/2015	TD6	0.001				<0.0001		
12/10/2015	TD6	<0.005				<0.005		
02/05/2016	TD6	0.002				0.003		
21/11/2016	TD6	0.002				0.002		
22/05/2017	TD6	0.002				0.003		
20/11/2017	TD6	<0.005				<0.005		
14/05/2018	TD6	0.003				0.003		

As table 2 shows arsenic exceedences are a regular occurrence in HL6, SH3 and TD4. Most other bores have either no, or sporadic, arsenic exceedences.

8.5 Cadmium

Table 3 shows groundwater cadmium concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 3: CADMIUM COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Dissolved Cadmium	CL	TL	Total Cadmium	CL	TL
14/10/2013	HL1	<0.0001			<0.0001		
24/05/2014	HL1	0.0001			<0.0001		
27/04/2015	HL1	<0.0001			<0.0001		
12/10/2015	HL1	<0.0001			<0.0001		
02/05/2016	HL1	<0.0001			<0.0001		
21/11/2016	HL1	<0.0001			<0.0001		
22/05/2017	HL1	<0.0001			<0.0001		
20/11/2017	HL1	<0.0001			<0.0001		
14/05/2018	HL1	<0.0001			<0.0001		
21/11/2018	HL1	<0.0001			<0.0001		
14/10/2013	HL3	<0.0001			<0.0001		
24/05/2014	HL3	0.0002			<0.0001		
27/04/2015	HL3	<0.0001			<0.0001		
12/10/2015	HL3	<0.0001			<0.0001		
02/05/2016	HL3	<0.0001			<0.0001		
21/11/2016	HL3	<0.0001			<0.0001		
22/05/2017	HL3	<0.0001			<0.0001		
20/11/2017	HL3	<0.0001			<0.0001		
14/05/2018	HL3	<0.0001			<0.0001		
21/11/2018	HL3	<0.0001			<0.0001		
14/10/2013	HL4	<0.0001			<0.0001		
24/05/2014	HL4	<0.0001			0.0001		
27/04/2015	HL4	<0.0001			<0.0001		
12/10/2015	HL4	<0.0001			<0.0001		
02/05/2016	HL4	<0.0001			<0.0001		
21/11/2016	HL4	<0.0001			<0.0001		
22/05/2017	HL4	<0.0001			<0.0001		
20/11/2017	HL4	<0.0001			<0.0001		
14/05/2018	HL4	<0.0001			<0.0001		
21/11/2018	HL4	<0.0001			<0.0001		
14/10/2013	HL5	<0.0001			<0.0001		
24/05/2014	HL5	0.0001			<0.0001		
27/04/2015	HL5	<0.0001			<0.0001		

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Cadmium			Cadmium		
12/10/2015	HL5	0.0002			0.0003		
02/05/2016	HL5	<0.0001			<0.0001		
21/11/2016	HL5	<0.0001			<0.0001		
22/05/2017	HL5	<0.0001			<0.0001		
20/11/2017	HL5	<0.0001			<0.0001		
14/05/2018	HL5	<0.0001			<0.0001		
21/11/2018	HL5	<0.0001			<0.0001		
14/10/2013	HL6	<0.0001			<0.0001		
24/05/2014	HL6	<0.0001			<0.0001		
27/04/2015	HL6	<0.0001			<0.0001		
12/10/2015	HL6	<0.0001			<0.0001		
02/05/2016	HL6	<0.0001			<0.0001		
21/11/2016	HL6	<0.0001			<0.0001		
22/05/2017	HL6	<0.0001			<0.0001		
20/11/2017	HL6	<0.0001			<0.0001		
14/05/2018	HL6	<0.0001			<0.0001		
21/11/2018	HL6	<0.0001			<0.0001		
14/10/2013	HL7	<0.0001			<0.0001		
24/05/2014	HL7	<0.0001			<0.0001		
27/04/2015	HL7	<0.0001			<0.0001		
12/10/2015	HL7	<0.0001			<0.0001		
02/05/2016	HL7	<0.0001			<0.0001		
21/11/2016	HL7	<0.0001			<0.0001		
22/05/2017	HL7	<0.0001			<0.0001		
20/11/2017	HL7	<0.0001			<0.0001		
14/05/2018	HL7	<0.0001			<0.0001		
21/11/2018	HL7	<0.0001			<0.0001		
14/10/2013	SH3	<0.0005			0.0001		
24/05/2014	SH3	0.0004		exceeded	0.0003		exceeded
27/04/2015	SH3	0.0001			0.0002		
12/10/2015	SH3	0.0008		exceeded	<0.0005		
02/05/2016	SH3	0.0006		exceeded	0.0004		exceeded
21/11/2016	SH3	0.0004		exceeded	0.0004		exceeded
22/05/2017	SH3	<0.0005			<0.0005		
19/11/2017	SH3	0.001		exceeded	0.001		exceeded
14/05/2018	SH3	0.0018		exceeded	0.0018		exceeded
21/11/2018	SH3	0.0025		exceeded	0.0042		exceeded
14/10/2013	TD3	<0.0001			<0.0001		
24/05/2014	TD3	<0.0001			<0.0001		
27/04/2015	TD3	<0.0001			<0.0001		
12/10/2015	TD3	<0.0001			<0.0001		

Date	Bore	Dissolved Cadmium	CL	TL	Total Cadmium	CL	TL
02/05/2016	TD3	<0.0001			<0.0001		
21/11/2016	TD3	<0.0001			<0.0001		
22/05/2017	TD3	<0.0001			<0.0001		
20/11/2017	TD3	<0.0001			<0.0001		
14/05/2018	TD3	<0.0001			<0.0001		
21/11/2018	TD3	<0.0001			<0.0001		
14/10/2013	TD4	<0.0001			<0.0001		
24/05/2014	TD4	<0.0001			<0.0001		
27/04/2015	TD4	<0.0001			<0.0001		
12/10/2015	TD4	<0.0001			<0.0001		
02/05/2016	TD4	0.0003		exceeded	0.0003		exceeded
21/11/2016	TD4	0.0003		exceeded	0.0004		exceeded
22/05/2017	TD4	0.0003		exceeded	0.0004		exceeded
20/11/2017	TD4	0.0004		exceeded	0.0003		exceeded
14/05/2018	TD4	<0.0005			0.0002		
21/11/2018	TD4	0.0002			0.0002		
14/10/2013	TD5	<0.0001			<0.0001		
24/05/2014	TD5	0.0001			0.0001		
27/04/2015	TD5	<0.0001			<0.0001		
12/10/2015	TD5	<0.0001			<0.0001		
02/05/2016	TD5	<0.0001			<0.0001		
21/11/2016	TD5	<0.0001			<0.0001		
22/05/2017	TD5	<0.0001			<0.0001		
20/11/2017	TD5	<0.0001			<0.0001		
14/05/2018	TD5	<0.0001			<0.0001		
14/10/2013	TD6	<0.0005			0.0001		
24/05/2014	TD6	<0.0001			0.0001		
27/04/2015	TD6	<0.0001			<0.0001		
12/10/2015	TD6	<0.0005			<0.0005		
02/05/2016	TD6	<0.0001			<0.0001		
21/11/2016	TD6	<0.0001			<0.0001		
22/05/2017	TD6	<0.0001			<0.0001		
20/11/2017	TD6	<0.0005			<0.0005		
14/05/2018	TD6	0.0001			<0.0001		

Cadmium exceedences are a regular occurrence in SH3 and TD4. Most other bores have either no, or sporadic, cadmium exceedences.

8.6 Copper

Table 4 shows groundwater copper concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 4: COPPER COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Dissolved Copper	CL	TL	Total Copper	CL	TL
14/10/2013	HL1	0.001			<0.001		
24/05/2014	HL1	0.001			<0.001		
27/04/2015	HL1	<0.001			<0.001		
12/10/2015	HL1	0.002		exceeded	0.001		
02/05/2016	HL1	0.002		exceeded	0.001		
21/11/2016	HL1	<0.001			<0.001		
22/05/2017	HL1	<0.001			<0.001		
20/11/2017	HL1	<0.001			<0.001		
14/05/2018	HL1	0.003		exceeded	0.002		exceeded
21/11/2018	HL1	0.001			<0.001		
14/10/2013	HL3	0.001			<0.001		
24/05/2014	HL3	0.001			0.002		exceeded
27/04/2015	HL3	<0.001			<0.001		
12/10/2015	HL3	0.002		exceeded	0.001		
02/05/2016	HL3	0.001			<0.001		
21/11/2016	HL3	<0.001			<0.001		
22/05/2017	HL3	0.001			<0.001		
20/11/2017	HL3	<0.001			0.002		exceeded
14/05/2018	HL3	0.002		exceeded	0.001		
21/11/2018	HL3	0.001			<0.001		
14/10/2013	HL4	0.001			<0.001		
24/05/2014	HL4	0.001			0.001		
27/04/2015	HL4	0.001			<0.001		
12/10/2015	HL4	0.003		exceeded	0.004		exceeded
02/05/2016	HL4	0.002		exceeded	0.002		exceeded
21/11/2016	HL4	0.001			<0.001		
22/05/2017	HL4	0.001			0.003		exceeded
20/11/2017	HL4	0.001			0.001		
14/05/2018	HL4	0.003		exceeded	0.002		exceeded
21/11/2018	HL4	0.001			<0.001		
14/10/2013	HL5	0.001			0.002		exceeded
24/05/2014	HL5	0.001			<0.001		
27/04/2015	HL5	<0.001			<0.001		
12/10/2015	HL5	0.002		exceeded	0.005		exceeded

Date	Bore	Dissolved Copper	CL	TL	Total Copper	CL	TL
02/05/2016	HL5	<0.001			<0.001		
21/11/2016	HL5	<0.001			<0.001		
22/05/2017	HL5	<0.001			0.002		exceeded
20/11/2017	HL5	<0.001			<0.001		
14/05/2018	HL5	0.002		exceeded	<0.001		
21/11/2018	HL5	<0.001			<0.001		
14/10/2013	HL6	0.001			0.003		exceeded
24/05/2014	HL6	0.001			0.002		exceeded
27/04/2015	HL6	0.002		exceeded	<0.001		
12/10/2015	HL6	0.004		exceeded	0.002		exceeded
02/05/2016	HL6	0.002		exceeded	0.001		
21/11/2016	HL6	0.001			0.001		
22/05/2017	HL6	0.002		exceeded	0.004		exceeded
20/11/2017	HL6	<0.001			0.001		
14/05/2018	HL6	0.002		exceeded	0.002		exceeded
21/11/2018	HL6	0.001			0.004		exceeded
14/10/2013	HL7	0.002		exceeded	<0.001		
24/05/2014	HL7	0.002		exceeded	0.001		
27/04/2015	HL7	0.001			0.002		exceeded
12/10/2015	HL7	0.005		exceeded	0.002		exceeded
02/05/2016	HL7	0.004		exceeded	0.003		exceeded
21/11/2016	HL7	0.003		exceeded	0.002		exceeded
22/05/2017	HL7	0.002		exceeded	0.001		
20/11/2017	HL7	0.002		exceeded	<0.001		
14/05/2018	HL7	0.003		exceeded	0.002		exceeded
21/11/2018	HL7	<0.001			0.002		exceeded
14/10/2013	SH3	<0.005			0.002		exceeded
24/05/2014	SH3	0.001			0.003		exceeded
27/04/2015	SH3	<0.001			<0.001		
12/10/2015	SH3	0.008		exceeded	0.007		exceeded
02/05/2016	SH3	0.001			0.002		exceeded
21/11/2016	SH3	<0.001			0.001		
22/05/2017	SH3	<0.005			<0.005		
19/11/2017	SH3	<0.005			<0.005		
14/05/2018	SH3	0.003		exceeded	0.004		exceeded
21/11/2018	SH3	<0.005			<0.005		
14/10/2013	TD3	<0.001			<0.001		
24/05/2014	TD3	0.001			0.001		
27/04/2015	TD3	<0.001			<0.001		
12/10/2015	TD3	0.002		exceeded	0.001		
02/05/2016	TD3	0.001			<0.001		

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Copper			Copper		
21/11/2016	TD3	<0.001			<0.001		
22/05/2017	TD3	<0.001			<0.001		
20/11/2017	TD3	<0.001			<0.001		
14/05/2018	TD3	0.001			<0.001		
21/11/2018	TD3	0.001			<0.001		
14/10/2013	TD4	<0.001			0.003		exceeded
24/05/2014	TD4	<0.001			0.001		
27/04/2015	TD4	<0.001			<0.001		
12/10/2015	TD4	0.001			0.001		
02/05/2016	TD4	0.002		exceeded	0.001		
21/11/2016	TD4	<0.001			0.002		exceeded
22/05/2017	TD4	0.002		exceeded	0.012		exceeded
20/11/2017	TD4	0.002		exceeded	0.003		exceeded
14/05/2018	TD4	<0.005			0.003		exceeded
21/11/2018	TD4	0.003		exceeded	0.003		exceeded
14/10/2013	TD5	0.002		exceeded	0.002		exceeded
24/05/2014	TD5	0.003		exceeded	0.002		exceeded
27/04/2015	TD5	0.002		exceeded	0.001		
12/10/2015	TD5	0.002		exceeded	0.002		exceeded
02/05/2016	TD5	0.002		exceeded	0.001		
21/11/2016	TD5	<0.001	exceeded	exceeded	0.004		exceeded
22/05/2017	TD5	0.001			<0.001		
20/11/2017	TD5	<0.001			<0.001		
14/05/2018	TD5	0.003		exceeded	0.003		exceeded
14/10/2013	TD6	<0.005			<0.001		
24/05/2014	TD6	0.002		exceeded	0.009		exceeded
27/04/2015	TD6	<0.001			<0.001		
12/10/2015	TD6	0.01		exceeded	0.006		exceeded
02/05/2016	TD6	0.002		exceeded	0.002		exceeded
21/11/2016	TD6	<0.001			0.001		
22/05/2017	TD6	0.003		exceeded	0.003		exceeded
20/11/2017	TD6	<0.005			<0.005		
14/05/2018	TD6	0.002		exceeded	0.002		exceeded

The EA copper concentration contaminant and trigger limits are regularly exceeded across the Yandan site. This is consistent with the mineralization that occurs at the site.

8.7 Lead

Table 5 shows groundwater lead concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 5: LEAD COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Lead			Lead		
14/10/2013	HL1	<0.001			<0.001		
24/05/2014	HL1	0.001			<0.001		
27/04/2015	HL1	<0.001			<0.001		
12/10/2015	HL1	<0.001			0.019		exceeded
02/05/2016	HL1	<0.001			<0.001		
21/11/2016	HL1	<0.001			<0.001		
22/05/2017	HL1	<0.001			<0.001		
20/11/2017	HL1	<0.001			<0.001		
14/05/2018	HL1	<0.001			<0.001		
21/11/2018	HL1	<0.001			<0.001		
14/10/2013	HL3	<0.001			<0.001		
24/05/2014	HL3	<0.001			<0.001		
27/04/2015	HL3	<0.001			0.002		
12/10/2015	HL3	<0.001			0.007		exceeded
02/05/2016	HL3	<0.001			<0.001		
21/11/2016	HL3	<0.001			<0.001		
22/05/2017	HL3	<0.001			<0.001		
20/11/2017	HL3	<0.001			<0.001		
14/05/2018	HL3	<0.001			<0.001		
21/11/2018	HL3	<0.001			<0.001		
14/10/2013	HL4	<0.001			<0.001		
24/05/2014	HL4	<0.001			0.003		
27/04/2015	HL4	<0.001			<0.001		
12/10/2015	HL4	<0.001			0.002		
02/05/2016	HL4	<0.001			<0.001		
21/11/2016	HL4	<0.001			<0.001		
22/05/2017	HL4	<0.001			0.004		exceeded
20/11/2017	HL4	<0.001			<0.001		
14/05/2018	HL4	<0.001			<0.001		
21/11/2018	HL4	<0.001			<0.001		
14/10/2013	HL5	<0.001			<0.001		
24/05/2014	HL5	0.004		exceeded	<0.001		
27/04/2015	HL5	<0.001			0.008		exceeded

Date	Bore	Dissolved Lead	CL	TL	Total Lead	CL	TL
12/10/2015	HL5	<0.001			0.003		
02/05/2016	HL5	<0.001			<0.001		
21/11/2016	HL5	<0.001			<0.001		
22/05/2017	HL5	<0.001			0.007		exceeded
20/11/2017	HL5	<0.001			<0.001		
14/05/2018	HL5	<0.001			<0.001		
21/11/2018	HL5	<0.001			<0.001		
14/10/2013	HL6	0.001			0.002		
24/05/2014	HL6	<0.001			0.005		exceeded
27/04/2015	HL6	<0.001			0.001		
12/10/2015	HL6	<0.001			0.018		exceeded
02/05/2016	HL6	<0.001			<0.001		
21/11/2016	HL6	<0.001			<0.001		
22/05/2017	HL6	<0.001			0.004		exceeded
20/11/2017	HL6	<0.001			<0.001		
14/05/2018	HL6	<0.001			<0.001		
21/11/2018	HL6	<0.001			0.002		
14/10/2013	HL7	<0.001			<0.001		
24/05/2014	HL7	<0.001			0.006		exceeded
27/04/2015	HL7	<0.001			0.002		
12/10/2015	HL7	<0.001			<0.001		
02/05/2016	HL7	<0.001			<0.001		
21/11/2016	HL7	<0.001			<0.001		
22/05/2017	HL7	<0.001			<0.001		
20/11/2017	HL7	<0.001			<0.001		
14/05/2018	HL7	<0.001			<0.001		
21/11/2018	HL7	<0.001			0.002		
14/10/2013	SH3	<0.005			<0.001		
24/05/2014	SH3	<0.001			0.002		
27/04/2015	SH3	<0.001			0.004		exceeded
12/10/2015	SH3	<0.005			<0.005		
02/05/2016	SH3	<0.001			<0.001		
21/11/2016	SH3	<0.001			<0.001		
22/05/2017	SH3	<0.005			<0.005		
19/11/2017	SH3	<0.005			<0.005		
14/05/2018	SH3	<0.001			<0.001		
21/11/2018	SH3	<0.005			<0.005		
14/10/2013	TD3	<0.001			<0.001		
24/05/2014	TD3	<0.001			0.001		
27/04/2015	TD3	<0.001			0.001		
12/10/2015	TD3	0.002			0.001		

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Lead			Lead		
02/05/2016	TD3	<0.001			<0.001		
21/11/2016	TD3	<0.001			<0.001		
22/05/2017	TD3	<0.001			<0.001		
20/11/2017	TD3	<0.001			<0.001		
14/05/2018	TD3	<0.001			<0.001		
21/11/2018	TD3	<0.001			<0.001		
14/10/2013	TD4	<0.001			0.004		exceeded
24/05/2014	TD4	<0.001			0.002		
27/04/2015	TD4	<0.001			0.003		
12/10/2015	TD4	<0.001			0.004		exceeded
02/05/2016	TD4	0.003			0.003		
21/11/2016	TD4	<0.001			0.003		
22/05/2017	TD4	<0.001			0.016		exceeded
20/11/2017	TD4	0.002			0.002		
14/05/2018	TD4	<0.005			0.004		exceeded
21/11/2018	TD4	0.002			0.003		
14/10/2013	TD5	0.002			0.001		
24/05/2014	TD5	<0.001			0.001		
27/04/2015	TD5	<0.001			<0.001		
12/10/2015	TD5	0.002			0.002		
02/05/2016	TD5	<0.001			<0.001		
21/11/2016	TD5	<0.001			<0.001		
22/05/2017	TD5	<0.001			<0.001		
20/11/2017	TD5	<0.001			<0.001		
14/05/2018	TD5	<0.001			<0.001		
14/10/2013	TD6	<0.005			<0.001		
24/05/2014	TD6	0.001			0.001		
27/04/2015	TD6	0.001			0.001		
12/10/2015	TD6	<0.005			<0.005		
02/05/2016	TD6	<0.001			<0.001		
21/11/2016	TD6	<0.001			<0.001		
22/05/2017	TD6	<0.001			0.001		
20/11/2017	TD6	<0.005			<0.005		
14/05/2018	TD6	<0.001			<0.001		

The contaminant limit for lead has only been exceeded once, in HL5, in 2014. The contaminant limit for lead has not otherwise been exceeded across the Yandan site. The trigger limit for lead is exceeded on irregular occasions across the site but there is no definitive pattern for these occurrences.

8.8 Mercury

Table 6 shows groundwater mercury concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 6: MERCURY COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Dissolved Mercury	CL	TL	Total Mercury	CL	TL
14/10/2013	HL1	<0.0001			<0.0001		
24/05/2014	HL1	<0.0001			<0.0001		
20/10/2014	HL1	<0.0001			<0.0001		
27/04/2015	HL1	<0.0001			<0.0001		
12/10/2015	HL1	<0.0001			<0.0001		
02/05/2016	HL1	<0.0001			<0.0001		
21/11/2016	HL1	0.0001			0.0002		
22/05/2017	HL1	<0.0001			<0.0001		
20/11/2017	HL1	<0.0001			<0.0001		
14/05/2018	HL1	<0.0001			0.0001		
21/11/2018	HL1	0.0002			0.0002		
14/10/2013	HL3	<0.0001			<0.0001		
24/05/2014	HL3	<0.0001			<0.0001		
20/10/2014	HL3	<0.0001			<0.0001		
27/04/2015	HL3	<0.0001			<0.0001		
12/10/2015	HL3	<0.0001			<0.0001		
02/05/2016	HL3	<0.0001			<0.0001		
21/11/2016	HL3	<0.0001			<0.0001		
22/05/2017	HL3	<0.0001			<0.0001		
20/11/2017	HL3	<0.0001			<0.0001		
14/05/2018	HL3	<0.0001			<0.0001		
21/11/2018	HL3	<0.0001			<0.0001		
14/10/2013	HL4	<0.0001			<0.0001		
24/05/2014	HL4	<0.0001			<0.0001		
20/10/2014	HL4	<0.0001			<0.0001		
27/04/2015	HL4	<0.0001			<0.0001		
12/10/2015	HL4	<0.0001			<0.0001		
02/05/2016	HL4	<0.0001			<0.0001		
21/11/2016	HL4	<0.0001			<0.0001		
22/05/2017	HL4	<0.0001			<0.0001		
20/11/2017	HL4	<0.0001			<0.0001		
14/05/2018	HL4	<0.0001			<0.0001		
21/11/2018	HL4	<0.0001			<0.0001		
14/10/2013	HL5	<0.0001			<0.0001		
24/05/2014	HL5	<0.0001			<0.0001		

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Mercury			Mercury		
20/10/2014	HL5	<0.0001			<0.0001		
27/04/2015	HL5	<0.0001			<0.0001		
12/10/2015	HL5	<0.0001			<0.0001		
02/05/2016	HL5	<0.0001			<0.0001		
21/11/2016	HL5	<0.0001			<0.0001		
22/05/2017	HL5	<0.0001			<0.0001		
20/11/2017	HL5	<0.0001			<0.0001		
14/05/2018	HL5	0.0001			0.0004		
21/11/2018	HL5	<0.0001			<0.0001		
14/10/2013	HL6	<0.0001			<0.0001		
24/05/2014	HL6	<0.0001			<0.0001		
20/10/2014	HL6	<0.0001			<0.0001		
27/04/2015	HL6	<0.0001			<0.0001		
12/10/2015	HL6	<0.0001			<0.0001		
02/05/2016	HL6	<0.0001			<0.0001		
21/11/2016	HL6	<0.0001			<0.0001		
22/05/2017	HL6	<0.0001			<0.0001		
20/11/2017	HL6	<0.0001			<0.0001		
14/05/2018	HL6	<0.0001			<0.0001		
21/11/2018	HL6	<0.0001			<0.0001		
14/10/2013	HL7	0.0002			<0.0001		
24/05/2014	HL7	<0.0001			<0.0001		
20/10/2014	HL7	<0.0001			<0.0001		
27/04/2015	HL7	<0.0001			<0.0001		
12/10/2015	HL7	0.0002			0.0002		
02/05/2016	HL7	0.0002			0.0002		
21/11/2016	HL7	0.0002			0.0002		
22/05/2017	HL7	<0.0001			<0.0001		
20/11/2017	HL7	<0.0001			<0.0001		
14/05/2018	HL7	<0.0001			<0.0001		
21/11/2018	HL7	<0.0001			<0.0001		
14/10/2013	SH3	<0.0001			<0.0001		
24/05/2014	SH3	<0.0001			<0.0001		
20/10/2014	SH3	<0.0001			<0.0001		
27/04/2015	SH3	<0.0001			<0.0001		
12/10/2015	SH3	<0.0001			<0.0001		
02/05/2016	SH3	<0.0001			<0.0001		
21/11/2016	SH3	<0.0001			<0.0001		
22/05/2017	SH3	<0.0001			<0.0001		
19/11/2017	SH3	<0.0001			<0.0001		
14/05/2018	SH3	<0.0001			<0.0001		
21/11/2018	SH3	<0.0001			<0.0001		

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Mercury			Mercury		
14/10/2013	TD3	<0.0001			<0.0001		
24/05/2014	TD3	<0.0001			<0.0001		
20/10/2014	TD3	<0.0001			<0.0001		
27/04/2015	TD3	<0.0001			<0.0001		
12/10/2015	TD3	<0.0001			<0.0001		
02/05/2016	TD3	<0.0001			<0.0001		
21/11/2016	TD3	<0.0001			<0.0001		
22/05/2017	TD3	<0.0001			<0.0001		
20/11/2017	TD3	<0.0001			<0.0001		
14/05/2018	TD3	<0.0001			<0.0001		
21/11/2018	TD3	<0.0001			<0.0001		
14/10/2013	TD4	<0.0001			<0.0001		
24/05/2014	TD4	<0.0001			<0.0001		
20/10/2014	TD4	<0.0001			<0.0001		
27/04/2015	TD4	<0.0001			<0.0001		
12/10/2015	TD4	<0.0001			<0.0001		
02/05/2016	TD4	<0.0001			<0.0001		
21/11/2016	TD4	<0.0001			<0.0001		
22/05/2017	TD4	<0.0001			<0.0001		
20/11/2017	TD4	<0.0001			<0.0001		
14/05/2018	TD4	<0.0001			<0.0001		
21/11/2018	TD4	<0.0001			<0.0001		
14/10/2013	TD5	<0.0001			<0.0001		
24/05/2014	TD5	<0.0001			<0.0001		
20/10/2014	TD5	<0.0001			<0.0001		
27/04/2015	TD5	<0.0001			<0.0001		
12/10/2015	TD5	0.0001			<0.0001		
02/05/2016	TD5	<0.0001			<0.0001		
21/11/2016	TD5	0.0003			0.0002		
22/05/2017	TD5	<0.0001			<0.0001		
20/11/2017	TD5	0.0005			0.0005		
14/05/2018	TD5	<0.0005			<0.0001		
14/10/2013	TD6	<0.0001			<0.0001		
24/05/2014	TD6	<0.0001			0.0012		
20/10/2014	TD6	0.0005			0.0006		
27/04/2015	TD6	<0.0001			<0.0001		
12/10/2015	TD6	0.0014			0.0014		
02/05/2016	TD6	<0.0001			<0.0001		
21/11/2016	TD6	<0.0001			<0.0001		
22/05/2017	TD6	<0.0001			<0.0001		
20/11/2017	TD6	<0.0001			<0.0001		
14/05/2018	TD6	<0.0001			<0.0001		

There have been no exceedences of mercury in the groundwater at the Yandan site over this data period.

8.9 Molybdenum

Table 7 shows groundwater molybdenum concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 7: MOLYBDENUM COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Molybdenum			Molybdenum		
14/10/2013	HL1	0.003			0.004		
24/05/2014	HL1	0.002			0.003		
27/04/2015	HL1	0.002			0.002		
12/10/2015	HL1	0.002			0.002		
02/05/2016	HL1	0.002			0.002		
21/11/2016	HL1	0.002			0.002		
22/05/2017	HL1	0.002			0.002		
20/11/2017	HL1	0.002			0.002		
14/05/2018	HL1	0.002			0.002		
21/11/2018	HL1	0.002			0.002		
14/10/2013	HL3	<0.001			<0.001		
24/05/2014	HL3	0.002			0.001		
27/04/2015	HL3	<0.001			<0.001		
12/10/2015	HL3	0.001			0.001		
02/05/2016	HL3	0.001			0.001		
21/11/2016	HL3	<0.001			0.001		
22/05/2017	HL3	0.001			0.001		
20/11/2017	HL3	<0.001			0.001		
14/05/2018	HL3	0.002			0.002		
21/11/2018	HL3	0.001			0.001		
14/10/2013	HL4	<0.001			<0.001		
24/05/2014	HL4	<0.001			<0.001		
27/04/2015	HL4	0.003			0.004		
12/10/2015	HL4	0.004			0.004		
02/05/2016	HL4	0.004			0.003		
21/11/2016	HL4	0.002			0.002		
22/05/2017	HL4	0.003			0.003		
20/11/2017	HL4	0.002			0.003		
14/05/2018	HL4	0.003			0.003		

Date	Bore	Dissolved Molybdenum	CL	TL	Total Molybdenum	CL	TL
21/11/2018	HL4	0.003			0.003		
14/10/2013	HL5	<0.001			<0.001		
24/05/2014	HL5	<0.001			<0.001		
27/04/2015	HL5	<0.001			<0.001		
12/10/2015	HL5	<0.001			<0.001		
02/05/2016	HL5	<0.001			<0.001		
21/11/2016	HL5	<0.001			<0.001		
22/05/2017	HL5	<0.001			<0.001		
20/11/2017	HL5	<0.001			<0.001		
14/05/2018	HL5	<0.001			0.001		
21/11/2018	HL5	<0.001			<0.001		
14/10/2013	HL6	0.006			0.006		
24/05/2014	HL6	0.004			0.005		
27/04/2015	HL6	0.003			0.003		
12/10/2015	HL6	0.002			0.003		
02/05/2016	HL6	0.003			0.002		
21/11/2016	HL6	0.002			0.002		
22/05/2017	HL6	0.002			0.002		
20/11/2017	HL6	0.002			0.003		
14/05/2018	HL6	0.002			0.002		
21/11/2018	HL6	0.002			0.003		
14/10/2013	HL7	<0.001			<0.001		
24/05/2014	HL7	<0.001			<0.001		
27/04/2015	HL7	<0.001			<0.001		
12/10/2015	HL7	<0.001			<0.001		
02/05/2016	HL7	<0.001			<0.001		
21/11/2016	HL7	<0.001			<0.001		
22/05/2017	HL7	<0.001			<0.001		
20/11/2017	HL7	<0.001			<0.001		
14/05/2018	HL7	<0.001			<0.001		
21/11/2018	HL7	<0.001			<0.001		
14/10/2013	SH3	0.006			0.006		
24/05/2014	SH3	0.004			0.007		
27/04/2015	SH3	0.005			0.005		
12/10/2015	SH3	<0.005			<0.005		
02/05/2016	SH3	0.003			0.003		
21/11/2016	SH3	0.004			0.004		
22/05/2017	SH3	<0.005			0.005		
19/11/2017	SH3	<0.005			<0.005		
14/05/2018	SH3	0.002			0.002		
21/11/2018	SH3	<0.005			<0.005		

Date	Bore	Dissolved Molybdenum	CL	TL	Total Molybdenum	CL	TL
14/10/2013	TD3	0.002			0.003		
24/05/2014	TD3	0.003			0.003		
27/04/2015	TD3	0.002			0.002		
12/10/2015	TD3	0.002			0.002		
02/05/2016	TD3	0.002			0.002		
21/11/2016	TD3	0.002			0.002		
22/05/2017	TD3	0.002			0.002		
20/11/2017	TD3	0.002			0.002		
14/05/2018	TD3	0.002			0.002		
21/11/2018	TD3	0.001			0.002		
14/10/2013	TD4	0.004			0.005		
24/05/2014	TD4	0.007			0.008		
27/04/2015	TD4	0.006			0.007		
12/10/2015	TD4	0.008			0.009		
02/05/2016	TD4	0.008			0.007		
21/11/2016	TD4	0.006			0.006		
22/05/2017	TD4	0.006			0.007		
20/11/2017	TD4	0.005			0.006		
14/05/2018	TD4	0.006			0.007		
21/11/2018	TD4	0.006			0.007		
14/10/2013	TD5	<0.001			<0.001		
24/05/2014	TD5	<0.001			<0.001		
27/04/2015	TD5	<0.001			<0.001		
12/10/2015	TD5	<0.001			<0.001		
02/05/2016	TD5	0.001			0.001		
21/11/2016	TD5	<0.001			<0.001		
22/05/2017	TD5	<0.001			<0.001		
20/11/2017	TD5	<0.001			<0.001		
14/05/2018	TD5	0.001			0.002		
14/10/2013	TD6	<0.005			<0.001		
24/05/2014	TD6	<0.001			<0.001		
27/04/2015	TD6	<0.001			<0.001		
12/10/2015	TD6	<0.005			<0.005		
02/05/2016	TD6	0.001			0.001		
21/11/2016	TD6	<0.001			<0.001		
22/05/2017	TD6	0.002			0.002		
20/11/2017	TD6	<0.005			<0.005		
14/05/2018	TD6	0.001			0.001		

There have been no exceedences of molybdenum in the groundwater at the Yandan site over this data period.

8.10 Selenium

Table 8 shows groundwater selenium concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 8: SELENIUM COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Dissolved Selenium	CL	TL	Total Selenium	CL	TL
14/10/2013	HL1	0.02		exceeded	0.03	exceeded	exceeded
24/05/2014	HL1	0.04	exceeded	exceeded	0.03	exceeded	exceeded
27/04/2015	HL1	0.04	exceeded	exceeded	0.04	exceeded	exceeded
12/10/2015	HL1	0.04	exceeded	exceeded	0.04	exceeded	exceeded
02/05/2016	HL1	0.05	exceeded	exceeded	0.04	exceeded	exceeded
21/11/2016	HL1	0.04	exceeded	exceeded	0.04	exceeded	exceeded
22/05/2017	HL1	0.04	exceeded	exceeded	0.05	exceeded	exceeded
20/11/2017	HL1	0.04	exceeded	exceeded	0.04	exceeded	exceeded
14/05/2018	HL1	0.04	exceeded	exceeded	0.04	exceeded	exceeded
21/11/2018	HL1	0.04	exceeded	exceeded	0.04	exceeded	exceeded
14/10/2013	HL3	<0.01			<0.01		
24/05/2014	HL3	<0.01			<0.01		
27/04/2015	HL3	<0.01			<0.01		
12/10/2015	HL3	<0.01			<0.01		
02/05/2016	HL3	<0.01			<0.01		
21/11/2016	HL3	<0.01			<0.01		
22/05/2017	HL3	<0.01			<0.01		
20/11/2017	HL3	<0.01			<0.01		
14/05/2018	HL3	<0.01			<0.01		
21/11/2018	HL3	<0.01			<0.01		
14/10/2013	HL4	<0.01			<0.01		
24/05/2014	HL4	<0.01			<0.01		
27/04/2015	HL4	<0.01			<0.01		
12/10/2015	HL4	<0.01			<0.01		
02/05/2016	HL4	<0.01			<0.01		
21/11/2016	HL4	<0.01			<0.01		
22/05/2017	HL4	<0.01			<0.01		
20/11/2017	HL4	<0.01			<0.01		
14/05/2018	HL4	<0.01			<0.01		
21/11/2018	HL4	<0.01			<0.01		
14/10/2013	HL5	<0.01			<0.01		
24/05/2014	HL5	<0.01			<0.01		
27/04/2015	HL5	<0.01			<0.01		

Date	Bore	Dissolved Selenium	CL	TL	Total Selenium	CL	TL
12/10/2015	HL5	<0.01			<0.01		
02/05/2016	HL5	<0.01			<0.01		
21/11/2016	HL5	<0.01			<0.01		
22/05/2017	HL5	<0.01			<0.01		
20/11/2017	HL5	<0.01			<0.01		
14/05/2018	HL5	<0.01			<0.01		
21/11/2018	HL5	<0.01			<0.01		
14/10/2013	HL6	<0.01			<0.01		
24/05/2014	HL6	<0.01			<0.01		
27/04/2015	HL6	<0.01			<0.01		
12/10/2015	HL6	<0.01			<0.01		
02/05/2016	HL6	<0.01			<0.01		
21/11/2016	HL6	<0.01			<0.01		
22/05/2017	HL6	<0.01			<0.01		
20/11/2017	HL6	<0.01			<0.01		
14/05/2018	HL6	<0.01			<0.01		
21/11/2018	HL6	<0.01			<0.01		
14/10/2013	HL7	<0.01			<0.01		
24/05/2014	HL7	<0.01			<0.01		
27/04/2015	HL7	<0.01			<0.01		
12/10/2015	HL7	<0.01			<0.01		
02/05/2016	HL7	<0.01			<0.01		
21/11/2016	HL7	<0.01			<0.01		
22/05/2017	HL7	<0.01			<0.01		
20/11/2017	HL7	<0.01			<0.01		
14/05/2018	HL7	<0.01			<0.01		
21/11/2018	HL7	<0.01			<0.01		
14/10/2013	SH3	<0.05			<0.01		
24/05/2014	SH3	<0.01			<0.01		
27/04/2015	SH3	<0.01			<0.01		
12/10/2015	SH3	<0.05			<0.05		
02/05/2016	SH3	<0.01			<0.01		
21/11/2016	SH3	<0.01			<0.01		
22/05/2017	SH3	<0.05			<0.05		
19/11/2017	SH3	<0.05			<0.05		
14/05/2018	SH3	<0.01			<0.01		
21/11/2018	SH3	<0.05			<0.05		
14/10/2013	TD3	<0.01			<0.01		
24/05/2014	TD3	<0.01			<0.01		
27/04/2015	TD3	<0.01			<0.01		
12/10/2015	TD3	<0.01			<0.01		

Date	Bore	Dissolved Selenium	CL	TL	Total Selenium	CL	TL
02/05/2016	TD3	<0.01			<0.01		
21/11/2016	TD3	<0.01			<0.01		
22/05/2017	TD3	<0.01			<0.01		
20/11/2017	TD3	<0.01			<0.01		
14/05/2018	TD3	<0.01			<0.01		
21/11/2018	TD3	<0.01			<0.01		
14/10/2013	TD4	<0.01			<0.01		
24/05/2014	TD4	<0.01			<0.01		
27/04/2015	TD4	<0.01			<0.01		
12/10/2015	TD4	<0.01			<0.01		
02/05/2016	TD4	<0.01			<0.01		
21/11/2016	TD4	<0.01			<0.01		
22/05/2017	TD4	<0.01			<0.01		
20/11/2017	TD4	<0.01			<0.01		
14/05/2018	TD4	<0.05			<0.01		
21/11/2018	TD4	<0.01			<0.01		
14/10/2013	TD5	<0.01			<0.01		
24/05/2014	TD5	<0.01			<0.01		
27/04/2015	TD5	<0.01			<0.01		
12/10/2015	TD5	<0.01			<0.01		
02/05/2016	TD5	<0.01			<0.01		
21/11/2016	TD5	<0.01			<0.01		
22/05/2017	TD5	<0.01			<0.01		
20/11/2017	TD5	<0.01			<0.01		
14/05/2018	TD5	<0.01			<0.01		
14/10/2013	TD6	<0.05			<0.01		
24/05/2014	TD6	<0.01			<0.01		
27/04/2015	TD6	<0.01			<0.01		
12/10/2015	TD6	<0.05			<0.05		
02/05/2016	TD6	<0.01			<0.01		
21/11/2016	TD6	<0.01			<0.01		
22/05/2017	TD6	<0.01			<0.01		
20/11/2017	TD6	<0.05			<0.05		
14/05/2018	TD6	<0.01			<0.01		

The groundwater in HL1 consistently exceeds both the EA contaminant and trigger limits. There are no other exceedences of either the contaminant or trigger limits in the groundwater across the Yandan site.

8.11 Zinc

Table 9 shows groundwater zinc concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 9: ZINC COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	Dissolved Zinc	CL	TL	Total Zinc	CL	TL
14/10/2013	HL1	<0.005			0.04		exceeded
24/05/2014	HL1	<0.005			<0.005		
27/04/2015	HL1	<0.005			<0.005		
12/10/2015	HL1	0.01		exceeded	<0.005		
02/05/2016	HL1	<0.005			<0.005		
21/11/2016	HL1	<0.005			<0.005		
22/05/2017	HL1	<0.005			<0.005		
20/11/2017	HL1	0.008			<0.005		
14/05/2018	HL1	<0.005			<0.005		
21/11/2018	HL1	<0.005			<0.005		
14/10/2013	HL3	<0.005			0.006		
24/05/2014	HL3	<0.005			<0.005		
27/04/2015	HL3	<0.005			<0.005		
12/10/2015	HL3	<0.005			<0.005		
02/05/2016	HL3	<0.005			<0.005		
21/11/2016	HL3	<0.005			<0.005		
22/05/2017	HL3	0.006			<0.005		
20/11/2017	HL3	0.013		exceeded	0.008		
14/05/2018	HL3	<0.005			<0.005		
21/11/2018	HL3	<0.005			<0.005		
14/10/2013	HL4	<0.005			0.006		
24/05/2014	HL4	<0.005			<0.005		
27/04/2015	HL4	<0.005			<0.005		
12/10/2015	HL4	0.005			<0.005		
02/05/2016	HL4	<0.005			<0.005		
21/11/2016	HL4	<0.005			<0.005		
22/05/2017	HL4	<0.005			<0.005		
20/11/2017	HL4	0.007			<0.005		
14/05/2018	HL4	<0.005			<0.005		
21/11/2018	HL4	<0.005			<0.005		
14/10/2013	HL5	<0.005			0.008		
24/05/2014	HL5	<0.005			<0.005		
27/04/2015	HL5	<0.005			<0.005		

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Zinc			Zinc		
12/10/2015	HL5	<0.005			0.011		exceeded
02/05/2016	HL5	<0.005			<0.005		
21/11/2016	HL5	<0.005			<0.005		
22/05/2017	HL5	<0.005			0.007		
20/11/2017	HL5	0.01		exceeded	<0.005		
14/05/2018	HL5	<0.005			<0.005		
21/11/2018	HL5	<0.005			<0.005		
14/10/2013	HL6	<0.005			0.007		
24/05/2014	HL6	<0.005			<0.005		
27/04/2015	HL6	0.005			<0.005		
12/10/2015	HL6	0.01		exceeded	<0.005		
02/05/2016	HL6	<0.005			<0.005		
21/11/2016	HL6	0.005			<0.005		
22/05/2017	HL6	0.005			0.009		exceeded
20/11/2017	HL6	0.007			<0.005		
14/05/2018	HL6	<0.005			<0.005		
21/11/2018	HL6	<0.005			<0.005		
14/10/2013	HL7	<0.005			0.007		
24/05/2014	HL7	0.012		exceeded	<0.005	exceeded	exceeded
27/04/2015	HL7	<0.005			0.026		exceeded
12/10/2015	HL7	0.011		exceeded	0.006		
02/05/2016	HL7	0.006			<0.005		
21/11/2016	HL7	0.012		exceeded	<0.005		
22/05/2017	HL7	0.005			<0.005		
20/11/2017	HL7	0.025		exceeded	<0.005		
14/05/2018	HL7	<0.005			<0.005		
21/11/2018	HL7	<0.005			0.008		
14/10/2013	SH3	<0.025			0.011		exceeded
24/05/2014	SH3	0.011		exceeded	0.019		exceeded
27/04/2015	SH3	0.011		exceeded	0.01		exceeded
12/10/2015	SH3	<0.025			0.03		exceeded
02/05/2016	SH3	0.013		exceeded	0.012		exceeded
21/11/2016	SH3	0.016		exceeded	0.017		exceeded
22/05/2017	SH3	<0.025			<0.026		
19/11/2017	SH3	0.063		exceeded	<0.026		
14/05/2018	SH3	0.018		exceeded	0.017		exceeded
21/11/2018	SH3	0.035		exceeded	<0.026		
14/10/2013	TD3	<0.005			<0.005		
24/05/2014	TD3	<0.005			<0.005		
27/04/2015	TD3	<0.005			<0.005		
12/10/2015	TD3	<0.005			<0.005		

Date	Bore	Dissolved	CL	TL	Total	CL	TL
		Zinc			Zinc		
02/05/2016	TD3	<0.005			<0.005		
21/11/2016	TD3	<0.005			<0.005		
22/05/2017	TD3	<0.005			<0.005		
20/11/2017	TD3	<0.005			<0.005		
14/05/2018	TD3	<0.005			<0.005		
21/11/2018	TD3	0.014		exceeded	0.007		
14/10/2013	TD4	<0.005			0.005		
24/05/2014	TD4	<0.005			<0.005		
27/04/2015	TD4	<0.005			<0.005		
12/10/2015	TD4	<0.005			<0.005		
02/05/2016	TD4	<0.005			<0.005		
21/11/2016	TD4	<0.005			<0.005		
22/05/2017	TD4	<0.005			0.022		exceeded
20/11/2017	TD4	0.007			<0.005		
14/05/2018	TD4	<0.025			<0.005		
21/11/2018	TD4	<0.005			<0.005		
14/10/2013	TD5	<0.005			<0.005		
24/05/2014	TD5	0.006			<0.005		
27/04/2015	TD5	0.006			<0.005		
12/10/2015	TD5	<0.005			<0.005		
02/05/2016	TD5	<0.005			<0.005		
21/11/2016	TD5	<0.005			<0.005		
22/05/2017	TD5	<0.005			0.006		
20/11/2017	TD5	0.006			<0.005		
14/05/2018	TD5	<0.005			<0.005		
14/10/2013	TD6	<0.025			<0.005		
24/05/2014	TD6	0.006			0.009		exceeded
27/04/2015	TD6	<0.005			<0.005		
12/10/2015	TD6	<0.025			<0.026		
02/05/2016	TD6	<0.005			<0.005		
21/11/2016	TD6	<0.005			<0.005		
22/05/2017	TD6	0.006			<0.005		
20/11/2017	TD6	<0.025			<0.026		
14/05/2018	TD6	<0.005			<0.005		

The contaminant limit for zinc in the groundwater at Yandan was not exceeded over the data period. The trigger limit for zinc in the groundwater at Yandan was exceeded on irregular occasions across the site with SH3 exceeding the limit for zinc most of the time.

8.12 WAD Cyanide

Table 10 shows WAD Cyanide concentrations in the Yandan EA monitoring bores assessed against the contaminant limit and trigger limit specified in the EA.

TABLE 10: WAD CYANIDE COMPARISONS IN YANDAN EA MONITORING BORES

Date	Bore	WAD	CL	TL
		Cyanide		
14/10/2013	HL1	0.006		
24/05/2014	HL1	0.005		
20/10/2014	HL1	0.004		
27/04/2015	HL1	<0.004		
12/10/2015	HL1	0.008		exceeded
02/05/2016	HL1			
21/11/2016	HL1			
22/05/2017	HL1			
20/11/2017	HL1			
14/05/2018	HL1			
21/11/2018	HL1			
14/10/2013	HL3	<0.004		
24/05/2014	HL3	<0.004		
20/10/2014	HL3	<0.004		
27/04/2015	HL3	<0.004		
12/10/2015	HL3	<0.004		
02/05/2016	HL3			
21/11/2016	HL3			
22/05/2017	HL3			
20/11/2017	HL3			
14/05/2018	HL3			
21/11/2018	HL3			
14/10/2013	HL4	<0.004		
24/05/2014	HL4	<0.004		
20/10/2014	HL4	<0.004		
27/04/2015	HL4	<0.004		
12/10/2015	HL4	<0.004		
02/05/2016	HL4			
21/11/2016	HL4			
22/05/2017	HL4			
20/11/2017	HL4			
14/05/2018	HL4			
21/11/2018	HL4			
14/10/2013	HL5	<0.004		

Date	Bore	WAD	CL	TL
		Cyanide		
24/05/2014	HL5	<0.004		
20/10/2014	HL5	<0.004		
27/04/2015	HL5	<0.004		
12/10/2015	HL5	<0.004		
02/05/2016	HL5			
21/11/2016	HL5			
22/05/2017	HL5			
20/11/2017	HL5			
14/05/2018	HL5			
21/11/2018	HL5			
14/10/2013	HL6	<0.004		
24/05/2014	HL6	<0.004		
20/10/2014	HL6	<0.004		
27/04/2015	HL6	<0.004		
12/10/2015	HL6	<0.004		
02/05/2016	HL6			
21/11/2016	HL6			
22/05/2017	HL6			
20/11/2017	HL6			
14/05/2018	HL6			
21/11/2018	HL6			
14/10/2013	HL7	<0.004		
24/05/2014	HL7	<0.004		
20/10/2014	HL7	<0.004		
27/04/2015	HL7	<0.004		
12/10/2015	HL7	<0.004		
02/05/2016	HL7			
21/11/2016	HL7			
22/05/2017	HL7			
20/11/2017	HL7			
14/05/2018	HL7			
21/11/2018	HL7			
14/10/2013	SH3	<0.004		
24/05/2014	SH3	<0.004		
20/10/2014	SH3	<0.004		
27/04/2015	SH3	<0.004		
12/10/2015	SH3	<0.004		
02/05/2016	SH3			
21/11/2016	SH3			
22/05/2017	SH3			
19/11/2017	SH3			
14/05/2018	SH3			

Date	Bore	WAD	CL	TL
		Cyanide		
21/11/2018	SH3			
14/10/2013	TD3	<0.004		
24/05/2014	TD3	<0.004		
20/10/2014	TD3	<0.004		
27/04/2015	TD3	<0.004		
12/10/2015	TD3	<0.004		
02/05/2016	TD3			
21/11/2016	TD3			
22/05/2017	TD3			
20/11/2017	TD3			
14/05/2018	TD3			
21/11/2018	TD3			
14/10/2013	TD4	<0.004		
24/05/2014	TD4	<0.004		
20/10/2014	TD4	<0.004		
27/04/2015	TD4	<0.004		
12/10/2015	TD4	<0.004		
02/05/2016	TD4			
21/11/2016	TD4			
22/05/2017	TD4			
20/11/2017	TD4			
14/05/2018	TD4			
21/11/2018	TD4			
14/10/2013	TD5	<0.004		
24/05/2014	TD5	<0.004		
20/10/2014	TD5	<0.004		
27/04/2015	TD5	<0.004		
12/10/2015	TD5	<0.004		
02/05/2016	TD5			
21/11/2016	TD5			
22/05/2017	TD5			
20/11/2017	TD5			
14/05/2018	TD5			
14/10/2013	TD6	0.004		
24/05/2014	TD6	<0.004		
20/10/2014	TD6	<0.004		
27/04/2015	TD6	<0.004		
12/10/2015	TD6	<0.004		
02/05/2016	TD6			
21/11/2016	TD6			
22/05/2017	TD6			
20/11/2017	TD6			

Date	Bore	WAD	CL	TL
		Cyanide		
14/05/2018	TD6			

The likelihood of cyanide contamination appears to be low however WAD Cyanide has not been analysed for at Yandan since 2015. Hence the site is not in compliance with the EA. It is recommended that Aeris Resources reinstate analysis of WAD Cyanide.

9.0 ADDITIONAL GROUNDWATER MONITORING BORES

9.1 Reference Bores

Reference bores should be installed at Yandan to comply with the EA. It is recommended that bore WSB2 should be included in the EA as a reference bore.

In addition to WSB2 two reference bores should be installed. RB1 should be located south of the tailings storage dam and RB should be located to the southwest of the tailings storage dam, at approximately the locations shown on Figure 12. Table 11 shows the eastings and northings of RB1 and RB2 obtained from Google Earth and the purposes of the reference bores. In each case the suffix S or D will apply to the shallow and deep bores respectively.

These locations should be validated in the field to assess their suitability for drilling rig access.

TABLE 11: REFERENCE BORE COORDINATES			
Monitoring Bore ID	Easting MGA94	Northing MGA94	Purpose
RB1S RB1D	500400	7645740	Located away from mine infrastructure to inform on hydrogeological regime unlikely to be impacted by mining activity
RB2S RB2D	498940	7646310	Located on a drainage feature downstream of the tailings storage dam to assess presence of, and impact of potential groundwater contamination from the tailings storage dam

It is considered that RB1 will fulfil the criteria required for reference bores:

- (a) *selected in accordance with the ANZECC & ARMCANZ 2000 methodology*
- (b) *be from the same bio-geographic and climatic region; and*
- (c) *have similar geology, soil types and topography; and*
- (d) *not be so close to the test sites that any disturbance at the test site also results in a change at the reference site.*

It is uncertain whether RB2 will detect groundwater contamination i.e. be impacted by site disturbance. However, this location does fulfil all the remaining criteria required for reference bores. This bore site has been suggested following indications from the administering authority (Department of Environment and Science) that they wish to assess whether groundwater contamination exists downstream of the tailings storage dam.

9.2 Replacement for TD6

Groundwater monitoring bore TD6 has been recently removed. It should be replaced as soon as ifs feasible. For convenience this monitoring bore should be designated TD6R.

Table 12 shows the eastings and northings of TD6R obtained from Google Earth. TD6R is shown on Figure 12.

TABLE 12: REPLACEMENT BORE COORDINATES			
Monitoring Bore ID	Easting MGA94	Northing MGA94	Purpose
TD6RS TD6RD	501010	7647150	Replacement for TD6. Located beside a north-south track and adjacent to the drainage feature on which the tailings storage dam has been constructed.

9.3 Drilling and Construction

Twinned monitoring bores should be installed at each site discussed in Tables 11 and 12.

A 10m deep bore should be installed to monitor shallow groundwater occurrence and flow and a 30m deep bore should be installed approximately six to ten metres from the shallow bore to monitor deeper groundwater occurrence and flow.

The shallow bores should be drilled to 10m depth and be constructed with machine slotted PVC screens over the basal 3m of the monitoring pipe.

The deeper bores should be drilled to 30m depth and be constructed with machine slotted PVC screens over the basal 6m of the monitoring pipe.

In both the shallow and deeper bores the screened interval should be sheathed in an inert gravel envelope and the annulus above the gravel pack sealed with 2m of bentonite and then cement grout back to the surface. The annular sealing will preclude the ingress of any contaminating fluids from the surface.

A drilling and construction specification for the bores is presented in the Appendix.

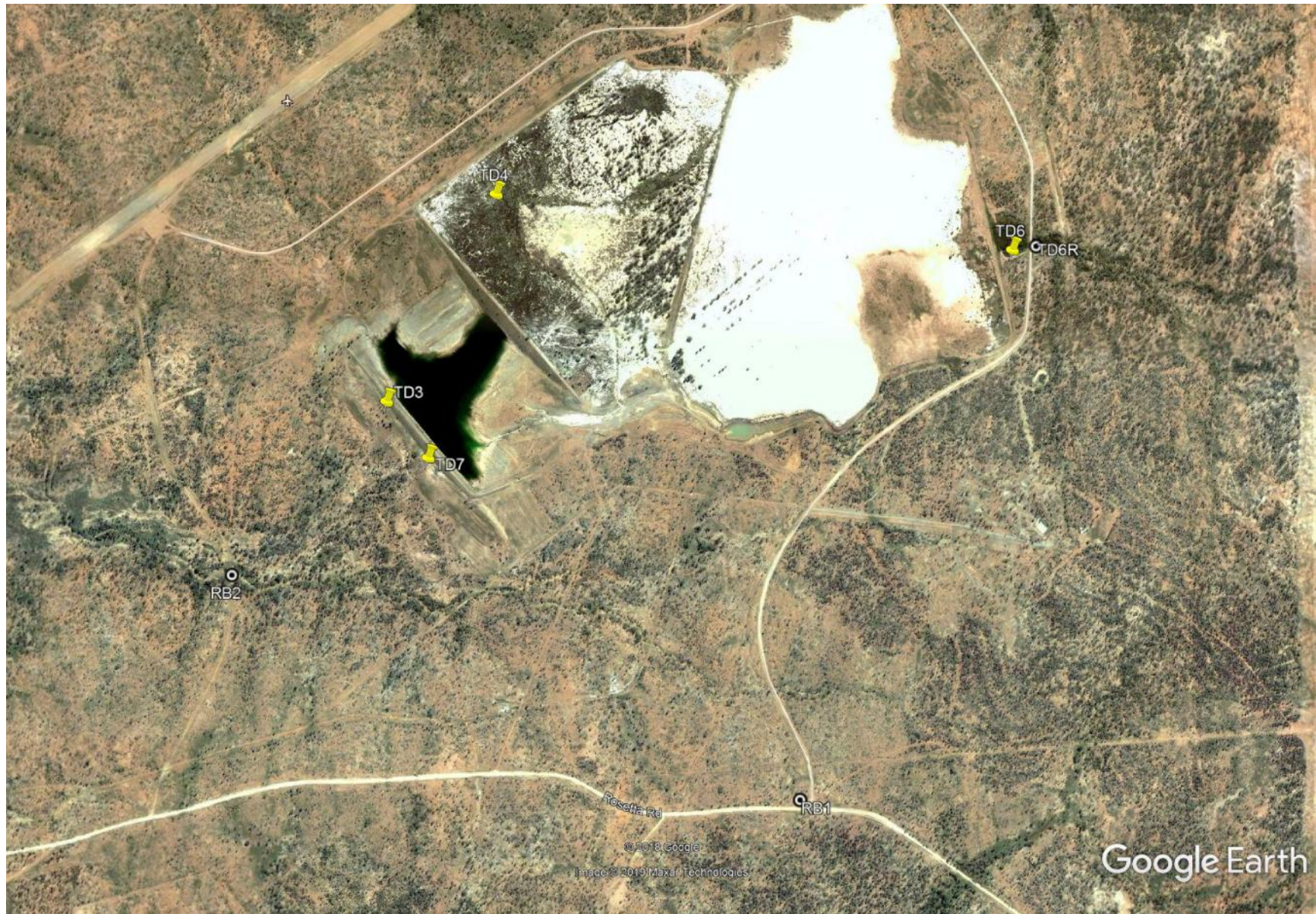


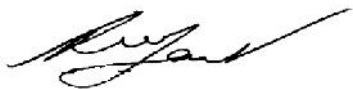
Figure 12: Google Earth Image showing Proposed Reference and Replacement Bore Sites

10.0 RECOMMENDATIONS

It is recommended that:

1. Aeris Resources increases groundwater monitoring to quarterly to comply with the EA;
2. Aeris Resources reinstates analysis of WAD Cyanide;
3. Bore WSB2 should be included in the EA as a reference bore
4. Two additional nested reference bores (at sites RB1 and RB2) should be installed as soon as possible to comply with the EA;
5. Bore TD6 should be replaced as soon as possible by nested shallow and deeper monitoring bores; and
6. Bore TD7 should be rehabilitated.

Rob Lait and Associates Pty Ltd

A handwritten signature in black ink, appearing to read 'Rob Lait', with a stylized flourish extending from the end.

ROB LAIT
Principal Hydrogeologist

APPENDIX: DRILLING AND CONSTRUCTION SPECIFICATION

DRILLING AND CONSTRUCTION SPECIFICATION YANDAN MONITORING BORES

The drilling program should proceed according to the following specifications:

- 1 Test holes should be drilled according to the 'Minimum Construction Standards for Water Bores in Australia' at the sites nominated in the table below.

YANDAN BORE COORDINATES			
Monitoring Bore ID	Easting MGA94	Northing MGA94	Purpose
RB1S RB1D	500400	7645740	Located away from mine infrastructure to inform on hydrogeological regime unlikely to be impacted by mining activity
RB2S RB2D	498940	7646310	Located on a drainage feature downstream of the tailings storage dam to assess presence of, and impact of potential groundwater contamination from the tailings storage dam
TD6RS TD6RD	501010	7647150	Replacement for TD6. Located beside a north-south track and adjacent to the drainage feature on which the tailings storage dam has been constructed.

- 2 A licensed water bore driller should drill the test holes with the capacity to drill to a depth of 400m. A rotary percussion drilling plant with sufficient capacity of compressed air to effectively drill a 125mm nominal diameter water bore will be required for drilling through the subsurface sequence.
- 3 The shallow bore at each site (suffix S) will be drilled to a depth of 10m and be constructed with 50mm PN 12 uPVC casing and a machine slotted PVC screen over the basal 3m of the monitoring pipe.
- 4 The deep bore at each site (suffix D) will be drilled to a depth of 30m and be constructed with 50mm PN 12 uPVC casing and a machine slotted PVC screen over the basal 6m of the monitoring pipe.
- 5 The shallow and deep bores should be separated by six to 10m to preclude loss of circulation.
- 6 A 50-mm bottom cap will be fitted to each monitoring pipe.
- 7 The annulus between the casing and the borehole wall should be gravel-packed with rounded 5 to 7mm gravel to 2m above the slotted interval.
- 8 An impermeable bentonite seal should be placed over a 2m interval above the gravel pack.
- 9 A cement grout seal should be placed in the annulus from the surface the top of the bentonite seal to prevent ingress of surface water and possible contaminants.

- 10 An accurate borehole log that records strata type, water intercepts, groundwater flow rates and standing water level should be kept.
- 11 Should groundwater supplies be encountered, the airlift yield, EC and pH of the water should be measured and recorded.
- 12 Monitoring bores should be developed using either compressed air or by surging with clean water until they discharge clear, sediment-free water.

Bore designs for the shallow and deep bores are shown below.

In addition to the above the drilling contractor will investigate the blockage in TD7 and provide advice on rehabilitating that bore if possible.

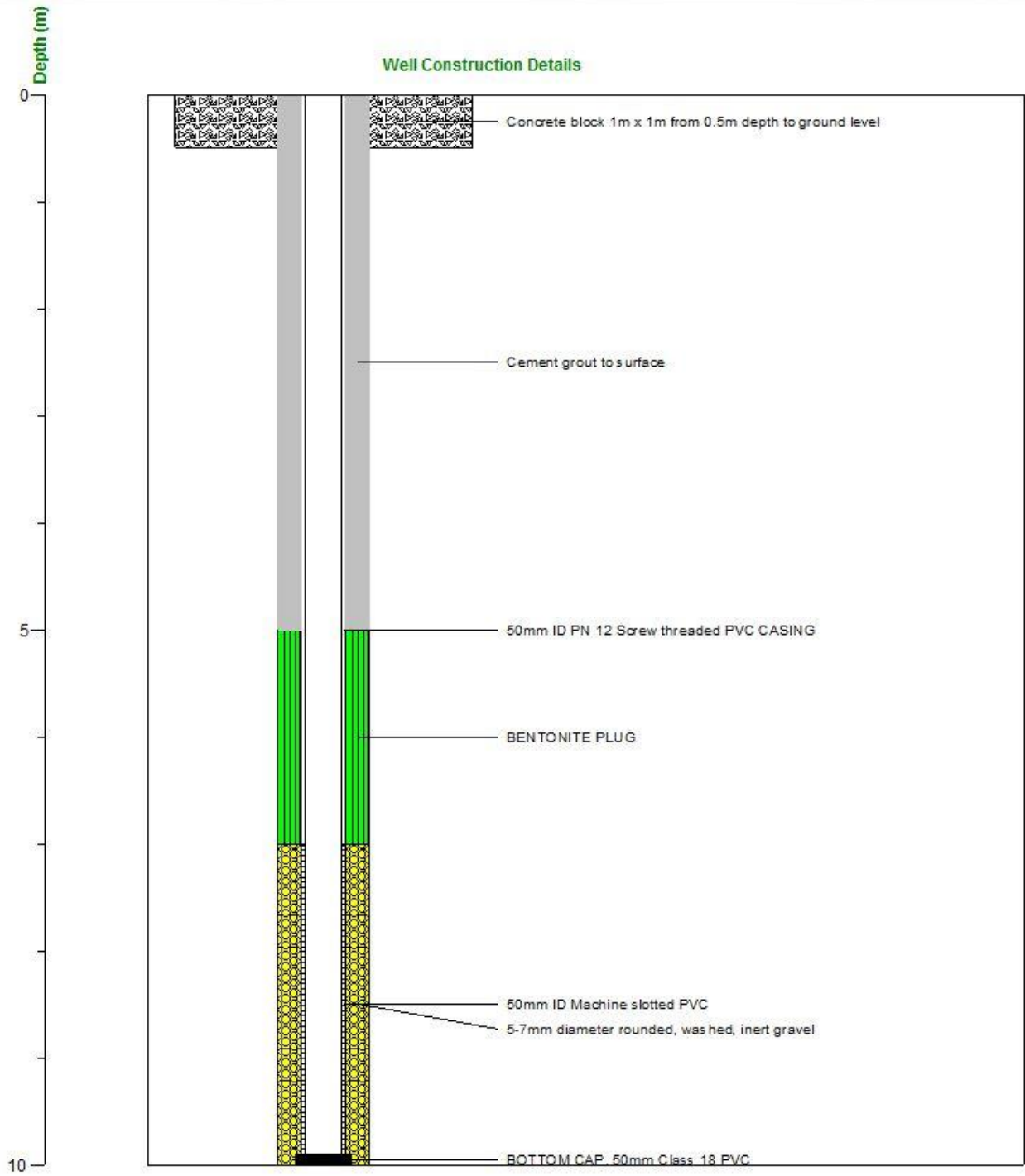
Borehole No: 10m Monitoring Bore

Client:

Location:
Easting:
Method:

Date Drilled:
Northing:
Driller:

Project No:
Elevation (m):
Drilling Rig:



Notes:

Datum:

General piezometer design
Depths for illustration purposes

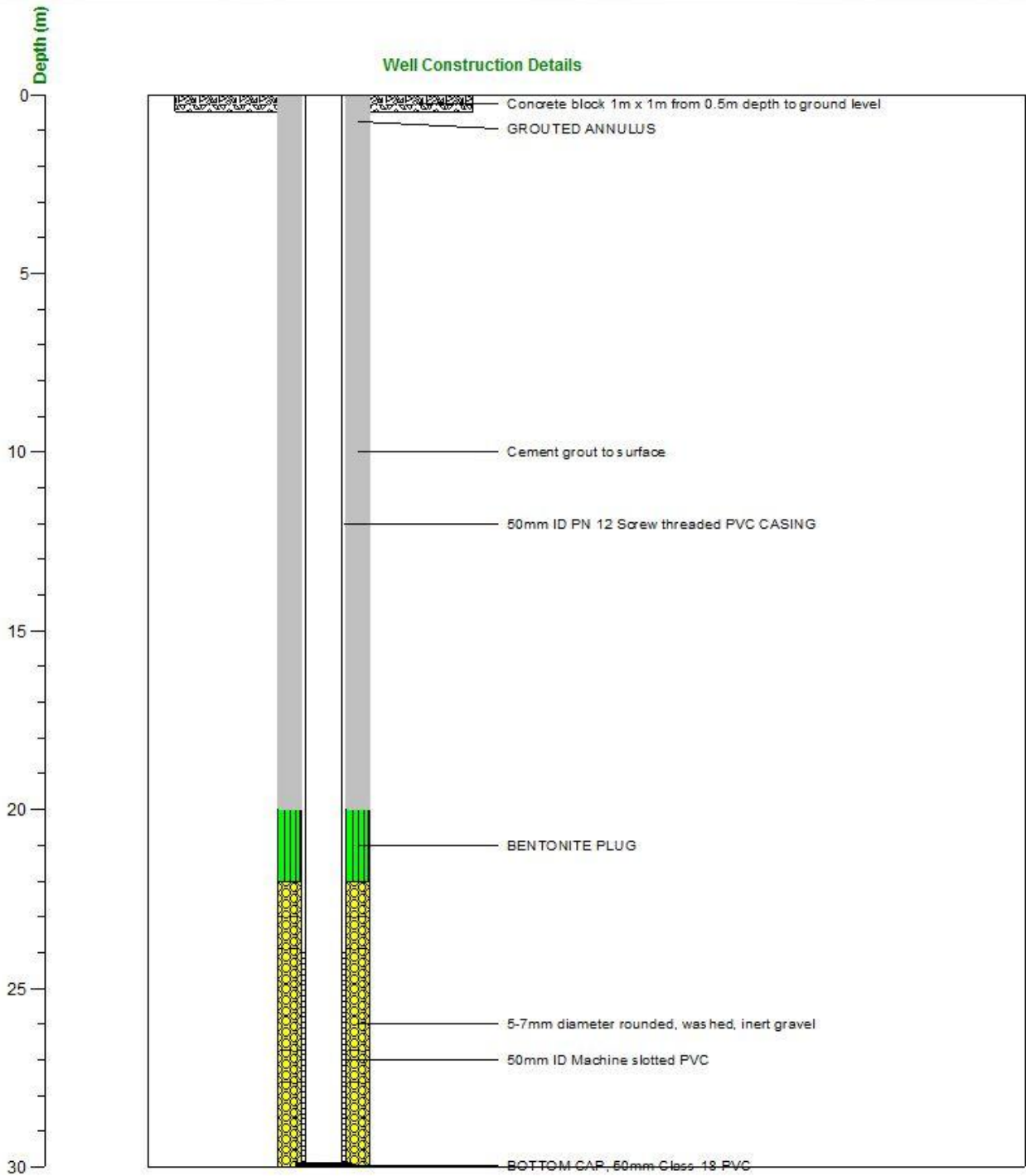
Borehole No: 30m Monitoring Bore

Client:

Location:
Easting:
Method:

Date Drilled:
Northing:
Driller:

Project No:
Elevation (m):
Drilling Rig:



Notes:

Datum:

General piezometer design
Depths for illustration purposes

ROSS MINING N.L.

YANDAN GOLD DEPOSIT
ENVIRONMENTAL MANAGEMENT
OVERVIEW STRATEGY

DECEMBER 1992

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APPENDICES

1. Department of Environment & Heritage Discharge Licence
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1.0

INTRODUCTION

The Yandan gold deposit is located 220 km south of Townsville and 230 km west of Mackay in Central Queensland (Figure 1). The nearest township of Mt. Coolon (population less than 20) is located 40 km to the east.

The site occupies three small hills at the confluence of the Suttor River and Yandan Creek. The Suttor River drains into Lake Dalrymple formed by the damming of the Burdekin River.

The deposit was discovered in 1986 by Western Mining Corporation Limited. An Impact Assessment Study was prepared for the project and this was accepted by the Department of Minerals and Energy. Mining Leases 1095 and 1096 were subsequently granted.

On the 10th July, 1992, Ross Mining N.L. completed the acquisition of the Yandan orebody, the Wirralie gold mine, a controlling interest in the Mt. Coolon joint venture, along with exploration tenements associated with all three assets. (Figure 2).

Ross Mining has made the decision to move the CIP plant from Wirralie to Yandan after completing the processing of stockpiled ore. The Yandan project will then serve as an operational base for Ross Mining to mine and process the Yandan orebody, rehabilitate the Wirralie site and to explore the tenements associated with Yandan, Wirralie and Mt. Coolon.

This EMOS has been prepared as part of the initial phase of development of the Yandan orebody. Under the development schedule mining will commence in June, 1993.

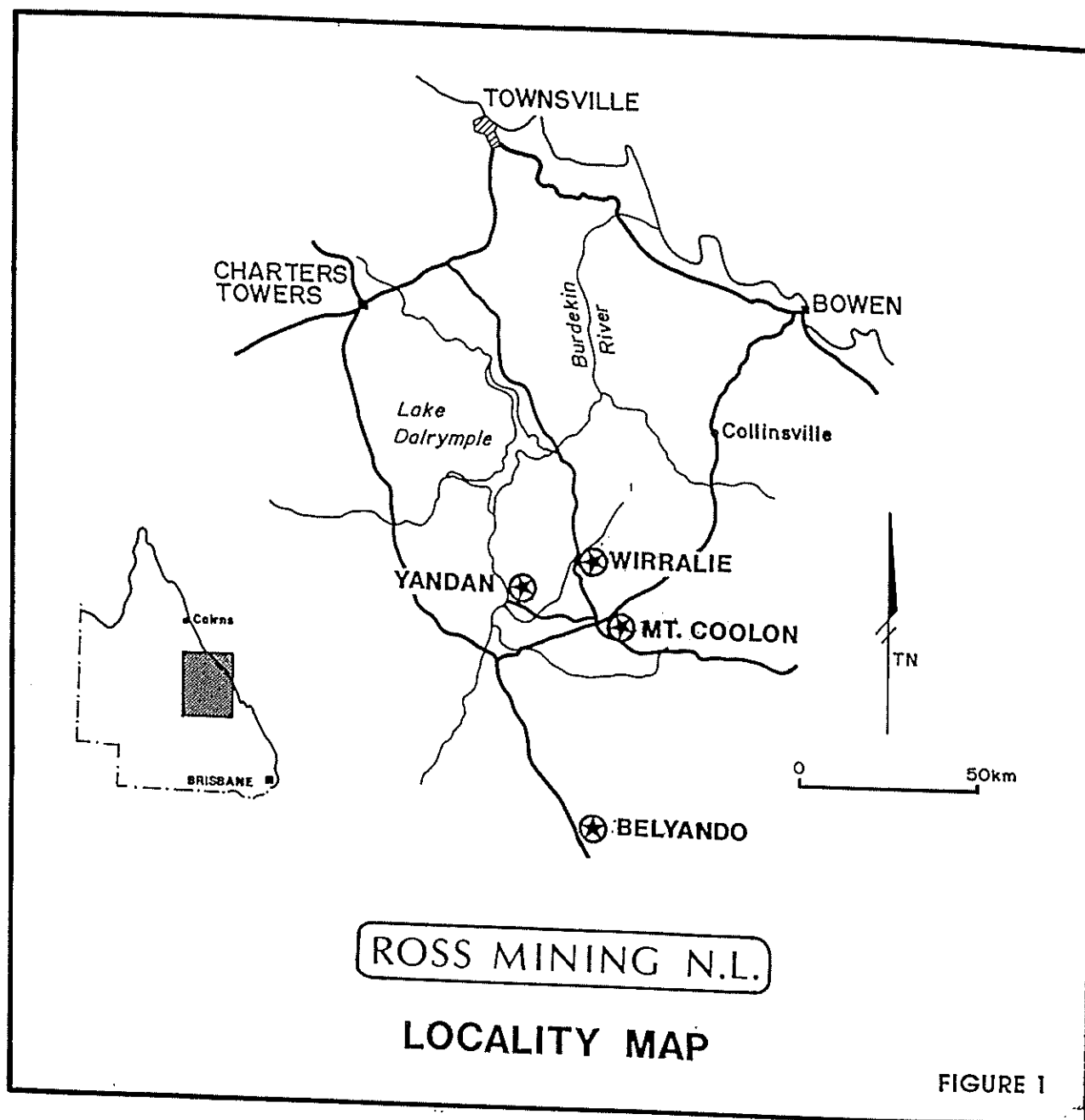
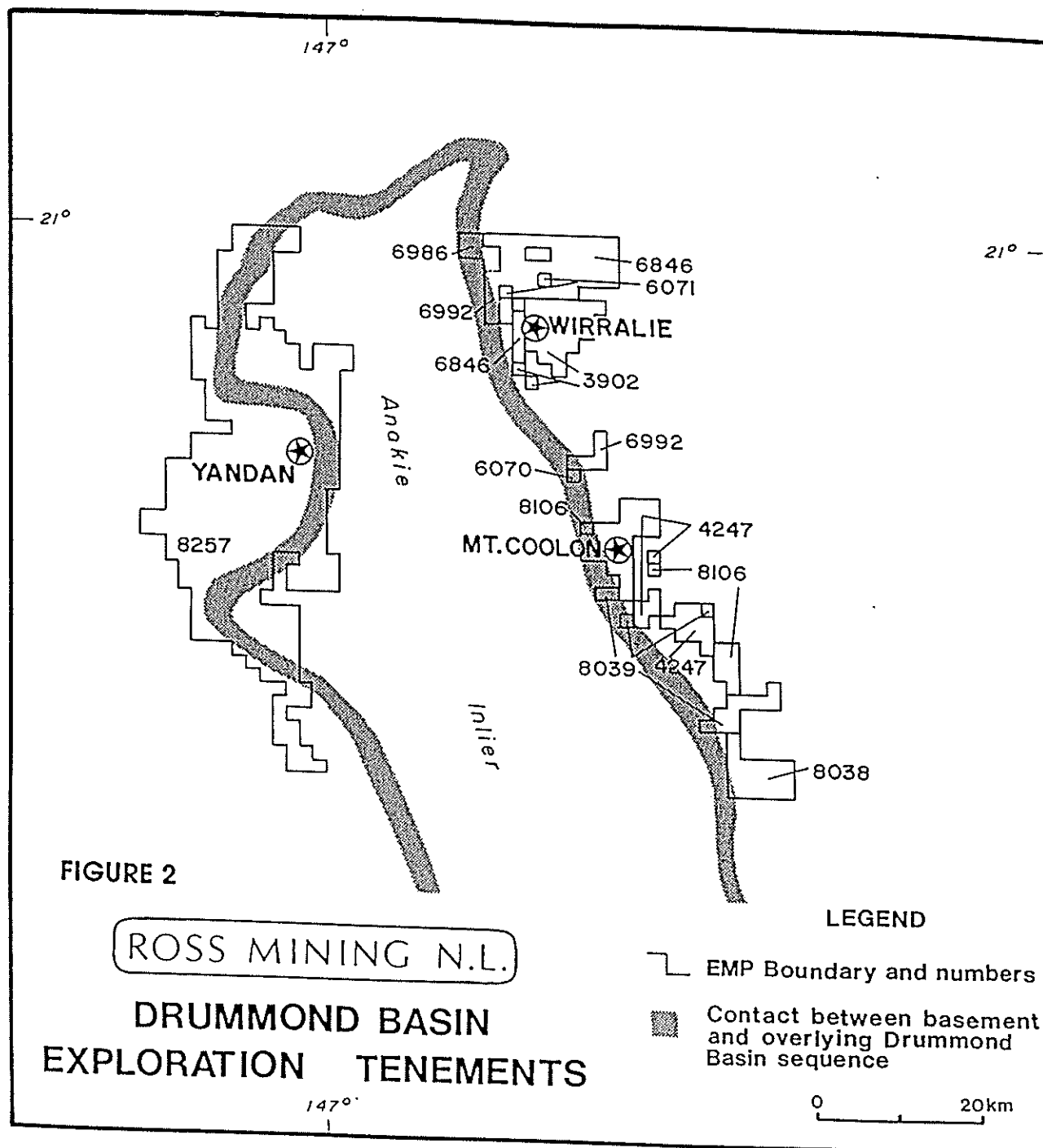


FIGURE 1



The Impact Assessment Study was used as the basis for developing the EMOS and variations from commitments made in the IAS due to changes in the development programme are explained. Further information, relevant to the tailings and groundwater management programmes, was taken from two reports supplied with the IAS. These reports are the "Geochemistry of Waste Rock, Ore and Tailings and Implications for Waste Management" by Stuart Miller and Associates and "Groundwater Dewatering Study" by C.F. Forbes.

This EMOS conforms with the Special Conditions of grant of Mining Leases (M.L.'s) 1095 and 1096, the Land Compensation Agreement with the pastoral leaseholder and the Department of Environmental and Heritage licence 915 regarding discharge of excess water.

2.0 PROJECT DESCRIPTION

The basic mining and processing operation is described in the IAS with significant changes to the operation as follows:

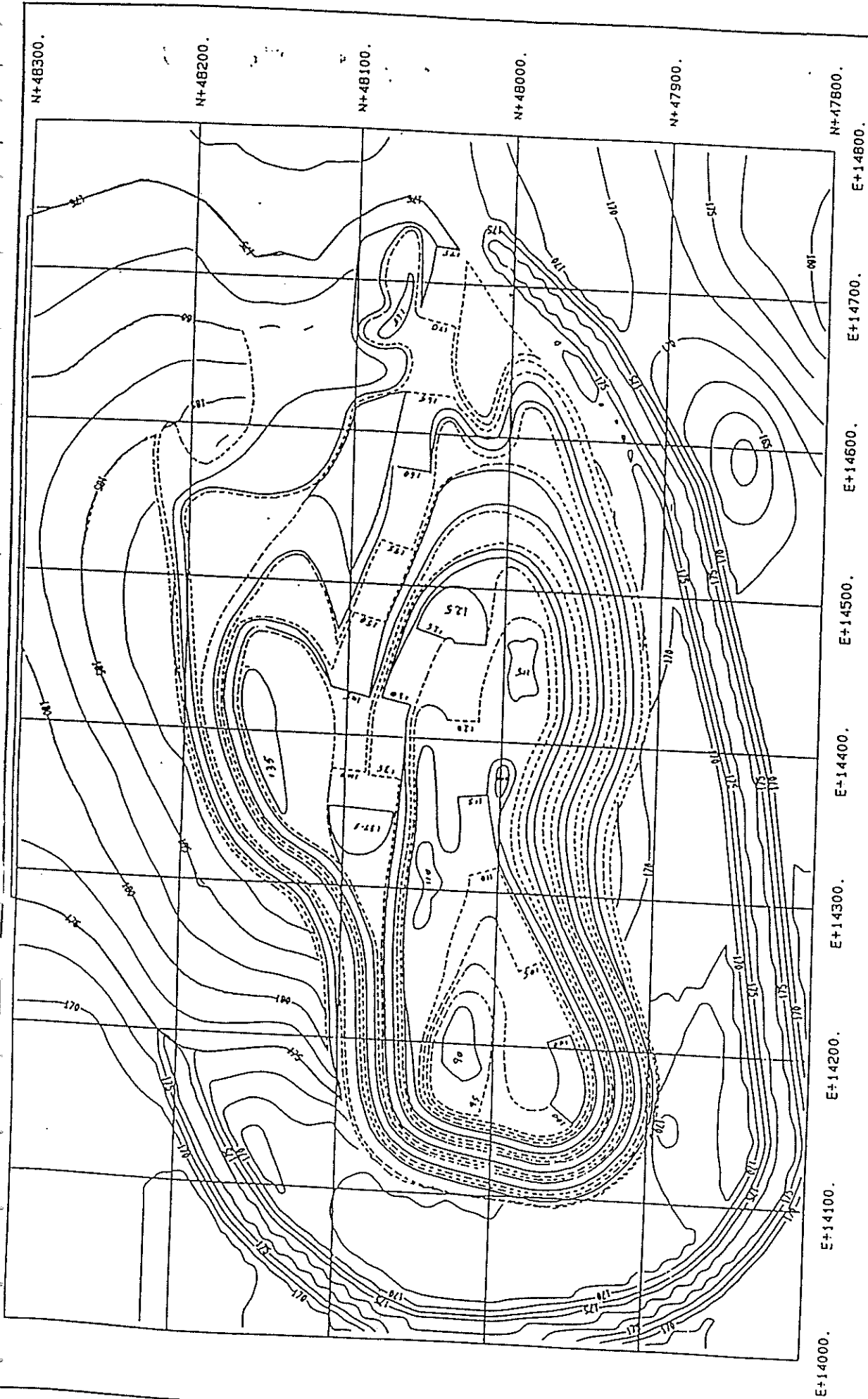
- The ore will be extracted over a 5 year life rather than 2.5 years.
- Low grade ore will be prepared and stored on a plastic lined pad for future leaching.
- The tailings management will divide the tailings area into two compartments and utilise the seepage pond as a decant pond.
- Tailings management will utilise the compartments to minimise the area affected by primary tailings during the later stages of the project.

2.1 Mining

The orebody will be mined using open cut mining methods. The pit design layout is presented in Figure 3. Overall pit slopes will vary between 40-53 degrees and bench heights from 5-20 metres vertically. The depth of the pit ranges from RL195 to RL110.

The groundwater in the area is moderately saline (TDS range 4000-15000 mg/L) and will be encountered by the pit at approximately RL158. Under the revised mining plan the pit will be dewatering at a reduced rate over the 5 year mining operation to manage the underground supply and minimise the quantity of excess water for containment.

The pit development may be subject to flooding from the Suttor River and a minimum height of RL178m has been selected for flood protection after analyses of major floods



Snowden Associates Pty. Ltd.
P.O. Box 77
41 Ord Street
West Perth, W.A. 6005

DATE: 09/04/92 TIME: 07:31:19

SCALE (HORIZ): 1:2500 SCALE (VERT): 1:2500

Drawn by: B. G. G. Services Inc.

ROSS MINING N.L. YANDAN GOLD PROJECT

FINAL PIT

SHOWING 176mRL BUND FOR FLOOD PROTECTION

Figure 3

of the Suttor River and allowing for a 5 metre increase in height of the Lake Dalrymple dam wall sometime in the future. A bund will be constructed at RL178 around the exposed end of the pit (Figure 4). This bund will not be required until the 1st of November 1994.

The revised mining and production schedule is presented in Table 1. The CIL ore will be trucked to the crusher stockpile for processing while the low grade ore will be stored on a prepared plastic lined pad for future dump leaching (Figure 4).

Waste from the mining operation will be transported to the waste dump site (Figure 4) and selectively dumped. The oxide waste will be placed in two arms of the dump so as to leave a wedge between the arms which will be filled with primary waste when produced. The volume of waste produced has increased from 1.22 Mm³ (IAS 2.3) to 1.784 Mm³ (Table 1) mostly due to the extraction of the low grade ore for dump leaching.

During 1994 approximately 150,000 m³ of the oxide waste will be required to build the flood protection bund around the western end of the pit.

Table 1 Mining and Production Schedule

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
CIP + ROM						
CIL ore Tonnes (000's)	1000	1000	1000	1000	959	4959
Low grade ore Tonnes (000's)	317	520	681	660	702	2880
Waste BCM (000's)	124	208	408	563	461	1784

2.2 Ore Processing

From a re-evaluation of the reserves the ore production suitable for the CIL process has increased from 3,862,488 (IAS Table 2.1) to 4,959,000t (Table 1). By introducing the dump leach process option a further 2,880,000t of low grade ore can be treated thus fully utilising the ore resource.

2.2.1 CIL Ore

The ore, after lime addition, will be ground via a semi-autogenous mill and a ball mill to produce a leach feed slurry of 45% solids with 80% of the slurry particle size less than 75 microns.

The slurry will be added to leach tanks where cyanide leaches gold from the ore. The slurry then passes to the adsorption tanks where gold in solution is adsorbed onto carbon.

After recovery from the tanks the gold loaded carbon is then washed with 3% hydrochloric acid to remove clay and ore fines to make the carbon more amenable to gold elution.

The carbon is stripped of the gold in the elution column, then reports to electrowinning cells where the gold is plated onto steel wool cathodes. The steel is acid treated, dried and smelted with various additives (fluxes) to produce dore.

2.2.2 Low Grade Ore

The low grade ore will be trucked to the low grade stockpile area directly from the pit and treated with lime before being stored on a plastic lined pad for future dump leaching (Figure 4). Initially a silt collection pond will be constructed to treat runoff from this stockpile and will be upgraded to a cyanide refractory dam prior to the leaching programme commencing. There is sufficient area between the leach pad and the silt collection pond to install the necessary liquor ponds associated with the leaching process.

The dump leaching programme will not be included in this EMOS but will be the subject of a variation at the appropriate time. However preliminary indications are that the dump leach option will be operational within eighteen months of commencement of CIL processing.

2.3 Waste Disposal

The waste will consist of waste rock and saline groundwater from the pit, tailings from the CIP process and the leached ore from the dump leach programme when installed.

2.3.1 Pit Waste

The pit waste will comprise approximately 1.59 Mm³ of oxide waste and 0.18 Mm³ of primary waste and altered andesite. Geotechnical test work has shown the oxide waste to be non acid forming and the fresh altered andesite to be acid forming. Tests were not carried out on the

primary waste with a sulphur level greater than 0.5% and it is thought that this material is potentially acid forming. (See report by Stuart Miller and Associates).

It is proposed to test the acid potential of this primary waste in the first half of 1993 to allow an accurate dumping schedule to be developed which will determine the size and structure of the waste dump. The testing will also develop a visual rating criteria which will allow pit supervisors to selectively place material (see section 4.4).

2.3.2 Groundwater

The schedule of mining proposed in the IAS required that the pit be dewatered at a rate of 5MI/day for the duration of the mining operation of 2.5 years. The groundwater investigation that established this rate also concluded that the pit could be dewatered over a 4 year period at lower rate of 4.6MI/day.

The present mining proposal of 5 years duration does not require access to the benches below the water table until 18 months after the start of mining operations so a lower, continuous, dewatering rate is feasible.

The management of the groundwater is discussed in Section 3.3.

The groundwater will have a total dissolved solids (TDS) range of 4000-15000 mg/l with individual bores differing in quality. The sulphate levels range from 440 to 1700 mg/l which could cause problems for stock at the higher levels.

2.3.3 Tailings

Approximately 5 million dry tonnes of tailings are to be deposited in the tailings dam at an estimated density of 1.1

t/m³. This low density is indicative of the low ore SG of 1.91.

The chemical composition of the tailings is determined by the composition of the ore and the chemicals added during processing. In the short term the cyanide and lime added to the process will have the major impact on the geochemistry of the tailings while in the long term the geochemical characteristics of the ore becomes important.

The tailings samples tested were of composite oxide ore and were non acid forming. The primary ore that will be mined in the later stages of the pit is potentially acid forming and will be assessed for net acid producing potential during the initial mining phase (see section 4.4). The proportion of primary ore increases with depth and represents less than 15% of the total ore.

The tailings management programme has been developed to accommodate possible acid producing tailings during the later stages of the milling operation.

The tailings have an initial permeability of 10^{-7} m/s and with consolidation this will decrease to at least 10^{-8} m/s.

The geochemical test work suggest that the tailings liquor when it enters the dam will contain 35-40 mg/L of moderate and weak cyanide complex (Cu, Zn and Ni), 100-150 mg/L of free cyanide and will have a pH of 10.5-11.0.

The geochemistry test work show that the rate of cyanide decay is 150-200 hours of exposure for free cyanide and 40-50 days for residual cyanide to reduce the total cyanide concentration to 10mg/L. However, the test work was done on a composite ore sample which contained some ore from outside the current pit limit. This ore contained a higher Cu concentration and therefore elevated the level of copper

cyanide complexes. Analyses of the ore from the pit confirm that the copper levels are low (5.35mg/kg range) and it is therefore expected that the level of copper cyanide complexes will be far lower than observed in the test.

Thus the 40-50 days to reduce the residual cyanide is considered to be the worst case and further work will be carried out on both types of ore from the pit to confirm the suspected lower levels of copper cyanide. Similar tests carried out on tailings decant from other operations indicate that 10mg/L residual cyanide can be achieved in only 7 to 10 days.

A compounding factor which contributed to the slow rate of decay of residual (complexed) cyanide was the level of dissolved salts. The two tailings samples were prepared with either demineralised water to simulate surface water or a salt prepared water to simulate bore water. The electrical conductivity (EC) of the surface water tailings was 1.74 mS/cm compared with 6.03mS/cm for the bore water tailings.

The high salt level in the bore water tailings caused the formation of a scum on the surface of the tailings liquor which could have affected volatilisation of cyanide from the solution. A scum formed on the surface water sample but was significantly weaker and easily broke up.

With the bore water tailings a total exposure time of at least 50 days was required to reduce the residual cyanide to 2-mg/l whereas with the surface water tailings this residual was achieved within 10-12 days. The quality of the process water will be addressed in the overall water management programme as the dewatering bores will have a range of quality and some selection may be possible to separate the water on TDS for either process water or for discharge.

2.3.4 Dump Leach

An estimated total of 2,880,000t of low grade material will be loaded onto the leach pad over the life of the mine. Approximately 10% will be primary ore which will have some acid producing potential.

3.0 MANAGEMENT PROGRAMMES

The following programmes have been developed to minimise the environmental effects of the project.

3.1 Tailings Management

The tailings deposition programme will aim to deposit the tailings in such a way as to promote the following:

- (a) the decay of both free and complexed cyanide
 - (b) maximise the deposition density
 - (c) minimise surface area of potential acid tailings
 - (d) a final land surface easily rehabilitated
-
- (a) The rate of cyanide decay will be maximised by sub-aerially beaching the tailings and ensuring the longest possible exposure period. This will be achieved by decanting the excess water from the tailings and maintaining the decant pond as low as possible.
 - (b) The sub-aerial technique maximises the potential for co-deposition of the coarse and fine fractions thus achieving a uniform settled density over the majority of the final surface. This uniform density ensures the most efficient use of the storage capacity and the ready access onto the final surface for rehabilitation. Past experience has shown that the free water in the deposition area must be kept as low as possible to ensure the development of long sub-aerial beaches.

If water encroaches onto the deposition zone the tailings are deposited sub-aqueously, resulting in rapid deposition of the coarse material while the fine clays are deposited under water at very low density. It is then virtually impossible to cover these low density

clays with further depositions of coarse material as the clays are displaced by the coarse fraction.

- (c) The geotechnical tests show that the primary ore that will be mined and milled late in the project life could be acid producing and, if so, would have to be covered with inert waste rock during the rehabilitation. This ore will be more fully investigated and provision made to restrict the area to be used for the deposition of this material.
- (d) The correct deposition procedure will ensure maximum settled density of the tailings and the sequence of deposition sites will ensure that the final surface of the tailings can be drained to a suitable outlet. This will ensure that the rehabilitated surface of the tailings is free draining.

A tailings management programme has been designed to ensure the above criteria are met.

3.1.1 Tailings System

3.1.1.1 Pipeline

Tailings slurry will be pumped to the disposal site located approximately 3.0 km from the plant site and 3.5 km from the Suttor River (Figure 4). The tailings pipeline route will be bunded to ensure spillage from pipeline failures are contained or flow back to the No.1 mine water pond. The pipeline will be located so as not to interfere with the natural runoff which could pipe through the bund walls. The upslope bund will also be protected by graded banks to run water away from the bund. The graded banks will be designed for a 1 in 20 year event.

3.1.1.2 Disposal Site

The disposal site is above RL180 AHD, the level below which the area is subject to inundation from the proposed Stage 2 of the Burdekin Dam. The present design allows for up to 5 million dry tonnes of tailings to be stored at an estimated density of 1.1t/m³.

The site, which covers 100 hectares, can store a much larger column by raising the walls and constructing bunds where necessary. This will allow for the containment of tailings from other projects, (such as Mt. Coolon), which may be milled at Yandan in the future.

The site also has the benefit of allowing the catchment to be limited to the final tailings surface by the construction of bunds. This is an important consideration when making provision for the Mandatory Reporting Level especially when the site is reaching capacity.

In the Impact Assessment Study a single deposition site coupled with a downstream seepage pond was proposed. From experience at the Wirralie mine it is difficult to ensure sub-aerial deposition of tailings after periods of excessive rain if there is no storage facility to allow the decant pond to be lowered.

To ensure sub-aerial storage is always available at Yandan the storage site has been divided into two compartments with a downstream return water pond (the previously proposed seepage pond). The decant level in the active deposition compartment can be kept as low as possible to ensure sub-aerial deposition by pumping water to the non-active compartment or to the return water pond. The wall separating the two compartments will act as an access to the decant towers. The tailings dam and the decant pond have been sized to contain an annual rainfall with an annual

exceedence probability (AEP) of 1 in 100 years. The spillway capacity for cyanide containing structures has been designed for an ARI of 1 in 100 years. Other dams have a spillway capacity for an ARI of 1 in 50 years.

The cyanide guidelines require sufficient storage capacity to be available at 1st November each year to contain the Design Storage Allowance (DSA). The DSA for the site is 3 months cumulative rainfall (losses ignored) plus process inputs.

Note: Nominated 72 hour event is not used for calculation of the DSA but determines Mandatory Report Level for system.

The tailings/return water pond system will provide the DSA for mine life assuming deposited tailings density of 1.1t/m^3 is achieved.

The wall of the return water pond and the wall between the decant pond and the tailings compartment A are both to be licensed as referable structures.

If necessary a small seepage collection pond is to be established downstream from the return water dam. The installation of this pond will depend on the ground conditions encountered when the keyway for the decant pond wall is excavated and monitoring of the water bores, installed below the dam wall, for water flow.

The location and layout of the storage is shown on Figure 4 and the cumulative storage tables and volume-area graphs for the compartments and the return water pond are presented in Figures 5-8.

3.1.1.3 Deposition Sequence

Initially the discharge pipeline will be laid around the compartments at approximately RL187 and the slurry discharged through spigots. The excess water will flow to the decant tower from where it will be pumped to the return water pond. The return water pond will act as a settling pond to partially remove suspended clays before the water is pumped to the processing plant.

The spigot points will be rotated around the perimeter but not along the dividing wall to ensure that the water flow is towards the decant tower. Once a tailings beach has been developed in a semi-circle around the decant tower the discharge will be shifted to the next compartment. Water will continue to be pumped from the tailings area to maximise the drying area while deposition continues in the second compartment.

Both compartments will be progressively filled and dried until the discharge line and spigots are relocated to the outer perimeter of the compartments. The same procedure will be repeated until the compartments are full.

3.1.1.4 Disposal Timing

(a) Cyanide Decay

The following table lists the exposure time for drying and cyanide decay that will occur for the various levels in each compartment.

TAILINGS STORAGE AREA 'A'			
CATCHMENT AREA : 395 100 s.q.m.			
R.L. m.	AREA s.q.m.	VOLUME cu.m.	CUMULATIVE VOLUME cu.m.
180	13 600	0	0
182	51 200	64 800	64 800
184	121 400	172 600	237 400
186	210 900	332 300	569 700
188	298 600	509 500	1 079 200
190	358 100	656 700	1 735 900
191	393 800	375 950	2 111 850

TAILINGS STORAGE AREA 'B'			
CATCHMENT AREA : 646 400 s.q.m.			
R.L. m.	AREA s.q.m.	VOLUME cu.m.	CUMULATIVE VOLUME cu.m.
1823	0	0	0
184	55 500	47 200	47 200
186	169 100	224 600	271 800
188	358 800	527 900	799 700
190	501 600	860 400	1 660 100
191	589 400	545 500	2 205 600

SEEPAGE POND			
CATCHMENT AREA : 226 700 s.q.m.			
R.L. m.	AREA s.q.m.	VOLUME cu.m.	CUMULATIVE VOLUME cu.m.
176	3300	0	0
178	17900	21200	21200
180	50600	68500	89700
182	95300	145900	235600
184	136900	232200	467800
184.7	152900	289800	757600

FRASER-OSBORN (QLD) PTY. LTD.

CONSULTING ENGINEERS

ACH 010 618 207

P.O. BOX 1124
TOWNSVILLE QLD. 4850

Client

ROSS MINING N.L.

Project

**WIRRALIE TO YANDAN
PLANT RELOCATION**

Designed

Drawn

Checked

Approved

Initial

Date

Scale

Job No. RMN 1400

Drawing No.

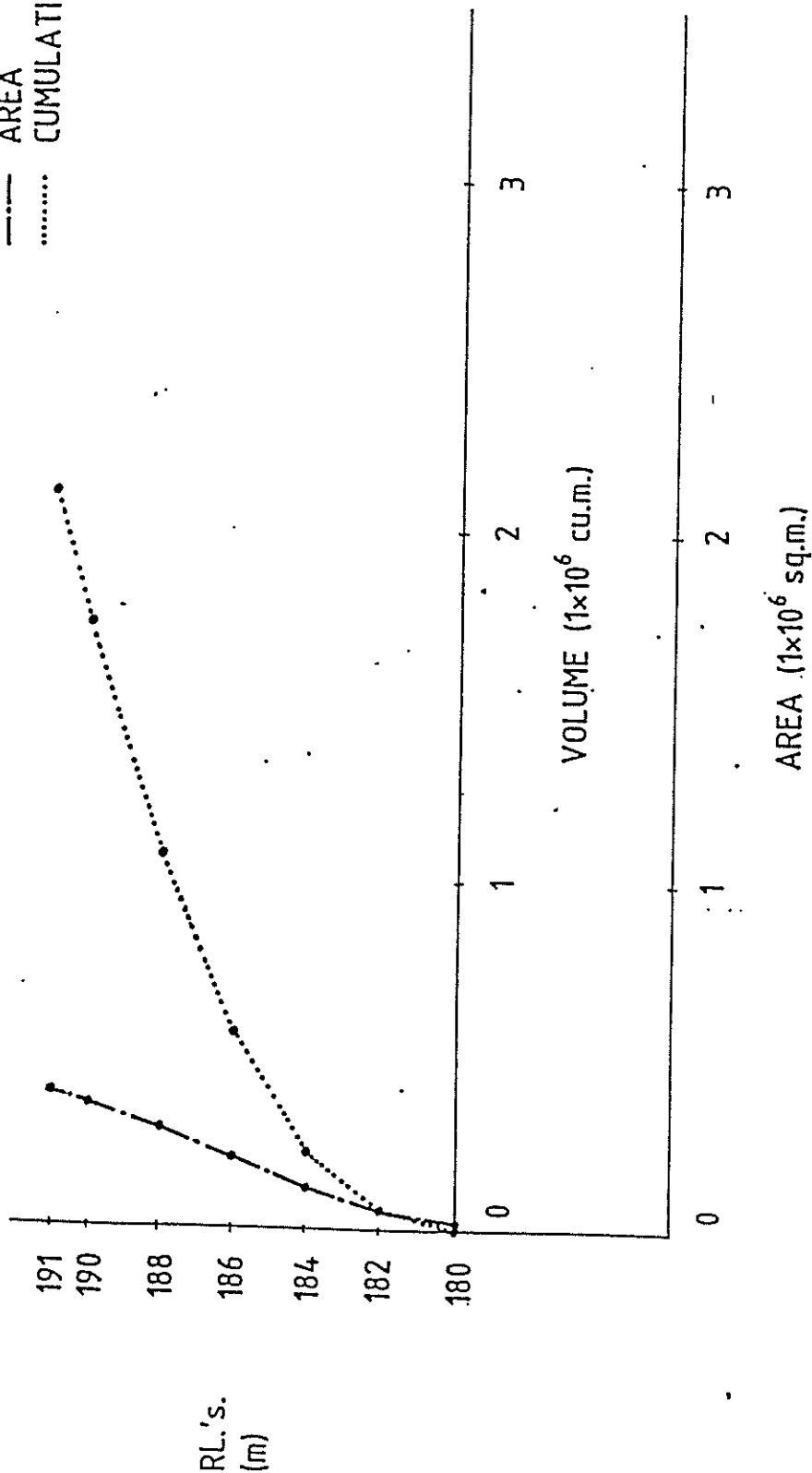
Figuré 5

Rev.

A

LEGEND

- AREA
- CUMULATIVE VOLUME



TAILINGS STORAGE AREA 'A'

FRASER OSBORN (QLD) PTY. LTD.

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Client

ROSS. MINING N.L.

Project WIRRALLIE TO YANDAN
PLANT RELOCATION

Designed

Drawn

Checked

Approved

Scale

Job No.

RMN 1400

Drawing No.

Figure 6

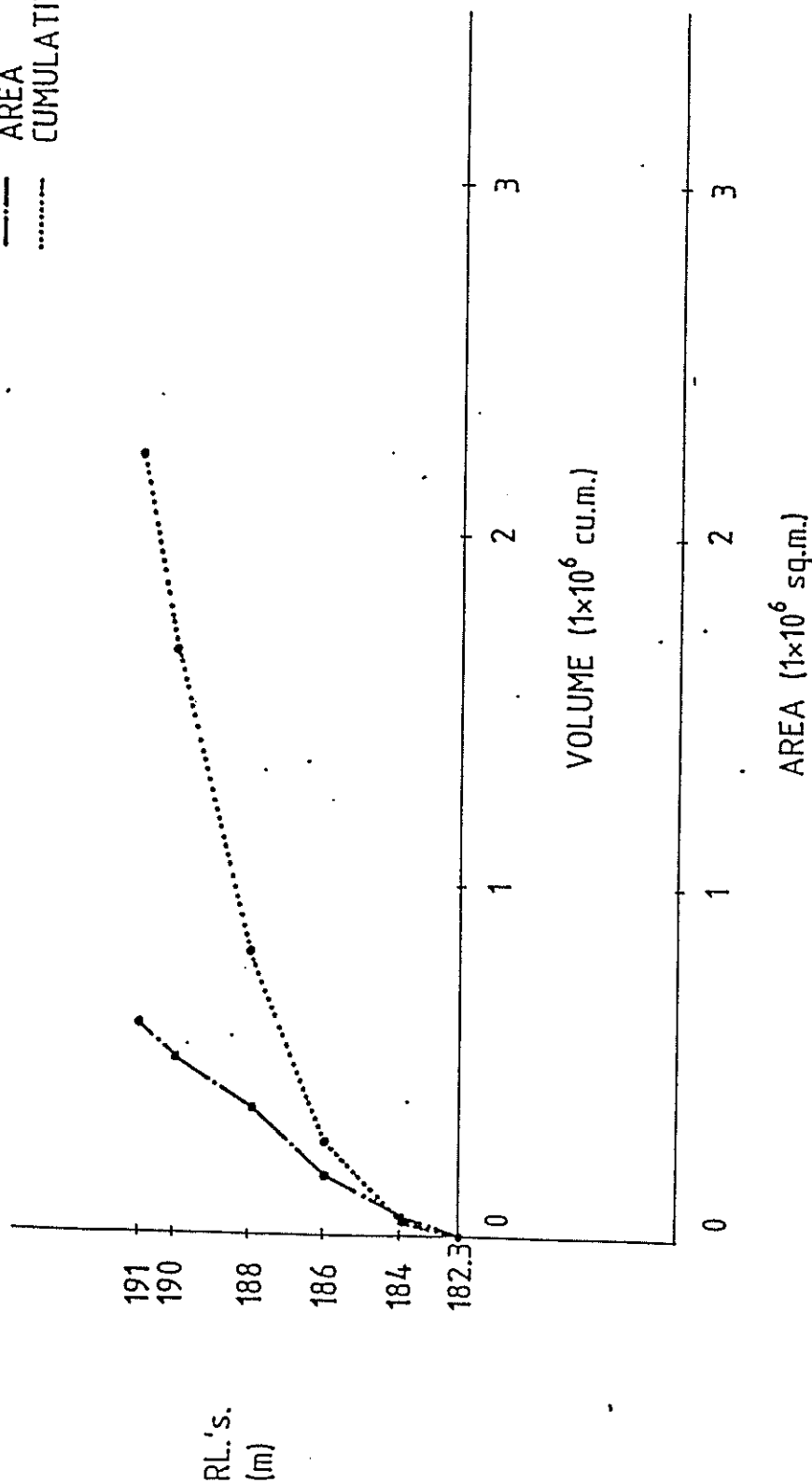
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LEGEND

- AREA
- CUMULATIVE VOLUME



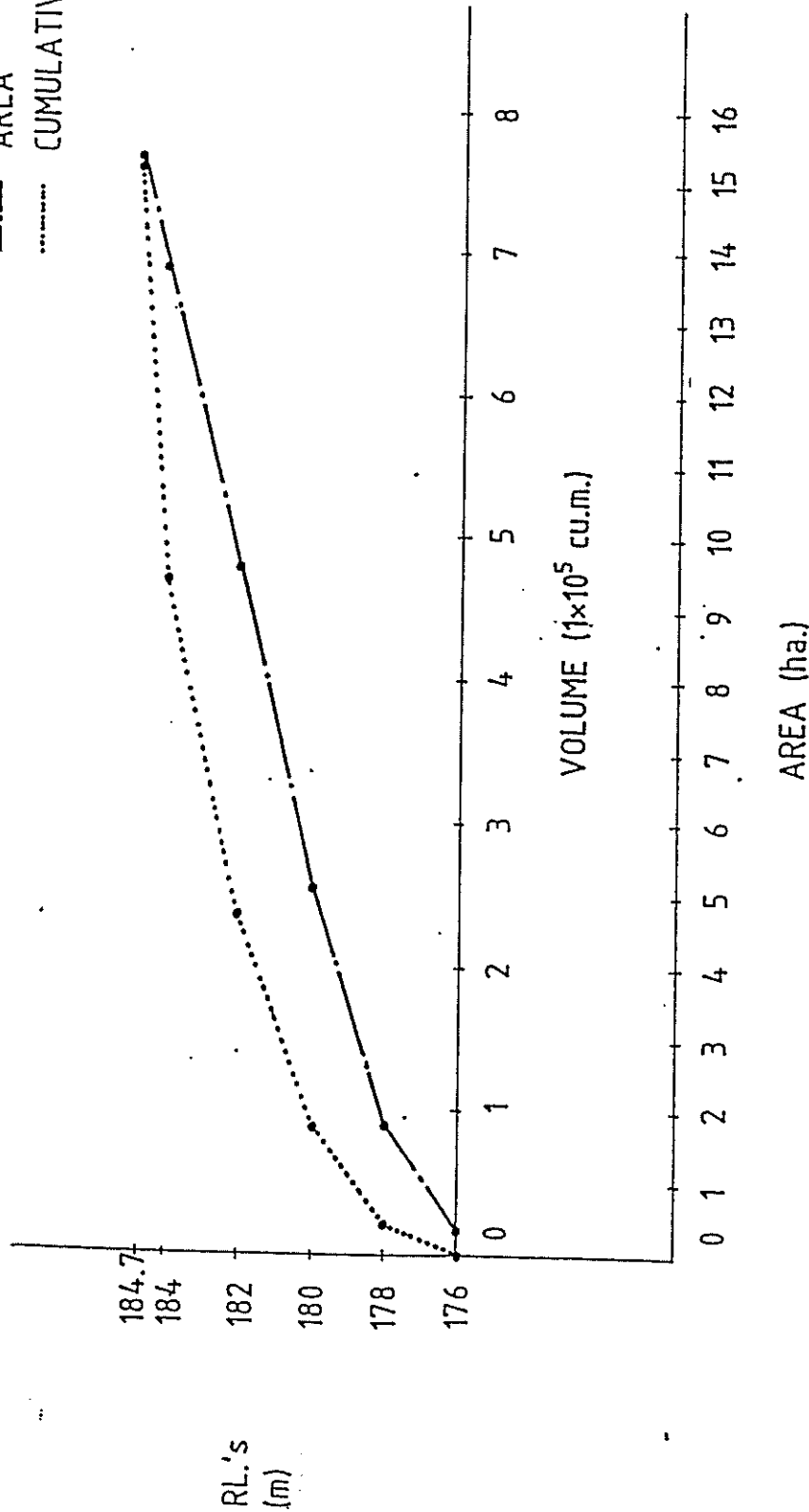
TAILINGS STORAGE AREA 'B'

FRASER OSBORN (QLD) PTY. LTD. CONSULTING ENGINEERS ACN 019 614 207 P.O. BOX 1224 TOWNSVILLE QLD. 4850		Client ROSS MINING N.L. Project WIRRALLIE TO YANDAN PLANT RELOCATION		Job No. RMN 1400 Drawing No. Figure 7 Rev. A	
(077) 727071 FAX (077) 211160		Designed Drawn Checked Approved Initial Date		Scale	

LEGEND

— AREA

..... CUMULATIVE VOLUME



SEEPAGE POND

FRASER OSBORN (QLD) PTY. LTD.		Client		ROSS MINING N.L.		Job No.		RMN 1400	
CONSULTING ENGINEERS		Project		WIRRALLIE TO YANDAN PLANT RELOCATION		Drawing No.		Figure 8	
PO BOX 1124 TOWNSVILLE QLD 4830		Initial		Date		Rev.		A	
FAX (077) 211100		Scale							

Table 2 Days Available for Drying

RL	Compartment A	Compartment B	A + B
188	20.5	21.3	41.8
190	26.4	34.5	60.9
191	30.2	43.8	74.0

The minimum drying times will occur in the first two years of operation when the surface area of the tailings is at a minimum. The extreme event of 942mm of rain received at the Wirralie mine during December 1990 to February 1991 (AEP 1 in 140 years) has been used to calculate minimum drying times. After this event one compartment would be required for water storage in addition to the return water pond. Deposition of tailings would be limited to one compartment for four months thus reducing drying time to that available at the particular RL in the compartment to be used for deposition.

The worst case of residual cyanide levels of 35-60 mg/l in the geochemical testing programme required an exposure period of 40-50 days which cannot be provided during this extreme event except in compartment B at RL191. However it is expected that the residual cyanide concentration will be much lower especially in the initial stages when the ore from the top 25 metres of the pit has lower copper levels.

(b) Sub-aerial Deposition

As a result of the above extreme rainfall event at Wirralie the tailings were deposited sub-aqueously in the Wirralie tailings dam. The fine clay fraction was deposited in the centre of the dam resulting in a large area of the final surface that will require an extended drying period before it can support traffic to carry out rehabilitation.

The decant pond at Wirralie would not be lowered as there was no available storage where for the excess decant water could be discharged.

The two compartment system proposed at Yandan will ensure that the co-deposition of fine and coarse tailings fractions can be achieved even after extreme rainfall events (AEP .01) as at least one of the compartments can be sufficiently dewatered to allow sub-aerial deposition of tailings.

3.1.1.5 Deposition of Potentially Acid Material

If further geochemical testing shows that the primary ore with a sulphur content greater than 0.5% is potentially acid forming, provision can be made later in the project life, to deposit the tailings from this ore in one compartment. This will minimise the surface area of potentially acid tailings that may need capping with inert material.

Primary waste with a sulphur content less than 0.5% was found to be non acid forming. (See report from Stuart Miller and Associates)

3.1.1.6 Rehabilitation

(a) Permanent Dam Slopes

The dam walls will be designed and constructed in accordance with the Australian National Committee on Large Dams (ANCOLD) Guidelines on Referable Dams.

The outer slopes of the walls will be constructed to a 1 in 3 grade and rock mulched with 500 mm of oxide waste rock. The waste will be selected to maximise the content of coarse, competent silica altered sandstone. The maximum slope length will be 36 metres with average length of 15 metres.

A layer of 150 mm of freshly stripped topsoil will be spread over the rock and incorporated into the top 200 mm by ripping. The area will then be seeded and fertilised. See criteria for successful rehabilitation 4.6.

(b) Tailings Surface

The tailings deposition will be managed so that the final surface of both compartments will slope to the decant towers. Once deposition has been completed a waterway will be established along the length of the partition wall to connect the decant area with the spillway of the tailings compartments. The spillway may need to be excavated so that runoff from the tailings can freely drain into the return water pond, thus keeping the tailings dry. The spillway excavation will be rock lined as will the waterway from the spillway to the return water pond.

The geochemical nature of the tailings on the surface will determine the surface covering. Non acid producing surfaces (i.e. less than 0.5% sulphur) will be covered with approximately 150 mm of the topsoil originally collected from the site. It is expected that the oxide tailings will act as a suitable subsoil and sustain plant growth. The suitability of this material for plant growth will be checked by pot trials that will be carried out in the first year of the mining programme. The results of the pot trials will determine if a capping of oxide waste is required as a substrate to the topsoil. This capping will be applied after further pot trials to determine capping depth.

The topsoil will initially be placed around the perimeter of the compartment and then progressively towards the centre as the surface dries and consolidates. An

area around the decant may remain too soft for access and will be consolidated with oxide waste.

Potentially acid producing surface material will be covered with oxide waste before topsoil is spread. The depth of the oxide cover will be determined after further geochemical test work on the primary ore. The result of this testwork will be used as the required depth of oxide cover to cap the sulphide tailings during rehabilitation. The rehabilitation programme in the IAS involved spreading a one metre layer of rock over the entire tailings area which was then to be covered with up to 0.75 metres of clay and topsoil.

This depth and composition of cover would only be necessary for extremely acid tailings. The data from the geochemical testing programme does not justify such a cover. Also it is doubtful if sufficient non acid producing waste rock would be available for a one metre layer over 100 hectares (1,000,000 m³) as the total waste for that pit was 1,220,000 m³ of which 150,000 m³ was to be used in constructing the flood bund. Also 10% of the waste would be potentially acid producing. If, after further geochemical testing, the capping depth requires material in excess of the projected quantity of oxide waste, further oxide material will be taken from suitable barren areas.

As topsoil is spread on either the tailings or the oxide waste it will be lightly ripped into the surface and seeded with a mixture of native grasses and tree seeds. A nitrogen and phosphorous fertiliser will be applied at a rate determined by the pot trials.

For calculation of security a depth of 100 mm of oxide waste will be placed over the oxide tailings and

500 mm over the sulphide tailings. When these capping thicknesses are finalised an amendment to the EMOS will be sought.

(c) Return Water Pond

This dam will function as a runoff storage pond while the tailings compartments are being rehabilitated.

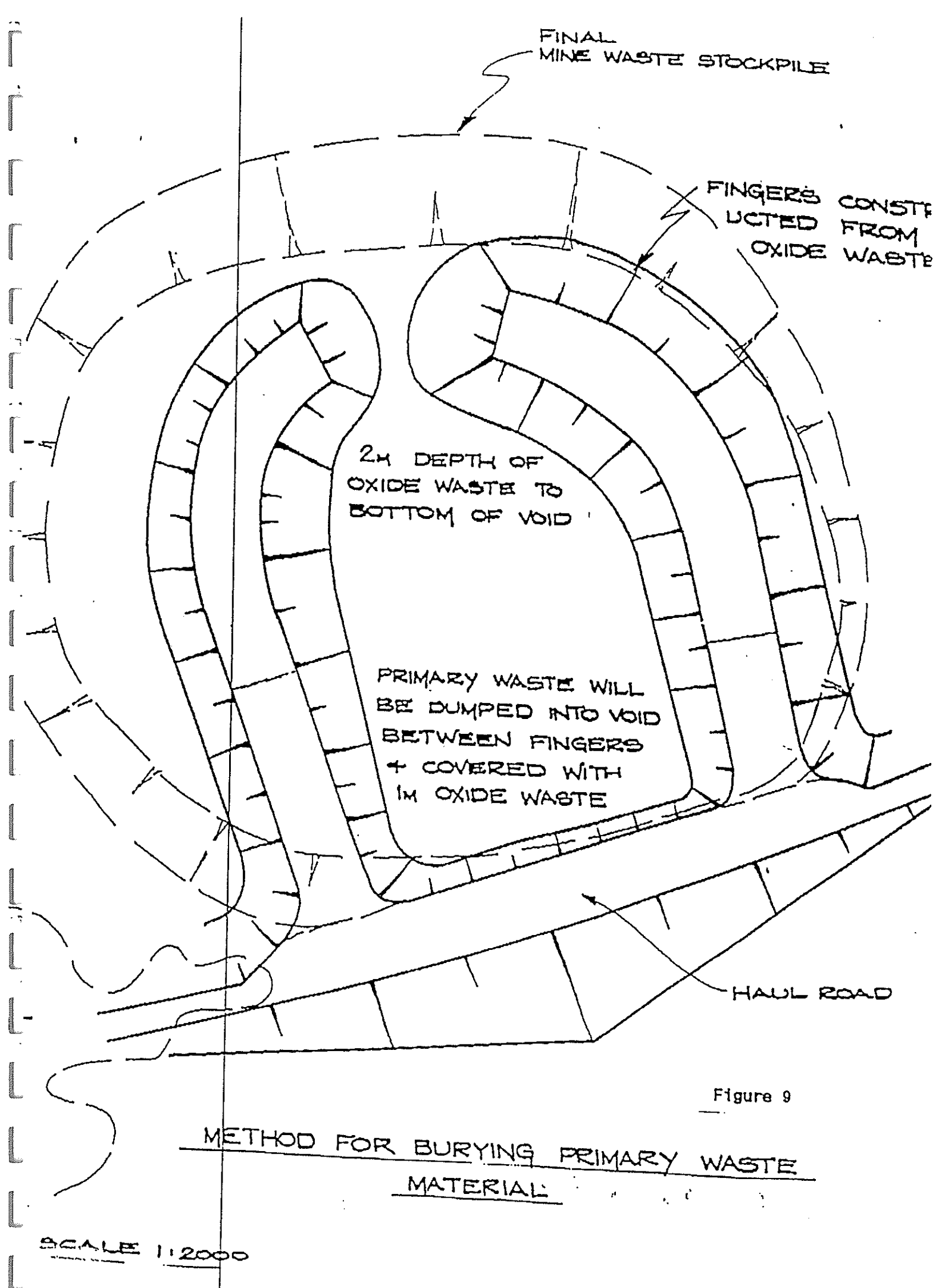
As the decant water will be pumped to this pond for final settling before the water is pumped to the processing plant there will be a deposit of fine clay material in the base of the dam that may contain residual cyanide. This material will need to be dried to break down the cyanide and consolidate the fines before rehabilitation.

After consolidated of the fines the material from the dam wall will be spread over the fines. Topsoil will then be spread to a depth of 150mm and the area seeded and fertilised.

Once rehabilitated the pond will not retain water and a waterway will be constructed to bypass this area and connect the spillway from the rehabilitated tailings compartments to a natural watercourse below the base of the return water pond dam (see figure 4). If installed the small seepage pond will remain to act as a sediment pond while the return water pond area is stabilising.

3.1.1.7 Monitoring

Seepage for the tailings site will be monitored by the installation of three bores downstream from the water return pond wall. Monitoring from these bores will commence on a weekly basis for the first six months and then continue on a monthly basis thereafter during the tailings deposition and



rehabilitation programme and for a year after rehabilitation of the return water pond. At the end of this period the results from this monitoring will be discussed with the Department of Minerals & Energy to determine further action if necessary.

3.2 Waste Rock Management

3.2.1 Waste Pit Rock

During the life of the proposed pit approximately 1,784,000BCM of waste rock will be generated of which less than 10% will be potentially acid producing. Oxide producing waste will be required to build the flood bund and also to rehabilitate acid producing tailings that may be produced later in the mine life. The research programme to be carried out in the first 6 months of the development programme will determine the total waste budget for the mine which will enable a waste management schedule to be developed. From this schedule the dimensions of the waste dump will be confirmed thus minimising the amount of area to be cleared for the lower dump lift which will be built from a defined outer edge.

The location of the waste dump is shown in Figure 4 and the method for selectively burying the potentially acid producing waste is shown in Figure 9. The geochemistry of the waste is discussed in the report by Stuart Miller and Associates and further research work on determining acid producing potential is discussed in section 4.4.

Initially the lower levels of the waste dump will be constructed of oxide material with the dumping operation commencing from the outer edges of the dump and retreating towards the haul road. The dump will be raised in

two metre lifts, with the outer face of each lift placed so that it can be shaped to blend with the lower slope which will have a slope of 1 in 4. After the second lift, approximately, a seven metre berm will be established to collect runoff from the upper slopes and convey the runoff to side drains. This berm will be designed for a 1 in 100 year event.

The outer face of each lift will be mulched with a mixture of rock and topsoil immediately it has been reshaped. This technique will allow progressive rehabilitation of the outer slopes. The maximum slope length of a reshaped outer slope will be 24 metres. (See section 4.6 for erosion standard).

The upper lifts will be dumped to form two arms of oxide waste enclosing a suitable sized void that will be used to contain acid producing material. Acid waste material will be dumped in layers and compacted by truck traffic. After the acid waste is placed it will be covered with oxide waste from the arms. Wherever feasible waste with a high neutralising value such as the material with carbonate veining will be dumped over the acid material to have some control over acid generation while the dump is open.

The drainage from the lift forming the base of the acid material will be drained via the berm drains to shed water away from the outer stabilised slope while the waste is being deposited. Drainage from the potential acid producing material will be directed into a shallow dug in the oxide material of the lower lift. This leachate will percolate into the oxide waste after low runoff events and will be diluted during high runoff events and conveyed along the berm drain to a silt collection pond where it will be further diluted.

Once the dumping has been completed the acid material will be covered with approximately two metres of oxidised

material and shaped to shed runoff away from the void containing the acid material. If necessary, this cover will be obtained from a suitable borrow area.

As the outer slopes of the lists have been progressively reshaped and topsoiled the final rehabilitation will involve the covering of the acid waste and reshaping the cover to shed runoff. The reshaped top of the dump will be spread with 150mm of topsoil, previously stripped from the site, contour ripped and seeded with a mixture of native grass and tree seeds. The area will be fertilised with a nitrogen and phosphorous fertiliser at a rate of 150kg/ha.

All runoff from the dump will be directed into sediment sumps before draining to Silt Collection Pond No.2 which has been designed to allow a stilling time of one hour for a 1 in 10 year event. The sediment sumps have been designed to provide a 120 sec. delay for runoff from a 1 in 5 year event and will be cleaned out after each wet season. This delay will allow sufficient time for the settling of particles greater than 0.5mm.

3.2.2 Dump Leach Rock

The low grade ore will be stockpiled for a future dump leach operation. Geochemical tests will be carried out to assess the acid producing potential of the primary ore containing greater than 0.5% sulphur. If found to be acid producing this ore will be selectively placed and covered with at least one metre of the low grade oxide ore.

Runoff from this stockpile is collected in the No.1 silt collection pond which will allow a stilling time of 1 hour for a 1 in 10 year event. The silt pond will be upgraded to a refractory cyanide pond before the dump leach programme commences.

If the dump leach programme is not initiated the ore stockpile will be reshaped to a 1 in 3 grade (maximum slope length 30 metres) and spread with 150mm of topsoil which will be contour ripped into the rocky surface. The area will be seeded with a mixture of grass and tree seeds and fertiliser with a nitrogen and phosphorus fertiliser at a rate of 150kg/ha.

Before the dump leach programme is initiated an amendment to this EMOS will be submitted to address the management of the cyanide leaching process and the subsequent rehabilitation of the dump leach site.

3.3 Groundwater Management

Western Mining Corporation undertook a Groundwater Dewatering Study in 1988 which indicated the presence of a high permeability zone coincident with the mineralisation and bounded on the north, west and south by faults. The measured transmissivity of this zone was 1000m²/day compared with the surrounding area measuring 50m²/day. The recharge to this system is small (300m³/km²/year). Total dissolved solids (TDS) for the four production bores tested by WMC ranged between 4000 and 15000 mg/l while sulphate ranged from 440-1700 mg/l.

The water balance calculated by WMC indicated that dewatering to a 100 metre depth could be achieved within a four year period at a rate of 4.6MI/day or approximately 1MI/day in excess of production requirements. As the life of mine is now envisaged to be five years the daily pumping rate, assuming constant recharge, can be reduced to approximately 4.4MI. Thus the daily excess can be reasonably estimated to be less than 0.8MI and further work will be undertaken during the first year of operation to more

fully quantify the groundwater resource and the process requirements.

Any ground water, excess to process requirements, will be stored in either of two mine water ponds to be constructed. Process water will not be discharged to these ponds.

as mining is above the water table
Mine Water Pond No.1 will have a capacity of 450 MI and will be constructed for the initial dewatering operation. At the expected excess of 0.8 MI/day the No.1 pond will have storage for 18 months which will cover the initial Plan of Operations. These ponds are not designed for an AEP as the volume of the ponds far exceeds the volume of runoff that could be generated from the catchments which will be further reduced by graded banks. However, an internal reporting level will be adopted to leave sufficient capacity for a 36 hour event with an ARI of 20 years. The spillway of these ponds will be designed for a 1 in 50 year event.

if
The Mine Water Pond No.2 will have a capacity of 1000 MI and would be constructed ~~of~~ test work during the first year of operation determines that extra storage was necessary. This test work will also determine if discharge will be necessary in excess of the current discharge license No. 915 which allows for overflow discharge caused by excessive rainfall.

If extra discharge is necessary at a later stage of the project an amendment to the EMOS will be sought and changes to the current discharge license will be sought from the Department of Environment and Heritage.

Prior to an application for amendment to the EMOS and the discharge license the mine will not discharge water from the site when the water quality exceeds the following levels:-

Conductivity	7000 ^{µs} /cm
Sulphate	250 mg/l
Magnesium	100 mg/l
Cyanide	0.1 mg/l
pH	5.5 - 7.0 (<or> this range)

These levels are 25% of the maximum suggested levels for stock use.

3.4 Surface Water Management

The surface water management will minimise the contamination of surface water leaving the lease. The following initiatives will be implemented from commencement of work on the lease:

3.4.1 Sediment Control

As a general rule clearing of vegetation and topsoil stripping will be kept to a minimum. Runoff from large sites to be stripped of topsoil, such as the plant site and waste rock dumps will be directed to sediment sumps before entering sediment dams.

Roads, pipelines and fences are to be sited so as to minimise erosion.

3.4.2 Waste Water

The management of saline groundwater and tailings liquor has been addressed in the relevant sections.

All runoff from plant sites will be directed into sediment dams. Chemical, oil spills, and process water spills will be contained in the plant drainage and collection system.

The sediment control system has been designed as a 2 stage system to prevent discharge of sediment loads in runoff from the Waste Dump Area.

The first stage is a silt trap which will provide a 120 sec delay for a 1 in 5 years event. This will permit sedimentation of the large particles (greater than .5mm) in the flow and reduce the load carried over to Silt Collection Pond No.2. The traps will be cleaned out after each wet season.

Silt Collection Pond No.2 provides a stilling time of 1 hour for a 1 in 10 year event.

Silt Collection Pond No.1 is designed to contain a 1 in 10 year storm from the final area of the low grade stockpile. This will act as a Silt Collection Pond for the low grade stockpile. It is proposed that this pond will be enlarged to become a storm pond for a dump leach operation when it proceeds.

The necessary amendments to the EMOS and Plan Of Operations will be lodged prior to dump leaching proceeding and the necessary licenses from WRC will be sought at this time.

Prior to the pond becoming part of the dump leach operation it will not receive any cyanide.

3.4.3 Flood Control

A flood protection bund will be constructed around the pit to RL178m AHD by late 1994 (Figure 4). This will be constructed from oxide waste and protected from flood erosion by rock armouring the outer slope. The stream bed of the Sutor River adjacent to the pit will be diverted around the bund to prevent undercutting of the bund. Sections of

the banks of the diversion where the flow is initially directed around the footwall of the bund will also be rock lined.

After the mining operations have been completed the bund will be partially removed at the intersection of the bund with the original river bed both upstream and downstream to allow the pit to fill with flood water. Channels will be excavated to ensure the pit fills in the first run of the river. The pit would then be seasonally flushed and eventually provide a valuable stock water storage facility.

Initially the water quality in the pit will reflect the salinity of the groundwater and the time available for recharge before runoff from Yandan Creek or the Suttor River enters the pit. Using the dewatering rate of 4.6MI/day over 4 years, the recharge into the Western Mining pit below RL158 (1229MI) is 1371MI/year or 3.75MI/day. Assuming that the recharge rate remains constant after the mining is complete, in 12 months 1371MI of groundwater (TDS approximately 12000) will seep into the pit.

The Ross Mining pit will have an approximate volume of 1325MI below RL158 so that the pit will be effectively filled to the previous groundwater level. The volume (RL158-170) remaining to be filled by river water (TDS 100) is approximately 1000MI and after this event the salinity of the resultant water will be approximately 6900mg/l, provided mixing is achieved. However, the sulphate level could still be above the level recommended for cattle (250mg/l). If complete mixing is not achieved the salinity of the surface water will be less.

This scenario can be considered the worst case as the flushing by the river flow will further dilute the groundwater and as the groundwater block is reasonably well confined the recharge rate will possibly be less than 3.7MI/day.

Once the initial flushing has occurred and the pit is full the groundwater will not move into the pit. In subsequent years the yearly addition of river water will continue to dilute the groundwater and the upper 12 meters of the pit will supply approximately 1000MI of good stock water. In such a water body evaporation will have little effect on water quality as an average evaporation rate of 1.8m per annum at the 170 RL is equivalent to 2% of the volume of water stored in the pit.

The chances of annually filling or topping up the pit are good as the average annual flow of the Suttor River is 1,950,000MI.

The characteristics of the bund will need to be studied by the Water Resources Commission as to the effect of leaving the bund intact although breached as there may be some adverse hydraulic effects on Yandan Creek. The degree to which the bund should be removed or rehabilitated will be discussed with the Water Resources once the bund is in place and an understanding of flood flows around the bund is obtained. If required the bund will be removed.

3.4.4 Water Balance

A water balance was developed for the IAS. This balance has been reworked for the revised mining schedule and a summary of the main changes follows.

The groundwater reserve will be pumped at a reduced rate of approximately 4.4MI/day which is 0.8MI/day in excess of process requirements. The Mine Water Pond No.1 (450MI) has storage capacity for eighteen months of the excess water disregarding evaporation.

After 18 months the Mine Water Pond No.2 (1000MI) will be constructed for extra storage or an application will be made to discharge water into the Suttor River when flowing.

3.5 Topsoil Management

Although topsoil stripping and return has been mentioned in the individual rehabilitation sections the following policy has been established:

All plant, storage and tailings sites will be stripped of approximately 150mm of topsoil which will be stored in selected sites away from general mining activity. The height of the storage sites will be limited to 1.5 metres. The stockpiles are to be protected from erosion and runoff.

Topsoil from roadways will be stripped to 150mm and stockpiled in windrows beside the roads.

The storage area of dams which will be used for the storage of salty water will be stripped of topsoil as will silt collection pond No.1 which will be used eventually as a cyanide treatment dam.

Topsoil from the pit area has been disturbed by exploration activities but will be stripped to a depth of 100mm and used for the rehabilitation of the waste dump.

Emphasis is to be placed on stockpiling the top 150mm of the soil profile on all sites rather than stripping a greater depth over a smaller area. On some areas near the pit and the waste dump the topsoil depth may be less than 150mm. Any deficit in the quantity required to return at least 150mm to all waste sites will be made up from the topsoil to be stripped from the pit area and the airstrip which occupy 35 hectares.

**AMENDMENT TO
PLAN OF OPERATIONS
TO ALLOW FLUSHING OF YANDAN PIT**

DEC 2003

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Table 1	<i>Water Monitoring (Metals) Results, Main Pit Discharge into Suttor River 24/02/00-07/03/00</i>
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Appendix A	<i>Water Monitoring Results, Yandan Pit Discharge 2000</i>
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1. INTRODUCTION

The Yandan Gold Mine is located 180km SSE of Charters Towers, on the eastern bank of the Suttor River, at the confluence with Yandan Creek. The Yandan pit is separated from the Suttor River by an earthen bund (Waterworks Licence G-55018).

The mine was commissioned in September 1993. Increasing sulphide rich ore and waste was encountered in the last two years of operation. Sulphidic waste rock was deposited within limited areas of the open pit before mining was completed in December 1998.

Flooding of the pit was determined to be the best long term rehabilitation option based on the findings of the Yandan Gold Mine Pit Water Quality Prediction (SRK 1999). Areas backfilled with sulphidic waste were dozed flat, treated with lime and capped with compacted oxide material in accordance with specifications detailed in Yandan Pit Reflooding Waste Rock Backfill Cover Placement Specification (SRK, 1999).

The pit was a third filled by volume late in the 1999 wet season and completely filled, via a constructed spillway, in early 2000.

This amendment to the Plan of Operations describes:-

1. The water quality of pit discharge and mixed waters during the 2000 flooding event,
2. An assessment of the mechanisms involved in pit acidification and pit flushing as a management option, and
3. Monitoring protocols for future pit discharge events.

2. WATER QUALITY OF PIT DISCHARGE AND MIXED WATERS

2.1 *Monitoring of Pit Discharge and Mixed Waters*

Water discharged from the Yandan pit from the 24/02/2000 to the 07/03/2000. Water samples were collected daily from:

1. Point of discharge
2. Confluence of Yandan Creek and Suttor River, and
3. Immediately downstream of pit.

Smith and Markham (1999) mass balance estimates of metal concentrations in mixed river waters identified aluminium, copper, and to a lesser extent iron, zinc and lead as metals of interest.

ICPAES metal scan and cation/anion analyses were undertaken on all samples. pH and conductivity were recorded at the time of sampling. Monitoring results for metals of interest and relevant guideline criteria are presented in Table 1. Complete monitoring results are presented in Appendix A

The conclusions of the monitoring are summarised as follows:

- pH of mixed waters was within ANZECC (1992) guidelines but approximately 0.7 pH units lower than baseline data values during the initial stages of pit water discharge.
- The high suspended clay content of flood waters resulted in elevated (max. 14.3 mg/L) concentrations of aluminium from the 24/02/00-02/03/00. The concentration of aluminium in pit water did not exceed 1.7 mg/L during the discharge event.
- Aluminium concentrations in mixed waters were below USEPA acute guidelines and Suttor River baseline data, but above ANZECC (1992) guidelines for the protection of aquatic ecosystems.
- Copper concentrations in mixed waters were generally within both USEPA and ANZECC (1992) guideline values.
- Iron concentrations (max. 5.5 mg/L) exceeded USEPA and ANZECC (1992) for the period of 24-27/02/00. Concentrations had returned to background levels by the 29/02/00. It is assumed that the iron concentrations are related to the sediment loading in the initial floodwaters, as the iron concentration of pit waters did not exceed 0.3 mg/L during the discharge event.
- Zinc and lead concentrations in mixed waters were within USEPA and ANZECC (1992) guideline values.

Table 1 – Water Monitoring (Metals) Results, Main Pit Discharge into
Suttor River 24/02/00-07/03/00

ID	LOCATION	DATE	pH	Al	Cu	Fe	Zn	Pb
ANZECC (1992)			6.5-9	0.1	0.005	1	0.05	0.005
USEPA Acute			-	0.75	0.007	-	0.064	0.032
Baseline (IAS)			7.4	1.54*	0.014	0.34*	0.05	<0.001
Suttor	Spillway	24/02/00	6.66	11.5	0.004	4.2	0.016	0.004
Suttor	100m	24/02/00	6.55	11.2	0.003	4.2	0.014	0.003
Suttor	200m	24/02/00	6.63	12.1	0.003	4.6	0.016	0.003
Suttor	300m	24/02/00	6.73	12.2	0.007	4.9	0.017	0.003
Suttor	660m	24/02/00	6.75	14.3	<0.001	5.5	<0.001	<0.001
Suttor	460m	26/02/00	6.36	1.45	0.021	0.09	0.196	<0.001
Suttor	660m	26/02/00	6.5	10.1	0.003	4.07	0.014	0.002
Suttor	860m	26/02/00	6.68	10	0.005	3.85	0.019	0.002
Suttor	Spillway	27/02/00	6.61	1.05	0.019	0.07	0.174	<0.001
Suttor	460m	27/02/00	6.57	8.65	0.004	3.76	0.011	0.001
Suttor	860m	27/02/00	6.61	9.58	0.004	3.94	0.019	0.002
Suttor	Spillway	29/02/00	4.05	<0.05	0.008	<0.1	0.198	<0.001
Suttor	200m	29/02/00	6.59	1.32	0.008	0.6	0.004	<0.001
Suttor	300m	29/02/00	6.71	1.39	0.02	0.6	0.005	<0.001
Suttor	Spillway	1/03/00	4.12	1.97	0.029	0.2	0.272	<0.001
Suttor	200m	1/03/00	6.52	0.91	0.003	0.5	0.012	<0.001
Suttor	300m	1/03/00	6.72	1.25	0.007	0.6	0.004	<0.001
Suttor	Spillway	2/03/00	4.34	1.74	0.028	0.3	0.277	0.002
Suttor	200m	2/03/00	6.71	0.91	0.003	0.4	0.007	<0.001
Suttor	300m	2/03/00	6.77	1.03	0.003	0.5	0.007	<0.001
Suttor	Spillway	3/03/00	4.07	1.99	0.03	0.3	0.24	<0.001
Suttor	200m	3/03/00	6.59	0.6	0.004	0.4	0.012	<0.001
Suttor	300m	3/03/00	6.7	0.66	0.016	0.3	0.015	<0.001
Suttor	Spillway	5/03/00	4.14	1.65	0.026	0.2	0.255	0.001
Suttor	200m	5/03/00	6.61	0.59	0.003	0.3	0.012	<0.001
Suttor	Crossing	5/03/00	7.03	0.39	0.002	0.4	0.004	<0.001
Suttor	Spillway	6/03/00	4.12	1.67	0.025	0.1	0.259	0.002
Suttor	200m	6/03/00	6.41	0.48	0.004	0.4	0.008	<0.001
Suttor	Crossing	6/03/00	6.84	0.5	0.002	0.4	0.002	<0.001
Suttor	Upstream	7/03/00	7.67	0.14	0.008	<0.1	0.005	<0.001
Suttor	Spillway	7/03/00	4.26	1.71	0.032	<0.1	0.249	0.008
Suttor	200m	7/03/00	6.65	0.38	0.004	0.6	0.002	<0.001
Suttor	Crossing	7/03/00	7.14	0.3	0.005	0.3	0.002	<0.001

* Average based on historical monitoring results.

IAS – Yandan Gold Project Impact Assessment Study WMC (1988)

3. MECHANISMS OF PIT ACIDIFICATION AND FLUSHING AS A MANAGEMENT OPTION

3.1 *Mechanisms of Pit Acidification*

The Department of Mines and Energy (DME) letter dated 20 July 2000 regarding water quality in the Yandan Main pit lake primarily requested further definition of pit acidification mechanisms and examination of water quality improvements through flushing with Suttor River flood water. HLA Envirosciences undertook a review of possible pit acidification mechanisms in November 2000. Key findings of the review, directly referenced to the DME letter, are extracted and quoted as follows:

Water Quality of Yandan Main Pit – Reply to DME Letter (20 July, 2000)
HLA –ENVIROSCIENCES PTY LIMITED

General Comments

"While the comment that it would seem unlikely that the discharge of the current pit water quality during flood events would breach the lease conditions of the EMOS/Plan of Operations discharge requirements, there are no data to determine whether this can be complied with. It may well be true that the discharge at the lease boundary will have no impact on the Suttor River and the ecosystem it supports, however there are no data to determine whether this is true. This will be addressed with the 2000/2001 pit discharge data.

We agree with the DME that the ecosystem guidelines at or near the discharge point from the pit are more appropriate than ANZECC Guidelines due to the ambient concentrations of metals in the "country rock" and river system that were present prior to commencement of mining."

Specific Issues

"Item 1: Reiterates the fact that there are no dry season waterholes present in the Suttor River and that Suttor River environ has been heavily impacted from grazing. This suggests that the receiving environment to pit discharge is already degraded prior to mining taking place."

"Item 2: Identifies natural concentration of metals in the Suttor River unrelated to mining, which again supports the premise that impact of discharge may be minimal. However this aspect needs to be quantified by both monitoring and modelling."

"Item 3: Relates to metal concentrations and quality of acid drainage in the pit. These statements are not quantifiable by the data at hand. The statements require quantifying by the modelling and monitoring of the pit and discharge."

"Item 4: Relates to metal availability and complexation and ion exchange that may occur within the pit prior and during the mixing process at the time of flushing with Suttor River water and later within the Suttor river as the discharge combines with the turbid river flood waters. These processes are very complex and may be quite difficult to measure. The 1-D geochemical modelling used by SRK is designed to be conservative and as stated above provides a static concentration output that relates directly to the chemical state of the pit at the time the model input data was collected. It does not provide a dynamic relationship of mixing and stratification when the River water is first added and during subsequent flushing periods."

"Item 5: We agree that a constructed spillway needs to be engineered to prevent the potential for catastrophic failure and uncontrolled discharge."

"Item 6: The pit was flooded recently by diverting the Suttor River. This would have caused considerable turbulence that would have resulted in re-suspension of any iron-rich sludge and redissolved any soluble salts associated with the sulphidic waste or wall rocks. Any accumulated low pH water within the pit prior to flooding would have been incorporated into the water mass.

Once the pit lake stabilises, seasonal patterns of thermal stratification and resultant seasonal pycnocline formation will have a significant effect on oxygen transport rates in the water column of the pit lake. Variations in soluble oxygen concentrations will affect the oxidation rate of submerged, exposed sulphide material as will the rate of vertical transport of this oxygen through the water column. Mechanisms governing oxygen transport in the Yandan pit lake water column will be crucially linked to a number of factors. These are dominated by:

- (1) Seasonal patterns of stratification and mixing
- (2) Water temperature
- (3) Oxygen demand in the lake's deeper regions (chemical &/or biochemical)
- (4) Seasonal (winter) cooling in the lake
- (5) Wind induced turbulence
- (6) Inflow/outflow induced turbulence

During the initially filling of the pit it is likely that significant turbulence of the water column occurred. This would have entrained oxygen through the column as well as mobilised soluble ions and re-suspended any loosely precipitated iron sludge that may have accumulated in the bottom of the pit. With the pit lake being only 55 metres deep it is likely that the water would have been well mixed by the initial flooding process. The flushing of the pit during subsequent flood events in the Suttor River will generate turbulence within the pit water column. The degree and depth of turbulence transport will vary but in any one event will be related to the stability (degree of stratification) in the water column of the lake. Thus, the intrusion point (into the water column) of inflowing water will be dependent on hydrodynamic conditions in the pit lake proper. These

conditions are in turn governed by the 6 factors described above. Depending on these factors, it is entirely possible that the turbulent effects of inflow (and outflow) will be confined to the upper layer of the pit lake with the deeper regions being relatively unaffected. It should be noted that the modelling undertaken by SRK was purely a 1 dimensional geochemical predictive model that gives the absolute stoichiometry of the solvent (water)-solute process, in other words it does not account for transport of the water components i.e. the soluble metals once the concentrations have been calculated. Thus it assumes that the Yandan pit will behave as a mixed reactor. This is in fact not correct in terms of seasonal hydraulic behaviour of pit lakes in this setting. Indeed there is likely to be considerable seasonal vertical discontinuity in the concentration of metals within the Yandan Pit (i.e. low at surface and high at deeper levels depending on a range of physiochemical conditions). The notional outputs of the SRK model do not account for issues such as stratification in particular density entrainment of inflows, e.g. as stated above it is likely that inflows will intrude into the water column considerably above the bed of the pit lake and will have very little effect on waters in the deeper regions of the Pit lake. This means that concentrations of metals in the outflow will be dependent not on the concentration in the gross mass of the lake volume but on that portion of the lake volume interacting with the said inflows. Therefore it is important to understand what the seasonal and environmental hydraulics of the water column proper as it relates to stratification and mixing. This approach is supported by numerous observations on sub-tropical and tropical lakes including pit lakes. If the hydraulic processes involved in Pit mixing and stratification are not clearly defined and understood at the outset then the strategy for dilution by flushing with Suttor River water is inherently flawed.

The entrainment of iron and other metal species precipitates and particulates, and the incorporation of dissolved ions associated with oxidation of sulphides into the pit water column during initial flooding contributed to the initial acidity of Pit. The data suggest that there was probably some low pH water with dissolved ions (principally iron) present in the pit at the time of flooding and this would have been a major contributor to acidity. It is likely that there was negligible buffering capacity in the River water used to flood the Pit. It is also likely that contribution to the neutralisation potential from the carbonate alteration in the pit walls was limited.

Once the water has been placed within the pit the oxidation of any exposed sulphides in the wallrocks and waste dumps will decrease significantly. However the water column will not eliminate oxygen entirely; it will slow the diffusion rate and therefore there will always be some oxidation processes occurring within the pit. These are likely to be greater in the near surface areas of the pit and water column.

Contribution of oxygenated ground water to the acidification process is likely to be small."

"Item 7: Continuous monitoring will be required most likely using a rising stage sampler that is designed and located where it is protected from erosive floodwaters. The same would apply for locating automatic pH and EC loggers. It maybe quite difficult to locate the rising stage sampler and automatic logger to collect a representative sample during periods of pit discharge that coincide with high river flow periods, where they are not going to be damaged or washed away by flood waters. Wirralie environmental staff should review this."

"Item 8: Again we concur with the DME that further assessment of impacts will be required if the monitoring of the discharge during flushing indicates potential impacts on ecosystem values."

4. PIT DISCHARGE MONITORING

4.1 Monitoring Protocols

Flushing events will be monitored at the northern point of discharge from the pit (Site 1), a point 150m downstream referred to as the 'crossing' (Site 2), and a point 500m downstream where the water harvesting channel point enters the Suttor River (Site 3). A fourth point where the Suttor River exits the northern ML 1095 boundary (Site 4) will be monitored should water quality impacts be detected at Site 3.

pH and conductivity data will be recorded by Ross Mining personnel at the monitoring points thrice daily (6:00am, 12:00pm and 6:00pm). Water samples collected will be analysed for metals. An assessment of bio-availability of metals in pit discharge waters will be undertaken. Water levels will be recorded and marked on each sample collected.

After each flood event pH and conductivity records will be matched against metal concentrations, bio-availability data and water levels. Further assessment will be undertaken should monitoring at the lease boundary indicate:-

1. Exceedance of ANZECC ecosystem guidelines, or
2. Exceedance of EMOS requirements, as outlined in Table 2.

Table 2 – EMOS Water Quality Requirements

Parameter	Concentration
Conductivity	7000 us/cm
Sulphate	250 mg/L
Magnesium	100 mg/L
pH	5.5-7.0 (<or> this range)

APPENDIX A
WATER MONITORING RESULTS
YANDAN PIT DISCHARGE 2000

WATER MONITORING DATA (METALS) – YANDAN PIT DISCHARGE 2000

LOCATION	DATE	pH	Al	Cu	Fe	Zn	Pb	As	Cd	Cr	Ni	B	Ba	Co	Mn	Mo	Si	Sr	V
Spillway	24/02/00	6.66	11.5	0.004	4.2	0.016	0.004	0.004	0.001	0.01	<0.01	<0.2	<0.1	<0.01	0.02	<0.01	23.1	0.04	<0.01
100m	24/02/00	6.55	11.2	0.003	4.2	0.014	0.003	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	0.02	<0.01	22.3	0.04	<0.01
200m	24/02/00	6.63	12.1	0.003	4.6	0.016	0.003	0.003	1.92	<0.01	<0.01	<0.2	<0.1	<0.01	0.02	<0.01	23.7	0.05	<0.01
300m	24/02/00	6.73	12.2	0.007	4.9	0.017	0.003	0.005	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	0.02	<0.01	24.2	0.04	<0.01
660m	24/02/00	6.75	14.3	<0.001	5.5	<0.001	<0.001	<0.001	<0.001	0.01	<0.01	<0.2	<0.1	<0.01	0.03	<0.01	25.9	0.05	0.01
460m	26/02/00	6.36	1.45	0.021	0.09	0.196	<0.001	0.002	0.002	<0.01	0.07	<0.2	<0.1	0.07	0.23	<0.01	4.8	0.11	<0.01
660m	26/02/00	6.5	10.1	0.003	4.07	0.014	0.002	0.002	0.022	<0.01	<0.01	<0.2	<0.1	<0.01	0.02	<0.01	22.3	0.05	<0.01
860m	26/02/00	6.68	10	0.005	3.85	0.019	0.002	0.004	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	0.01	<0.01	19.5	0.05	<0.01
Spillway	27/02/00	6.61	1.05	0.019	0.07	0.174	<0.001	0.002	0.001	<0.01	0.05	<0.2	<0.1	0.06	0.22	<0.01	4.9	0.1	<0.01
460m	27/02/00	6.57	8.65	0.004	3.76	0.011	0.001	0.003	0.002	<0.01	<0.01	<0.2	<0.1	<0.01	0.01	<0.01	19.9	0.05	<0.01
860m	27/02/00	6.61	9.58	0.004	3.94	0.019	0.002	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	0.01	<0.01	20.5	0.05	<0.01
Spillway	29/02/00	4.05	<0.05	0.008	<0.1	0.198	<0.001	<0.001	0.001	<0.01	0.07	<0.2	<0.1	0.07	0.24	<0.01	-	0.12	<0.01
200m	29/02/00	6.59	1.32	0.008	0.6	0.004	<0.001	0.005	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
300m	29/02/00	6.71	1.39	0.02	0.6	0.005	<0.001	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
Spillway	1/03/00	4.12	1.97	0.029	0.2	0.272	<0.001	0.001	0.001	<0.01	0.08	<0.2	<0.1	0.08	0.22	<0.01	-	0.09	<0.01
200m	1/03/00	6.52	0.91	0.003	0.5	0.012	<0.001	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
300m	1/03/00	6.72	1.25	0.007	0.6	0.004	<0.001	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
Spillway	2/03/00	4.34	1.74	0.028	0.3	0.277	0.002	0.002	0.001	<0.01	0.08	<0.2	<0.1	0.07	0.23	<0.01	-	0.08	<0.01
200m	2/03/00	6.71	0.91	0.003	0.4	0.007	<0.001	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
300m	2/03/00	6.77	1.03	0.003	0.5	0.007	<0.001	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
Spillway	3/03/00	4.07	1.99	0.03	0.3	0.24	<0.001	<0.001	0.001	<0.01	0.08	<0.2	<0.1	0.07	0.23	<0.01	-	0.09	<0.01
200m	3/03/00	6.59	0.6	0.004	0.4	0.012	<0.001	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
300m	3/03/00	6.7	0.66	0.016	0.3	0.015	<0.001	0.004	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.07	<0.01
Spillway	5/03/00	4.14	1.65	0.026	0.2	0.255	0.001	0.002	0.001	<0.01	0.08	<0.2	<0.1	0.07	0.23	<0.01	-	0.08	<0.01
200m	5/03/00	6.61	0.59	0.003	0.3	0.012	<0.001	0.003	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.06	<0.01
Crossing	5/03/00	7.03	0.39	0.002	0.4	0.004	<0.001	0.002	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.05	<0.01
Spillway	6/03/00	4.12	1.67	0.025	0.1	0.259	0.002	0.002	0.002	<0.01	0.07	<0.2	<0.1	0.07	0.23	<0.01	-	0.08	<0.01
200m	6/03/00	6.41	0.48	0.004	0.4	0.008	<0.001	0.006	<0.001	<0.01	<0.1	<0.2	<0.1	<0.01	0.32	<0.01	-	0.07	<0.01
Crossing	6/03/00	6.84	0.5	0.002	0.4	0.002	<0.001	0.002	<0.001	<0.01	<0.1	<0.2	<0.1	<0.01	0.02	<0.01	-	0.07	<0.01
Upstream	7/03/00	7.67	0.14	0.008	<0.1	0.005	<0.001	0.006	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.07	<0.01
Spillway	7/03/00	4.26	1.71	0.032	<0.1	0.249	0.008	0.002	0.002	<0.01	0.07	<0.2	<0.1	0.07	0.25	<0.01	-	0.1	<0.01
200m	7/03/00	6.65	0.38	0.004	0.6	0.002	<0.001	0.001	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	0.04	<0.01	-	0.12	<0.01
Crossing	7/03/00	7.14	0.3	0.005	0.3	0.002	<0.001	0.008	<0.001	<0.01	<0.01	<0.2	<0.1	<0.01	<0.01	<0.01	-	0.09	<0.01

WATER MONITORING DATA (IONIC) – YANDAN PIT DISCHARGE 2000

LOCATION	DATE	Conductivity	TDS	SO4	Ca	Mg	Na	K	CaCO3	P	S	Bicarbonate
Spillway	24/02/00	na	212	na	6	2	9	5	<1	<1	<1	26
100m	24/02/00	na	184	na	5	2	9	6	<1	<1	<1	25
200m	24/02/00	na	176	na	5	3	9	6	<1	<1	<1	25
300m	24/02/00	na	192	na	5	3	9	6	<1	<1	<1	26
660m	24/02/00	na	200	na	5	3	8	6	<1	<1	<1	24
660m	24/02/00	na	188	na	6	2	8	6	<1	<1	<1	24
Spillway	26/02/00	236	na	na	na	na	na	na	na	na	na	na
80m	26/02/00	239	na	na	na	na	na	na	na	na	na	na
160m	26/02/00	200	na	na	na	na	na	na	na	na	na	na
260m	26/02/00	158	na	na	na	na	na	na	na	na	na	na
360m	26/02/00	145	na	na	na	na	na	na	na	na	na	na
460m	26/02/00	110	na	na	na	na	na	na	na	na	na	na
460m	26/02/00	na	204	77	16	4	15	5	na	<1	26	na
660m	26/02/00	103.3	na	na	na	na	na	na	na	na	na	na
660m	26/02/00	na	212	3	5	2	14	5	na	<1	<1	na
860m	26/02/00	105	na	na	na	na	na	na	na	na	na	na
860m	26/02/00	na	200	8	5	3	11	6	na	<1	3	na
Spillway	27/02/00	na	204	71	15	4	15	5	na	<1	24	na
460m	27/02/00	na	196	3	5	3	11	5	na	<1	<1	na
860m	27/02/00	na	192	3	5	3	11	5	na	<1	1	na
Spillway	29/02/00	na	204	83	24	4	15	4	na	na	na	na
200m	29/02/00	na	220	7	6	2	16	5	na	na	na	na
300m	29/02/00	na	216	3	6	2	11	4	na	na	na	na
Spillway	1/03/00	na	216	82	15	4	15	11	na	na	na	na
200m	1/03/00	na	176	12	7	3	11	4	na	na	na	na
300m	1/03/00	na	196	4	7	2	11	4	na	na	na	na
Spillway	2/03/00	na	212	83	16	4	25	14	na	na	na	na
200m	2/03/00	na	176	7	7	3	11	5	na	na	na	na
300m	2/03/00	na	168	5	7	3	11	5	na	na	na	na
Spillway	3/03/00	na	216	81	16	4	16	7	na	na	na	na
200m	3/03/00	na	180	14	8	3	13	5	na	na	na	na
300m	3/03/00	na	172	10	8	3	15	6	na	na	na	na
Spillway	5/03/00	na	216	82	16	4	15	5	na	na	na	na
200m	5/03/00	na	148	6	7	3	11	6	na	na	na	na
Crossing	5/03/00	na	196	2	8	3	9	5	na	na	na	na
Spillway	6/03/00	na	220	81	16	5	16	5	na	na	na	na
200m	6/03/00	na	116	14	9	3	19	6	na	na	na	na
Crossing	6/03/00	na	196	2	8	3	10	5	na	na	na	na
Upstream	7/03/00	na	172	2	8	3	15	5	na	na	na	na
Spillway	7/03/00	na	212	83	16	5	16	4	na	na	na	na
200m	7/03/00	na	260	7	22	5	12	6	na	na	na	na
Crossing	7/03/00	na	220	3	14	3	10	5	na	na	na	na
160m	12/03/00	150	na	na	na	na	na	na	na	na	na	na
260m	12/03/00	149	na	na	na	na	na	na	na	na	na	na
360m	12/03/00	169	na	na	na	na	na	na	na	na	na	na
660m	12/03/00	164	na	na	na	na	na	na	na	na	na	na
Crossing	12/03/00	136	na	na	na	na	na	na	na	na	na	na
160m	20/03/00	151	na	na	na	na	na	na	na	na	na	na
360m	20/03/00	158	na	na	na	na	na	na	na	na	na	na
660m	20/03/00	232	na	na	na	na	na	na	na	na	na	na
Crossing	20/03/00	156	na	na	na	na	na	na	na	na	na	na

na – not analysed

28 MARCH
2022



21°18' S
146°58' E

Water performance of Yandan Mine landscape at closure

March 2022

GBM RESOURCES LIMITED



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GBM Resources

Water performance of Yandan mine landscape

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1 Introduction

1.1 Location & project background

The Yandan mine project lays in the Central Highlands region of Queensland within the Charters Towers, Bowen and Clermont mining districts. The site is very central to Queensland – laying approximately 230 kilometres west of Mackay & south of Townsville in the Whitsunday Shire, 220km north of Moranbah, and 40km west of the regional town of Mount Coolon (Figure 1). The lease area is currently held by GBM Resources.

Yandan mine operated between 1993 to 1999 extracting gold hosted in hydrothermal & volcanic complex via three (3) open pits and a heap leach pad, with processing & tailings storage onsite. The project is currently in care & maintenance, though is subject to active exploration by GBM Resources. The site lays within the Burdekin River catchment within the Brigalow Biozone (Queensland Government 2021b).

1.2 Context & purpose

As part of implementation of Queensland state environment reforms Yandan is required to undertake technical review & post-mining land use outcomes to inform submission & approval of a Progressive Rehabilitation & Closure Plan (PRCP).

This program of work is to provide technical evaluation of water performance for the Yandan mine landscape against closure requirements, inform post-mining land uses (PMLUs) & risk assessment relating to any non-use management areas (NUMAs).

1.3 Scope

This study provides description, analysis & findings of water-related risk areas as landform fates & permanent landscape, including an assessment of the current situation, how the water systems work across the project with the mix of materials, hydrology & landforms, & scenarios of future states. In detail, scope includes:

- Overview of Yandan site framework: including operations summary, monitoring network & regulatory environment, planned rehabilitation outcomes & status.
- Description of the project water setting: landscape, surface water, geology, materials characterisation, climate, flooding (including PMF), climate change expectations, groundwater and regional water values.
- Characterisation & analysis of Yandan mine landforms & domains: analysis of current state of water quality & movement, including surface water & catchments, groundwater levels & water quality to identify trends & processes underway.
- Construction & assessment of pit void water balance and fate modelling.
- Recommended water completion criteria.
- Key findings & water-related risk assessment.

Scope of the study also included a 2-day site visit to Yandan understand the site & landforms to inform assessment through observations & review.



Figure 1 - Location of Yandan mine project



1.4 Rehabilitation fates & key questions for water performance at closure

Table 1 - Planned rehabilitation outcomes & key questions for study

Landform	Rehabilitation fate	Land-use	Closure questions
Heap Leach Pad (16.9 ha)	Cover system for low risk - gravel layer at a minimum of 0.5 m thickness & topsoil	Low hill	Water system response to landform (quality & quality). Final landform design needs, risk & appropriate cover for water performance stability. Potential water-related impacts & required monitoring to completion criteria.
HL Stormwater Pond (1.59ha)	Dam wall removed & area rehabilitated.	Low hill	Leakage & potential groundwater containment. Indication of landform surface water drainage.
Pregnant Pond (0.16 ha)	Dam wall removed & area rehabilitated.	Low hill	
Barren Pond (0.18 ha)	Dam wall removed & area rehabilitated.	Low hill	
Tailings Cell A (4.5 ha)	Repair of existing rehabilitation & regrading of surface (low risk cover)	Open pasture	Water system response to landform (quality & quality). Final landform design needs, risk & appropriate cover for water performance stability. Potential water-related impacts & required monitoring to completion criteria.
Tailings Cell B (70.8 ha)	Cover system for low risk: - Rock cover of 1.0 m; and - Growth media of 0.15 m.	Open pasture	
Tailings Water Return Dam (18.37ha)	Dam wall removed & area rehabilitated.	Open pasture	Leakage & potential groundwater containment. Indication of landform surface water drainage.
East Hill Pit (0.5 ha)	Partially backfilled with concrete from infrastructure area, and sediment from water storage structures.	Lake	Water system response as a landform/pit lake (quality & quality). Water level stability to cover fresh rock. Water quality stability & risk as pit lake. Fate of pit wall bund.
Main Pit (17.8 ha)	Maintain water cover & connectivity with two spillways. Query whether bund wall required longer term.	Lake	
South Pit (3.1 ha)	No major works required.	Open pasture	Not required – rehabilitated & fully infilled. Water risk is low & stable.
Water Storage / Raw Water Dam (35.2 ha)	Maintain, will remain.	Lake	Not required – water risk is low & stable.
Mine Water Dam (14.17 ha)	Dam wall removed & area rehabilitated.	Open pasture	Not required – water risk is low & stable.
All of site			Flooding profile for landforms & potential risk as permanent landforms. Responses of pit voids to climate change or rare rainfall events. Receiving environment stability & risk – surface water & groundwater.



2 Overview of Yandan mine site & project

2.1 Background of the site

Yandan as a project commenced development in 1988 & operated between 1993 to 1999. The project extracted gold from a series of three (3) pits of varying size, creating 2 pit voids & the third now refilled, a tailings landform, heap leach pad, & supporting dam infrastructure. Notably processing methods used cyanide in leach (CIL) in milling & leaching processes.

Current Yandan lease area is ~2,500 hectares, though mine-related disturbance is only a portion of the total lease. A general layout map of Yandan site with landforms, features & water sampling network is provided in Figure 2.

Mined ore sources at Yandan are described as two major sources: oxide (weathered or altered) ore & sulphide (fresh rock) ore. Notably, sulphide ore is applied as a mining term to signify fresh rock ore in comparison to oxide & differing hydrothermal alteration. In fresh rock, sulphides are not weathered or altered (hence the presence of sulphides), whereas oxide rock is leached, weathered, or hydrothermally altered where fresh sulphides minerals are removed.

Mining applied processes of milling/cyanide in leach of oxide & fresh (sulphides) ore, & low-grade ore leaching via the leach pad. Both methods applied large volumes of lime or limestone to lift pH & increase mobility of gold. As a result, both the tailings & the heap leach pad can be expected to yield water higher in alkalinity.

In the time since 1998, much of the surface infrastructure used during active mining has been removed from Yandan site, leaving remnant landforms able to be reactivated in the event of discovery, or to be prepared for final closure fate. Table 2 provides a summary of current landforms, related infrastructure with a description of construction & nature.

2.2 Monitoring network & framework

Yandan mine is currently permitted for Environment Authority under EPML00771913 (Appendix A).

The broader monitoring program includes regional sites as upstream & downstream reference sites on the Suttor River, Yandan Creek & local drainage lines, plus groundwater bores surrounding landforms and surface water storages.

Details of the current monitoring network, including compliance monitoring sites are listed in:

- Table 3 lists receiving environment sites & purpose.
- Table 4 lists surface water storage & ponding sampling locations as available.
- Table 5 lists groundwater monitoring by domain & depth.

Eight (8) new groundwater wells were drilled in late 2020 at Yandan as replacement wells for compliance, with two wells retired. There is limited information available for historical wells & review of network may be required as several appeared in disrepair on inspection & during sampling.

There are currently no production wells on site for water use or points of groundwater extraction. Raw water is sourced via mine water dam or the water supply dam.



Table 2 - Summary of Yandan landforms & current state

Landform	Features included	Description
Main pit	Pit void (currently a pit lake) berm wall to control water reaching the pit, borrow pit on southern side which hosts throughflow of Yandan Creek. Oxide & sulphide zones mined.	Main pit to maximum depth of 60m & surface area of ~ 22 hectares. Pit is open at two engineered “spillways” at 169mAHD which allows flow in & flow out of the pit during periods of higher rainfall & creek flow to refresh the pit. The pit wall and constructed pit berm around the perimeter of the pit contains the pit unless in high flow: diverts additional surface water catchment flow around the pit to the creek, & with the pit wall is able to contain water within the pit whilst the pit drains. Pit lake has an obligation to remain above fresh (sulphide) rock & maintain a minimum 160mAHD water level. Borrow pit is 3-4m depth maximum, captures flow down Yandan Creek (undisturbed catchment) which flows to Suttor River & to eastern pit intake at 169mAHD.
East pit	Narrow pit void with flow & safety restriction berm. Oxide & sulphides zones mined.	East pit is 0.9ha surface area as a narrow entrance pit & appears to be to depth of at least 20m (184mAHD at surface to water surface at 168mRL) from surface to water surface. Historical knowledge of the complete pit void is currently unknown. A partial pit lake, water will spill only if water levels exceed 184mAHD. Obligation to keep pit lake levels above 160m AHD.
South pit	Filled in pit void to surface & above: only oxide ore mined.	
Heap leach pad	Leaching stockpile, perimeter water capture drain, leach pond, process pond & levee banks. Contains oxide materials.	Surface area of 17.5 hectares, ranging up to 38m high from 212mAHD to 174mAHD. Situated at the highest elevation of the site wrapped across the top of a low hill. Constructed from low grade oxide materials, interbedded with limestone to lift pH to liberate gold through cyanide leaching. Likely to be unlined or prepared ground. Leach & process pond lay on downgradient side of leach pad, ponds were originally lined but are currently in disrepair. Perimeter drain contains a large amount of sediment & is likely to be only partially effective.
Tailings	Tailings landform & embankment & landform, containment dam (borrow pit), spillway & additional borrow pits around perimeter. Contains oxide & sulphides materials.	Low lying & gradient landform wrapped across the landscape in broad pad like form wrapped across landscape with minimal gradient change. Tailings embankment is generally 1-5m around most of the perimeter, extending to 12m height at highest point at the lower embankment (179mAHD to 191mAHD). Two cells: Cell A (western & partly rehabilitated) contains predominantly oxide tailings, Cell B contains a mix of oxide & fresher rock (sulphide) tailings, which is not rehabilitated. Cell A appears to be to form a surface pond, with an overflow to the returns dram. Cell B has no formed drainage but flows to Cell A. Materials in the tailings dam may be enriched in alkalinity given the amount of lime applied in CIL processing. Series of shallow & small borrow pits around the perimeter of the tailings embankment(s). Tailings containment (or returns dam) has a 9m dam wall for a storage capacity estimate of 1,035ML.
Water storage dam(s)	Raw water dam (water supply dam) – wall height of 7.5m, capacity of 1300m. Downstream of tailings & tailings containment dam. Mine water (or process water dam) – wall height of 8m, currently raw water, full capacity 450ML. Diversion drain from Suttor River not in use.	



Table 3 - Receiving environment sites & purpose

Site	MPID	Status	Role	Description	East	North
REMP1	SR3a	Reference	Compliance	Upstream of project site on Suttor River	496050	7644545
REMP2	SR3b	Reference	Compliance	Eastern side of the Tailings dams, along Sandy Creek	501308	7647055
REMP3	SR4	Reference	Compliance	East of REMP7, upstream on Yandan Creek	499214	7645089
REMP4	SR1	Impact	Compliance	Downstream of release point (REMP6) on Suttor River	496750	7645460
REMP5	SR2	Impact	Compliance	Downstream of site & release point on Suttor River	496820	7646759
REMP6	MP1	Impact	Compliance	West Main Pit Dam Spillway Overflow on Suttor River	496790	7645177
REMP7	MP2	Impact	Compliance	East Main Pit Dam Spillway Overflow on Suttor River	497191	7644940

Table 4 - Surface water & storages monitoring locations

SiteID	Site area	Frequency	Northing	Easting
HLPP1	HL Pregnant Pond	Regular	7645013	498090
HLSP1	HL Stormwater	Regular	7644897	498141
TRD1	Tailings Return Dam	Regular	7646643	499476
MW1	Mine Water Dam	Regular	7646108	497791
EHP1	East Hill Pit	Regular	7645142	497674
WS1	Water Storage Dam	Regular	7646481	497641
TD Cell A	Tailings Dam Cell A	As possible	7647146	499717
TD Cell B	Tailings Dam Cell B	As possible	7646668	500289
GIL6	Below Water Supply Dam	As possible	7646511	497593
TDP1	Pond Near Cell B of TSF	As possible	7647130	500950
TDP2	Pond Near Cell B of TSF	As possible	7647157	501071



Table 5 - Groundwater monitoring bores & purpose

	Site area	Bore purpose	Aquifer	Depth	East	North	mAHD
RB1D	Reference	Reference	Siltstone	30m	500400	7645740	193
RB1S	Reference	Reference	Siltstone	10m	500400	7645740	193
RB2D	Reference	Due diligence	Siltstone	30m	498940	7646310	174
RB2S	Reference	Due diligence	Siltstone	10m	498940	7646310	174
HL1	Heap Leach	Compliance	Unknown (historical)	~18m	498095	7644871	172
HL3	Heap Leach	Compliance	Unknown (historical)	~18m	498285	7644838	172
HL4	Heap Leach	Compliance	Unknown (historical)	~17m	497914	7644965	177
HL5	Heap Leach	Compliance	Unknown (historical)	~24m	498359	7645104	177
HL6	Heap Leach	Compliance	Unknown (historical)	~25m	498322	7645359	180
HL7	Heap Leach	Compliance	Unknown (historical)	~25m	498145	7645428	179
SH3	South Hill pit	Compliance	Unknown (historical)	~19m	497421	7644571	169
TD3	Tailings	Compliance	Unknown (historical)	~15m	499334	7646725	179
TD4	Tailings	Compliance	Unknown (historical)	~16m	499617	7647435	188
TD5	Tailings	Compliance	Unknown (historical)	~16m	500549	7647883	192
TD6	Tailings	(Retired)	Unknown (historical)	Unknown	499436	7646581	178
TD6D	Tailings	Compliance	Siltstone	30m	501010	7647150	188
TD6S	Tailings	Compliance	Siltstone	10m	501010	7647150	188
TD7	Tailings	(Retired)	Unknown (historical)	Unknown	500549	7647883	192
TD7D	Tailings	Compliance	Siltstone	30m	499436	7646581	178
TD7S	Tailings	Compliance	Siltstone	10m	499436	7646581	178
WSB1	Water supply dam	Water supply	Unknown (historical)	~24m	497598	7646464	169
WSB2	Water supply dam	Water supply	Unknown (historical)	~24m	497588	7646599	169



Yandan site layout

Figure 2 - Overview of Yandan site, monitoring locations & landscape



3 Water systems setting

3.1 Landscape

3.1.1 Regional

Yandan sits within the broad valley of the Burdekin catchment on the Suttor River, 50km upstream of the Burdekin dam. Topography of the area generally consists of broad valleys & relatively low gradient areas, with isolated low elevation hills formed through rocky outcrop.

Drainage lines are low gradient, forming broad, predominantly ephemeral & generally alluvial rich drainage lines. Soils range from black & sandy soils across river alluvial areas through to poorly developed & rocky soils from volcanics & meta-sediments on slopes & near absent on hilltops.

Vegetation zone is eucalypt woodland to grasslands as part of the Brigalow BioZone (Queensland Government 2021). However, the broad region is extensively cleared for agricultural purposes, as dryland & stock farming, but with occasional irrigation areas. There are a number of other historical gold mines both upstream & downstream of the site.

3.1.2 Yandan site

Yandan site is a gently undulating site, rising from adjacent to the Suttor River at around 168mAHD to 191mAHD at the tailings area in the east over 3 kilometers (Figure 3). There are three (3) small hills on the site, rising generally 5-10m, but up to 30m from the broad depression where the Suttor River flows. The highest elevation on the site is 212mAHD as the top of the heap leach pad. Mount Coolon township lays at ~230mAHD.

Grass is developed across much of the site, with few trees. In previous mining areas (including infrastructure) the site remains disturbed but is predominantly stable, with infrastructure & landforms in place for more than 20 years.



Figure 3 - View north over Yandan project site from top of heap leach pad

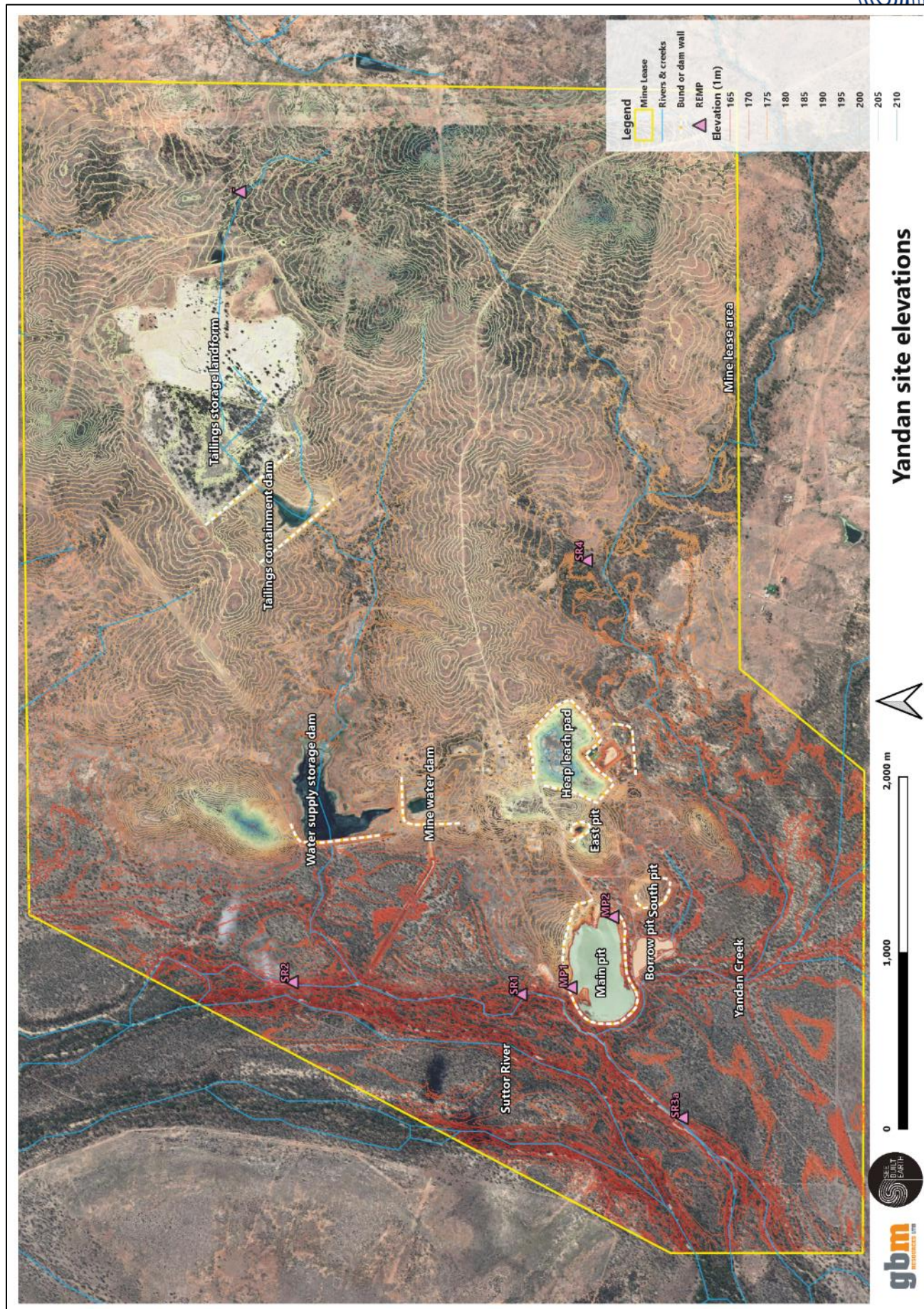


Figure 4 – Contours & elevation of Yandan site & landscape



3.2 Surface water

3.2.1 Regional

Yandan sits within the Burdekin River catchment in the mid-reaches of the catchment supplying Burdekin dam & downstream of the township of Mount Coolon on the Suttor River, just after the confluence of the Suttor River, Police Creek & Belyando River (Figure 6).

The Suttor River is a wide, ephemeral braided river, flowing after rainfall over wet seasons in wide & low energy flow as observed during the site visit for the project (Figure 5). Most local creeks & rivers around the project site are ephemeral, flowing only after rainfall & acting as losing streams (not fed by groundwater), & forming water holes during drier seasons.

There are two relevant gauging sites upstream & downstream of Yandan which track flow, water levels & quality since the 1970's:

- Belyando near Gregory Highway (Mount Douglas) (120301A/B upstream) with records since
- St Anns Station (120303A downstream).

Flow records for both stations are provided in Figure 7, showing the seasonal nature of flow & the capacity of the system to convey large volumes of water. Notably, there is a step up in flow volumes/rates at St Anns from flow measured at Mt Douglas given St Anns lays further down the catchment. Figure 8 shows river heights over the same record: with an interpolated base of river at 163mAHD, the Suttor River regularly rises 5-8m in flood to around at 168-170mAHD.

Both gauges also provide an electrical conductivity (uS/cm) record measured only during flow events (Figure 9, Figure 10) showing salinity generally remaining below 500 uS/cm over the past 20 years with the exception of short-term higher salinity experienced during the major regional flooding event in 2011. Comparison of upstream & downstream salinity would suggest an additional salt load entered the river during this significant event, similar to occurrences across the Queensland region for this event. A Yandan downstream receiving environment (SR1) sample collected during this time placed electrical conductivity at ~1,200uS/cm.



Figure 5 -Suttor River approximately 50km upstream of Yandan

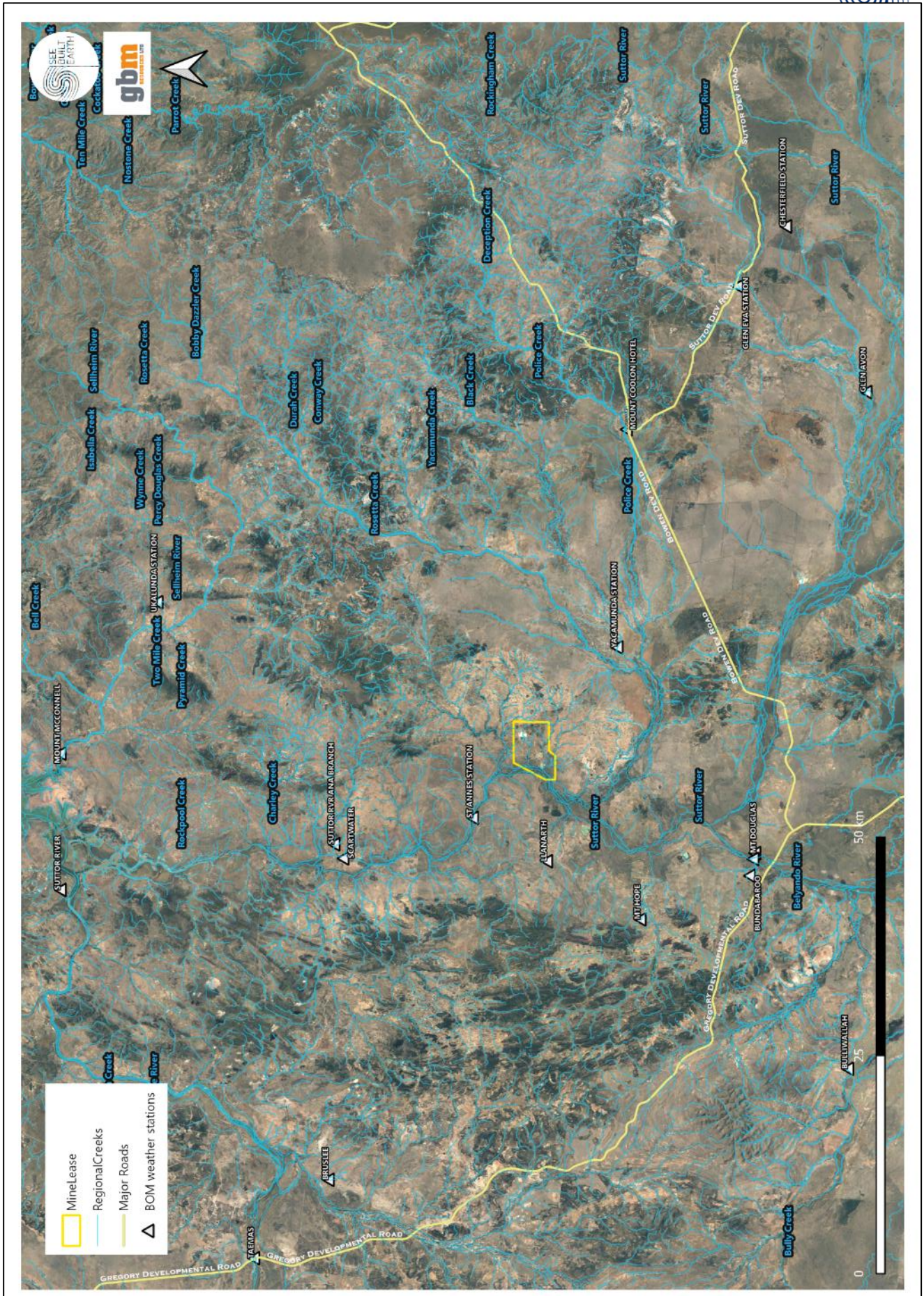
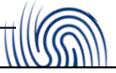


Figure 6 - Regional surface water setting of Yandan

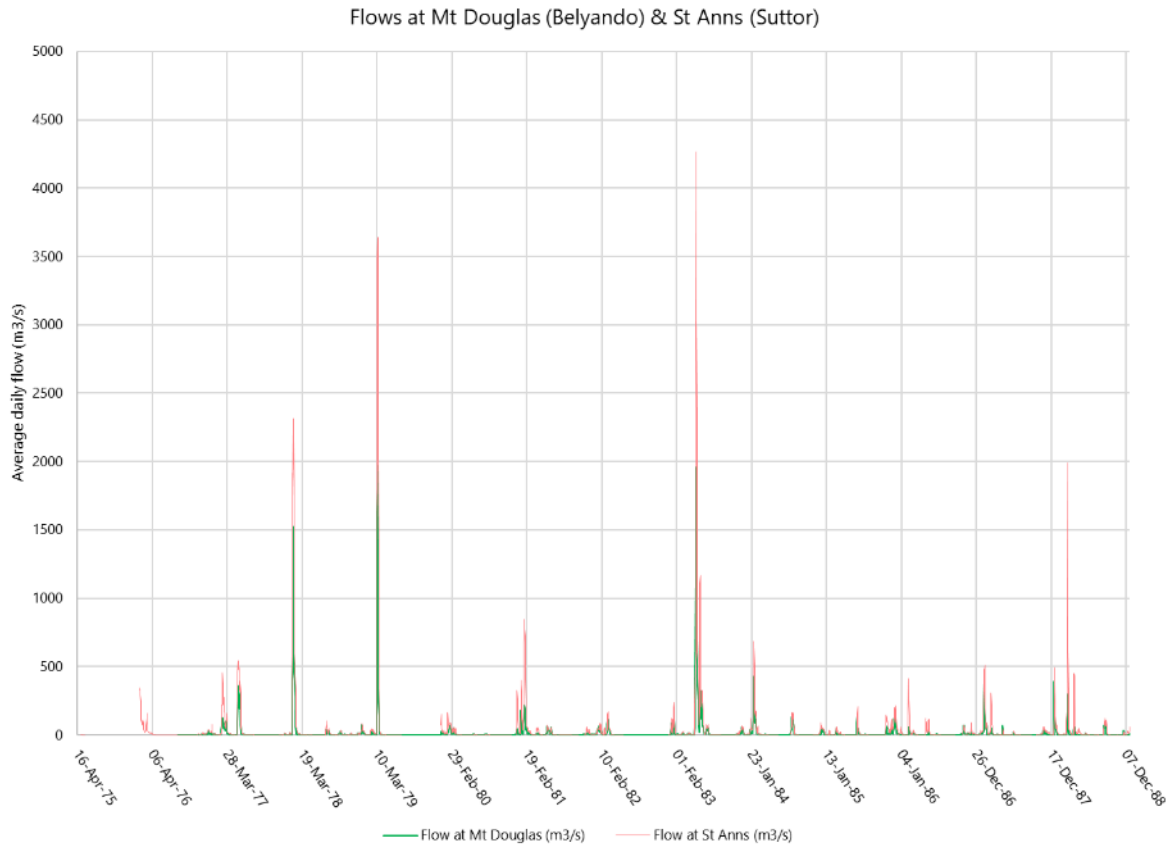


Figure 7 - Average daily flows at regional river gauging stations

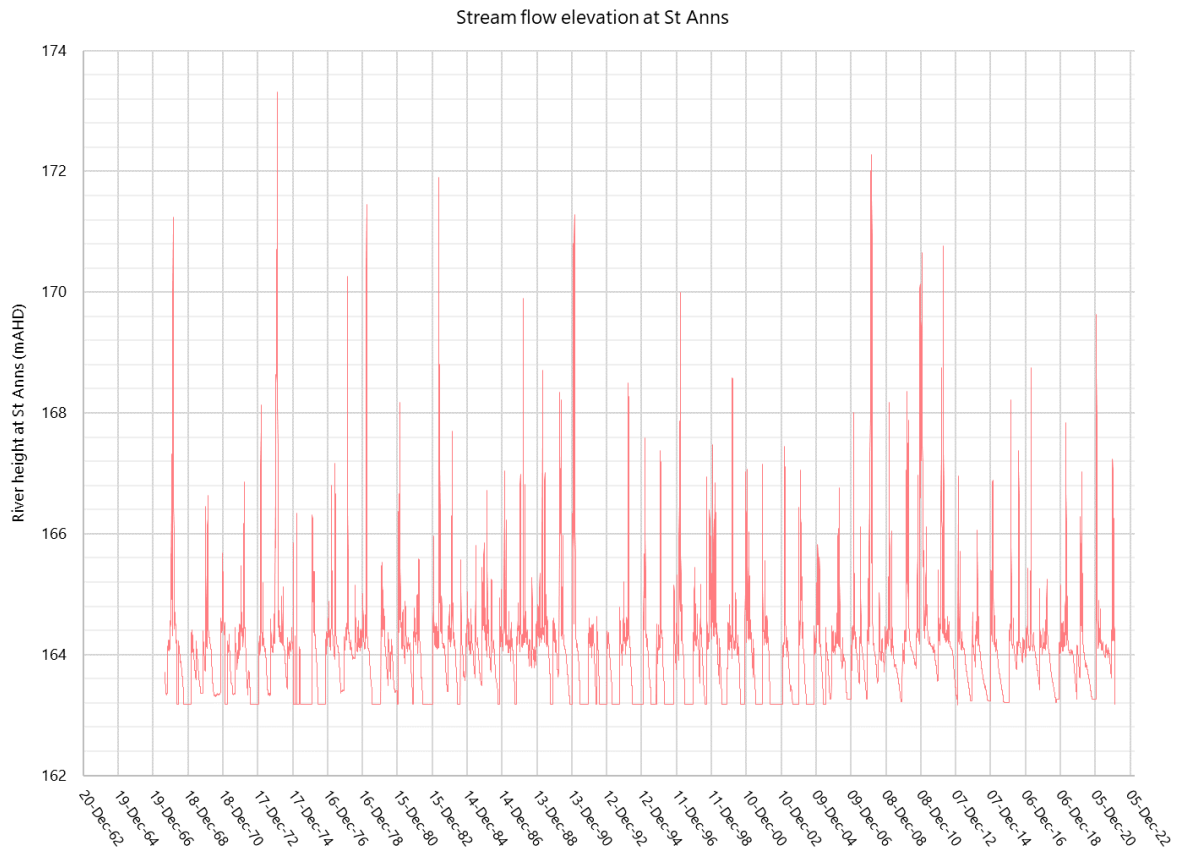


Figure 8 – River heights at St Anns Station

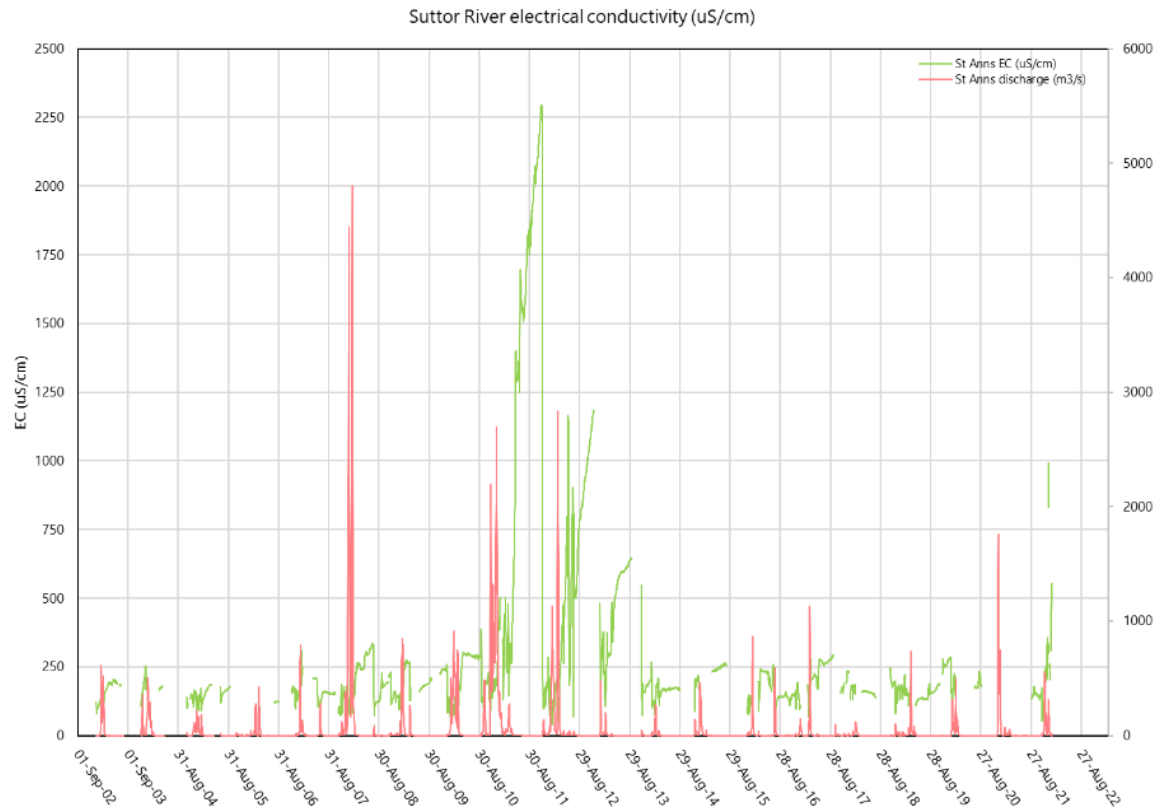


Figure 9 - St Anns Suttor River flow & conductivity

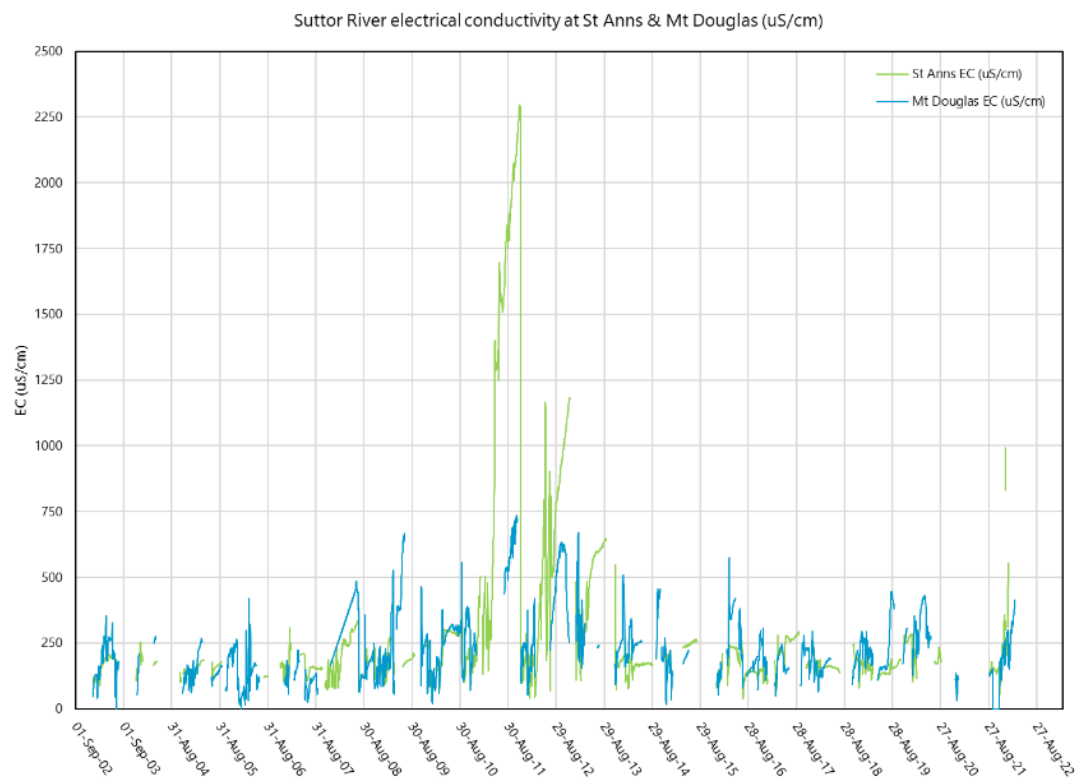


Figure 10 - Suttor River electrical conductivity since 2002



3.2.2 Yandan site

Drainage of the current Yandan site is formed through a combination of natural topography & mining landforms. Drainage direction is generally east to west with topography, with some bund walls creating flow diversions or containment. The project area sits close to the top of a small sub-catchment draining to the Suttor River (Figure 12).

Figure 13 shows site catchments with marked up flow directions & nature of catchment (green – undisturbed catchment, yellow – potentially mine impacted). Details of catchments are detailed in Table 6, with a map of catchments & flow directions across the site in Figure 13. Monitoring locations for site storages & water ponds are shown, along with receiving environment. Notably several sampling sites are borrow pits or ponded areas, near to Main Pit & also around the tailings storage. Further information relating to surface water of Yandan site is provided in the domain assessment.

The Suttor River runs along the western extent, flowing north towards Burdekin Dam 50km to the north. The Suttor River runs close to the periphery of Main Pit, & Main pit has two spillways which enable hydraulic connections between the pit lake & river flow from the Suttor or Yandan Creek when water level exceeds 169mAHD. Yandan Creek enters the project area from the south & is diverted around Main Pit before joining the Suttor River. Conditions are generally dry, with drainage lines only flowing after rainfall.

The pit is required to maintain a minimum water level of 160mAHD to minimise water quality impacts. Views of the Suttor River near the discharge point are shown in Figure 11.

Table 6 - Summary of surface water catchments

Code	Description	Area m ²	Area ha	Status
B-01	Borrow pit catchment (Yandan Creek)	60,537,540	6,054	Undisturbed
B-WS	Borrow pit water surface	26,258	2.6	Undisturbed
E-01	Catchment reporting to East Pit	28,827	2.9	Mine impacted
E-Pit	East pit direct area	9,048	0.9	Mine impacted
E-WS	Water surface of East pit	1,190	0.1	Mine impacted
L-02	Leach pad stormwater area	53,560	5.4	Mine impacted
L-Dam	Leach pad stormwater pond	16,344	1.6	Mine impacted
L-Pad	Leach pad direct catchment	174,152	17.4	Mine impacted
L-Pond	Leach pad ponds	3,990	0.4	Mine impacted
M-01	Catchment reporting to Main Pit	224,625	11.3	Mine impacted
M-Pit	Main pit area	63,049	21.9	Mine impacted
M-WS	Main pit water surface	156,207	15.6	Mine impacted
S-Pit	South pit direct area (rehabilitated)	29,567	3.0	Undisturbed
T-01	Catchment reporting to tailings storage	919,825	92.0	Undisturbed
T-02	Catchment reporting to tailings storage	260,723	26.1	Undisturbed
T-03	Catchment reporting to tailings storage	282,502	28.3	Undisturbed
T-CellA	Cell A of tailings storage	426,307	42.6	Mine impacted
T-CellB	Cell A of tailings storage	726,984	72.7	Mine impacted
T-Dam	Tailings dam water catchment	36,689	3.7	Mine impacted
WS-01	Catchment reporting to water supply dam	3,257,776	325.8	Undisturbed
WS-Dam	Water supply dam surface	410,325	41.0	Undisturbed
MW-01	Mine water dam catchment	42,336	4.2	Undisturbed



Figure 11 - View of Suttor River near discharge zone of Main Pit

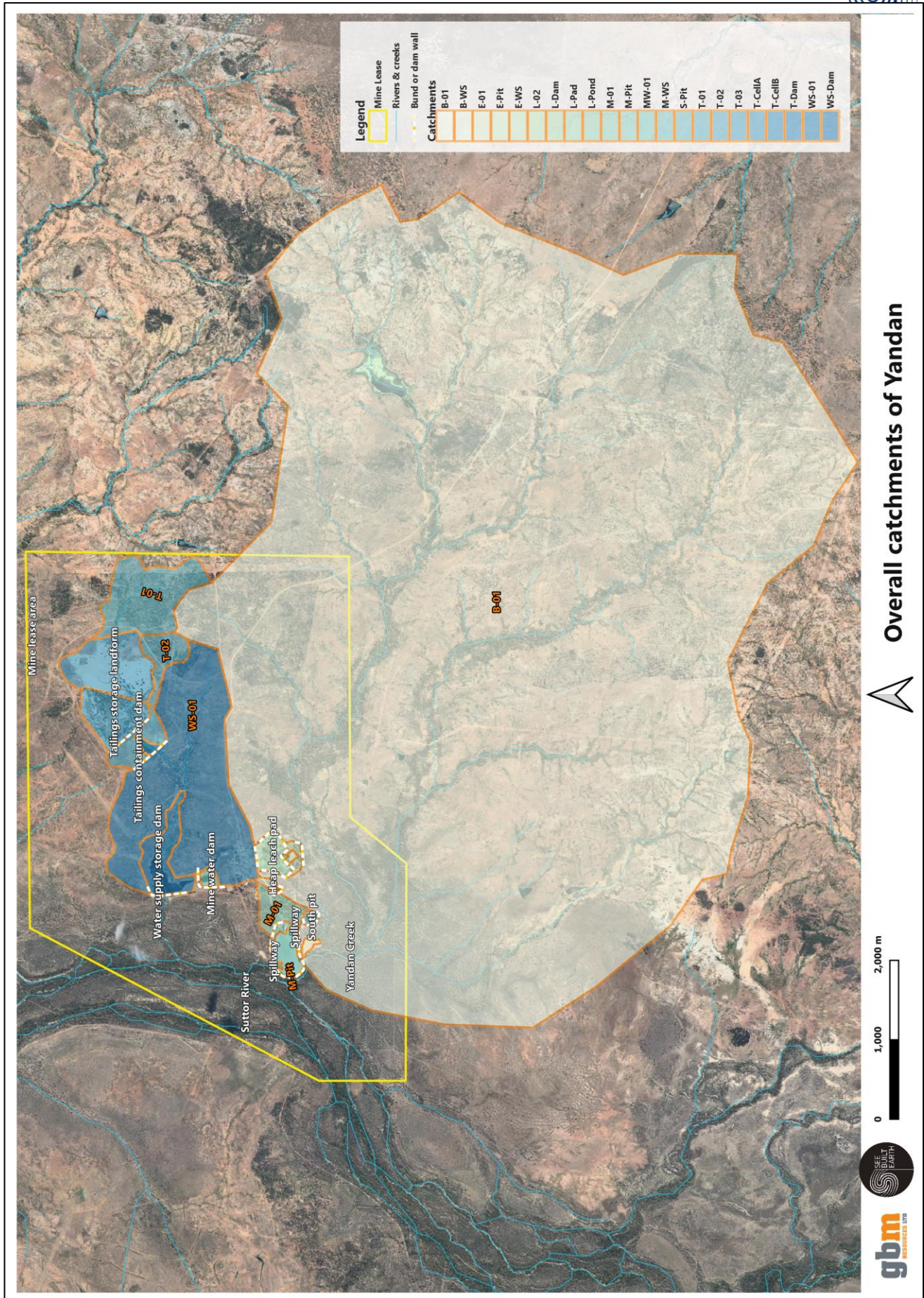


Figure 12 – Broader surface water catchments of Yandan site

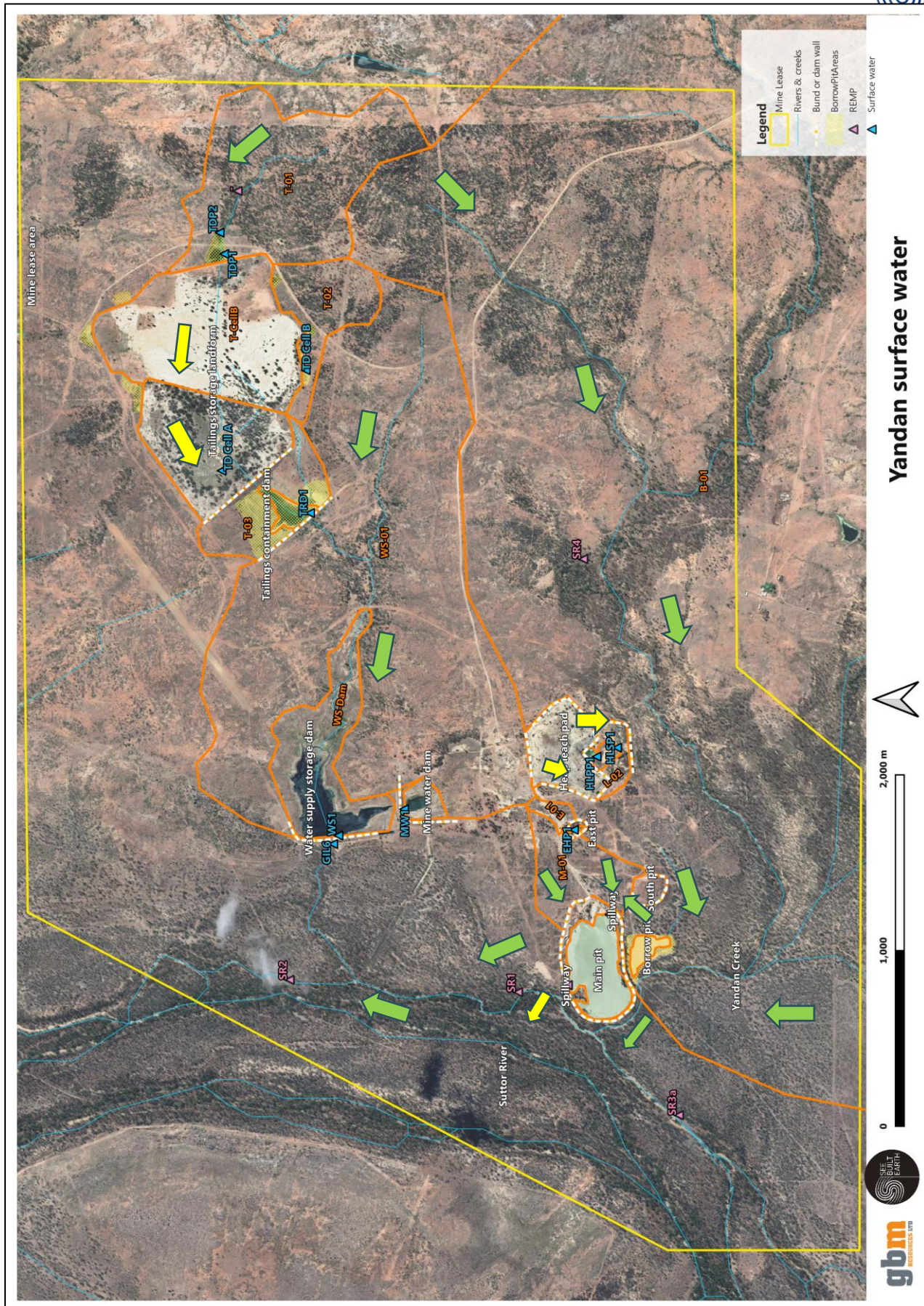


Figure 13 – Surface water framework of Yandan site with catchments & drainage directions



3.3 Geology

3.3.1 Regional

Regional geology of Yandan lays in the broad basin of the Drummond Basin, consisting of volcanics & sediments of Middle Devonian to Lower Carboniferous age (Carver & Chenoweth 2003). The Drummond Basin forms a broad valley, extensively overlain with alluvial deposits around the Suttor River.

Volcanic rocks generally occur as hills or rocky areas as more resistant to erosion. Where altered through hydrothermal activity such as associated with gold, weathering can be more extensive. Common volcanic rocks are dacite, andesite, ignimbrite & sinter. Sedimentary rocks of the Drummond Group occur as siltstone, limestone & sandstone.

Peaks around the area are often the Suttor Formation: sandstones units which are Tertiary in age & have been eroded & incised to form the modern landscape.

3.3.2 Yandan site

Yandan mine is situated on the Anakie High consisting of volcanics, sandstones & siltstones at the base of the Drummond Trough. The Anakie High abuts the alluvium of the Suttor River & St Anns Formation, likely via a structural contact. Ukalunda Formation of siltstones lays to the east, with sandstone & limestone, also likely via a fault contact.

Gold extraction accesses low-sulphidation epithermal gold deposits from surface which occur as hydrothermal veins & zones, with a hydrothermal alteration including a porous boiling zone. Mineralisation occurs as oxide in the altered & weathered zone, or in fresh rock lenses & veins at depth as sulphides (Figure 14).

Oxide & fresh rock are both present & are loosely termed oxide & sulphides as different ore types, however the overall system is low-sulphidation. Oxide ores are formed through hydrothermal alteration of rocks & then subsequent leaching through fluids or rainfall which oxidises sulphur to form changed minerals & often more porous materials, whereas fresh rock mineralisation occurs at depth & tend to be highly silicified, crystalline, brittle & low porosity.

Faults occur across the site, particularly around mineralised zones, with the most important being the Yandan East fault to the east of mineralised areas. Structural trends follow north/south & north-east/southwest orientations.

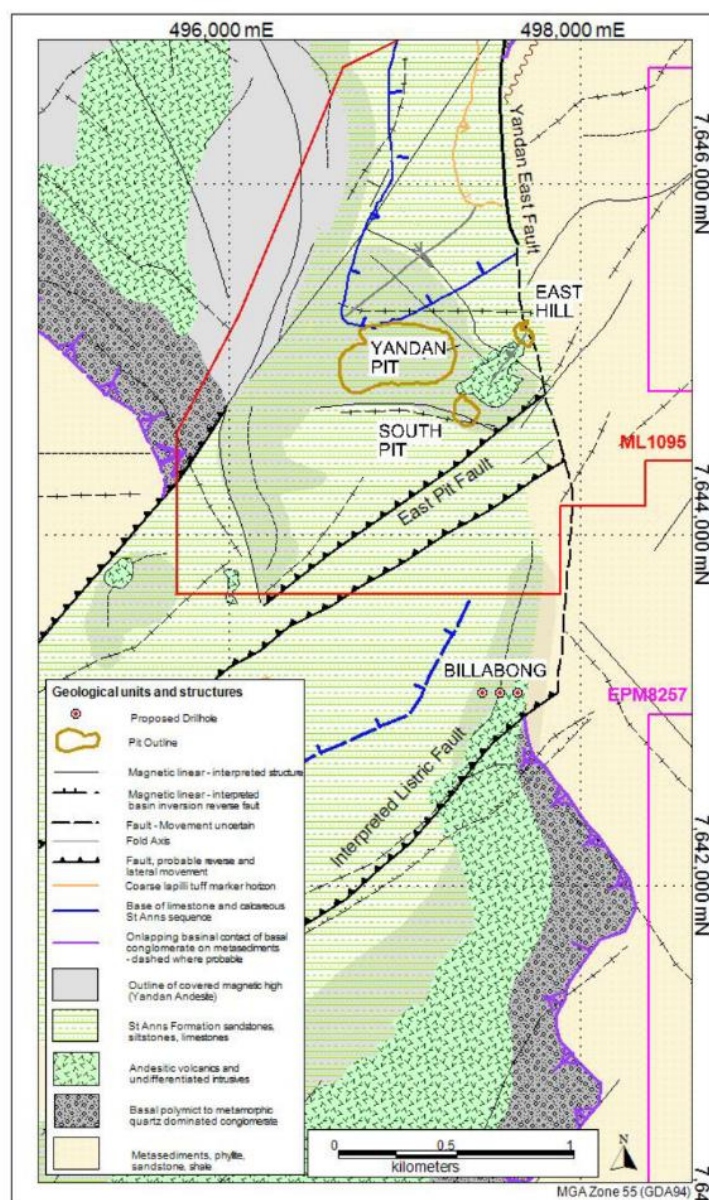


Figure 14 - Geology of Yandan site



3.4 Materials geochemistry characterisation (ARD/AMD)

3.4.1 Tailings & leach pad

Geochemical assessment of host materials at Yandan is informed by four (4) main studies:

- Tailings rehabilitation studies – 26 samples Dwyer (internal), circa 1999 for Ross Mining.
- Heap leach assessment – 20 samples - EGI 2002 for Warralie Mines.
- Combined heap leach & Cell B tailings – 6 samples - RGS 2013 for Straits Resources.
- Oxide & tailings assessment – 85 samples – RGS 2015 for Straits Resources.

Outcomes from each study are presented into an ARD classification matrix in Figure 15.

Heap leach pad characterisation as low-grade oxide materials is expected to be:

- Non-acid forming but may generate saline runoff & seepage.
- Likely to increase calcium, sulphate, chloride & sodium runoff given the extent of lime addition through the heap leach.
- Enriched & metals of interest are arsenic, mercury, antimony, silver, lead & selenium. Mercury is not anticipated to be mobile.

Review of heap leach materials in 2002 & 2013 characterised heap leach materials as benign.

Tailings (particularly sulphide tailings) has changed in characterisation in the twenty (20) years since tailings construction. Initial assessment in 1999 indicated:

- Tailings as oxide materials are uncertain, but do not have a clear ARD signature.
- Potential for saline drainage.
- Enriched elements of interest of arsenic, copper, zinc, manganese, chromium, antimony & cobalt with changing profiles across oxide & sulphides zones (Figure 16).
- Tailings as fresh materials is higher in sulphur (Figure 17) has a low marker to potentially acid forming, but when combined with oxide tailings (such as in Cell B) reduces.

However, subsequent review in 2015 of 76 tailings samples found nearly all were essentially now either low acid forming potential (LAFP) to inert. The study concluded that there was an absence of sulphides mineralisation remaining given leaching over the past 20 years (Figure 17) with complete oxidation & precipitation of sulphate minerals such as jarosite ($\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$), & no longer qualified as potentially acid forming (RGS 2013, 2015).

3.4.2 Main pit

Yandan main pit exists as a pit lake since 1999, designed as a water cover closure outcome to encapsulate both fresh sulphides ore in pit walls & waste rock deposited into the pit prior to filling with water.

Figure 18 shows a map of where & what materials were placed in the pit prior to filling (SRK 1999), with a backfill cover of lime layers to offset short term acidity until the cover could be established.

To ensure coverage of materials & not expose pit walls or materials to oxidation, pit lake water levels are required to remain above 160mAHD to maintain water cover & control oxidation.



Acid base accounting - all known samples

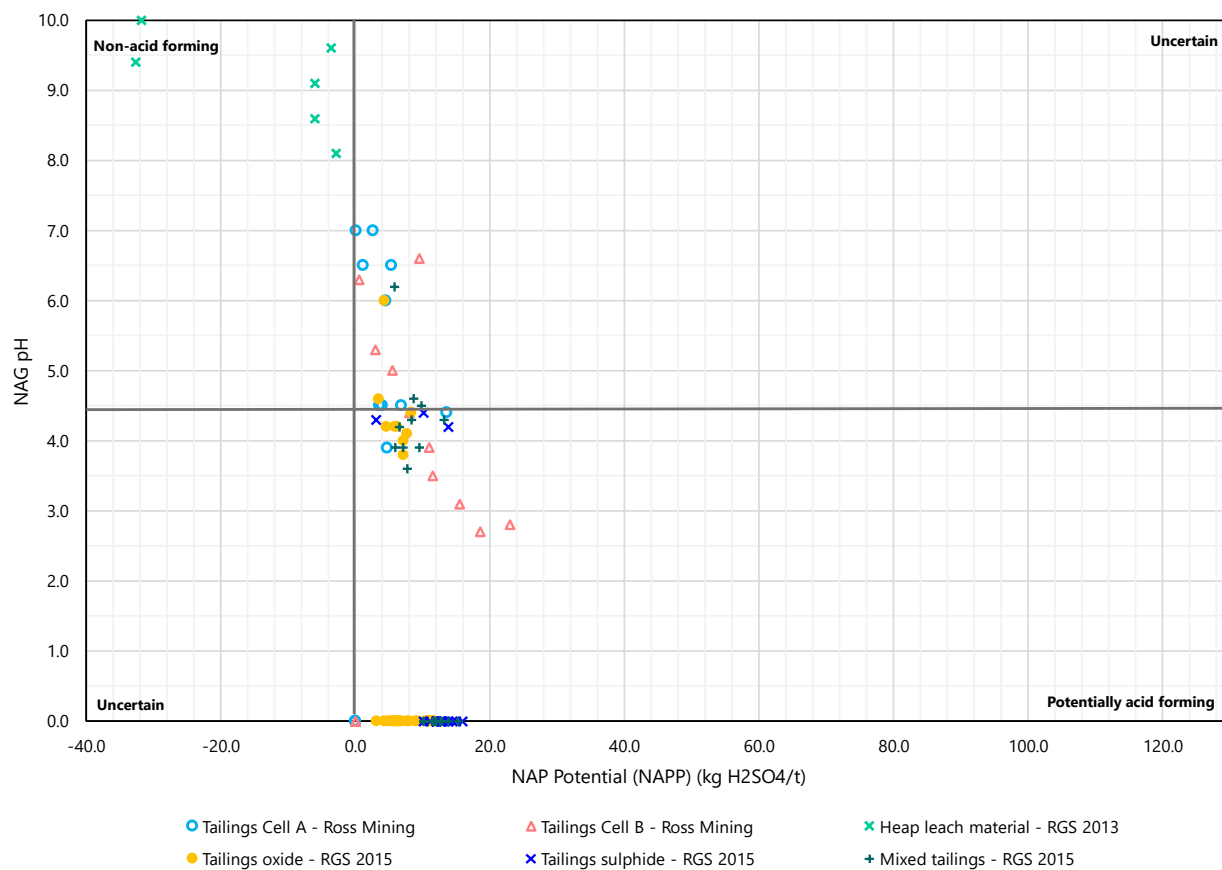


Figure 15 – Acid base accounting matrix for all known tailings & leach samples

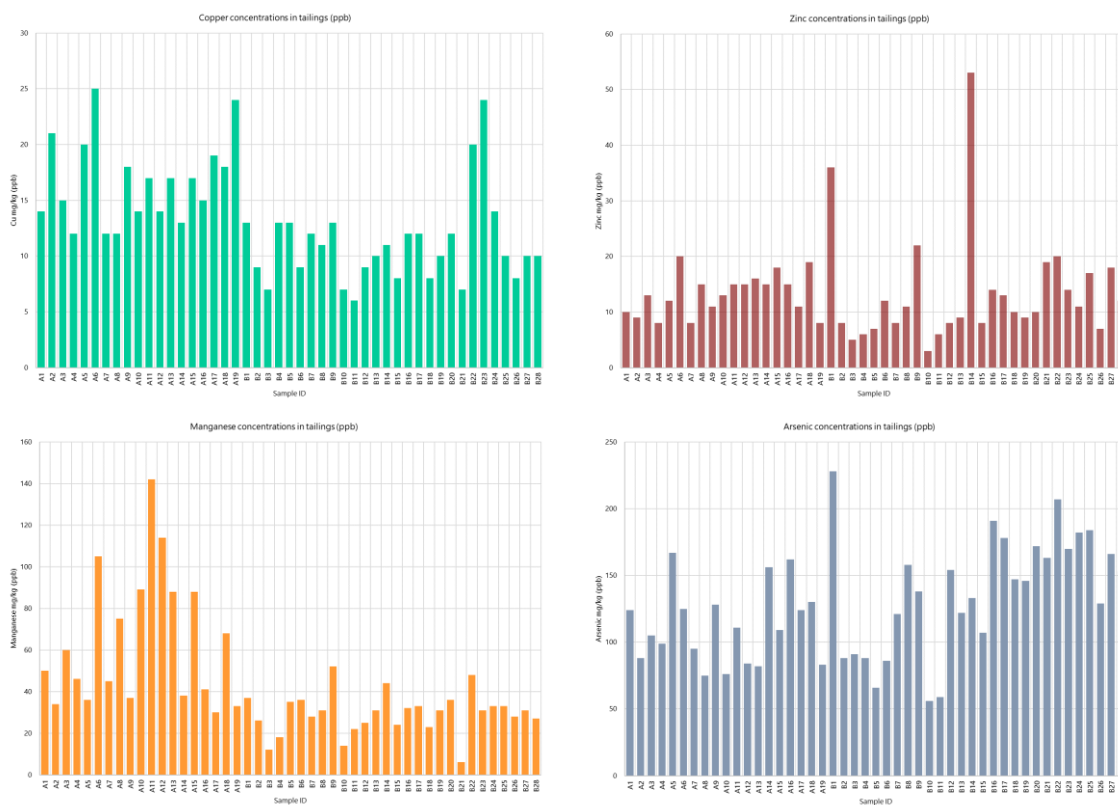


Figure 16 – Key metals concentration distribution (ppb) in tailings from Dwyer (1999)

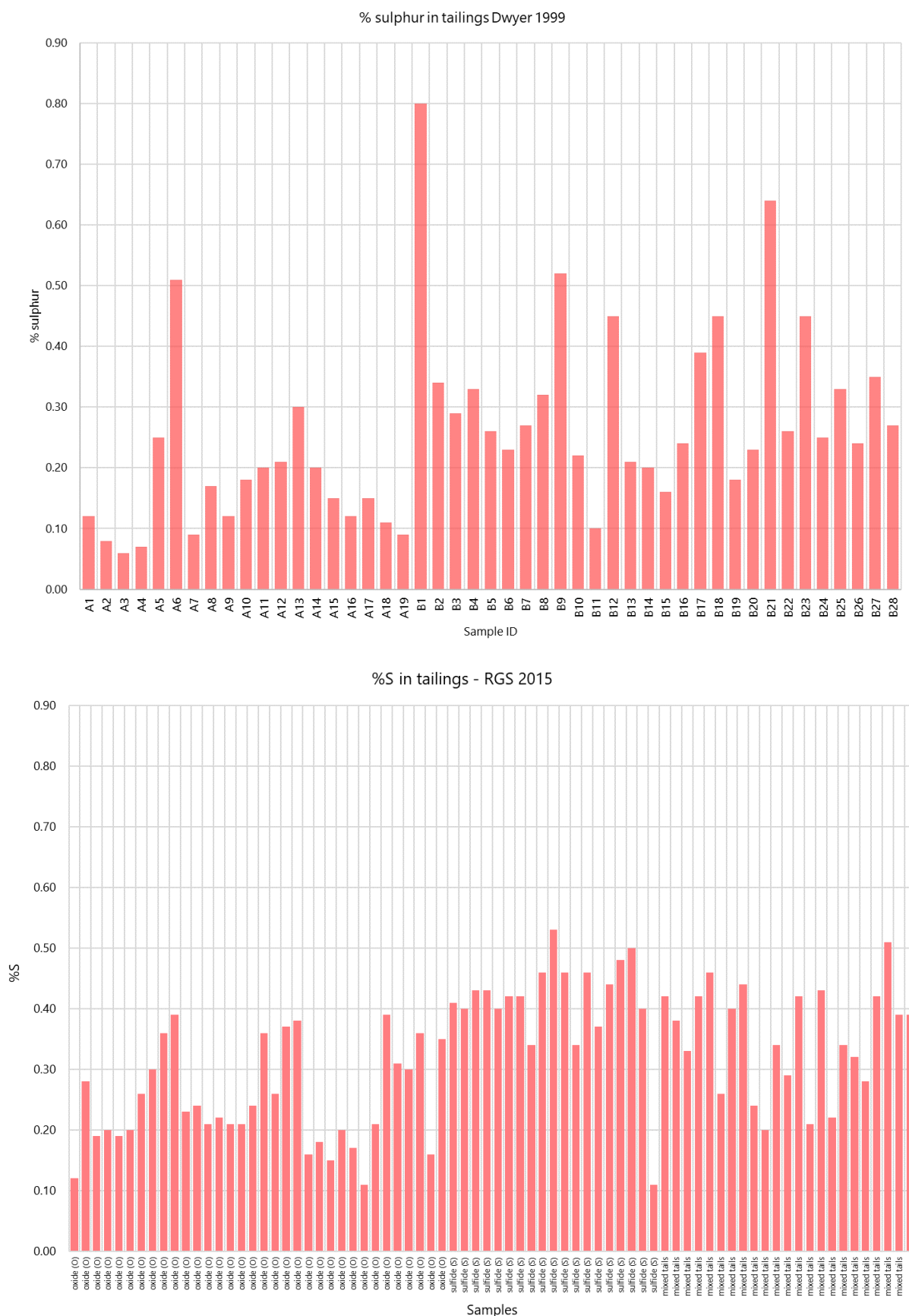


Figure 17 - % sulphur in tailings changes over time

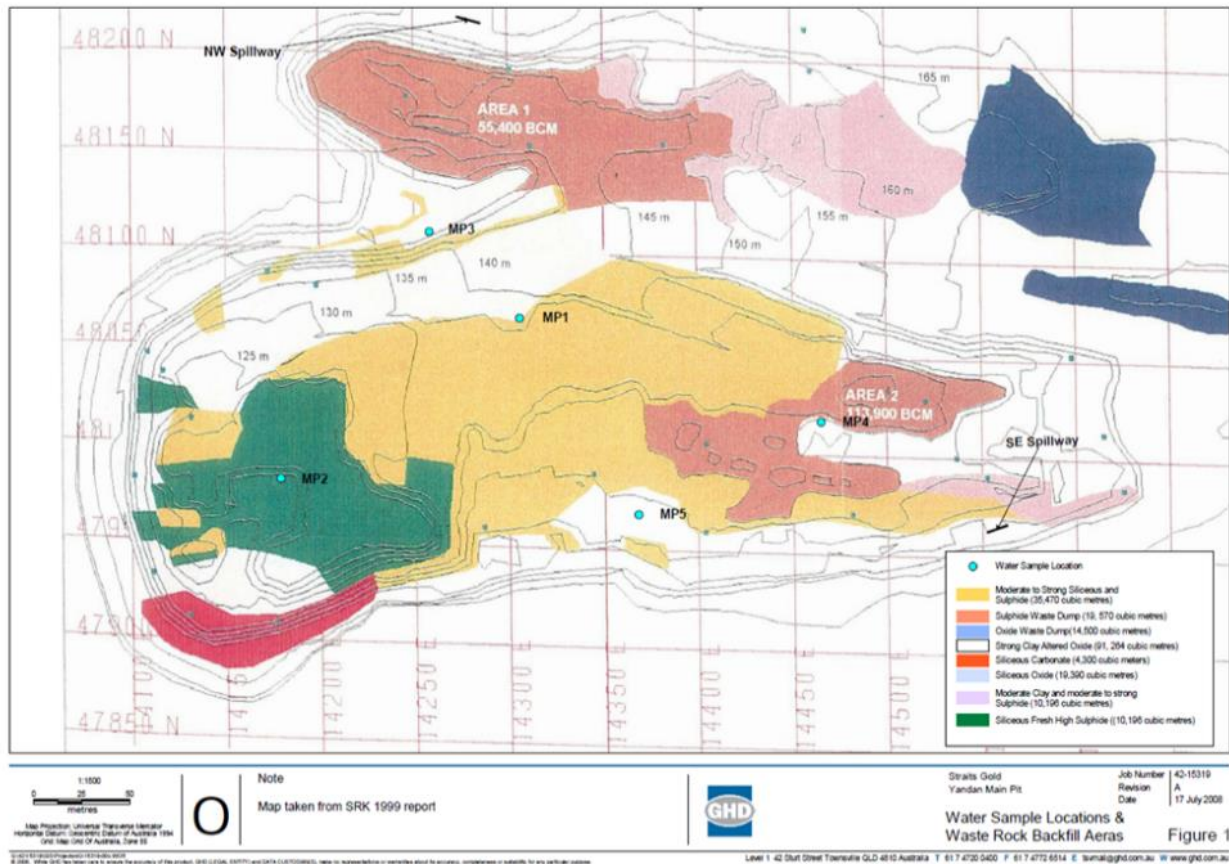


Figure 18 - View of reactive materials stored & in wall rock of Main pit



3.5 Climate

3.5.1 Rainfall

The central highlands of Queensland sits in a sub-tropical to semi-arid savannah climate, with hot, dry to wet summers & mild, dry winters. The area frequently experiences extended dry periods, interrupted by tropical wet season rainfall, characterised by downpours or larger tropical low systems crossing the coast. When rain does occur, it can be intense & highly localised, capable of depositing large depths of rain & varying significantly across the landscape.

Specific rainfall data is not available for Yandan site area, however good records are available at Mount Douglas (50km south) & St Anns (10km north) as Bureau of Meteorology sites (locations in Figure 19).

Since 1900, rainfall predominantly varies between 400-800mm/year, though can range from as low as 200mm/year & or up to 1,100mm/year associated with cyclones & tropical lows into Mackay. Dry conditions prevail – with an average of 315 days without rain per year: rainfall occurs of annual rainfall occurs in just a few events each year. Figure 20 plots daily & seasonal cumulative rainfall (July to June) for the past 20 years.

Rainfall also varies over time: a residual rainfall chart (deviation from average) in Figure 21 shows the seasonal cycle of rain, with broader cycles of wetter & drier periods over the record, with clear capacity for extreme wets events & severe dries. Since 2012, the region has experienced drought conditions & the last two years average rainfall. Since Yandan was mined, the region has undergone a drier period, then a wetter period & since 2012 another wet period except since 2012.

3.5.2 Evaporation & wind

Daily rates of evaporation & average wind speeds for the project are adapted from pan evaporation measured at the closest regional station available: Moranbah Water Treatment plant, Twin Hills & Collinsville Post office. Table 7 summarises average daily evaporation by month for each station.

Evaporation ranges from ~3mm/day over the cooler winter period, through to ~8.0mm/day in November-December, in demonstration of the heat capacity in summer, particularly in the absence of seasonal rains. Average annual potential evaporation equates to approximately 2,094mm. Wind speeds (Table 8) range around 5kph to 9.6kph across a year.

Table 7- Evaporation rates for the Mount Coolon area

Station	Dir	J	F	M	A	M	J	J	A	S	O	N	D	Average/day	Total/year
MoranbahWater Treatment	SE	8	7.4	6.8	5.7	4.3	3.5	3.7	4.9	6.6	8	8.5	8.5	6.3mm	2,306mm
Twin Hills	SW	7.5	6.5	6.1	5.2	3.6	2.9	3.1	4.2	6.1	7.9	8.6	8.7	5.9mm	2,140mm
Collinsville Post Office	NE	6.2	5.7	5.2	4.4	3.5	2.9	3.2	4.1	5.3	6.5	6.9	6.9	5.1mm	1,840mm
Average/month		7.2	6.5	6.0	5.1	3.8	3.1	3.3	4.4	6.0	7.5	8.0	8.0	5.8mm	2,094mm

Table 8 - Temperature & wind speeds at Moranbah Water Treatment Plant

Station	J	F	M	A	M	J	J	A	S	O	N	D	Average annual
9am temperature (°C)	26.4	25.8	24.7	22.1	18.9	15.4	14.7	16.6	20.6	24.0	25.3	26.4	21.7
9am wind (km/h)	7.5	7.7	8.1	7.6	6.2	5.5	5.3	6.6	7.7	8.4	8.4	8.4	7.3
3pm temperature (°C)	32.7	31.9	31.2	28.6	25.8	22.9	22.9	24.6	28.3	31.4	32.2	33.0	28.8
3pm wind (km/h)	8.8	9.6	9.4	8.7	6.9	6.6	7.0	7.7	8.3	8.4	8.9	8.8	8.3

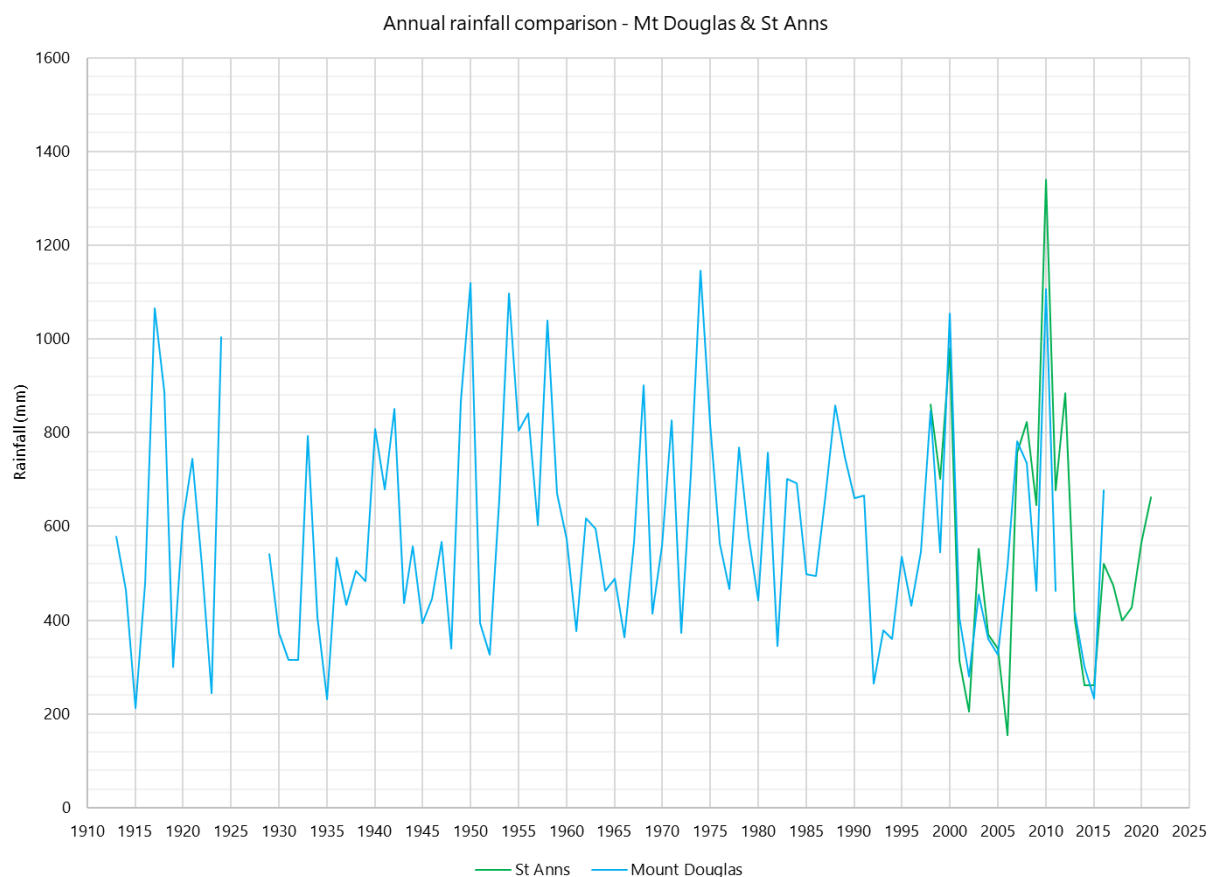


Figure 19 - Annual rainfalls of local stations

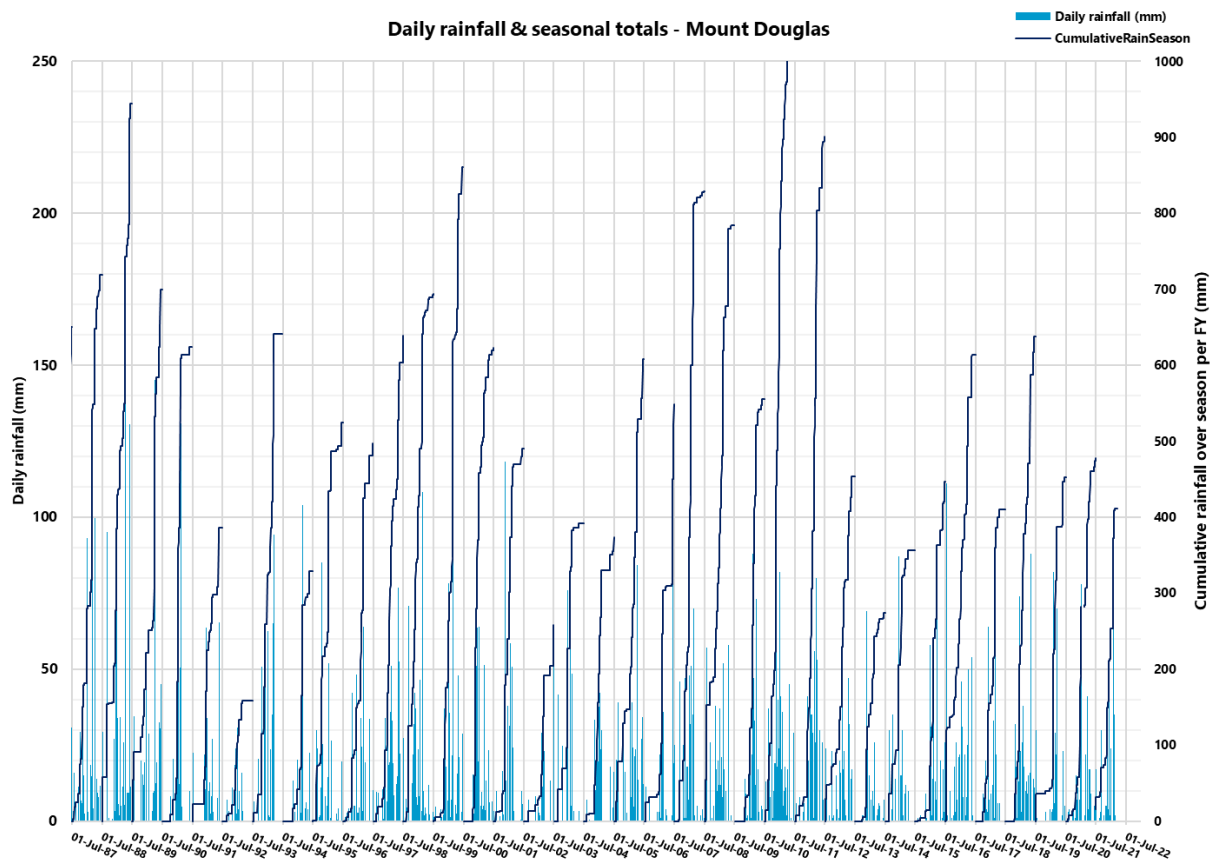


Figure 20- Seasonal annual rainfall in region 1987-2021

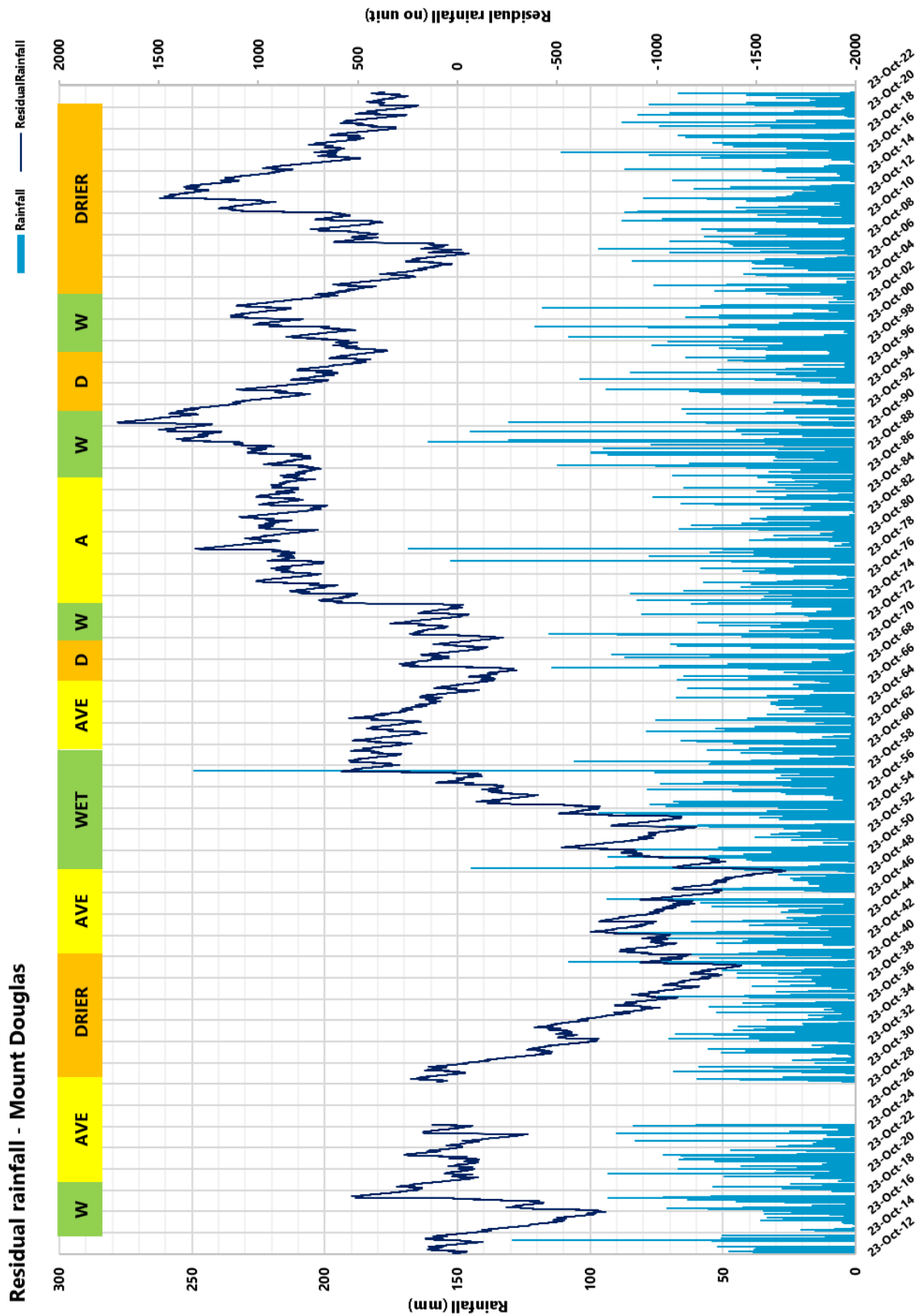
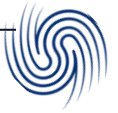


Figure 21 - Residual rainfall of Mount Douglas rainfall station



3.5.3 Design rainfall (Annual Exceedance Probability AEP)

Guidance on design rainfall for Yandan site is provided by Bureau of Meteorology Australia. Design rainfall refers to the statistical profile of rainfall event intensity & duration for a site, or Annual Exceedance Probability (AEP), & is useful in planning for significant rain events & design of water infrastructure such as drainages, spillway capacities & pipelines.

Annual Exceedance Probability (AEP) profiles indicate the probability an event will occur – as defined by a depth of rainfall over a time frame. For Yandan, the 1% AEP event over 24 hours is 241mm, & the 10% AEP event over 24 hours is 142mm or over 72 hours is 191mm.

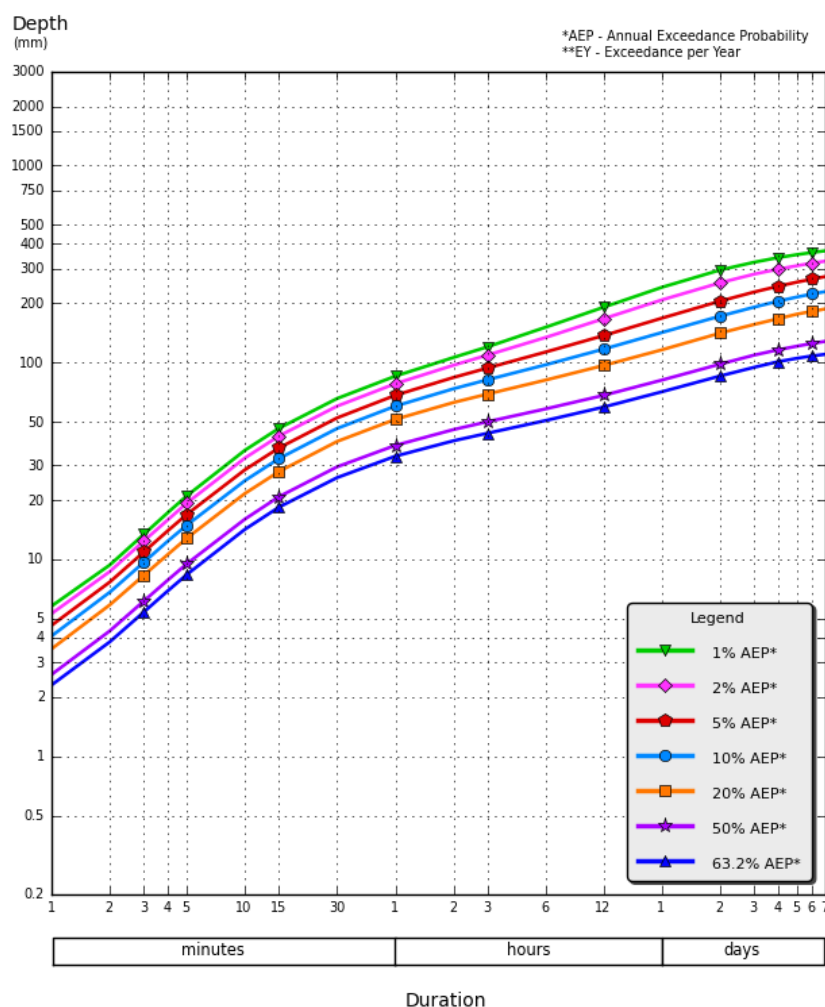


Figure 22 - Rainfall intensity frequency durations

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Table 9 - AEP (design rainfall) table of duration & rainfall depth

Annual Exceedance Probability (AEP)															
Duration	63.20%	50%	20%	10%	5%	2%	1%		63.20%	50%	20%	10%	5%	2%	1%
5 min	8.36	9.48	12.8	14.9	16.9	19.3	21	24 hour	71	81.4	116	142	168	208	241
10 min	14.2	16	21.6	25.1	28.5	32.7	35.8	48 hour	85.4	98.1	141	172	205	254	295
30 min	26	29.5	39.7	46.2	52.3	60	65.6	72 hour	94.5	109	156	191	228	281	323
1 hour	33.4	37.9	51.4	60	68.1	78	85.2	96 hour	101	116	167	205	244	298	341
2 hour	40	45.6	62.6	73.5	83.9	96.8	106	120 hour	105	121	176	215	256	310	353
6 hour	50.7	58.1	81.4	97.3	113	134	151	144 hour	108	125	182	223	265	320	362
12 hour	59.4	68.1	96.6	117	137	167	191	168 hour	110	128	187	229	273	327	369



3.6 Calculation of Probable Maximum Flood event (PMF)

Probable maximum flood (PMF) event is calculated using the Generalised Short Duration Method (BOM 2003). Applied variables are shown in Table 10, with reference table in Appendix B.

PMF event for Yandan is calculated at 1,233mm over 6 hours.

Table 10 - Variables determined as applied in PMF calculation

Zone	GTSMR coastal zone
Duration limit	6 hours (1,000km ²) (Yandan & are 1.3km ² & 1.5km ² respectively)
Terrain factor	Rough (Dr) – due to waste rock & other
Elevation adjustment factor (EAF)	1 (200mAHD, below 1500mAHD)
Moisture adjustment factor (MAF) based on location	0.85
Point value	1450

Calculation

$$\begin{aligned}
 \text{PMF} &= (S \times D_s) (R \times D_r) \times \text{MAF} \times \text{EAF} \\
 &= 1450\text{mm in 6 hours} \times 0.85 \\
 \text{PMF} &= 1,233\text{mm in 6 hours}
 \end{aligned}$$

3.7 Flooding

3.7.1 Extents by exceedance probability

Regional flood extents as published by Queensland Spatial Services for the Burdekin Basin for a 1% annual exceedance probability (AEP) event & extreme event (PMF) are shown in Figure 25, & demonstrate the large extents of significant rainfall & flooding events are for the region.

At Yandan scale, flooding was considered from project design: with WMC (1998) following construction of all major infrastructure above 180mAHD. Flood extents for Yandan are shown in Figure 26, both as base model output & aligned contours of:

- 1% AEP event – 179mAHD
- PMF event – 187mAHD

The heap leach pad lays above the 1% AEP flood extent, & the tailings facility lays above the PMF flood extent for the site. Note with the top of the heap leach pad elevation peak at 212mRL, the leach pad will not be fully submerged but may have partial flooding through the base. East pit lays above a 1% AEP event, & Main pit is submerged in both events & will be in direct connection with the river.

3.7.2 Reference elevations for pit flooding & connection

Estimation of flood duration for Main pit can be based from St Anns river gauge downstream. AECOMM (2020) calculated reference levels of St Ann gauge river levels to Main pit as follows:

- At 3.8m river height, or flow elevation of 165.8m AHD at St Anns river gauge, flow to Main pit is established at 169.05mAHD at Yandan. This equates to when flows exceed 500m³/s.



3.7.3 Flow durations

Flow durations developed from St Anns gauge & confirmed with BOM analysis tools are shown in Figure 27.

Conversion of river height where hydraulic connection from the river to the pit matches 3.8m depth at the gauge to a flow rate of 500m³/s at St Anns. The equivalent flow rate averages around 10% AEP, or once in every 10 years, but with variable rainfall & flow over the record, varies from 5% AEP to up 25% AEP.

Based on AECOM (2020) records, the pit & river have connected (either through inflow or releases) 6 times since installed (2000, 2001, 2003, 2004, 2007, 2011) over 22 years, which would support an AEP based on past climate of 25%. A view of Main Pit & Suttor River in flood from 2000.



Figure 24 - View of Main pit during flood in 2020

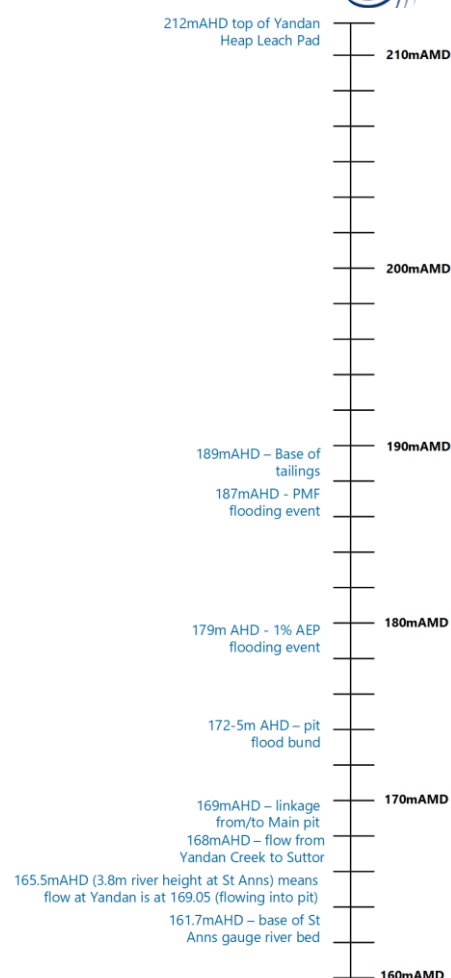


Figure 23 - Reference elevations for Yandan river & flood system

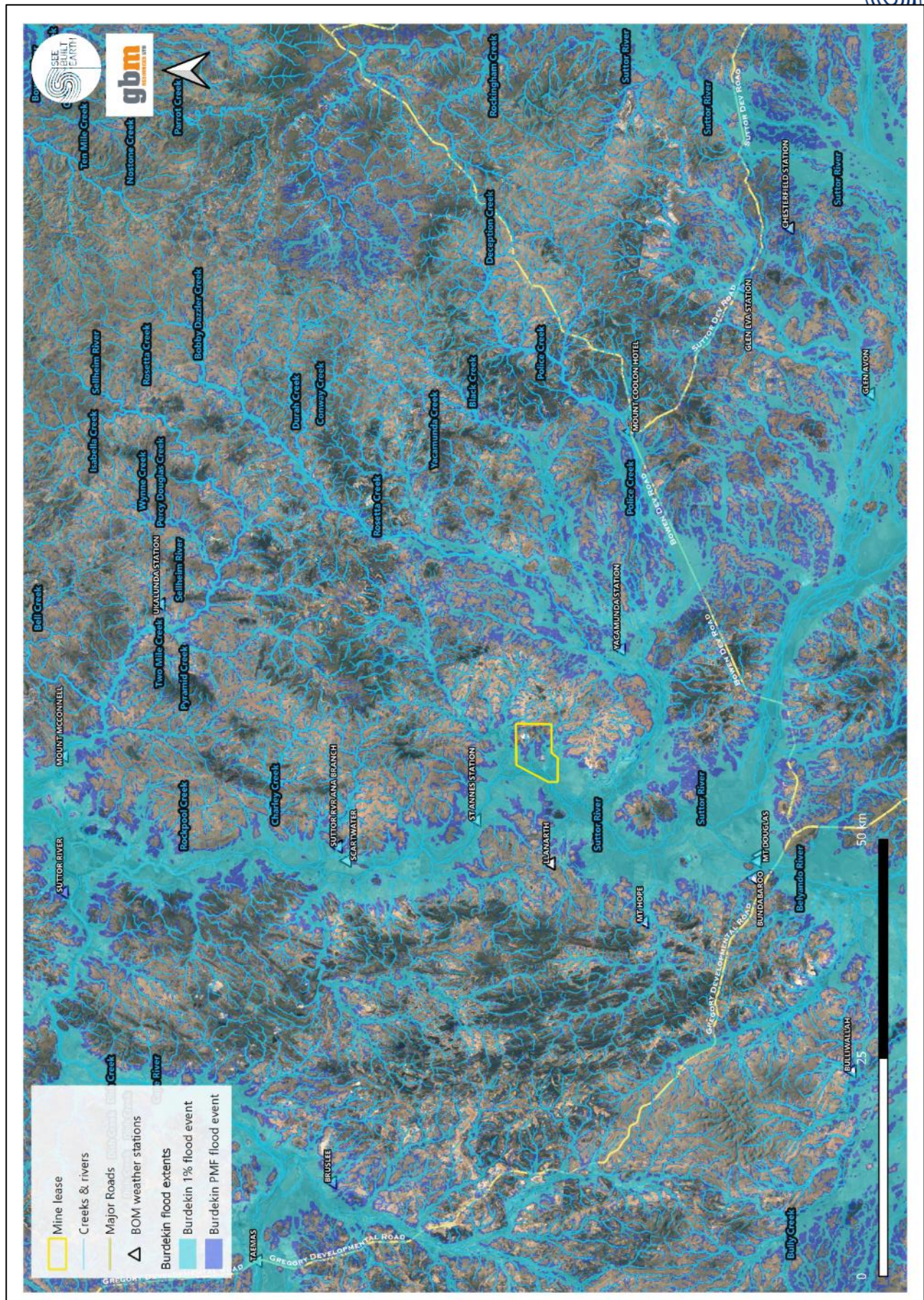


Figure 25 - Regional flooding profiles – 1% AEP & PMF events

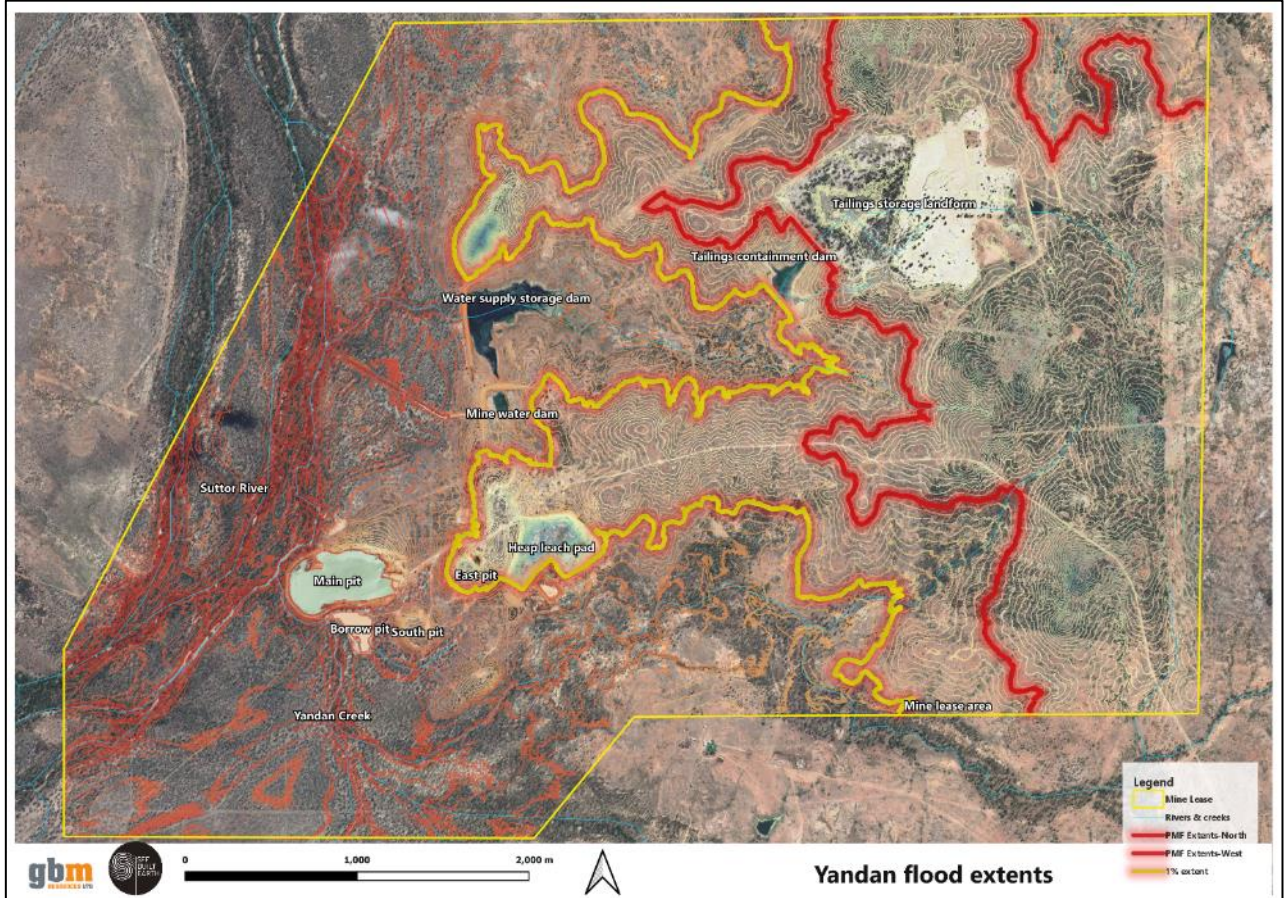
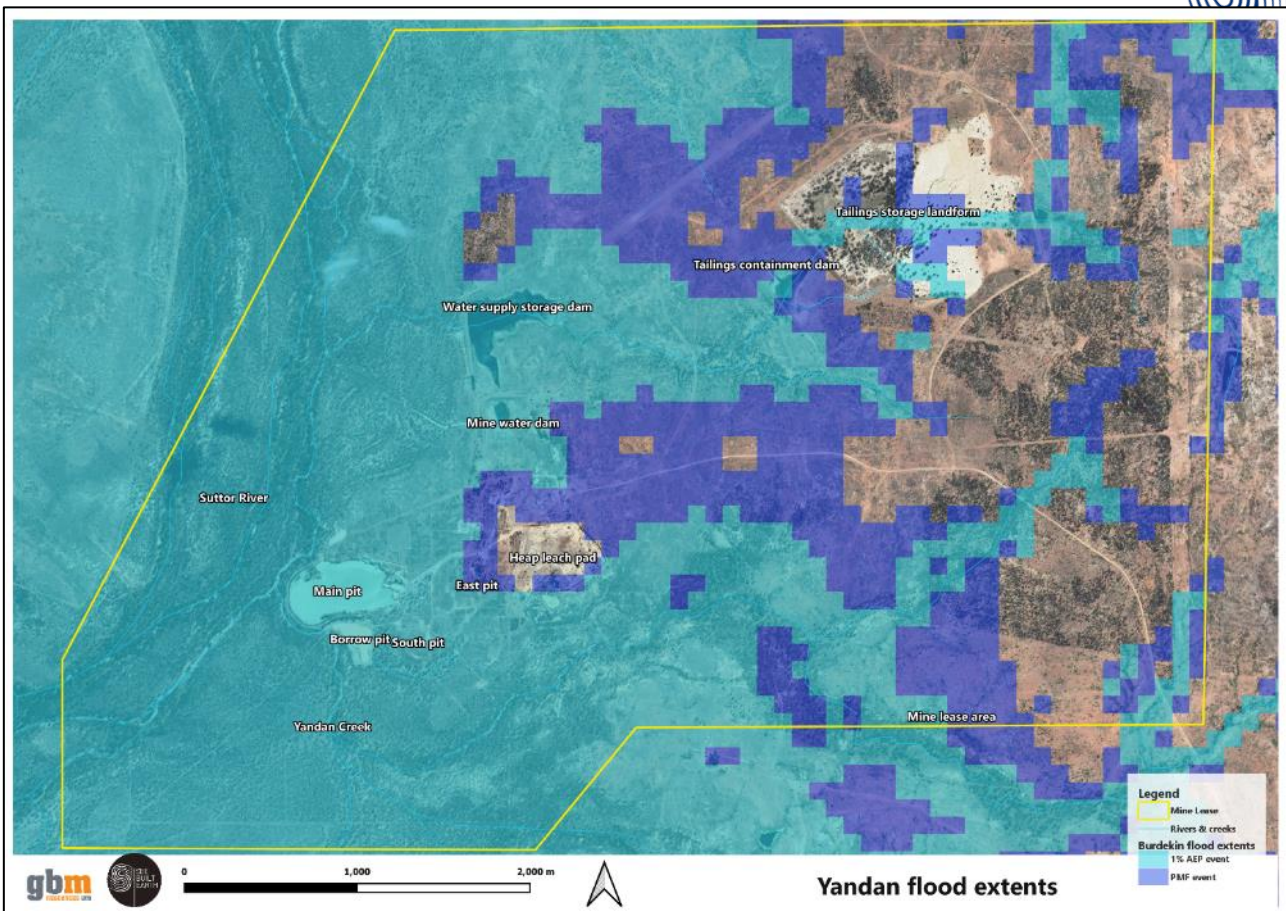


Figure 26 - Flooding extents for Yandan site

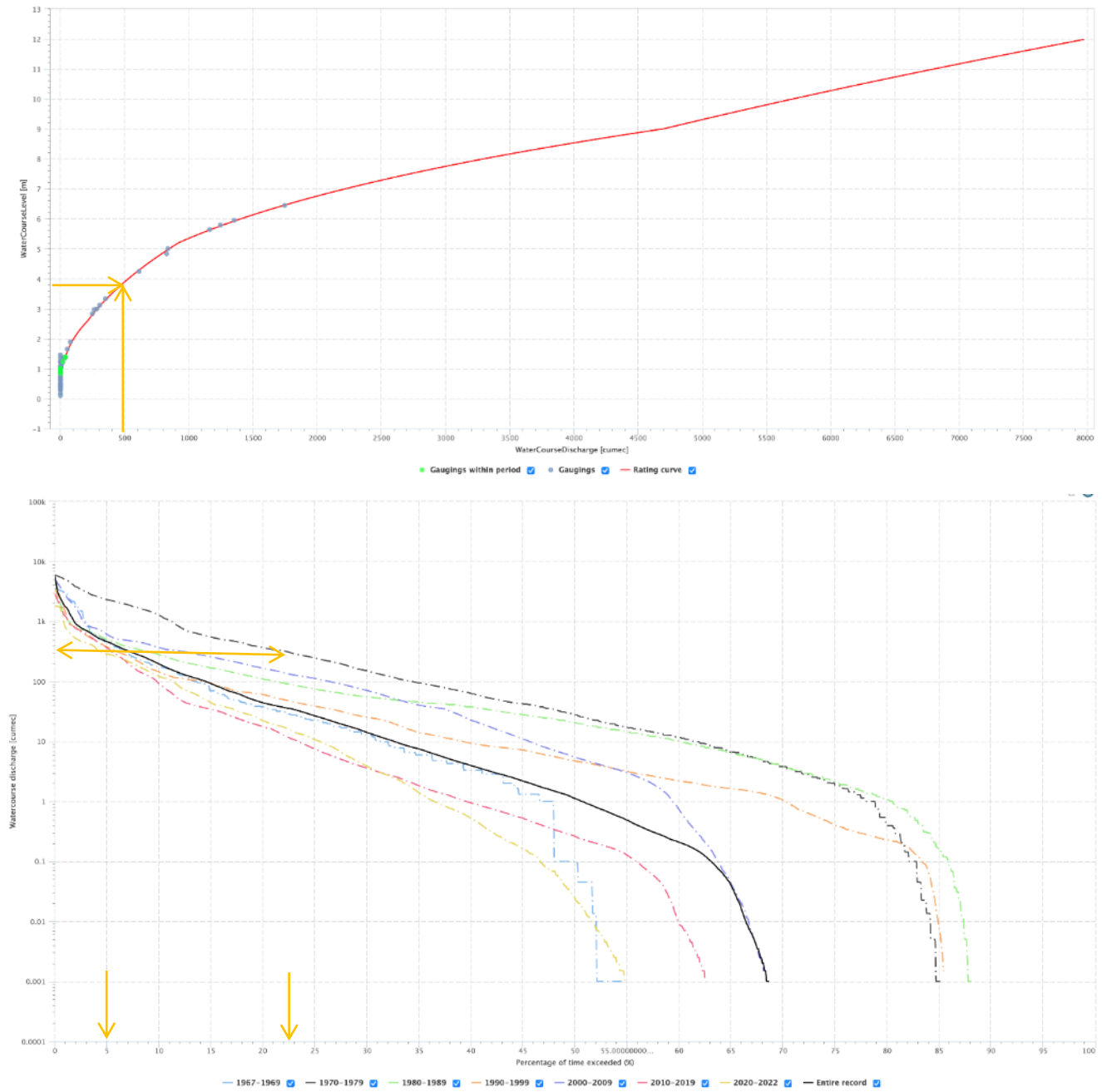


Figure 27 - River gauging & flood duration curve for St Anns river gauge



3.8 Climate change expectations

Climate change model scenarios are compiled & available from the Future Climate Dashboard (Queensland Government 2021a) at time series snapshots of 2030, 2050, 2070, 2090. The resource brings together scenarios predicted by 12 major climate models & provides a magnitude change ranked by probability (percentiles) of changes to daily precipitation & evaporation (pan) rates.

Model outcomes per season & time snapshot from 2030 to 2090 are shown in Figure 28 (Queensland Government 2021a). Expected median rainfall suggests rates will continue but will have potential to vary much more widely over time, particularly after 2050. However, evaporation rates will continually increase, with median rates up 1.8mm/day in 2090 (increase of ~30%), but at least 0.7mm/day & at most 3.6mm/day.

Regional changes in 2090 are shown in Figure 29 & Figure 30 (Yandan project area highlighted).

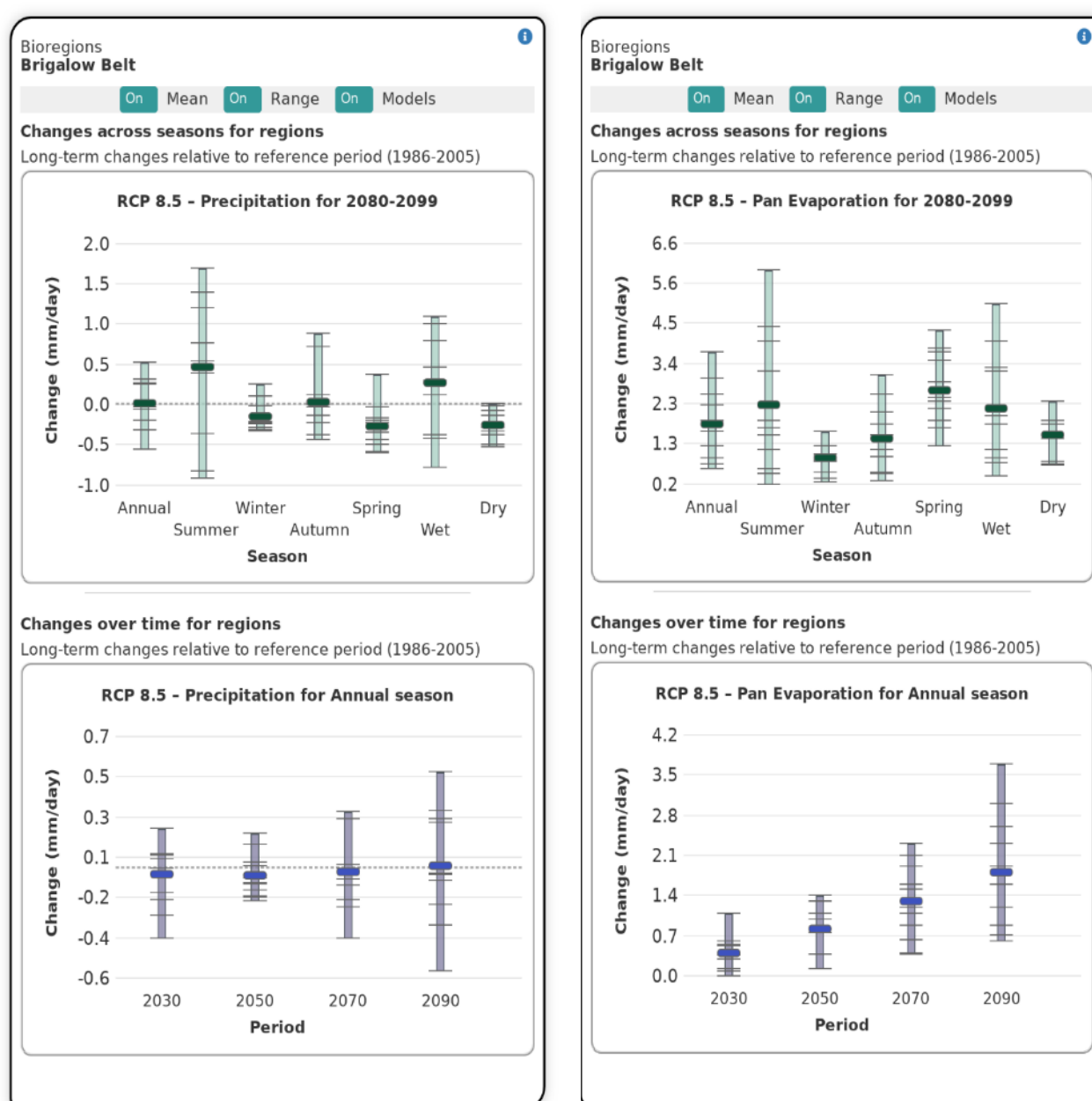


Figure 28 - Climate change scenario predicted changes for major water balance

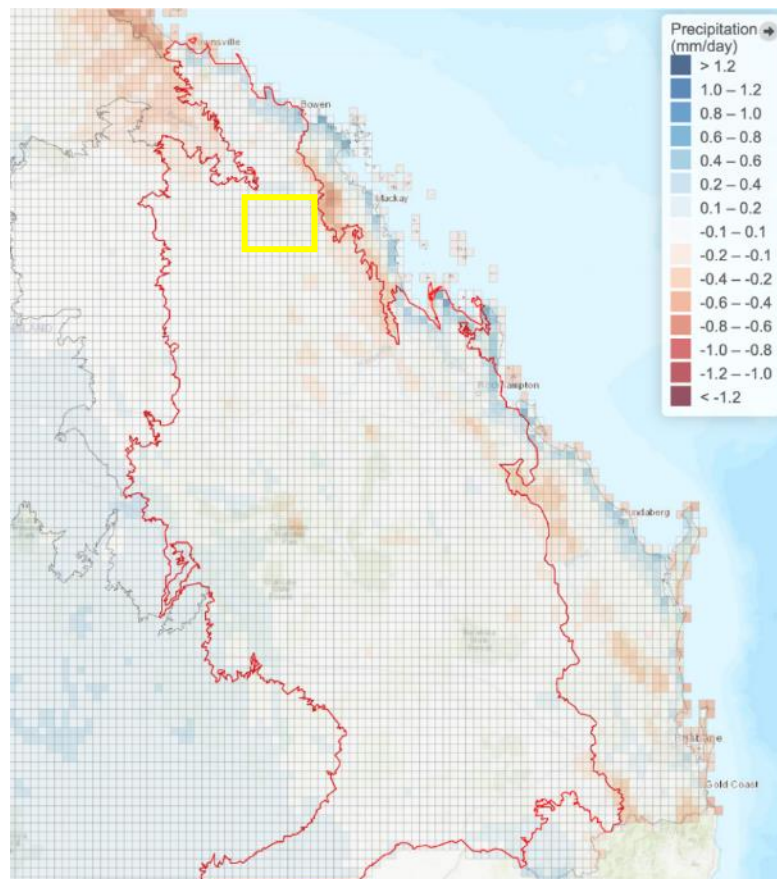


Figure 29 - 2090 median precipitation changes across region

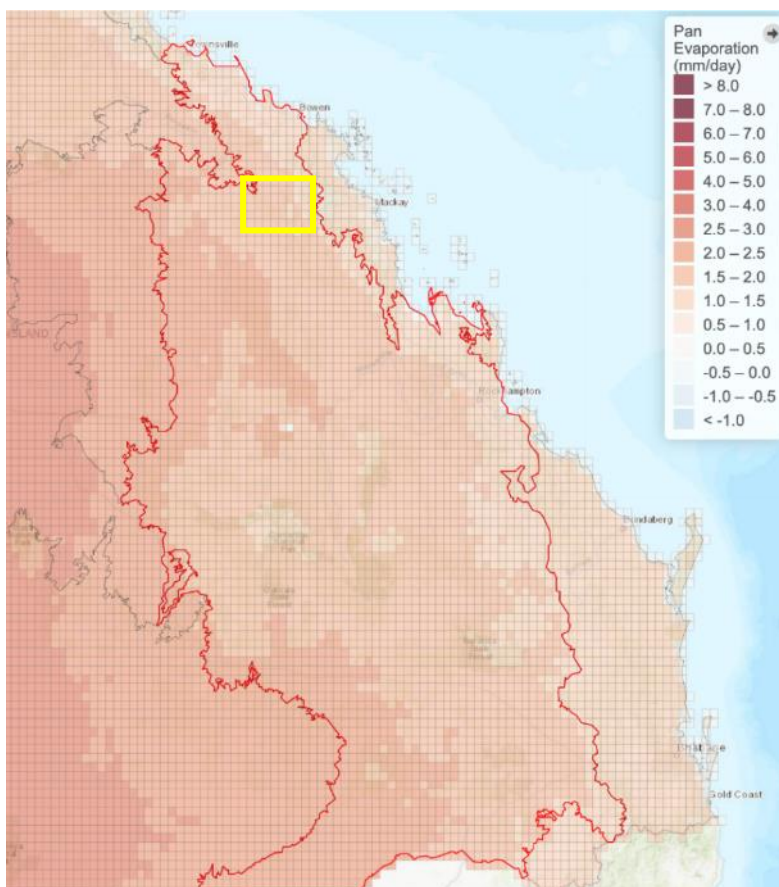


Figure 30 - 2090 median evaporation changes across region



3.9 Hydrogeology & groundwater

Aquifers of the Yandan project area occur as (Forbes 1988):

1. East of the mining area – low to very low permeability siltstones, sandstones & metamorphics, with limited groundwater occurrence.
2. Through the central area, a limited extent fracture hosted aquifer associated with the Yandan Fault.
3. West of the Yandan Fault in the mineralised zone, a porous unit associated with mineralisation & is likely the boiling zone of the epithermal mineralised system.
4. Alluvial aquifer as part of the Suttor River alluvium, reaching up to 30m depth.

The boiling zone & Yandan Faults appears to be relatively conductive, with pre-project dewatering (Forbes 1988, WMC 1998) studies suggesting dewatering demand rates of up to 5,000m³/d to keep Main pit dry, & pump test finding the fault & (what would appear to be) the boiling zone yielding draining storativity & transmissivities of 50-1,000m²/d. The study notes an expectation of finding connection to alluvial aquifers, but which was not identified at the time. It is not known of actual dewatering rates experienced during mining.

Groundwater is also described as flowing from east to west with topography, but with strong changes of hydraulic head changes between wells, indicating structural control & compartmentalisation with volcanic intrusions or contacts in geology & potential hydraulic separation.

Recent water level results for regional wells RB1D, RB2D, & SH3 support a westward flow (Figure 31 & Figure 32), moving from 177.7mAHD at RB1D in the east, to 168.4mAHD westward & to 162.5mAHD at SH3 close to main pit.

A groundwater surface of Yandan using February 2022 groundwater levels confirms groundwater flow direction in Figure 33, with groundwater levels dropping towards towards Yandan Creek. Note RB series are only recently installed, & the exclusion of levels from HL4, HL6 & TD5 bores given likely integrity issues.

Pre-mining groundwater quality is described as moderately saline with total dissolved salts (TDS) between 4,000 to 15,000mg/l.

3.10 Regional water values

3.10.1 Other water users

With rainfall between 200-1,100mm/year against an evaporation capacity of 2,094mm/year, the Yandan site & region is currently a strongly water negative balance site (as with much of the Central Highlands region).

Groundwater is not well developed in the area, with state registered showing only a few bores within Yandan for the region (Figure 34). An upstream neighbour appears to be running a very large irrigation operation, with a significant dam storage & cultivated field.

3.10.2 Presence of RAMSAR wetlands, GDE's or water values

Review of published RAMSAR wetlands (WetlandsMap, 2022) indicate there are no recorded sites in the region (Figure 35). There are also no occurrences of artesian or groundwater mounds in the area.

The Suttor River & Yandan Creek are mapped as wetlands & potential terrestrial river GDE's.

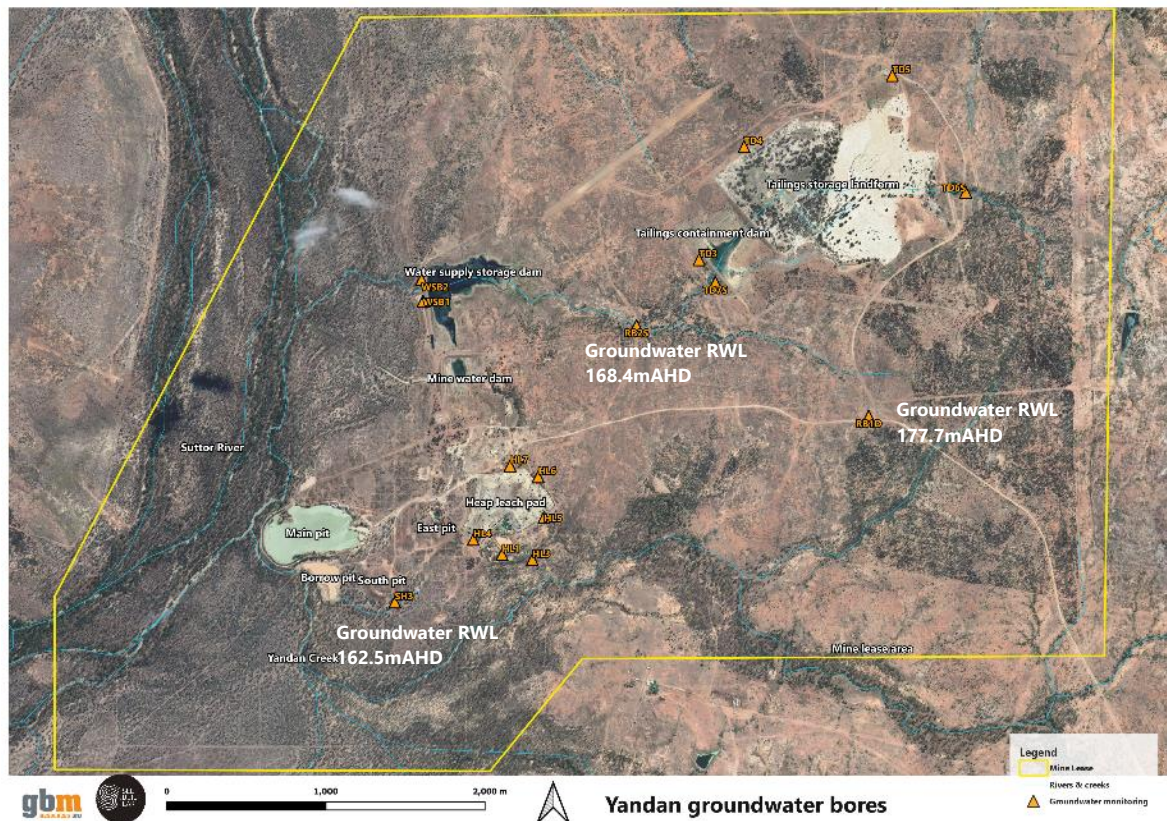


Figure 31 - Yandan groundwater bores & Feb-2022 groundwater relative levels for regional wells

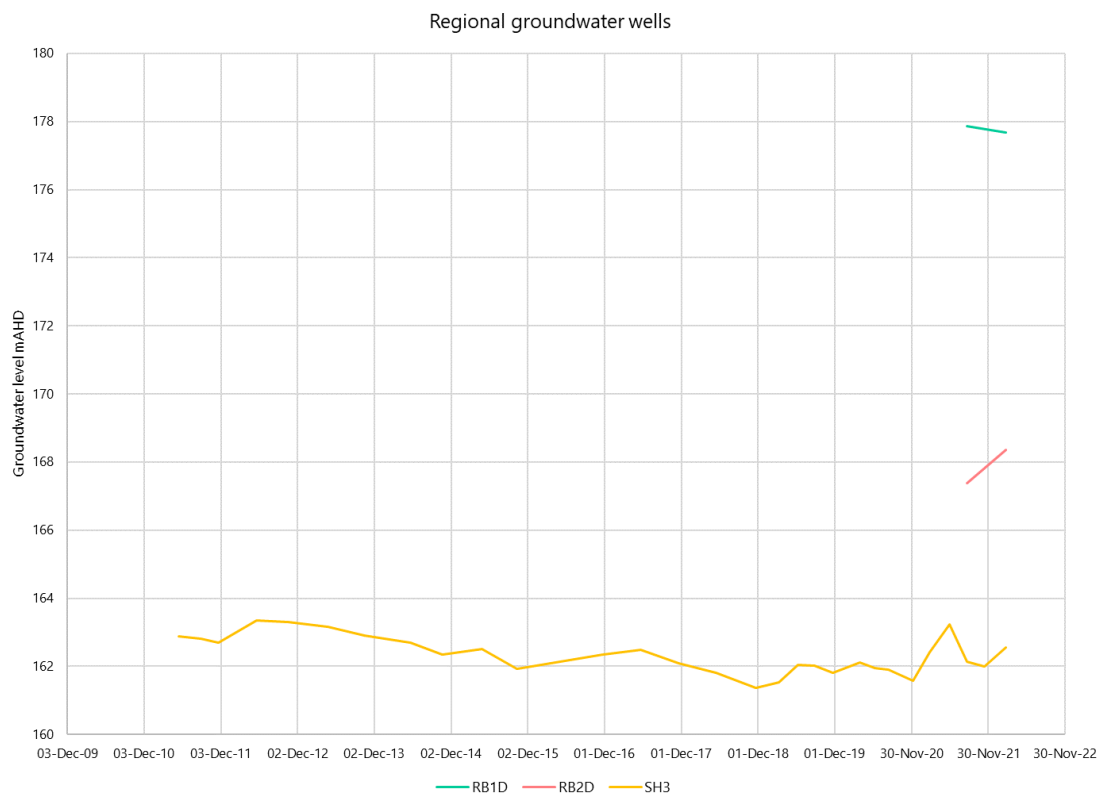


Figure 32-Relative water levels of regional groundwater wells (RB series recently installed)

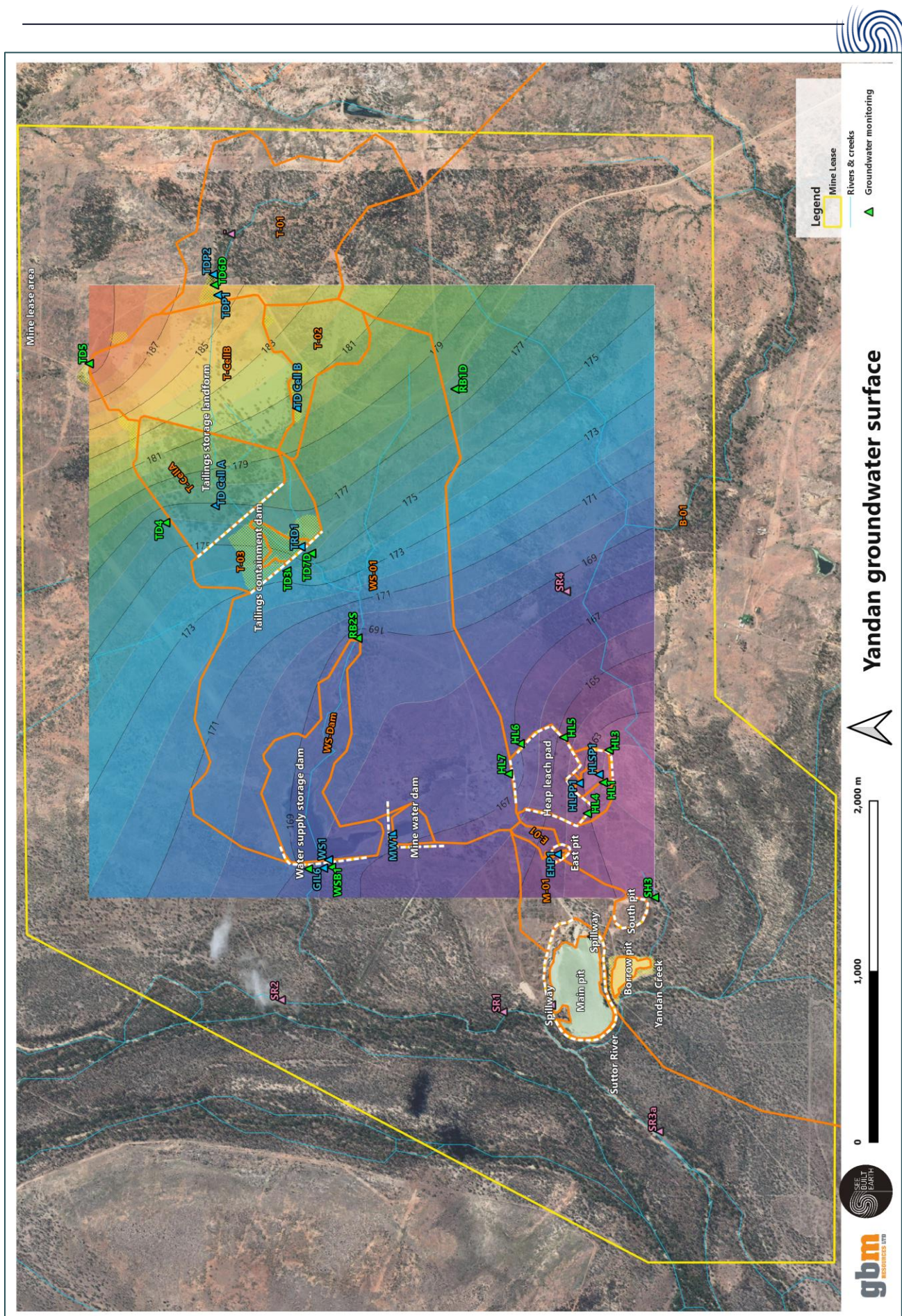


Figure 33 – Yandan groundwater surface



Figure 34 - State registered well locations & nearby water users

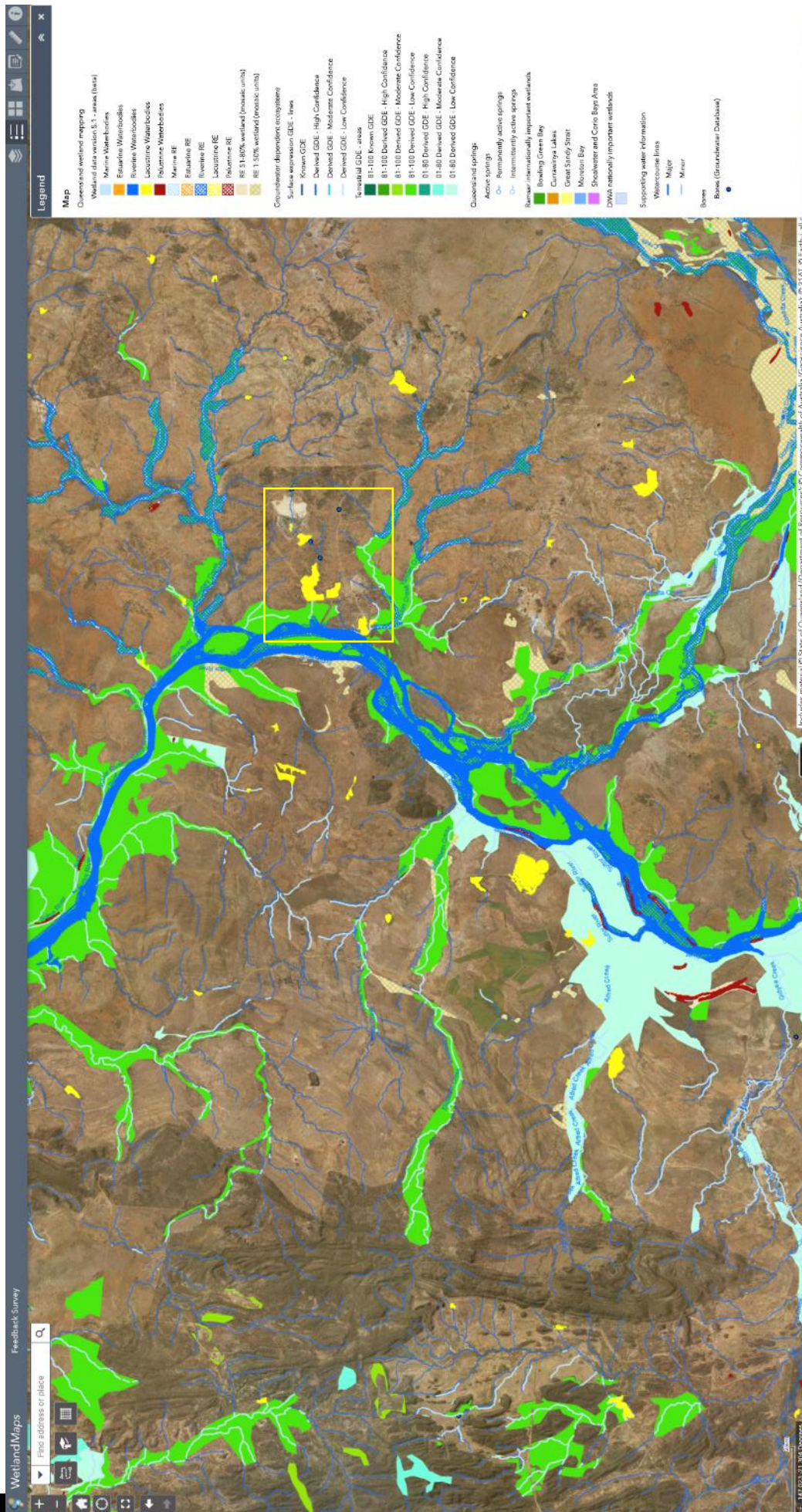


Figure 35 – Wetland & GDE map



4 Site landforms & domain characterisation

4.1 Overview

Piper plots of all groundwater & surface water sample sites from February 2022 sampling (following rainfall) are shown in Figure 36 & Figure 37 as a overview snapshot of water quality types across Yandan site. In groundwater, water tends to be sodium/potassium in cations, with bicarbonate or sulphate anions, with no clear populations between areas. This would indicate different processes underway. Similarly in surface water, storage waters plots as consistently of mixed types without clear populations, though remain sodium/potassium dominant, along with carbonate/sulphate.

Populations of water become more pronounced with detailed cation/anion analysis (Figure 38):

- Log Cl to Log Na chart identifies populations of increased sodium
 - Increased sodium - surface water storages in east hill pit, heap leach ponds with bores of TD6D&S with TD4 to identify the likely group of most impacted waters.
 - Remainder of groundwater bores for tailings & heap leach.
 - Fresher water & regional groundwater as the lowest sodium.
- Ca:Mg to Na:Cl shows groupings of surface water storage & groundwater, separated into levels of impact: TD4 & TD6D at the tailings dams are most affected in groundwater; East Hill pit & heap leach ponds most affected in surface water storages.
- Ca:Mg to pH shows clear:
 - Close grouping of groundwater populations migrating to fresher surface water storage sources.
 - Altered surface water storage populations, including most impacted surface waters of East Hill pit, tailings return dam (note after rainfall) & heap leach ponds.

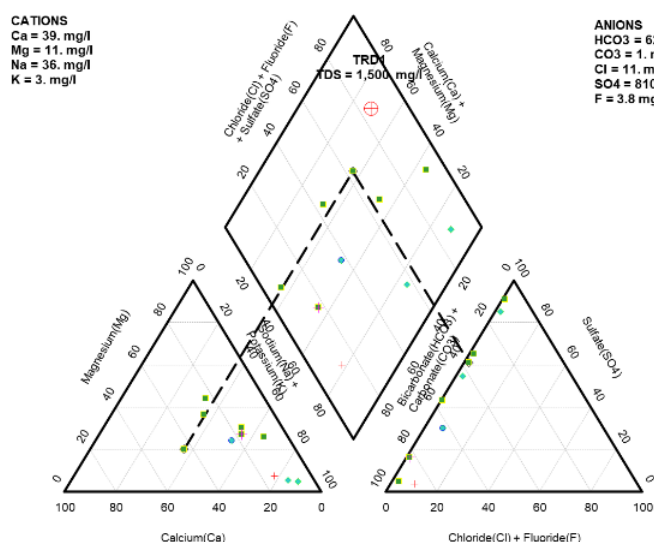


Figure 36 - Piper plot of groundwater water quality

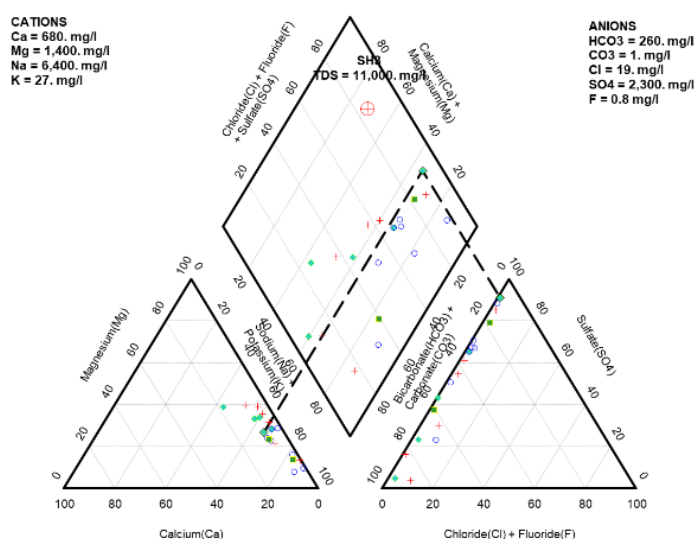


Figure 37 - Piper plot of water storages & bodies water

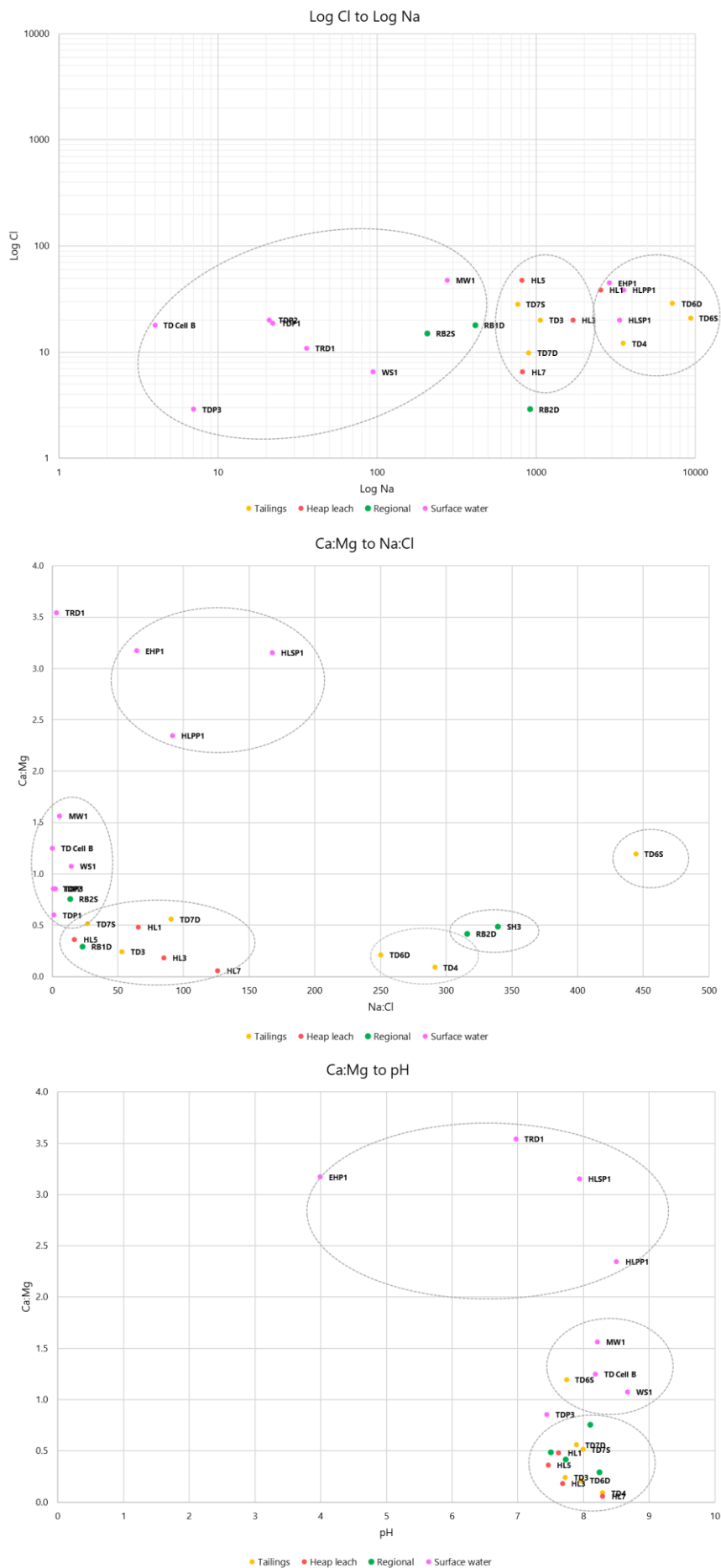


Figure 38 - Geochemical populations of groundwater & surface storages (Feb 22 sampling)



4.2 Tailings landform

4.2.1 Description & observations

Yandan tailings is stored in a broad & low relief 115ha landform (Figure 39) which begins as a low 1-3m embankment from the top of catchment & wraps over the landscape in a platform to a 12m earthen embankment downstream (Figure 40 & Figure 41). The landform sits above maximum flooding elevations of current PMF & consists of two cells: Cell A & Cell B.

Cell A is classed as rehabilitated (Figure 42) & Cell B is yet to be rehabilitated (Figure 43). The surface of the facility is very low gradient (flat): rainfall flows across the surface of Cell B to a broad depression area in Cell A where it ponds & likely seeps into the tailings storage below (Figure 44). When Cell A when pond capacity is exceeded, excess water flows over the spillway on the south side when the pond fills. Spillway flow is directly contained by the tailings return dam (containment dam).

Around the perimeter of the landform, there are several borrow pits directly adjacent to tailings embankment, presumably for use of material in construction (Figure 45 & Figure 46). With rainfall, these borrow pits are acting as places for additional ponding & actively store water given the low relative level to tailings & ground surface: it is likely the ponds are a mix of tailings seepage water & rainfall. On the eastern side, the landform is not quite at the top of catchment & has a small drainage line above which has a retaining structure as a dam wall with an access road, & a storage lays beneath (TDP).

Inspection of the tailings surface identified several areas of internal erosion & small voids observed into the tailings (Figure 47), likely associated with either differential settling & increased flow with the lack of drainage, taking advantage of decomposed tree roots which when removed leave a preferential pathway for water flow. Ripple marks from over-surface flow from rainfall is also present.

Monitoring consists of several groundwater wells of historical & recent construction around the perimeter of the landform, generally located close to tailings embankments & some within borrow pit areas, with background wells up-gradient & two wells downstream of the containment dam. Underlying geology is predominantly siltstone. Surface water quality is monitored where possible, both upstream & downstream in the containment dam, & at other locations as available.

4.2.2 Water responses

Groundwater elevations over time are shown in Figure 48 in relative water level (mAHD). The wells show a clear response to rainfall, declining in drier times since 2012, stabilising in 2020 & then rising for 2021 wet season. This may be in response to direct rainfall, or from increased water storage within the facility given the lack of drainage & their close location to embankments. Note TD5 on the north side of the facility appears to have lost surface integrity is connected to surface (matching reduction in salinity), as well as being sited in a borrow pit pond.

Groundwater flow direction follows the landscape as expected: with highest elevations at TD6S/D to TD4 & then TD3 downstream of the containment dam. Note TD7D/S indicates a high elevation & suggests the well may be potentially monitoring the containment dam wall potentiometric surface rather than groundwater. Both TD6D/S & TD7D/S are monitoring a similar aquifer given the similar responses & generally can not be regarded as nested bores, though show variation in salinity due to density settling in the bore water column.

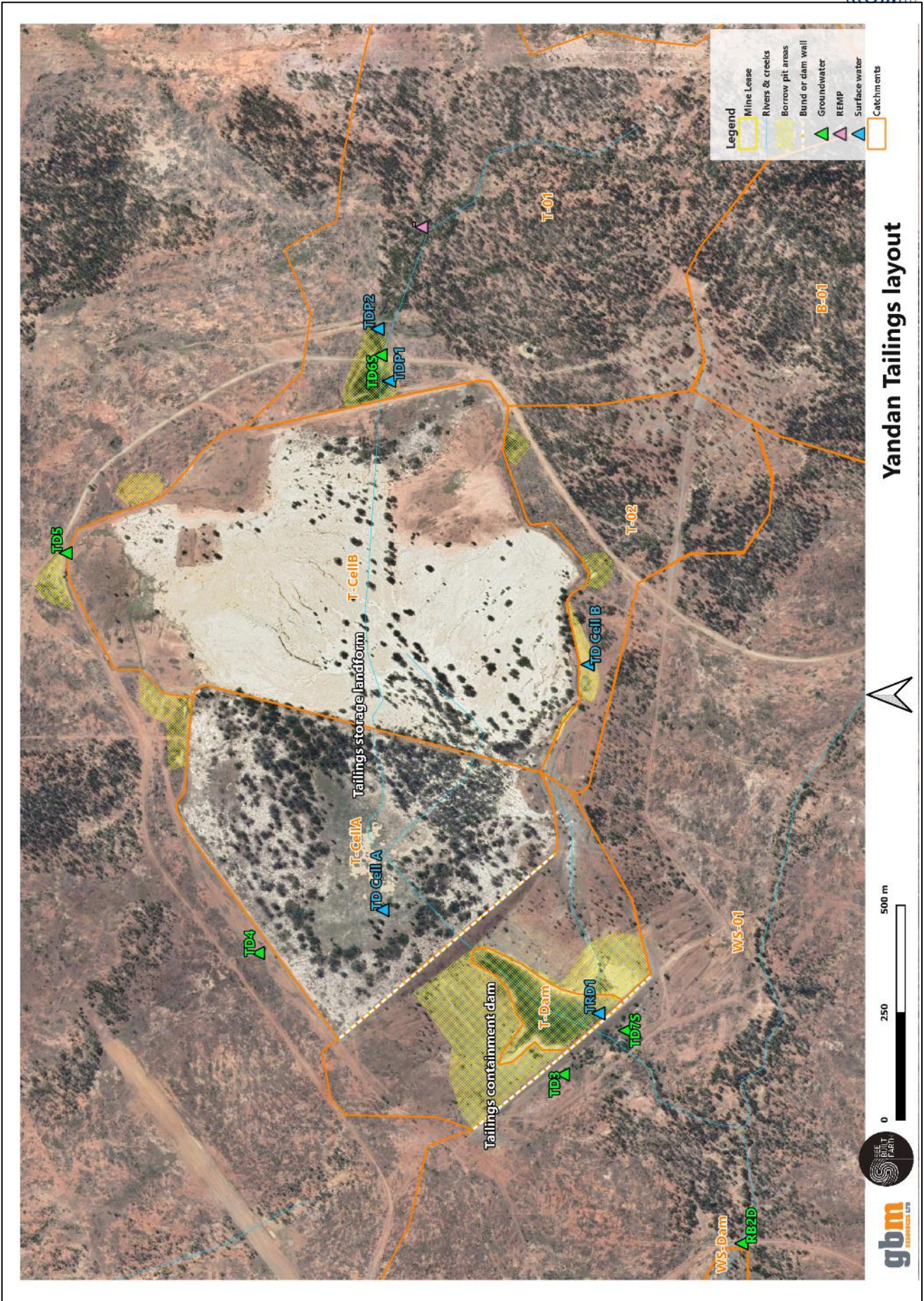




Figure 40 - View of low relief tailings landform at top of catchment



Figure 41 - View from downstream of facility looking at downstream embankment from containment dam



Figure 42 - Views of surface of Cell A (rehabilitated)



Figure 43 - Views of surface of Cell B tailings



Figure 44 - View of broad depression & ponding area on Cell A



Figure 45 - South borrow pit ponding against embankment (TD Cell B)



Figure 46 - North borrow pit ponding against embankment (TD5)



Figure 47 - Views of differential settling & internal erosion visible on the tailings surface

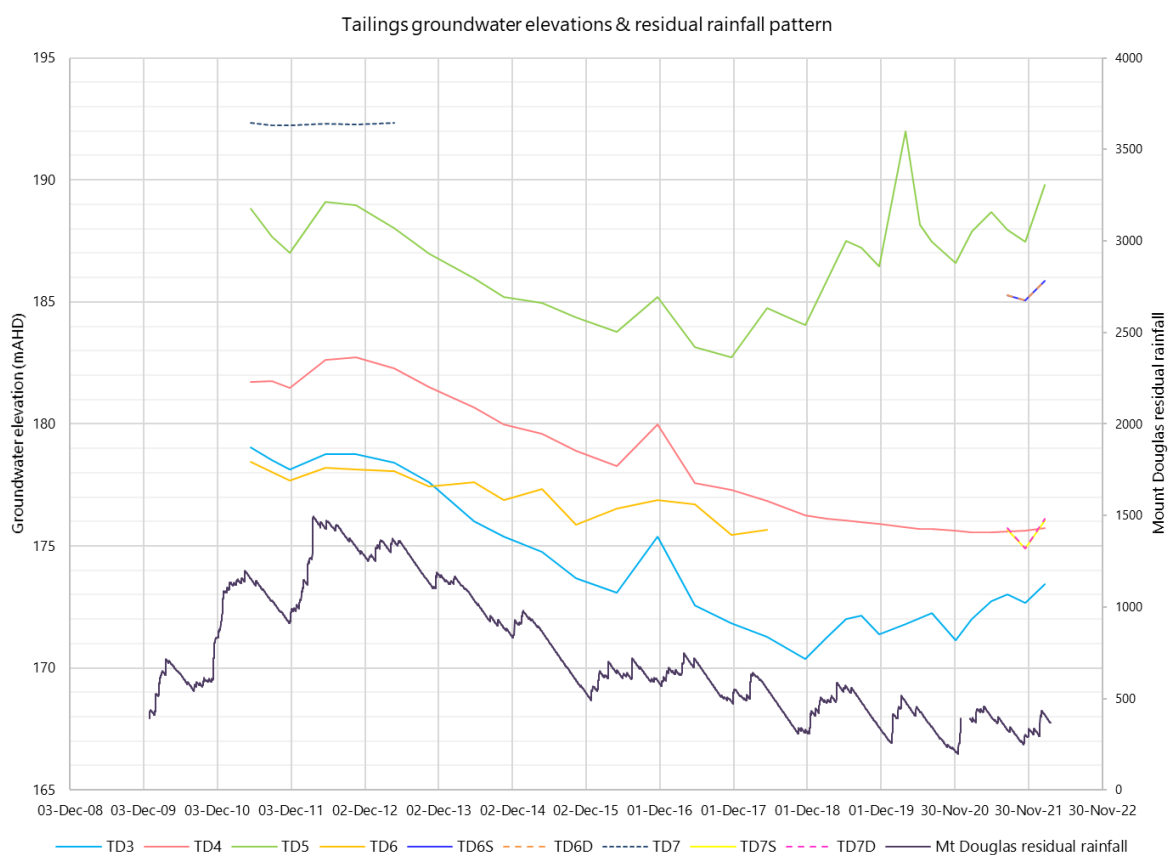
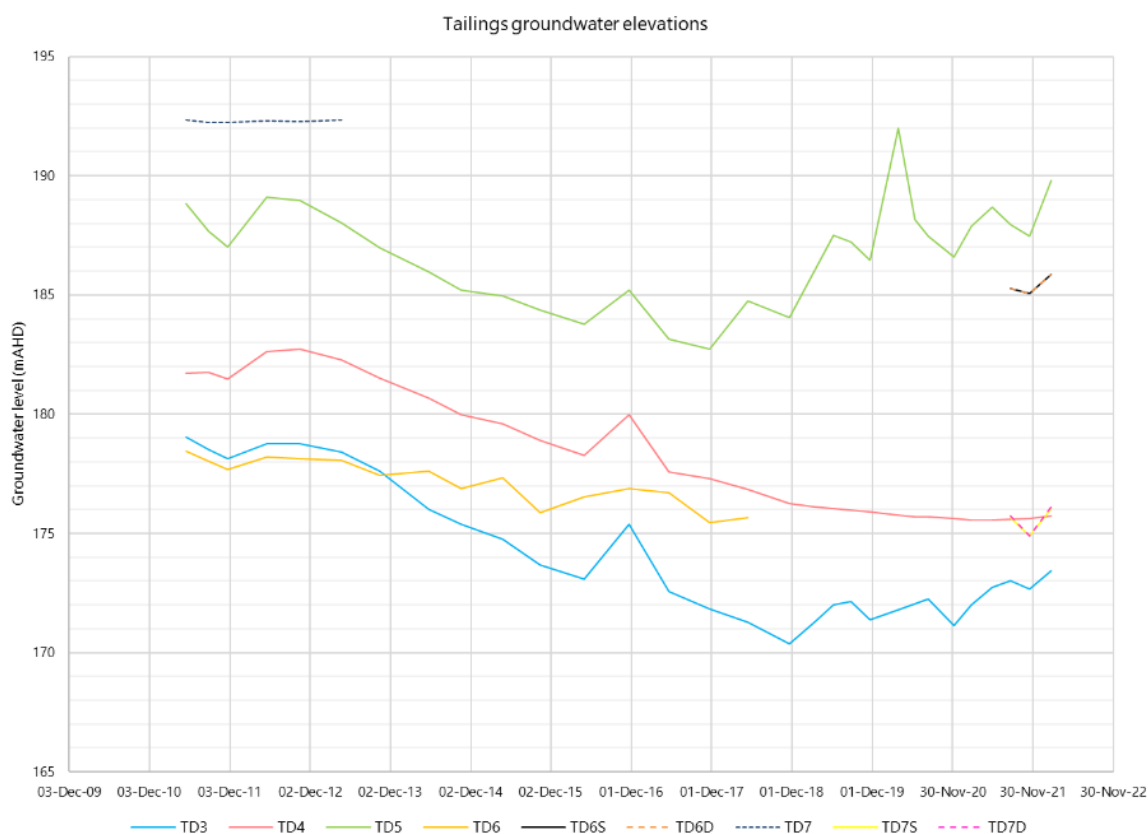


Figure 48 - Tailings groundwater elevations over time & with residual rainfall



4.2.3 Water quality & containment

Materials characterisation identified salinity, sulphate, mercury, arsenic, copper, zinc, manganese, chromium, antimony & cobalt as potential water quality threats associated with tailings materials. Review of monitoring records since 2011 across groundwater & surface water results for water quality, trends & likely drivers is provided below & summarised in Table 11, with charts in Figure 49, Figure 50 & Figure 51 to demonstrate key parameters & trends. Key observations include:

- Overall, pH is stable, though has increasing alkalinity in surface water after rainfall approaching pH 10 which is driven by rainfall.
- Groundwater has elevated salinity at northern wells: TD4 which is the closest to the ponding area on Cell A & adjacent to the facility itself, plus the eastern upgradient wells, & TD6S/D, though both wells are installed well below relative elevations of the tailings facility. Notably for salinity - both downstream wells show no sign of changed salinity down gradient, indicating containment is maintained. Salinity is less in both upstream & downstream dams.
- Sulphate is relatively stable in groundwater at <1,000mg/l, but is relatively higher for upstream groundwater by early indications (new wells). The tailings return dam periodically experiences peaks of higher sulphate in clear association with rainfall patterns. Most monitoring records as "dry" conditions show a much lower sulphate level, but following rainfall (with lag time), a peak reports. Whether this peak is via infiltration, or loss of dilution over the dry season is uncertain given 6-month sampling frequencies.
- In metals: mobility in groundwater is limited to arsenic at TD4 which is elevated & on an increasing trend. TD4 is closest to the ponding area of Cell A & situated directly next to the facility, & it is likely TD4 is monitoring water in direct contact with tailings. All other metals are generally not detected, with some gaps to address in monitoring parameters. In surface water, several metals appear to peak associated with rainfall (like sulphate) – including arsenic, cadmium (Figure 51), copper, nickel & zinc. Further work is needed to identify mechanisms.

4.2.4 Findings

- Tailings impacts are characterised by low-risk saline drainage, not acid rock processes (either pH or sulphate). Sulphate may be elevated; however levels have been stable for some time & likely indicates production of sulphate has reduced.
- Primary metals of interest (mobile) are arsenic, cadmium, copper, nickel, zinc (mobile at neutral to alkaline pH).
- Downgradient wells demonstrate containment of potential impacts is effective: in surface water, the tailings return dam (TRD) is capturing surface water runoff. Whilst there may be some quality concerns for perimeter monitoring wells, these impacts are likely to be limited by topography & geology & will require further investigation.
- The current form of the tailings facility captures & stores water on the facility, which maximises infiltration & percolation of water through stored tailings: a design & function which must be avoided.
- Groundwater wells on the perimeter are generally located in borrow pits & near the facility & are likely monitoring direct tailings water. Likewise, TD6S/D as upgradient wells are further away, but are at a much lower relative level & will be in a direct area of the potentiometric surface (Figure 52).



Table 11 - Summary of water quality trends for surface water & groundwater for tailings

Parameter	Groundwater	Surface storage
pH	Stable & within normal ranges	Varies with rainfall for both TRD1/3 (dam downgradient) & TDP (dam upgradient), approaching pH 10
Salinity (EC)	Elevated in TD4 to 25,000EC (north Cell A), TD5 (prior to breakdown) at 15,000EC (north Cell B), TD6S/D (upstream) at 35,000, & stable downgradient at 1,000EC at TD3 & TD7D/S well within background.	<5,000EC for all sites, TRD1 varies with rainfall, likely through dilution with freshwater.
Sulphate	All relatively stable at 1,000mg/l or less, except for TD6S/D (upgradient) at 1,400mg/l.	Peaks at TRD1 after rainfall, <5,000mg/l. Either dilution or pulse driven through rainfall. (not tested at TDP)
Arsenic	All stable to not detected except for TD4, which is on an increasing trend.	Peaks at <u>low levels</u> associated with rainfall or lack of rainfall.
Antimony	Not currently monitored	Not tested.
Cadmium	Not detected to around detection	Peaks associated with rainfall above compliance.
Chromium	Not detected to around detection	Single sampling event (not detected)
Cobalt	Not currently monitored	Not currently monitored.
Copper	Not detected to around detection	Peaks at <u>low levels</u> associated with rainfall.
Cyanide	Not detected	Not detected
Lead	Not detected to around detection	Not detected to around detection
Manganese	Single sampling event	Single sampling event
Mercury	Not detected	Not detected
Molybdenum	Not detected to around detection	Not currently monitored
Nickel	Single sampling event	Peaks at <u>low levels</u> associated with rainfall.
Selenium	Not detected to around detection	Not currently monitored.
Zinc	Not detected to around detection	Peaks at <u>low levels</u> associated with rainfall.

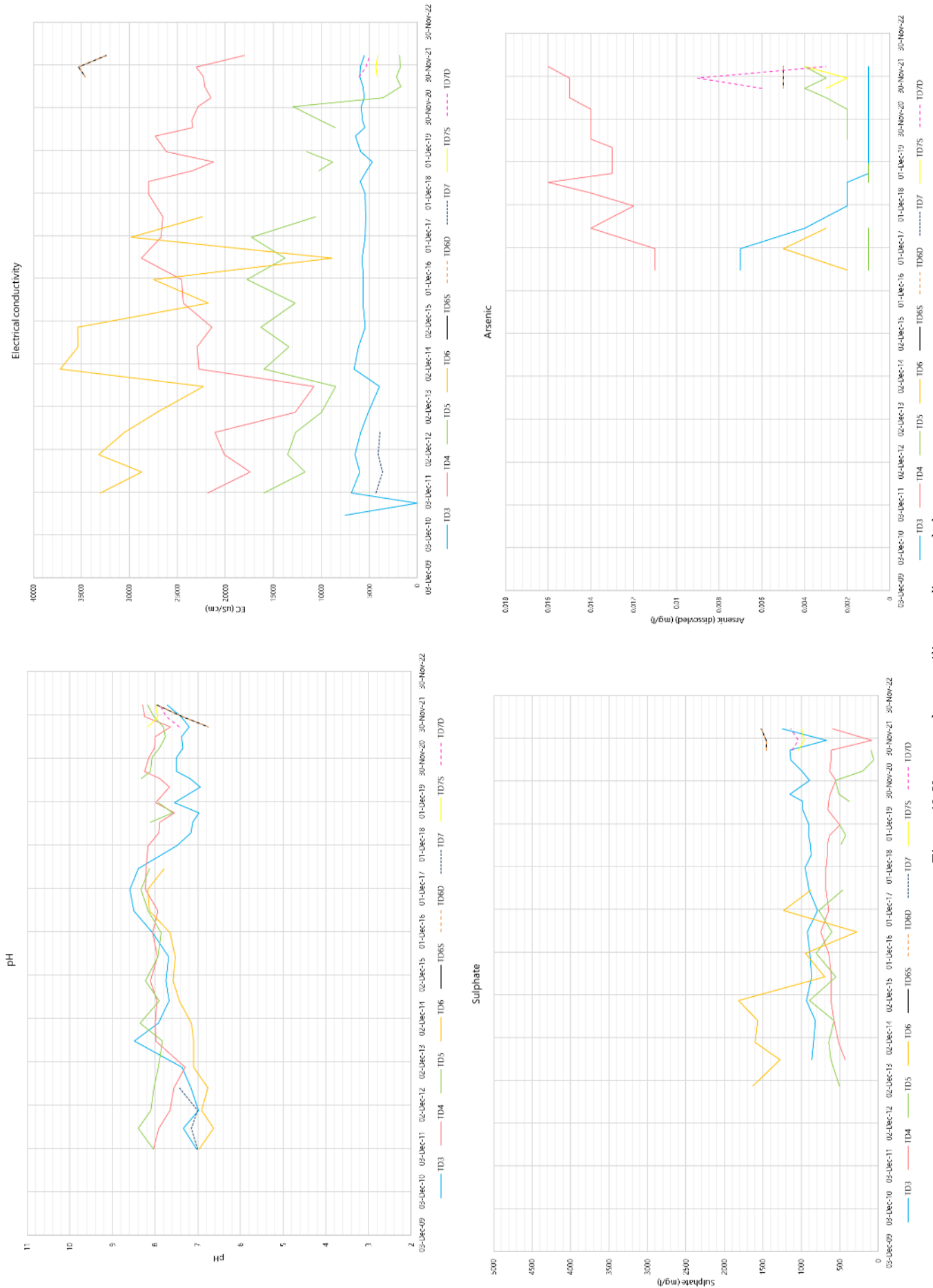
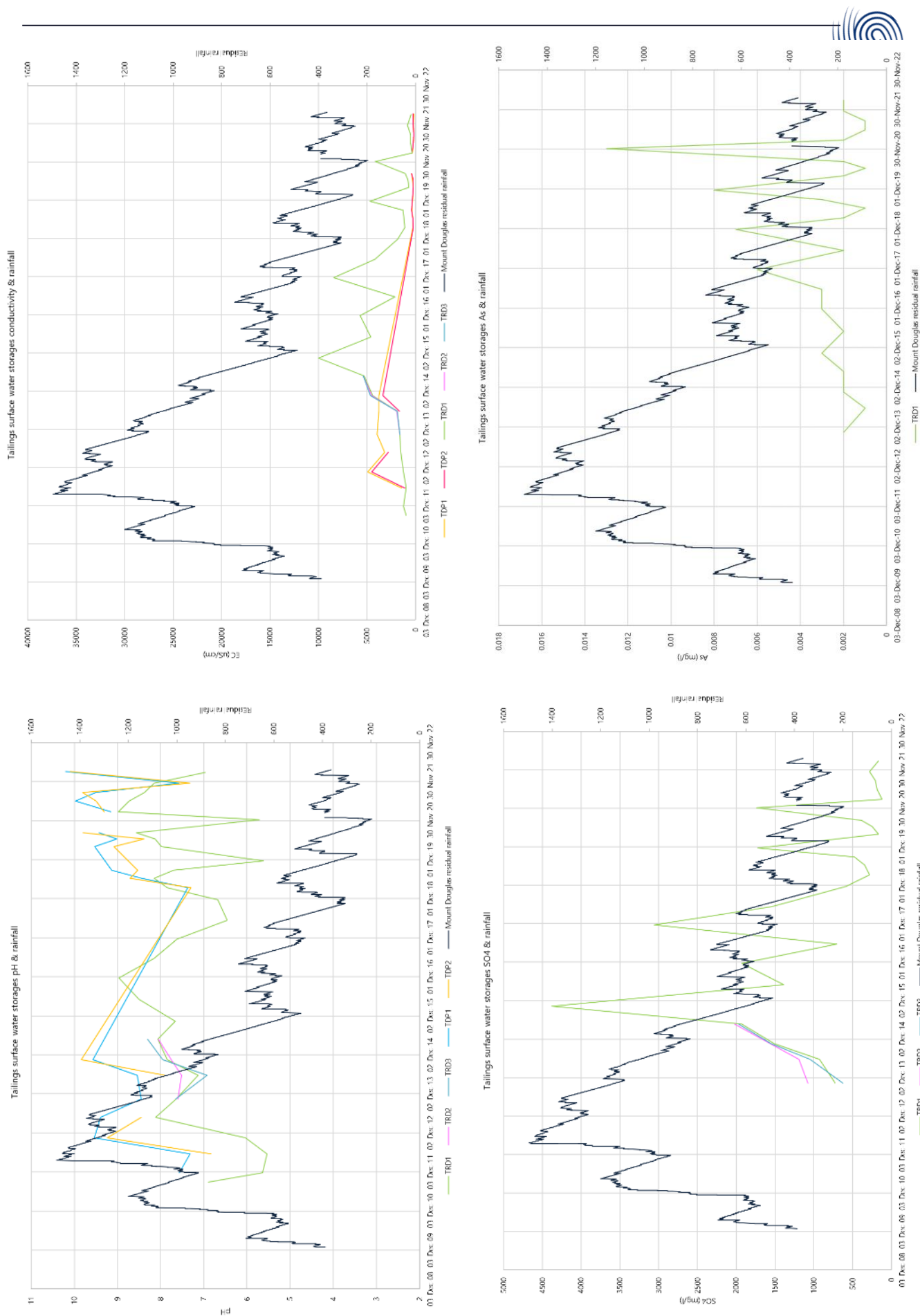


Figure 49-Key groundwater tailings quality trend charts



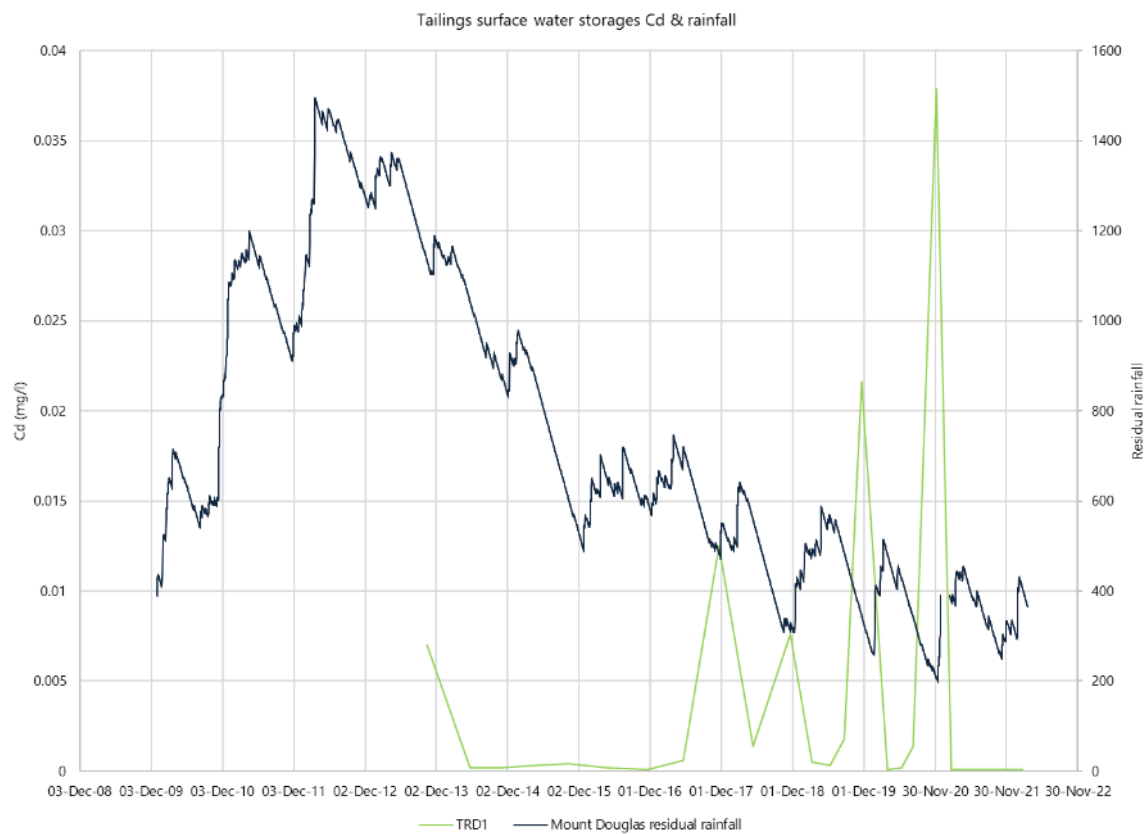


Figure 51 - Surface water cadmium peaks

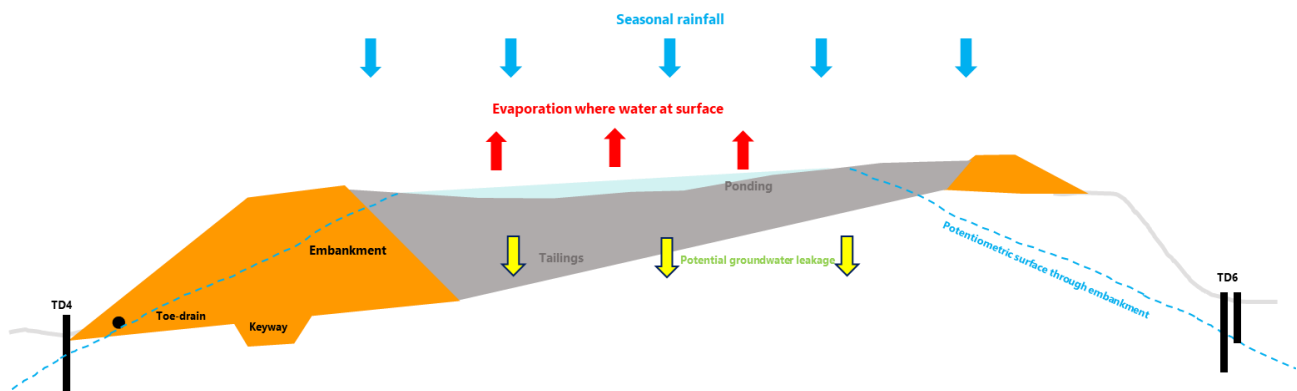


Figure 52 - Schematic of tailings & monitoring locations



4.3 Heap leach landform

4.3.1 Description & observations

The legacy Yandan heap leach is a 25m high, 17.4 hectare landform, constructed at the top of a small hill upgradient from Main pit (Figure 53 & Figure 54). Construction at the top of the hill & to the south side enabled the heap leach to remain above the 1% AEP flood levels & to direct water flow downgradient towards containment ponds. At 212mAHD, the top of the heap leach landform is the highest point across the site. During operation, the leaching process involved application of lime within the facility, & cyanide to liberate the fine gold. The process of leaching is based on infiltration through a landform: spraying a low cyanide concentration water across the leach pad, which percolates through the landform & is captured as a leachate for processing & gold recovery.

The heap leach drains from north to south, & consists of the constructed landform of low grade oxide rock, a perimeter capture drain (Figure 55), a remnant leach collection pond area, and stormwater capture dam (Figure 56). A bund wall lays further to the south as secondary protection from overland flow. Groundwater monitored by six (6) shallow monitoring wells around the perimeter & near to the leach ponds, plus a downgradient well, HL3. The site is likely to lay on geology of volcanics & siltstone.

Inspection of the heap leach landform & surrounding infrastructure indicated a broadly sound structure: degradation of the perimeter drain through sediment fill has occurred in multiple locations & would not function well as a containment drain. The lining of the leach pond is also ripped & would no longer be acting as containment (Figure 56). HL1 close to the embankment of the leach pond & is likely in connection with the water storage.

4.3.2 Water responses

Review of groundwater levels of the heap leach area indicates a broad trend of groundwater decline, consistent with draining of the landform since leaching operations stopped (Figure 57). The exception is HL4 on the southwest extent showing a rise: with no clear linkage to rainfall or water, this rise is unexplainable & may indicate a loss of well integrity. HL6 is also beginning to show signs of loss of integrity, as indicated by groundwater surface construction.

4.3.3 Water quality & containment

Materials classification identified heap leach as non-acid forming, but likely saline drainage, with potential to increase calcium, sulphate, chloride & sodium loading given the extent of lime addition through the heap leach. Metals of interest are arsenic, mercury, antimony, silver, lead & selenium.

Review of monitoring records since 2011 across groundwater & surface water results for water quality, trends & likely drivers is provided below & summarised in Table 11, with charts in Figure 58, to demonstrate key parameters & trends. Key observations include:

- Overall, pH is stable & within normal ranges.
- Groundwater has elevated salinity in HL1 & HL3 near to the leach pad pond & stormwater pond, which lifted around 2012/13 at a similar time to a strong reduction in rainfall, & has stayed higher since at around 15,000EC. Conductivity is also high in both surface water ponds at around 20,000EC.



- Sulphate in groundwater is generally <1,000mg/l, with the exception of HL1 adjacent to the leach pond, which is in decline since 2012 & currently around 2,500mg/l. Both ponds record sulphate levels of ~5,000mg/l, which has reduced to date & is currently stable.
- In metals: mobility in groundwater is limited to arsenic at HL6 on the north eastern extent which seems localised, but which is on a decreasing trend. Arsenic & selenium is also present at elevated levels at the leach pond but is currently stable suggesting the process has ceased.

4.3.4 Findings

- Heap leach impacts are characterised by low-risk saline drainage, not acid rock processes. Sulphate may be elevated; however levels are stable & likely indicates the rate of sulphate production has reduced.
- The landform is actively draining post operations & groundwater quality is likely to improve over time. The current form of the heap leach actively sheds water effectively, though sedimentation of the perimeter drains may not keep all surface runoff water within the heap leach catchment during periods of rainfall.
- Leakage from the leach ponds is likely contributing to elevated conductivity & sulphate in groundwater of HL1, with quality likely relating to remnant quality from within & around the ponds acquired during operation.
- Primary metals of interest (ie. mobile) are arsenic, & potentially copper & zinc.
- Downgradient well HL3 shows elevated salinity, but with limited other potential contaminants indicates lower risk of impact.

Table 12 - Summary of water quality trends for heap leach surface water & groundwater

Parameter	Groundwater	Surface storage
pH	Stable & within normal ranges	Stable & within normal ranges
Salinity (EC)	HL1 & HL3 at 15,000EC	Generally around 20,000EC
Sulphate	HL1 around 2,500mg/l, others <1,000mg/l	Generally around 5,000mg/l
Arsenic	Stable except for HL6	Leach ponds elevated.
Aluminium	Not detected to around detection	Not detected to around detection.
Cadmium	Not detected to around detection	Single sampling event.
Chromium	Single sampling event	Not currently monitored.
Cobalt	Not currently monitored	Not currently monitored.
Copper	Not detected to around detection	Not detected to around detection
Cyanide	Not detected	Not detected
Lead	Not detected to around detection	Not detected to around detection
Manganese	Single sampling event	Single sampling event
Mercury	Not detected	Not detected
Molybdenum	Not detected to around detection	Single sampling event
Nickel	Single sampling event	Not detected to around detection
Selenium	Not detected to around detection, varies.	Not currently monitored.
Zinc	Not detected to around detection	Not detected to around detection.

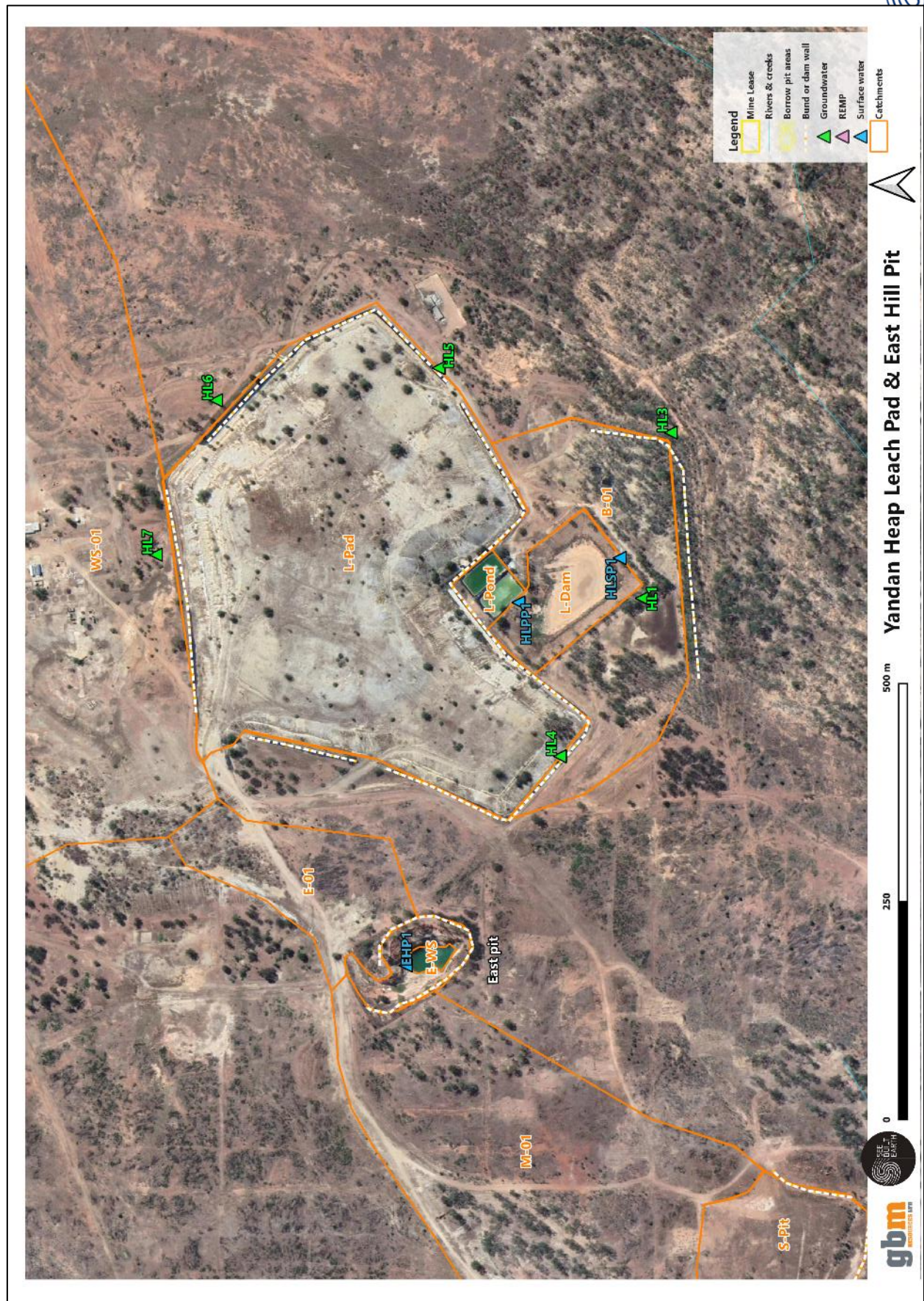


Figure 53 – Map of Heap Leach Landform



Figure 54 - View of heap leach pad (distance & nearby wall)



Figure 55 - Views of leach pad drainage with some erosion & minor wall slumping



Figure 56 - View of leach ponds & stormwater

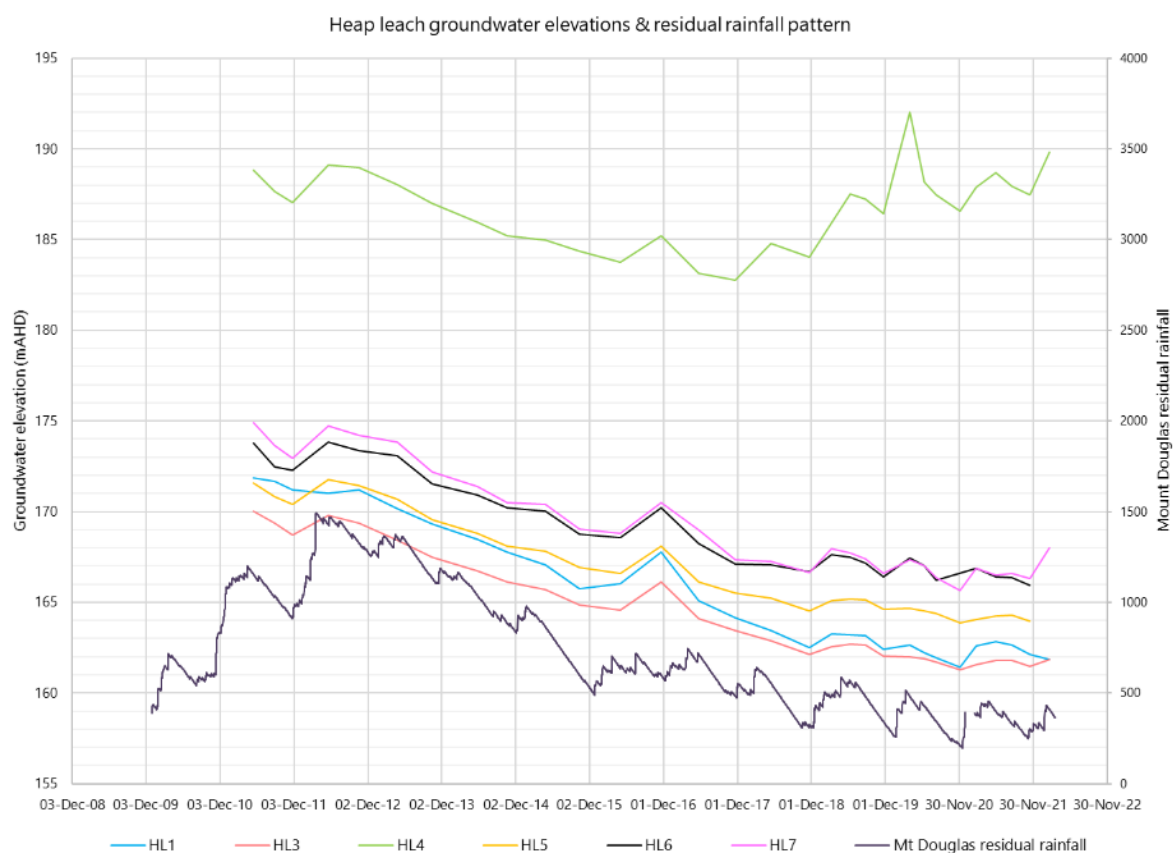
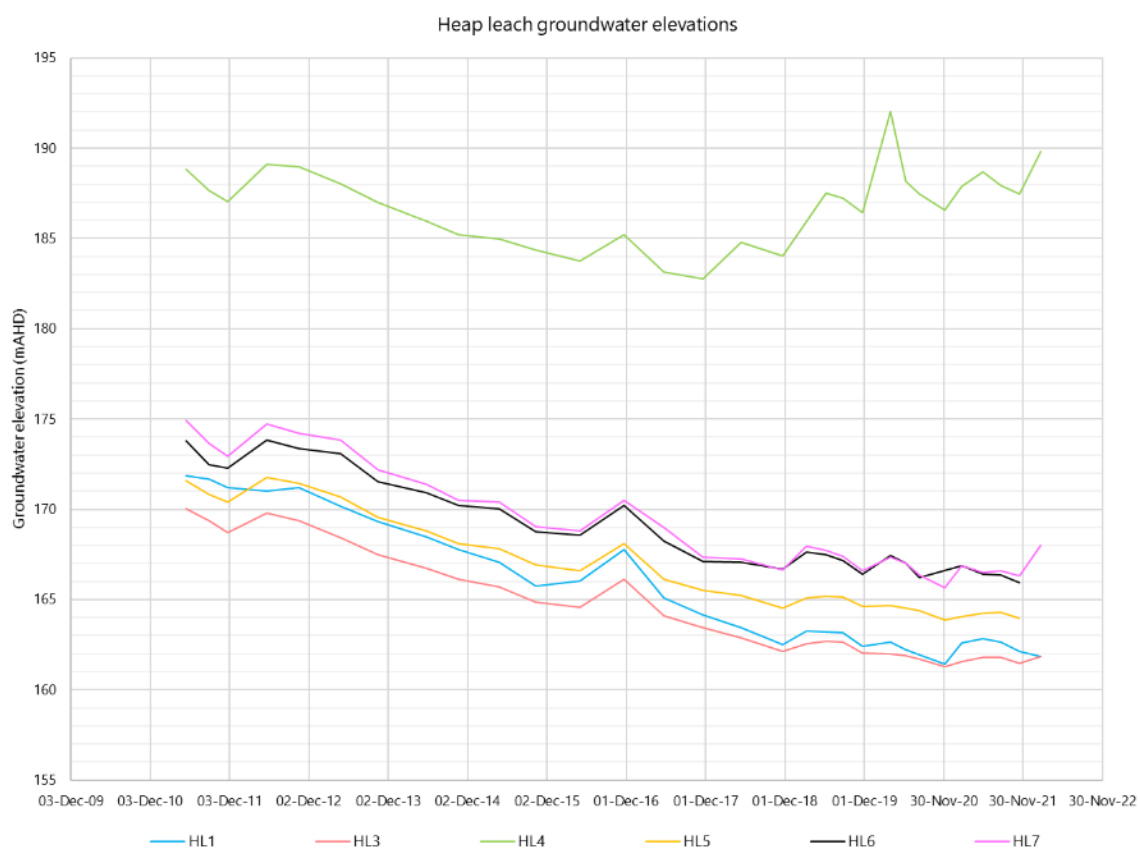


Figure 57 - Groundwater elevations of heap leach groundwater with residual rainfall

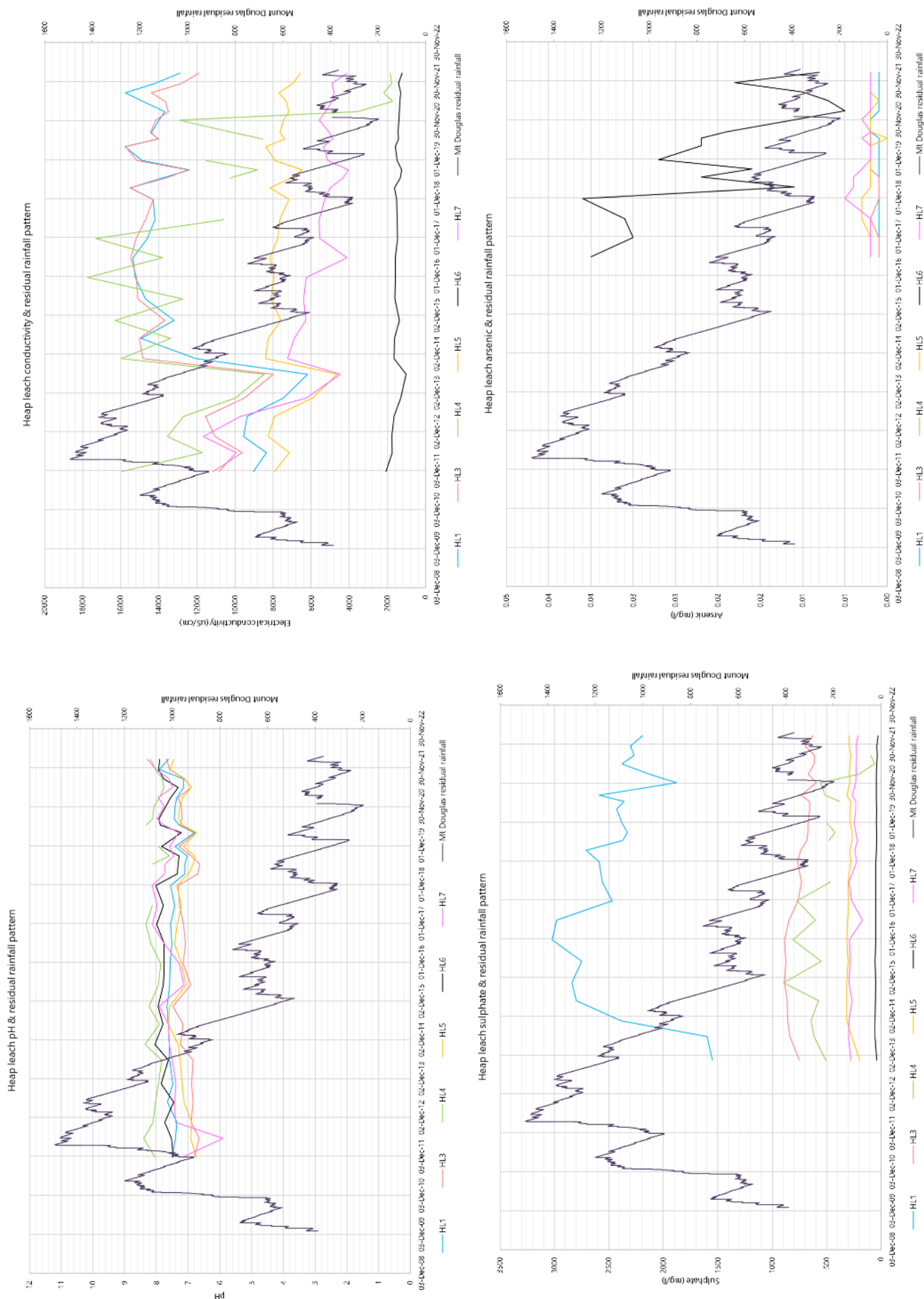


Figure 58 - Key water groundwater quality trends for heap leach

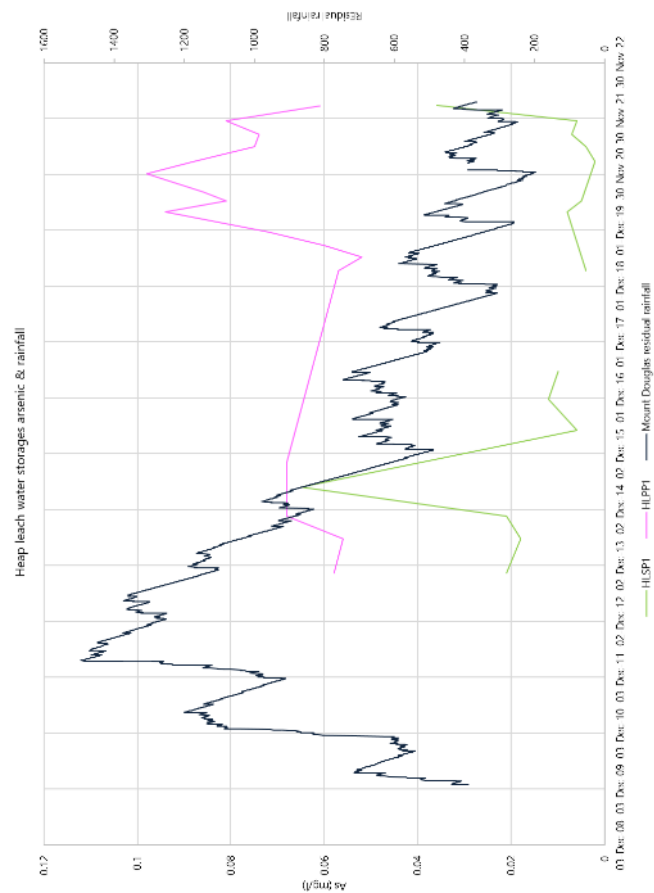
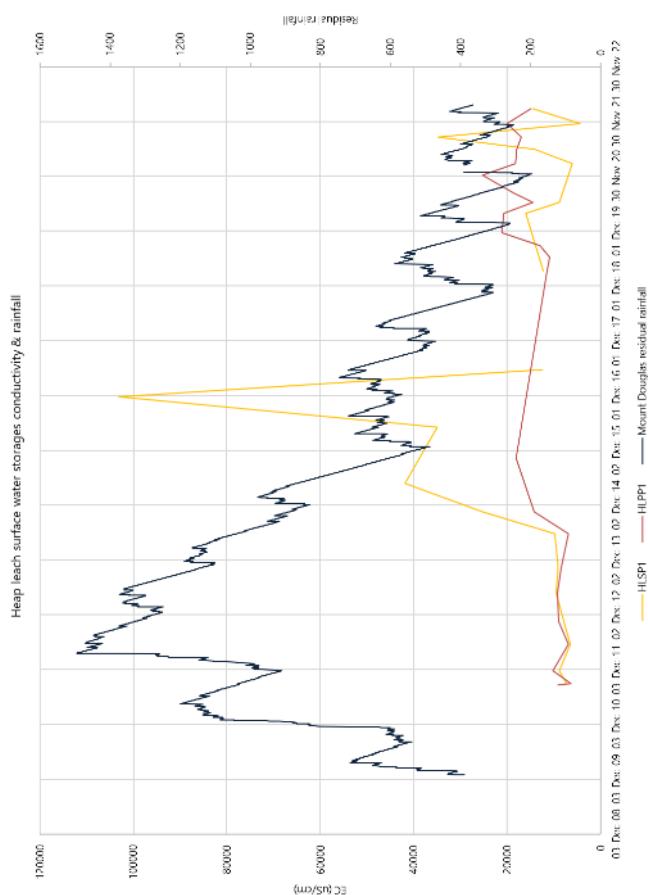
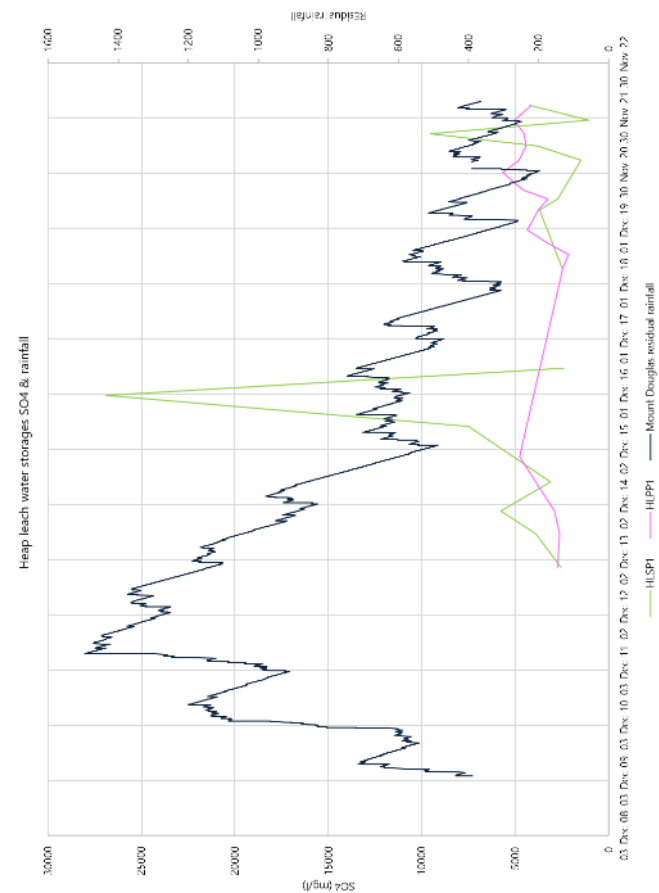


Figure 59 – Key surface water quality trends for heap leach



4.4 Main pit void

4.4.1 Description & observations

Main pit is a 22ha historical mine void formed during open pit mining which has operated since 1999 as a water cover legacy landform (Figure 60, Figure 61). To be successful, water cover requires water levels to always remain above 160mAHD to cover waste rock placed into the pit base at closure to avoid oxygen exposure & potential acid rock drainage. At full capacity, the pit is estimated to hold up to 6.8 gigalitres of water based on historical mine shells. Based on historical studies of dewatering (Forbes 1988), there is strong potential for groundwater connection to Main Pit with an estimated demand of 5,000m³/d to maintain dry operations within the pit. It not clear if this is sourced from a fault or from a porous boiling zone unit. Notably the pit is defined as being hydraulically separate to the alluvial aquifer of the Suttor River.

The pit is located close to the Suttor river & lays within the flood plain: when river levels or pit water level reach 169mAHD, the pit & river connect & flow in/out via excavated spillways (Figure 62) on the north west & the south east of the pit (@ 169mAHD). Design of the pit void & spillways was extensively developed throughout 1999-2000 for hydraulic design, positioning/height of the spillways & achieving water cover: R&D Environmental 1999; Chapman & Dwyer 1999; SRK Consulting 1999a; SRK Consulting 1999b & HLA EnviroSciences 2001. There are two ways for water to enter the pit (via surface flow): from the Suttor River when at level >169mAHD, or from Yandan Creek (south) where the borrow pit constructed to the south fills & flows to the pit.

To manage water levels within the pit & limit interactions unless in appropriate flood for flow mixing, there are two primary bunds around pit:

- Along the northern catchment of the pit (a relatively clean catchment): to divert flow around the pit & to the Suttor River without interaction with pit waters. This is required to ensure water levels do not increase dramatically due to flow from the catchment without ensuring flow in the Suttor River to enable mixing & protect receiving environment health through water quality.
- Along the western extent (between the pit & the Suttor River) to hold a short head of water within the pit & manage flow by the constructed spillways.

Catchments that directly report include the pit itself & drainage area shown in Figure 60.

On inspection, the pit lake & surrounding infrastructure appeared stable with robust design (including spillways) with some maintenance required on the western bund. Further information on the pit void is developed in the void water balance section.

4.4.2 Water responses

As part of regular water quality monitoring of the Main Pit, a water level by depth is recorded by sampling teams. Review of the water levels recorded shows reads likely lack precision (Figure 63): with different reads & responses between MP1 & MP2 of the same elevation surface, & limited indication of rainfall response. This reduces the confidence of these recorded pit water levels to indicative only.



4.4.3 Water quality & receiving environment

Water quality of Main Pit (including at depth) has been monitored since 2011 & is neutral pH (Figure 65), consistent temperature (Figure 66), low salinity (<350EC uS/cm, Figure 67), and low sulphate(<100mg/l). As a water body, it is lower in dissolved oxygen than for a healthy lake environment (Figure 68), & like other parts of the site, elevated arsenic occurs (Figure 69) with trace copper & zinc (though at trace levels).

Minimal mixing will be required with site or river water to meet receiving environment requirements: releases have been monitored in two spill events of 2011 & 2017 with samples taken at release points & SR1 downstream, with results fully compliant & no impact to environment health (Figure 64). A summary of water quality within the pit & receiving environment is provided in Table 13.

4.4.4 Findings

- The water cover of Main Pit is successful to design in managing risk of materials exposure & maintaining a pit lake which is relatively self-sustaining, consistent water quality & stable.
- Water quality is stable over time & at depth, with no observable signs of ARD or water quality issues, except for elevated arsenic & lower rates of dissolved oxygen than required to sustain healthy plant life. The pit is contained except for times of higher water flow in the Suttor River (>500m³/s) with more than adequate levels of mixing to achieve water quality objectives.
- The water profile shows water mixing is excellent throughout the water column with no thermocline or zoning – quality is consistent at depth & across the lake. Times of inflow from Suttor River increase dissolved oxygen throughout the pit lake.
- Average recurrence interval of hydraulic connection between pit & Suttor River/Yandan Creek is 5-15 years, or an average of 10 years as a natural refresh of water & part of the flood plain activity: receiving water quality is stable & meets water health objectives.
- Groundwater inflow into the pit lake is likely: historical records suggest strong groundwater inflow (separate to alluvial aquifers) & water level appears to be relatively constant.

Table 13 - Summary of water quality trends of Main Pit in-pit water & receiving environment

Parameter	Pit water	Receiving environment
pH	Stable & average	Stable & within normal ranges
Temperature	Stable & average	
Sulphate	<100mg/l	<50mg/l
Electrical conductivity (EC)	<350 uS/cm	1300 & <200 uS/cm
Dissolved oxygen (DO)	10mg/l	N/A
Arsenic	Elevated <0.07mg/l	Around detection limits to not detected.
Cadmium	Not detected to around detection	Around detection limits to not detected.
Copper	Elevated to trace levels at times	Around detection limits to not detected.
Lead	Not detected to around detection	Not detected.
Mercury	Not detected	Not detected
Molybdenum	Not detected to around detection	Not detected.
Selenium	Not detected to around detection	Not detected.



Zinc

Elevated to trace levels at times

Around detection limits to not detected.

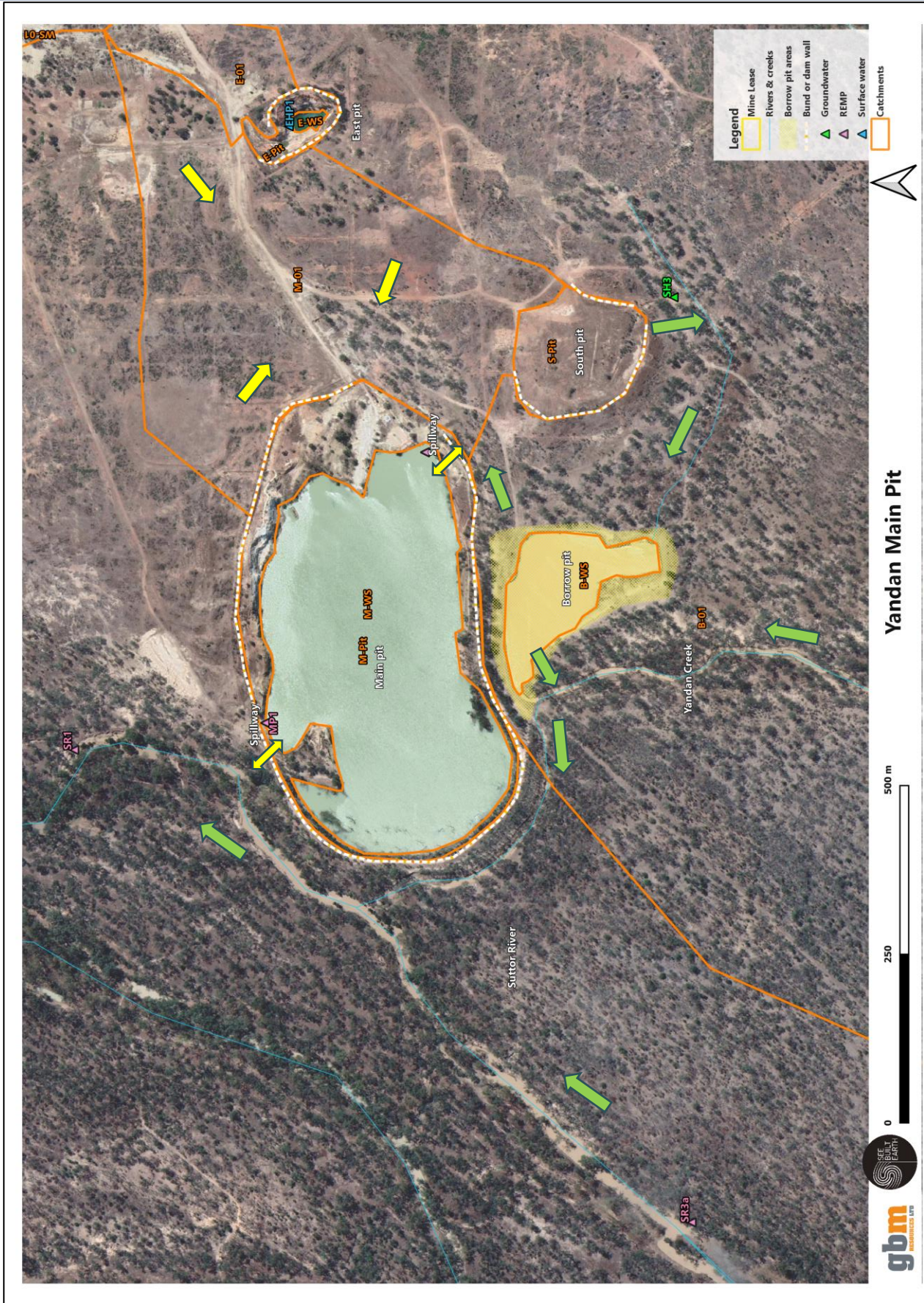


Figure 60 – Map of Main Pit Landform



Figure 61 - Views of Main Pit



*Figure 62 - Views of spillways at
south east & north west ends of Main
pit*



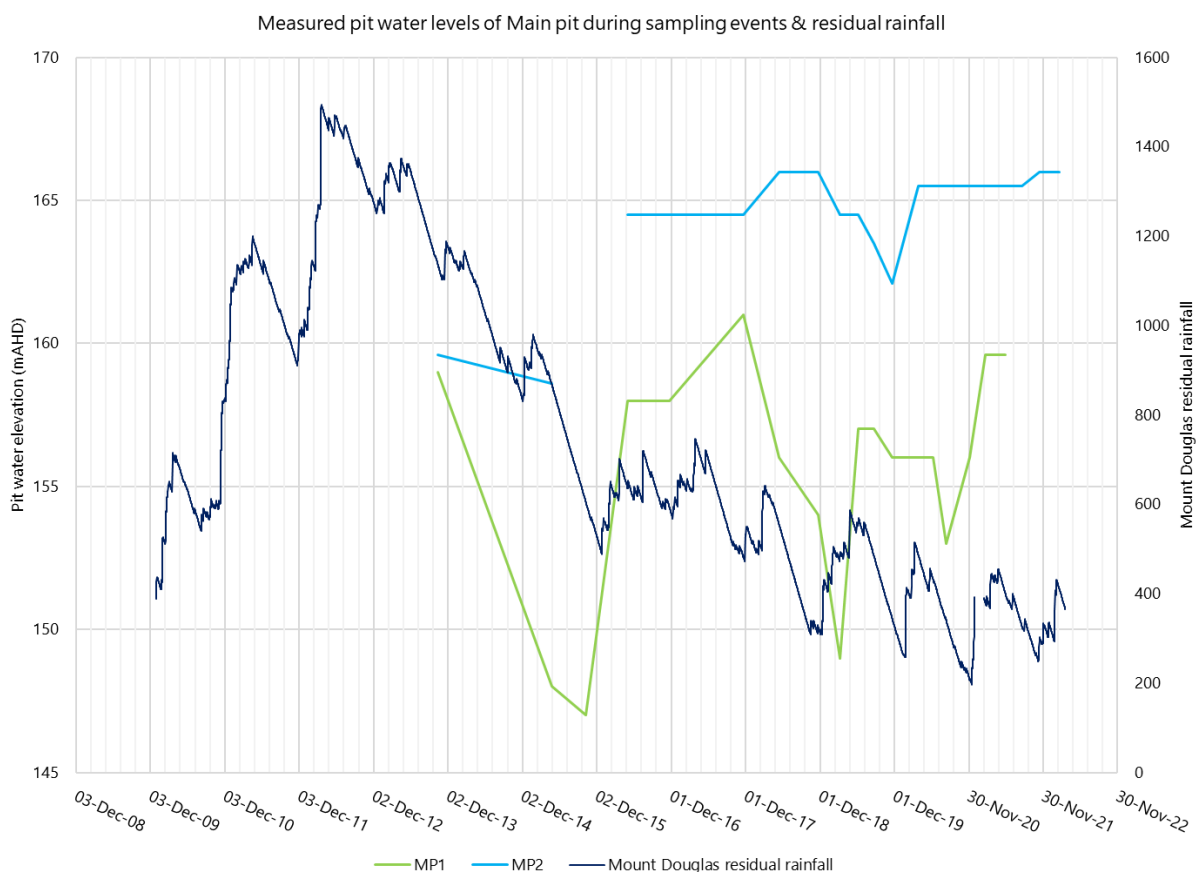


Figure 63 - Pit water level elevations as measured during sampling events (wide range of error)

Yandan Gold Mine Discharge Monitoring Database		Parameter			Total Metals										Dissolved Metals									
			pH	EC	Sulphate	Arsenic	Cadmium	Copper	Lead	Mercury	Molybdenum	Selenium	Zinc	Aluminium	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Nickel	Zinc	Hardness	
		Unit	pH Units	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	
EA LIMITS		Release Limits (If Limit is exceeded, check against 95th Percentile of Reference Data):	6-9	1000	1000	0.5	0.01	0.5	0.1	0.002	0.05	0.02	20											
		Trigger Levels (If Trigger is exceeded, check against 80th Percentile of Reference Data):	6-7.5	250	0										55	13	0.2	1.4	3.4	0.6	11	11	8	N/A
Sample No.	Sample Date	Site ID.																						
EB1707881	10-04-17	MP1	7.38	113	7	0.008	<0.0001	0.003	0.004	<0.0001	<0.001	<0.01	0.01	not taken										
EB1707881	10-04-17	MP2	7.39	151	10	0.028	<0.0001	0.003	0.003	<0.0001	<0.001	<0.01	0.008	not taken										

Release Monitoring Points (Compliance Points & Reference Points)		Parameter					Total Metals								
			pH	EC	Sulphate	Hardness	Aluminium	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Nickel	Zinc
		Unit	pH Units	µs/cm	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EA Limits		EA Release Contaminant Trigger Levels	6 -7.5 (or 20th percentile of reference of 6.0, whichever is lower. 80th percentile of reference or 7.5, whichever is higher)	250 (or 80th percentile of reference or 250, whichever is higher)	80th percentile or reference	NA	55	13	0.2	1.4	3.4	0.6	11	11	8
Sample Date	Sample Time	EA Monitoring Point													
	18-May-11	SR1	8.32	1330											
EB1117232003	23-Aug-11	SR1	8.05	1620	22										
EB1707881	10-Apr-17	SR1	7.37	152	5	36000									
	10-Apr-17	SR3a	7.36	152	4		7.52	0.0001	0.008	0.004	<0.0001	0.001	<0.01	0.018	

Dissolved Metals								
Aluminium	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Nickel	Zinc
µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
55 (or 80th percentile of reference or 55, whichever is higher)	13 (or 80th percentile of reference or 13, whichever is higher)	0.2 (or 80th percentile of reference or 0.2, whichever is higher)	1.4 (or 80th percentile of reference or 1.4, whichever is higher)	3.4 (or 80th percentile of reference or 3.4, whichever is higher)	0.6 (or 80th percentile of reference or 0.6, whichever is higher)	11 (or 80th percentile of reference or 11, whichever is higher)	11 (or 80th percentile of reference or 11, whichever is higher)	8 (or 80th percentile of reference or 8, whichever is higher)
980	2	<0.1	4	1	<0.1	<10	3	38
950			4					55

Figure 64 - Release point & receiving environment sampling from 2011 & 2017 release events

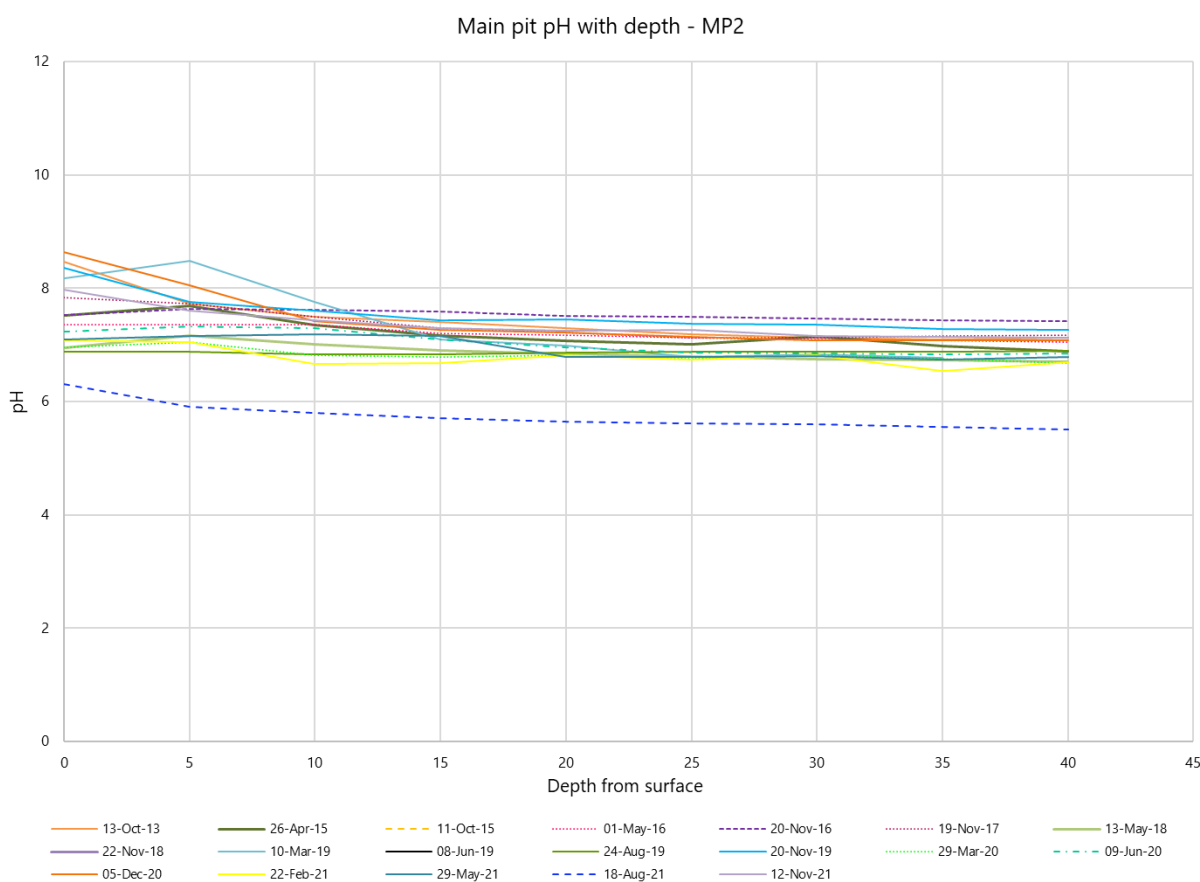
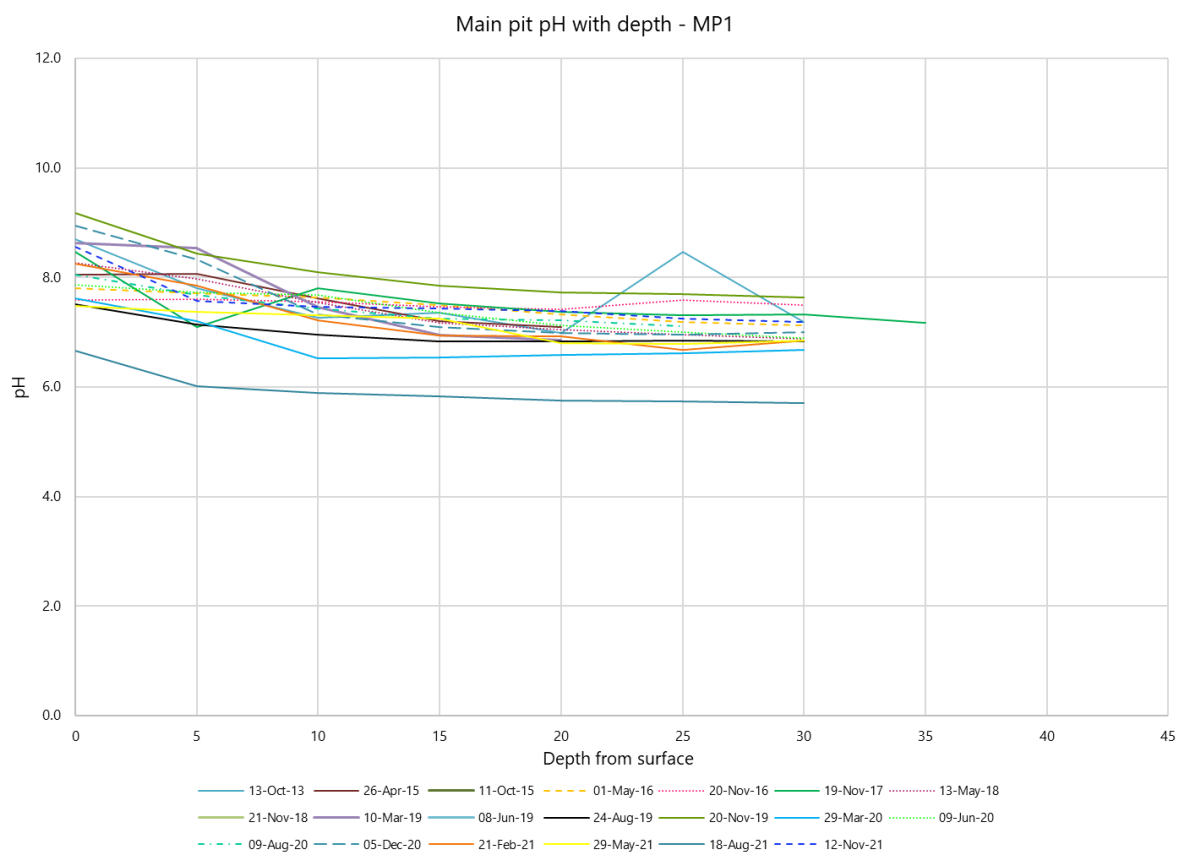
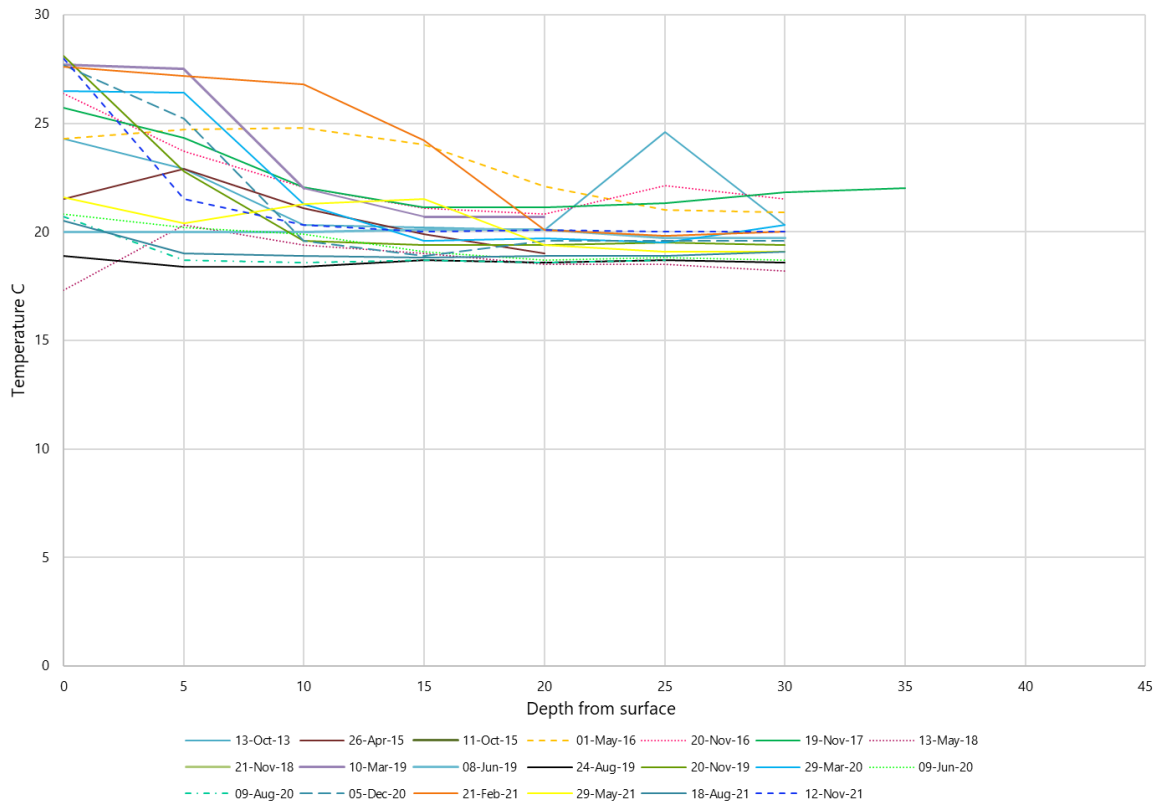


Figure 65 - pH at depth within Main pit



Main pit temperature with depth - MP1



Main pit temperature with depth - MP2

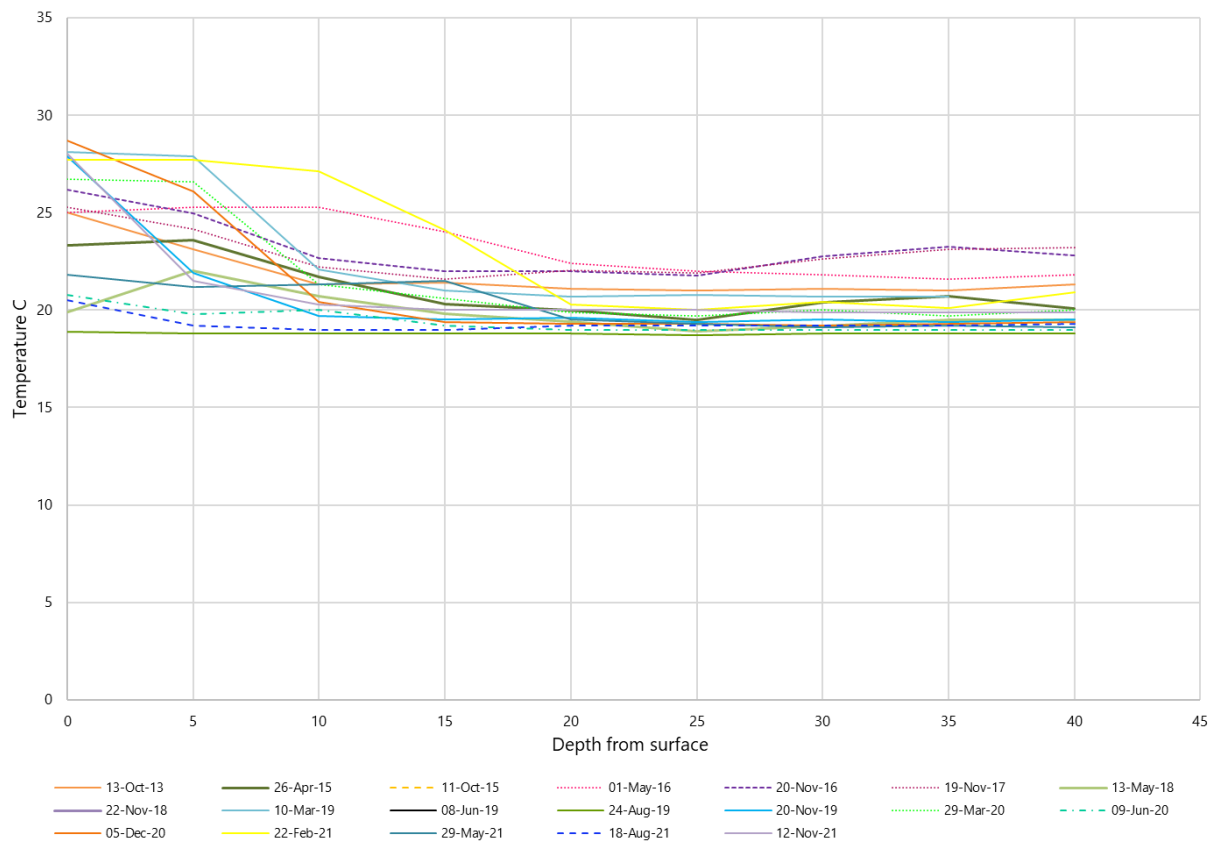
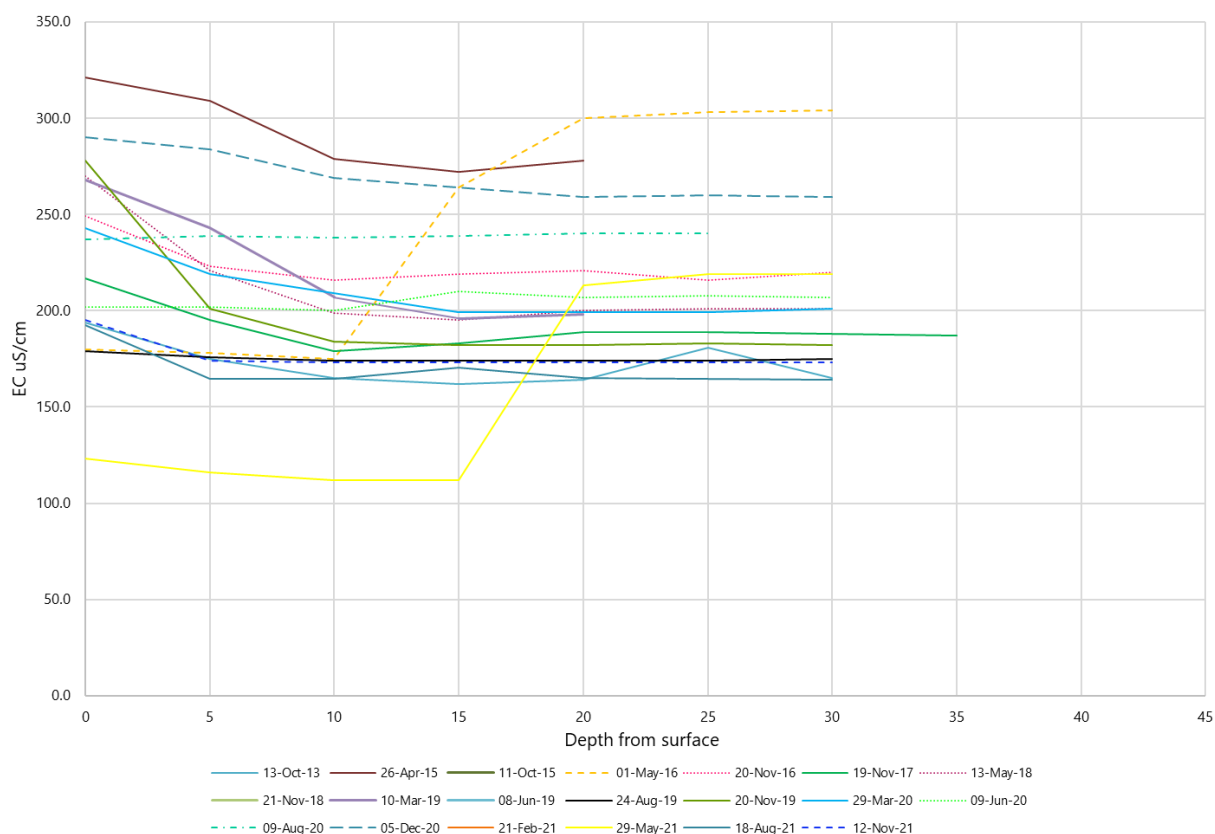


Figure 66 - Temperature at depth within main pit



Main pit conductivity with depth - MP1



Main pit conductivity with depth - MP2

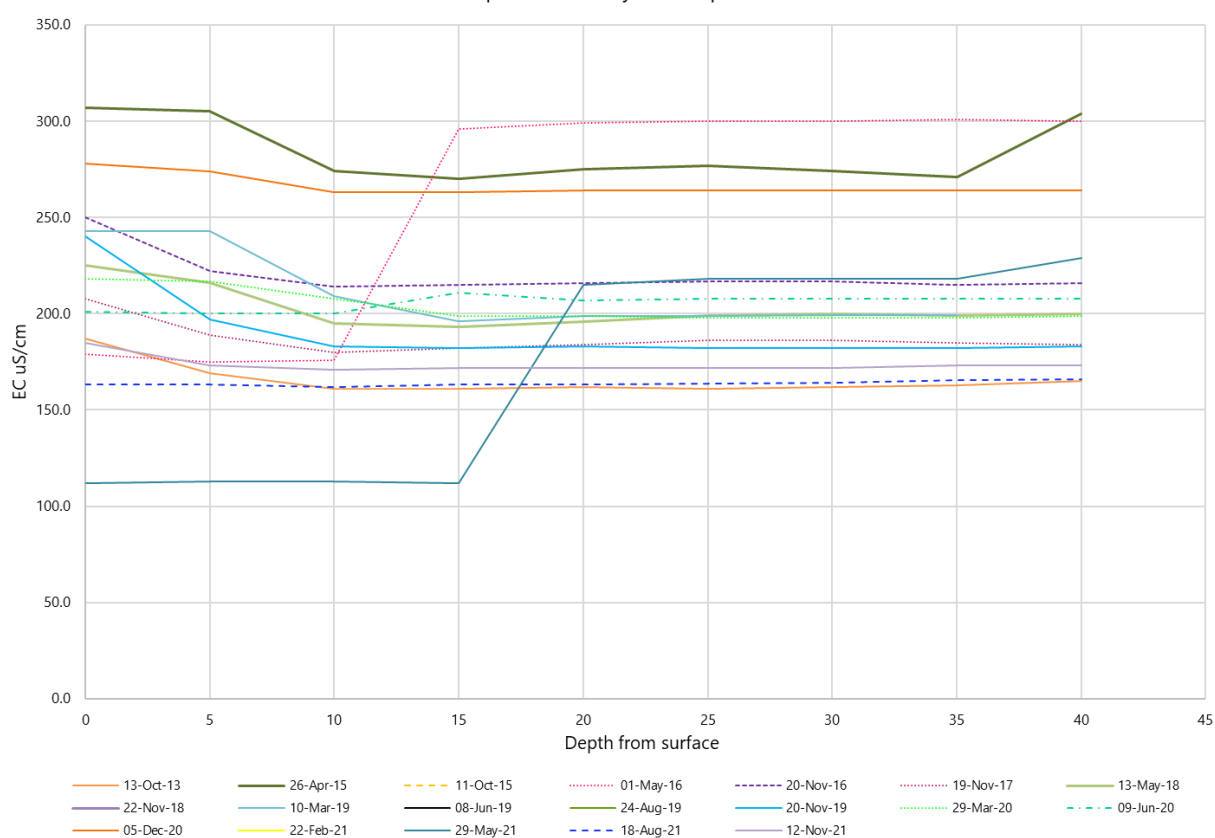


Figure 67 - Electrical conductivity at depth within Main pit

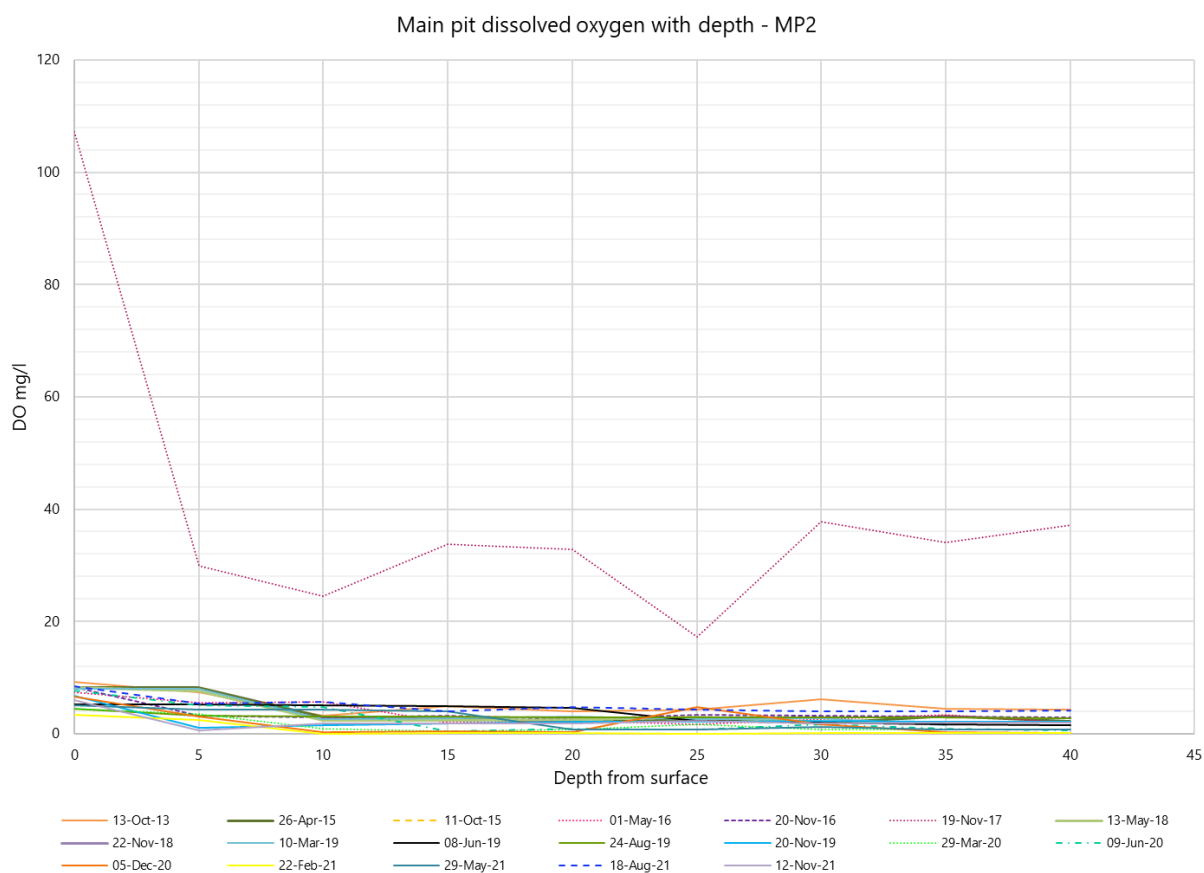
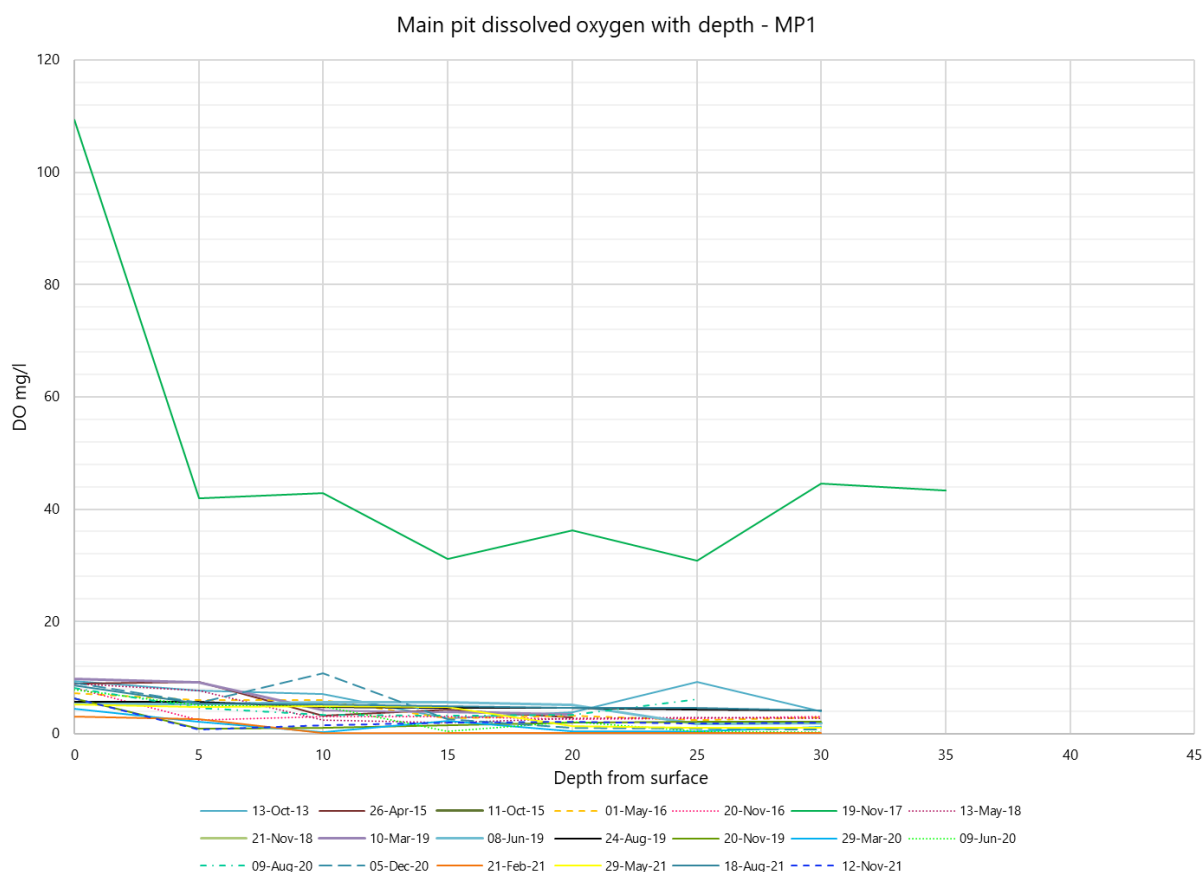


Figure 68 - Dissolved oxygen at depth within Main Pit

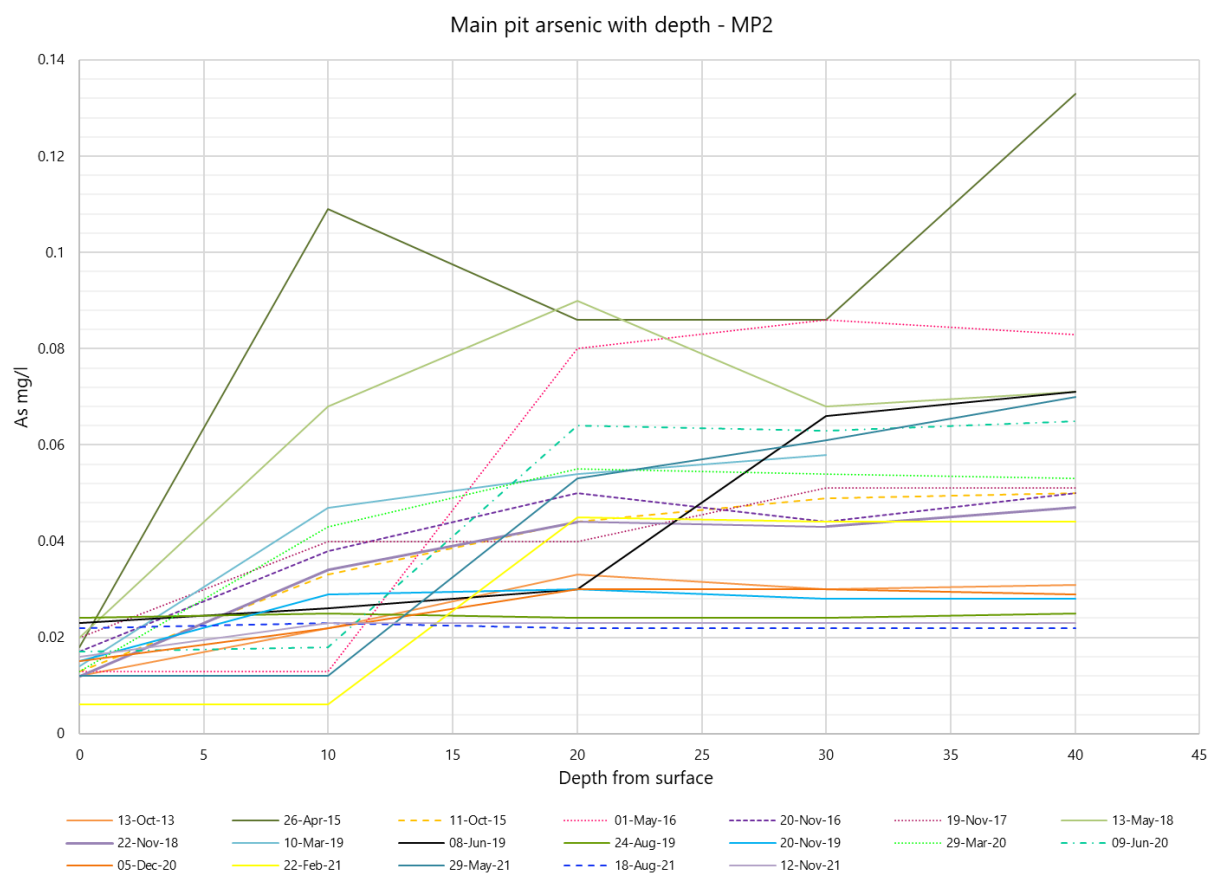
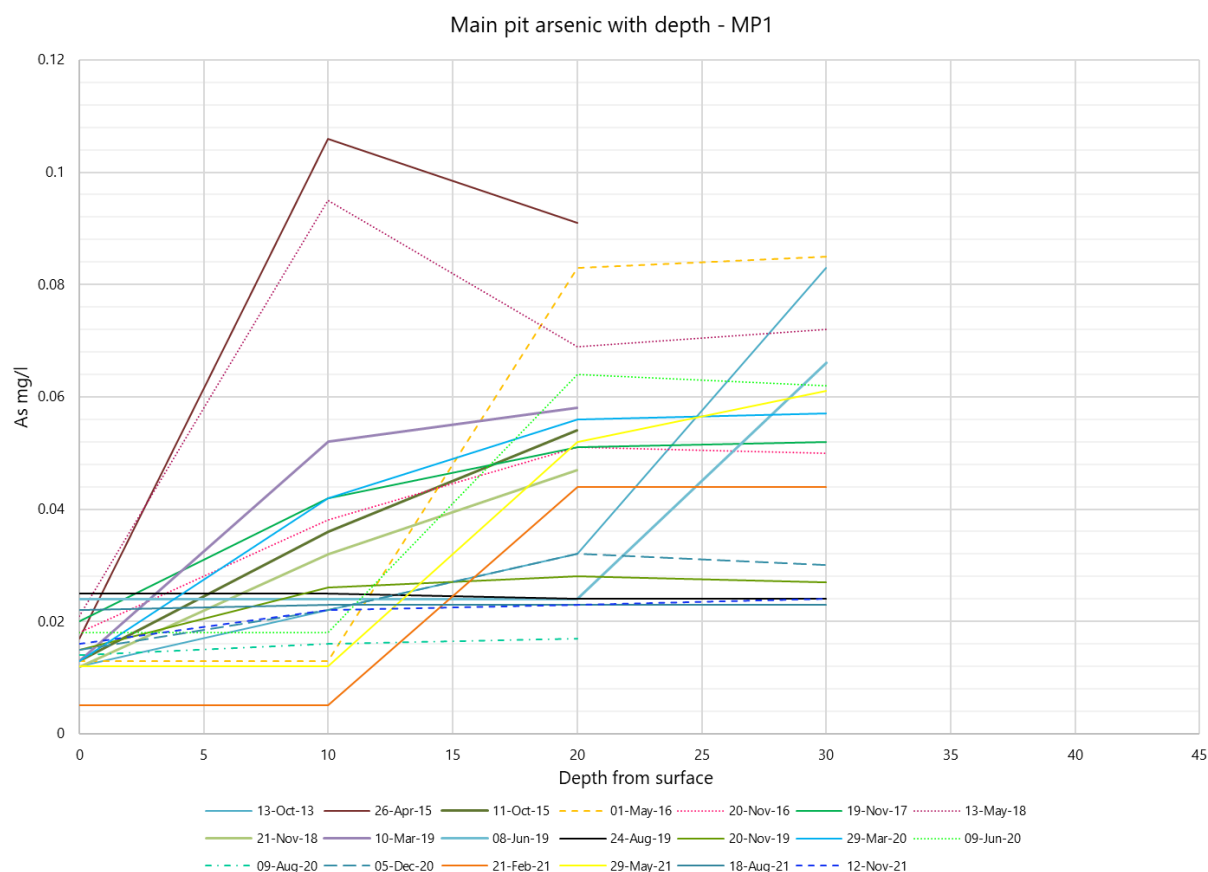


Figure 69 – Arsenic at depth within Main Pit



4.5 East pit void

4.5.1 Description & observations

East Hill pit is a small, limited surface footprint pit of only 0.9 hectares area, 60m width & a limited catchment from part of a road (Figure 70) between the Heap Leach Pad & Main pit. The pit has limited access, with 20m of exposed pit walls above a pit lake.

4.5.2 Water responses

No water level measurements are available for East Hill Pit lake, however water remains at low levels within the pit. Relative water levels plot above site groundwater levels (168mAHD versus 163mAHD) which suggest hydraulic separate from site groundwater or different aquifers. Water balance assessments (Section 5) also suggest there is no groundwater contribution, though there is potential for connection to the Main pit lake through faulting.

4.5.3 Water quality & containment

East Hill Pit has hosted acidic water of around pH 4 since 2011 & is stable (Figure 71). Over that time, electrical conductivity & sulphate have increased & now sit around 20,000 uS/cm & 5,000 mg/l respectively. Materials characterisation metals expected to be mobile are mobile at East Hill pit: with elevated arsenic, copper, nickel & zinc. No mercury or cyanide is detected.

4.5.4 Findings

East Hill pit is a low-lying pit lake, with reactive materials & acidic water quality with increasing salts & metals. The pit appears contained at low levels & is unlikely to be connected to groundwater unless through faulting to the Main Pit.

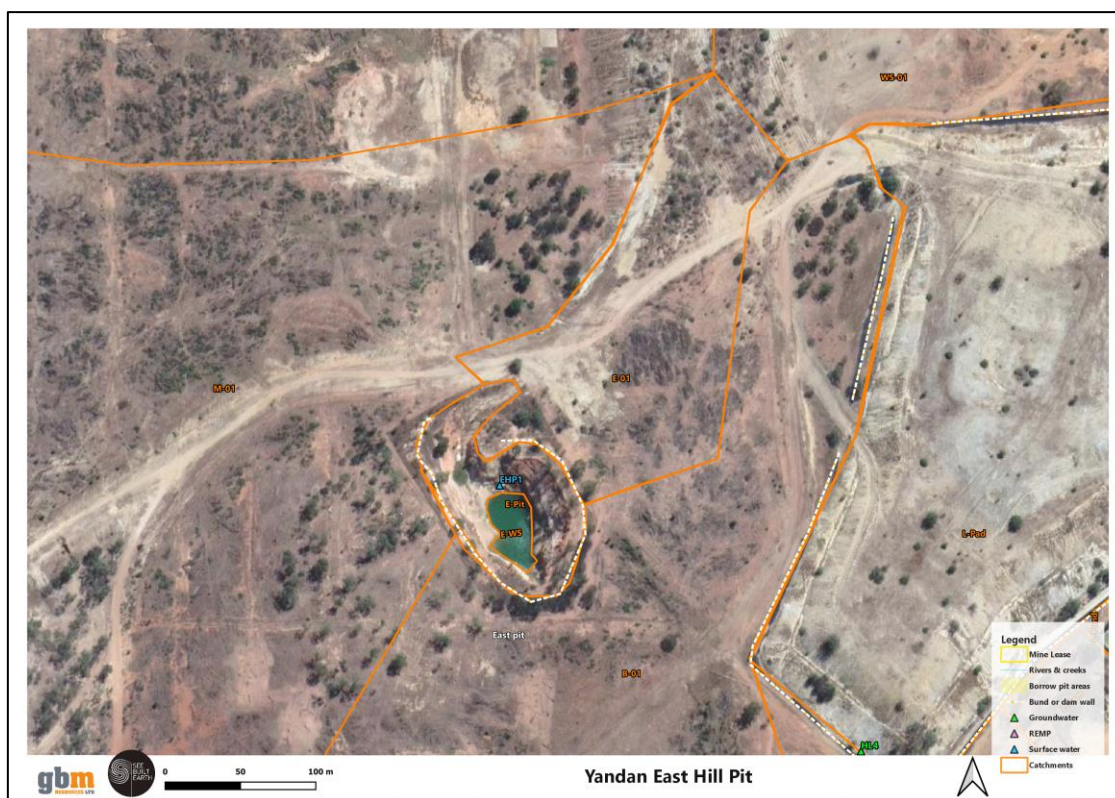


Figure 70 - Map of East Hill Pit

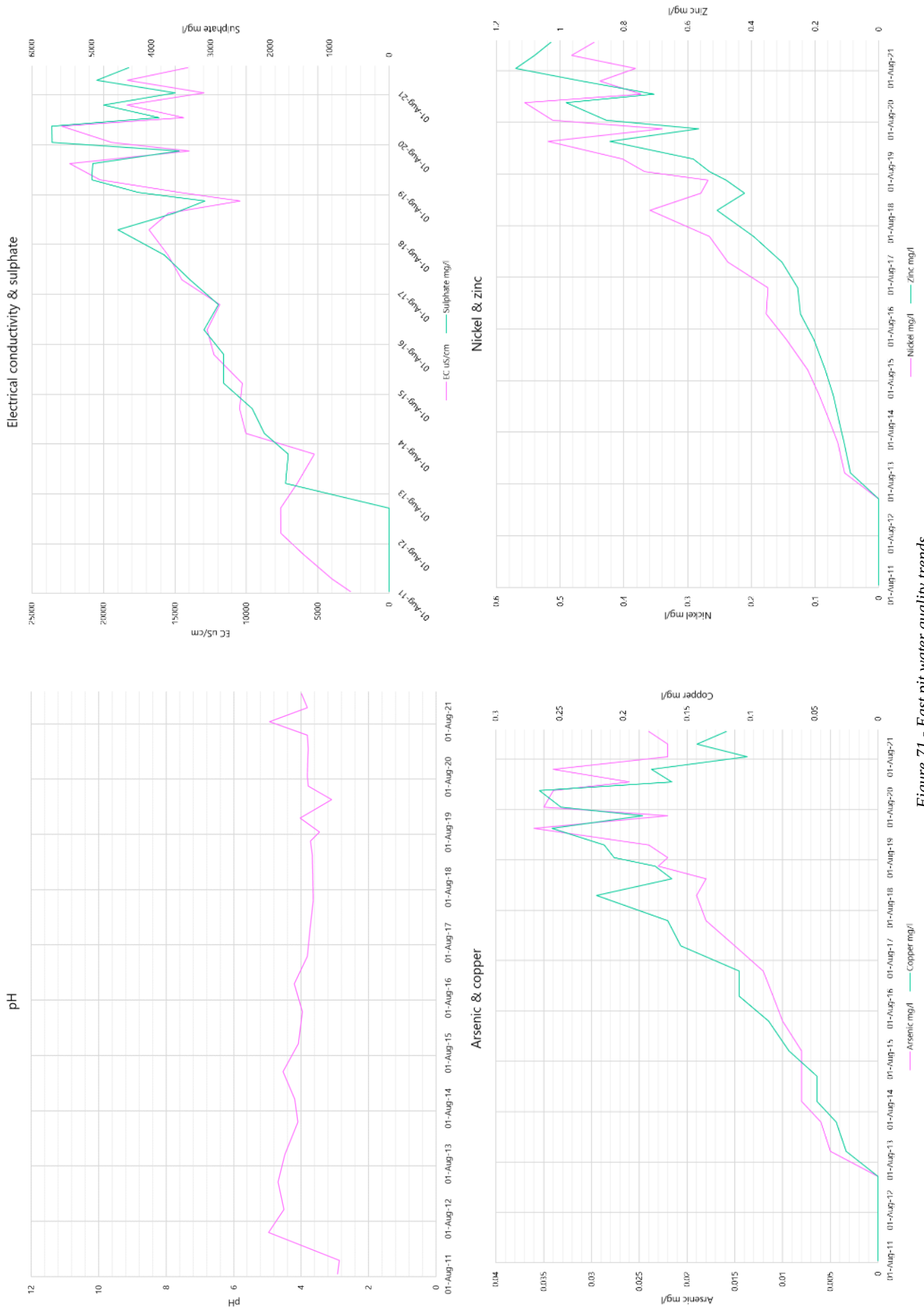


Figure 71 - East pit water quality trends



5 Pit voids fates - water balances & quality outcomes

5.1 Approach

The selected method for water system simulation at Yandan is a void mass balance: a transparent, & practical approach which is a good fit to the pit void systems. The selection of method is based on the dominance of the key driving forces of rainfall, evaporation (& evaporation surface) in pit lake levels, & the ability to include groundwater & river inflow/outflow to directly inform closure states of the pits. The model is analytical, & assesses a range of rainfall conditions over a 108-year timeframe, with a catchment based approach applying runoff factors common to Rational Method to solve for overall flow volumes. To capture rainfall variation, a 108-year rainfall record from 1913 to 2021 is applied, which is explored further in variations to simulate climate change scenarios at time steps through to 2090. Simulations are developed as a base case to which variations for State forecasts climate change are applied.

The water balance builds from available data & applied logics of a historical pit void as a conceptual model, including knowable pit geometry as storage curves & elevations, then water system interactions of rainfall & evaporation in the region, catchments reporting & nature, & looks to simulate a model response which reflects observed or recorded behaviour of the pit lake. Yandan Main pit as a pit lake has been in commission since 2000, & since (20 years) the pit has not dried or dropped below minimum levels, & has taken in flood waters up to 6 times. Vegetation & setting around the pit lake suggests a level of consistency in water levels when not in flood. For East Hill pit: the pit has never overflowed & has limited exposure to sunshine given the narrow pit crest.

Each pit has a character of design which enables informed assumptions to guide the water balance where data is limited & setup a useful model. The intent of modelling pit void fates is to simulate how a pit void (& catchments) will react over the longer term in water level & to gain insight as to other potential sources of the water balance such as potential groundwater inflow or loss. The approach is structured & objective. following a calibration & reasoning process to ensure relevance, transparency & credibility for each pit void in the landscape.

5.2 Pit geometry & storage curves

Pit geometry was developed with the following process:

- For Yandan, last known survey of the pit was used. To create the void model, pit shapes were sliced at 0.5m RL intervals in 3D software Vulcan, & void space estimated through applying a 0.5m unit to the surface area by elevation. The cumulative volumes of each slice through the pit from deepest to top of the pit provides the void storage curve.
- For East Hill pit, with no mining survey available an estimation of storage curve was calculated using surface area LiDAR elevation contours as unit widths (1m), & extrapolation for pit wall curve for extra pit below the water surface at 168mAHD to 166mAHD.

Each pit is very different in size & dimensions:

- Main pit extends from ~110mAHD up to 169mAHD to spill level at 59m depth, for a total void capacity of 6,800 megaliters at fill supply capacity.
- East Hill pit runs between 166mAHD at base of pit to 184mAHD at the top of the pit to spill level & contains only 45 megaliters of void capacity.

Slices & volumes used in each void model are available in Appendix D.



Main pit storage curve

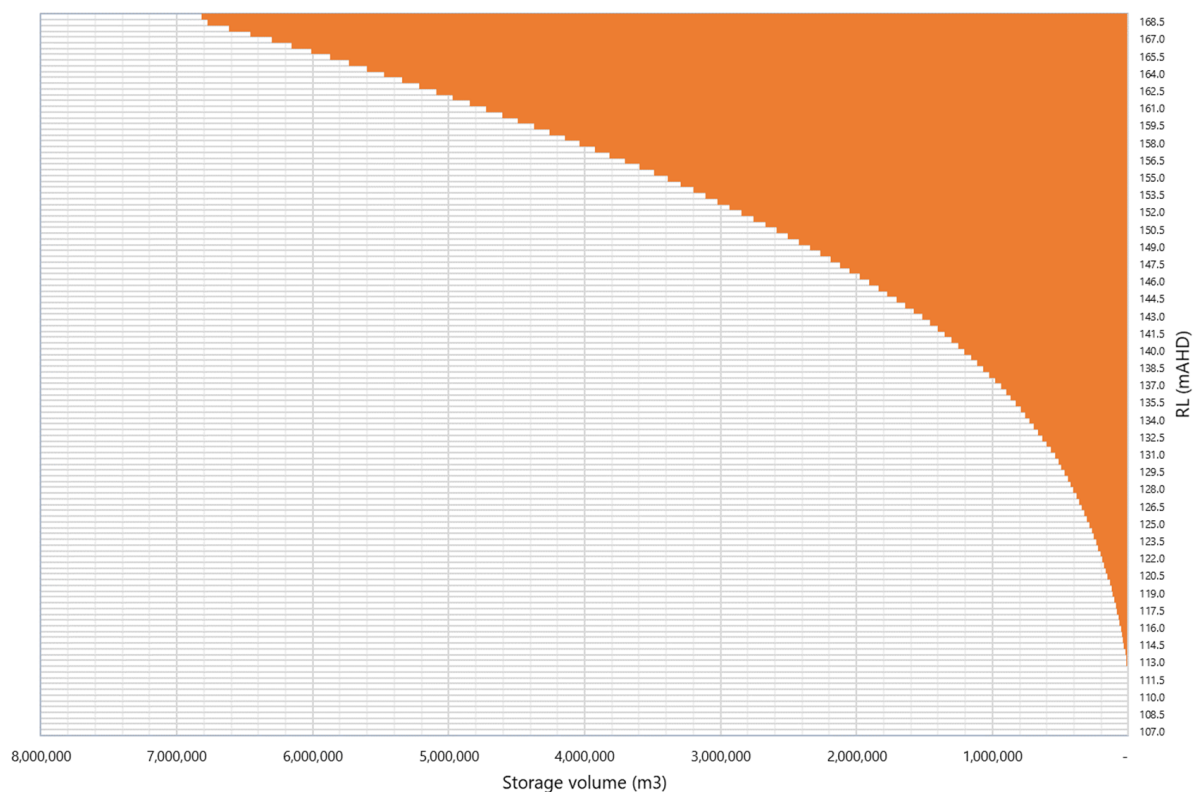


Figure 72 - Main pit void storage curve

East Hill pit storage curve

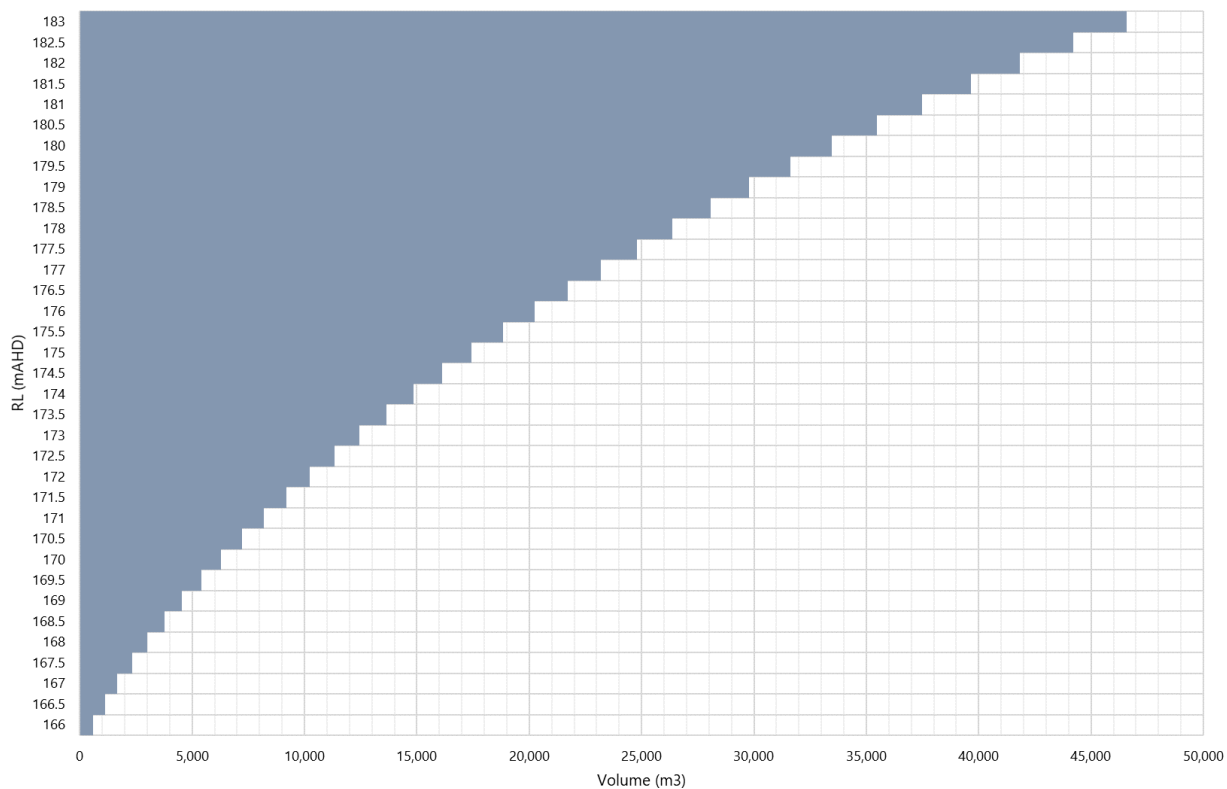


Figure 73 - East Hill pit void storage curve



5.3 Conceptual model

Both Main pit & East Hill pit lay within volcanic geology, which is fault bounded, variable from porous to crystalline & highly compartmentalized. Pumping tests as part of impact studies for the original project around Main Pit (Forbes 1988) encountered flow boundaries & estimated up to 5ML/day of dewatering per day, identifying two possible groundwater sources: either the Yandan Fault, or a porous “boiling zone” alteration horizon formed as part of hydrothermal activity. The study calculated transmissivities (conductivity over the width of a unit) of 60-200m²/d, & identified no connection with the alluvial aquifer to groundwater. Like many ephemeral drainages, the Suttor River is likely to be a losing river system, where water recharges into alluvial aquifers rather than being permanently groundwater fed as part of a natural system.

Inside the fault boundaries, both pits are comprised of altered andesite & sinter, with shears & silicified veining hosting the mineralisation. Oxidised zones are likely be more porous/conductive than fresh, crystalline rock, & there is likely to a change in hydraulic conductivity between the types of materials which is depth & fault dependent. The conductivity of crystalline rock is low given the lack of porosity (examples in Figure 74), & suggests much of the transmissivity observed in early pumping tests is primarily through the boiling zone unit, or the Yandan Fault. Faults are more capable of conveying volumes of water, as is porous & altered rocks such as a boiling zone unit.

Crystalline Rocks	
Material	Hydraulic Conductivity (m/sec)
Permeable basalt	4×10^{-7} to 2×10^{-2}
Fractured igneous and metamorphic rock	8×10^{-9} to 3×10^{-4}
Weathered granite	3.3×10^{-6} to 5.2×10^{-5}
Weathered gabbro	5.5×10^{-7} to 3.8×10^{-6}
Basalt	2×10^{-11} to 4.2×10^{-7}
Unfractured igneous and metamorphic rock	3×10^{-14} to 2×10^{-10}

Figure 74 - Typical conductivity values of crystalline rocks (Domenico & Schwartz 1990)

Unfortunately, the locations of pump tested wells have since been lost from reporting & the spatial dynamics of the work is not known to gain greater insight into unit & fault occurrences. However, we can assume Main pit to be connected to groundwater & that there will be a groundwater inflow component rather than loss to groundwater, & it is likely to be around current pit water levels as potentiometric equilibrium is likely to be reached after 20 years (aligned with the apparent consistency of pit water level at Main pit).

At East Hill pit, there is limited information to determine if groundwater is a factor: what is known is that water levels are low in the East Hill pit & sulphides are exposed leading to the observed water quality degradation in the pit over time. There may be signs of a potential hydraulic link between the pits: LiDAR imagery in 2021 identified similar water elevations for both pits at 168mAHD.

Linkage is possible, most likely through faulting: East Hill pit is higher in elevation, but water level is near to the base of the pit, whereas Main pit is lower elevation but has a greater water depth. If so, a level of groundwater leakage from East Hill pit may occur via the fracture, but would be towards Main pit discharge only, & be protected from environment harm.

Risk of groundwater transmission away from the pits is considered low as a conceptual model as:



- Main Pit is likely a gaining pit & be the lowest groundwater level in the landscape & will act as a groundwater sink given unconfined/open to air & position next to the Suttor River. Groundwater will flow towards Main Pit.
- East Pit is either hydraulically separate to Main pit, or may be connected through a discrete structures/or discrete boiling zone which is able to host water, where the rest of the crystalline rock will not. If connected, water will only flow towards Main pit when the hydraulic gradient between the pits allows it to (East Hill pit lake would need to have elevation greater than Main Pit pit lake water elevation), & if so, would be captured as a small volume contribution into a much larger volume pit lake (order of magnitude difference even at full supply level), & be measured by the water quality observations of the Main pit over the past 20 years.
- There is no known connection to alluvial aquifers, with pump tests in 1988 identifying no response from alluvial areas & a fault bounded geology, & evidence Suttor River is a losing stream into almost 30m of alluvials below current stream bed.

In surface water & pit lake interactions, three other key factors for Main Pit conceptual model are:

- Requirement for the pit lake to remain above 160mAHD to maintain water cover.
- Hydraulic separation of the pit lake to the river through the western bund wall.
- Interaction with the Suttor River & Yandan Creek at flood heights of 169.05mAHD (spillway at 169mAHD), with observed periodic flood events in the order of 5-15 year AEP. Size & magnitude of flows can be estimated from a known relationship of flows at St Anns gauge & relative elevations where inflow from the Suttor River or Yandan Creek occurs at flow rates of >500m³/s.

Risk of pit water quality impacting surface water quality is considered very low as:

- Main pit
 - Engineering controls restricting interaction of pit water except in flood conditions.
 - Main pit lake water quality is very good except for arsenic levels, & which will be adequately addressed with dilution from flood waters mixing as part of discharge.
 - Lack of groundwater hydraulic connection to alluvial aquifers.
- East Hill pit
 - Catchment for pit is very small & likelihood of spill is negligible except in rare flooding events where inflow may come from external sources.
 - East Hill pit is not hydraulically connected to any drainage lines.

Schematics of conceptual models for each pit are shown in Figure 75 & Figure 76.

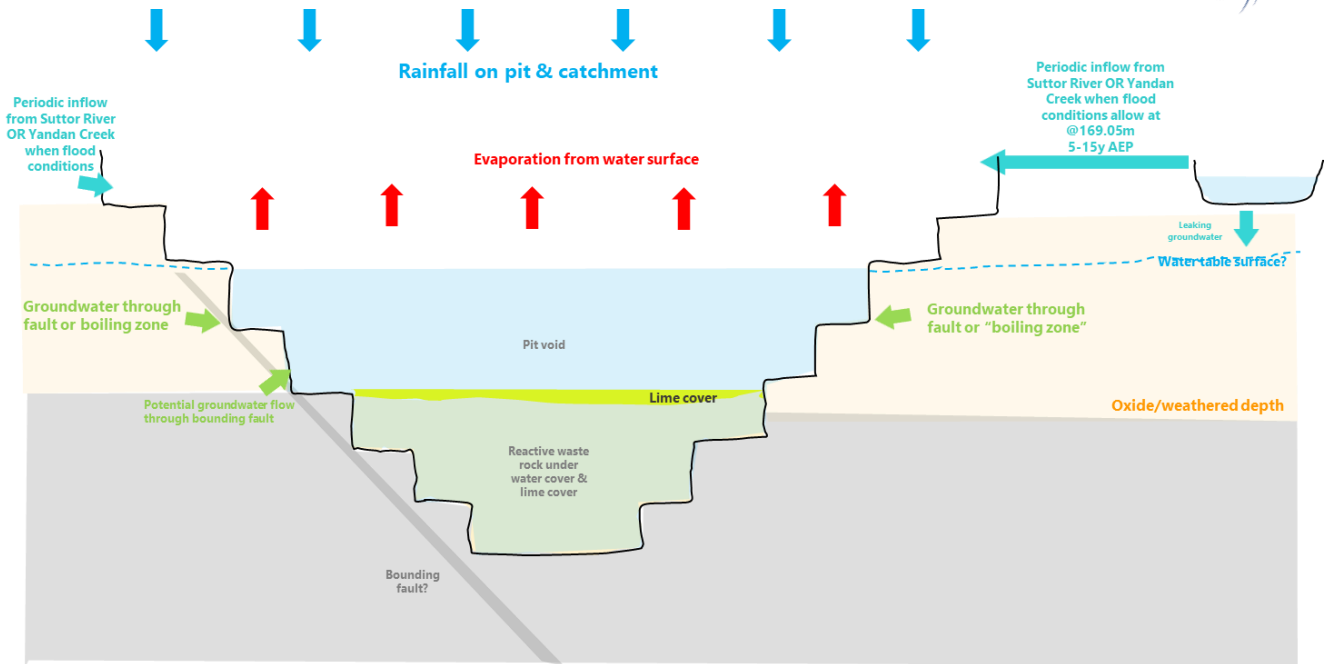


Figure 75 - Conceptual model for Main pit lake

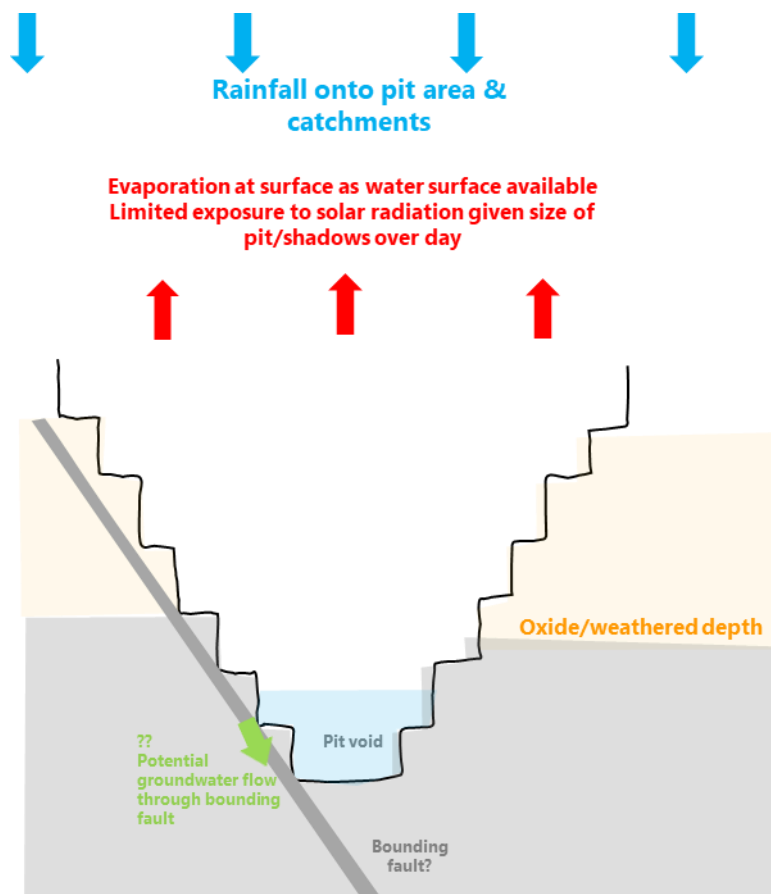


Figure 76 - Conceptual model for East Hill pit



5.4 Water balance construction

5.4.1 Structure

The void mass balance applies a time step application of mass flow change, creating a rolling change in storage or flows over the period of the water balance:

- *Initial starting volume + mass inflows/gains – mass outflows/losses = Δ (change) in storage (including overflow if storage capacity is reached or dry to zero if reached)*

A map of components possible in each day step in the void mass balance model is outlined in Figure 77, which are configured to be in alignment with the conceptual model.

Mechanics of the water balance are:

Pit void profiles are referenced to a table, where elevation, mine RL, volume & pond surface area (water surface) are cross referenced to each other, enabling mapping of geometry & volume parameters.

Water inputs (mass inflows) are built up for sources of gains:

- Rainfall & runoff factors with initial losses & runoff factors, potential groundwater gain, stormwater river inflow when flows exist, potential other sources. Rainfall is the primary source for Yandan site: loss & runoff factors are adjusted to be reasonable for catchment, landscape/infrastructure, soils, or types of events.
- Stormwater inflow as a major source of event-based inflow for Main pit, applied based on flows recorded at St Anns gauge above 500m³/s (condition for elevation to allow inflow), & a relative factor of 5% of greater than 500m³/s flows. Storm inflow is considered a normal event as part of managing quality & quantity in the pit, particularly mixing & increased dissolved oxygen, but is also a factor of available storage capacity in the pit at the time which is dependent on scenario.

Water outputs (mass outflows) are built up for sources of loss:

- Evaporation based on water surface & changes for rain, groundwater leakage & pumping. Evaporation is the primary driver of loss for Yandan, factored by whether the day is wet or not & then rated by how similar the pond will behave to pan evaporation rates. With ongoing solar radiation & shallow depths, it is expected pit lakes have a slightly higher evaporation rate given the lack of “refill” adapting quality with high evaporation conditions. Evaporation is applied by average BOM monthly rates. Evaporation rates vary based on average BOM daily rates by month & water surface from rolling water storage volume/elevations surface area.

For objectivity & rigour, conservative rates & settings are applied as to water related risk outcomes & also applied consistently across the life of the model (unless clear differences are required), such as river flood event inflow. Starting levels are set to actual levels taken at time of the LiDAR as start of model (168mAHD).

5.4.2 Scenarios

Scenarios assessed include:

- Base case – which is used to set rates & settings for balance then applied across all scenarios.
- Climate change scenarios based on 50th percentile - 2030, 2050, 2070, 2090
- Climate change scenarios for extreme wet & dry (90th/10th percentile) – 2090
- PMF event.

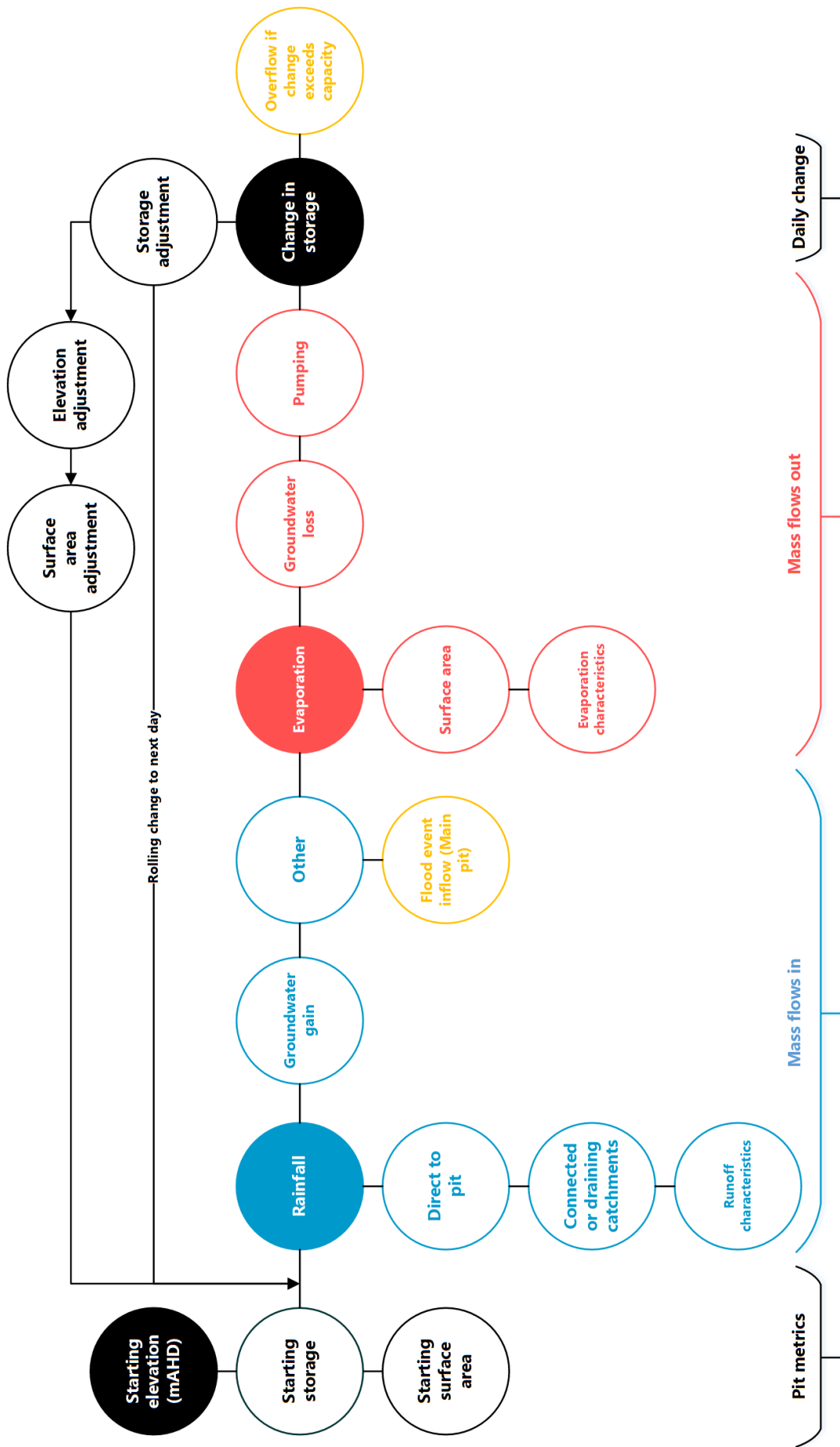


Figure 77 - Schematic of water balance logics

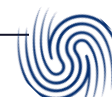


Table 14 – Main pit water balance model settings & parameters

#	Parameter	Comments
0	Model period, time step & starting setup	108 years: 1 July 1913 through to 31 December 2021 - Daily time step, calibrated via achieving relative stability & close in proximity to pit water level reads (used as a guide) in base case - Starting water levels: 168mAHD (based off LiDAR survey in 2016)
1	Rainfall	Mount Douglas station, up to 31 December 2021. Large break in record (18 months) replaced by St Anns gauge rainfall record for same period.
2	Evaporation	- Average of three regional stations as in Table 7 - Rainfall limit above which daily evaporation does not occur: 10mm - Pan factor applied: 1.1 based on long term exposure of pit lake, except 2090 dry scenario which has 1.2 pan factor
3	Catchments & runoff factors	- Main pit catchments reporting as in Table 6 & Figure 13. - M-WS - 0mm initial loss before runoff, 100% reporting - M-Pit (pit catchment not water surface) – 5mm initial loss, 95% runoff factor - M-01 (reporting catchment) – 15mm initial loss, 70% runoff factor
4	Groundwater	“Balance” achieved via inferring the mass flow discrepancy between rainfall & evaporation to manage roughly stable conditions (same RL/volume from start to finish) – 14l/s (1.2 ML/d)
5	Water movement	None
6	River inflow	- Applied over 9 days of “average” actual event in 1981 from St Anns for only drying events of 2070, 2090, 2090 dry - Applied each 10 years to mimic AEP - Volume of >500m³/s extracted, rate of 5% of excess flow available for pit
7	Pit bottom & spill	- Base ~110mAHD, spill 169mAHD - Storage capacity - 6,800,000m³

Table 15 – East Hill pit water balance model settings & parameters

#	Parameter	Comments
0	Model period, time step & starting setup	108 years: 1 July 1913 through to 31 December 2021 - Daily time step, calibrated via achieving relative stability & close in proximity to pit water level reads (used as a guide) in base case - Starting water levels: 168mAHD (based off LiDAR survey in 2016)
1	Rainfall	Mount Douglas station, up to 31 December 2021. Large break in record (18 months) replaced by St Anns gauge rainfall record for same period.
2	Evaporation	- Average of three regional stations as in Table 7 - Rainfall limit above which daily evaporation does not occur: 10mm - Pan factor applied: 1.1 based on long term exposure of pit lake, except 2090 dry scenario which has 1.2 pan factor
3	Catchments & runoff factors	- Main pit catchments reporting as in Table 6 & Figure 13 - E-WS - 0mm initial loss before runoff, 90% reporting - E-Pit (pit catchment not water surface) – 25mm initial loss, 70% runoff - E-01 (reporting catchment) – 30mm initial loss, 40% runoff factor
4	Groundwater	None
5	Water movement	None
6	River inflow	None
7	Pit bottom & spill	- Base ~166mAHD, spill 184mAHD - Storage capacity – 45,000m³



5.4.3 Calibration

The key control in construction of a model reflective of pit lake systems is to set ranges of parameters based on the framework & known dynamics of the system: physical space, measured applicable rates, & honour observations of the system: groundwater contributions at Main pit, variable rainfall, geometry of voids/water surfaces & catchments.

In setting the framework of the system based on known observations, the broad performance of the model is shaped, & the major dynamics represent a reasonable simulation. The knowledge of both pits forming pit lakes since 2000 & have neither completely dried nor overflowed as boundaries, plus records of six flooding inflow events since provides outlying boundaries. And as closed pits, there is no extraction or pumping.

Calibration stages involved setting up base parameters as a starting point, & adjusting parameter within reasonable ranges for initial loss, rainfall limits on evaporation occurring per day, runoff factors & evaporation rates to fit for purpose & gain a relative stability in the system (not drying or overflowing). Over 108 years, minor tweaks of settings plays out to show if the system is aligned.

For each pit, where the system indicated an ongoing loss or ongoing gain because of rainfall/evaporation differentials & resulting in an unstable system (ie dries or overflows in the model), groundwater gain or river inflow was adjusted into the mass flow as a constant to achieve relative stability in a conservative way. To ensure integrity & objectivity as a system model, factors are applied consistently across the length of the model based on parameters set: there is no adjustment of parameters over time to assess overall performance & fate.

The construction & calibration achieved a reasonable fit & profile for each pit: including alignment of model predictions to recent elevation reads & gradients, with commonality applied between both where appropriate.

5.5 Model outcomes

5.5.1 Base case

Base case outcomes achieved relative stability of pit lakes consistent with observations over past 20 years (Figure 78). Note storage & elevation are shown on different sides of the chart.

Main pit is shown independent of river inflow & with 14l/s (or 1.2MI/d) groundwater contribution, which is within reasonable scale limits with active mining dewatering rates of 5MI/d with mining drawdown. Note:

- Minimum pit water storage levels remain above 160mAHD.
- Elevation variation is minimal given baseflow contribution.
- Elevation generally aligned with in-pit monitoring (MP2) & scale of model variations.
- Low risk of spilling from the pit without river inflow which ensures mixing with stormwater for water quality outcomes.

East Hill pit, with a very limited catchment reporting & a lack of groundwater inflow demonstrates strong variation in water level (also factor of size of pool with rainfall/evaporation) & water level elevation remains low within the pit. Risk of spilling is almost negligible: by water balance the only means the pit may fill is through flooding in a potential PMF event, with flood waters entering the pit from above.

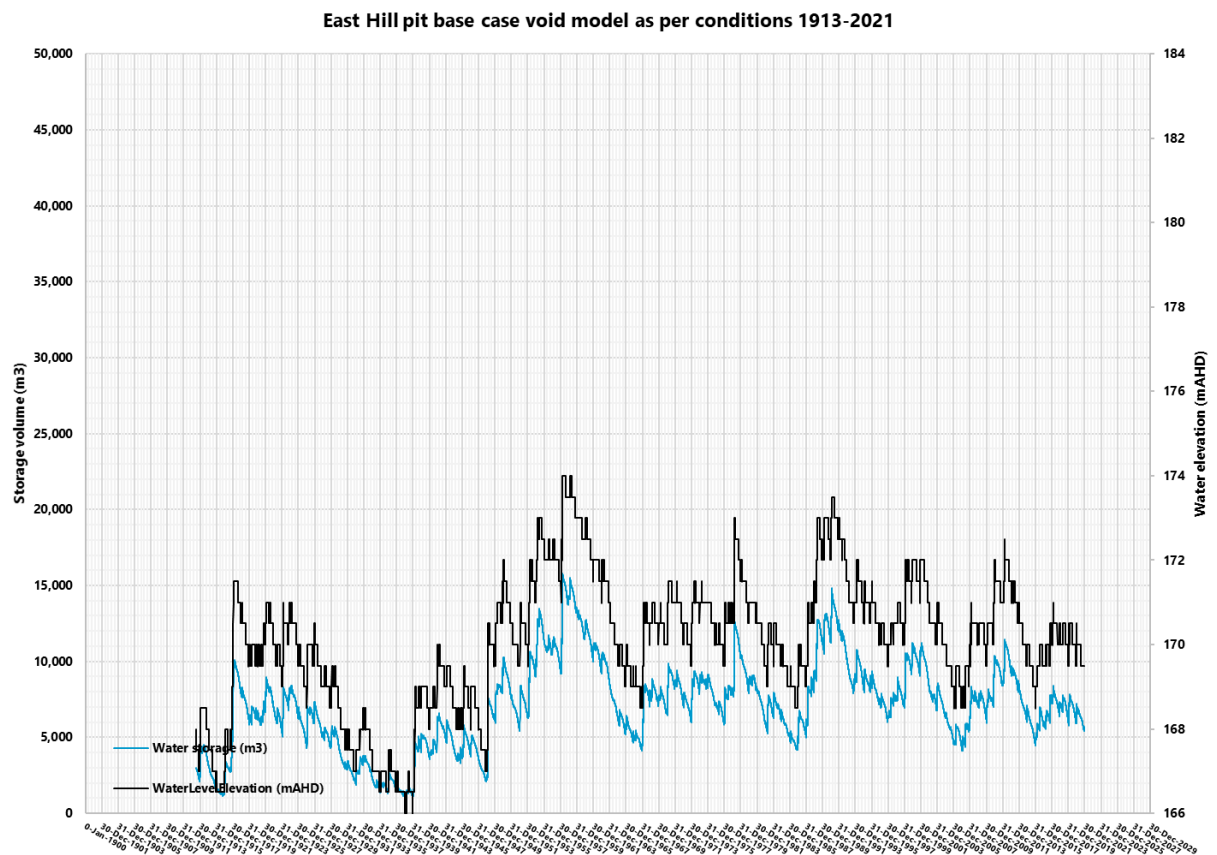
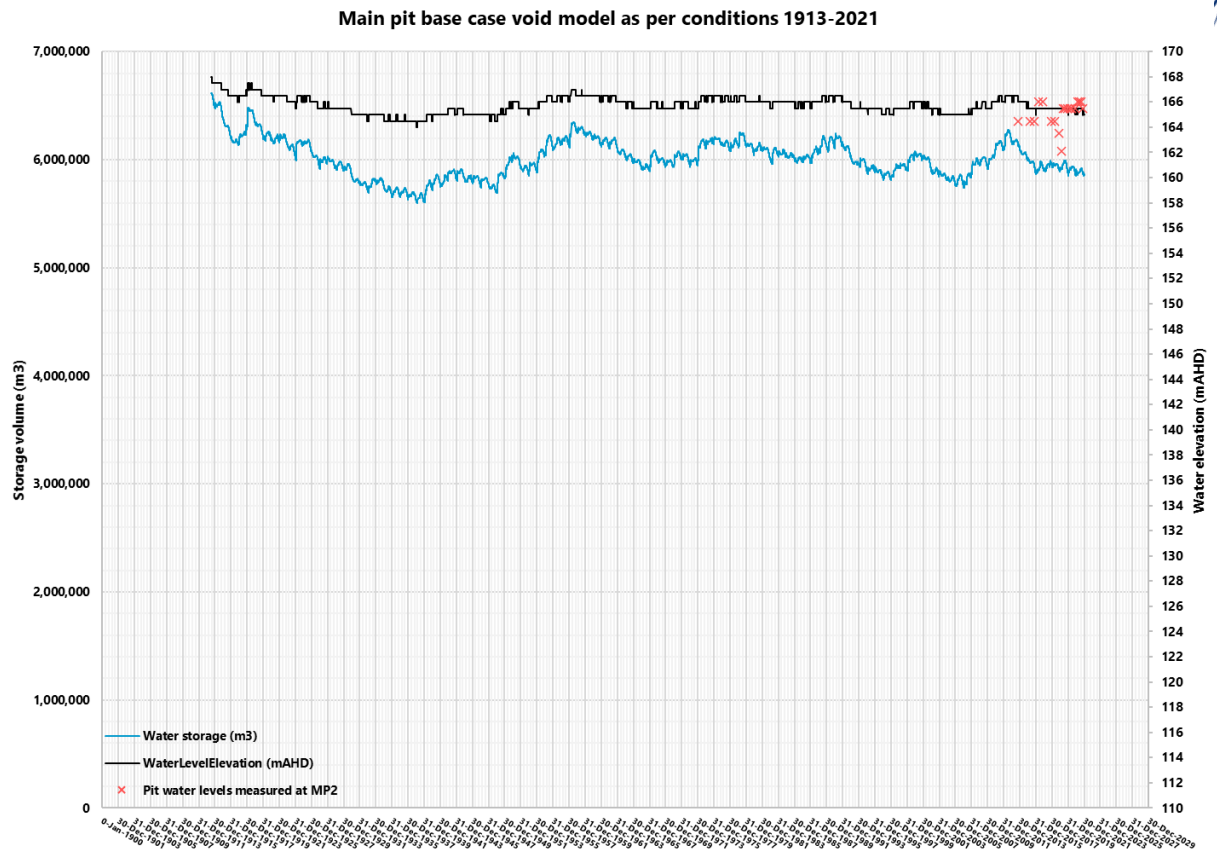


Figure 78 - Base case void model outcomes & profiles



5.6 Void response under PMF

To assess if a PMF event is likely to result in pit water release, application of PMF rainfall rates of 1232.5mm in 6 hours have been applied to both water balance models of Yandan.

Outcomes are plotted with overall volume capacity of the pit based on pit void storage curves, & base of pit to spill elevation as each axis in Figure 79, with metrics in Table 16.

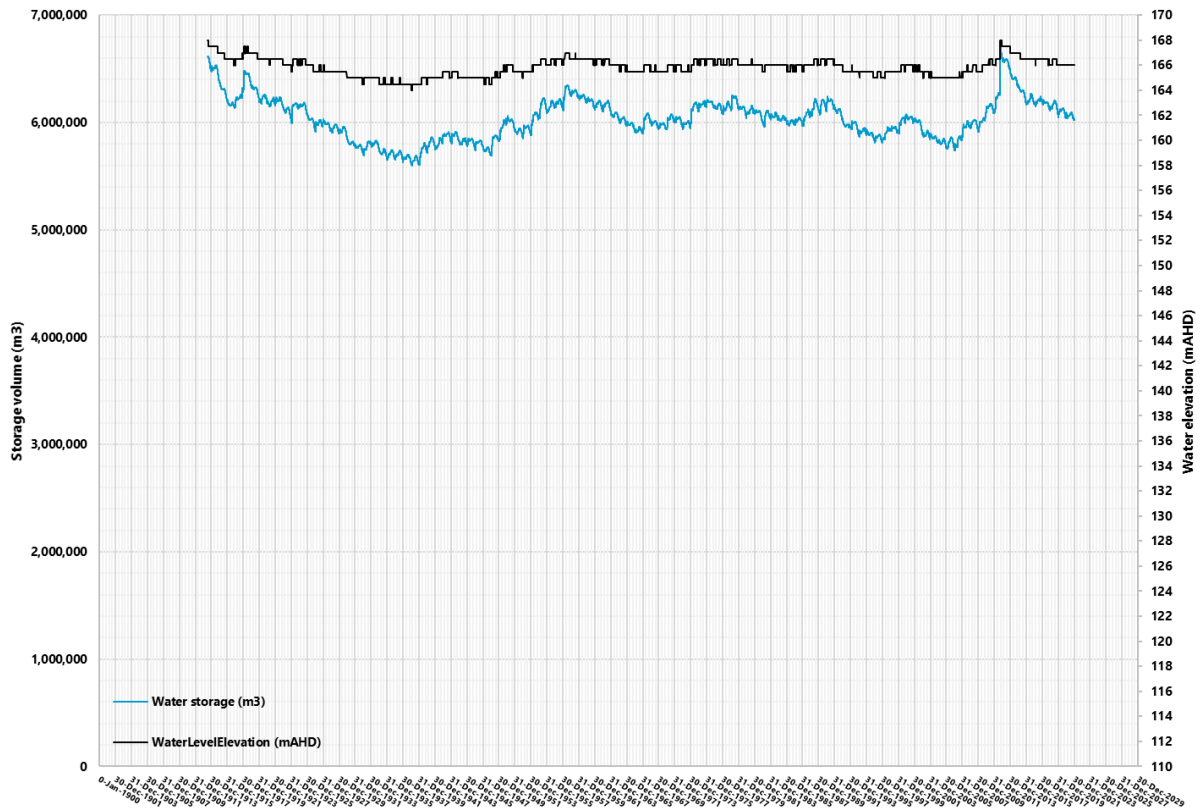
Simulations indicate both pits have a substantial capacity to absorb major or extreme rainfall events with low risk of spilling in a range of conditions. Note, in a PMF event the catchment will be hosting dramatically increased volumes of freshwater as well as clear hydraulic connection between Main pit & Yandan Creek/Suttor River for mixing of any potential impacted water. Likewise, East Hill pit may run close to filling in a PMF event, but with rapid fill will achieve substantial mixing as part of regional flooding of the area.

Table 16 - Metrics of PMF event on pit lake storage

PMF – 1232.5mm in 6 hours - applied date 10 September 2012 (high water level point)						
	Relative current storage (m3)	Change in storage (m3)	Change in void water height (m)	Outcome for pit volume	Potential increase in groundwater flow	Return to historical levels
Main Pit	285,497	458,880	2.5m	Contained within storage	Unlikely given large scale flooding across region, plus flooding from Yandan Creek & Suttor River	Falls rapidly under evaporation ~10-15 years
East Hill Pit	10,499	21,818	7.5m	Contained within storage	Unlikely given large scale flooding across region.	Falls rapidly under evaporation ~10-15 years



Main pit base case void model as per conditions 1913-2021 - PMF



East Hill pit base case void model as per conditions 1913-2021 - PMF

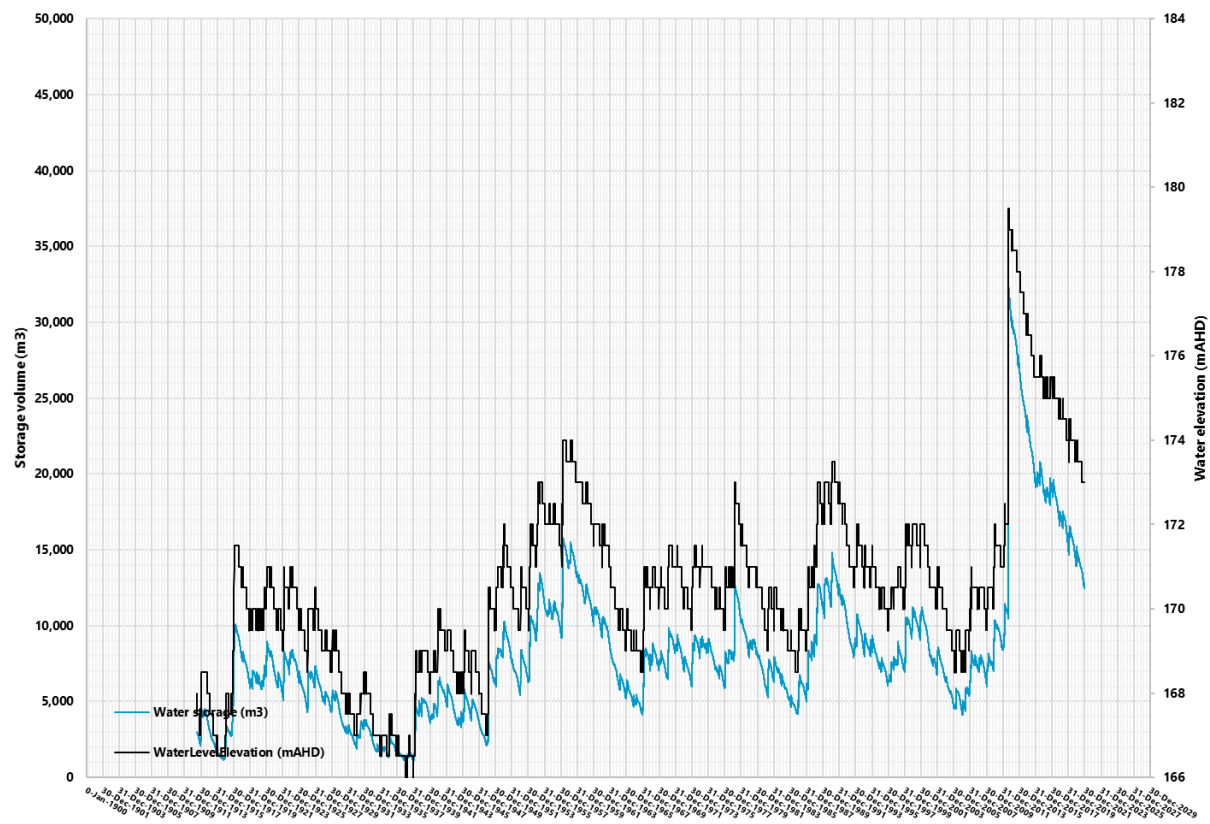


Figure 79 - View of PMF event into Main & East Hill pit: standard (top), increased runoff rates(bottom)





5.7 Void responses under climate change

5.7.1 Approach

As pits are proposed as remaining legacy landforms, an assessment of changing climate is required to review for potential impacts & implications of changing rainfall & evaporation to the pit void & lake.

Scenarios & changes apply parameters provided by the Queensland Government Future Climate (2021a) for the Mount Coolon region. Model scenarios of assess changes in evaporation & rainfall rates, with the following cases selected for scenarios:

50th percentile (mean) changes for rain & evaporation at: 2030, 2050, 2070, 2090

As a measure of potential extremes bounds, 90th/10th percentile scenarios in 2090:

- Wetter/lower evaporation.
- Drier/higher evaporation.

Table 17 presents the summary of expected changes suggested by climate change models as applied into the void water model. In application of the changes into the model:

Evaporation - updated tables by month were developed applying the average daily change (available in Appendix G).

Rainfall - change to annual rainfall depth was allocated to rainfall days as recorded over the record, as a ratio of the total weight of rainfall for the year (ie. Weighted increase to recorded rainfall events relative to their significance to simulate events).

In terms of changes to the system: in average scenarios, it is anticipated evaporation will increase in the order of 20% across a given year, & rainfall will reduce by 5-10%. Bounding scenarios indicate evaporation may increase by up to 35-50%, & rainfall either increase or decrease by 25%.

For drier scenarios (2050, 2070, 2090 & 2090 dry), an allowance for flood inflow is also modelled: applying an "average" Suttor River flooding event over 9 days of >500m³/s flow each 10 years as an average recurrence interval & allowing for 5% of the available flow above 500m³/s to be available as inflow to Main pit. The approach discounts additional flow which may come from Yandan Creek flow which would likely offer additional inflow. Values applied are provided in Table 18. Flows are applied every 10 years on 1-9 January from 1920 through to 2021.

5.7.2 Outcomes

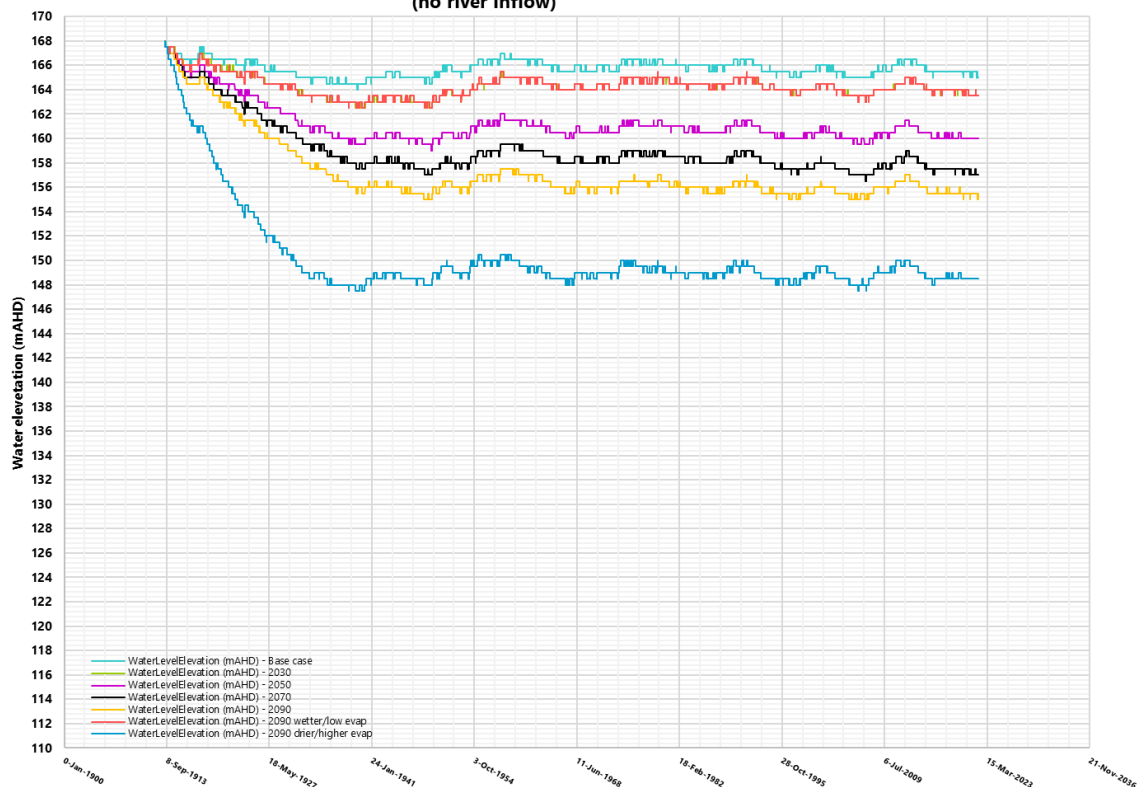
Figure 80 & Figure 80 presents outcomes of pit lake elevations comparison across the range of climate change scenarios.

In Main pit, climate change scenarios to 2050 & 2090 wet maintain minimum water elevation in storage above 160mAHD. For 2070, 2090 & 2090 dry however – drop below 160mAHD without additional river inflow from flooding events. However, with application of an average flow event every 10 years pit water levels are more generally maintained except in the 2090 extreme dry scenario. Scenario 2090 extreme wet is also contained unless a flood event occurs & allowing mixing.

In East Hill pit, climate scenarios of 2070, 2090 & 2090 extreme dry each result in a relatively dry pit which supports containment. Scenarios 2030, 2050 & 2090 extreme wet maintain water level within the pit & are contained, although 2050 may have periods of wet & dry for pit storage.



**Main pit - 108 year base case pit water levels through climate change scenarios
(no river inflow)**



**Main pit - 108 year base case pit water levels through climate change scenarios
(river inflow)**

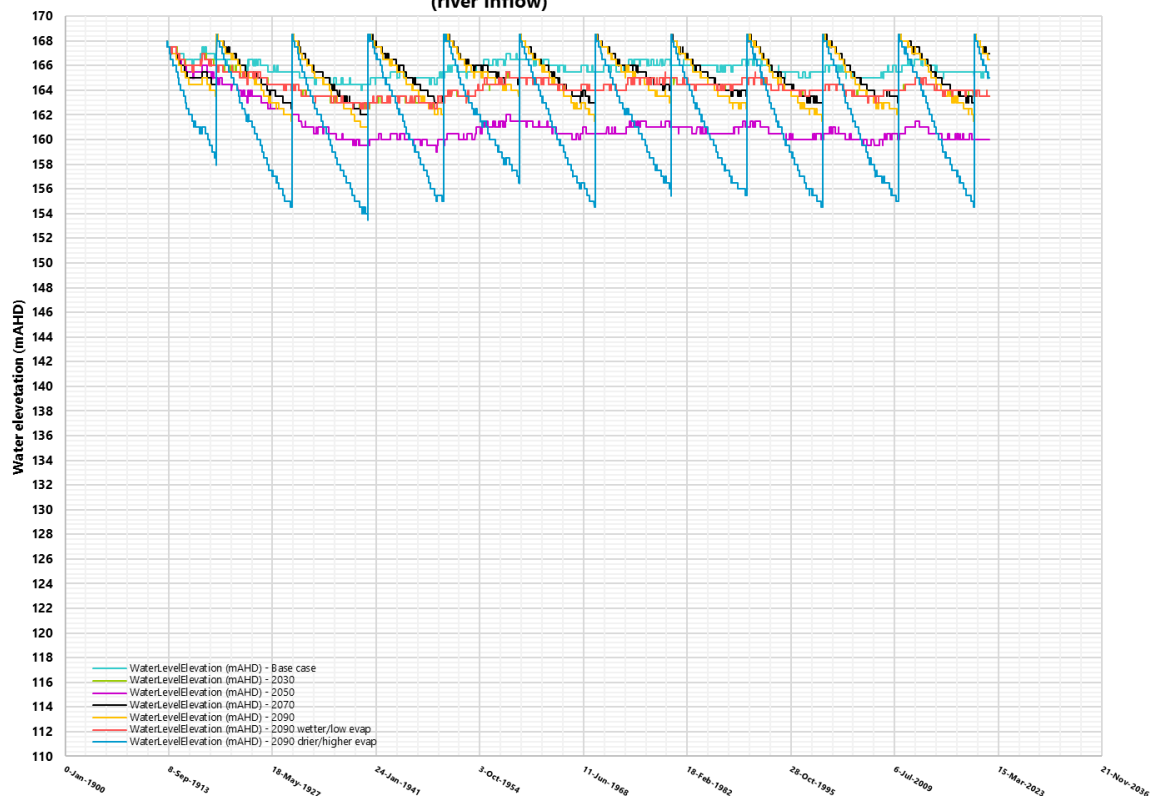


Figure 80 - Main pit void model under climate change scenarios – without & with river inflow



East Hill pit - 108 year base case pit water levels through climate change scenarios

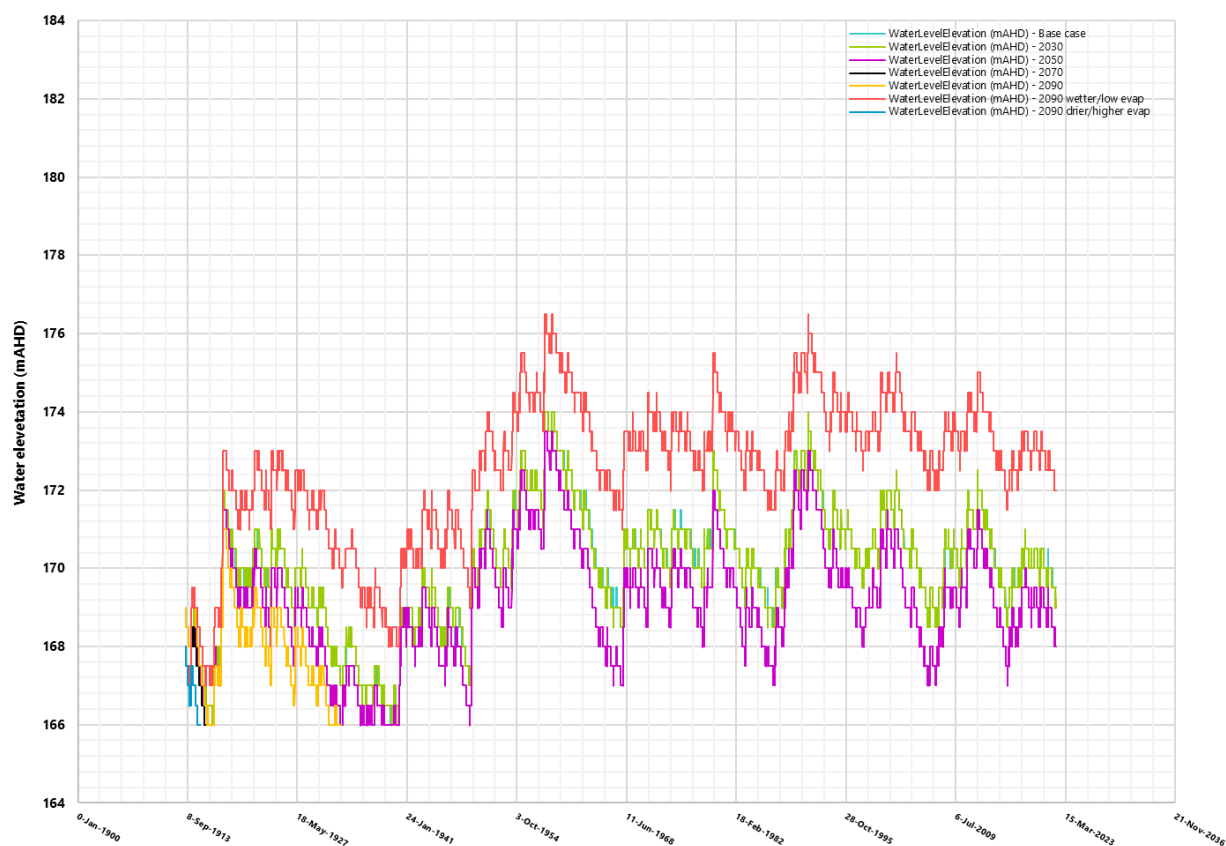


Figure 81 –East Hill void model outcomes under climate change scenarios

Table 17 - Summary of climate change values

Climate time frame	Selected probability profile	Rainfall (mm/y)	Evaporation (mm/d)
2030	50 th percentile (mean)	18.2	0.36
2050	50 th percentile (mean)	-29.2	0.8
2070	50 th percentile (mean)	-21.9	1.2
2090	50 th percentile (mean)	-10.96	1.6
2090 Wet	90 th /10 th percentile (upper bound)	116.9	0.7
2090 Dry	90 th /10 th percentile (lower bound)	-113.2	3.0

Table 18 - Summary of values from 1981 flood applied to simulate flooding inflow every 10 years AEP

Minimum flooding flow			500	m3/s
Date	Average flow recorded m3/s	Available flow > flood m3/s	m3/s to m3/d	5% of available flow
05-02-81	640.1	140.1	12,108,096	605,405
06-02-81	674.7	174.7	15,097,795	754,890
07-02-81	707.8	207.8	17,951,846	897,592
08-02-81	779.7	279.7	24,169,104	1,208,455
09-02-81	846.1	346.1	29,906,064	1,495,303
10-02-81	772.2	272.2	23,522,054	1,176,103
11-02-81	721.1	221.1	19,100,794	955,040
12-02-81	654.1	154.1	13,312,858	665,643
13-02-81	551.2	51.2	4,426,618	221,331



5.8 Potential for pit water stratification

Pit lake stratification describes a condition where vertical layering of the water column of a pit lake, based on physical or chemical factors, such as temperature or salinity, respectively. Stratification can influence the state of safety & health of the pit lake, for example, in oxygenation of water, or if gases are produced.

Key conditions in the potential for pit water stratification include (Jewell 2009):

Stability variables – wind & temperature, or formation of pit lake thermocline thickness as factor of effective pit length. Exposure to wind ripples the surface, changes in temperature over a year each contribute to the turnover of water in a water column.

Density gradients – density gradients of water between the base of pit & surface of pit must be large enough for when freshwater runoff enters the lake, the freshwater remains separate.

Water balances - Permanent stratification requires a positive water balance, where rainfall & runoff is greater than evaporation, as evaporation also creates mixing through changes of water heights, differential rates of evaporation, & density changes.

In evaluation of potential pit water stratification of Main & East Hill pits, formation of pit water stratification is unlikely based on the following factors:

- Main pit:
 - Monitoring results at depth show complete mixing of the water column across all parameters (Figure 65 to Figure 69).
 - River inflow results in increased oxygenation & mixing.
 - Groundwater inflow creating movement & mixing.
 - Wind is present throughout the year across the pit lake surface, & there are strong temperature differentials throughout the year, creating conditions conducive to mixing & oxygenation of the water column.
- East Hill pit:
 - Minimal water storage is in the pit (often only a few meters) which is not conducive to development of thermoclines or development of density gradients.



6 Recommendations for path forward

Landform	Recommendations
Tailings	Establish water shedding cover design for the final landform as a priority. Water flow must be managed & shed across the surface of the facility and must not be allowed to pool on the surface. Reducing percolation through managed drainage is the primary way to reduce risk for Yandan tailings storage. Regrade borrow pits to remove ponding around perimeter of facility. Construction of updated groundwater well network at a setback distance from the facility to monitor groundwater outside of the direct influence of the tailings on north, south & eastern sides of the facility. These wells should be considered life of mine wells for closure criteria monitoring. Update monitoring program to be consistent across all metals of interest. Consider technical investigation to mechanism & timings to explain how peaks of metals are occurring in surface water storages.
Heap leach	Rehabilitate leach ponds as soon as practical, removing material from the area & regrading. The stormwater pond can be maintained until final landform closure. Maintenance of existing drain or bunding to direct water to managed stormwater storage as practical. Check of HL4 integrity, installation of additional wells downgradient of HL1 & HL3 to provide closure monitoring.
Main pit void & receiving environment	Maintain water cover post-closure with existing bunding, particularly western sections. Increase groundwater knowledge: installation of groundwater wells around the mine domain to obtain groundwater information to assist hydrogeology and water balance modelling, including identification of where boiling zone unit occurs. Installation of logging equipment to capture water level measurement of pit water & groundwater. Review if diversion of Yandan Creek requires further engineering for longer term. Update & review of water balance modelling in 3-5 years for final position & long purpose of bund. Review potential of sustainable options to improve dissolved oxygen or reduce arsenic concentrations.
East pit void	If pit is to be left as a NUMA, recommend bunding across road access way to limit inflow in flooding conditions. Increase groundwater knowledge: installation of 2-3 wells around East pit void to obtain groundwater information to assist hydrogeology and water balance modelling, including if boiling zone unit or Yandan fault occurs. Installation of logging equipment to capture water level measurement of pit water & groundwater. Review options to fill or partially fill East Hill pit to reduce exposure to materials or change nature of the pit given poor water quality.



7 Findings & water-related risk

Table 19 - Summary of water-related risk

Landform	Rehabilitation fate	Land-use	Closure questions	Water risk outcomes
All of site			Flooding profile for landforms & potential risk as permanent landforms.	The site lays in a frequent flood area given the Suttor River wide valley, & which the Main Pit water cover relies on. Pit voids are stable under climate & PMF (rare) rainfall events for quality & level for water performance. Receiving environment quality & quantity is stable during flooding & release events & supports environment health. Flooding is considered for the site as the site infrastructures is designed above 1% AEP flooding events generally, with tailings laying above expected PMF flooding levels.
Heap Leach Pad (16.9 ha)	Cover system for low risk - gravel layer at a minimum of 0.5 m thickness & topsoil	Low hill	Water system response to landform (quality & quality). Final landform design needs, risk & appropriate cover for water performance stability. Potential water-related impacts & required monitoring to completion criteria.	Yandan heap leach is characterised by low-risk saline drainage. Sulphate & salinity are elevated around leach ponds; however levels are stable & likely indicates the rate of sulphate production has ceased or reduced. The landform is actively draining post operations & groundwater levels are declining to stabilising. The current form of the heap leach actively sheds water effectively, though sedimentation of the perimeter drains may not keep all surface runoff water within the heap leach catchment during periods of rainfall.
HL Stormwater Pond (1.59ha)	Dam wall removed & area rehabilitated.	Low hill	Leakage & potential groundwater containment. Indication of landform surface water drainage.	Groundwater quality is likely to improve over time. Primary metals of interest are arsenic, & potentially copper & zinc.
Pregnant Pond (0.16 ha)	Dam wall removed & area rehabilitated.	Low hill		Downgradient well HL3 shows elevated salinity but limited other potential contaminants as an indicator of overall contained risk & impact. An additional well downgradient of HL3 is recommended.
Barren Pond (0.18 ha)	Dam wall removed & area rehabilitated.	Low hill		Leakage from the leach ponds is likely contributing to elevated conductivity & sulphate in groundwater near to HL1, with quality likely relating to remnant quality from within & around the ponds acquired during operation. Removal of HL ponds is recommended.



Landform	Rehabilitation fate	Land-use	Closure questions	Water risk outcomes
Tailings Cell A (4.5 ha)	Repair of existing rehabilitation & regrading of surface (low risk cover)	Open pasture	Water system response to landform (quality & quantity). Final landform design needs, risk & appropriate cover for water performance stability. Potential water-related impacts & required monitoring to completion criteria.	Tailings impacts are characterised by low-risk saline drainage, with evidence of acid rock processes (either pH or sulphate). Sulphate & salinity are elevated; however, levels have been stable for some time & likely indicates production of sulphate has ceased or reduced.
Tailings Cell B (70.8 ha)	Cover system for low risk: - Rock cover of 1.0 m; and - Growth media of 0.15 m.	Open pasture		Whilst there may be some quality concerns for perimeter monitoring wells, these impacts are likely to be limited by topography & geology for water movement. Downgradient wells demonstrate containment of potential impacts is effective: in surface water, the tailings return dam (TRD) is effectively capturing runoff via the spillway. Groundwater wells on the perimeter are generally located in borrow pits & near the facility & are likely monitoring direct tailings water – further wells are recommended away from the dam potentiometric surface as indicative groundwater quality. Likewise, TD6S/D as upgradient wells are further away, but are at a much lower relative level & will be in a direct area of the potentiometric surface. It is recommended to rehabilitate borrow pits to ensure drainage.
Tailings Water Return Dam (18.37 ha)	Dam wall removed & area rehabilitated.	Open pasture	Leakage & potential groundwater containment. Indication of landform surface water drainage.	The current low gradient & depression form of the surface of the tailings facility allows ponding to occur on the facility, which maximises infiltration & percolation of water through stored tailings: a design & function which must be avoided for containment. Infiltration is likely exacerbating groundwater & surface water quality given the increased rates of infiltration & percolation through tailings material. A change to a water shedding facility is strongly recommended with a suitable low-risk tailings cover based on materials characterisation & water quality performance. Primary metals of interest (mobile) are arsenic, cadmium, copper, nickel & zinc (mobile at neutral to alkaline pH). Flushes of metals & salts are related to rainfall events, bringing peaks to shallow groundwater bores & returns dam alike as rainfall flushes through the facility.



Landform	Rehabilitation fate	Land-use	Closure questions	Water risk outcomes
Main Pit (17.8 ha)	Maintain water cover & connectivity with two spillways. Query whether bund wall required longer term.	Lake	Water system response as a landform/pit lake (quality & quality). Water level stability to cover fresh rock. Water quality stability & risk as pit lake. Fate of pit wall bund. Responses of pit voids to climate change or rare rainfall events. Receiving environment stability & risk – surface water & groundwater.	The water cover of Main Pit is successful & stable to design in managing risk of materials exposure & maintaining a pit lake which is relatively self-sustaining. Flooding events & releases are an expected & normal part of pit operation to maintain water levels & freshening of water, with floods every 5-15 years. Receiving waters monitoring shows during releases, water quality targets are achieved, both in sampling events & ongoing salinity via St Anns over the past 20 years. In alignment with detailed studies for pit flooding design, the pit is unlikely to spill without flooding flow from Suttor River or Yandan Creek with adequate surface water for mixing (with excess flow rates of 500m³/s or more). Water quality within the pit is stable over time & at depth, with no observable signs of ARD or water quality issues except for elevated arsenic & lower rates of dissolved oxygen. Times of inflow from Suttor River increase dissolved oxygen throughout the pit lake. The water profile shows water mixing is excellent throughout the water column with no thermocline or zoning – quality is consistent at depth & across the lake. Further works for closure might consider how dissolved oxygen could be increased. Pit water levels remain above minimum levels of 160mAHD in all climate change scenarios when regular inflow into the pit is considered in the water balance. The pit is also likely groundwater gaining from either a fault or a porous zone which requires further investigation. It is recommended to continue with current bunds to manage catchments & contain pit water unless Suttor River is in flood & review in several years.
East Hill Pit (0.5 ha)	Partially backfilled with concrete from infrastructure area, and sediment from	Lake	Water system response as a landform/pit lake (quality & quality). Water level stability to cover fresh rock. Water	East Hill pit is a low lying pit lake, with reactive materials & acidic water quality with increasing salts & metals. The pit is contained however at low levels & is unlikely to be connected to groundwater (confirmed through water balance) though may have some level of connection to Main Pit via a



Landform	Rehabilitation fate	Land-use	Closure questions	Water risk outcomes
	water storage structures.		quality stability & risk as pit lake. Fate of pit wall bund. Responses of pit voids to climate change or rare rainfall events. Receiving environment stability & risk – surface water & groundwater.	structural fault dependent on relative levels. A limited groundwater investigation is recommended to confirm groundwater nature. The site groundwater is highly compartmentalised with hydraulic boundaries between volcanic areas of the pits & other formations. Water quality is acidic & increasing in metals: however exposure to receiving environment is limited & volume of water is limited given the size of the pit & rainfall over time. The pit does not spill in PMF or in climate change scenarios, but maybe susceptible to inflow at PMF flood conditions from surface. An access bund across the lowest point on the north access road is recommended as a final fate.



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Appendix A – Environment Authority - water sections



Schedule C - Water

General

(C1-1) Contaminants that will, or have the potential to cause environmental harm, must not be released directly or indirectly to any waters except as permitted under the conditions of this environmental authority.

(C1-2) The release of contaminants directly or indirectly to waters must not:

- (a) produce any visible discolouration of receiving waters; or
- (b) produce any slick or other visible or odorous evidence of oil, grease or petrochemicals nor contain visible floating oil, grease, scum, litter or other objectionable matter.

(C1-3) All determinations of water quality must be:

- (a) performed by a person or body possessing appropriate experience and qualifications to perform the required measurements;
- (b) made in accordance with methods prescribed in the latest edition of the latest edition of the Administering Authority's monitoring and sampling manual;
- (c) collected from the monitoring locations identified within this environmental authority, within 2 hours of each other where possible;
- (d) carried out on representative samples; and
- (e) for laboratory determinations, carried out in a laboratory accredited (e.g. NATA) for the method of analysis being used.

Contaminant Release to Waters

(C2-1) The release of contaminants to waters must only occur from the release points specified in Schedule C - Table 1 (Contaminant Release Points) and depicted in Schedule J - Figure 1.

Schedule C - Table 1 (Contaminant Release Points)

Release Point	Easting GDA94	Northing GDA94	Description of Release Point	Monitoring Point	Receiving Waters Description
MP1	496790	7645177	Northwest Main Pit Dam Spillway Overflow	Dam Spillway	Suttor River
MP2	497191	7644940	Southeast Main Pit Dam Spillway Overflow	Dam Spillway	Suttor River

(C2-2) The release of contaminants to waters from the release points must be monitored at the locations specified in Schedule C - Table 1 (Contaminant Release Points) for each quality characteristic and at the frequency specified in Schedule C - Table 2 (Contaminant Release Limits).



Schedule C - Table 2 (Contaminant Release Limits)

Parameter	Units	Limit type	Limit	Monitoring Frequency
pH	pH Unit	Range	6 – 9	A first flush sample at commencement of release A sample within 48 hours of the commencement of release Weekly sampling thereafter until the release ceases
EC	µS/cm	Maximum	1000 ² or 95th percentile ³ of reference, whichever is higher	
Sulfate	mg/L	Maximum	1000 ¹ or 95th percentile ³ of reference, whichever is higher	
Arsenic	mg/L	Maximum	0.5 ¹ or 95th percentile ³ of reference, whichever is higher	
Cadmium	mg/L	Maximum	0.01 ¹ or 95th percentile ³ of reference, whichever is higher	
Copper	mg/L	Maximum	0.5 ¹ or 95th percentile ³ of reference, whichever is higher	
Lead	mg/L	Maximum	0.1 ¹ or 95th percentile ³ of reference, whichever is higher	
Mercury	mg/L	Maximum	0.002 ¹ or 95th percentile ³ of reference, whichever is higher	
Molybdenum	mg/L	Maximum	0.05 ¹ or 95th percentile ³ of reference, whichever is higher	
Selenium	mg/L	Maximum	0.02 ¹ or 95th percentile ³ of reference, whichever is higher	
Zinc	mg/L	Maximum	20 ¹ or 95th percentile ³ of reference, whichever is higher	

1. Measured as a total unfiltered concentration and based on ANZECC (2000) stock water quality guidelines
2. DERM Scientific services, 2009
3. Where the 95th percentile of reference is exceeded and the reference site also exceeds the value during the same event, the value of the reference for the same event applies.

(C2-3) Waters potentially affected by the release of contaminants must be monitored at the locations specified in Schedule C - Table 3 (Release Monitoring Points) for each quality characteristic and at the frequency specified in Schedule C - Table 4 (Release Contaminant Trigger Levels).

Schedule C - Table 3 (Release Monitoring Points)

Monitoring Point	Easting GDA94	Northing GDA94	Description of Monitoring Point
Compliance Points			
SR1	496750	7645460	Monitoring point in the Suttor River at Suttor River causeway approximately 150 meters downstream of the MP1 contaminant release point
SR2	496820	7646759	Monitoring point in the Suttor River approximately 1.7 kilometres downstream of MP1 contaminant release point
Reference Points			
SR3a	496050	7644545	Monitoring point in Suttor River upstream of the main pit on the western side
SR3b	495734	7645032	Monitoring point in the Suttor River upstream of the main pit on the western side. (Alternative monitoring point to SR3a to be used when access to SR3a is restricted due to flood waters)
SR4	498842	7645095	Monitoring point upstream of the main pit in Yandan Creek branch on the eastern side of the Suttor River

Schedule C - Table 4 (Release Contaminant Trigger Levels)

Quality Characteristic	Unit	Trigger Levels	Monitoring Frequency
pH	pH Unit	20 th percentile ^{2,5} of reference or 6.0 ⁴ , whichever is lower. 80 th percentile ^{2,5} of reference or 7.5 ⁴ , whichever is higher	A first flush sample at commencement of release
EC	µS/cm	80 th percentile ^{2,5} of reference or 250 ⁴ , whichever is higher	
Sulphate	µg/L	80 th percentile ^{2,5} of reference	
Aluminium	µg/L	80 th percentile ^{3,5} of reference or 55 ⁴ , whichever is higher	
Arsenic	µg/L	80 th percentile ^{3,5} of reference or 13 ^{4,6} , whichever is higher	
Cadmium	µg/L	80 th percentile ^{3,5} of reference or 0.2 ⁴ , whichever is higher	A sample within 48 hours of the commencement of release
Copper	µg/L	80 th percentile ^{3,5} of reference or 1.4 ⁴ , whichever is higher	
Lead	µg/L	80 th percentile ^{3,5} of reference or 3.4 ⁴ , whichever is higher	
Mercury	µg/L	80 th percentile ^{3,5} of reference or 0.6 ⁴ , whichever is higher	Weekly sampling thereafter until the release ceases
Selenium	µg/L	80 th percentile ^{3,5} of reference or 11 ⁴ , whichever is higher	
Nickel	µg/L	80 th percentile ^{3,5} of reference or 11 ⁴ , whichever is higher	
Zinc	µg/L	80 th percentile ^{3,5} of reference or 8 ⁴ , whichever is higher	
Hardness ⁷	mg/L	N/A	

1. All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/metalloids apply if dissolved results exceed trigger.
2. An interim trigger value can be derived from ≥ 8 but ≤ 17 consecutive reference site samples, derived using the methodology described in the Queensland Water Quality Guidelines (2009).
3. For toxicants, trigger values are based on the 80th percentile of at least 10 and no more than 24 consecutive reference site samples, derived using the methodology described in the Queensland Water Quality Guidelines (2009).
4. Default trigger values from ANZECC (2000)
5. 20th, 80th and 95th percentiles are calculated using ANZECC (2000) methodology (section 7.4.4.1)

Residual Void Outcome

- (F7-1) Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself, and subject to any other condition within this environmental authority.

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- (F7-2) Mining voids must be managed during the operation and decommissioning phases to maximise the potential post mine beneficial uses, by consideration of the following:
- (a) limiting sulphide exposures in void walls; and
 - (b) capping of sulphide exposures in void base; and
 - (c) limiting period of exposure of sulphides in void walls and base to oxidising conditions; and
 - (d) managing catchment into the void; and
 - (e) geo-technical stability of final void.
- (F7-3) Decommissioning strategies for the final voids must be updated with each update of the Plan of Operations.





Main Pit Water Cover

- (C4-1) The depth of water in the main pit must be measured quarterly in order to ensure water depth within the pit is maintained greater than 160m AHD.
- (C4-2) Water in the main pit must be monitored quarterly for the parameters and depth intervals defined in Schedule C – Table 7 (Main pit water quality parameters).

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Schedule C - Table 7 (Main pit water quality parameters)

Parameter	Units	Depth intervals
pH		5m and 10m
Temperature	°C	5m and 10m
Electrical Conductivity	uS/cm	5m and 10m
Salinity	Ppm	5m and 10m
Dissolved Oxygen	DO	5m and 10m
Oxidation Reduction Potential	mV / Eh	5m and 10m
Total Dissolved Solids	mg/L	10m
Sulfate	mg/L	10m
Arsenic	mg/L	10m
Cadmium	mg/L	10m
Copper	mg/L	10m
Lead	mg/L	10m
Mercury	mg/L	10m
Molybdenum	mg/L	10m
Selenium	mg/L	10m
Zinc	mg/L	10m





Groundwater

- (C7-1) Within 12 months of the date of approval of this environmental authority, the holder of the environmental authority must establish suitable reference bores for the establishment of background groundwater quality. Reference sites must:
- (a) be selected in accordance with the ANZECC & ARM CANZ 2000 methodology
 - (b) be from the same bio-geographic and climatic region; and
 - (c) have similar geology, soil types and topography; and
 - (d) not be so close to the test sites that any disturbance at the test site also results in a change at the reference site.
- (C7-2) Groundwater quality and level must be monitored at the locations and frequencies defined in Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency) & Schedule J - Figure 3 for quality characteristics identified in Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits).
- (C7-3) If quality characteristics of groundwater from compliance bores identified in Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency) exceed any of the trigger levels stated in Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits), the holder of this environmental authority must compare the compliance monitoring bore results to the reference bore results and:
- (a) if the level of contaminants at the compliance monitoring bore does not exceed the reference bore results, then no action is to be taken; and

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- (b) if the level of contaminants at the compliance monitoring bore is greater than the reference bore results, complete an investigation in accordance with the ANZECC & ARM CANZ 2000, into the potential for environmental harm and provide a written report to the administering authority within 3 months, outlining:
 - (i) details of the investigations carried out; and
 - (ii) actions taken to prevent environmental harm.

Note: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with this condition, no further reporting is required for subsequent trigger events for that quality characteristic within the three month investigation period.

- (C7-4) Monitoring of groundwater from compliance bores identified in Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency), must not exceed any of the limits defined in Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits).
- (C7-5) Groundwater monitoring bores must be constructed and operated in accordance with methods prescribed in the latest edition of the Agriculture and Resource Management Council of Australia and New Zealand manual titled *Minimum Construction Requirements for Water Bores in Australia*.
- (C7-6) Annual groundwater monitoring reports analysing groundwater chemistry and hydro-geological status of all groundwater bores and groundwater conditions must be prepared and submitted to the administering authority with each annual return.

Schedule C - Table 10 (Groundwater Monitoring Locations and Frequency)

Monitoring Point	Easting (GDA94)	Northing (GDA94)	Surface RL ¹ (m)	Monitoring Frequency
Compliance Bores				
Yandan – Tailings Dam (TD) South Bore 3	499333	7646724	To be advised ³	Quarterly
Yandan – TD West Bore 4	499616	7647434	To be advised ³	Quarterly
Yandan – TD North Bore 5	500548	7647882	To be advised ³	Quarterly
Yandan – TD East Bore 6	500941	7647110	To be advised ³	Quarterly
Yandan – TD South Bore 7	499440	7646580	To be advised ³	Quarterly
Yandan – South Hill pit bore 3	497420	7644570	To be advised ³	Quarterly
Yandan – Heap Leach west bore 1	498094	7644870	To be advised ³	Quarterly
Yandan – Heap Leach west bore 3	498284	7644837	To be advised ³	Quarterly
Yandan – Heap Leach west bore 4	497913	7644964	To be advised ³	Quarterly
Yandan – Heap Leach east bore 5	498308	7645064	To be advised ³	Quarterly
Yandan – Heap Leach north bore 6	498321	7645358	To be advised ³	Quarterly
Yandan – Heap Leach north bore 7	498144	7645427	To be advised ³	Quarterly
Reference Bores²				
To be determined within 12 months of the date of approval of this licence, in accordance with condition C7-1				

¹ RL measurement to be taken from top of bore casing and measured to nearest 0.05m

² Reference sites must:

- (a) be from the same bio-geographic and climatic region; and
- (b) have similar geology, soil types and topography; and
- (c) not be so close to the test sites that any disturbance at the test site also results in a change at the reference site

³ within three months of the date of approval of this environmental authority



Schedule C - Table 11 (Groundwater Contaminant and Trigger Limits)

Parameter	Units	Limit type	Contaminant limit	Trigger Level
pH		Range	6 – 8.5 ³	6.0 – 7.5
Sulfate	mg/L	Maximum	1000 ⁵	The 80% percentile of the background reference
Arsenic	mg/L	Maximum	0.5 ¹	0.013 ^{2,4} or the 80% percentile of the background reference
Cadmium	mg/L	Maximum	0.5 ¹	0.0002 ⁴ or the 80% percentile of the background reference
Copper	mg/L	Maximum	0.5 ¹	0.0014 ⁴ or the 80% percentile of the background reference
Lead	mg/L	Maximum	0.1 ¹	0.0034 ⁴ or the 80% percentile of the background reference
Mercury	mg/L	Maximum	0.1 ¹	0.0006 ⁴ or the 80% percentile of the background reference
Molybdenum	mg/L	Maximum	0.05 ¹	The 80% percentile of the background reference
Selenium	mg/L	Maximum	0.02 ¹	0.011 ⁴ or the 80% percentile of the background reference
Zinc	mg/L	Maximum	20 ¹	0.008 ⁴ or the 80% percentile of the background reference
WAD Cyanide	mg/L	Maximum	0.2	0.007 ⁴ or the 80% percentile of the background reference

1. All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered).
2. If arsenic (soluble) exceeds 13ug/L then speciation to As(III) and As(V) must be conducted. The As(III) and As(V) levels must not exceed the 80th percentile of reference site samples or the respective trigger level: As(III) – 24ug/L; As(V) – 13ug/L.
3. Based on ANZECC (2000) primary industries guidelines
4. Default trigger values from ANZECC 2000 for aquatic ecosystems
5. Based on ANZECC (2000) Livestock Drinking Water Guidelines

Receiving Environment Monitoring Program (REMP)

(C8-1) A REMP must be developed and implemented within 3 months of the date of approval of this environmental authority to monitor and record the effects of the release of contaminants on the receiving environment periodically and whilst contaminants are being discharged from the site, with the aims of identifying and describing the extent of any adverse impacts to local environmental values, and monitoring any changes in the receiving water. A copy of the REMP must be provided to the administering authority prior to its implementation and due consideration given to any comments made on the REMP by the administering authority.

For the purposes of the REMP, the receiving environment is the waters of the Sutor River and connected waterways within 2 kilometres downstream of the release.

(C8-2) The REMP must address (but not necessarily be limited to) the following:

- (a) Description of potentially affected receiving waters including key communities and background water quality characteristics based on accurate and reliable monitoring data that takes into consideration any temporal variation (e.g. seasonality);
- (b) Description of applicable environmental values and water quality objectives to be achieved (i.e. as scheduled pursuant to the Environmental Protection (Water) Policy 2009);
- (c) Any relevant reports prepared by other governmental or professional research organisations that relate to the receiving environment within which the REMP is proposed;
- (d) Water quality targets within the receiving environment to be achieved, and clarification of contaminant concentrations or level indicating adverse environmental impacts during the REMP;
- (e) Monitoring for any potential adverse environmental impacts caused by the release;



Residual Void Outcome

- (F7-1) Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself, and subject to any other condition within this environmental authority.

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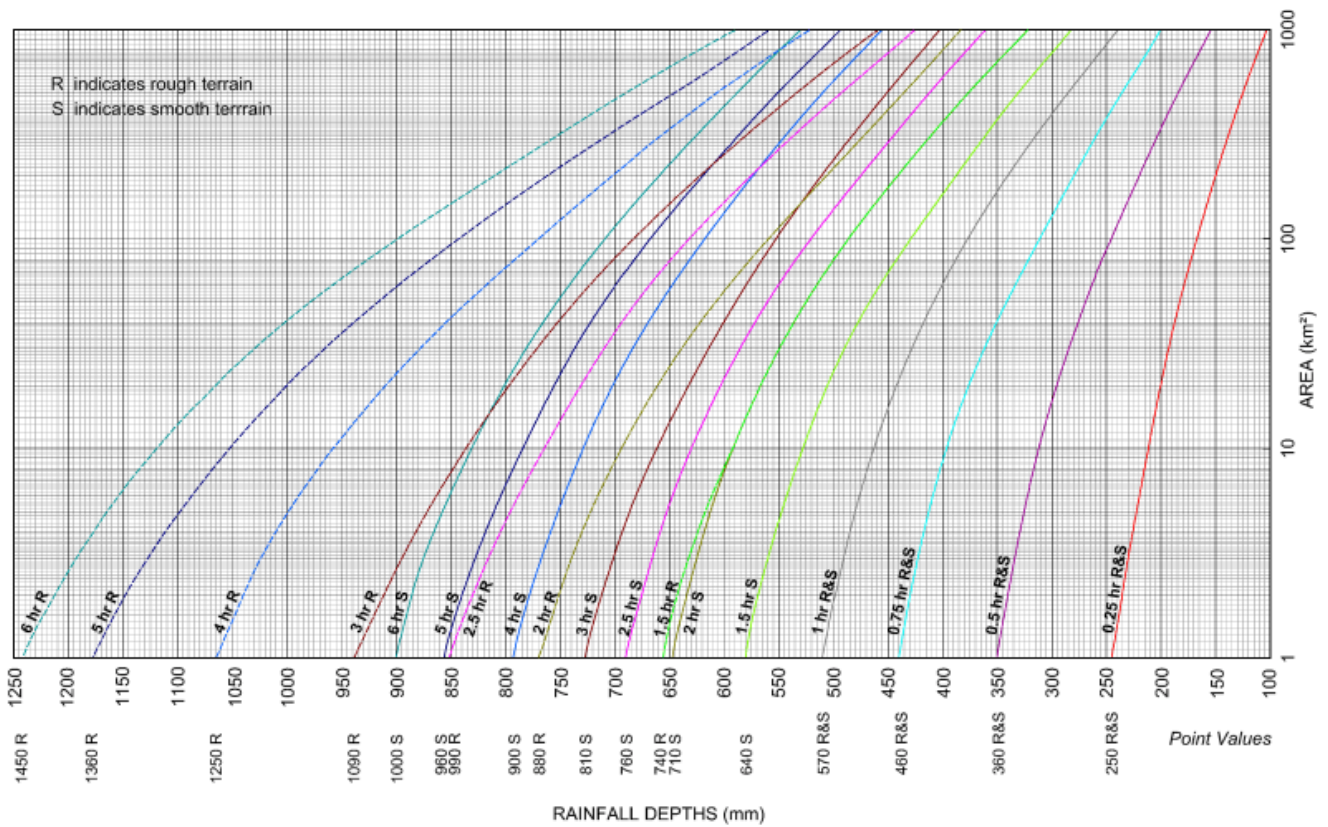
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- (F7-2) Mining voids must be managed during the operation and decommissioning phases to maximise the potential post mine beneficial uses, by consideration of the following:
- (a) limiting sulphide exposures in void walls; and
 - (b) capping of sulphide exposures in void base; and
 - (c) limiting period of exposure of sulphides in void walls and base to oxidising conditions; and
 - (d) managing catchment into the void; and
 - (e) geo-technical stability of final void.
- (F7-3) Decommissioning strategies for the final voids must be updated with each update of the Plan of Operations.





Appendix B – PMF reference event table for GSDM method (BOM 2003)





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Appendix D – Void slice tables for Main Pit & East Hill Pit

Main pit

RL	Surface area m2	Cumulative volume m3	Cumulative m3	Surface area m2	RL
107.0	353	177	177	353	107.0
107.5	921	461	637	921	107.5
108.0	1,228	614	1,251	1,228	108.0
108.5	1,337	668	1,920	1,337	108.5
109.0	1,477	739	2,658	1,477	109.0
109.5	1,609	805	3,463	1,609	109.5
110.0	1,742	871	4,334	1,742	110.0
110.5	1,978	989	5,323	1,978	110.5
111.0	2,152	1,076	6,399	2,152	111.0
111.5	2,349	1,175	7,573	2,349	111.5
112.0	2,587	1,293	8,867	2,587	112.0
112.5	2,948	1,474	10,341	2,948	112.5
113.0	4,386	2,193	12,534	4,386	113.0
113.5	10,701	5,350	17,884	10,701	113.5
114.0	14,046	7,023	24,908	14,046	114.0
114.5	14,484	7,242	32,150	14,484	114.5
115.0	15,016	7,508	39,657	15,016	115.0
115.5	15,656	7,828	47,486	15,656	115.5
116.0	16,364	8,182	55,668	16,364	116.0
116.5	17,067	8,534	64,201	17,067	116.5
117.0	17,868	8,934	73,136	17,868	117.0
117.5	18,644	9,322	82,457	18,644	117.5
118.0	19,392	9,696	92,153	19,392	118.0
118.5	20,540	10,270	102,423	20,540	118.5
119.0	22,056	11,028	113,451	22,056	119.0
119.5	24,512	12,256	125,707	24,512	119.5
120.0	25,169	12,584	138,292	25,169	120.0
120.5	25,799	12,900	151,191	25,799	120.5
121.0	26,412	13,206	164,397	26,412	121.0
121.5	27,111	13,555	177,952	27,111	121.5
122.0	27,887	13,944	191,896	27,887	122.0
122.5	29,020	14,510	206,406	29,020	122.5
123.0	30,155	15,077	221,483	30,155	123.0
123.5	30,850	15,425	236,908	30,850	123.5
124.0	31,612	15,806	252,714	31,612	124.0
124.5	32,337	16,169	268,883	32,337	124.5
125.0	33,339	16,669	285,552	33,339	125.0
125.5	36,906	18,453	304,005	36,906	125.5
126.0	38,180	19,090	323,095	38,180	126.0
126.5	38,957	19,478	342,573	38,957	126.5
127.0	39,768	19,884	362,457	39,768	127.0
127.5	40,590	20,295	382,752	40,590	127.5
128.0	41,462	20,731	403,483	41,462	128.0
128.5	42,568	21,284	424,767	42,568	128.5
129.0	43,739	21,870	446,637	43,739	129.0
129.5	44,821	22,410	469,047	44,821	129.5
130.0	46,033	23,017	492,064	46,033	130.0
130.5	47,560	23,780	515,844	47,560	130.5
131.0	51,702	25,851	541,695	51,702	131.0
131.5	57,865	28,933	570,628	57,865	131.5
132.0	59,702	29,851	600,479	59,702	132.0
132.5	60,910	30,455	630,934	60,910	132.5
133.0	62,087	31,043	661,977	62,087	133.0
133.5	63,262	31,631	693,609	63,262	133.5
134.0	64,580	32,290	725,898	64,580	134.0
134.5	66,453	33,226	759,125	66,453	134.5
135.0	68,020	34,010	793,135	68,020	135.0
135.5	69,517	34,758	827,893	69,517	135.5
136.0	71,142	35,571	863,464	71,142	136.0
136.5	73,118	36,559	900,023	73,118	136.5

136.5	73,118	36,559	900,023	73,118	136.5
137.0	77,205	38,603	938,626	77,205	137.0
137.5	82,847	41,424	980,049	82,847	137.5
138.0	86,169	43,085	1,023,134	86,169	138.0
138.5	88,289	44,145	1,067,279	88,289	138.5
139.0	90,004	45,002	1,112,281	90,004	139.0
139.5	91,843	45,922	1,158,203	91,843	139.5
140.0	93,951	46,975	1,205,178	93,951	140.0
140.5	96,603	48,302	1,253,479	96,603	140.5
141.0	98,608	49,304	1,302,783	98,608	141.0
141.5	100,356	50,178	1,352,961	100,356	141.5
142.0	102,336	51,168	1,404,129	102,336	142.0
142.5	106,011	53,006	1,457,135	106,011	142.5
143.0	113,028	56,514	1,513,649	113,028	143.0
143.5	124,575	62,287	1,575,936	124,575	143.5
144.0	128,748	64,374	1,640,310	128,748	144.0
144.5	131,372	65,686	1,705,996	131,372	144.5
145.0	133,275	66,638	1,772,634	133,275	145.0
145.5	135,542	67,771	1,840,405	135,542	145.5
146.0	137,682	68,841	1,909,246	137,682	146.0
146.5	139,483	69,741	1,978,987	139,483	146.5
147.0	141,020	70,510	2,049,497	141,020	147.0
147.5	142,553	71,277	2,120,774	142,553	147.5
148.0	144,167	72,083	2,192,857	144,167	148.0
148.5	146,059	73,030	2,265,887	146,059	148.5
149.0	151,878	75,939	2,341,826	151,878	149.0
149.5	160,218	80,109	2,421,935	160,218	149.5
150.0	165,068	82,534	2,504,469	165,068	150.0
150.5	167,194	83,597	2,588,066	167,194	150.5
151.0	169,232	84,616	2,672,682	169,232	151.0
151.5	170,797	85,399	2,758,080	170,797	151.5
152.0	173,408	86,704	2,844,784	173,408	152.0
152.5	175,351	87,675	2,932,459	175,351	152.5
153.0	177,100	88,550	3,021,010	177,100	153.0
153.5	178,646	89,323	3,110,333	178,646	153.5
154.0	180,178	90,089	3,200,422	180,178	154.0
154.5	181,918	90,959	3,291,381	181,918	154.5
155.0	191,894	95,947	3,387,328	191,894	155.0
155.5	207,124	103,562	3,490,890	207,124	155.5
156.0	213,563	106,781	3,597,671	213,563	156.0
156.5	215,449	107,725	3,705,396	215,449	156.5
157.0	217,357	108,679	3,814,074	217,357	157.0
157.5	219,832	109,916	3,923,990	219,832	157.5
158.0	221,776	110,888	4,034,878	221,776	158.0
158.5	224,491	112,245	4,147,123	224,491	158.5
159.0	226,134	113,067	4,260,190	226,134	159.0
159.5	227,746	113,873	4,374,063	227,746	159.5
160.0	229,374	114,687	4,488,750	229,374	160.0
160.5	231,641	115,821	4,604,571	231,641	160.5
161.0	235,939	117,969	4,722,540	235,939	161.0
161.5	245,924	122,962	4,845,502	245,924	161.5
162.0	246,823	123,412	4,968,914	246,823	162.0
162.5	248,720	124,360	5,093,274	248,720	162.5
163.0	250,611	125,305	5,218,579	250,611	163.0
163.5	252,575	126,287	5,344,866	252,575	163.5
164.0	256,614	128,307	5,473,173	256,614	164.0
164.5	259,896	129,948	5,603,121	259,896	164.5
165.0	263,328	131,664	5,734,785	263,328	165.0
165.5	272,793	136,397	5,871,182	272,793	165.5
166.0	278,146	139,073	6,010,255	278,146	166.0
166.5	285,497	142,748	6,153,003	285,497	166.5
167.0	294,573	147,286	6,300,290	294,573	167.0
167.5	309,961	154,981	6,455,270	309,961	167.5
168.0	317,116	158,558	6,613,828	317,116	168.0
168.5	322,475	161,237	6,775,066	322,475	168.5
169.0	80,669	40,334	6,815,400	80,669	169.0



East Hill pit

RL	Surface area m2	Cumulative volume m3	Cumulative m3	Surface area m2	RL
166.0	600.0	600.0	600	600	166.0
166.5	825.0	825.0	1125.0	825.0	166.5
167.0	1050.0	1050.0	1,650	1,050	167.0
167.5	1196.3	1196.3	2321.3	1196.3	167.5
168.0	1342.6	1342.6	2,993	1,343	168.0
168.5	1444.4	1444.4	3765.7	1444.4	168.5
169.0	1546.2	1546.2	4,539	1,546	169.0
169.5	1643.6	1643.6	5409.3	1643.6	169.5
170.0	1740.9	1740.9	6,280	1,741	170.0
170.5	1817.0	1817.0	7226.2	1817.0	170.5
171.0	1893.0	1893.0	8,173	1,893	171.0
171.5	1971.9	1971.9	9198.1	1971.9	171.5
172.0	2050.8	2050.8	10,224	2,051	172.0
172.5	2137.5	2137.5	11335.7	2137.5	172.5
173.0	2224.2	2224.2	12,448	2,224	173.0
173.5	2306.9	2306.9	13642.6	2306.9	173.5
174.0	2389.6	2389.6	14,837	2,390	174.0
174.5	2493.7	2493.7	16136.3	2493.7	174.5
175.0	2597.8	2597.8	17,435	2,598	175.0
175.5	2694.3	2694.3	18830.6	2694.3	175.5
176.0	2790.8	2790.8	20,226	2,791	176.0
176.5	2877.5	2877.5	21708.1	2877.5	176.5
177.0	2964.2	2964.2	23,190	2,964	177.0
177.5	3069.5	3069.5	24777.6	3069.5	177.5
178.0	3174.8	3174.8	26,365	3,175	178.0
178.5	3290.2	3290.2	28067.8	3290.2	178.5
179.0	3405.6	3405.6	29,771	3,406	179.0
179.5	3547.8	3547.8	31615.6	3547.8	179.5
180.0	3690.1	3690.1	33,461	3,690	180.0
180.5	3846.0	3846.0	35461.6	3846.0	180.5
181.0	4001.8	4001.8	37,462	4,002	181.0
181.5	4180.1	4180.1	39641.7	4180.1	181.5
182.0	4358.5	4358.5	41,821	4,358	182.0
182.5	4557.2	4557.2	44199.0	4557.2	182.5
183.0	4756.0	4756.0	46,577	4,756	183.0





Appendix E – Evaporation across climate change scenarios

Station		StationID	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	AnnualAverage	Years
MoranbahWaterTreatment	SE	34038	8	7.4	6.8	5.7	4.3	3.5	3.7	4.9	6.6	8	8.5	8.5	6.3	1986-2012
TwinHills	SW	36047	7.5	6.5	6.1	5.2	3.6	2.9	3.1	4.2	6.1	7.9	8.6	8.7	5.9	1967-1985
CollinsvillePostOffice	NE	33013	6.2	5.7	5.2	4.4	3.5	2.9	3.2	4.1	5.3	6.5	6.9	6.9	5.1	1967-2017
Average			7.2	6.5	6.0	5.1	3.8	3.1	3.3	4.4	6.0	7.5	8.0	8.0	5.8	
2030		0.36														
Station		StationID	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	AnnualAverage	Years
MoranbahWaterTreatment	SE	34038	8.36	7.76	7.16	6.06	4.66	3.86	4.06	5.26	6.96	8.36	8.86	8.86	6.69	
TwinHills	SW	36047	7.86	6.86	6.46	5.56	3.96	3.26	3.46	4.56	6.46	8.26	8.96	9.06	6.23	
CollinsvillePostOffice	NE	33013	6.56	6.06	5.56	4.76	3.86	3.26	3.56	4.46	5.66	6.86	7.26	7.26	5.43	
Average			7.6	6.9	6.4	5.5	4.2	3.5	3.7	4.8	6.4	7.8	8.4	8.4	6.1	
2050		0.82														
Station		StationID	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	AnnualAverage	Years
MoranbahWaterTreatment	SE	34038	8.82	8.22	7.62	6.52	5.12	4.32	4.52	5.72	7.42	8.82	9.32	9.32	7.15	
TwinHills	SW	36047	8.32	7.32	6.92	6.02	4.42	3.72	3.92	5.02	6.92	8.72	9.42	9.52	6.69	
CollinsvillePostOffice	NE	33013	7.02	6.52	6.02	5.22	4.32	3.72	4.02	4.92	6.12	7.32	7.72	7.72	5.89	
Average			8.1	7.4	6.9	5.9	4.6	3.9	4.2	5.2	6.8	8.3	8.8	8.9	6.6	
2070		1.2														
Station		StationID	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	AnnualAverage	Years
MoranbahWaterTreatment	SE	34038	9.2	8.6	8	6.9	5.5	4.7	4.9	6.1	7.8	9.2	9.7	9.7	7.53	
TwinHills	SW	36047	8.7	7.7	7.3	6.4	4.8	4.1	4.3	5.4	7.3	9.1	9.8	9.9	7.07	
CollinsvillePostOffice	NE	33013	7.4	6.9	6.4	5.6	4.7	4.1	4.4	5.3	6.5	7.7	8.1	8.1	6.27	
Average			8.4	7.7	7.2	6.3	5.0	4.3	4.5	5.6	7.2	8.7	9.2	9.2	7.0	
2090		1.6														
Station		StationID	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	AnnualAverage	Years
MoranbahWaterTreatment	SE	34038	9.6	9	8.4	7.3	5.9	5.1	5.3	6.5	8.2	9.6	10.1	10.1	7.93	
TwinHills	SW	36047	9.1	8.1	7.7	6.8	5.2	4.5	4.7	5.8	7.7	9.5	10.2	10.3	7.47	
CollinsvillePostOffice	NE	33013	7.8	7.3	6.8	6	5.1	4.5	4.8	5.7	6.9	8.1	8.5	8.5	6.67	
Average			8.8	8.1	7.6	6.7	5.4	4.7	4.9	6.0	7.6	9.1	9.6	9.6	7.4	
2090 Wetter/Low Evap		0.72														
Station		StationID	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	AnnualAverage	Years
MoranbahWaterTreatment	SE	34038	8.72	8.12	7.52	6.42	5.02	4.22	4.42	5.62	7.32	8.72	9.22	9.22	7.05	
TwinHills	SW	36047	8.22	7.22	6.82	5.92	4.32	3.62	3.82	4.92	6.82	8.62	9.32	9.42	6.59	
CollinsvillePostOffice	NE	33013	6.92	6.42	5.92	5.12	4.22	3.62	3.92	4.82	6.02	7.22	7.62	7.62	5.79	
Average			8.0	7.3	6.8	5.8	4.5	3.8	4.1	5.1	6.7	8.2	8.7	8.8	6.5	
2090 Drier/higher evap		3														
Station		StationID	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	AnnualAverage	Years
MoranbahWaterTreatment	SE	34038	11	10.4	9.8	8.7	7.3	6.5	6.7	7.9	9.6	11	11.5	11.5	9.33	
TwinHills	SW	36047	10.5	9.5	9.1	8.2	6.6	5.9	6.1	7.2	9.1	10.9	11.6	11.7	8.87	
CollinsvillePostOffice	NE	33013	9.2	8.7	8.2	7.4	6.5	5.9	6.2	7.1	8.3	9.5	9.9	9.9	8.07	
Average			10.2	9.5	9.0	8.1	6.8	6.1	6.3	7.4	9.0	10.5	11.0	11.0	8.8	

To Tom Cooney, GBM Resources
CC Kate Jeffrey, AARC
Project Yandan, North central Queensland
Purpose **Summary tailings & heap leach landforms risk review for cover design**

1. Background

GBM Resources has requested a summary risk review of the legacy Yandan tailings storage & heap leach landforms as advice into PRCP final design requirements. This review is supplementary to the full PRCP water performance report for Yandan (SBE 2022) as a summary: further details are available in the full report. The SBE (2022) report assessed both landforms to be low risk category.

Yandan gold mine operated between 1993 to 1999, when the tailings storage & leach pad were constructed & formed. Part of the tailings storage area was rehabilitated. The landforms have now existed in the Yandan landscape for 23 years with minimal change or disturbance since, forming part of the landscape. The landform systems are stable, & whilst closure clean up & covers are required, it is reasonable to expect any potential environment harm would already be evident.

2. Mechanisms of environment harm & basis of cover design

A general schematic of an earthen constructed landform is shown in Figure 1. The potential for environment harm via legacy mining landforms are shaped by a cumulative process:

1. Nature of materials stored within the landform – redox potential, acidity or alkalinity, metals.
2. Exposure of materials to air or oxygen to commence the ARD/AMD/NMD process.
3. Contact of water through the oxygenated materials – through percolation or entrainment. Most landforms will host water entrained into pore spaces as part of sitting in the landscape as some water will be unable to flow. This entrained water forms a minor potentiometric surface through the landform as part of standard practice.
4. Water being able to continue to flow to reach outside of the landform area & travel away.

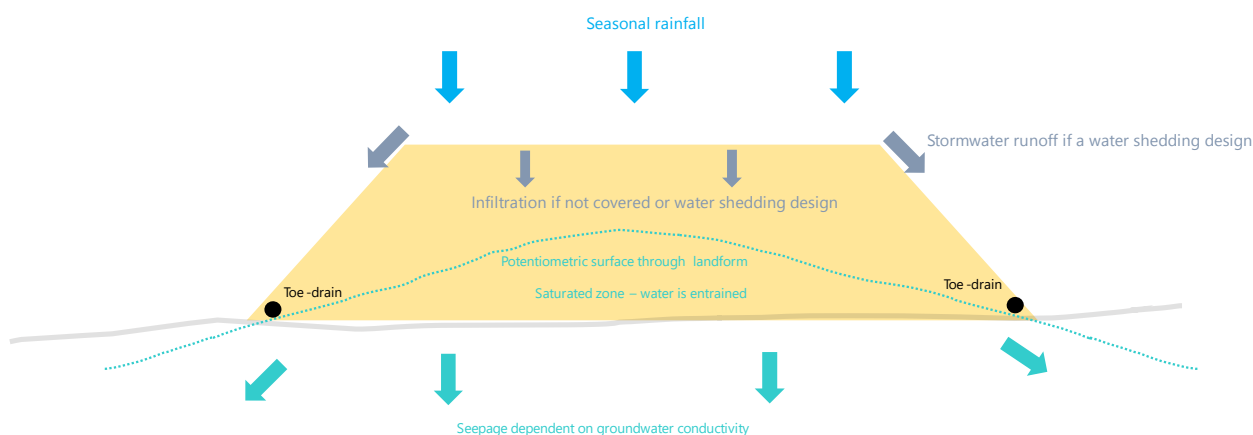


Figure 1 - General schematic of an earthen constructed landform & factors of water interaction

3. Purpose of cover designs in legacy landforms

The core intent of cover design is to:

1. Achieve containment or limiting one or more of the harm process steps: nature of materials, exposure of air, percolation of water through the landform, or outside of the landform – having low conductivity groundwater or surface water interception.
2. Create a sustainable, stable & preferably useful landform in the landscape to restore the landscape & environment values.

Cover designs need to be fit for purpose for the landform system to suit landscape, climate setting, geology, nature of materials, water interactions & revegetation for landuse. Rather than a blanket approach, learning what works in what landscape to design is fundamental to sustainable outcomes.

4. Major role of climate & landscape in risk of landforms

The setting of a landform plays a major role in relative risk of any mining landform:

- Nature & position in a landscape shape contact of the landform with water: proximity to flow through or saturation areas, topography & contour gradients of the landform.
- Rainfall & climate as a major driver of potential infiltration & percolation.
- Geology as the host of groundwater: shaping formation & quality of aquifers & hydraulic conductivity.

In landscape, the Yandan project area is gently undulating (Figure 2), with both the tailings storage & the heap leach landform at or very near to the top of catchments. The only source of water to interact with the landforms will be rainfall direct onto the landform itself, & how the cover sheds rainfall from the landform.

The Yandan climate is predominantly very dry: with an average annual rainfall of 583mm (varying from 213-1200mm) against an evaporation potential of 2,100 to 2,300mm/year, the site is strongly water balance negative to an average of 1.5-1.7mm/year. Exposure to infiltration as a period of risk in quantitative terms is very low: the site experiences rainfall of >10mm (10mm minimum before runoff after loss to soil moisture & vegetation) just 20 days per year, or 5.6% of days per year (Figure 4).

Geology of Yandan severely restricts groundwater development in general, but particularly around the tailings & heap leach landforms. Both landforms lay near the top of hills with as more erosion resistance than other areas & shallow soil development. Geology consists of crystalline volcanic rocks or siltstones: heap leach area lays on volcanic andesite rocks & siltstones, whilst the tailings area lays on siltstones. In volcanic geology, rocks are crystalline & groundwater can only exist in fractures as there is no primary porosity. Although siltstone is sedimentary rock, it is a poor aquifer host with very low water presence & low hydraulic conductivity (1×10^{-11} to 1.4×10^{-8} (Fetter 1994)), which is akin or greater to target conductivity of a clay liner conductivity) given the fine grained & compacted nature of the materials.

The nature of siltstone as a poor aquifer is confirmed at Yandan: groundwater is difficult to intersect, with minimum water intersected in recent drilling, & where constructed all bores constructed across Yandan (where logged) are recorded as siltstone. Notably whilst water is detected in these wells, each well has a very low yield/rate of recharge. Groundwater sampling often requires 1-2 days of recharge after purging to obtain enough water in the bore column to sample.

Both the tailings storage & heap leach landforms lay on geology which has minimal presence of groundwater & in rocks of low to minimal hydraulic conductivity: water percolating through the tailings or heap leach will be strongly restricted in reaching groundwater past the landform zones or operating footprints.



Figure 2 - View north over Yandan project site from top of heap leach pad

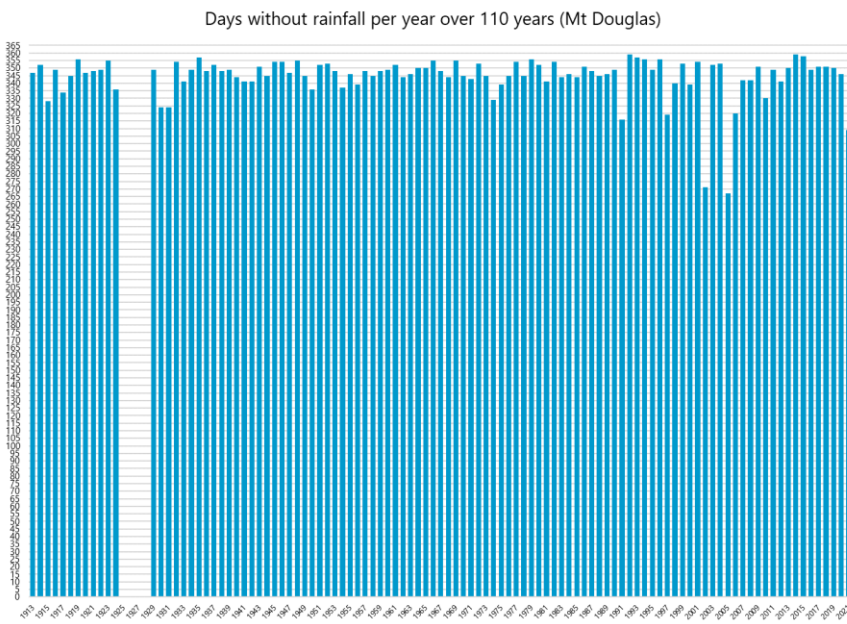


Figure 4 - Days without rainfall per year at Yandan site

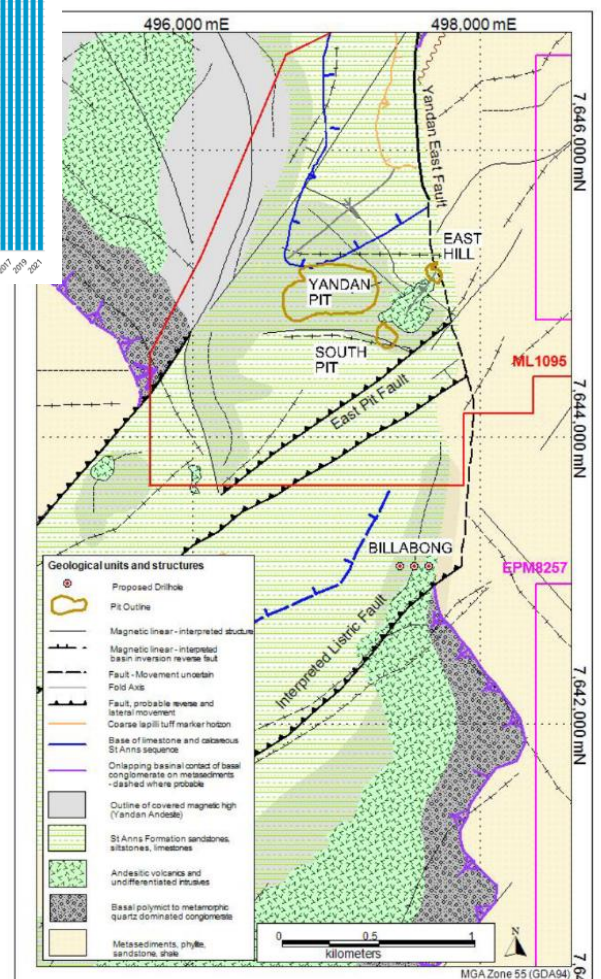


Figure 3 - Geology of Yandan site

5. Risk characterisation framework

Risk characterisation guidance is provided in the DES Estimated Rehabilitation Calculation guidelines:

- User Guide for Estimated Rehabilitation Cost Calculator for Mining (2019).
- Estimated rehabilitation cost under the Environmental Protection Act Guideline (2021).

The 2019 User Guide provides further clarification of risk category categories from very low to high risk categories (Figure 5). The 2021 guideline provides the following high-level definition of high risk landforms as:

- Contain Potentially Acid Forming (PAF) material.
- Have observed contaminated seepage that is capable of causing environment harm.

The ERC User Guide provides clear delineation of characteristics of each landform & risk category, & will provide the framework applied in this risk review for Yandan tailings & heap leach closure risk.

Table 6-1 Risk Category Characteristics

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High Select this category if the waste structure has one or more of the following characteristics:	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm.	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tails materials Requiring composite liners (e.g. HDPE) Embankments > 30 metres high Observed contaminated seepage capable of causing environmental harm.
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end Low strength consolidated tailings land use objectives for the facility Embankments 15 to 30 m high
Low	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD) Moderate to low salinity Moderate strength consolidated tailings Embankments less than 15 m high
Very Low	Benign materials	Benign materials	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments less than 15 m high

Figure 5 - Guidance of risk category characteristics (DES 2019)

6. Tailings storage landform assessment

Materials characterisation

Geochemical assessment of tailings host materials at Yandan is informed by four (4) main studies:

- Tailings rehabilitation studies – 26 samples Dwyer (internal), circa 1999 for Ross Mining.
- Combined heap leach & Cell B tailings – 6 samples - RGS 2013 for Straits Resources.
- Oxide & tailings assessment – 85 samples – RGS 2015 for Straits Resources.
- Discussion of tailings assessment results – 15 samples - RGS 2022 for GBM Resources.

The RGS (2013, 2015) study reviewed previous work & reclassified the nature of materials from system response over the past 23 years, with materials now essentially low acid forming potential (LAFP) to inert, with almost complete oxidation & precipitation of sulphides within the tailings area as jarosite. In 2022, RGS testing a further 15 samples (including 3x natural soil) for further static & kinetic testing, & assessed insitu conductivity as a measure of percolation potential of the top of the facility. Key findings include:

- Confirmation that oxidation of sulphides has occurred with likely conversion to jarosite within the landform, as all tailings materials now classified as non-acid forming (Figure 6).
- Low porosity of materials within the tailings facility below that of natural soils, inhibiting infiltration & percolation (Figure 7)
- Low sulphate responses in water within tailings samples & kinetic leaching results with a maximum of 2,000mg/l potential (Figure 8 & Figure 9).
- Key base materials enrichment metals of aluminium, arsenic, cadmium, chromium, copper, manganese, nickel & zinc, but which have limited mobility.

Sample No.	RGS Sample ID	ALS Lab ID	Sample Material	Sample Location	Easting	Northing	pH _(1:5) ¹	EC _(1:5) ¹ (µS/cm)	pH based Acid Forming Potential	Total S (%)	Scr ² (%)	MPA ² (kg H ₂ SO ₄ /t)	ANC ²	NAPP ²	ANC: MPA Ratio	Geochemical Classification ³
GDA 94 Z 55																
1	2022017_0001	EB2210698001	Soil	Outside TSF	500,759	7,646,672	5.1	29	LAFP	0.01		0.31	3.1	-2.79	10.12	Non-Acid Forming (Barren)
2	2022017_0002	EB2210698002	Soil	Outside TSF	500,904	7,647,693	6.2	87	Inert	0.01		0.31	5.1	-4.79	16.65	Non-Acid Forming (Barren)
3	2022017_0003	EB2210698003	Soil	Outside TSF	499,625	7,647,575	6.6	28	Inert	0.01		0.31	7.2	-6.89	23.51	Non-Acid Forming (Barren)
4	2022017_3001	EB2210698004	Tailings	TSF Cell B	500,342	7,647,447	4.1	1910	LAFP	0.35	0.014	0.43	2.7	-2.27	6.30	Non-Acid Forming (Barren)
5	2022017_3002	EB2210698005	Tailings	TSF Cell B	500,498	7,647,477	3.9	1760	MAFP	0.26	0.021	0.64	3.0	-2.36	4.66	Non-Acid Forming (Barren)
6	2022017_3003	EB2210698006	Tailings	TSF Cell B	500,605	7,647,353	3.9	2860	MAFP	0.59	0.019	0.58	2.1	-1.52	3.61	Non-Acid Forming (Barren)
7	2022017_3004	EB2210698007	Tailings	TSF Cell B	500,262	7,647,227	4.0	800	LAFP	0.31	0.017	0.52	1.0	-0.48	1.92	Non-Acid Forming (Barren)
8	2022017_3005	EB2210698008	Tailings	TSF Cell B	500,434	7,647,242	3.9	2360	MAFP	0.41	0.017	0.52	1.1	-0.58	2.11	Non-Acid Forming (Barren)
9	2022017_3006	EB2210698009	Tailings	TSF Cell B	500,540	7,647,146	3.8	2900	MAFP	0.81	0.016	0.49	1.3	-0.81	2.65	Non-Acid Forming (Barren)
10	2022017_3007	EB2210698010	Tailings	TSF Cell B	500,226	7,646,940	4.3	1280	LAFP	0.36	0.031	0.95	2.2	-1.25	2.32	Non-Acid Forming (Barren)
11	2022017_3008	EB2210698011	Tailings	TSF Cell B	500,380	7,646,930	4.0	1790	LAFP	0.38	0.025	0.77	6.0	-5.23	7.84	Non-Acid Forming (Barren)
12	2022017_3009	EB2210698012	Tailings	TSF Cell B	500,487	7,646,819	3.7	2600	MAFP	0.53	0.018	0.55	0.6	-0.05	1.09	Non-Acid Forming (Barren)
13	2022017_3010	EB2210698013	Tailings	TSF Cell A	499,874	7,647,368	8.5	780	Inert	0.08		2.45	10.3	-7.85	4.20	Non-Acid Forming (Barren)
14	2022017_3011	EB2210698014	Tailings	TSF Cell A	499,842	7,647,167	4.2	4010	LAFP	1.33	0.022	0.67	0.3	0.42	0.37	Non-Acid Forming (Barren)
15	2022017_3012	EB2210698015	Tailings	TSF Cell A	499,853	7,646,938	5.2	3390	LAFP	0.31	0.028	0.86	4.1	-3.24	4.78	Non-Acid Forming (Barren)

Notes:

1. pH and EC for 1:5 sample:water extracts

2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; NAPP = Net Acid Production Potential.

3. Sample classification criteria detail provided in report text. LAFP = Low acid forming Potential. MAFP = Mild Acid Forming Potential.

Figure 6 - Acid base accounting from recent assessment (RGS 2022)

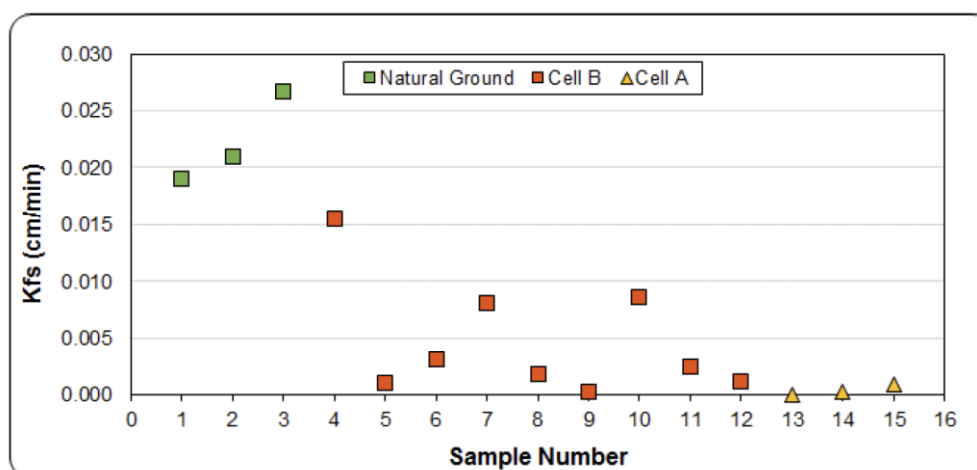


Figure 7 - In situ porosity of tailings facility (RGS 2022)

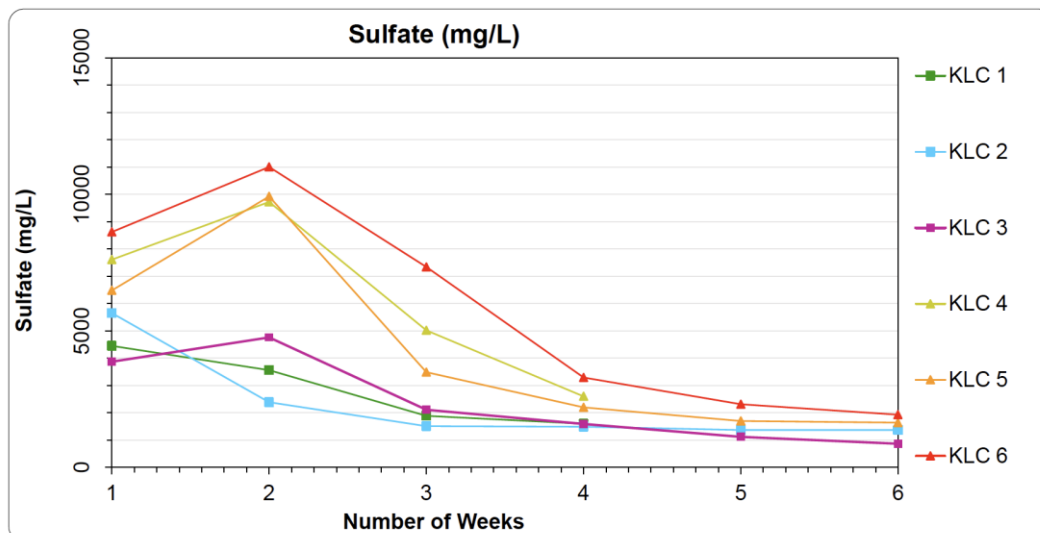


Figure 8 - Sulphate production through rapid kinetic testing (RGS 2022)

Parameters		Limit of Reporting	ROS Sample Number		2020/17_0001	2020/17_0002	2020/17_0003	2020/17_0004	2020/17_0005	2020/17_0006	2020/17_0007
			Sample Date		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022	
			ALS Laboratory ID		EB212/171001	EB212/171002	EB212/171003	EB212/171004	EB212/171005	EB212/171006	
			Aquatic Ecosystems (freshwater)	Livestock Drinking Water	Sample 5 TSF Cell B	Sample 7 TSF Cell B	Sample 1 TSF Cell B	Sample 4 TSF Cell B	Sample 6 TSF Cell B	Sample 3 TSF Cell B	Sample 2 TSF Cell B
pH	0.01 pH unit	8 to 9	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Electrical Conductivity (µS/cm)	1 µS/cm	<1000	3,580	25	65	65	1,910	1,600			
Carbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	49	49	49	49	49	49	49	49
Bicarbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	49	49	49	49	49	49	49	49
Total Alkalinity (mg CaCO ₃ /L)	0.2	-	-	152	152	152	152	152	152	152	152
Acidity (mg CaCO ₃ /L)	0.2	-	-	152	152	152	152	152	152	152	152
Net Alkalinity (mg CaCO ₃ /L)	0.2	-	-	153	153	153	153	153	153	153	153
Major Ions											
Calcium (Ca)	2	-	1,000	10	10	10	336	142	115		
Magnesium (Mg)	2	-	100	10	10	10	18	18	18	18	18
Potassium (K)	2	-	10	10	10	10	2	2	2	2	2
Sodium (Na)	2	-	10	10	10	10	136	180	180	180	180
Chloride (Cl)	2	-	10	10	10	10	152	152	152	152	152
Fluoride (F ⁻)	0.4	-	2	2	2	2	0.4	0.4	0.4	0.4	0.4
Sulfate (SO ₄ ²⁻)	2	-	1,000	10	10	10	336	336	336	336	336
Trace Metals/Metalloids											
Aluminum (Al)	0.02	0.005	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Arsenic (As)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Boron (B)	0.002	0.37	5	0.308	0.068	0.016	0.002	0.002	0.002	0.002	0.002
Barium (Ba)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Beryllium (Be)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cadmium (Cd)	0.002	0.0002	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt (Co)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Chromium (Cr)	0.002	0.001	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Copper (Cu)	0.002	0.0014	1	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Iron (Fe)	0.2	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	0.068	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Molybdenum (Mo)	0.002	0.002	0.15	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Antimony (Sb)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01	0.74	0.89			

Parameters		Limit of Reporting	ROS Sample Number		2020/17_0001	2020/17_0002	2020/17_0003	2020/17_0004	2020/17_0005	2020/17_0006	2020/17_0007
			Sample Date		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022	
			ALS Laboratory ID		EB212/171001	EB212/171002	EB212/171003	EB212/171004	EB212/171005	EB212/171006	
			Aquatic Ecosystems (freshwater)	Livestock Drinking Water	Sample 5 TSF Cell B	Sample 7 TSF Cell B	Sample 1 TSF Cell B	Sample 4 TSF Cell B	Sample 6 TSF Cell B	Sample 3 TSF Cell B	Sample 2 TSF Cell B
pH	0.01 pH unit	8 to 9	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Electrical Conductivity (µS/cm)	1 µS/cm	<1000	3,580	25	65	65	1,910	1,600			
Carbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	49	49	49	49	49	49	49	49
Bicarbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	49	49	49	49	49	49	49	49
Total Alkalinity (mg CaCO ₃ /L)	0.2	-	-	152	152	152	152	152	152	152	152
Acidity (mg CaCO ₃ /L)	0.2	-	-	152	152	152	152	152	152	152	152
Net Alkalinity (mg CaCO ₃ /L)	0.2	-	-	153	153	153	153	153	153	153	153
Major Ions											
Calcium (Ca)	2	-	1,000	10	10	10	336	142	115	104	104
Magnesium (Mg)	2	-	100	10	10	10	18	18	18	18	18
Potassium (K)	2	-	10	10	10	10	2	2	2	2	2
Sodium (Na)	2	-	10	10	10	10	96	136	180	180	180
Chloride (Cl)	2	-	10	10	10	10	152	152	152	152	152
Fluoride (F ⁻)	0.4	-	2	2	2	2	0.4	0.4	0.4	0.4	0.4
Sulfate (SO ₄ ²⁻)	2	-	1,000	10	10	10	336	336	336	336	336
Trace Metals/Metalloids											
Aluminum (Al)	0.02	0.005	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Arsenic (As)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Boron (B)	0.002	0.37	5	0.308	0.068	0.016	0.002	0.002	0.002	0.002	0.002
Barium (Ba)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Beryllium (Be)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cadmium (Cd)	0.002	0.0002	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt (Co)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Chromium (Cr)	0.002	0.001	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Copper (Cu)	0.002	0.0014	1	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Iron (Fe)	0.2	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	0.068	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Molybdenum (Mo)	0.002	0.002	0.15	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
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Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	0.012	0.002	0.002	0.002	0.002	0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	1.98	0.86	1.18	0.86				

Parameters		Limit of Reporting	ROS Sample Number		2020/17_0001	2020/17_0002	2020/17_0003	2020/17_0004	2020/17_0005	2020/17_0006	2020/17_0007
			Sample Date		03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022	03/05/2022	
			ALS Laboratory ID		EB212/171001	EB212/171002	EB212/171003	EB212/171004	EB212/171005	EB212/171006	
			Aquatic Ecosystems (freshwater)	Livestock Drinking Water	Sample 5 TSF Cell B	Sample 7 TSF Cell B	Sample 1 TSF Cell B	Sample 4 TSF Cell B	Sample 6 TSF Cell B	Sample 3 TSF Cell B	Sample 2 TSF Cell B
pH	0.01 pH unit	8 to 9	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Electrical Conductivity (µS/cm)	1 µS/cm	<1000	3,580	25	65	65	1,910	1,600			
Carbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	49	49	49	49	49	49	49	49
Bicarbonate Alkalinity (mg CaCO ₃ /L)	0.2	-	-	49	49	49	49	49	49	49	49
Total Alkalinity (mg CaCO ₃ /L)	0.2	-	-	152	152	152	152	152	152	152	152
Acidity (mg CaCO ₃ /L)	0.2	-	-	152	152	152	152	152	152	152	152
Net Alkalinity (mg CaCO ₃ /L)	0.2	-	-	153	153	153	153	153	153	153	153
Major Ions											
Calcium (Ca)	2	-	1,000	10	10	10	336	142	115	104	104
Magnesium (Mg)	2	-	100	10	10	10	18	18	18	18	18
Potassium (K)	2	-	10	10	10	10	2	2	2	2	2
Sodium (Na)	2	-	10	10	10	10	96	136	180	180	180
Chloride (Cl)	2	-	10	10	10	10	152	152	152	152	152
Fluoride (F ⁻)	0.4	-	2	2	2	2	0.4	0.4	0.4	0.4	0.4
Sulfate (SO ₄ ²⁻)	2	-	1,000	10	10	10	336	336	336	336	336
Trace Metals/Metalloids											
Aluminum (Al)	0.02	0.005	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Arsenic (As)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Boron (B)	0.002	0.37	5	0.308	0.068	0.016	0.002	0.002	0.002	0.002	0.002
Barium (Ba)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Beryllium (Be)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cadmium (Cd)	0.002	0.0002	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cobalt (Co)	0.002	-	-	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Chromium (Cr)	0.002	0.001	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Copper (Cu)	0.002	0.0014	1	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Iron (Fe)	0.2	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	0.068	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Molybdenum (Mo)	0.002	0.002	0.15	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002</

Figure 9 - Sulphate present in tailings samples (RGS 2022)

Observed system response

Groundwater is at the highest elevation across the project near to the tailings dam, with the groundwater surface extending out to the southwest. Any groundwater flow is likely to be strongly constrained given the siltstone underlaying the storage.

Groundwater levels are subtly responsive to overall rainfall, declining over the dry period from 2012 to 2021, with some local changes. TD5 is identified as a failed well. Groundwater quality of other wells are generally stable as per electrical conductivity & sulphate (Figure 10), though represent a well network monitoring mixed sources.

As the main wells downgradient of the tailings dam, TD3 & TD7 (S/D) shows containment of any entrained water within the tailings storage area is effective, demonstrating normal salinity & sulphate. TD3 lays close to the tailings dam storage embankment & may in part be monitoring the embankment potentiometric surface.

Electrical conductivity shows elevated salinity in three locations – TD4, TD5, TD6 (S/D), with values of 10,000-30,000uS/cm. However, these wells are not representative of groundwater, as they lay within influence of the potentiometric surface of the tailings facility itself. The locations of these wells indicate they are likely monitoring quality of entrained (captured) water within the tailings facility, & are not representative of groundwater (see system diagram). Installation of additional wells stepped out from the area are recommended.

Sulphate generally remains below 1,000mg/l, below the stock water quality limit except for TD6 (which is likely in connection with tailings entrainment).

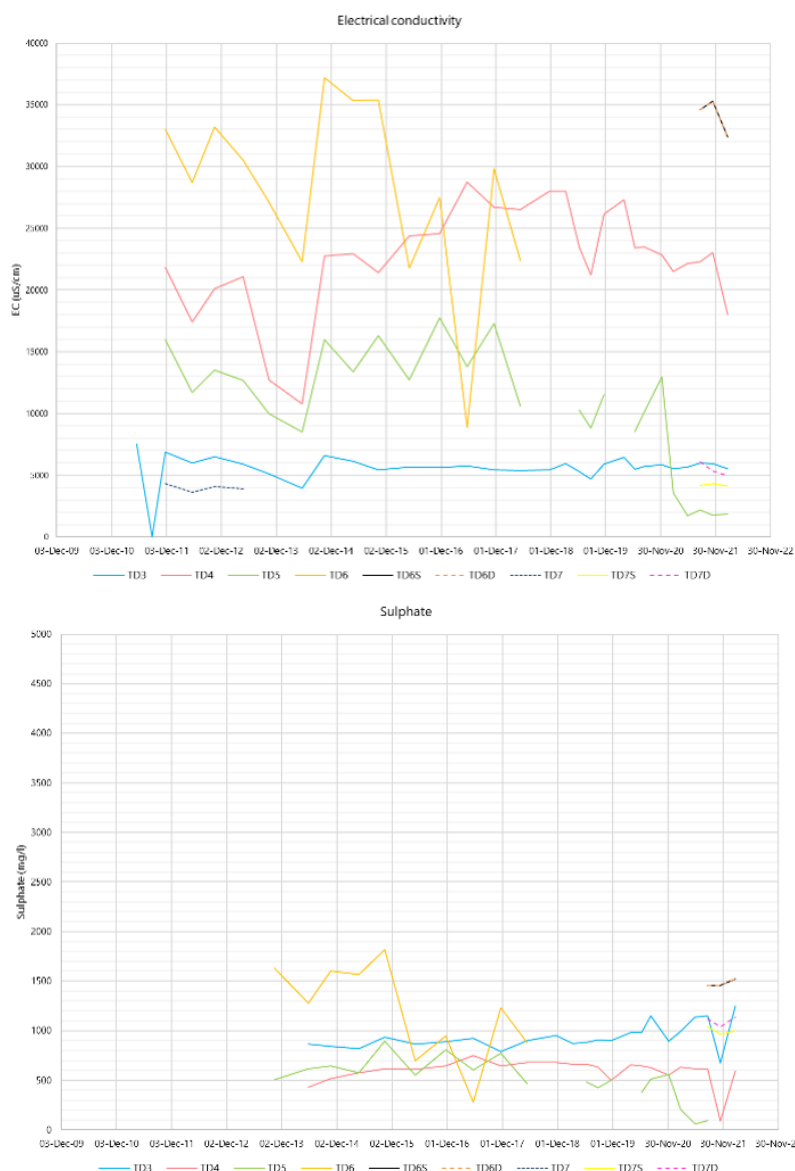


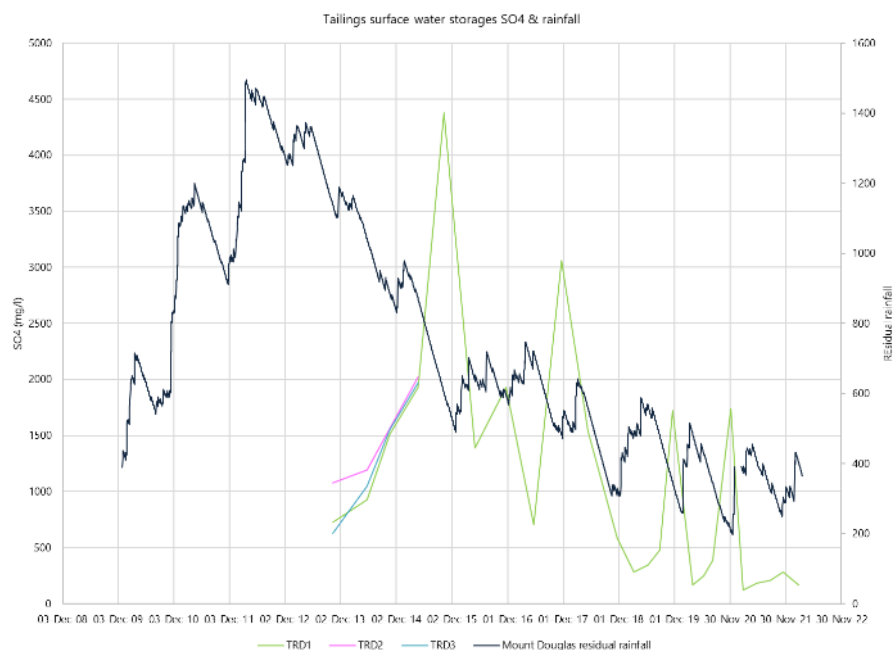
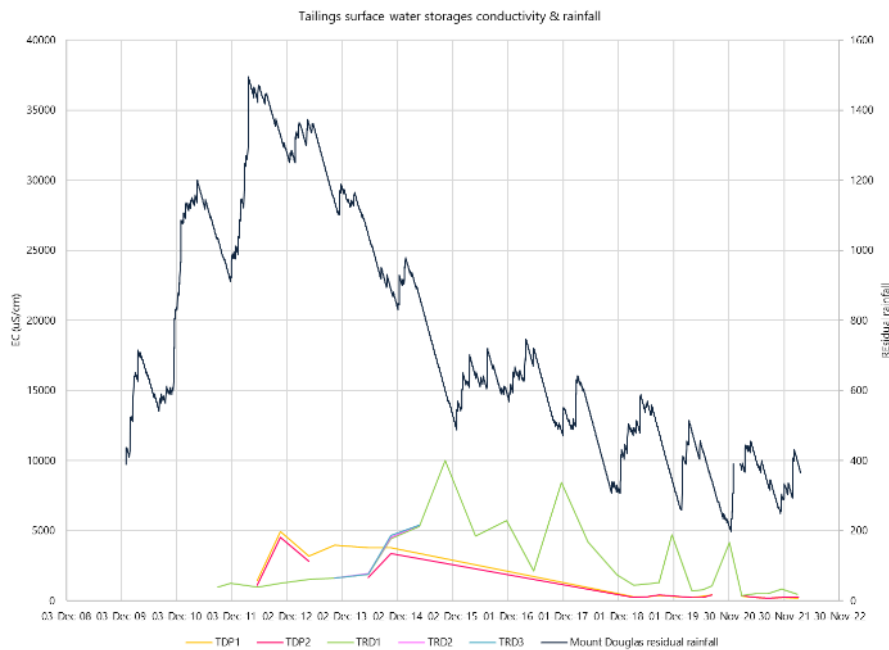
Figure 10 - Bore water quality for tailings area

In surface water at the containment dam, quality is linked to rainfall & evaporation (Figure 11), with electrical conductivity & sulphate increasing over dry seasons during periods of an absence of rainfall which acts to concentrate salts within the dam with evaporation.

The original assessment (SBE 2022) identified the peaks of quality in relationship with rainfall in the tailings downstream containment dam, & identified two possible scenarios: evaporation & extended dry seasons leading to concentration of salts in the dam, or flushing of the system with rainfall. An overall trend of reducing salinity & salts was also noted, with troughs & peaks in continual decline to close to fresh water at troughs, indicating the system was stabilised & improving in quality.

Further detailed review of water quality, rainfall, & conductivity results via RGS (2022) is now able to dismiss the latter scenario of a flushing system, to identify that the driving factor for salinity & sulphate peaks as dry periods where salts show increasing concentrations with evaporation & which are refreshed during rainfall wet season & rainfall. The system is contained, as during low dam levels there is ample storage available for containment. This is evident through comparison & coincident timing of troughs in the residual rainfall chart to the peaks of conductivity & sulphate, or the peaks of rainfall to the lowering of salinity & sulphate concentrations.

The longer-term trend of reducing salinity & sulphate continues to be evident, with levels now down below 500 uS/cm, & 250 mg/l sulphate: indicating system stabilisation & improved water performance.



System model

A working system model of the Yandan tailings landform (at closure) is shown in Figure 12.

Key features of the model include:

- Low elevation profile of the tailings facility over the top of the landscape, from 1 to a maximum of 15 metres at the highest point.
- Low conductivity of geology below the tailings facility, severely retarding any groundwater seepage.
- Seasonal rainfall may lead to some ponding at present, which is subject to evaporation & low rates of infiltration (based on conductivity testing by RGS 2022). This can be addressed through a water shedding cover design.
- Potentiometric surface through the landform via entrained water, where TD4, TD5, TD6 are likely not representative of actual groundwater, but representative of the entrained water in the landform & the saturation within the tailings facility itself.
- Unaffected water downgradient at TD3 & TD7 (D/S) & in the tailings containment dam, demonstrating containment of any potentially impacted water & low potential for environment harm.

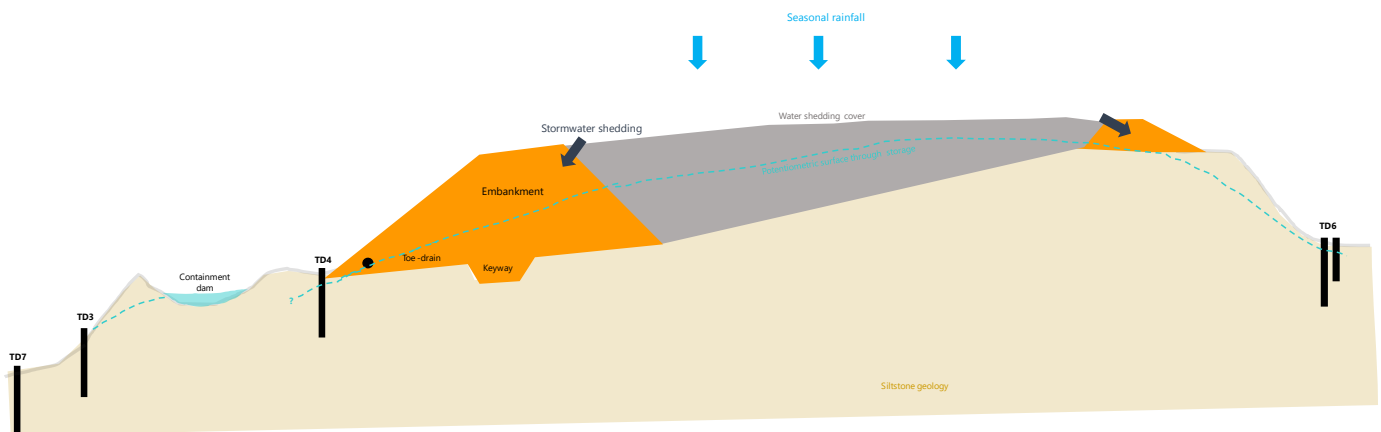


Figure 12 - Schematic of tailings & monitoring locations (shown with water shedding closure design)

Fit against risk category

Review of the Yandan tailings storage facility materials, compaction, height & water performance places the facility in the low risk category, as:

- Low reactive materials in AMD, ARD, NMD, or saline drainage.
- Moderate to low salinity is evident in surface water & groundwater.
- Very low conductivity in underlying geology.
- Tailings have at least moderate strength & consolidation.
- Embankment is <15m.

Table 6-1 Risk Category Characteristics

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High Select this category if the waste structure has one or more of the following characteristics:	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm.	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tails materials Requiring composite liners (e.g. HDPE) Embankments > 30 metres high Observed contaminated seepage capable of causing environmental harm.
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end Low strength consolidated tailings land use objectives for the facility Embankments 15 to 30 m high
Low	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD) Moderate to low salinity Moderate strength consolidated tailings Embankments less than 15 m high
Very Low	Benign materials	Benign materials	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments less than 15 m high

7. Heap leach landform

Materials characterisation

Geochemical assessment of heap leach host materials at Yandan is informed by two (2) main studies:

- Heap leach assessment – 20 samples - EGI 2002 for Warralie Mines.
- Combined heap leach & Cell B tailings – 6 samples - RGS 2013 for Straits Resources.

Both studies identified heap leach materials as:

- Benign, low-grade which were non-acid forming but may generate saline runoff & seepage.
- Potential enrichment of calcium, sulphate, chloride & sodium runoff given the extent of lime addition through the heap leach as part of extraction processes.

Observed system response over time

The heap leach system consists of two main parts:

- The heap leach landform itself.
- The leachate pond & stormwater pond system with surface water sampling in both, which was the source of feed water to the plant when in operation & captures excess rainfall. The stormwater pond is essentially dry except in rainfall situations.

The bore network is placed largely directly around the heap leach landform, with historical monitoring wells of unknown geology & construction. The bore HL4 is likely a failed well given responses to rainfall, & potentially also HL6 given the wide range of variability of arsenic results (groundwater is usually more stable & there is wide variability). There is one well (HL3) roughly downgradient of the heap leach, & another well (HL1) which lays directly adjacent to the historical leachate pond. Given the proximity in the pond embankment, HL1 is likely in direct connection with the pond water & unlikely to represent groundwater. As part of closure the leachate pond & related materials will be removed & rehabilitated. Several additional wells are recommended for downgradient of the heap leach pond.

In groundwater quality observations:

- Electrical conductivity is elevated at bores HL1 & HL3:
 - HL1 is elevated given likely direct connection to leach pond.
 - HL3 is elevated in electrical conductivity, as a single point: no other wells have elevated salinity around the landform, including wells upgradient, & the elevated salinity is not matched with sulphate as could be expected if water quality at HL3 was influenced via the leach pad through groundwater seepage. The elevated salinity may be natural with volcanic geology below.
- Sulphate is only elevated at the leachate pond well, HL1 as part of being directly connected to the highest concentration source.
- Arsenic concentrations are low to not detected in all wells except for one well on the northeast side, HL6. However, concentrations are highly variable in coincidence with rainfall, with a longer-term trend of decline. HL6 is a failed bore is marked for replacement.

In surface water quality observations:

- Electrical conductivity is elevated in both the leachate & stormwater pond (20,000uS/cm), well above any groundwater salinity. This is likely to be a factor of the ponds historical purpose & concentration of applied salts.
- Sulphate is elevated to 5,000mg/l in both ponds, however is stable in the leachate pond, & stable to improving in the stormwater pond.
- Arsenic is elevated within the leach pond but improving (reducing), & is likely a legacy of historical operations rather than current drainage. The stormwater pond is low in arsenic.

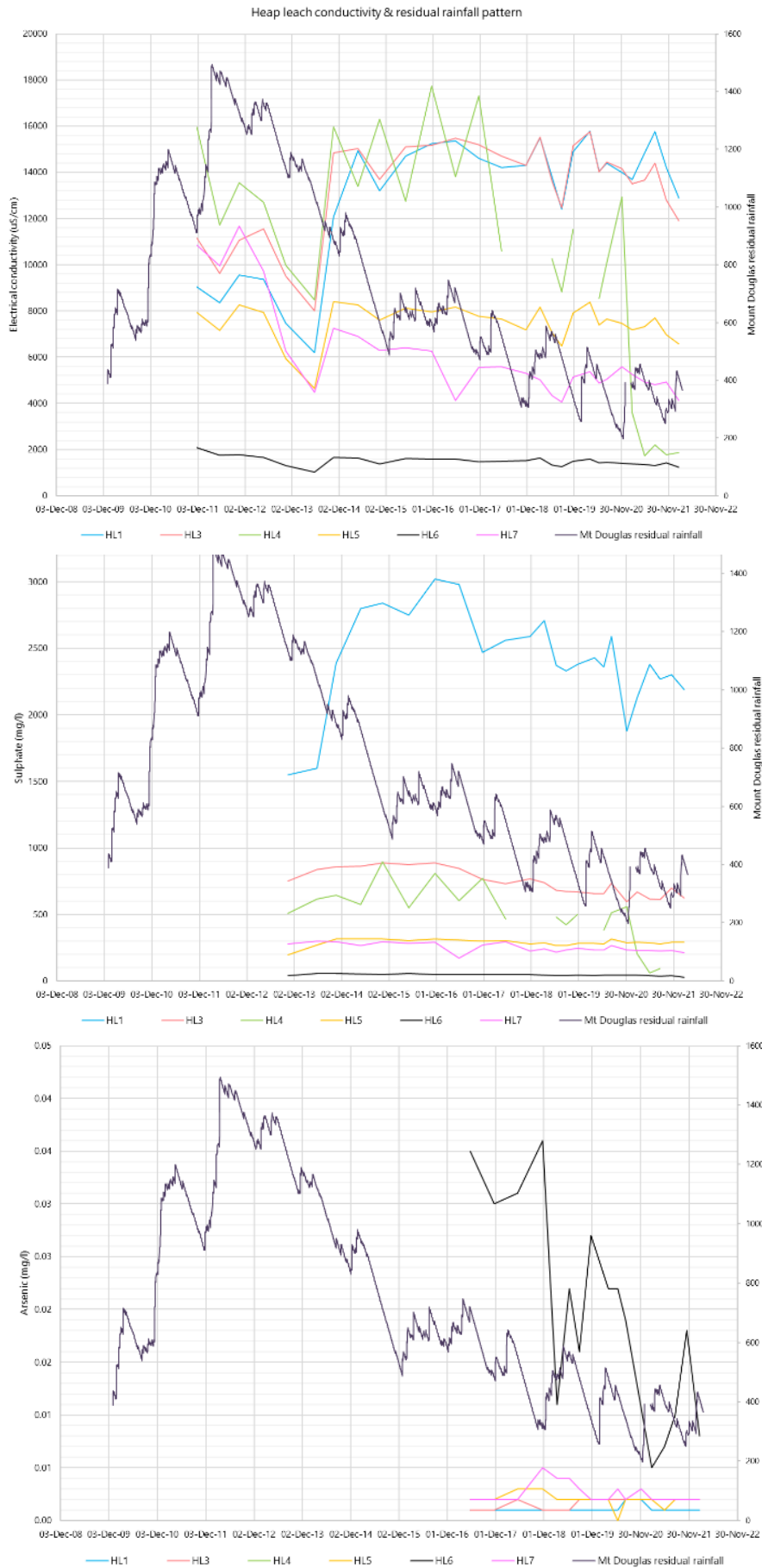


Figure 13 - Bore water quality for heap leach

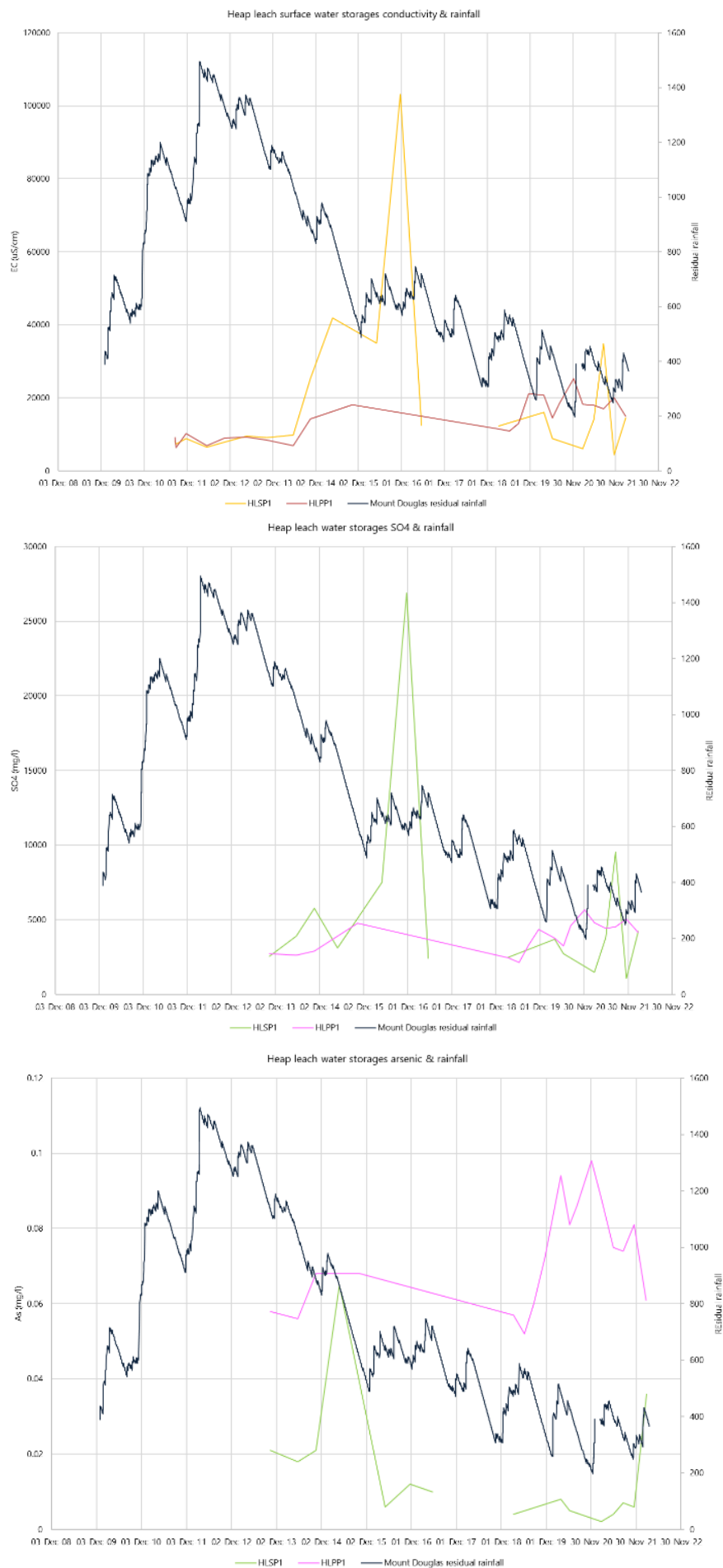


Figure 14 - Surface water quality around heap leach

System model

A working system model of the Yandan heap leach landform in Figure 15.

Key features of the model include:

- Placement of the heap leach across a low level surface divide.
- Likely crystalline volcanic rocks or siltstone underlying the facility which strongly restricts groundwater seepage.
- Limited evidence of groundwater change, with most wells declining in levels & improved water quality. There is some elevated salinity at HL3, but at no other locations (including upgradient), & no other elevated concentrations of other quality parameters & may be natural. Additional wells are recommended for closure.
- Elevated salinity & sulphate in the leach pond & adjacent embankment water, which are scheduled to be removed & rehabilitated as part of closure.

With removal of the leachate pond & associated materials as part of closure, there is low potential for environment harm from surface water release. Based on groundwater monitoring, groundwater water quality is stable & indicates the heap leach has the low potential for environment harm with a water shedding cover design.

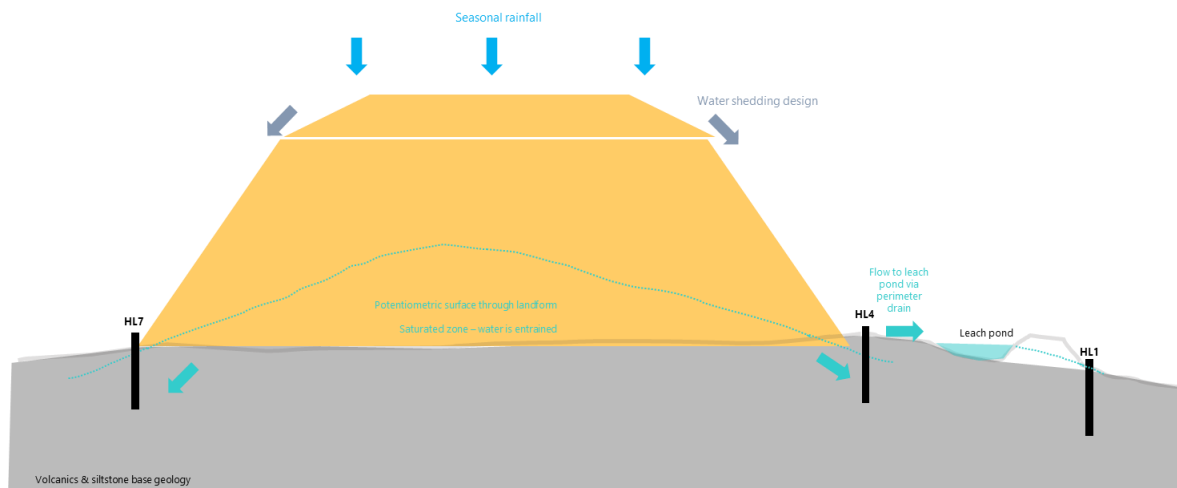


Figure 15 - Schematic of heap leach water system (noting leach pond is planned for removal at closure)

Fit against risk category

Review of the Yandan tailings storage facility materials, compaction, height & water performance places the facility in the low to very low risk category, as:

- Low reactive to benign host materials in ARD/AMD/NMD, with low potential for salinity through addition of salts to the HL (limited compared to size of facility).
- Groundwater largely reflective of benign materials, with quality improving over time & the facility draining.
- Removal of leachate ponds.
- Very low conductivity in underlying geology.

Table 6-1 Risk Category Characteristics

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High Select this category if the waste structure has one or more of the following characteristics:	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm.	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tails materials Requiring composite liners (e.g. HDPE) Embankments > 30 metres high Observed contaminated seepage capable of causing environmental harm.
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end Low strength consolidated tailings land use objectives for the facility Embankments 15 to 30 m high
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Very Low	Benign materials	Benign materials	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments less than 15 m high

8. References

- Department of Environment & Science, Queensland Government 2019, *User Guide for Estimated Rehabilitation Cost Calculator for Mining*, https://environment.des.qld.gov.au/_data/assets/pdf_file/0029/89615/rs-gl-user-guide-erc-calculator-mining.pdf, accessed 30 August 2022.
- Department of Environment and Science Queensland Government 2021, *Guideline Estimated rehabilitation cost under the Environmental Protection Act 1994*, ESR/2018/4425 v4 (August 2021), https://environment.des.qld.gov.au/_data/assets/pdf_file/0028/87517/rs-gl-erc-ep-act.pdf, accessed 30 August 2022.
- Fetter CW 1994, *Applied Hydrogeology*, 3rd edition, Prentice Hall Inc, 691pp.
- RGS 2022, *Discussion of tailings assessment results*, released to GBM Resources.
- SeeBuiltEarth 2022, *Water performance of Yandan Mine landscape at closure March 2022*, released to GBM Resources.

28 APRIL
2023



21°18' S
146°58' E

PRCP & ERC Water Performance of TSF & Heap Leach Landforms

April 2023



Summary

This report is undertaken for GBM Resources, comprising a review of the legacy Yandan Tailings Storage Facility (TSF) and Heap Leach (HL) landforms to inform risk evaluation for Estimated Rehabilitation Calculation (ERC) financial provisioning. Table 1 summarises key components of work and findings below.

Table 1 - Summary of assessment and review findings

Component	Findings
1. Setting and nature of Yandan site as the natural framework.	• Historical mining TSF & HL landforms of Yandan have existed for ~25-30 years. Yandan is a historical mining site in a mineralised province of gold mineralisation. • Landforms are hosted on top of geology from the Anakie Inlier, consisting of siltstones, clays, and mudstones, which are low conductivity geology. Faulting may occur, however is likely discontinuous given the history of deformation and folding present, which reduces permeability of units. • Groundwater associated with both landforms occurs infrequently and is generally highly constrained at Yandan: evidenced by a lack of groundwater intersections in bore drilling, isolated water occurrences and very poor yields observed in bore sampling. Occurrence of groundwater is more likely in mineralised areas associated with faulting and hydrothermal units than near the TSF or Heap Leach. • Climate of Yandan is predominantly dry across most of the year reducing rainfall percolation exposure risk. • System responses are observed in drier periods with an extended low rainfall period from 2012-2020, and in wetter periods with La Nina high rainfall season in 2020-2022.
2. Site-wide water quality characterisation via sulphate and chloride ratios.	• Key populations of impacted water (elevated sulphate) associated with historical Heap Leach ponds and East Hill. • Wide range of chloride (up to 14,000mg/l) and sulphate (up to 2,500mg/l) in background and regional bores, suggesting a range of natural backgrounds for the region. Notably sulphate and chloride can be enriched in clay-rich geology with disconnected (isolated) groundwater. • Remainder of surface water and groundwater results are low in sulphate and chloride, indicating strong connection to recent rainfall and fresh water.
3. Groundwater monitoring review.	• Hydrogeology models of relative elevations and sections of both the TSF and HL landforms with topography and wells in combination with review of bore results (SBE 2022a) identified several wells in the current bore network that are not representative given either: ▪ A loss of well integrity, or ▪ Location is not representative of groundwater outside of the landform embankment and are likely monitoring the potentiometric zone from water entrained in the landform or dam. These wells lay





Component	Findings
	against or in embankments of the tailings, dams or ponds, and were likely constructed as engineering piezometers to monitor for toe drainage associated with the landform, and by nature are not groundwater monitoring wells. • Several replacement wells and additional wells are recommended, stepped back from each landform to ensure monitoring of representative groundwater and include all potential flowpaths. ▪ Note stepping wells back from the landform does not impede assessment of groundwater impact given the intent is to detect mobility of potentially impacted waters.
4. Tailings landform assessment classified the TSF as low risk.	• Low reactive materials, with low AMD, ARD, NMD, or saline drainage. • Limited to no signs of PAF drainage. • Moderate to low salinity is evident in surface water and groundwater. • Cell A and Cell B tailings are low permeability, reducing potential for infiltration. • Very low conductivity in underlying geology. • Limited seepage to groundwater. • Tailings have at least moderate strength and consolidation. • Embankment is <15m.
5. Heap leach landform assessment classified the HL as very low to low risk.	• Low reactive to benign host materials in ARD/AMD/NMD, with low potential for salinity through the addition of salts to the HL (limited compared to the size of the facility). • Limited to no signs of PAF drainage. • Groundwater largely reflects benign materials, with quality improving over time and the facility draining. • Underlying geology is low conductivity. • Limited seepage to groundwater.





Responses to agreed mediation actions map

Action item	Comment & section
Action 1. – Provide the Department of Environment and Science (Respondent) with the locations of several proposed new monitoring bores and the hydrogeological modelling on which the choice of locations is based.	Refer Chapter 6 – Groundwater monitoring fit for purpose review. See geological sections showing monitoring infrastructure with existing well network and proposed wells.
Action 2. – Review and revise the SBE Report in the light of comments provided by the Department of Environment and Science (Respondent) concerning incomplete sentences and difficulties it had in understanding the supporting arguments and conclusions drawn in the report.	The incomplete sentence is updated as a simple error with document styles. Refer Chapter 7 – Tailings Storage landform assessment. Additional and clarifying information is provided, including relevant dates of spikes (end of dry season), and context of reducing contaminant loading, suggesting improved water quality over time. This differs from SBE 2022a assessment given additional time and interpretation of data as a system. This is selection of one of the two hypothesis/explanation options proposed, not a new proposal, and is identified as part of ongoing learnings and observations of Yandan site.
Action 6 <i>Matter 3: Clarification on water quality statements in surface water</i>	See Action 2 above





Document history and status

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1 Introduction

1.1 Purpose

GBM Resources has requested a summary review of the legacy Yandan tailings storage and heap leach landforms to inform risk assessment of PRCP design requirements and ERC financial provisioning. This review provides the following:

1. Context and framing of GBM requirements, and nature of Yandan as a site.
2. Background principles of constructed landform systems and interactions with natural systems:
 - How potential environment harm can occur with materials interactions.
 - Role of landform setting in the potential for environment harm.
 - Landform cover objectives.
3. Overview of the DES ERC Guidelines (DES 2019, 2021, 2022) Risk Characterisation Framework.
4. Description of the landscape system at Yandan site:
 - Climate, terrain, geology, hydrogeology.
5. Diagnostic site wide water quality profile of Yandan.
6. Fit for purpose review of the current Yandan monitoring network and program capacity:
 - Provide representative data and systems information to inform ERC/PRCP conditions and completion criteria.
 - Recommendations to address gaps, ensure fit for purpose and monitor long-term performance.
7. Risk ranking of the Tailings Storage Facility (TSF) and Heap Leach (HL) landform in the potential for environment harm based on:
 - Technical assessment of materials characterisation, observed system response, water system model and classification to DES ERC risk category.

This report provides an update to the previous SBE memo dated 3 February 2023 with increased depth of TSF information, including:

- Further geology and hydrogeology information.
- Clarification of hydrogeological model as a basis for system understanding and monitoring requirements.
- Details regarding updated investigation of tailings return surface water quality variation.

Overall, both memos are supplementary to the full Yandan PRCP water performance report (SBEa 2022), which classified both TSF and Heap Leach Landforms as low risk according to DES classifications.

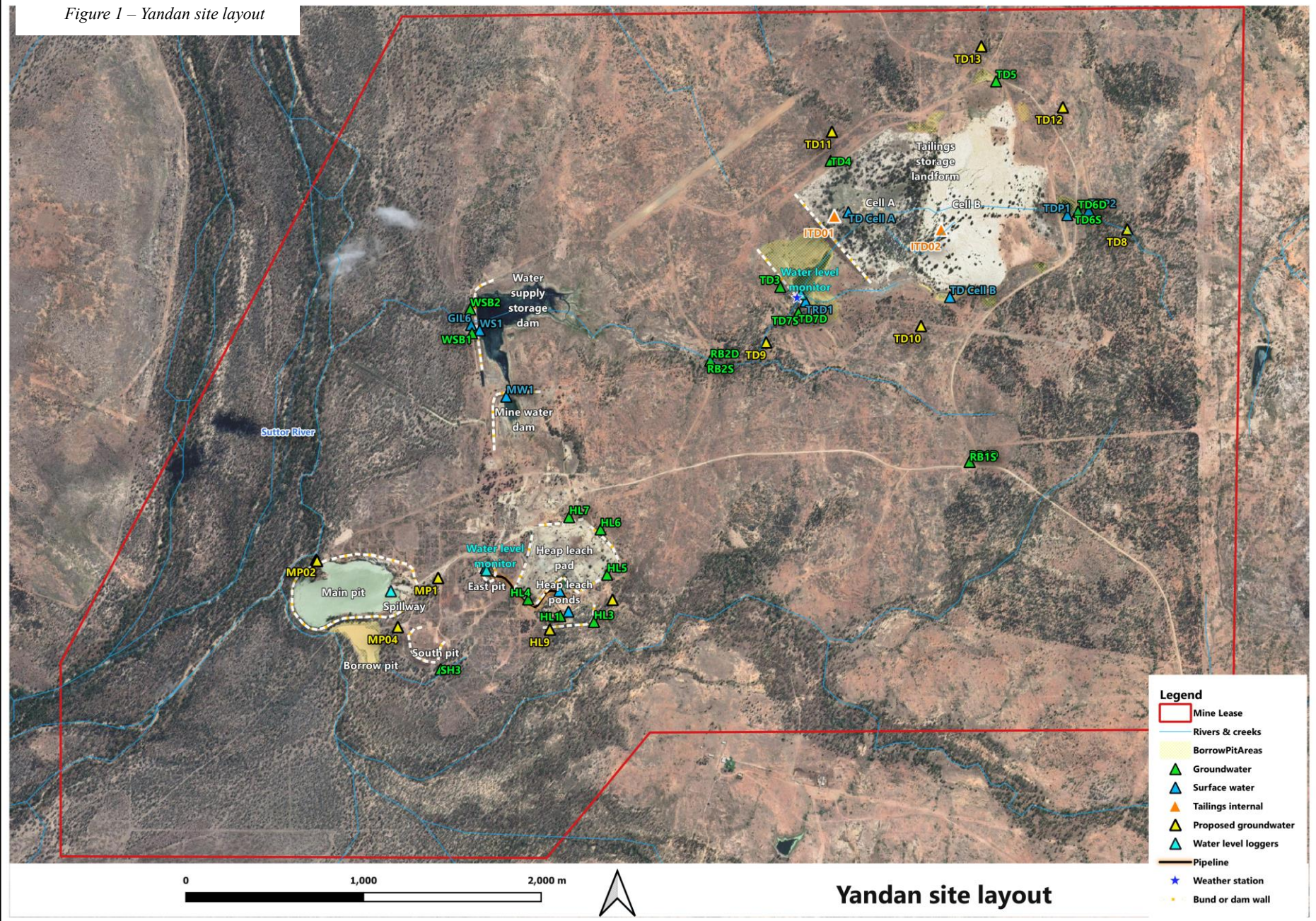
1.2 Context of Yandan as a historical mine site

Yandan gold mine operated between 1993 to 1999, when the tailings storage, pits and leach pad were constructed and formed. The tailings storage western cell (Cell A) was rehabilitated as mining operations went into care and maintenance in the 1990's. A map of Yandan site layout, landforms, monitoring, and features is shown in Figure 1.

In the present tense, the landforms have now existed in the Yandan landscape for 24 years as a legacy of mining past: there has been minimal change or disturbance since, and the landforms are now part of the landscape. The landform systems are generally stable, and whilst closure reshaping and covers are required as part of planned site release in perpetuity, it is reasonable to expect that if environment harm is likely to occur at Yandan from historical landforms, it would already be evident.



Figure 1 – Yandan site layout





2 Principles of approach

2.1 Mechanisms of environment harm in constructed landforms

A general schematic of an earthen-constructed landform is shown in Figure 2. A cumulative process shapes the potential for environment harm via legacy mining landforms:

1. Nature of materials stored within the landform – redox potential, acidity or alkalinity, metals.
2. Exposure of materials to air or oxygen to commence the ARD/AMD/NMD process.
3. Contact of water through the oxygenated materials – through percolation or entrainment. Most landforms will host water entrained into pore spaces as part of sitting in the landscape as some water will be unable to flow. This entrained water forms a minor potentiometric surface through the landform as part of standard practice.
4. Water can continue to flow to reach outside of the landform area and travel away.

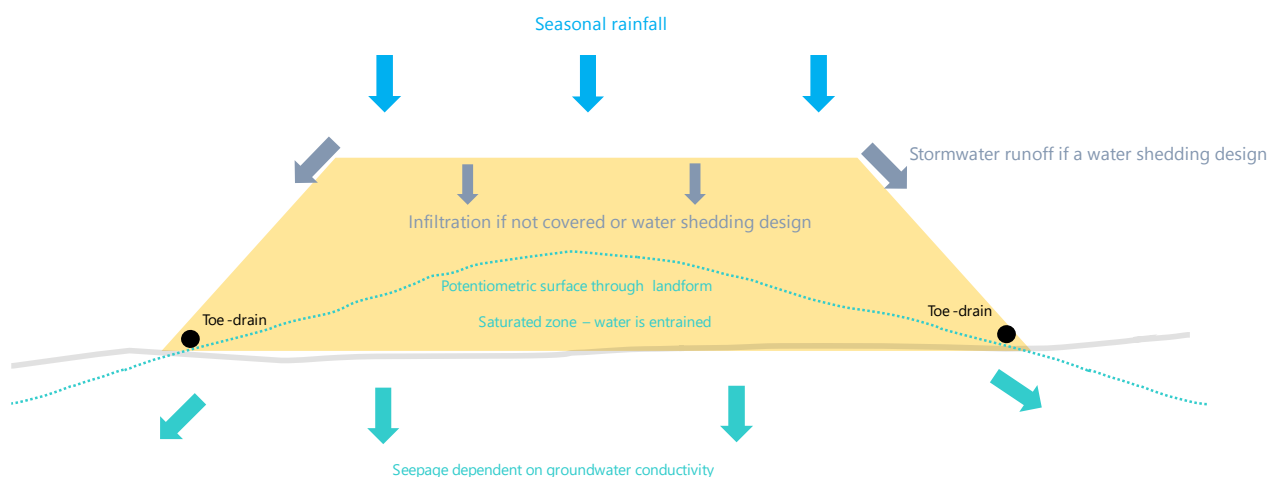


Figure 2 - General schematic of an earthen-constructed landform and factors of water interaction

2.2 Objectives of landform cover designs

The core intent of a cover design is to:

1. Achieve containment or limiting one or more of the harm process steps: nature of materials, exposure of air, percolation of water through the landform, or outside of the landform – having low conductivity groundwater or surface water interception.
2. Create a sustainable, stable, use-based landform to restore the landscape and environment values.

Cover designs need to be fit for the landform system to suit the landscape, climate setting, geology, nature of materials, water interactions and revegetation for land use. Rather than a blanket approach, learning what works in what landscape to design is fundamental to sustainable outcomes.

2.3 Role of landform setting in risk of environment harm

The setting of a landform plays a significant role in the relative risk of any mining landform:

- Nature and position in a landscape shape contact of the landform with water: proximity to flow through or saturation areas, topography and contour gradients of the landform.
- Rainfall and climate as a major driver of potential infiltration and percolation.
- Geology as the host of groundwater: shaping formation and quality of aquifers and hydraulic conductivity.





3 Risk characterisation framework

Risk characterisation guidance is provided in the DES Estimated Rehabilitation Calculation (ERC) guidelines, which are:

- User Guide for Estimated Rehabilitation Cost Calculator for Mining (2019).
- Estimated rehabilitation cost under the Environmental Protection Act Guideline (2021).
- User Guide for Estimated Rehabilitation Cost Calculator for Mining (2022).

The 2019 ERC User Guide (DES 2019) – current at the time of Yandan application - further clarifies risk categories from very low to high-risk in Figure 3. The DES ERC User Guide was updated in late 2022, and applies an updated criteria as shown in Table 2.

In addition, the 2021 guideline provides the following high-level definition of high-risk landforms:

- Contain Potentially Acid Forming (PAF) material.
- Have observed contaminated seepage that can cause environment harm.

The combination of guides and guidelines clearly delineates each landform classification by risk category, and are the frameworks applied in this review for Yandan tailings and heap leach closure risk.

Table 6-1 Risk Category Characteristics

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High Select this category if the waste structure has one or more of the following characteristics:	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm.	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tails materials Requiring composite liners (e.g. HDPE) Embankments > 30 metres high Observed contaminated seepage capable of causing environmental harm.
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end Low strength consolidated tailings land use objectives for the facility Embankments 15 to 30 m high
Low	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD) Moderate to low salinity Moderate strength consolidated tailings Embankments less than 15 m high
Very Low	Benign materials	Benign materials	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments less than 15 m high

Figure 3 - Guidance of risk category characteristics (DES 2019)





Table 2 – Guidance of risk category characteristics (DES 2022)

Risk category	Waste rock dumps	Heap leach pads	Tailings storage facilities
High	- Potentially acid forming waste rock materials (PAF). - Other highly reactive materials including (acid rock drainage (ARD) / acid mine drainage (AMD) / neutral mine drainage (NMD)). - Observed contaminated seepage (PAF) capable of causing environmental harm.	- Potentially acid forming heap leach materials (PAF). - Other highly reactive materials including (ARD/AMD/NMD). - Observed contaminated seepage (PAF) capable of causing environmental harm.	- Potentially acid forming tailings materials (PAF). - Other highly reactive materials including (ARD/AMD/NMD). - Poor consolidation and low shear strength tails materials. - Requiring composite liners (e.g. HDPE) - Embankments > 30 metres high. - Observed contaminated seepage (PAF) capable of causing environmental harm.
Medium with low permeability layer	- Waste rock material that could adversely impact on the proposed end land use and/or vegetation function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Significant (non-PAF) seepage capable of causing environmental harm.	- Heap leach materials that could adversely impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Significant (non-PAF) seepage capable of causing environmental harm.	- Tailings materials that could impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Low strength consolidated tailings embankments 15 to 30 m high.
Medium	- Waste rock material that could adversely impact on the proposed end land use and/or vegetation function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Seepage (non-PAF) capable of causing environmental harm.	- Heap leach materials that could adversely impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Seepage (non-PAF) capable of causing environmental harm.	- Tailing's materials that could impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Low strength consolidated tailings embankments 15 to 30 m high. - Seepage (non-PAF) capable of causing environmental harm.
Low	- Waste rock material that may have some impact on the proposed end land use and/or vegetation cover - Minor (non-PAF) seepage.	- Heap leach material that may have some impact on the proposed end land use and/or vegetation cover - Minor (non-PAF) seepage.	- Moderate strength consolidated tailings. - Tailing's material that may have some impact on the proposed end land use and/or vegetation cover. - Embankments less than 15 m high. - Minor (non-PAF) seepage.
Very low	Benign waste rock materials Minor (non-PAF) seepage.	Benign heap leach materials Minor (non-PAF) seepage.	- No likely impacts on the proposed end land use and/or vegetation covers. - Moderate strength consolidated tailings - Embankments less than 15 m high. - Minor (non-PAF) seepage.



4 Landscape and water system at Yandan

4.1 Landscape

The Yandan project area in the modern day comprises a gently undulating landscape (Figure 4), with both the tailings storage and the heap leach landform constructed above ground at or near the top of the catchment (Figure 1). Tops of catchments are characterised by greater erosion resistance than downstream areas and shallow soil development.

The original landscape of the site (Figure 5) indicates the TSF area elevation lies at 180mAHD to 192mAHD, which is now lifted from 190mAHD to 193mAHD (Figure 6) with the landform. Likewise, the Heap Leach landscape has risen from ~190mAHD initially to 212mAHD. The position of the TSF and Heap Leach landforms above ground level restricts water interaction with the landforms to direct rainfall only, where interactions with stored materials as a driver of potential environment harm will be controlled and limited by how the cover sheds rain and handles flow.



Figure 4 - View north over Yandan project site from top of heap leach pad

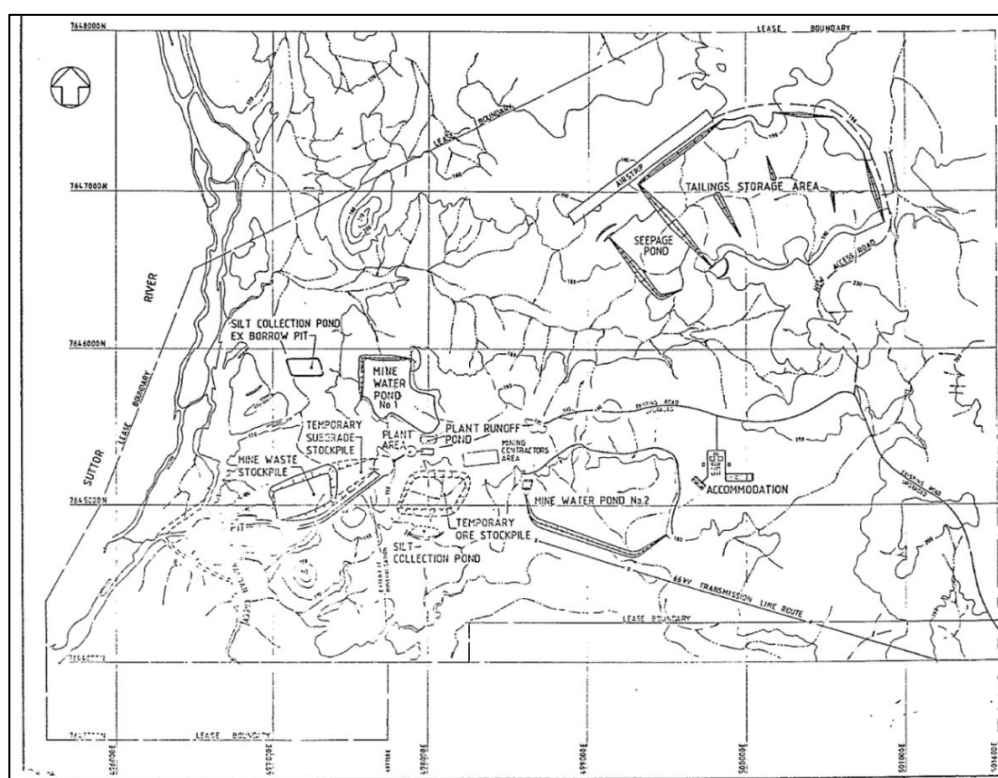


Figure 5 - Original landscape across Yandan project with planned site layout (Kinhill 1988)

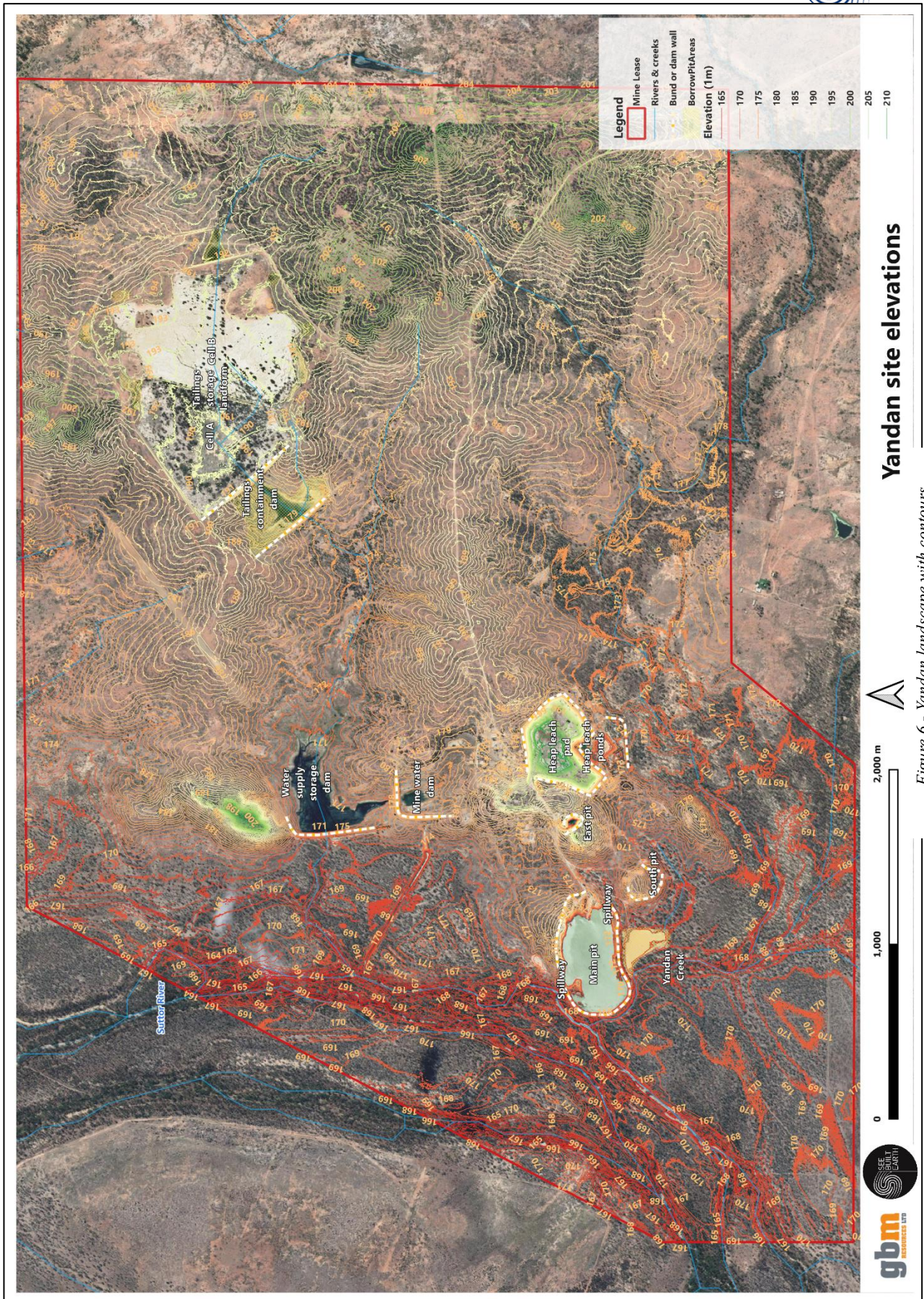


Figure 6 - Yandan landscape with contours





4.2 Geology

4.2.1 Regional geology

Yandan mine site lays near an internal boundary of the regional Drummond Basin and the Anakie Inlier (Figure 7). The Anakie Inlier (also known as Anakie High) consists of metamorphosed sediments as basement, whilst the Drummond Basin includes a series of sediments, volcanics, sinter and alteration systems (Carver and Chenoweth 2003, Purdy DJ, Withnall IW & Bultitude 2016, de Caritat & Braun 1992). The Drummond Basin and Anakie Inlier have undergone significant tectonic activity, resulting in the formation of several geological features such as faults, folds, and intrusions. The Drummond Basin is known for significant mineral deposits, including epithermal gold, copper, and silver.

At Yandan, the Anakie Inlier is represented by meta-siltstones with intermittent meta-sandstone and limestone of the Ukalunda Formation, which outcrop across the eastern parts of the mining lease (Figure 8) (Purdy DJ, Withnall IW & Bultitude 2016). The Drummond Basin extends west into the valley towards the Suttor River, with sediments of St Anns Formation and volcanics of Yandan andesite and sinter associated with mineralisation and historical mining areas. Weathering can be more extensive and to greater depths around faults, or where volcanics are altered through hydrothermal activity. Suttor River alluvium develops near to the Suttor River in the west of the lease at surface.

A review of landform locations to underlying geology show the TSF and the Heap Leach lay on Ukalunda Formation, or metasediment (siltstones and mudstones) of the Anakie Inlier. As checks and confirmation, a review of recent and historical drilling logs (GBM Resources) found:

- Heap Leach is underlain by siltstone geology, identified through several records of early geotechnical drillholes. There are no bore drilling or geology available for current wells at HL.
- TSF is also underlain by siltstone geology, identified through several recent bore logs (Appendix A). Whilst there are records of several geotechnical drillholes being drilled near the TSF, there are no lithology logs recorded.

4.2.2 Mineralisation in the province

Mineralisation of Yandan occurs as structurally controlled, low sulphidation epithermal system (Figure 9). Typical mineralogy includes gold, silver, copper, zinc, molybdenum and iron-copper-arsenic sulphides. Mineralisation is possible within a large area of interest across the lease, and is subject to active exploration.

The Yandan mineralisation materials include:

- Oxide zone: characterised by highly weathered, clay rich materials.
- Sulphide zone: characterised by fresh rock and sulphide-rich veins.

4.2.3 Structures and faults

Structures and faults generally align to a northeast-southwest orientation, with offset structures striking northwest-southeast (Figure 7 and Figure 8) as interpreted from geophysics across the mine lease (GBM Resources).

Drainage lines appear to partially align to structural directions and may indicate more subtle structures running parallel to more detectable larger faults. Faulting is heavily developed to the west near the known mineralised zones, the most significant being the Yandan East Fault.

Current and proposed additional groundwater wells are shown with mapped or known faults in Figure 9 and Figure 10.



4.2.4 Hydrogeology

Groundwater occurs infrequently across Yandan site, strongly controlled by geology, permeability, and structures. Groundwater flow direction as a potentiometric surface is shown in Figure 11, showing groundwater as a subdued profile of topography from east to west. The classification of groundwater and rock types as aquifers across the site includes:

1. Volcanics (west of the lease):
 - Oxide: Clay rich materials with very poor permeability and porosity with no records of groundwater recorded.
 - Boiling zone: a relatively narrow zone formed through boiling of the hot fluids circulating within an epithermal system, through heat and mineral replacement, a boiling zone can consist of voids and fractures which are more permeable to groundwater flow. Currently, this zone may have a role in groundwater flow into Main Pit (outside of this study).
 - Fresh: Crystalline rocks provide very poor permeability without secondary porosity or void spaces such as faults or vugs where groundwater could occur.
2. Meta-sediments of the Ukalunda Formation (east of the lease, TSF & HL):
 - Siltstones and mudstones consisting of fine-grained, silt-sized particles which are compacted and folded in the lease area (Purdy DJ, Withnall IW & Bultitude 2016) are create very poorly drained and low conductivity aquifers. What water is absorbed into a meta-sediment aquifer is unlikely to
3. Faults (across the lease):
 - Faults are capable of both hindering or facilitating groundwater as a factor of void space and connectivity. Faults may host water is storage is available as a highly localised system, but can only flow if connected, and are limited by the nature of connection. Away from mining areas, no other significant faults are currently defined or known. In the meta-sediment region, whilst there are fault lineations indicated from remote sensing, given the series of deformations and fine grained nature of materials of the Anakie Inlier and Drummond Basin, it is unlikely conductive faults are present, and where faults are more likely to act as hydraulic barriers than conduits.
4. Suttor River alluvium aquifer (Suttor River):
 - Occurs only in the western extent of the lease, with limited information except conceptual alluvial storage associated with surface water flow. Early studies (Forbes 1988) identified no connection between Yandan mine and alluvial aquifers.

Indicative conductivities by rock type are shown in Figure 12, and shows the range of conductivity of consolidated siltstones (similar to mudstones) in the ranges of 1.4×10^{-8} to 1×10^{-11} m/s (Fetter (1994), Freeze and Cherry (1979)) to represent conductivity of geology underlying the TSF and HL. This can be considered an upper bound, as siltstones and mudstones of the Anakie Inlier are metamorphosed, folded, and faulted which would only serve to reduce conductivity as porosity and permeability is reduced with deformation, pressure and heat. As a comparison, modern geotechnical clay liners or synthetic liners intended to limit seepage are designed to achieve conductivities of 10^{-8} m/s.

Site experience of groundwater occurrence and nature aligns with these expectations, such as:

- During drilling and mining, groundwater is infrequently occurring, highly localised and generally low conductivity groundwater.
- Of the eight wells recently constructed as regional or tailings wells, five were dry when drilled, with the remaining three intersections described only as 'damp' (Appendix A, Table 3).
- Independent groundwater sampling methods rely on two days of recharge after purging to allow enough water to return into the bore column to be representative, indicating very slow yields (Appendix B, Table 1).

The highly localised and low groundwater conductivity in the siltstone and clays means water that percolates through the Heap Leach or TSF to underlying groundwater will be constrained.



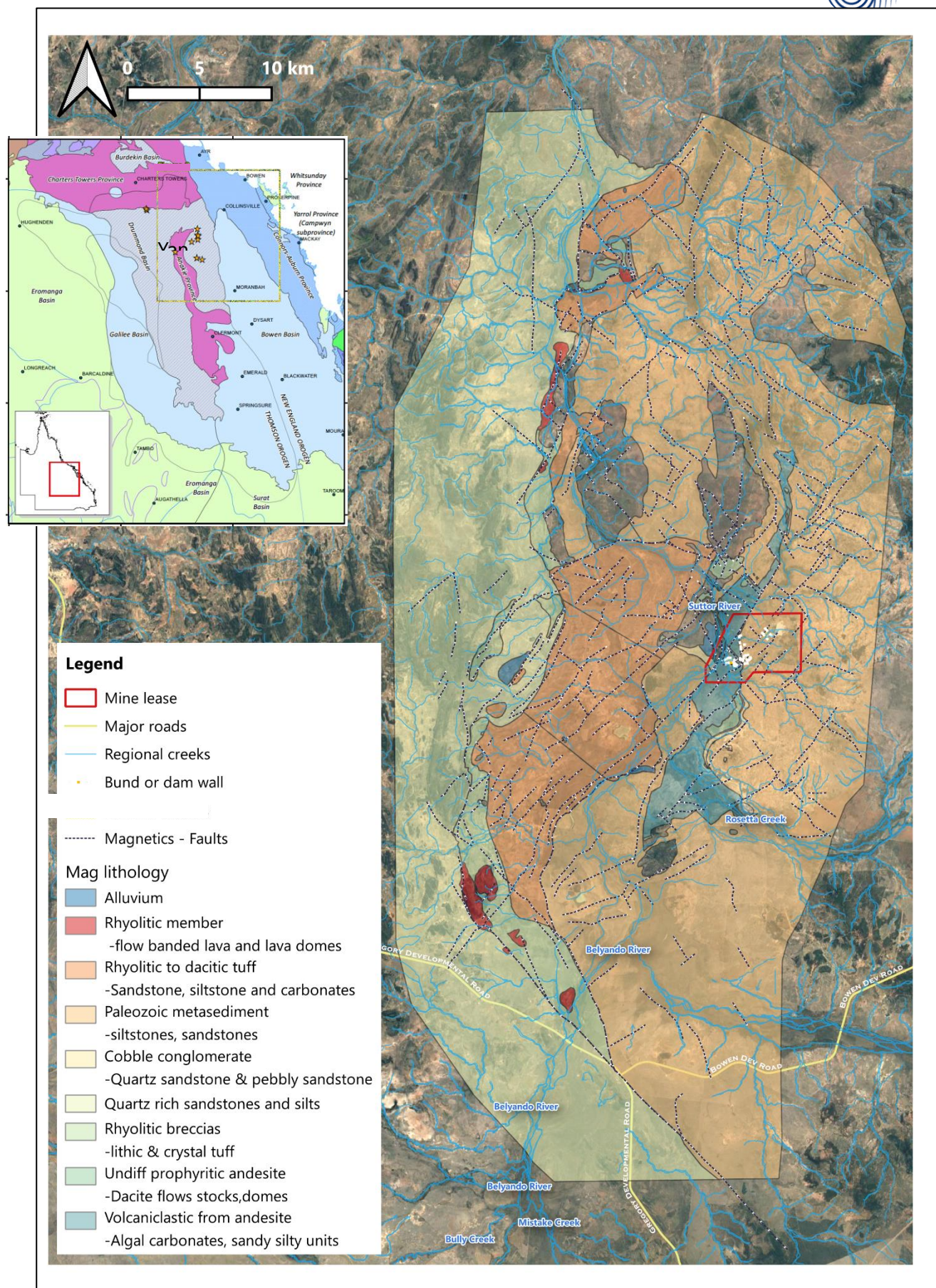


Figure 7- Regional geology in structures and lithology types (Purdy DJ, Withnall IW & Bultitude 2016, GBM Resources)



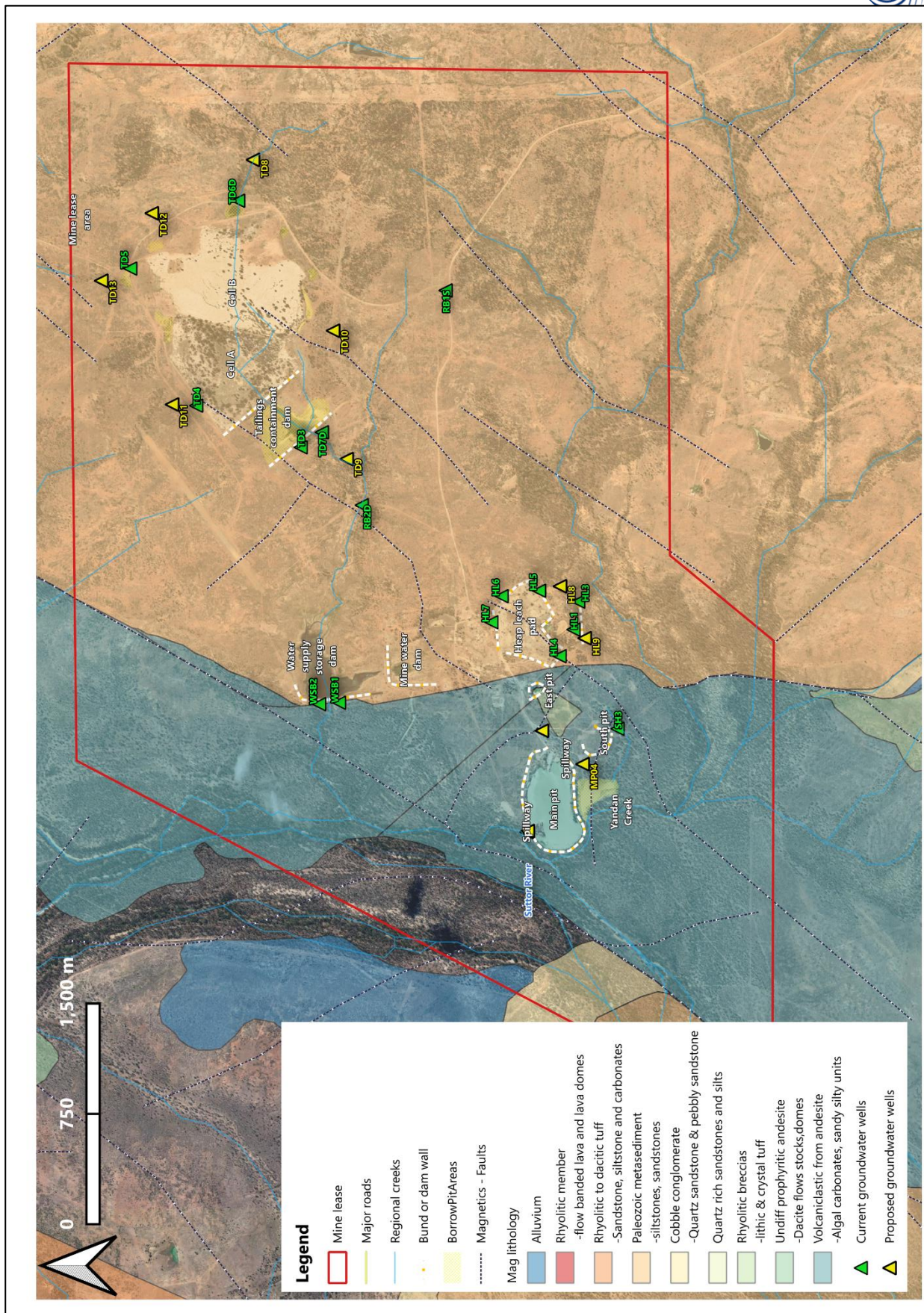


Figure 8 - Lease scale geology showing Yandan site locations



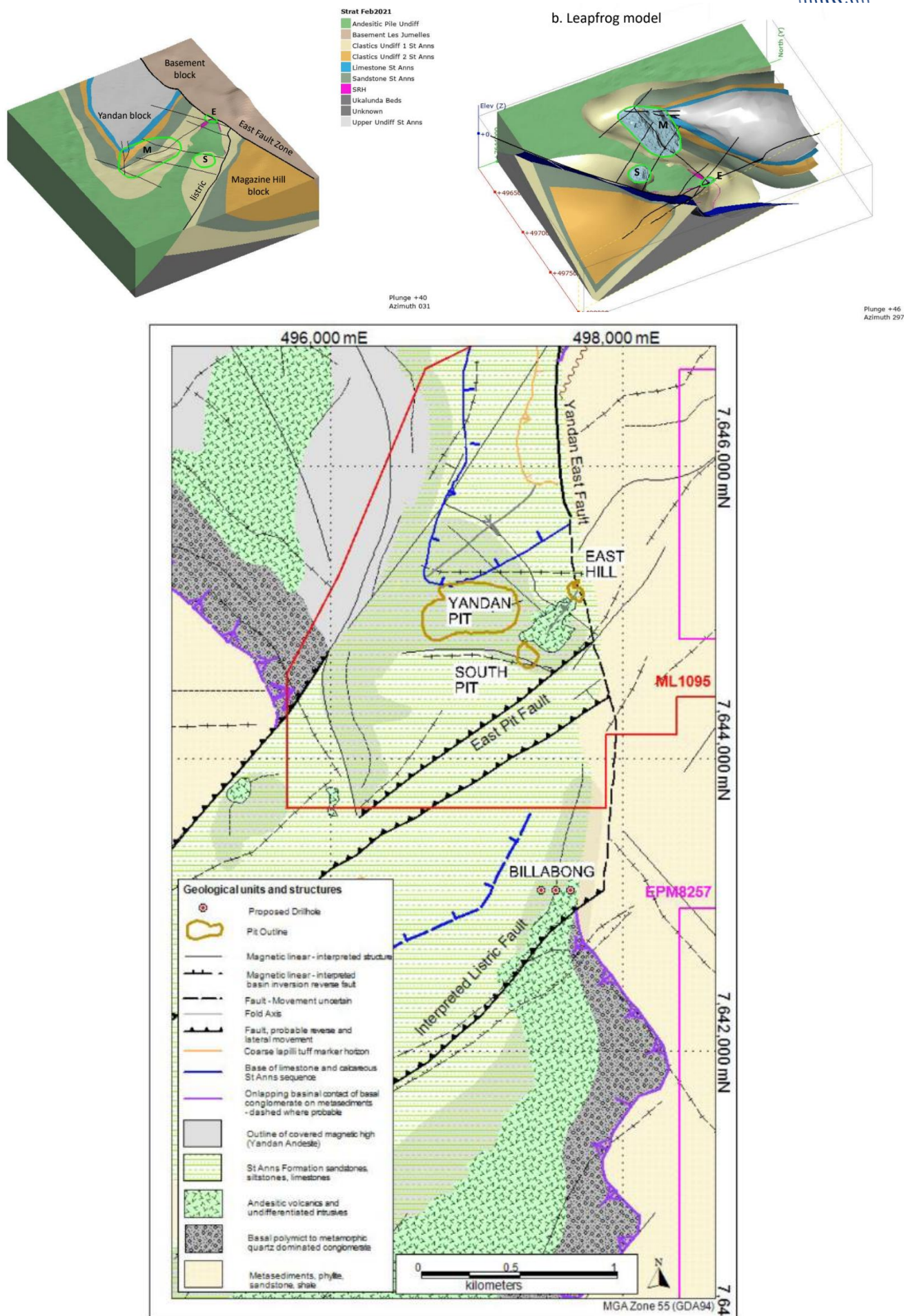


Figure 9 - Geology of pits and Heap leach areas of Yandan site



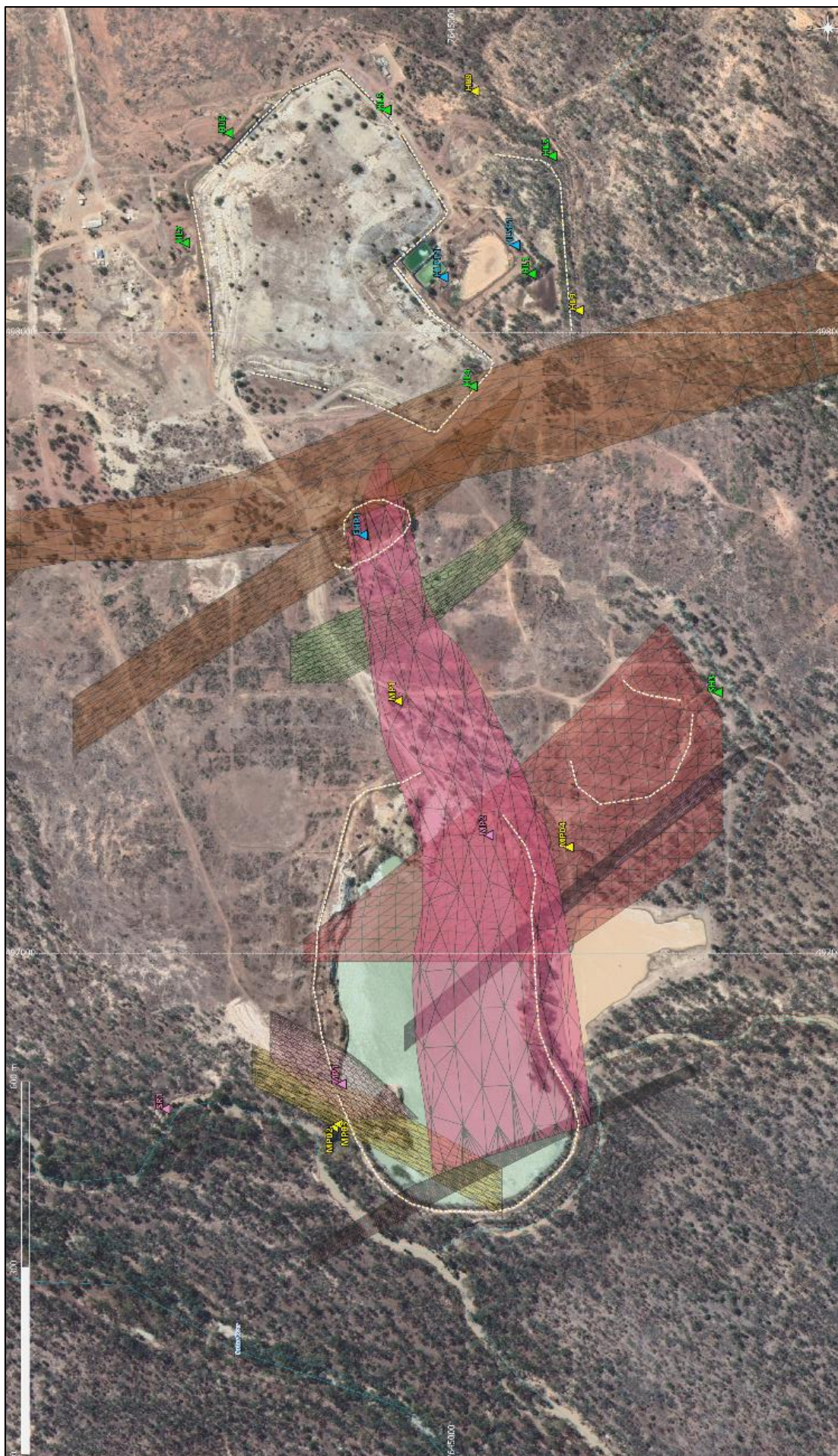


Figure 10 - View of pit area, faults plotted with proposed new wells

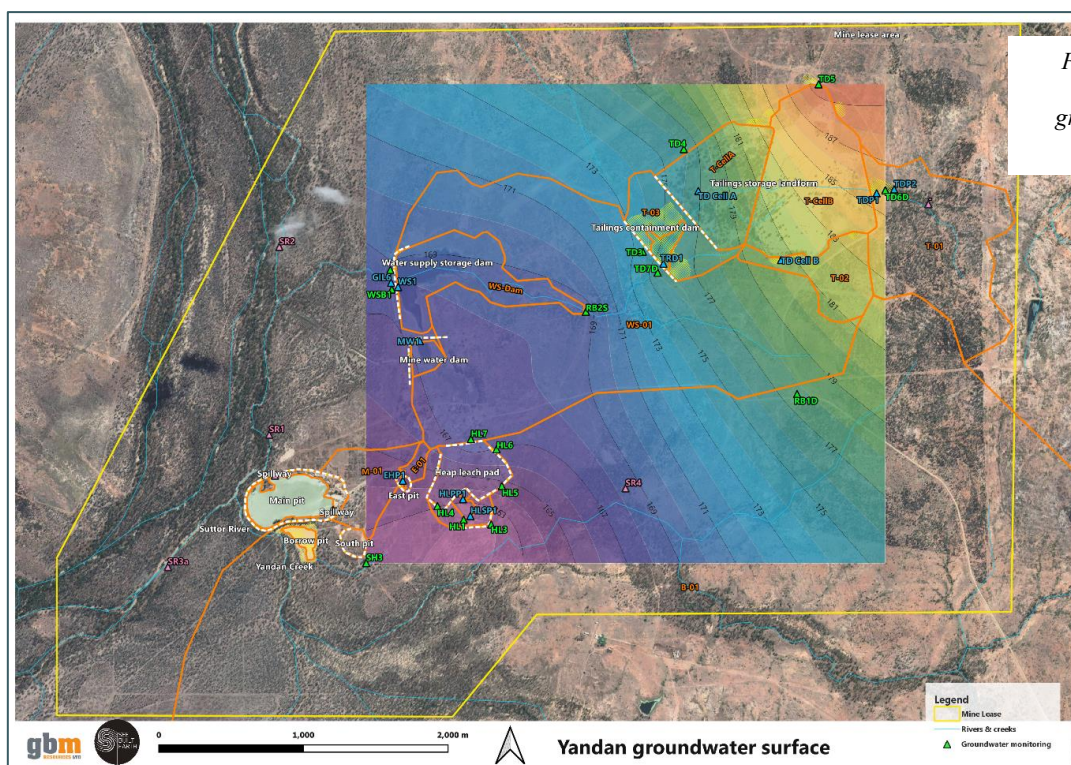


Figure 11 –
Yandan
groundwater
surface

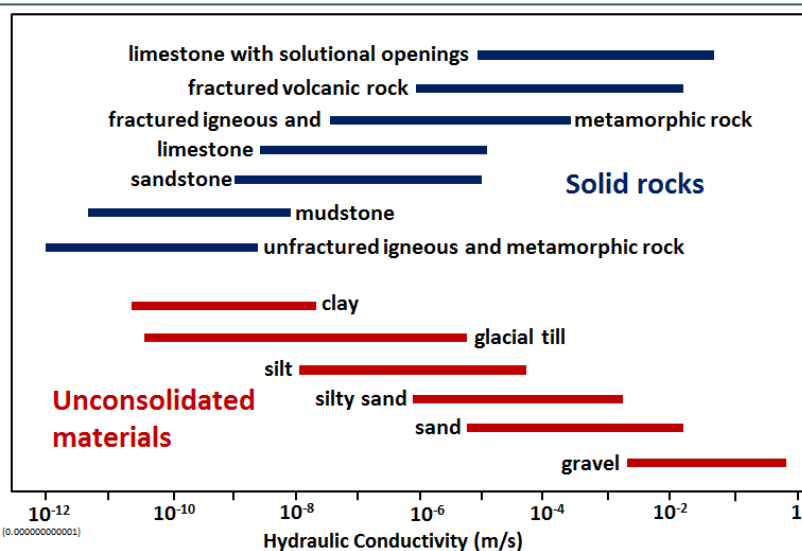


Figure 12 - Range of typical hydraulic conductivity by rock type (adapted from Freeze and Cherry 1979)

Table 3 - Summary of 2021 Yandan bore drilling results (note earlier well logs unknown)

BHID	Lithology recorded	Groundwater intersection	Purge to sample time
RB1S	Tuffaceous siltstone	Dry	Two days
RB1D	Tuffaceous siltstone	Dry	Two days
RB2S	Tuffaceous siltstone	Dry	Two days
RB2D	Tuffaceous siltstone	Damp at 17m	Two days
RB6S	Tuffaceous siltstone	Dry	Two days
RB6D	Tuffaceous siltstone	Damp at 22m	Two days
RB7S	Tuffaceous siltstone	Dry	Two days
RB7D	Tuffaceous siltstone	Damp at 18m	Two days





4.3 Climate

The Yandan climate is predominantly dry, with an average annual rainfall of 583mm, varying from 213-1200mm against an evaporation potential of 2,100 to 2,300mm/year (BOM, 2023). The deficit between rainfall and evaporation potential in any year gives the site a strongly negative water balance. Figure 13 shows seasonal rainfall since 1987, indicating higher than average wet seasons for 2021/22 and 2022/23 of 600-800mm.

As a water balance negative site, rainfall greater than 10mm only falls at Yandan on average 20 days (or 5.6% of days) per year (10mm as assumed rainfall where soil moisture may be exceeded for excess water). The limitation on rain days constricts exposure periods with the potential to lead to environment harm (Figure 14) through infiltration or percolation through landforms and contributes to a low-risk environment at Yandan.

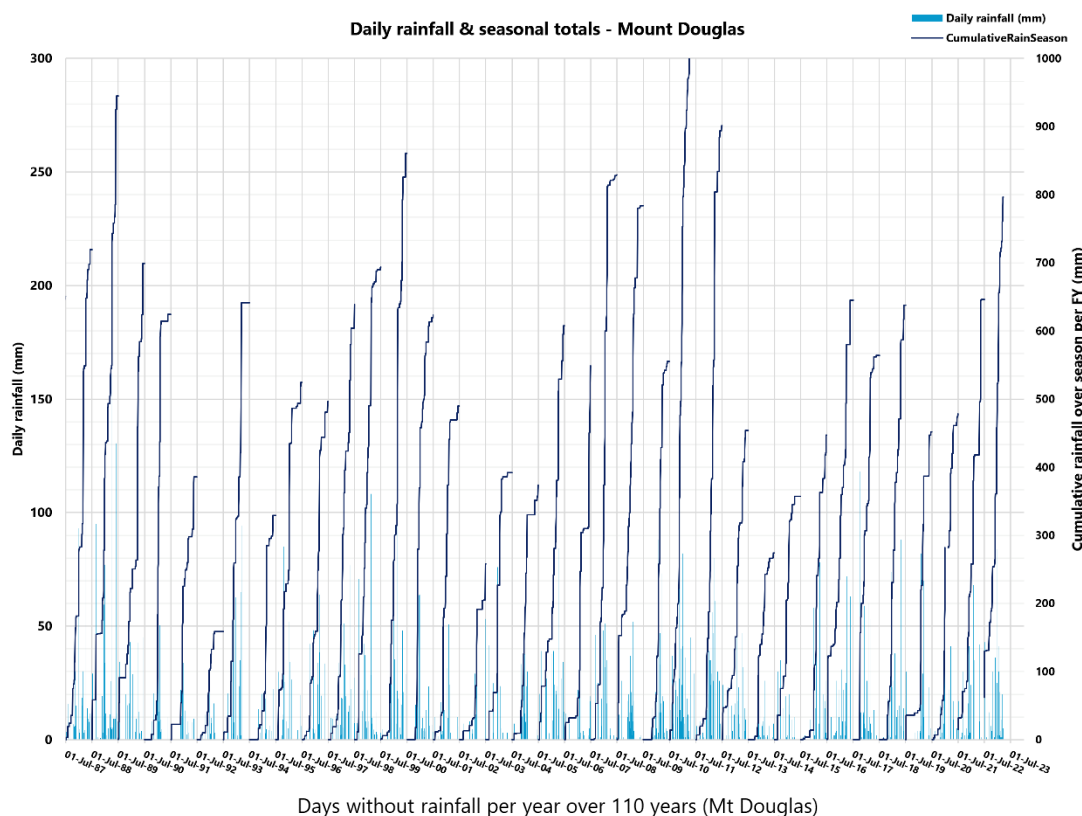


Figure 13 -
Seasonal
rainfall of
Mount Douglas
near Yandan

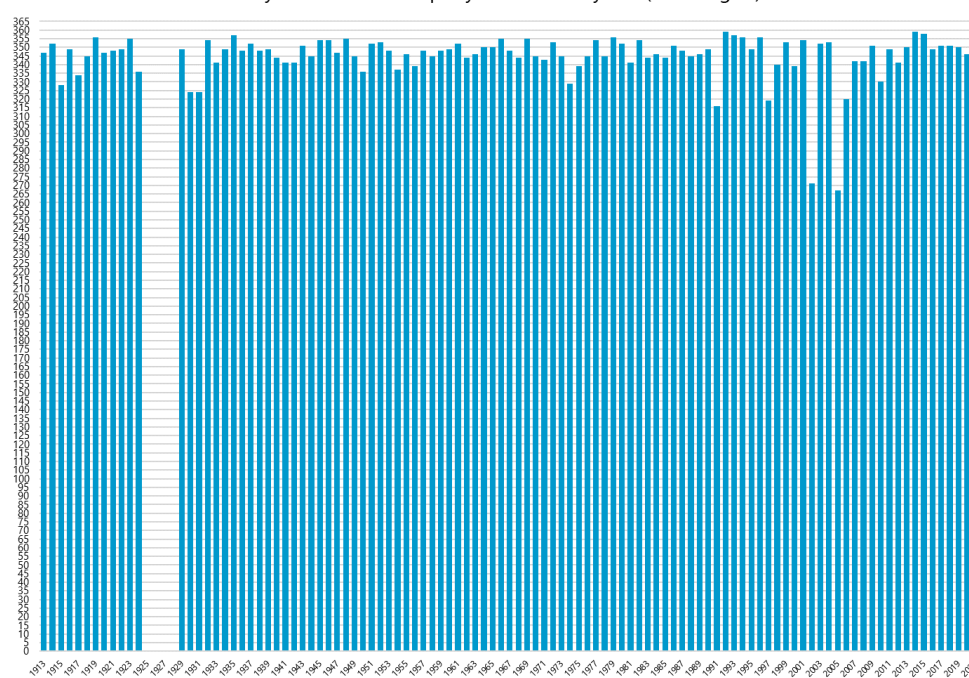


Figure 14 -
Days without
rainfall per
year at Yandan
site



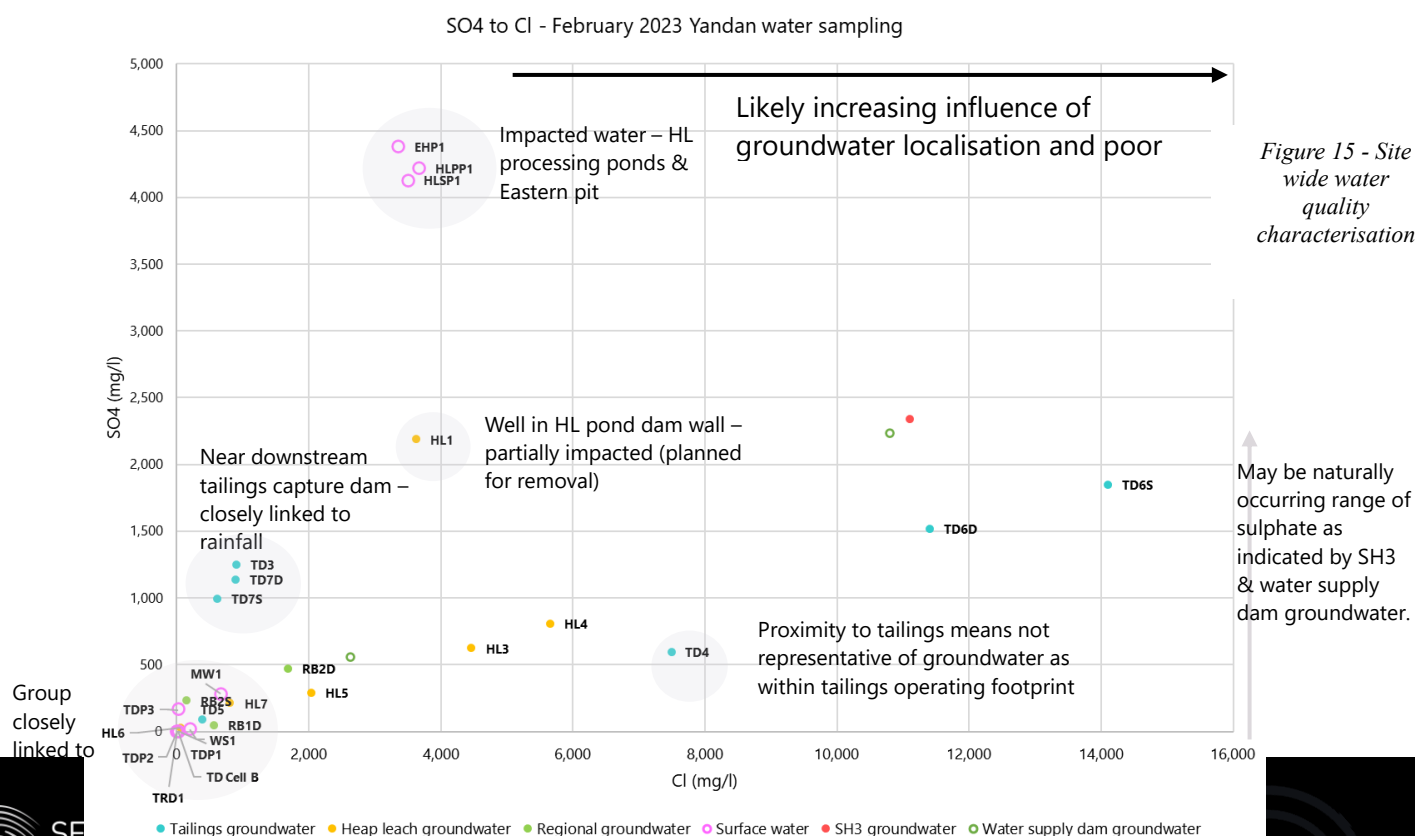


5 Diagnostic site-wide water quality characterisation

Three key drivers of water quality at Yandan site include:

- Influence and connection to rainfall: low chloride concentrations often indicate a source closely connected or directly related to rainfall sources.
- Naturally occurring geology influences, including:
 - Contact with mineralised systems, often leading to ambient metals, sulphate and chloride in groundwater as a natural background.
 - Localisation of groundwater in low permeability siltstone and clays, leading to elevated chloride levels (Koretsky 2016, Merritts and Walter 2008)). Chloride is enriched through contact with siltstone and clay as groundwater is in prolonged contact. As areas saturate and remain localised, an exchange of chloride from the host rock to water occurs.
 - Presence of naturally occurring gypsum in siltstones through naturally elevated sulphate in groundwater from reducing environments (Schreiber ME, & Elrick 2006).
- Potential interactions with exposed mineralised material, either as:
 - Contact with legacy pit shells, heap leach or tailings landforms, generally with neutral pH and low risk saline drainage (except for East Hill Pit), with or without metal mobilisation.
 - Influence of the formation of sulphate minerals such as jarosite, which is indicated to be occurring around the Yandan TSF by RGS (2022). Jarosite formation conditions and processes are described as oxidised mineralised areas where sulphate & iron are present (Nordstrom & Alpers 1999).

Figure 15 presents sulphate to chloride across site and all water sources from February 2023 with annotations as explanation. The site experienced significant rainfall over 2021/22, and the ratios are useful to identify key influences and populations of groundwater and surface water. Some sources are linked to rainfall, some that show impact, with a range of chloride and sulphate in siltstones and mineralised areas. These set a relevant precedent in the natural groundwater background for Yandan, particularly from unimpacted areas such as the water supply dams. Outside of impacted areas of East Pit and the Heap Leach ponds, sulphate remains below 2,500 mg/l.





6 Groundwater monitoring fit for purpose review

6.1 Frame of review

As part of PRCP studies, a review of the groundwater monitoring network and program for Yandan Progressive Rehabilitation and Closure Planning in July 2022 (SBE 2022b) recommended changes to the groundwater monitoring network. The review was undertaken in two stages:

- As a first pass, the status of current wells and monitoring program to bore functionality and horizon being monitored and required monitoring frequency to observed variation.
- As a second pass, to design a network for each landform to ensure representative monitoring of long-term and closure environment performance.

6.2 First pass - existing network review

The first pass review assessed the current Yandan bore network through review of monitoring records in levels and quality, and recommended:

- Several wells to be decommissioned given likely failures of casing and seal of the bores.
- Several wells to be decommissioned as monitoring a different horizon to required, most notably where monitoring direct tailings water, pond water or dam water in close connection with entrained water within the facility or earthen embankment. These wells are likely relics of civil engineering water pressure monitoring constructed at the toe of engineered structures for engineering purposes, not groundwater monitoring, and are too close to the fill or mining materials to be representative of groundwater. Note: each well nominated are replaced in a new network design, but at a suitable distance (plus others for full coverage) to be monitoring representative groundwater performance from the landform. There is no increased risk in stepping back slightly as wells are intended to monitor migrating groundwater.
- Reduction of monitoring frequency for several wells given stability/lack of change, or in preference to other wells in a similar location.

Table 4 - First pass review recommendations for current Yandan bore network

BHID	Domain	Recommendation & reasoning
HL1 [#]	Heap leach	Decommission – monitoring heap leach pond water.
HL3 [#]	Heap leach	Continue as current.
HL4 [#]	Heap leach	Decommission as likely has integrity issues.
HL5 [#]	Heap leach	Continue as current.
HL6 [#]	Heap leach	Decommission as likely has localised integrity issues.
HL7 [#]	Heap leach	Continue as current.
RB1D	Background	Continue as current, review in 1 year.
RB1S	Background	Likely reduce to 12 monthly or retire (often dry)
RB2D	Background	Continue as current, review in 1 year.
RB2S	Background	Continue as current, review in 1 year.
SH3	Near South Hill pit	Reduce to 12 monthly – largely monitoring dam water.
TD3 [#]	Tailings	Reduce to 12 monthly – largely monitoring dam water
TD4 [#]	Tailings	Decommission – monitoring tailings water
TD5 [#]	Tailings	Decommission – monitoring tailings water & lost integrity
TD6D	Tailings	Only one of 6D/S required as similar water quality/levels D/S
TD6S	Tailings	Reduce to 12 monthly as check sample.
TD7D	Tailings	Only one of 7D/S required as similar water quality/levels D/S
TD7S	Tailings	Reduce to 12 monthly as check sample.
WSB1 [#]	Water supply dam	Reduce to 12 monthly – largely monitoring dam water
WSB2 [#]	Water supply dam	Reduce to 12 monthly – largely monitoring dam water

[#] historical well, with no construction records

A summary of recommendations is shown in Table 4. Note historical wells denoted by #: these wells were likely constructed as part of the original operation, and construction records are not available.





6.3 Second pass assessment – what is fit for purpose, representative & long term

6.3.1 Geological cross sections

To demonstrate physical relationships between landforms, geology, bores and infrastructure, a series of geological cross sections through the landscape are prepared for the TSF and HL landforms. Each section demonstrates:

- How the TSF or HL sits in the landscape from near the top of the catchment as the valley fills across a pre-existing drainage line, noting other features and bores along section.
- How the current landform rests relative to surrounding pre-existing topography and geology, including natural gradients, geological extents and likely zones of entrainment around the landforms.
- Potential flow directions of rainfall onto the TSF/HL if/how water infiltrates and percolates through the tailings facility with the current configuration (noting recommended closure design is a water-shedding design).

6.3.2 Tailings Storage Facility landform hydrogeology

A series of re-constructed schematic sections of Yandan TSF are presented in Figure 16, Figure 17 and Figure 18 using pre-mining topography sourced from Fraser & Osborn 1997 (shown in Figure 19) to current-day contours. The original topography drawing also includes TSF embankment designs clearly showing a clay core and keyway included in each embankment for stability. There are three sections provided, all of which lay on a host geology of meta-siltstone, mudstone and related:

1. West to east along the pre-existing drainage line of the TSF (Figure 16), as the most likely of seepage directions for groundwater.
 - Sections shows the raised embankment and excavated capture ponds upstream and downstream of the TSF.
 - Given vertical gradients, potential for internal potentiometric surface to extend to the east (upstream) and west (downstream). Potential seepage from the TSF is most likely reflected in the quality of the downstream containment pond (tailings return pond).
 - Bores TD6S/D are located adjacent to the tailings zones, such as have the potential to be monitoring saturated zones of entrained water directly associated with tailings.
 - Bores TD3 and TD7S/D are located close to the tailings dam return embankment as toe piezometers and may not be representative of groundwater. Both are strongly reactive to rainfall (see Section 7.2), lay within a historical downstream dam area used as a pump back pump during operational days (GBM Resources, personal communication Greg Duncan).
 - Additional monitoring sites are recommended downstream and upstream as definitive background and down gradient monitoring.
2. North-west to south-east across Cell A across the valley (Figure 17).
 - Section shows the tailings cross-valley fill. Currently groundwater is only monitored in a single location, TD4. However, TD4 is likely unrepresentative as has been constructed directly at the embankment wall and is likely monitoring tailings entrained water, or a saturated component. This may also be supported by the “pullback” visible on the groundwater surface at TD4 as a localised elevated surface, (see Figure 11) (surface constructed via standard kriging).
 - Additional test monitoring sites are recommended slightly further north from TD4 outside the zone of tailings, and also to the south (previously not monitored).
3. North-east to south-west across Cell B (Figure 18).
 - Second view of cross valley fill, relative to ephemeral creek north and south.
 - Additional monitoring sites recommended to the north (two sites: first as shown on section, second to the central north as replacement for TD5 failed well, see Figure 1)

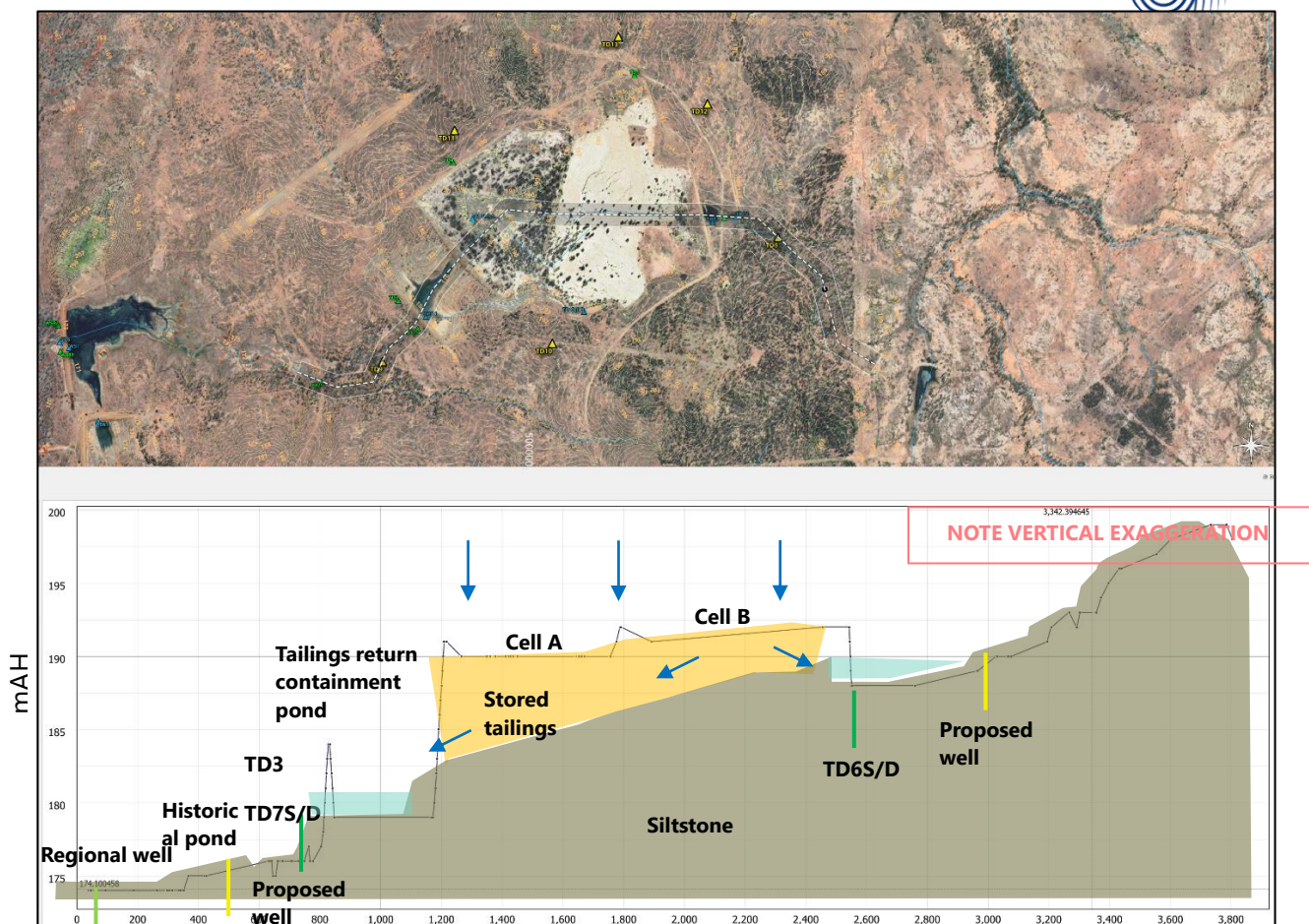


Figure 16 - East-West section through TSF and landscape

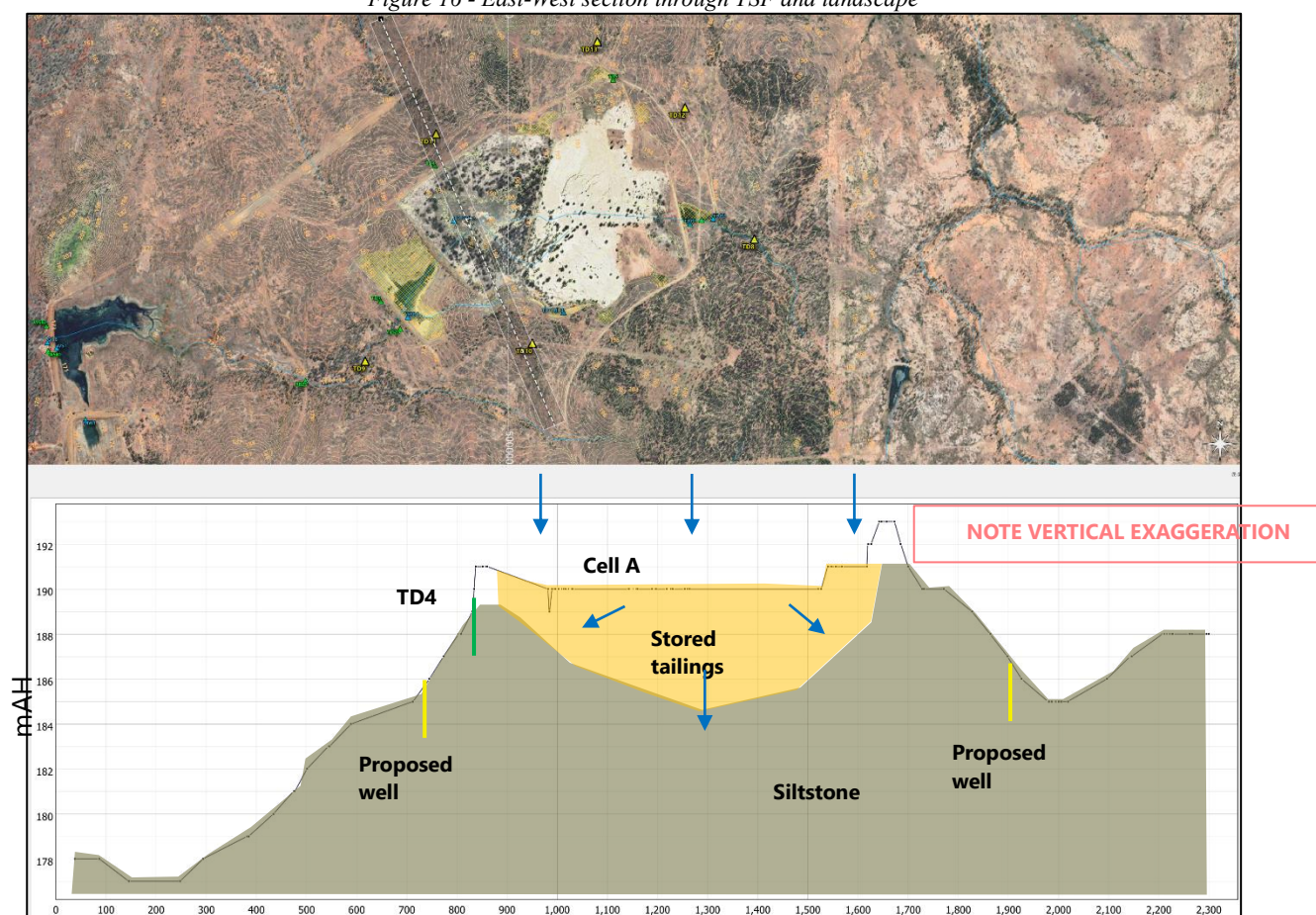


Figure 17 - Northwest-Southeast section through TSF



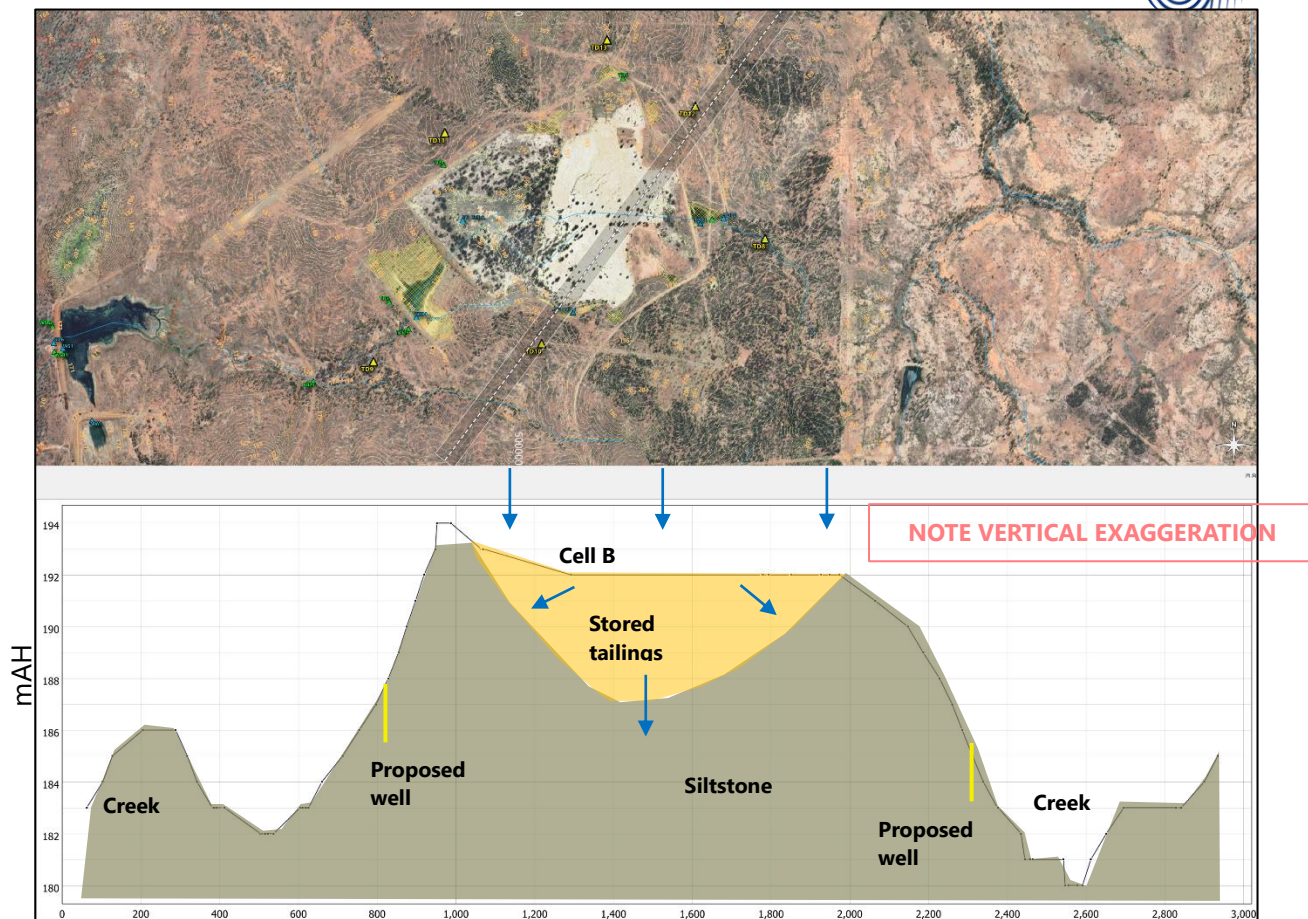


Figure 18 - Northeast-southwest section through TSF

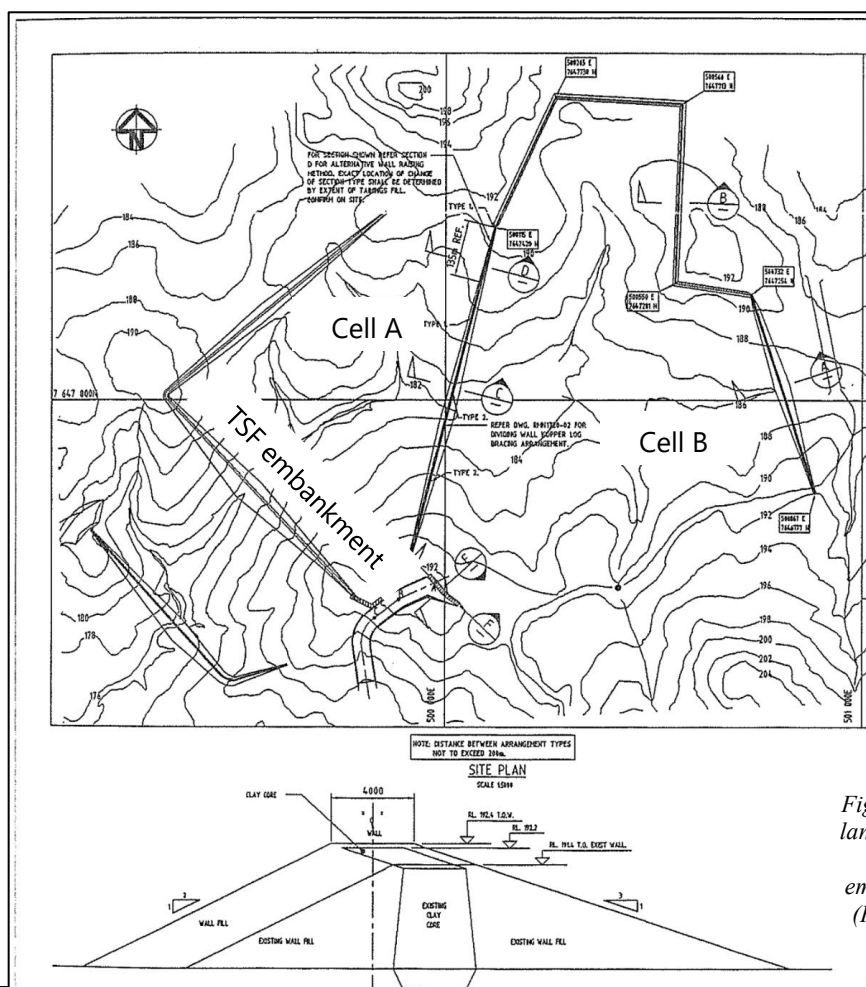


Figure 19 - Original landscape of tailings area and main embankment design (Fraser & Osborn)





6.3.3 Heap Leach landform hydrogeology

Two re-constructed sections of the original landscape, heap leach landform, infrastructure, and wells are presented in Figure 20 and Figure 21 using current day contours and reasonable assumptions of pre-existing landscape.

Figure 20 shows a north-south section through the heap leach, showing:

- An original topography running from north to south of siltstone: indicating it can be expected that most drainage coming from the heap leach will drain to the south, including groundwater.
- Location of HL7 directly upgradient from the heap leach adjacent to the upper drainage bund.
- Relative location of processing ponds and stormwater pond to the heap leach, including location of HL1 on the dam wall of the heap leach stormwater/overflow pond and which is heavily influenced by mining uses of the area. H1 is unlikely to be representative of groundwater as a shallow well in this location, and needs replacement.
- An additional monitoring location is recommended stepped back from the stormwater pond further downgradient.

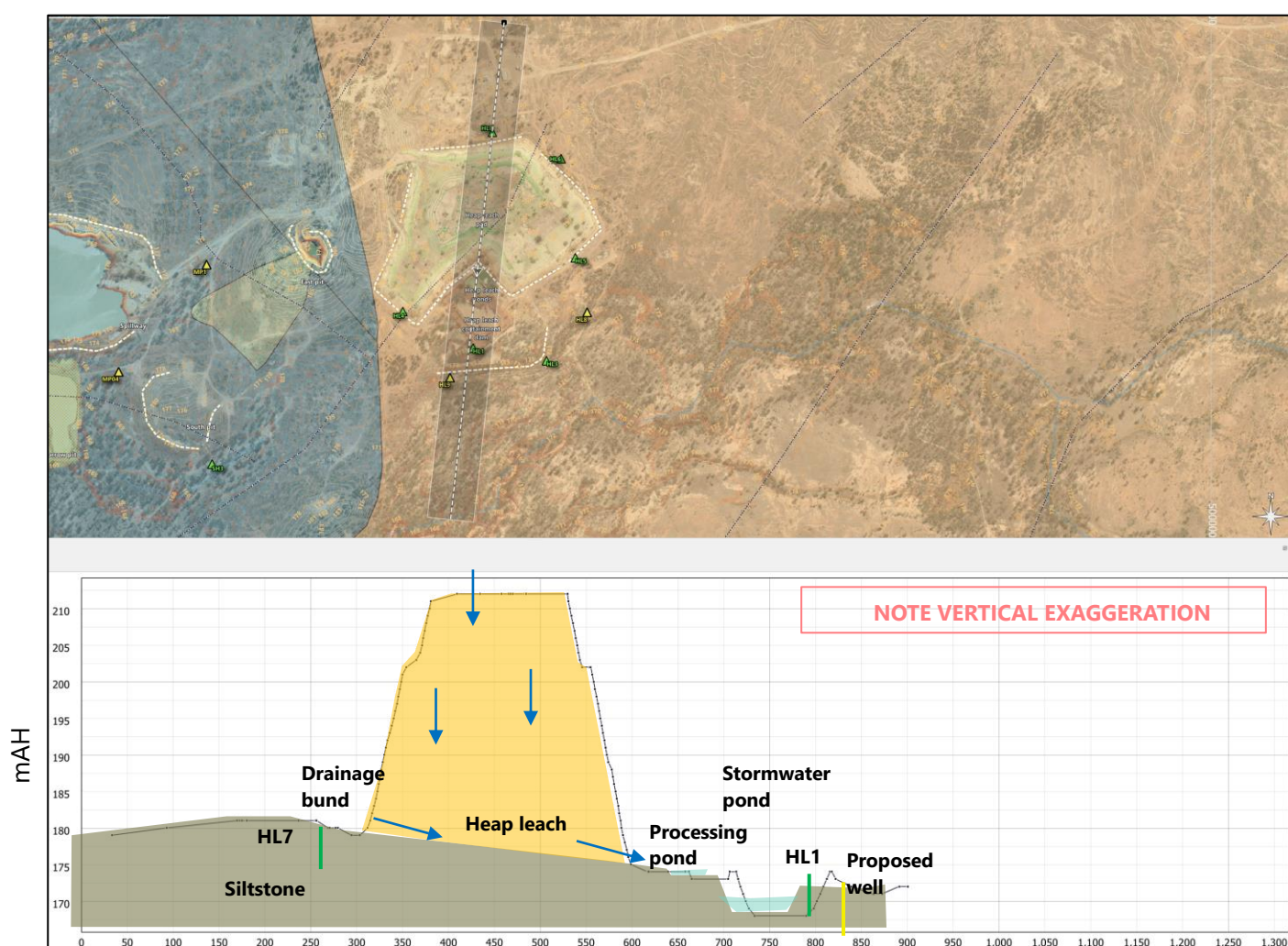


Figure 20 - North-south section through Heap Leach Landform & ponds





Figure 21 marks out a staggered west-east section from East Hill pit through the HL and out to the eastern extends, showing:

- A change in geology from East Hill pit volcanics to Heap Leach siltstone along the section (boundary estimated). The nature of the boundary is undefined at this stage; however East Hill pit has a lower RL than the heap leach.
- Location of bore HL4 directly on the southwest drainage bund and bore HL5 on the southeast drainage bund. There are no construction logs available for the current HL bore network.
- A proposed additional monitoring location stepped back and downgradient from HL5 to ensure representative monitoring downgradient from the heap leach for long-term environment performance.

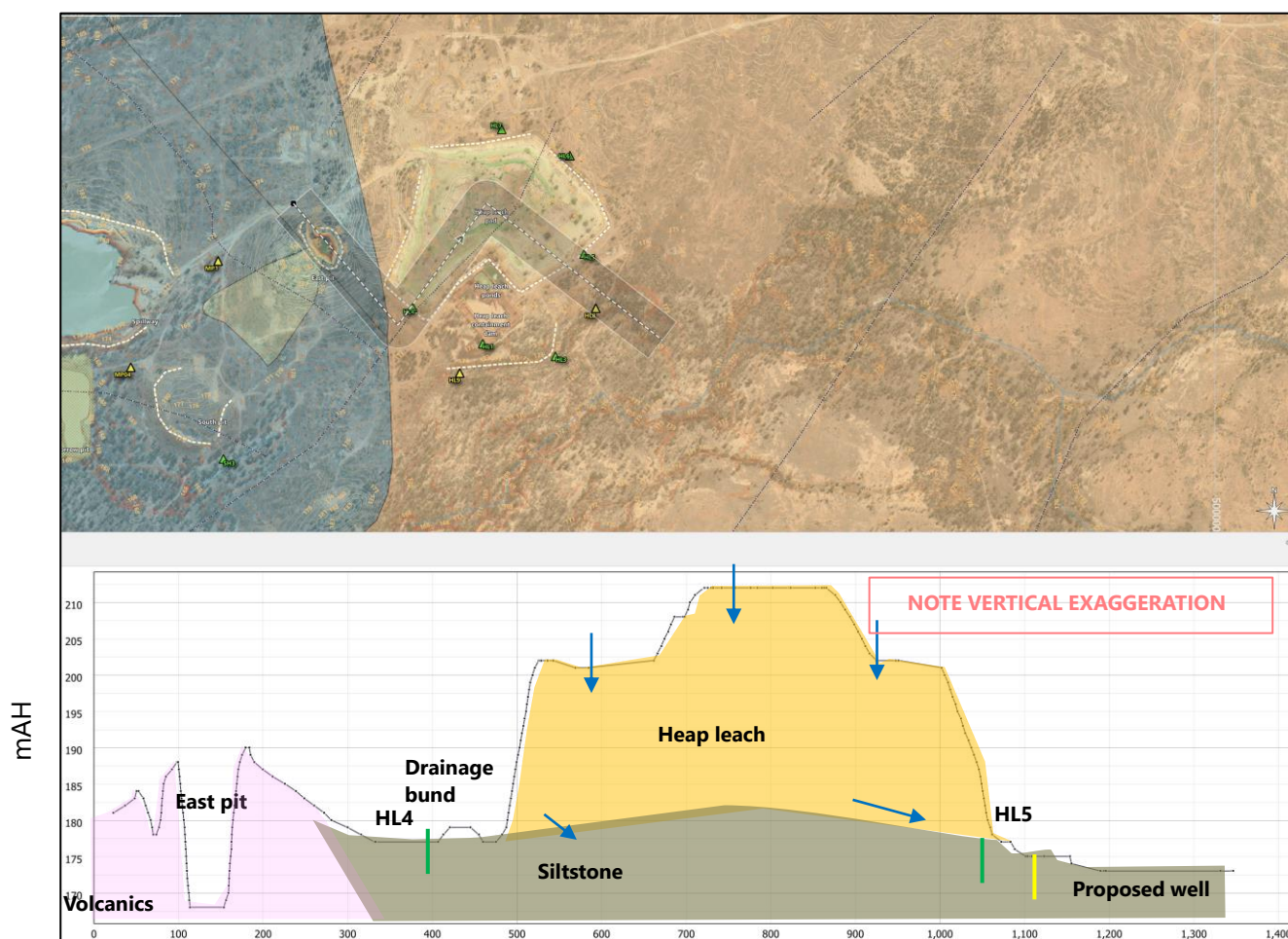


Figure 21 - West-East staggered section of Heap Leach



6.4 Monitoring review outcomes

Figure 1 provides a map of current and proposed monitoring installations across Yandan site, with an additional view with geology and faults shown in Figure 9 and Figure 10.

Location and selection of proposed new or replacement bores applied the following reasoning:

1. Monitor across the system of a landform and environment, including surface water, rainfall, infiltration and groundwater as background and potential receiving environment.
 - Re-position groundwater bore sites to ensure locations and horizon are representative of groundwater as it occurs across Yandan project site and placed to detect any migration of potential contaminants.
 - Able to act to inform closure outcomes and performance criteria over the long term, including if Yandan is reactivated as an active site.
2. For practicality, sites were positioned:
 - As close to existing tracks as possible to minimise impact and provide reasonable access.
 - Nearby to drainage lines to increase the likelihood of intersecting water based on potential joints or faults underlying drainage zones.

Recommended sites, depths and target reasoning for new wells are listed in Table 5 and include monitoring inclusive of:

1. Water levels via data loggers in three locations:
 - Tailings runoff containment dam to gain representative data for runoff capture, system response and water quality controls.
 - Both open pit voids (East and Main) to test water balance models, groundwater contributions and potential connections.
2. Installation of new replacement or additional groundwater wells:
 - Tailings: 4-6 wells which are representative of potential groundwater flow directions and groundwater quality (rather than the potentiometric water within the tailings).
 - Heap leach: 2 wells downgradient of the heap leach to monitor overall groundwater performance.
 - Main and East pits: 4 wells to monitor potential connections between pits and surface water, reaction to rainfall, and groundwater water quality performance.
3. Infiltration wells within the tailings footprint in Cell A and Cell B to monitor for infiltration and entrainment water column height and quality before and after further rehabilitation.
4. A site-based weather station to gain accurate rainfall and weather data for the site.
5. Where possible, opportunistic water quality sampling of runoff following rainfall over spillways from the tailings and heap leach landform to directly inform surface water quality performance.

Table 5 - Recommended changes to the Yandan water monitoring network and monitoring program

Site	Domain	Target and reasoning	Priorit y	Comments
Water level monitoring in storage (data loggers)				
TDRL	Tailings containment dam	Water level responses to rainfall and runoff.	1	Remain under surface
MPRL	Main pit lake	Water level responses to rainfall, potential groundwater connection.	1	Remain under surface
EPRL	East pit lake	Water level responses to rainfall, potential groundwater connection.	1	Remain under surface
Groundwater wells				
MP01	Main pit	Fault between East pit and Main pit. Test hydraulic connection between pits and quality.	3	Expected maximum depth ~25m, may be as shallow as 10m.
MP02	Main pit	Nested site with MP03. Shallow targeting alluvial aquifer.	1	Expected maximum depth ~10m.
MP03	Main pit	Nested site with MP02. Deeper targeting faults and fresh rock.	2	Expected maximum depth ~70m. Construct at depth if the alluvial aquifer is still present at 70m.
MP04	Main pit	NW-SE fault between South and Main pit.	4	Expected maximum depth ~25m.
HL8	Heap leach	Shallow well downgradient of heap leach	1	Expected maximum depth ~20m, may be shallower.
HL9	Heap leach	Shallow well downgradient of heap leach	2	Expected maximum depth ~20m, may be shallower.
TD8	Tailings	Background well upgradient of tailings (outside of TD influence and near to REMP site)	1	Expected maximum depth ~20m, may be shallower.
TD9	Tailings	Shallow well downstream of tailings (outside of influence)	2	Expected maximum depth ~20m, may be much shallower ~10m.
TD10	Tailings	Shallow/moderate well downstream of tailings (outside of TD saturated zone)	3	Expected maximum depth ~20m, may be shallower.
TD11	Tailings	Shallow/moderate well downstream of tailings (outside of TD saturated zone)	4	Expected maximum depth ~20m, may be shallower.
TD12	Tailings	Shallow/moderate well downstream of tailings (outside of TD saturated zone)	Option	Expected maximum depth ~20m, may be shallower.
TD13	Tailings	Shallow/moderate well downstream of tailings (outside of TD saturated zone)	Option	Expected maximum depth ~20m, may be shallower.
Inter-tailings and infiltration monitoring				
ITD0 1	Within tailings	Ponding area of Cell A. Near surface water site-testing infiltration rates (water level response). Potential data logger location.	1	Expected depth ~10-12m.
ITD0 2	Within tailings	Near drainage line through cell B. Indication of infiltration rates (water level response). Potential data logger location.	2	Expected depth ~6-8m.
Rainfall and weather data station - near tailings landform				
Opportunistic monitoring of runoff				
	Tailings spillway	Surface water performance of runoff from tailings landform	2	As possible with access.
	HL runoff to ponds	Surface water performance of runoff from HL landform	2	As possible with access.





7 Tailings storage landform assessment

7.1 Materials characterisation

Geochemical assessment of tailings host materials at Yandan is assessed in four (4) main studies:

- Tailings rehabilitation studies – 26 samples Dwyer (internal), circa 1999 for Ross Mining.
- Combined heap leach and Cell B tailings – 6 samples - RGS 2013 for Straits Resources.
- Oxide and tailings assessment – 85 samples – RGS 2015 for Straits Resources.
- Discussion of tailings assessment results – 15 samples - RGS 2022 for GBM Resources.

The RGS (2013, 2015) study reviewed previous work and assessed new samples, resulting in the classification of tailings materials to inert to low acid forming potential (LAFP) given almost complete oxidation and precipitation of sulphides within the tailings area. In 2022, RGS tested 15 samples (including 3x natural soil) for further static and kinetic testing and assessed in-situ conductivity as a measure of the percolation potential of the facility's top. Key findings include:

- Low porosity of compacted tailings materials in Cell A and B (mostly oxide tailings), inhibiting infiltration and percolation as a primary control (Figure 22).
- Low sulphate responses in water within tailings samples and kinetic leaching results with a maximum of 2,000mg/l SO₄ potential, indicating sulphate generation is low (Figure 23).
- Confirmation that oxidation of sulphides has occurred within the landform with likely conversion to jarosite, as all tailings materials are classified as non-acid forming (Figure 24).
- Key base materials enrichment metals of aluminium, arsenic, cadmium, chromium, copper, manganese, nickel, and zinc are identified as only partially mobile.

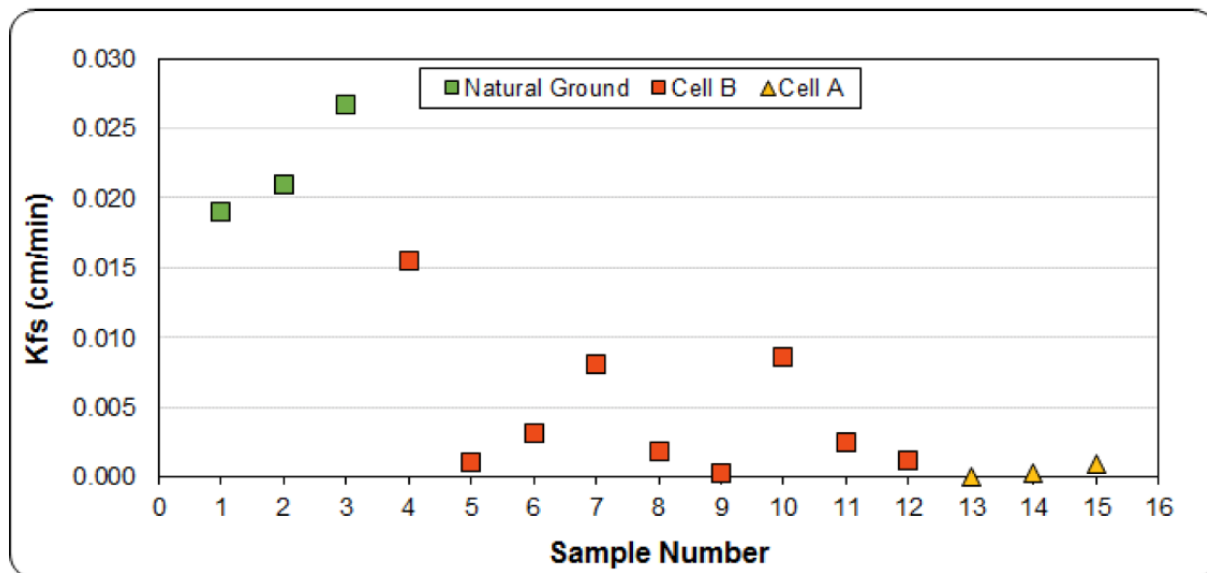


Figure 22 - In situ porosity of tailings facility (RGS 2022)

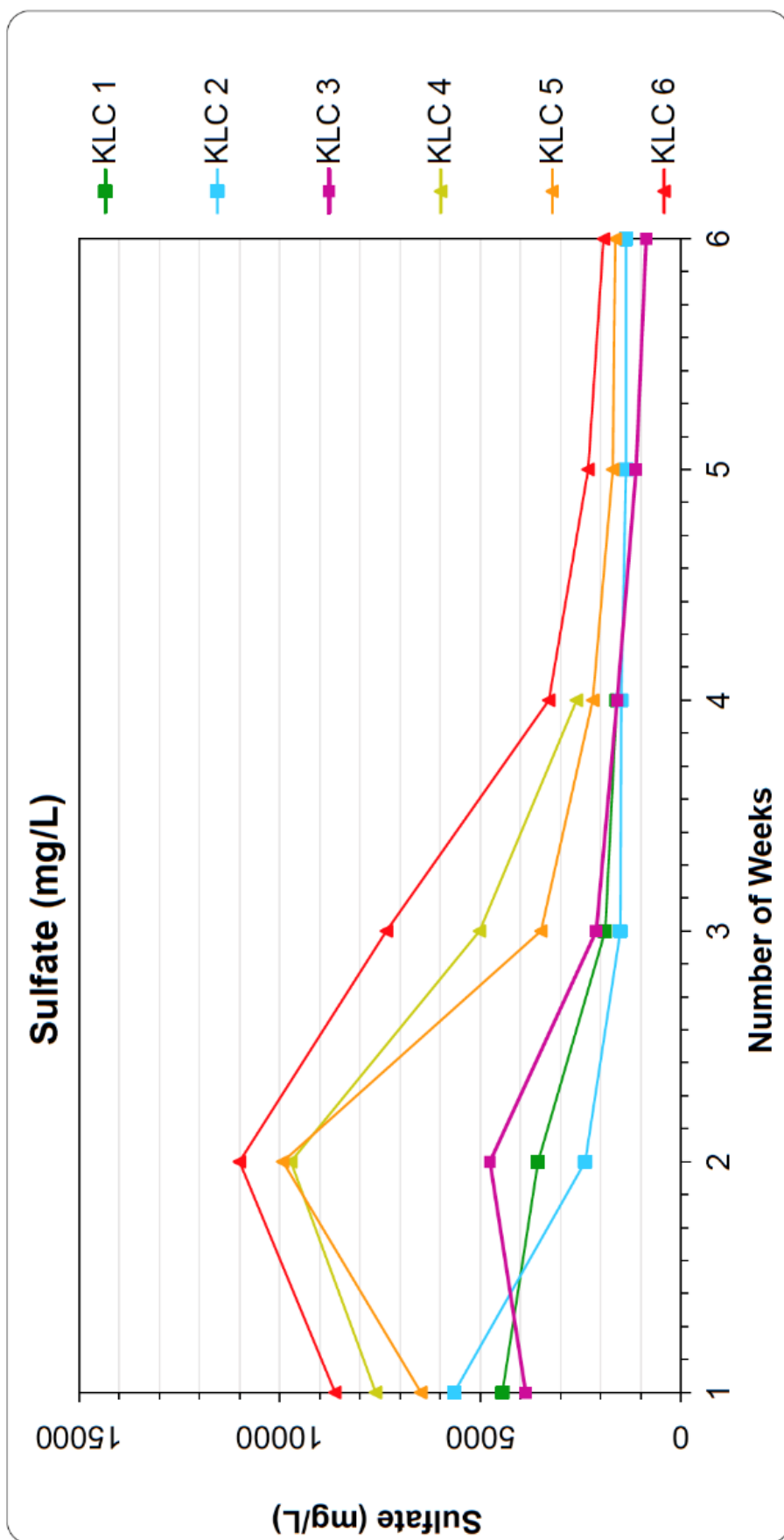


Figure 23 - Sulphate production through rapid kinetic testing (RGS 2022)



Sample No.	RGS Sample ID	ALS Lab ID	Sample Material	Sample Location	Easting	Northing	pH _(1:5) ¹	EC _(1:5) ¹ (µS/cm)	pH based Acid Forming Potential	Total S (%)	Scr ² (%)	MPA ²	ANC ² (kg H ₂ SO ₄ /t)	NAPP ²	ANC: MPA Ratio	Geochemical Classification ³
1	2022017_0001	EB2210698001	Soil	Outside TSF	500,759	7,646,672	5.1	29	LAFP	0.01		0.31	3.1	-2.79	10.12	Non-Acid Forming (Barren)
2	2022017_0002	EB2210698002	Soil	Outside TSF	500,904	7,647,893	6.2	87	Inert	0.01		0.31	5.1	-4.79	16.65	Non-Acid Forming (Barren)
3	2022017_0003	EB2210698003	Soil	Outside TSF	499,625	7,647,575	6.6	28	Inert	0.01		0.31	7.2	-6.89	23.51	Non-Acid Forming (Barren)
4	2022017_3001	EB2210698004	Tailings	TSF Cell B	500,342	7,647,447	4.1	1910	LAFP	0.35	0.014	0.43	2.7	-2.27	6.30	Non-Acid Forming (Barren)
5	2022017_3002	EB2210698005	Tailings	TSF Cell B	500,498	7,647,477	3.9	1760	MAFP	0.26	0.021	0.64	3.0	-2.36	4.66	Non-Acid Forming (Barren)
6	2022017_3003	EB2210698006	Tailings	TSF Cell B	500,605	7,647,353	3.9	2860	MAFP	0.59	0.019	0.58	2.1	-1.52	3.61	Non-Acid Forming (Barren)
7	2022017_3004	EB2210698007	Tailings	TSF Cell B	500,262	7,647,227	4.0	800	LAFP	0.31	0.017	0.52	1.0	-0.48	1.92	Non-Acid Forming (Barren)
8	2022017_3005	EB2210698008	Tailings	TSF Cell B	500,434	7,647,242	3.9	2360	MAFP	0.41	0.017	0.52	1.1	-0.58	2.11	Non-Acid Forming (Barren)
9	2022017_3006	EB2210698009	Tailings	TSF Cell B	500,540	7,647,146	3.8	2900	MAFP	0.81	0.016	0.49	1.3	-0.81	2.65	Non-Acid Forming (Barren)
10	2022017_3007	EB2210698010	Tailings	TSF Cell B	500,226	7,646,940	4.3	1280	LAFP	0.36	0.031	0.95	2.2	-1.25	2.32	Non-Acid Forming (Barren)
11	2022017_3008	EB2210698011	Tailings	TSF Cell B	500,380	7,646,930	4.0	1790	LAFP	0.38	0.025	0.77	6.0	-5.23	7.84	Non-Acid Forming (Barren)
12	2022017_3009	EB2210698012	Tailings	TSF Cell B	500,487	7,646,819	3.7	2600	MAFP	0.53	0.018	0.55	0.6	-0.05	1.09	Non-Acid Forming (Barren)
13	2022017_3010	EB2210698013	Tailings	TSF Cell A	499,874	7,647,368	8.5	780	Inert	0.08		2.45	10.3	-7.85	4.20	Non-Acid Forming (Barren)
14	2022017_3011	EB2210698014	Tailings	TSF Cell A	499,842	7,647,167	4.2	4010	LAFP	1.33	0.022	0.67	0.3	0.42	0.37	Non-Acid Forming (Barren)
15	2022017_3012	EB2210698015	Tailings	TSF Cell A	499,853	7,646,938	5.2	3390	LAFP	0.31	0.028	0.86	4.1	-3.24	4.78	Non-Acid Forming (Barren)

Notes:

1. pH and EC for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; NAPP = Net Acid Production Potential.
3. Sample classification criteria detail provided in report text. LAFP = Low acid forming Potential. MAFP = Mild Acid Forming Potential.

Figure 24 – Acid-base accounting from recent assessment (RGS 2022)



7.2 Observed system response over time

Groundwater is at the highest elevation across the project near the tailings dam, with the groundwater surface gradient to the southwest (Figure 11). Groundwater levels are subtly responsive to overall rainfall (Figure 25), declining gently over the dry period from 2012-2020 and increasing over 2020-23 with increased wet seasons (note TD5 is identified as a failed well). The decline rate is slower than rising water levels, aligning with siltstone physical and chemical (chloride) analysis of siltstone being a poor aquifer, where groundwater flow away from the TSF is constrained.

The groundwater quality of wells is generally stable in pH, electrical conductivity, and sulphate (Figure 26, Figure 27), noting that the network is monitoring various sources.

- Electrical conductivity is elevated in three locations – TD4, TD5, TD6 (S/D), with values of 10,000-30,000uS/cm EC. TD5 lies in a borrow pit with a failed casing (SBE 2022a). TD4 and TD6S/D are also unreliable representations of groundwater, given their locations adjacent to the tailings landform and lying within a likely potentiometric surface of entrained materials (Figure 16-Figure 18). TD6S/D lies in a potential background location; however, it may not be representative, and a further upstream location is recommended. At this stage, there is no clear indication if the detected salinity is natural or impacted and requires further investigation.
- Sulphate is stable and below 1,000mg/l, below the stock water quality limit except for TD6S/D: no active process of acid or alkaline drainage is underway from tailings materials.

Figure 28 shows electrical conductivity and sulphate plotted with residual rainfall of the surface water storage:

- EC and sulphate show an ongoing declining trend at troughs and peaks, indicating water quality is improving with time and indicating containment of the dam or cessation of drainage processes as suggested by RGS (2022).
- Peaks coincide each year near the end of the dry season, typically in October or November at a similar time when the residual shows a robust negative decline for little to no rainfall, which allows the driving force of evaporation to reduce available water in the dam and leaving salts behind and increasing concentration.
- As the wet season commences, rainfall provides a freshening of water and lowers salinity and sulphate. Levels are now below 500 uS/cm EC and 250 mg/l SO₄ and approaching freshwater quality, indicating system stabilisation and improved water performance¹.

TD3 and TD7D/S also strongly link to rainfall (Figure 29), showing a direct correlation to the residual rainfall trend, suggesting both wells are related to surface water or shallow water in the zone.

Sulphate is slightly elevated at both TD3 and TD7S/D at 1500mg/l SO₄, however this is unlikely to be AMD or SMD as:

- pH remains neutral (Figure 26).
- There is no indication of metals mobility (SBE 2022a)
- Water quality in the tailings return pond is freshening rapidly and is already far fresher, indicating the source of sulphate is unlikely to be sourced from the TSF.

A further monitoring location is recommended downstream and upstream of the TSF for end-of-domain groundwater performance.

¹ Note this is an updated interpretation from the PRCP assessment (SBEa 2022): monitoring of water levels in the dam is recommended to complete the system understanding

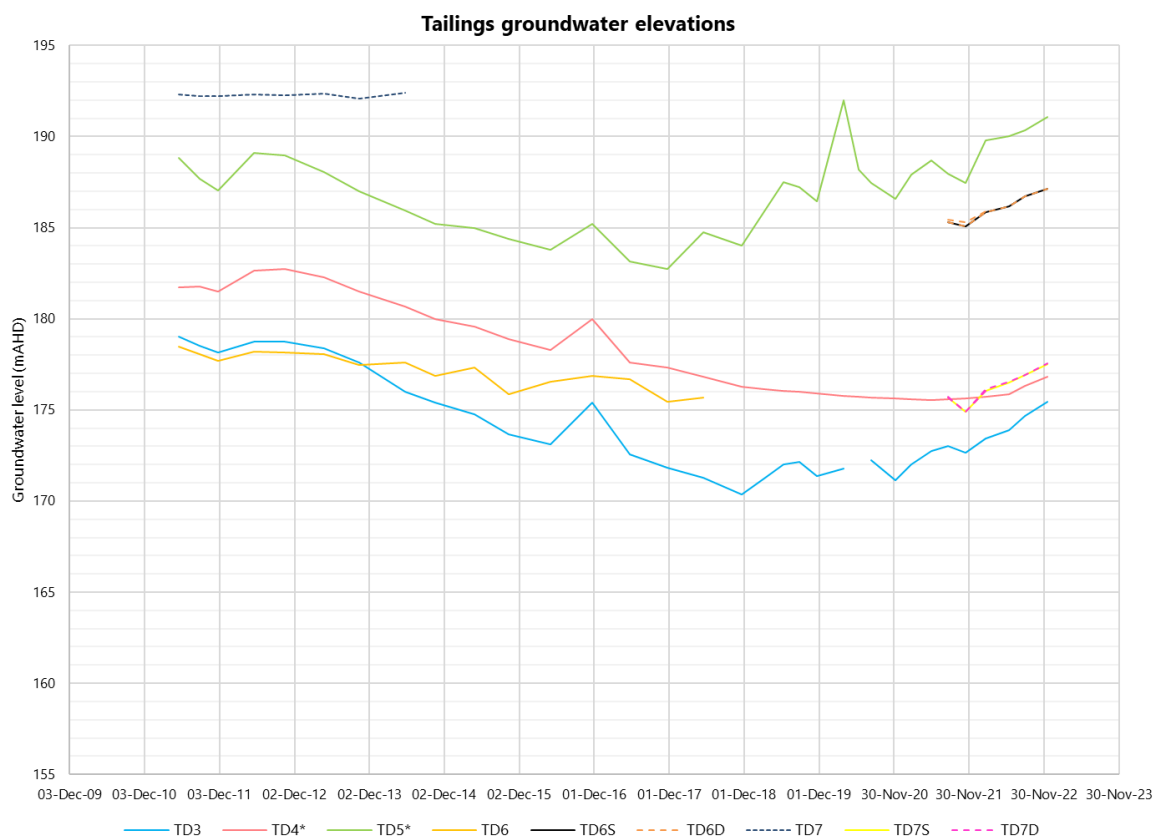


Figure 25 - Tailings groundwater relative levels

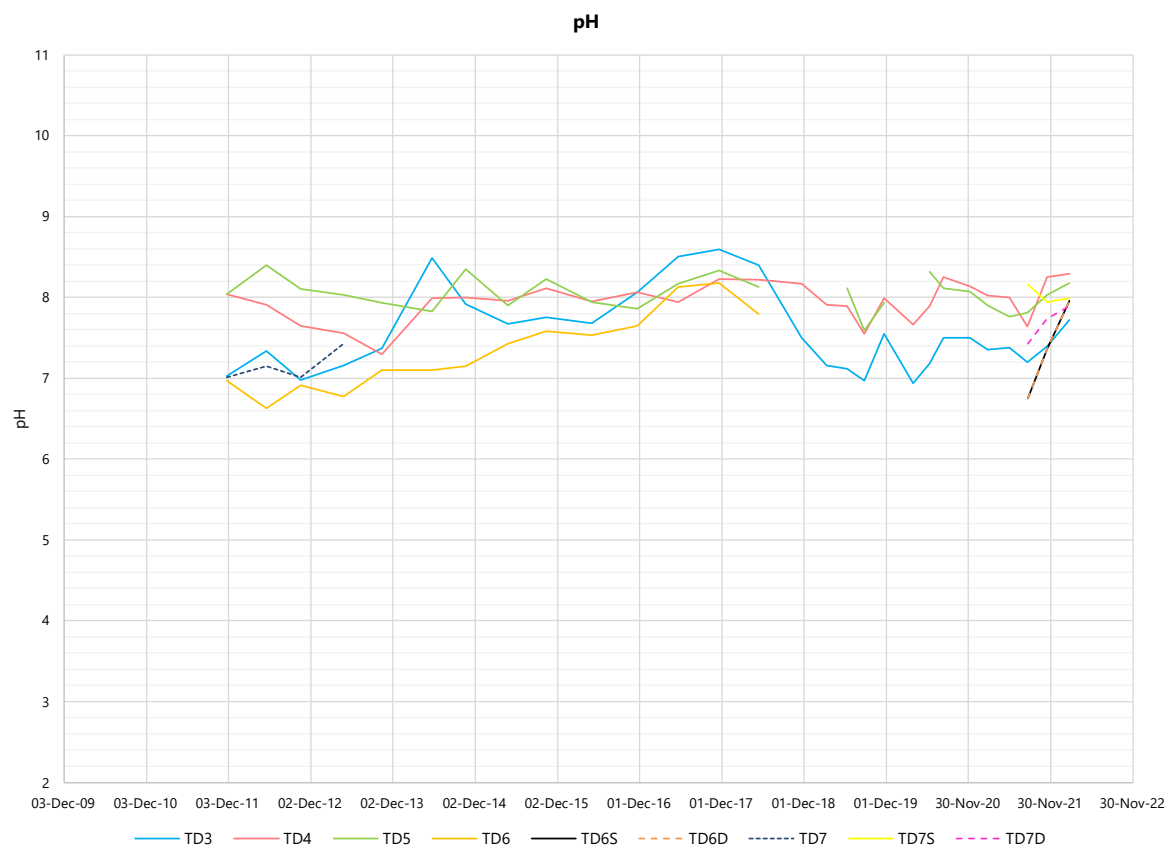


Figure 26 - Tailings pH relative levels

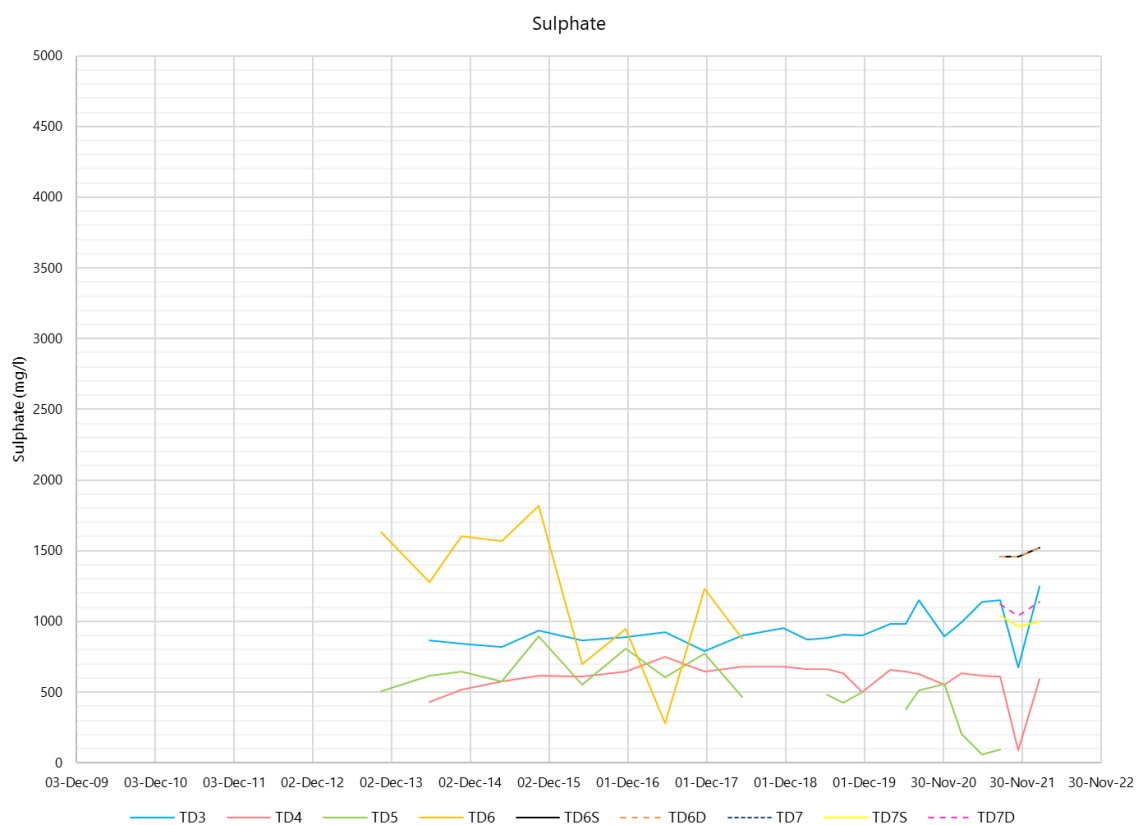
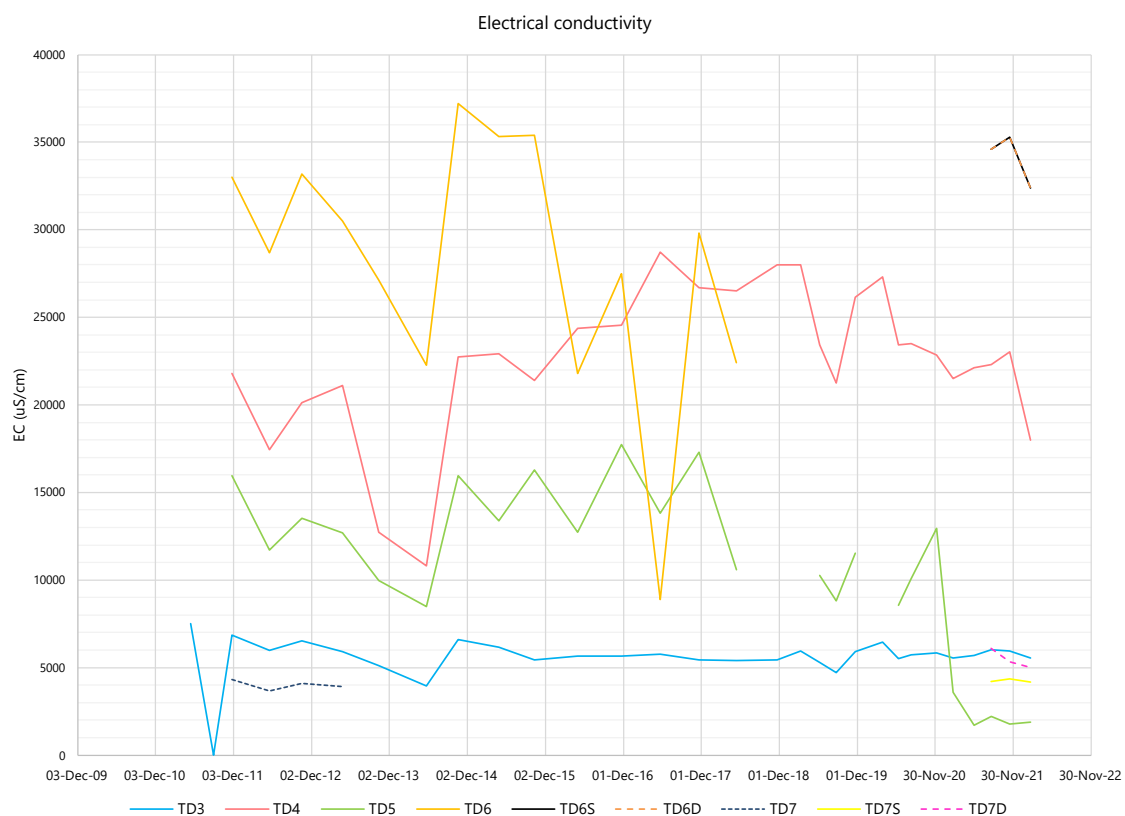


Figure 27 - Groundwater electrical conductivity and sulphate at TSF

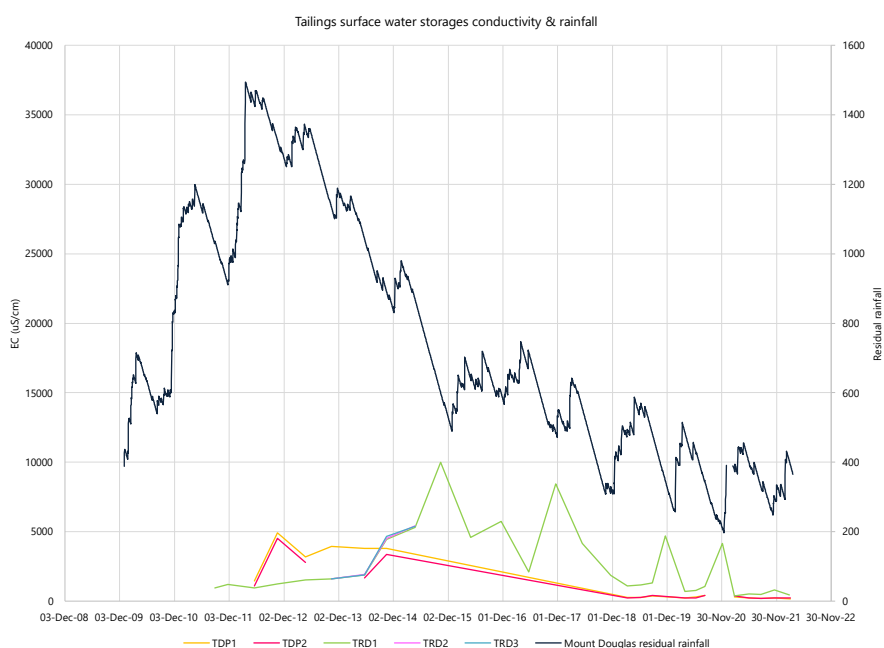
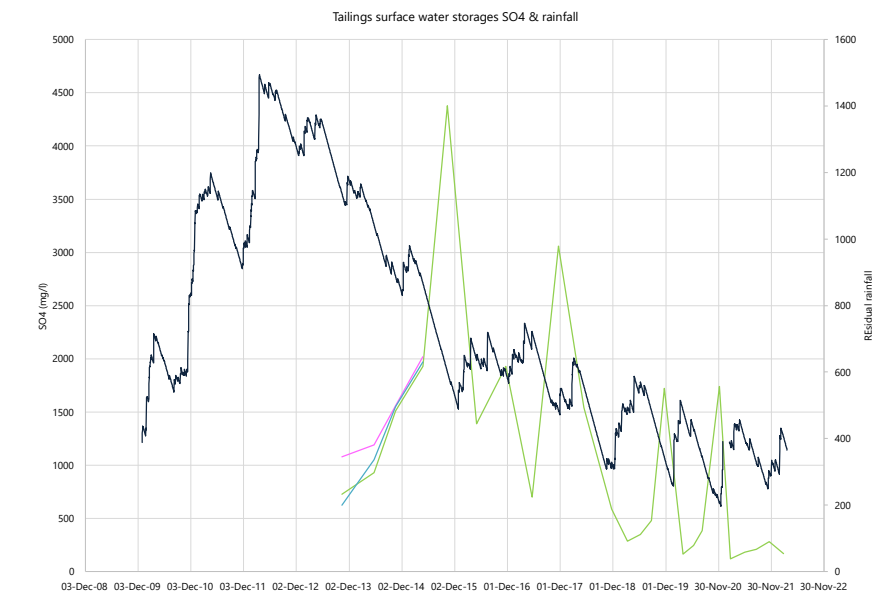


Figure 28 – EC and sulphate surface water quality of the tailings domain with residual rainfall

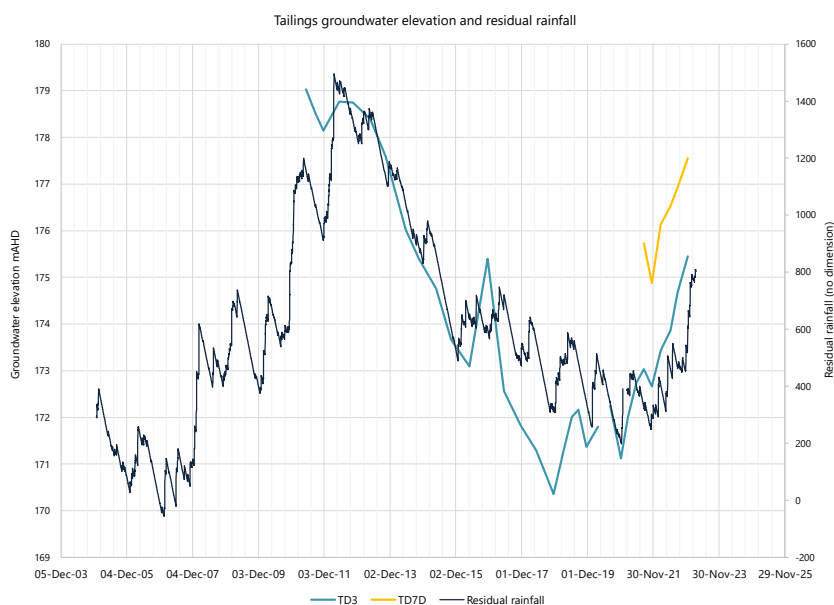


Figure 29 – Groundwater levels at the containment dam with residual rainfall



7.3 Generalised system model

A working system model of the Yandan tailings landform (at closure) is shown in Figure 30. Key features of the model include:

- Low elevation profile of the tailings facility over the top of the landscape, from 1 to a maximum of 15 metres height at the highest point.
- Low conductivity geology below the tailings facility, severely retarding any groundwater from reaching the base of the tailings and seepage.
- Seasonal rainfall may lead to some ponding at present, which is subject to evaporation and low infiltration rates (based on conductivity testing by RGS 2022). Ponding can be avoided through the installation of a water-shedding cover design.
- Bores TD4, TD5, and TD6 are likely not representative of actual groundwater but representative of the entrained water in the landform. Further wells are recommended.
- TD3 and TD7 (D/S) and in the tailings containment dam demonstrates containment of any potentially impacted water and low potential for environment harm.

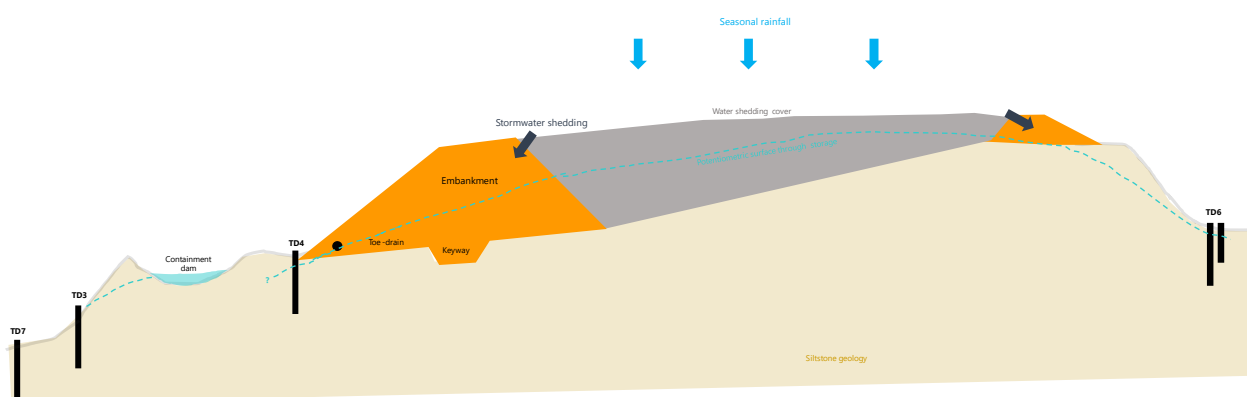


Figure 30 – Example schematic of tailings and monitoring locations (shown with water shedding closure design)

7.4 Risk classification

A review of the Yandan tailings storage facility materials, compaction, height and water performance places the facility in the low-risk category:

- Low reactive materials, with low AMD, ARD, NMD, or saline drainage.
- Limited to no signs of PAF drainage.
- Moderate to low salinity is evident in surface water and groundwater.
- Cell A tailings are low permeability, reducing potential for infiltration.
- Very low conductivity in underlying geology.
- Limited seepage to groundwater.
- Tailings have at least moderate strength and consolidation.
- Embankment is <15m.

Figure 31 and Figure 32 identify the risk classification in the DES category framework (2019, 2022) of the TSF landform.



Table 6-1 Risk Category Characteristics

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High Select this category if the waste structure has one or more of the following characteristics:	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm.	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tails materials Requiring composite liners (e.g. HDPE) Embankments > 30 metres high Observed contaminated seepage capable of causing environmental harm.
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end Low strength consolidated tailings land use objectives for the facility Embankments 15 to 30 m high
Low	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD) Moderate to low salinity Moderate strength consolidated tailings Embankments less than 15 m high
Very Low	Benign materials	Benign materials	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments less than 15 m high

Figure 31 - TSF risk classification DES 2019

Risk category	Waste rock dumps	Heap leach pads	Tailings storage facilities
High	- Potentially acid forming waste rock materials (PAF). - Other highly reactive materials including (acid rock drainage (ARD) / acid mine drainage (AMD) / neutral mine drainage (NMD)). - Observed contaminated seepage (PAF) capable of causing environmental harm.	- Potentially acid forming heap leach materials (PAF). - Other highly reactive materials including (ARD/AMD/NMD). - Observed contaminated seepage (PAF) capable of causing environmental harm.	- Potentially acid forming tailings materials (PAF). - Other highly reactive materials including (ARD/AMD/NMD). - Poor consolidation and low shear strength tails materials. - Requiring composite liners (e.g. HDPE) - Embankments > 30 metres high. - Observed contaminated seepage (PAF) capable of causing environmental harm.
Medium with low permeability layer	- Waste rock material that could adversely impact on the proposed end land use and/or vegetation function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Significant (non-PAF) seepage capable of causing environmental harm.	- Heap leach materials that could adversely impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Significant (non-PAF) seepage capable of causing environmental harm.	- Tailings materials that could impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Low strength consolidated tailings embankments 15 to 30 m high.
Medium	- Waste rock material that could adversely impact on the proposed end land use and/or vegetation function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Seepage (non-PAF) capable of causing environmental harm.	- Heap leach materials that could adversely impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Seepage (non-PAF) capable of causing environmental harm.	- Tailing's materials that could impact on the proposed end land use and/or vegetation eco- function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Low strength consolidated tailings embankments 15 to 30 m high. - Seepage (non-PAF) capable of causing environmental harm.
Low	- Waste rock material that may have some impact on the proposed end land use and/or vegetation cover - Minor (non-PAF) seepage.	- Heap leach material that may have some impact on the proposed end land use and/or vegetation cover - Minor (non-PAF) seepage.	- Moderate strength consolidated tailings. - Tailing's material that may have some impact on the proposed end land use and/or vegetation cover. - Embankments less than 15 m high. - Minor (non-PAF) seepage.
Very low	Benign waste rock materials Minor (non-PAF) seepage.	Benign heap leach materials Minor (non-PAF) seepage.	- No likely impacts on the proposed end land use and/or vegetation covers. - Moderate strength consolidated tailings - Embankments less than 15 m high. - Minor (non-PAF) seepage.

Figure 32 - TSF risk classification DES 2022





8 Heap leach landform assessment

8.1 Materials characterisation

Two (2) central studies characterise the geochemical assessment of heap leach host materials:

- Heap leach assessment – 20 samples - EGI 2002 for Wirralie Mines.
- Combined heap leach and Cell B tailings – 6 samples - RGS 2013 for Straits Resources.

Both studies identify heap leach materials as:

- Benign, low-grade, non-acid forming, but may generate saline runoff and seepage.
- Potential enrichment of calcium, sulphate, chloride and sodium runoff given the extent of lime addition through the heap leach as part of extraction processes.

8.2 Observed system response over time

The heap leach system consists of two main parts:

- The heap leach landform itself.
- The leachate pond and stormwater pond system which were the source of feed water to the process plant during operation, and also capture excess rainfall. The stormwater pond is dry except after rainfall.

The heap leach bore network is located directly around the heap leach landform. Wells are historical and of unknown geology and construction, and bore HL4, and HL6 are likely compromised wells given responses to rainfall and erratic variability of arsenic results (groundwater is usually more stable, and there is wide variability observed). There is a single well (HL3) downgradient of the heap leach. Near the historical leachate pond, the HL1 well lies directly adjacent to the pond within the embankment. It is likely directly connected with the pond water through the embankment potentiometric surface, and the pond contained materials and materials and is unlikely to represent groundwater. Several additional wells are recommended for downgradient of the heap leach pond to be representative. Closure works propose the leachate pond and related materials will be removed.

In groundwater quality observations:

- Groundwater levels linked to rainfall patterns (Figure 33).
- Stable, neutral pH (Figure 34).
- Elevated electrical conductivity at bores HL1 and HL3:
 - HL1, given the proximity and direct connection to the leach pond.
 - HL3 as a single point is unusual as no other wells closer to the heap leach landform have elevated salinity. The elevated salinity is not matched with sulphate, as could be expected if water quality at HL3 was influenced via the leach pad through groundwater seepage. The elevated salinity may be ambient, given volcanic geology.
- Single instance of elevated sulphate at HL1, likely as part of being directly connected to the leachate pond and likely the highest concentration of leached materials in the area.
- Arsenic concentrations are low to undetected in all wells except for one on the northeast side, HL6. HL6 is compromised and marked for replacement. Concentrations are highly variable in coincidence with rainfall, with a longer-term trend of decline.

In surface water quality observations:

- Electrical conductivity in leachate and stormwater pond ranges up to 20,000uS/cm, elevated above natural groundwater salinity. This is likely a factor of the pond's historical purpose as a capture pond, increased through the historical practice of lime application to facilitate the leaching, leaving a legacy of saline materials (to be removed at closure).
- Sulphate is elevated to 5,000mg/l in both ponds. However, the system response shows stability in the leachate pond and stable to improvement in the stormwater pond.
- Arsenic is elevated within the leach pond but improving (reducing) and is likely a legacy of historical operations rather than current drainage. As a result, the pond is low in arsenic.



Heap leach groundwater elevations & residual rainfall pattern

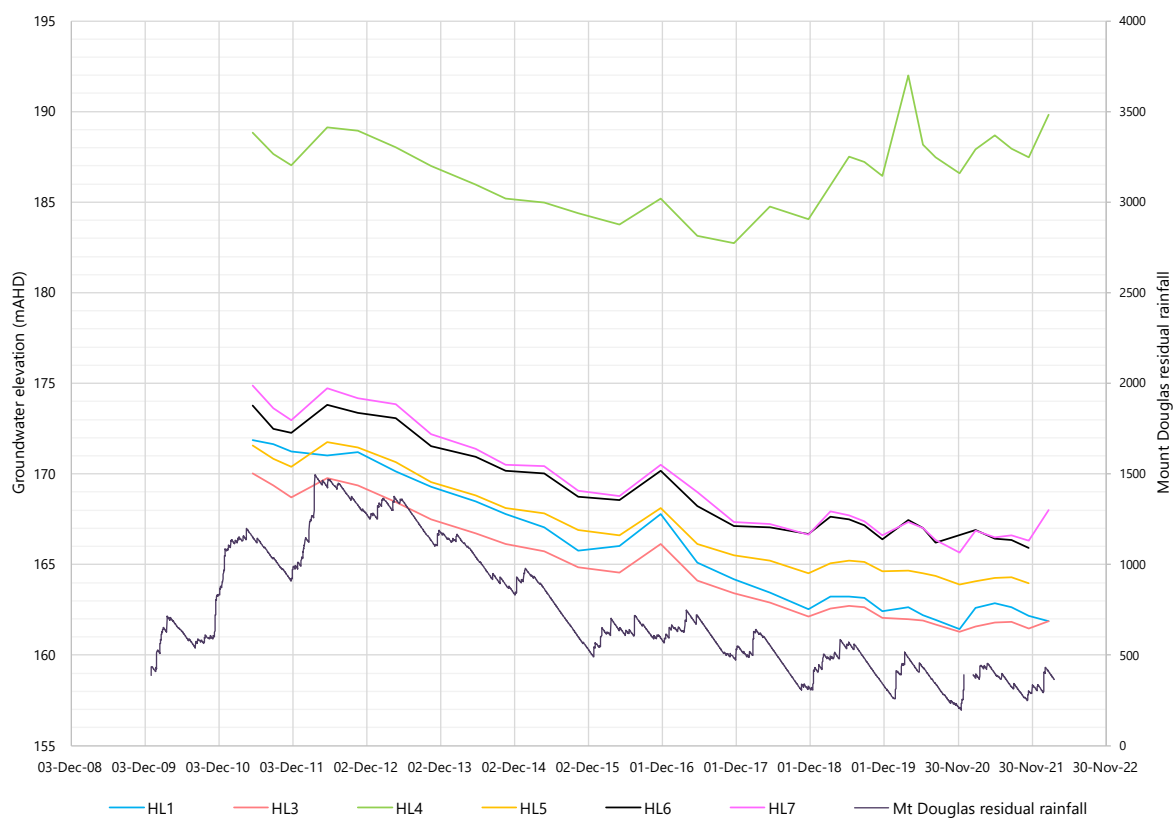


Figure 33 - View of HL groundwater level & residual rainfall

pH

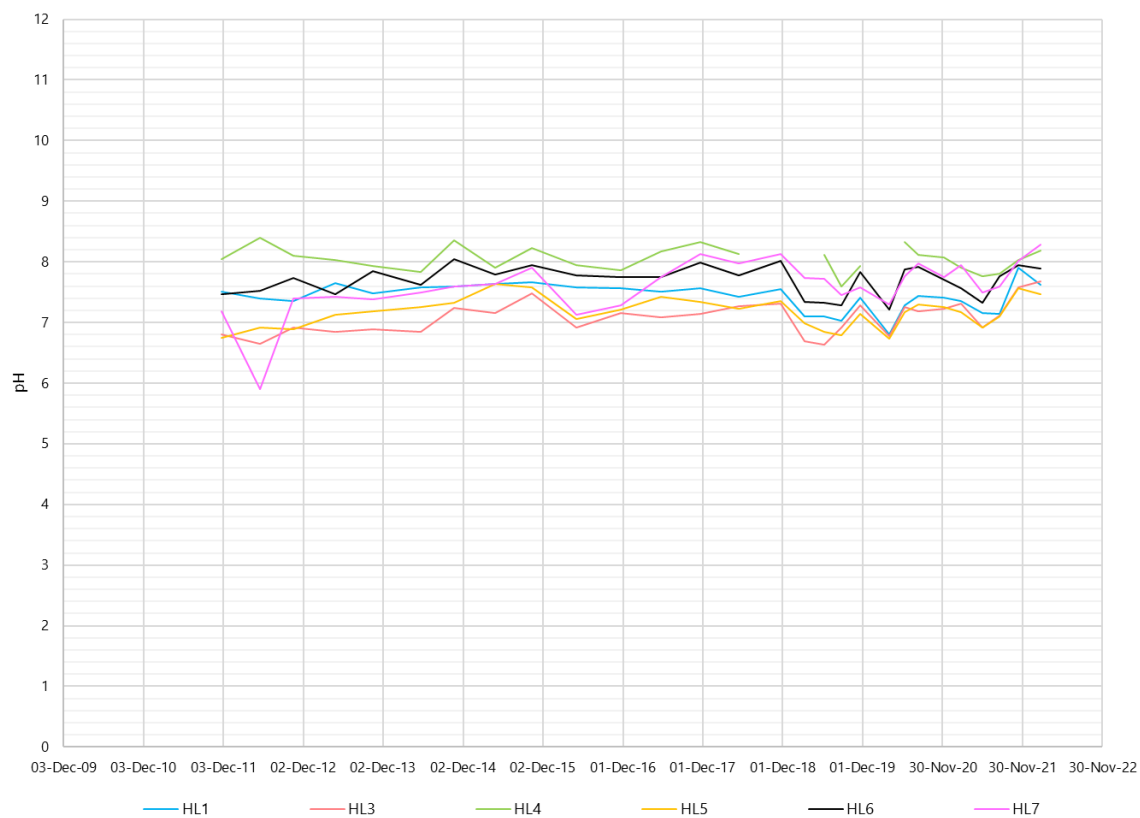




Figure 34 - Heap leach groundwater pH

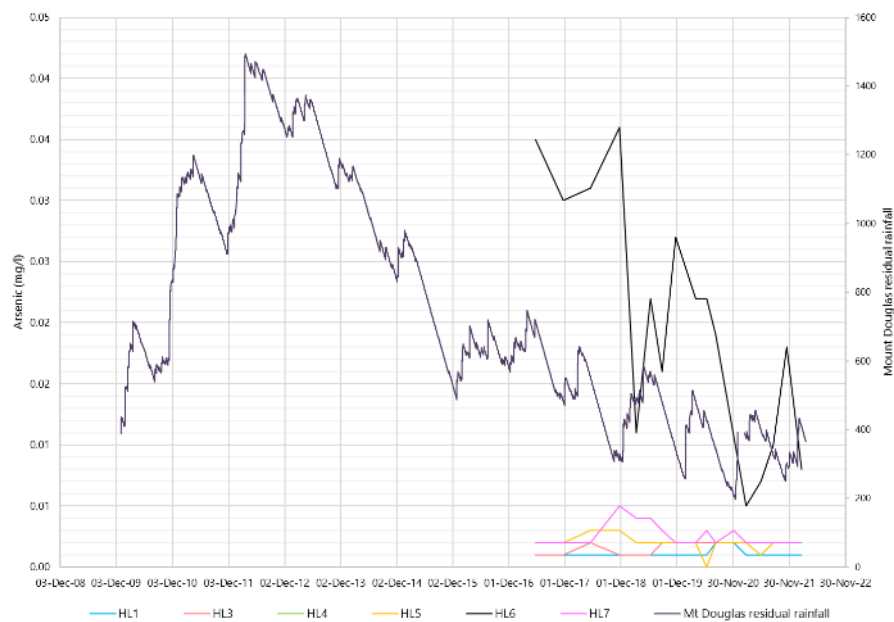
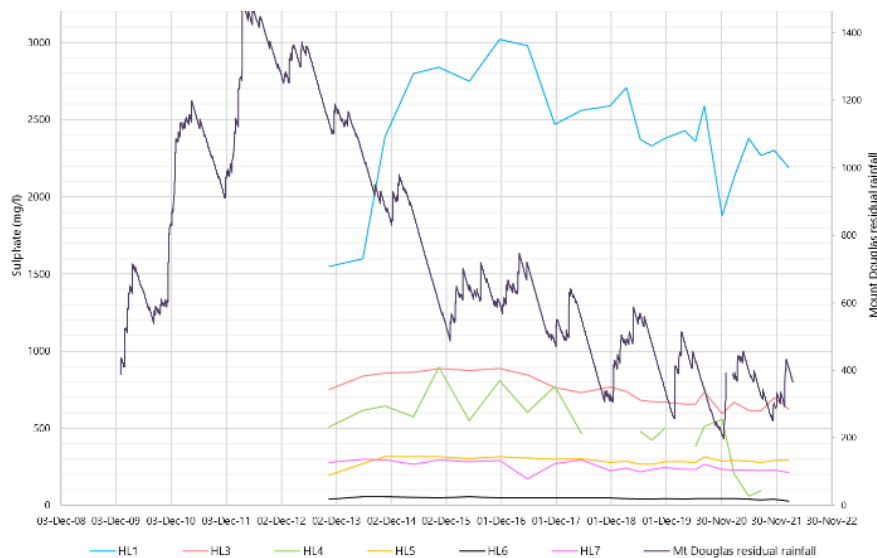
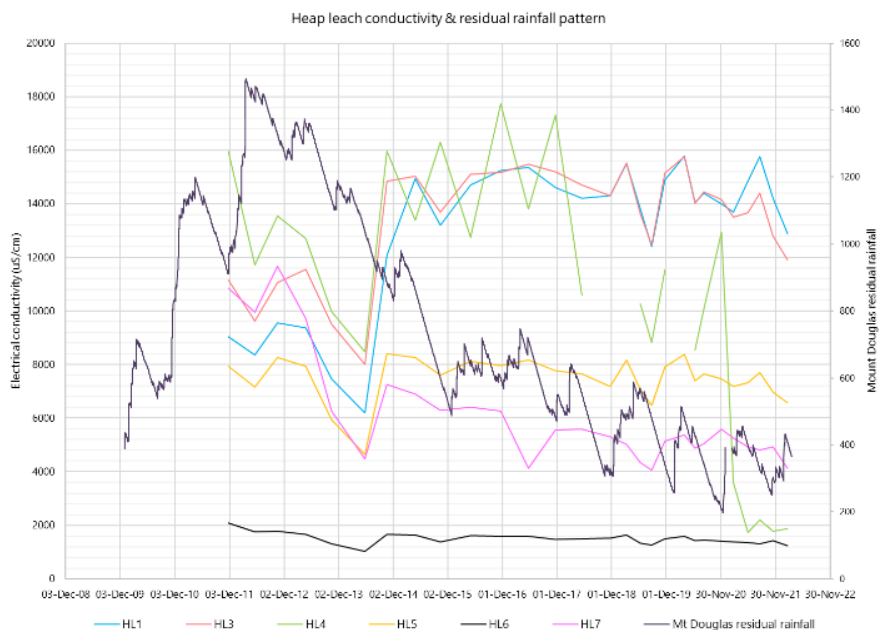


Figure 35 - Groundwater water quality for heap leach

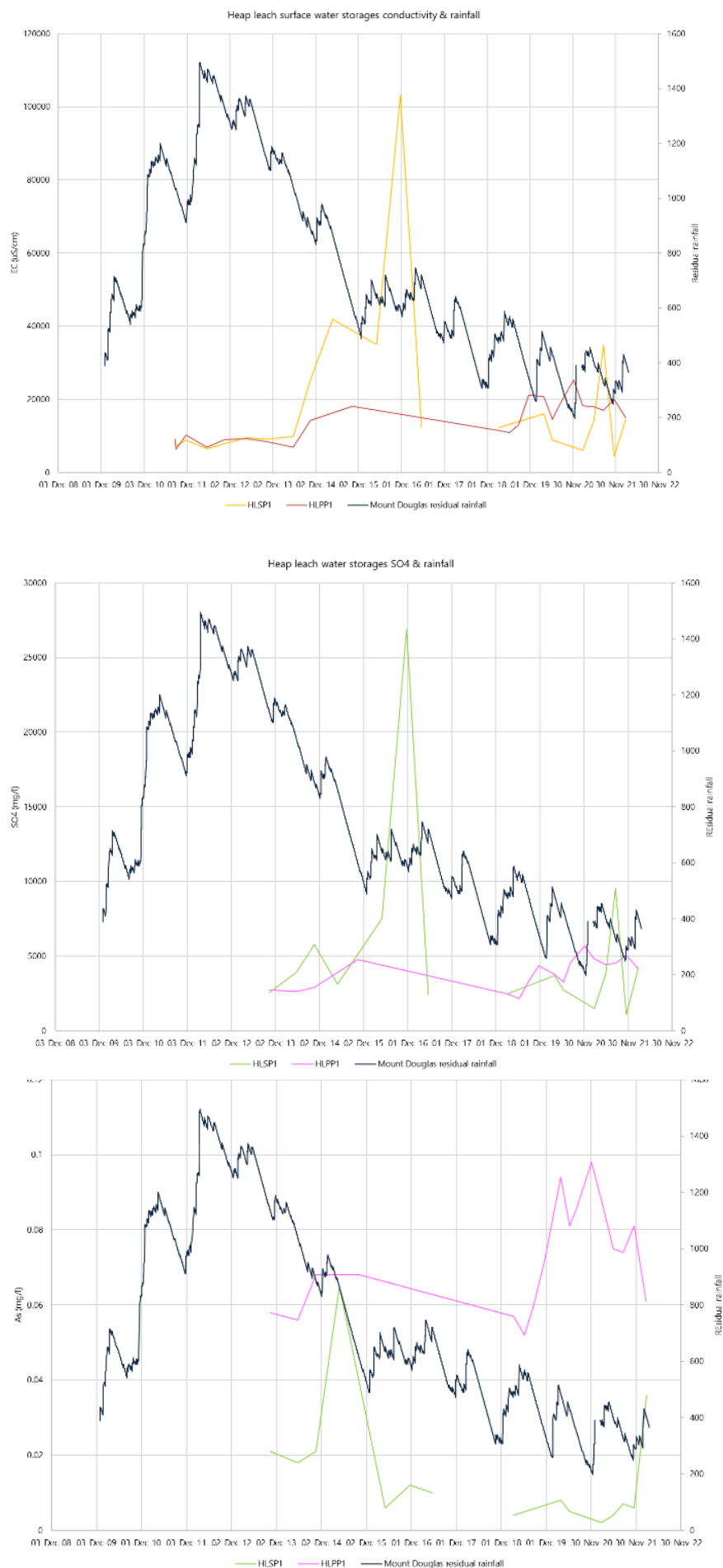


Figure 36 - Surface water quality at heap leach



8.3 Generalised system model

A working system model of the Yandan heap leach landform is in Figure 37. Key features of the model include:

- Placement of the heap leach across a low-level surface divide.
- Crystalline volcanic rocks or siltstone underlying the facility strongly restricts groundwater seepage.
- Limited evidence of groundwater change, with most wells declining in levels and improved water quality. There is some elevated salinity at HL3, but at no other locations (including upgradient), and no other elevated concentrations of other quality parameters may be natural. Therefore, additional wells are recommended for closure.
- Elevated salinity and sulphate in the leach pond and adjacent embankment water are scheduled to be removed and rehabilitated as part of the closure.

On the basis of removing the leachate pond and associated materials as part of the closure, following rehabilitation there is a low potential for environmental harm from surface water release. In addition, groundwater monitoring shows that groundwater quality is stable and indicates the heap leach has a low potential for environmental harm with a water-shedding cover design installation.

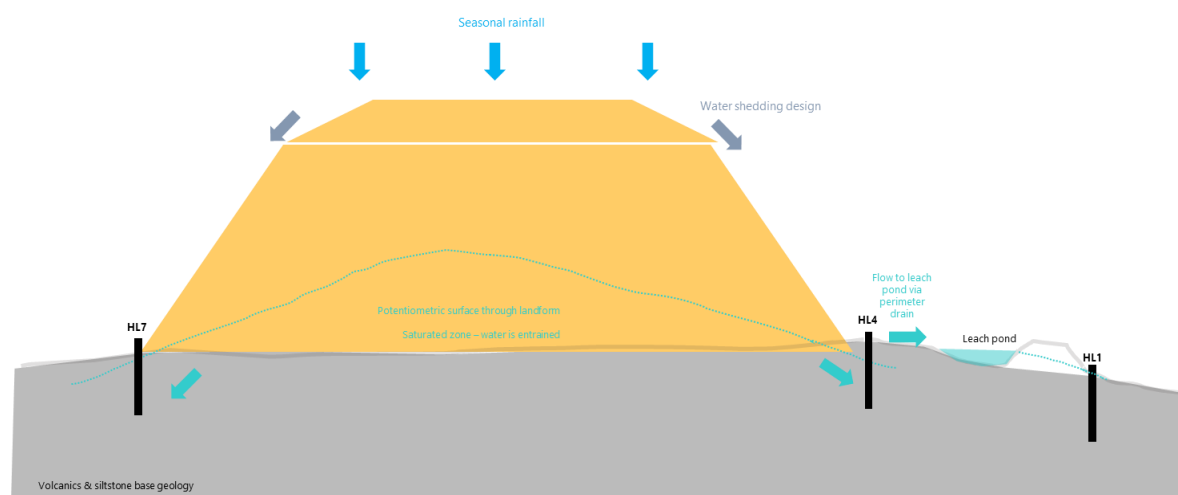


Figure 37 - Schematic of heap leach water system (noting leach pond is planned for removal at closure)

8.4 Risk classification

A review of the Yandan heap leach materials and water performance places the facility in the low to a very low risk category as:

- Low reactive to benign host materials in ARD/AMD/NMD, with low potential for salinity through the addition of salts to the HL (limited compared to the size of the facility).
- Limited to no signs of PAF drainage.
- Groundwater largely reflects benign materials, with quality improving over time and the facility draining.
- Underlying geology is low conductivity.
- Limited seepage to groundwater.

Figure 38 and Figure 39 identify the risk classification in the DES category framework (2019, 2022) for the heap leach landform.



Table 6-1 Risk Category Characteristics

Risk Category	Waste Rock Dumps	Heap Leach Pads	Tailings Storage Facilities
High Select this category if the waste structure has one or more of the following characteristics:	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm	Potentially acid forming material (PAF) Other highly reactive materials including (ARD/AMD/NMD) Observed contaminated seepage capable of causing environmental harm.	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tails materials Requiring composite liners (e.g. HDPE) Embankments > 30 metres high Observed contaminated seepage capable of causing environmental harm.
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end Low strength consolidated tailings land use objectives for the facility Embankments 15 to 30 m high
Low	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD)	Low reactive materials (ARD/AMD/NMD) Moderate to low salinity Moderate strength consolidated tailings Embankments less than 15 m high
Very Low	Benign materials	Benign materials	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments less than 15 m high

Figure 38 - Heap leach risk classification DES 2019

Risk category	Waste rock dumps	Heap leach pads	Tailings storage facilities
High	- Potentially acid forming waste rock materials (PAF). - Other highly reactive materials including (acid rock drainage (ARD) / acid mine drainage (AMD) / neutral mine drainage (NMD)). - Observed contaminated seepage (PAF) capable of causing environmental harm.	- Potentially acid forming heap leach materials (PAF). - Other highly reactive materials including (ARD/AMD/NMD). - Observed contaminated seepage (PAF) capable of causing environmental harm.	- Potentially acid forming tailings materials (PAF). - Other highly reactive materials including (ARD/AMD/NMD). - Poor consolidation and low shear strength tails materials. - Requiring composite liners (e.g. HDPE) - Embankments > 30 metres high. - Observed contaminated seepage (PAF) capable of causing environmental harm.
Medium with low permeability layer	- Waste rock material that could adversely impact on the proposed end land use and/or vegetation function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Significant (non-PAF) seepage capable of causing environmental harm.	- Heap leach materials that could adversely impact on the proposed end land use and/or vegetation eco-function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Significant (non-PAF) seepage capable of causing environmental harm.	- Tailings materials that could impact on the proposed end land use and/or vegetation eco-function if salinity or materials are exposed, e.g., hypersaline / sodic materials, highly dispersive clay materials. - Low strength consolidated tailings embankments 15 to 30 m high.
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Very low	Benign waste rock materials Minor (non-PAF) seepage.	Benign heap leach materials Minor (non-PAF) seepage.	- No likely impacts on the proposed end land use and/or vegetation covers. - Moderate strength consolidated tailings - Embankments less than 15 m high. - Minor (non-PAF) seepage.

Figure 39 - Heap leach risk classification DES 2022



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SeeBuiltEarth 2022a, *Water performance of Yandan Mine landscape at closure March 2022*, released to GBM Resources.

SeeBuiltEarth 2022b, *Additional proposed wells for Yandan: design and locations*, developed for Straits Resources (GBM).





Appendix A – Bore logs



Water bore drilling log

GENERATE LOG ID

Authorisation details

Registered number _____ Development permit number _____

Works reference number _____

RB2S

Log ID # 8743991

SECTION A—LOCATION DETAILS

Name of landholder **Straits Gold Pty Ltd**

Phone No. **0402109833**

SECTION B—BORE COMPLETION DETAILS

Date commenced **07/06/21**

Date completed **7/6/21**

Postal address **22 Bunowang St, Balmoral Qld,**

Postcode **4171**

Real property address **L1, MLG 1096, Yacamunda Rd, Mt Coolon - YANDAN GOLD MINE**

Postcode _____

Real property description Lot _____ Plan _____

or Bore location GPS, latitude _____

Easting **498940**

Longitude _____

Northing **7646310**

Datum _____

SECTION C—DRILLING METHOD

☐ Rotary mud ☐ Cable tool

☐ Auger ☒ Rotary air

☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	From	Location (metres) To
190	0	6
140	6	10

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	Location (metres) To
PVC	150	6.3	0	6
PVC	50	2.4	0	10

SECTION F—CENTRALISERS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	Location (metres) To
PVC	50	1	7	10

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	Location (metres) To
PVC	50	1	7	10

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	Location (metres) To
CEMENT	190	150	0	6
CEMENT	140	50	0	6
BEDNITE	140	50	6	7
3-5MM GRAVEL	140	50	7	10

SECTION I—BORE PURPOSE

SECTION I—PARTICULARS OF STRATA	From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed (thus*)
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial	0	2	brown tuffaceous siltstone weathered	
☐ Urban ☐ Industrial ☐ Other (please specify)	2	3	dark red tuffaceous siltstone weathered	
	3	4	light red tuffaceous siltstone weathered	
	4	7	grey tuffaceous siltstone weathered	
	7	10	light red tuffaceous siltstone weathered	

SECTION J—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

SECTION K—SUB ARTESIAN BORE ON COMPLETION

Conductivity ($\mu S/cm$)	pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION

Depth to standing water level from ground level	Depth to pump suction or bottom of drill stem

SECTION M—ARTESIAN BORE ON COMPLETION

Type of test used	Estimated supply (litres/second)	Duration of test (hours)	Drawdown level from surface (metres)
☐ Air ☐ Bail ☐ Pump			

SECTION N—REMARKS

Shut-in pressure (KPa)	Free flow (litres/second)	Temperature ($^{\circ}C$)

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.
--

SECTION P—TRAINING

Driller T. Schonknecht Driller's licence no. 3538
Trainee Gavin Fox Driller's licence no. _____
Signature of driller _____ Date 17/06/21
Contractor Eagle Drilling NO

WZF136 v5

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2021

Collection of information on this form is authorised by section 983L of the *Water Act 2000* and will be used by the Department for the purpose of processing your application. For these purposes disclosure to other third parties may be required by or of the Department. The information may be searchable, disclosed to and used by the public as allowed, authorised or required by legislation. A copy of the completed log must be provided to the Department. It is recommended that a copy is also provided to the landholder and a copy retained by the driller.



Water bore drilling log

GENERATE LOG ID

Authorisation details

Registered number _____ Development permit number _____

Works reference number **RB1S**

Log ID # **19599005**

SECTION A—LOCATION DETAILS

Name of landholder **Straits Gold Pty Ltd**

Phone No. **0402109833**

SECTION B—BORE COMPLETION DETAILS
Date commenced **06/06/21**

Postal address **22 Bunawang st, Balmoral, Qld**

Postcode **4171**

Date completed **6/6/21**

Real property address **L1, MLG 1096, Yacamunda, Mt Coolon**

Postcode _____

SECTION C—DRILLING METHOD
☐ Rotary mud ☐ Cable tool

Real property description Lot _____ Plan _____

or Bore location GPS, latitude _____

longitude _____

Postcode _____

Datum _____

☐ Auger ☒ Rotary air

Easting **500400**

Northing **7645740**

Zone _____

SECTION D—HOLE SIZE

Diameter (mm)	From	Location (metres) To
190	0	6
140	6	10

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial ☐ Other (please specify) _____

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	150	6.3	0	6
PVC	50	2.4	0	10

SECTION J—PARTICULARS OF STRATA
From (metres) **0** To (metres) **10**
Strata description
(use more than one line if required)
light grey/brown lufuacolis siltstone weathered

Conductivity ($\mu S/cm$) _____ pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level _____
Depth to pump suction or bottom of drill stem _____

SECTION F—CENTRALISERS

Type	Location (metres) From	To

Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply (litres/second) _____ Duration of test (hours) _____
Drawdown level from surface (metres) _____

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	50	1	7	10

SECTION M—ARTESIAN BORE ON COMPLETION
Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____

SECTION N—REMARKS
DRY
Cement block and stand pipe installed

SECTION H—CEMENTING/GRAVEL PACK/ ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	190	150	0	6
CEMENT	140	50	0	6
BEDNITE	140	50	6	7
3-5MMGRAVEL	140	50	7	10

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.

Driller **T. Schonknecht** Driller's licence no. **3538**

Trainee driller **Gavin Fox** Driller's licence no. _____

Signature of driller *[Signature]* Date **17/06/21**

Contractor **Eagle Drilling NO**

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GENERATE LOG ID

2021

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Water bore drilling log

GENERATE LOG ID

Authorisation details

Registered number _____ Development permit number _____

Works reference number _____

TD7D

Log ID # 67350433

SECTION A—LOCATION DETAILS

Name of landholder **Straits Gold Pty Ltd**

Phone No. **+6189316 9100**

Postal address **22 Bunawang st, Balmoral, Qld**

Postcode **0402109833**

Real property address **L1 MLG 1096, Yacamunda rd, Mt Coolon - YANDAN GOLD MINE**

Postcode **4171**

Real property description Lot _____ Plan _____

or Bore location GPS. Latitude _____

Longitude _____

Easting **499436**

Northing **7646581**

Datum _____

Zone _____

SECTION B—BORE COMPLETION DETAILS

Date commenced **06/06/21**

Date completed **6/6/21**

SECTION C—DRILLING METHOD

☐ Rotary mud ☐ Cable tool

☐ Auger ☒ Rotary air

☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	From	Location (metres) To
190	0	6
140	6	30

SECTION I—BORE PURPOSE

☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) _____

SECTION I—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed (thus*)
0	18	red/brown tuffaceous silstone weathered	
18	30	light grey tuffaceous silstone weathered	

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	150	6.3	0	6
PVC	50	2.4	0	30

Conductivity (uS/cm)	pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION	Depth to standing water level from ground level (metres)	Depth to pump suction or bottom of drill stem (metres)

SECTION F—CENTRAUSERS

Type	Location (metres) From	To

surface		(metres)
(litres/second)	(hours)	

Estimated supply (litres/second)	Shut-in pressure (kPa)	Free flow (litres/second)	Temperature (°C)

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	50	1	24	30

SECTION M—ARTESIAN BORE ON COMPLETION	Shut-in pressure (kPa)	Free flow (litres/second)	Temperature (°C)

SECTION N—REMARKS

Damp 18m Cement block and stand pipe installed

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.

Driller **T. Schonknecht** Driller's licence no. **3538**

Trainee driller **Gavin Fox** Driller's licence no. _____

Signature of driller **[Signature]** Date **17/06/21**

Contractor **Eagle Drilling NO**



Water bore drilling log

GENERATE LOG ID

Authorisation details

Registered number _____ Development permit number _____

Works reference number _____

Log ID # 82209549

SECTION A—LOCATION DETAILS

Name of landholder **Straits Gold Pty Ltd**

Phone No. 0402109833

Postal address **22 Bunawang St Balmoral, Qld**

Postcode 4171

Real property address **L1, MLG 1096, Yacamunda Rd, Mt Coolon - YANDAN GOLD MINE**

Postcode _____

Real property description Lot _____ Plan _____

or Bore location GPS. Latitude _____

Longitude _____

Easting 499436

Northing 7646581

Datum _____

Zone _____

SECTION D—HOLE SIZE

Diameter (mm)	From	Location (metres) To
190	0	6
140	6	10

SECTION I—BORE PURPOSE

☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial ☐ Other (please specify) _____

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	150	6.3	0	6
PVC	50	2.4	0	10

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed (thick*)
0	10	red/brown lutite/siltstone weathered	

SECTION L—SUB ARTESIAN BORE ON COMPLETION

Conductivity (µS/cm)	pH
Depth to standing water level from ground level	Depth to pump suction or bottom of drill stem

SECTION F—CENTRALISERS

Type	Location (metres) From	To

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	50	1	7	10

SECTION M—ARTESIAN BORE ON COMPLETION

Shut-in pressure (kPa)	Free flow (litres/second)	Temperature (°C)

SECTION N—REMARKS

Dry Cement block and stand pipe installed

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.

Driller **T. Schonknecht** Driller's licence no. **3538**

Trainee driller **Gavin Fox** Driller's licence no. _____

Signature of driller *[Signature]* Date **17/06/21**

Contractor **Eagle Drilling NO**



Water bore drilling log

GENERATE LOG ID

Authorisation details

Registered number _____ Development permit number _____

Works reference number _____

TD6D

Log ID # 64542614

SECTION A—LOCATION DETAILS

Name of landholder **Straits Gold Pty Ltd**

Phone No. **0402109833**

Postal address **22 Bunowang st, Balmoral Qld**

Postcode **4171**

Real property address **L1, MLG 1096, Yamacamunda Rd, Mt Coolon - YANDAN GOLD MINE**

Postcode _____

Real property description Lot _____ Plan _____

or Bore location GPS, latitude _____

Easting **501010**

Longitude _____

Northing **7647150**

Datum _____

Zone _____

SECTION B—BORE COMPLETION DETAILS

Date commenced **07/06/21**

Date completed **7/6/21**

SECTION C—DRILLING METHOD

☐ Rotary mud ☐ Cable tool

☐ Auger ☒ Rotary air

☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	From	Location (metres) To
190	0	6
140	6	30

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial ☐ Other (please specify) _____

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed (thus*)
0	1	dark red/brown lutiteaceous siltstone weathered	
1	15	grey/brown lutiteaceous siltstone weathered	
15	30	oil white lutiteaceous siltstone weathered	

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To
PVC	150	6.3	0	6
PVC	50	2.4	0	30

Conductivity (µS/cm)	pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION	Depth to standing water level from ground level	Depth to pump suction or bottom of drill stem

SECTION F—CENTRALISERS

Type	Location (metres) From	To

Type of test used	☐ Air ☐ Bail ☐ Pump	
Estimated supply (litres/second)	Duration of test (hours)	Drawdown level from surface (metres)

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To
PVC	50	1	24	30

SECTION M—ARTESIAN BORE ON COMPLETION	Shut-in pressure (kPa)	Free flow (litres/second)	Temperature (°C)

SECTION N—REMARKS
Damp 22m Cement block and stand pipe installed

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To
CEMENT	190	150	0	6
CEMENT	140	50	0	6
SAMPLE	140	50	6	21
BEDRITE	140	50	21	23
3.5MM GRAVEL	140	50	23	30

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.

Driller **T. Schonknecht** Driller's licence no. **3538**

Trainee driller **Gavin Fox** Driller's licence no. _____

Signature of driller Date **17/06/21**

Contractor **Eagle Drilling NO**

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Water bore drilling log

GENERATE LOG ID

Authorisation details

Registered number _____ Development permit number _____

Works reference number **TD6S**

Log ID # **37064923**

SECTION A—LOCATION DETAILS

Name of landholder **Straits Gold Pty Ltd**

Phone No. **0402109833**

SECTION B—BORE COMPLETION DETAILS

Postal address **22 Bunowang St, Balmoral, Qld 4171**

Postcode **4171**

Date commenced **7/6/21**

Real property address **L1, MLG 1096, Yacamunda Rd, Mt Coolon - YANDAN GOLD MINE**

Postcode _____

SECTION C—DRILLING METHOD

Real property description Lot _____ Plan _____

or Bore location GPS. Latitude _____

Longitude _____

Datum _____

Easting **501010**

Northing **7647150**

Zone _____

☐ Rotary mud ☐ Cable tool
☐ Auger ☒ Rotary air
☐ Other _____

SECTION D—HOLE SIZE

Diameter (mm)	From	Location (metres) To
190	0	6
140	6	10

SECTION E—CASING DETAILS

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	Location (metres) To
PVC	150	6.3	0	6
PVC	50	2.4	0	10

SECTION F—CENTRALISERS

Type	Location (metres) From	Location (metres) To

SECTION G—PERFORATIONS/SLOTS/SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	Location (metres) To
PVC	50	1	7	10

SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS

Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	Location (metres) To
CEMENT	190	150	0	6
CEMENT	140	50	0	6
BEDNITE	140	50	7	7
3-5MM GRAVEL	140	50	7	10

SECTION I—BORE PURPOSE

☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) _____

SECTION J—PARTICULARS OF STRATA

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed (thus*)
0	1	dark red tuffaceous siltstone weathered reddish brown tuffaceous siltstone weathered	

SECTION K—WATER BEARING BEDS

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

Conductivity ($\mu S/cm$) _____

pH _____

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level _____ (metres)
Depth to pump suction or bottom of drill stem _____ (metres)

Type of test used ☐ Air ☐ Bail ☐ Pump
Estimated supply _____ (litres/second)
Duration of test _____ (hours)
Drawdown level from surface _____ (metres)

SECTION M—ARTESIAN BORE ON COMPLETION

Shut-in pressure _____ (kPa)
Free flow _____ (litres/second)
Temperature _____ (°C)

SECTION N—REMARKS

Dry
Cement block and stand pipe installed

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.

Driller **T. Schonknecht** Driller's licence no. **3538**

Trainee **M. Burton** Driller's licence no. _____
Signature of driller _____ Date **17/06/21**

Contractor **Eagle Drilling NO**

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Water bore drilling log

GENERATE LOG ID

Authorisation details

Registered number _____ Development permit number _____

Works reference number

RB2D

Log ID # 82400066

SECTION A—LOCATION DETAILS

Name of landholder **Straits Gold Pty Ltd**

Phone No. **0402109833**

SECTION B—BORE COMPLETION DETAILS

Date commenced **07/06/21**

Postal address **22 Bunawang St, Balmoral, Qld**

Postcode **4171**

Real property address **L1, MLG 1096, Yacamunda Rd, Mt Coolon - Yandan Gold Mine**

Postcode _____

Real property description Lot _____ Plan _____

or Bore location GPS, latitude

Easting **498940**

Longitude

Northing **7646310**

Datum _____

Zone _____

SECTION C—DRILLING METHOD

☐ Rotary mud ☐ Cable tool

☐ Auger ☒ Rotary air

SECTION D—HOLE SIZE

Diameter (mm)	From	Location (metres) To
190	0	6
140	6	30

SECTION I—BORE PURPOSE
☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial
☐ Urban ☐ Industrial Other (please specify) _____

SECTION J—PARTICULARS OF STRATA

Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	Location (metres) To
PVC	150	6.3	0	6
PVC	50	2.4	0	30

From (metres)	To (metres)	Strata description (use more than one line if required)	Water bed (thus*)
0	2	brown lutiteaceous siltstone weathered	
2	7	grey/brown lutiteaceous siltstone weathered	
7	10	light red lutiteaceous siltstone weathered	
10	17	off white lutiteaceous siltstone weathered	
17	30	grey, lutiteaceous siltstone weathered	

Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)

Conductivity (µS/cm)

pH

SECTION L—SUB ARTESIAN BORE ON COMPLETION
Depth to standing water level from ground level _____ (metres)
Depth to pump suction or bottom of drill stem _____ (metres)

SECTION F—CENTRALISERS

Type	Location (metres) From	Location (metres) To
------	------------------------	----------------------

SECTION G—PERFORATIONS/ SLOTS/ SCREENS

Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	Location (metres) To
PVC	50	1	24	30

SECTION N—REMARKS

Damp 17m
Cement block and stand pipe installed

SECTION O—CERTIFICATION

I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.

Driller **T. Schonknecht** Driller's licence no. **3538**

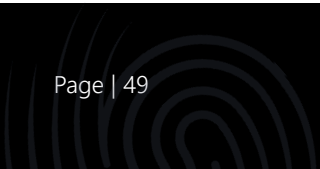
Trainee driller **Gavin Fox** Driller's licence no. _____

Signature of driller **[Signature]** Date **17/06/21**

Contractor **Eagle Drilling NO**



Appendix B – Bore field sampling records





GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd

BORE ID: HL7

Project: Mt Coolon Regional

Site: Yandan

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	498144	7645427	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	11.66
Total Depth of Bore (m BRP)	≈ 25
Depth of Water in Column (m)	13.4
Casing Height (Ref Point) (m AGL)	0.46
Approximate casing volume (L)	26.8
Approximate 3 x casing volume (L)	80.4
Approximate Total Volume Purged (L)	105

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 7.20	7.86	4333

SAMPLING RECORD

Samples Taken?	<u>YES</u> / NO	Bailer
Duplicate Samples Taken?	YES / <u>NO</u>	
Samples Filtered?	<u>YES</u> / NO for <u>Metals</u> / Other:	
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>	
Water Quality Meter type:	YSI Pro Plus	
Purging Method:	Submersible Pump / <u>Compressed Air</u> / Bailer	
Sampling Method:	Submersible Pump / <u>Bailer</u>	

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Dirty & Silty at End



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd

BORE ID: HL6 *

Project: Mt Coolon Regional

Site: Yandan

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	498321	7645358	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	12.99
Total Depth of Bore (m BRP)	≈ 25
Depth of Water in Column (m)	12
Casing Height (Ref Point) (m AGL)	0.47
Approximate casing volume (L)	24
Approximate 3 x casing volume (L)	72
Approximate Total Volume Purged (L)	40 L b Dry.

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 7.45	7.61	1256

SAMPLING RECORD

Samples Taken?	YES / NO	Bailer
Duplicate Samples Taken?	YES / NO	
Samples Filtered?	YES / NO for Metals / Other: As	
Filter Method:	0.45mm filter & syringe / Stericup	
Water Quality Meter type:	YSI Pro Plus	
Purging Method:	Submersible Pump / Compressed Air / Bailer	
Sampling Method:	Submersible Pump / Bailer	

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
1	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water is Silty Brown at End.
Light Sulphur Smead



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: HL5

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	498358	7645103	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	12.84
Total Depth of Bore (m BRP)	≈ 24
Depth of Water in Column (m)	11.16
Casing Height (Ref Point) (m AGL)	0.49
Approximate casing volume (L)	22.32
Approximate 3 x casing volume (L)	67
Approximate Total Volume Purged (L)	80L

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 8:15	7.08	7540

SAMPLING RECORD

Samples Taken?	YES / NO (Bailer)
Duplicate Samples Taken?	YES / NO
Samples Filtered?	YES / NO for Metals/Other:
Filter Method:	0.45mm filter & syringe / Stericup
Water Quality Meter type:	YSI Pro Plus
Purging Method:	Submersible Pump / Compressed Air / Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Clear Then Dirty
with Sand & Gravel - suspended



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: HL3

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	498284	7644837	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	10.45
Total Depth of Bore (m BRP)	≈ 18
Depth of Water in Column (m)	7.5
Casing Height (Ref Point) (m AGL)	0.52
Approximate casing volume (L)	15
Approximate 3 x casing volume (L)	45
Approximate Total Volume Purged (L)	40 to Dry

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 8:30	7.12	14210

SAMPLING RECORD

Samples Taken?	YES / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / <u>NO</u>
Samples Filtered?	<u>YES</u> / NO for Metals/Other:
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air / Bailer</u>

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Brown + Silty.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: HL1

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	498094	7644870	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	8.51
Total Depth of Bore (m BRP)	≈ 18
Depth of Water in Column (m)	9.5
Casing Height (Ref Point) (m AGL)	0.43
Approximate casing volume (L)	19
Approximate 3 x casing volume (L)	52
Approximate Total Volume Purged (L)	100L

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 9.15	7.17	15350

SAMPLING RECORD

Samples Taken?	YES / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / NO
Samples Filtered?	YES / NO for Metals / Other:
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	Submersible Pump / <u>Compressed Air / Bailer</u>

DUPLICATE

No.	Container:
1,1	250 MI Green Plastic
2,2	60 MI Plastic Metals (Total & Dissolved)
1,1	60 MI Blue & White Cyanide pre treatment
1,1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water stayed clear throughout.
Good Supply.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: HL4 *

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	497913	7644964	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	<u>11.85</u>
Total Depth of Bore (m BRP)	<u>≈ 17</u>
Depth of Water in Column (m)	<u>5</u>
Casing Height (Ref Point) (m AGL)	0.64
Approximate casing volume (L)	<u>10</u>
Approximate 3 x casing volume (L)	<u>30</u>
Approximate Total Volume Purged (L)	<u>20 L to Dry</u>

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
<u>12/6/22 9:35</u>	<u>8.10</u>	<u>14360</u>

SAMPLING RECORD

Samples Taken?	<u>YES</u> / NO <u>Bailer</u>
Duplicate Samples Taken?	<u>YES</u> / NO
Samples Filtered?	<u>YES</u> / NO for Metals/Other: <u>(B)</u>
Filter Method:	<u>0.45mm filter & syringe / Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air / Bailer</u>

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
1	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Chocolate Brown & Silky Water
Also Supply



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: SH3 *

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	497420	7644570	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	6.85
Total Depth of Bore (m BRP)	≈ 19
Depth of Water in Column (m)	12.2
Casing Height (Ref Point) (m AGL)	0.46
Approximate casing volume (L)	24.4
Approximate 3 x casing volume (L)	73.2
Approximate Total Volume Purged (L)	75

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 10:00	6.65	35 467

SAMPLING RECORD

Samples Taken?	YES / NO	Bailer
Duplicate Samples Taken?	YES / NO	
Samples Filtered?	YES / NO for Metals/Other	AS
Filter Method:	0.45mm filter & syringe / Stericup	
Water Quality Meter type:	YSI Pro Plus	
Purging Method:	Submersible Pump / Compressed Air / Bailer	

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
1	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water dark brown silty.
numerous Pine Tree roots.
High Sulphur smell.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: WSB2

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	497587	7646598	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	<u>1.94</u>
Total Depth of Bore (m BRP)	<u>≈ 24</u>
Depth of Water in Column (m)	<u>22</u>
Casing Height (Ref Point) (m AGL)	0.52
Approximate casing volume (L)	<u>44</u>
Approximate 3 x casing volume (L)	<u>132</u>
Approximate Total Volume Purged (L)	<u>80 L</u>

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
<u>12/6/22</u> <u>10:30</u>	<u>6.56</u>	<u>33060</u>

SAMPLING RECORD

Samples Taken?	<u>YES</u> / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / <u>NO</u>
Samples Filtered?	<u>YES</u> / NO for Metals / Other:
Filter Method:	<u>0.45mm filter & syringe / Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air / Bailer</u>

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Approx 2kg of weathered formation blown out of bottom of hole possibly due to casing parting or problems with end cap (if any).
note - Casing is below standard

with a wall thickness of only about 1mm. water chocolate brown



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: WSB1

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	497597	7646463	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	0.54
Total Depth of Bore (m BRP)	
Depth of Water in Column (m)	
Casing Height (Ref Point) (m AGL)	0.28
Approximate casing volume (L)	
Approximate 3 x casing volume (L)	
Approximate Total Volume Purged (L)	250L

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 11:00	7.83	9291

SAMPLING RECORD

Samples Taken?	YES / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / <u>NO</u>
Samples Filtered?	YES / NO for <u>Metals</u> / Other:
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump</u> / <u>Compressed Air</u> / Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Clear



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: RB1D

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	500393	7645748	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	15-72
Total Depth of Bore (m BRP)	30
Depth of Water in Column (m)	14-25
Casing Height (Ref Point) (m AGL)	.59
Approximate casing volume (L)	28-5
Approximate 3 x casing volume (L)	85.5
Approximate Total Volume Purged (L)	55 L to Dry.

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 12:30	8.05	3115

SAMPLING RECORD

Samples Taken?	<u>YES</u> / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / <u>NO</u>
Samples Filtered?	<u>YES</u> / NO for Metals/Other:
Filter Method:	<u>0.45mm filter & syringe / Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air / Bailer</u>

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Brown & Silty.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd

Project: Mt Coolon Regional

Site: Yandan

BORE ID: RB1S

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	500384	7645748	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	DRY at 10.45m
Total Depth of Bore (m BRP)	10
Depth of Water in Column (m)	
Casing Height (Ref Point) (m AGL)	0.58
Approximate casing volume (L)	
Approximate 3 x casing volume (L)	
Approximate Total Volume Purged (L)	

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (μ S/CM)

SAMPLING RECORD

Samples Taken?	YES / NO	Bailer
Duplicate Samples Taken?	YES / NO	
Samples Filtered?	YES / NO for Metals/Other:	
Filter Method:	0.45mm filter & syringe / Stericup	
Water Quality Meter type:	YSI Pro Plus	
Purging Method:	Submersible Pump / Compressed Air / Bailer	

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: TD7D

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	499438	7646579	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	2.06
Total Depth of Bore (m BRP)	30
Depth of Water in Column (m)	28
Casing Height (Ref Point) (m AGL)	.59
Approximate casing volume (L)	56
Approximate 3 x casing volume (L)	168
Approximate Total Volume Purged (L)	70L TO DRY.

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 12:55	7.60	5595

SAMPLING RECORD

Samples Taken?	YES / NO Bailer
Duplicate Samples Taken?	YES / NO
Samples Filtered?	YES / NO for Metals/Other:
Filter Method:	0.45mm filter & syringe / Stericup
Water Quality Meter type:	YSI Pro Plus
Purging Method:	Submersible Pump / Compressed Air / Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

First 50L Clear
Lasts 20L still Dry - Dark Grey Silty.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd

BORE ID: TD7S

Project: Mt Coolon Regional

Site: Yandan

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	499429	7646580	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	<u>2.11</u>
Total Depth of Bore (m BRP)	10
Depth of Water in Column (m)	<u>8</u>
Casing Height (Ref Point) (m AGL)	0.63
Approximate casing volume (L)	<u>16</u>
Approximate 3 x casing volume (L)	<u>58</u>
Approximate Total Volume Purged (L)	<u>30L to Dry</u>

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
<u>12/6/22</u> <u>13:15</u>	<u>7.70</u>	<u>4520</u>

SAMPLING RECORD

Samples Taken?	<u>YES</u> / NO <u>Bailer</u>
Duplicate Samples Taken?	<u>YES</u> / <u>NO</u>
Samples Filtered?	<u>YES</u> / NO for <u>Metals</u> / Other:
Filter Method:	<u>0.45mm filter & syringe / Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air / Bailer</u>

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd

BORE ID: TD6D

Project: Mt Coolon Regional

Site: Yandan

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	500928	7647097	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	2.36
Total Depth of Bore (m BRP)	30
Depth of Water in Column (m)	28
Casing Height (Ref Point) (m AGL)	0.53
Approximate casing volume (L)	56
Approximate 3 x casing volume (L)	168
Approximate Total Volume Purged (L)	170

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 13:40	7.05	349 80 80
		34980

SAMPLING RECORD

Samples Taken?	YES / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / NO
Samples Filtered?	YES / NO for <u>Metals</u> / Other:
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	Submersible Pump / <u>Compressed Air / Bailer</u>

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Slightly Dirty
Good Supply



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: TD6S

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	500928	7647107	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	2.32
Total Depth of Bore (m BRP)	10
Depth of Water in Column (m)	7.7
Casing Height (Ref Point) (m AGL)	0.60
Approximate casing volume (L)	16
Approximate 3 x casing volume (L)	48
Approximate Total Volume Purged (L)	23 to Dry

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 13:55	7.25	42340

SAMPLING RECORD

Samples Taken?	YES / NO (Bailer)
Duplicate Samples Taken?	YES / NO
Samples Filtered?	YES / NO for Metals / Other:
Filter Method:	0.45mm filter & syringe / Stericup
Water Quality Meter type:	YSI Pro Plus
Purging Method:	Submersible Pump / Compressed Air / Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Dirty
No Supply



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd

BORE ID: TD5

Project: Mt Coolon Regional

Site: Yandan

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	500548	7647882	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	2.49
Total Depth of Bore (m BRP)	≈ 17
Depth of Water in Column (m)	14.5
Casing Height (Ref Point) (m AGL)	0.49
Approximate casing volume (L)	29
Approximate 3 x casing volume (L)	78
Approximate Total Volume Purged (L)	406 to Day

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 14:25	7.84	3540

SAMPLING RECORD

Samples Taken?	YES / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / <u>NO</u>
Samples Filtered?	<u>YES</u> / NO for Metals/Other:
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air / Bailer</u>

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Ten & Silty No Supply.

Pond water surrounding bore.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd

BORE ID: TD4 *

Project: Mt Coolon Regional

Site: Yandan

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	499616	7647434	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	12.66
Total Depth of Bore (m BRP)	≈ 16
Depth of Water in Column (m)	3.4
Casing Height (Ref Point) (m AGL)	0.53
Approximate casing volume (L)	6.8
Approximate 3 x casing volume (L)	20.4
Approximate Total Volume Purged (L)	7.7

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 14:45	7.23	22216

SAMPLING RECORD

Samples Taken?	YES / NO (Bailer)
Duplicate Samples Taken?	YES / NO
Samples Filtered?	YES / NO for Metals/Other: AS
Filter Method:	0.45mm filter & syringe / Stericup
Water Quality Meter type:	YSI Pro Plus
Purging Method:	Submersible Pump / Compressed Air / Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
1	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Insufficient water to satisfactorily
purge

No supply.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: TD3

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	499333	7646724	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	5.62
Total Depth of Bore (m BRP)	≈ 15
Depth of Water in Column (m)	9.4
Casing Height (Ref Point) (m AGL)	0.49
Approximate casing volume (L)	19
Approximate 3 x casing volume (L)	57
Approximate Total Volume Purged (L)	200 to 250

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (μS/CM)
12/6/22 15-10	7.39	6130

SAMPLING RECORD

Samples Taken?	YES / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / <u>NO</u>
Samples Filtered?	YES / NO for <u>Metals</u> / Other:
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	Submersible Pump / <u>Compressed Air</u> / Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Water Clear Throughout.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: RB2D

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	498946	7646305	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	6.07.
Total Depth of Bore (m BRP)	30
Depth of Water in Column (m)	24
Casing Height (Ref Point) (m AGL)	0.55
Approximate casing volume (L)	48
Approximate 3 x casing volume (L)	144
Approximate Total Volume Purged (L)	110 to Dry.

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 15:25	7.02	7261

SAMPLING RECORD

Samples Taken?	YES / NO <u>Bailer</u>
Duplicate Samples Taken?	YES / <u>NO</u>
Samples Filtered?	YES / NO for Metals/Other:
Filter Method:	0.45mm filter & syringe / <u>Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air</u> Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Slightly Grey.



GROUNDWATER SAMPLING RECORD FORM FIELD PARAMETER MEASUREMENTS

Client: GBM Resources Ltd
Project: Mt Coolon Regional
Site: Yandan

BORE ID: RB2S

Date of Purging/SWL: 10/6/22

Location:	Eastings	Northings	Zone
GDA94	498936	7646308	55K

Sampled By: A. McDonald

GROUNDWATER BORE DATA

Diameter of Casing (mm)	50
Standing Water Level (m BRP)	6.12
Total Depth of Bore (m BRP)	10
Depth of Water in Column (m)	4
Casing Height (Ref Point) (m AGL)	.61
Approximate casing volume (L)	8
Approximate 3 x casing volume (L)	24
Approximate Total Volume Purged (L)	16 L to Dry

FIELD ANALYSES

DATE/TIME SAMPLED	pH	EC (µS/CM)
12/6/22 15:45	7.74	1962

SAMPLING RECORD

Samples Taken?	<u>YES</u> / NO <u>Bailer</u>
Duplicate Samples Taken?	<u>YES</u> / NO
Samples Filtered?	<u>YES</u> / NO for <u>Metals</u> / Other:
Filter Method:	<u>0.45mm filter & syringe / Stericup</u>
Water Quality Meter type:	YSI Pro Plus
Purging Method:	<u>Submersible Pump / Compressed Air</u> / Bailer

No.	Container:
1	250 MI Green Plastic
2	60 MI Plastic Metals (Total & Dissolved)
1	60 MI Blue & White Cyanide pre treatment
1	60 MI Blue WAD Cyanide
	60ml plastic (Moroon & White) As and Se Speciation (Field Filtered)

COMMENTS

Dirty Gray

18 MAR
2024



21°18' S
146°58' E

Main Pit and Suttor River characterisation

Yandan Mine

March 2024



Document history and status

Version	Date	Released by	To	Status
1.0	18 March 2024	Tania Kennedy, SBE	Tom Cooney GBM Resources Natasha Jensen, AARC Hollie Dick, AARC	Draft
1.1	28 March 2024	Tania Kennedy, SBE	Tom Cooney GBM Resources Natasha Jensen, AARC Hollie Dick, AARC	Final

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1 Introduction

1.1 Background

GBM Resources Limited is currently in transitional Progressive Rehabilitation and Closure Planning (PRCP) with the Department of Environment, Science and Innovation (DESI) for the Yandan mine, located in north Queensland, approximately 40km west of Mount Coolon.

Yandan is a historical mine site with several legacy landforms, including two (2) pit voids (including the Main pit adjacent to the Suttor River and the focus of this assessment), a tailings storage landform, and a heap leach landform. With the initial Yandan PRCP submission early in 2022, subsequently DESI (former DES) issued a request for information (RFI) listing several queries around water-related risk and requests to clarify closure outcomes.

As supplements to SBE (2022), additional packages of work are prepared to respond to the RFI around water-related risk, structured as three separate (3) technical updates:

- Yandan site flooding profile characterisation.
- Main pit and Suttor River water system characterisation (this report).
- Yandan groundwater and conceptual model characterisation.

1.2 Changes since the initial PRCP submission

As core additional information for PRCP and a related program for Estimated Rehabilitation Calculation (ERC), in 2023, GBM embarked on a robust data collection program to obtain representative and seasonal information, including additional groundwater wells and water storage monitoring.

The additional data and information obtained over the past year provide a material step change in representative data, understanding, and technical confidence of the Yandan water systems. Information and data gained to date are incorporated into this updated assessment. The updated network provides closure monitoring capacity, offering an excellent site management tool in the future.

1.3 Intent of this work package

This report captures, expands, and assesses the nature and relationship of Main Pit and Suttor River as closure landforms, including:

- Setting of Main Pit and Suttor River, including layout and relationship, monitoring network, geology, climate (past, present and future), flooding profile, and nature of closure landforms.
- Water quality characterisation of Main Pit lake, Suttor River and groundwater.
- Water quantity and levels characterisation of Main Pit and groundwater.
- Updated conceptual model of Main Pit and how the water system works.
- Closure outcomes for Main Pit and risk assessment.
- Key findings and recommendations for any further work or review required.

1.4 Scope

The scope of this work is to satisfy reasonable requirements of the *Progressive rehabilitation and closure plans* (Queensland Government 2023) for a historical site under transitional provisions by addressing and resolving key questions in the 2023 Request for Information (RFI). A map of RFI to responses is provided in Appendix A. This update report should supplement SBE (2022) for overall site characterisation and further information.



2 Water systems of the Main Pit and Suttor River

2.1 Setting and landscape

The Yandan project and the Main Pit landform lay within a sub-catchment of the mid-Suttor River in the greater Burdekin catchment of central to northern Queensland, approximately 240km inland from Mackay and 60km upstream of Burdekin Dam near Townsville (Figure 1).

The Suttor River drains through broad valleys, dotted with isolated low-elevation hills often marked by rocky outcrops. Drainage lines are generally low gradient and highly ephemeral, flowing only after significant rainfall. The river forms broad and braided alluvial flood plains across much of the basin (Figure 2).



Figure 1 - Yandan site location within the Burdekin Basin



Figure 2 - Suttor River near the Yandan site



2.2 Main pit and Suttor River geometry

2.2.1 Surface water framework

The Yandan site (ML1095 and ML1096) lies across and east of the Suttor River in low hills, covering an area of 25.5 km². The total catchment area extends outside the lease (67.6 km²), with two main drainage lines through the site: Yandan Creek and Sandy Creek (Figure 3).

Yandan Creek comprises a reasonable catchment upstream of the Main Pit, mostly outside the mine infrastructure. The creek drains the southern extent of the lease and flows either around or through the Main Pit into the Suttor. Yandan Creek also feeds shallow borrow pit pond just south of the Main Pit (Figure 4). The other drainage line, Sandy Creek, drains the project's north to the Suttor River and does not interact with the Main Pit.

For the pit itself, the Main Pit was mined during the 1990s and, following rehabilitation, has existed as a large, permanent water body since 1999 (Figure 5). Water levels within the pit would appear to remain relatively consistent based on vegetation and water marks around the pit.

Figure 7 shows a detailed map of the main pit with water flow directions, contours and monitoring locations. The Main Pit lies within 80m of the Suttor River, and a dry Suttor River bed lays at 164-165.5mAHD). By design, the water in the Main Pit is expected to connect to the Suttor River and Yandan Creek during minor flood events once river levels reach 169mAHD (SRK 1999b & c, Chapman and Dwyer 1999). Connection and mixing of Main Pit lake water and Suttor River/Yandan Creek water occurs via designed spillways at the northwest and southeast of the pit (for frequency of flooding please refer to Section 2.8). The schematic in Figure 8 shows the relative levels of the main pit, river, and spillways.

The Main pit does not overflow independently given its very limited catchment: the total catchment directly flowing to the pit without flow from Yandan Creek or Suttor River is 59 hectares. Pit lake water remains contained until the flow height from either the Suttor or Yandan Creek is sufficient to flow into the pit lake and undergo mixing before any pit lake water leaves the site.

2.2.2 Main Pit as a closure landform

The pit lake has a surface area of 32.2 hectares, a maximum storage capacity of 6.78Gt gigalitres (based on the final pit void), and typically ranges from 35-60m depth. The pit area is largely encircled by a levee constructed during operation to an elevation of 172-175mAHD (Figure 7), except for the spillways allowing river water in and out of the pit lake.

A stable, sustainable and self-renewing pit lake NUMA was a preferred closure outcome to perpetually contain reactive materials in remnant pit walls and waste rock to actively protect water quality and is consistent with the Project EA. This closure outcome underwent environment assessment at the time and was approved circa 2000.

Studies such as SRK (1999a, b & c), Chapman and Dwyer (1999), R&D (1999) and HLA (2001) assessed how this outcome could be achieved and the potential impacts. The final design and delivery of rehabilitation (SRK 1999c) involved stockpiling waste materials into the lower reaches of the pit void below 160mAHD: why now, the minimum water levels to be maintained within the pit for containment remains as 160mAHD. Figure 9 shows a map of materials storage from the time of rehabilitation. Rehabilitation involved establishing a 0.3m soil cover across all stockpiles and applying lime at 1kg/m².

In the time since, the Main Pit has remained at water levels above 160mAHD, containing stored waste materials and reactive pit walls below water. This design strategy is consistent with contemporary guidelines such as the Leading Practice Sustainable Development Program for the Mining Industry guideline 'Preventing acid and metalliferous drainage' (DISR & DFAT 2016).

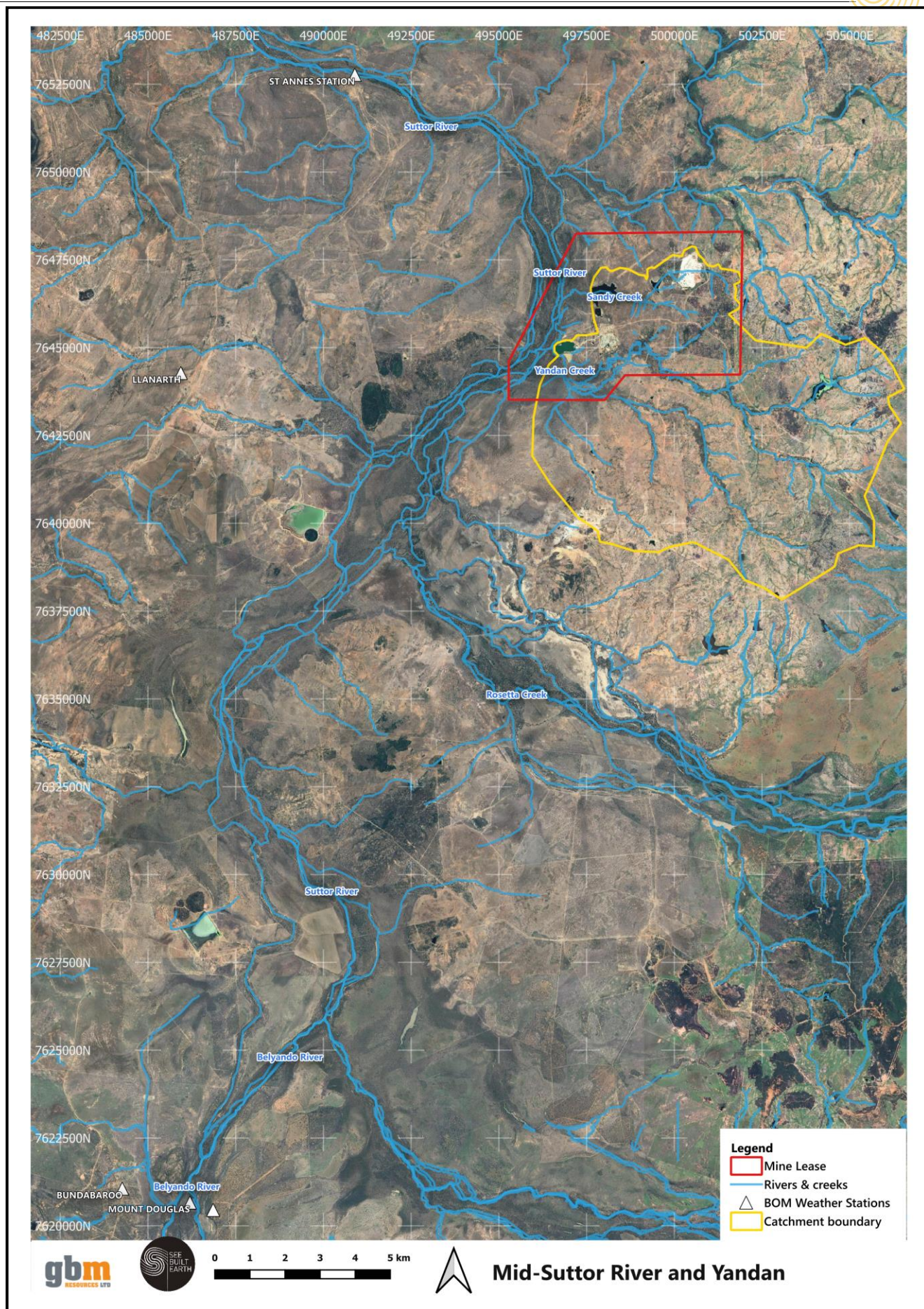


Figure 3 – Yandan mine lease, catchment, Sutor River and weather stations



Figure 4 – View of borrow pit pond looking west on Yandan Creek with levee



Figure 5 – View of Main Pit from northwest looking south east



Figure 6 – View of Main Pit northwest spillway

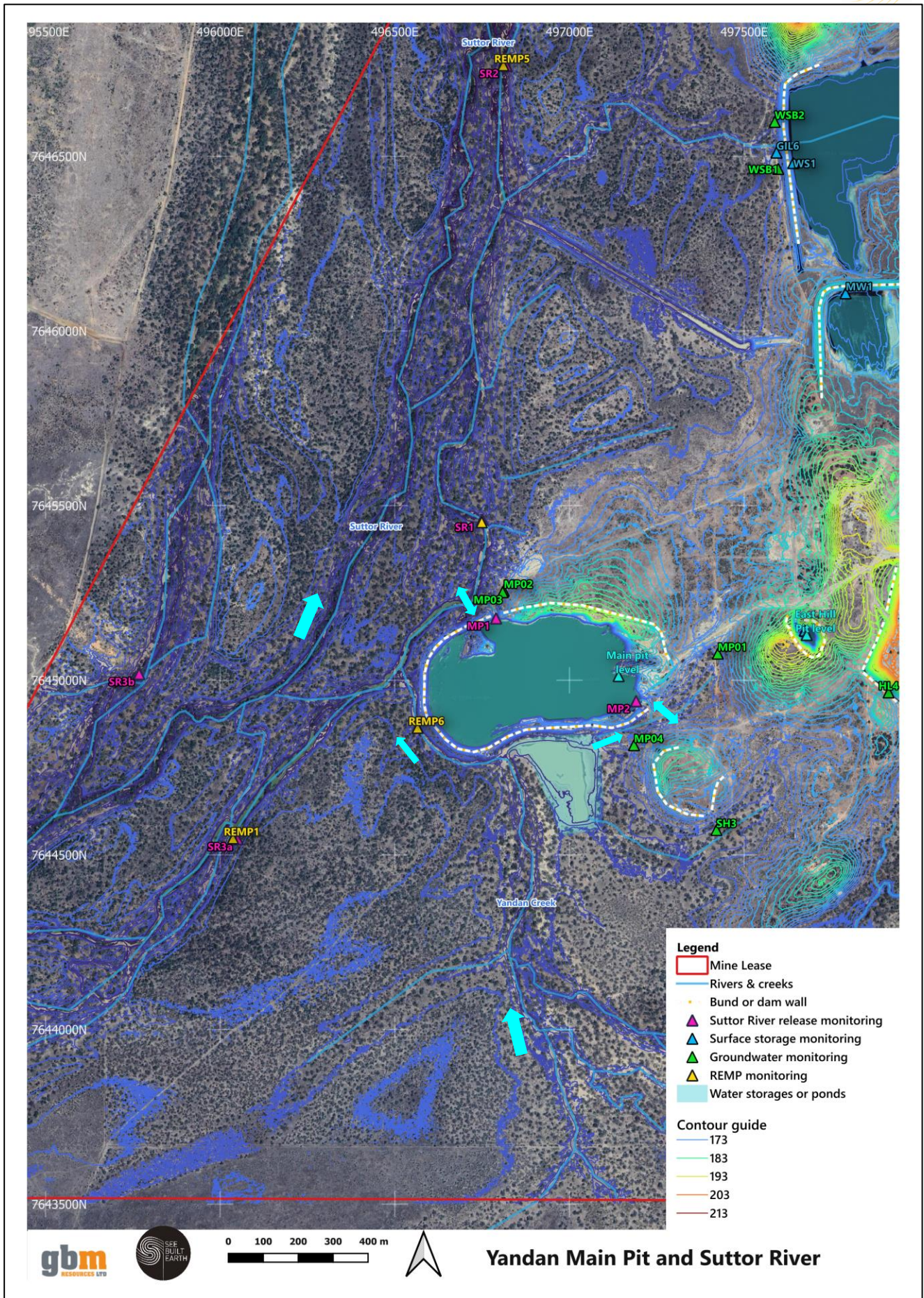


Figure 7 - Main Pit and Sutter River with contours and monitoring network showing direction of flow

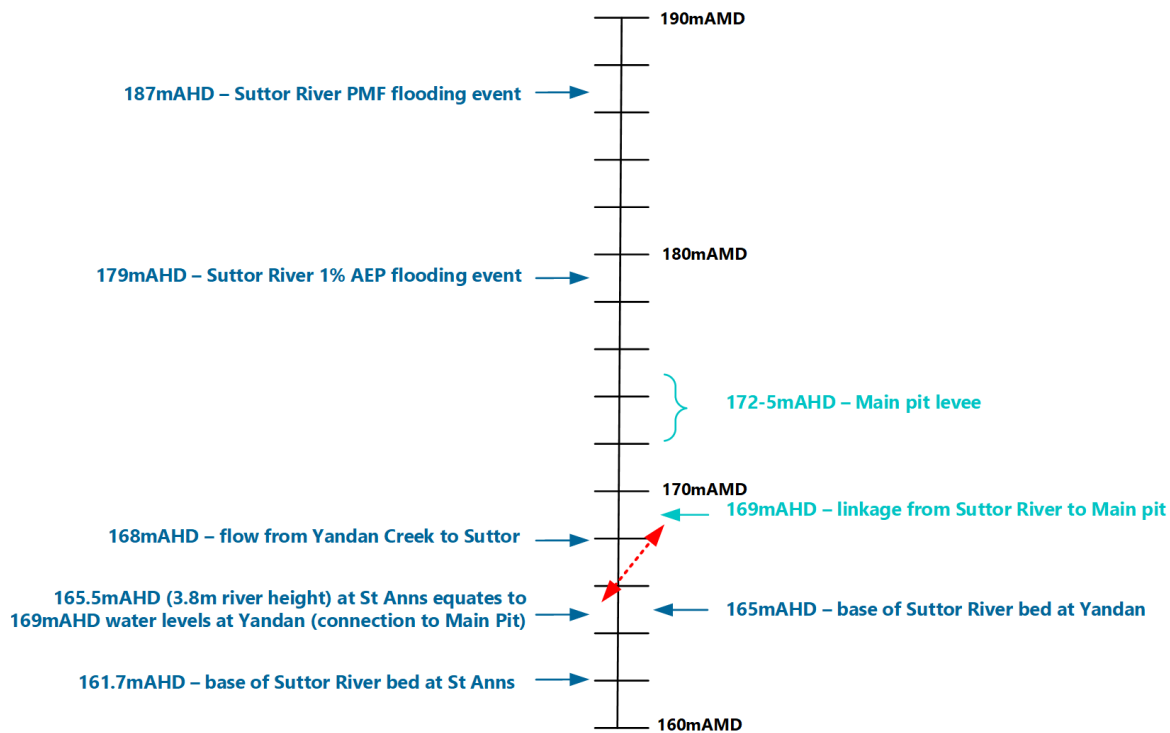


Figure 8 - Elevation profile of Yandan site and Suttor River

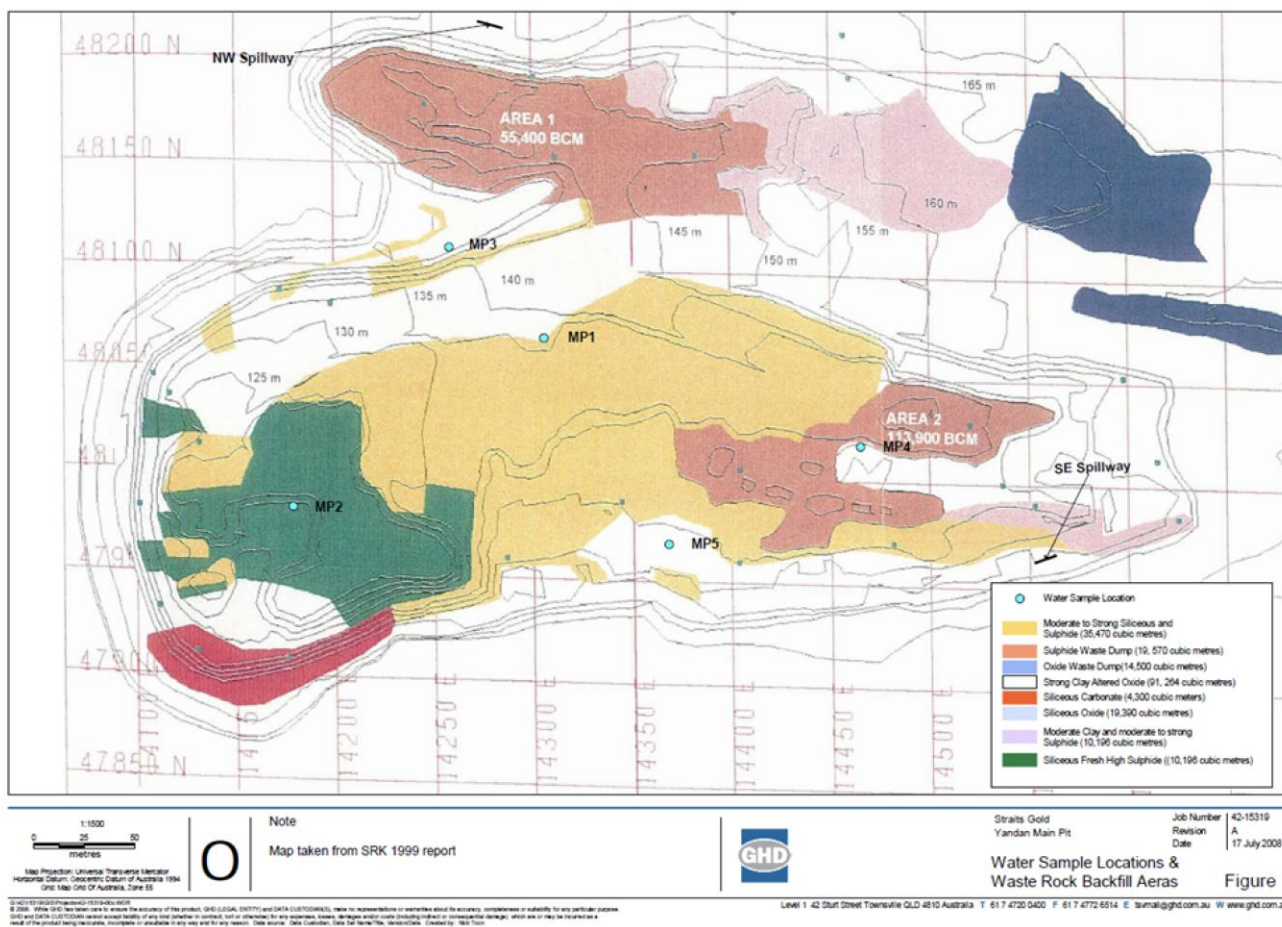


Figure 9 - Reactive waste storage (SRK 1999b,c)





2.3 Monitoring network and program

Main Pit has an established monitoring network and program across rainfall, streamflow, stream and receiving and pit water quality. Additional monitoring infrastructure was installed during 2023/4 to increase water system understanding, namely:

- Installation of a pit water level logger into the Main Pit Lake.
- Construction of 4 wells around the Main Pit to gain groundwater knowledge.

Table 1 below summarises all monitoring, with locations shown in Figure 7 (note that weather station locations are shown in Figure 3).

Table 1 - Monitoring network for Main Pit and Suttor River

	Site ID	Details
Rainfall, stream flow and quality (BOM site) Flow since 1976, EC since 2007, rainfall since 1913	Mount Douglas 120310A	Upgradient from the Yandan site on Suttor/Belyando River, 26.6km south It is also called the 'Suttor River at Gregory Development Road.'
	St Anns 120303A	Downgradient from Yandan site on Suttor River, 9.7km northwest
Pit water storage Ongoing since 2013	MP1	Pit lake near the western spillway, sampled across multiple depths
	MP2	Pit lake near the eastern spillway, sampled across multiple depths
Groundwater Installed early 2024, single monitoring event, except SH3 installed in 2013 (multiple monitoring events)	MP01	Upgradient of Main Pit, between East Hill Pit and Main Pit
	MP02/MP03 nested site	Near the western spillway, between Main Pit and Suttor River
	MP04	Southeast of Main Pit, between South Hill Pit and Main Pit and near the Yandan Creek drainage line
	SH3	Southeast of the rehabilitated South Hill Pit
Surface water & receiving environment Various since 2011, up to 8 connection events monitored	SR3a REMP1	Background – upgradient of Yandan site on Suttor River
	SR3b	Background – upgradient of the Yandan site on Yandan Creek
	REMP2	Background – upgradient of the Yandan site on Sandy Creek
	SR4 REMP3	Background - upgradient of mining landforms on Yandan Creek
	REMP6	Background - Yandan Creek on diversion around Main Pit
	SR1 REMP4	Down-gradient - immediately downstream of Yandan pit and spillway
	SR2 REMP5	Downgradient - downstream of the Yandan site and Sandy Creek
	REMP7	Mid-Yandan Creek - downstream of drainage from Heap Leach
Level logger Installed 12 th May 2023	Main pit logger	Continuous water level transducer and logger installed into pit lake



2.4 Nature of climate and net water balance

2.4.1 Net water balance

Yandan sits in a sub-tropical to semi-arid savannah climate, with mild, dry winters and hot summers, which can be very dry or wet. The area frequently experiences extended dry periods and drought but can also deposit large, intense rain depths in short timeframes in downpours or tropical low systems. Rainfall averages around 545mm/year (Table 2) but can vary from 220 to 1,200mm (BOM 2024). Evaporation potential is higher, with averages between 1,800 to 2,300mm/year. The deficit between rainfall and evaporation creates a strong deficit (highly net negative) in the water balance for the Yandan site and Main Pit.

Table 2- Evaporation and rainfall rates for the Mount Coolon area (BOM 2024)

Station	J	F	M	A	M	J	J	A	S	O	N	D	Average/ day	Total/ year
Evaporation														
Moranbah Water Treatment	8	7.4	6.8	5.7	4.3	3.5	3.7	4.9	6.6	8	8.5	8.5	6.3	2,306
Collinsville Post Office	6.2	5.7	5.2	4.4	3.5	2.9	3.2	4.1	5.3	6.5	6.9	6.9	5.1	1,840
Rainfall														
Mount Douglas	97.7	95.4	49.4	11.0	12.2	16.0	2.5	5.0	1.6	16.0	42.8	64.0		545.9

2.4.2 Climate over the past 100 years

Since the start of records in 1913, rainfall at Yandan has varied across seasons and in longer-term wetter and drier cycles. Figure 10 shows residual rainfall as a deviation to average (relative to average over the entire record), highlighting rainfall variability over time. Analysis of the trends shows seasonal changes in rainfall and broader wet, dry and average cycles over the record. Since its establishment, the main pit has experienced severe damp and dry cycles and multiple extreme dry and minor to moderate flooding events.

Residual rainfall - Mount Douglas

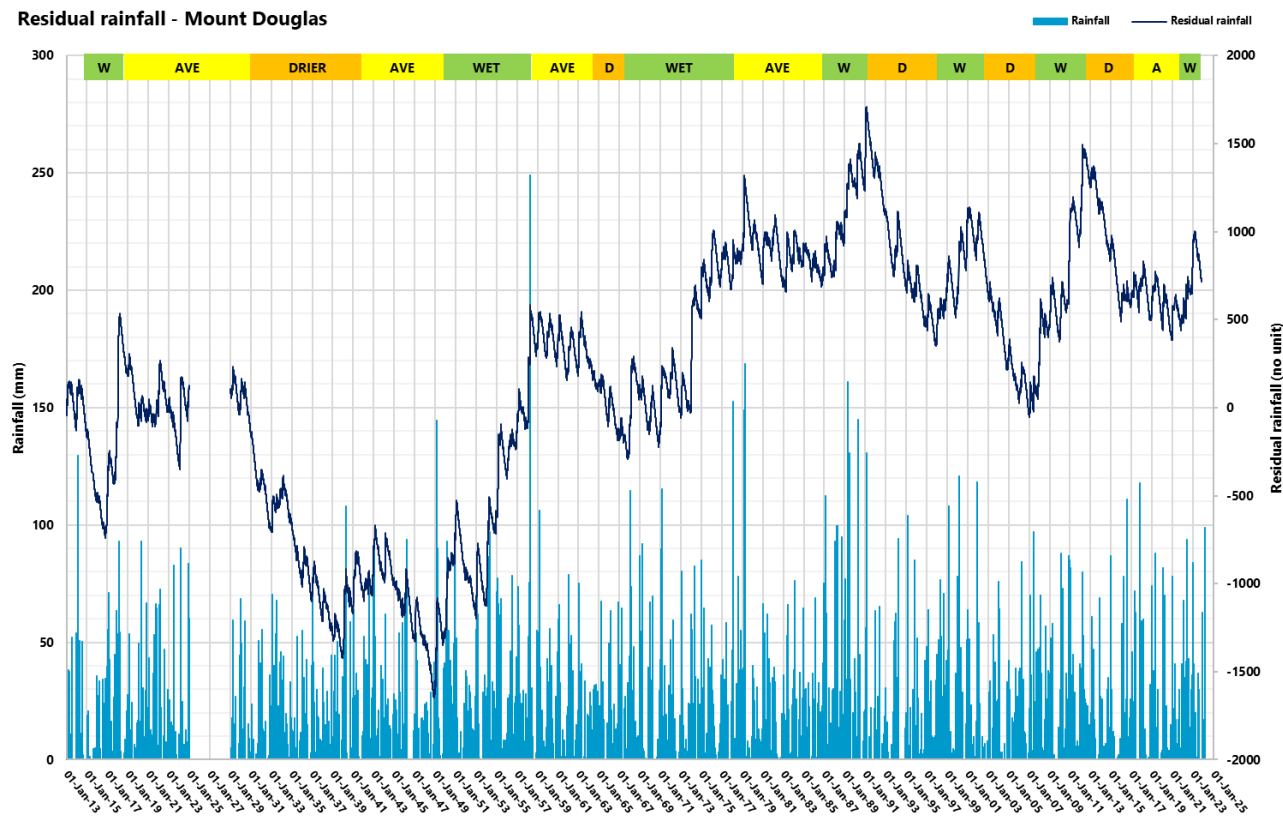


Figure 10 - Residual rainfall - Mount Douglas



2.4.3 Future climate scenarios to 2090

Future scenarios for the climate in evaporation and rainfall are available through the Queensland Government Future Climate (2021a) dashboard for the Mount Coolon region from the present day to 2090. Current climate change modelling anticipates an increase of 20% in average evaporation and a 5-10% reduction in rainfall. At edging bounds, scenarios indicate evaporation may increase by 35-50%, and rainfall either increases or decreases by 25%.

Table 3 presents a summary of expected climate changes as applied to the Main Pit void water balance, including:

- 50th percentile changes for rain & evaporation at 2030, 2050, 2070, 2090
- As a measure of potential extremes bounds, 90th/10th percentile scenarios in 2090:
 - Wetter/lower evaporation.
 - Drier/higher evaporation.

Table 3 - Summary of climate change values

Climate time frame	Selected probability profile	Rainfall (mm/y)	Evaporation (mm/d)
2030	50 th percentile (mean)	18.2	0.36
2050	50 th percentile (mean)	-29.2	0.8
2070	50 th percentile (mean)	-21.9	1.2
2090	50 th percentile (mean)	-10.96	1.6
2090 Wet	90 th /10 th percentile (upper bound)	116.9	0.7
2090 Dry	90 th /10 th percentile (lower bound)	-113.2	3.0

2.5 Geological setting

Gold deposits (and pit areas) of Yandan are classed as low-sulphidation epithermal style mineralisation, formed through a low sulphur hydrothermal process at shallow depths, and generally creates a halo of alteration into the surrounding country rock from the hydrothermal activity.

The Yandan deposits are hosted by Middle Devonian to Lower Carboniferous volcanics, clayey limestones and meta-sediments of the Drummond Basin and St Anns Formation (Carver and Chenoweth 2003; Global Ore Discovery 2021), overlain by alluvial deposits of the Suttor River. The Suttor River alluvials are considered to range up to 30m depth near the Main Pit as an unconsolidated and variable unit atop underlying country rock geology (Forbes 1988).

Figure 11 shows a 3D model of stratigraphy looking northeast across the Main Pit (MP), East Hill (EHP) and South Hill (SHP) Pits. The primary rock material for the Main Pit area is andesite surrounded by metasediments, undifferentiated clastics such as clays, and calcareous (lime-rich and altered) fine siltstones and sandstones. Structures within the Main Pit are well developed (and play a major role in mineralisation), with the Yandan Fault striking east-west along and across the pit's length and several cross-cutting faults identified striking northwest-southeast. Notably, surface drainage lines broadly align to structural alignments or approximate changes in geology. They are likely initially orientated based on differential weathering or elevation changes in the underlying host geology.

To the east, the Yandan block is bounded by the Yandan East Fault (east of East Hill Pit), and on the other side of the fault, geology changes to the Anakie Metamorphics. The Anakie Metamorphics are regional basement and are metamorphosed to mid-greenschist facies, with meta-siltstones and mudstones to phyllites and fine-grained sandstones. Joints and veins through the Anakie are sealed and filled by quartz and silica.

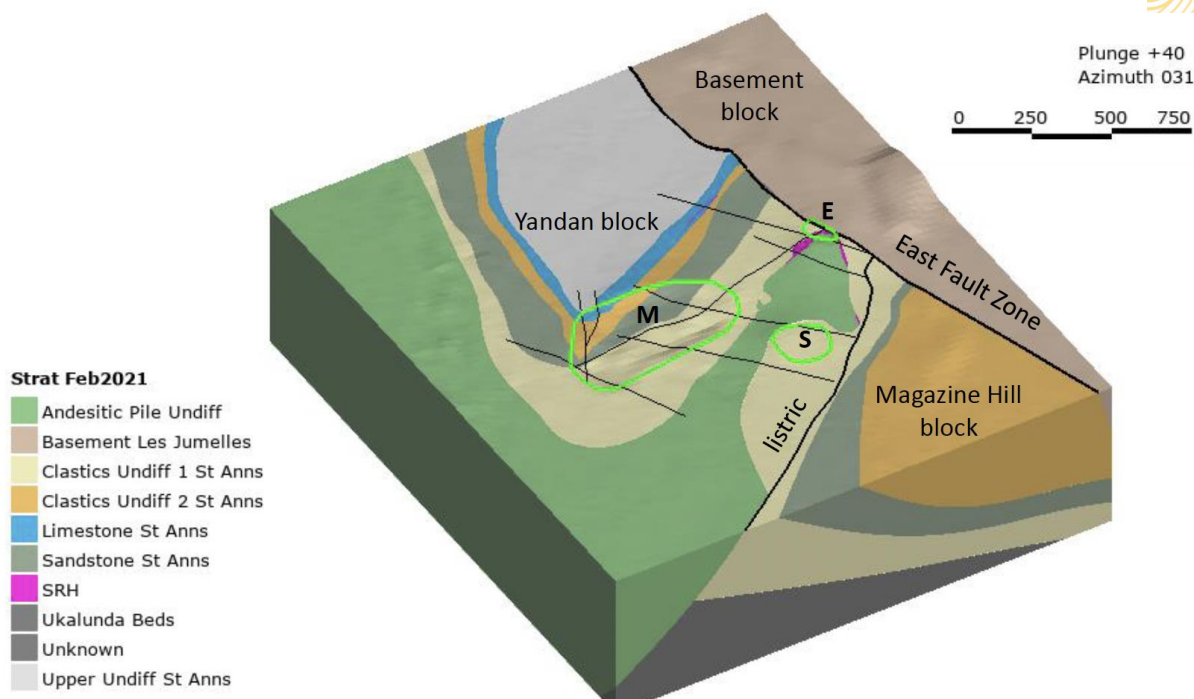


Figure 11 - Main Pit and surrounding area geology, looking southwest (Global Ore Resource 2021)

2.6 Nature of groundwater

2.6.1 General site

Groundwater generally occurs infrequently across the Yandan site, as the nature of the geology constrains its presence and yield. The prevalence of crystalline volcanics hosting mineralised areas and compacted meta-sediments strongly restricts conductivity and effective porosity in most areas.

This is confirmed on the ground by historical experience and recent to current practice: groundwater is rarely developed by local landholders for agriculture unless in alluvials, and both Yandan site drilling and sampling practices find groundwater at low yield yields and predominantly dry conditions. Most wells constructed on site are 'damp' wells (Table 4 and Appendix B), and groundwater sampling often requires two days of recharge after purging to allow enough water to return into the bore column (SBE 2022).

2.6.2 Historical experience and knowledge of groundwater

Groundwater in and around the Main Pit varies slightly from the rest of the site, with the Yandan Fault and alteration of host rocks associated with the deposit. Forbes (1988) historically describes aquifers in the vicinity of the Main Pit as:

- Highly localised groundwater is hosted in fractures as secondary porosity, such as the Yandan Fault and cross-cutting fractures.
- A likely more permeable and intermittent zone associated with mineralisation is the boiling zone, where host geology has been hydrothermally altered.
- Separate alluvial aquifer(s) hosted in the Suttor River alluvium, reaching up to 30m depth.

Historical investigations and pump tests for Main Pit as part of feasibility studies (Forbes 1988, WMC 1998) found the following:

- The boiling zone and Yandan Fault around the Main Pit appear relatively conductive, with pre-project dewatering studies suggesting dewatering demand rates of up to 5,000m³/d through pump test for the overall pit void. Storativity and transmissivities are estimated at 50-1,000m²/d.



- There is no evidence of a connection between the Main Pit and the alluvial aquifers of the Suttor River. While the connection was expected, no response in alluvium was detected during pump tests, and it was determined the mining area was not hydraulically connected to the Suttor River.

Unfortunately, there are no records of dewatering rates during the mining of the Main Pit to confirm if estimated flow rates were realised initially or over time. However, a level of groundwater connection with Main Pit remains likely: SBE (2022) constructed a pit void mass water balance, which indicated a limited but ongoing flow of ~14l/s into the Main Pit lake from groundwater.

2.6.3 New bore monitoring network

Four (4) groundwater wells were constructed in and around the Main Pit in early 2024 to obtain groundwater information around the pit by Eagle Drilling to Australian Bore Construction Standards (2020). Bore locations are shown in Figure 7, bore construction details are summarised in Table 4, and drill logs and photos are available in Appendix B. Previously, only a single well (SH3) was available to the south of the rehabilitated South Pit, and given location lacked specific application to Main Pit.

Bore design targeted interpreted fault locations around Main Pit: between the pit, Suttor River and potential connection to alluvium (MP02/03 as a nested site), potential faults south to Yandan Creek (MP04), and potential Yandan Fault extension between Main Pit and East Hill Pit (MP01). The geology encountered is typical of the St Anns Formation: tightly packed metasediments and cherts, plus carbonaceous and chlorite alteration associated with the mineralisation. MP03 (deeper hole west of MP) intersected disseminated iron sulphide minerals, clay development and low-yield water in a likely structure at a depth (of 38m). Each of the remaining wells (MP01-MP04) encountered very limited groundwater, having damp sections in the hole, but no specific “aquifer” was intersected.

Like historical investigations, there is no evidence of site groundwater and Suttor River alluvium. A conceptual model of the Main Pit and surrounding water systems is discussed in Chapter 5.

Table 4 - Main pit groundwater wells summary

BoreID	Location	Depth	Screen	Water	Geology
MP01	Upgradient from Main Pit, between East Pit	25m	20-23m	Largely dry	Tan to green fine-grained sandstones and siltstones, +/- quartz, some saprolite, calcareous and sericite alteration at depth
MP02/03 Nested site	Alluvium and on fault between Main Pit and Suttor River	11m/41m	6.5-9.5m 32-38m	MP02 Damp at 10m MP03 Water at 38m, low yield	Very fine-grained brown to green siltstone, chert and clay, calcareous alteration. At depth, fine pyrite/marcasite, carbonate veining minor calcite crystals from 17m.
MP04	South of Main pit	14	10-13m	Minor water at 10-11m	Fine-grained, grey to black metasediment of sandstone and siltstone, clay, clay crusts and chert
SH3	South of South Hill Pit	~19m	Unknown	Unknown	Unknown

2.6.4 Groundwater quality

Groundwater quality surrounding Main Pit wells is in the early stages of definition, with four of the five wells only having a single monitoring event, and may be subject to variability over time (note SH3 has been in place and monitored since 2013). A single sampling event is not definitive for groundwater, and the characterisation results discussed below should be considered preliminary only.



Groundwater quality results for Main pit wells are presented as an initial population ternary diagram in Figure 12; general parameters and dissolved metals results in Table 5; charted results in Figure 13. Results show Main Pit groundwater as a similar population, indicating all bores share a common provenance and environment. Electrical conductivity is highly elevated to around seawater density (25,000 to 45,000uS/cm), pH remains neutral, and sulphate levels are moderate.

Salinity is elevated given high chloride levels, commonly occurring in groundwater around areas of past or present to hydrothermal activity (Stumm & Morgan 2013): hydrothermal fluids are chloride-rich brines, which also play a role in chlorite alteration, as seen in bore logs of the new wells (Appendix B). Chloride and salts can also further develop through leaching from rocks when groundwater sits in contact with host rocks for extended periods and slowly leeches salts from the rocks into solution. This is a clear factor for chloride at Yandan given the constrained nature of movement of groundwater in the Yandan setting.

Within the mineralised zone groundwater, metals of arsenic, molybdenum, nickel, manganese and zinc are present at concentrations of <0.05mg/l, and are likely to be naturally occurring given the association to metal enriched orebodies and consistency across the wells. Site MP01 shows elevated manganese, nickel and zinc between Main Pit and East Hill Pit, site MP04 on the south side of Main Pit also has elevated manganese. SH3, to the south of East Hill pit, returns elevated arsenic. Zinc is slightly higher at 0.15-0.2mg/l. Aluminium, chromium, lead, and selenium are generally undetected or near the detection limit; cadmium and copper are at low levels or often undetected.

These results support the conceptual model developed for the Project in 2022 (SBE), including the lack of connection to Suttor River: there is no detectable presence of elevated metals or salinity in the pit lake or in the Suttor River in the 25 years since the water cover has been established. Further review will be required as more information becomes available.

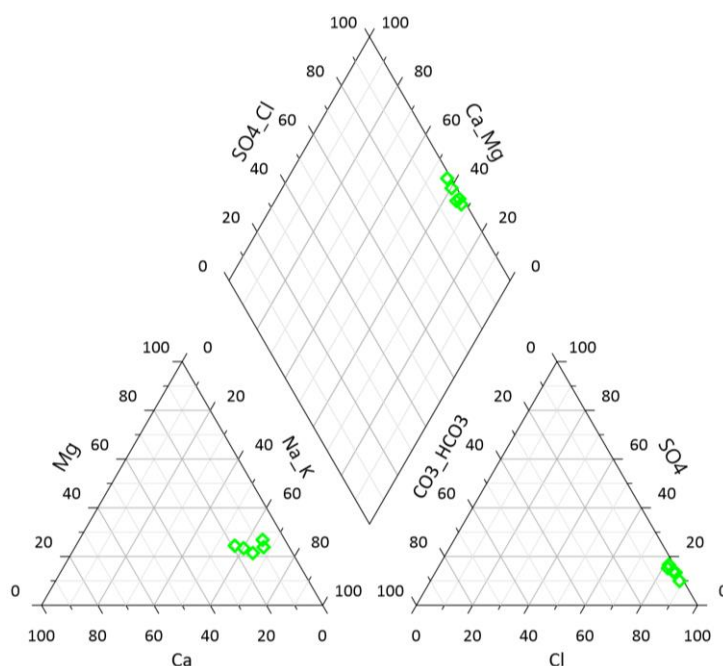


Figure 12 – Main pit groundwater populations

Table 5 - Groundwater quality of Main Pit bore (first sampling event only)

BHID	Date	pH	EC	SO4	Al	As	Cd	Cr	Cu	Pb	Mn	Mo	Ni	Se	Zn
			µs/cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
SH3	22-Jan-24	6.66	44,666	3,240		0.022	0.0009		-0.005	-0.005		0.006		-0.05	0.045
MP01	05-Feb-24	7.47	29,200	2,670	-0.01	0.002	0.0003	-0.001	0.003	0.001	6.61	0.034	0.028	-0.01	0.165
MP02	05-Feb-24	7.08	34,700	2,590	-0.05	-0.005	-0.0005	-0.005	-0.005	-0.005	0.323	-0.005	-0.005	-0.05	0.076
MP03	05-Feb-24	7.12	26,600	1,400	0.01	0.005	-0.0001	-0.001	0.001	-0.001	1.05	0.001	0.004	-0.01	0.062
MP04	05-Feb-24	7.21	24,600	2,000	-0.01	0.017	0.0003	-0.001	0.001	-0.001	0.873	0.004	0.013	-0.01	0.188

Note: a negative result indicates a lab result of not detected

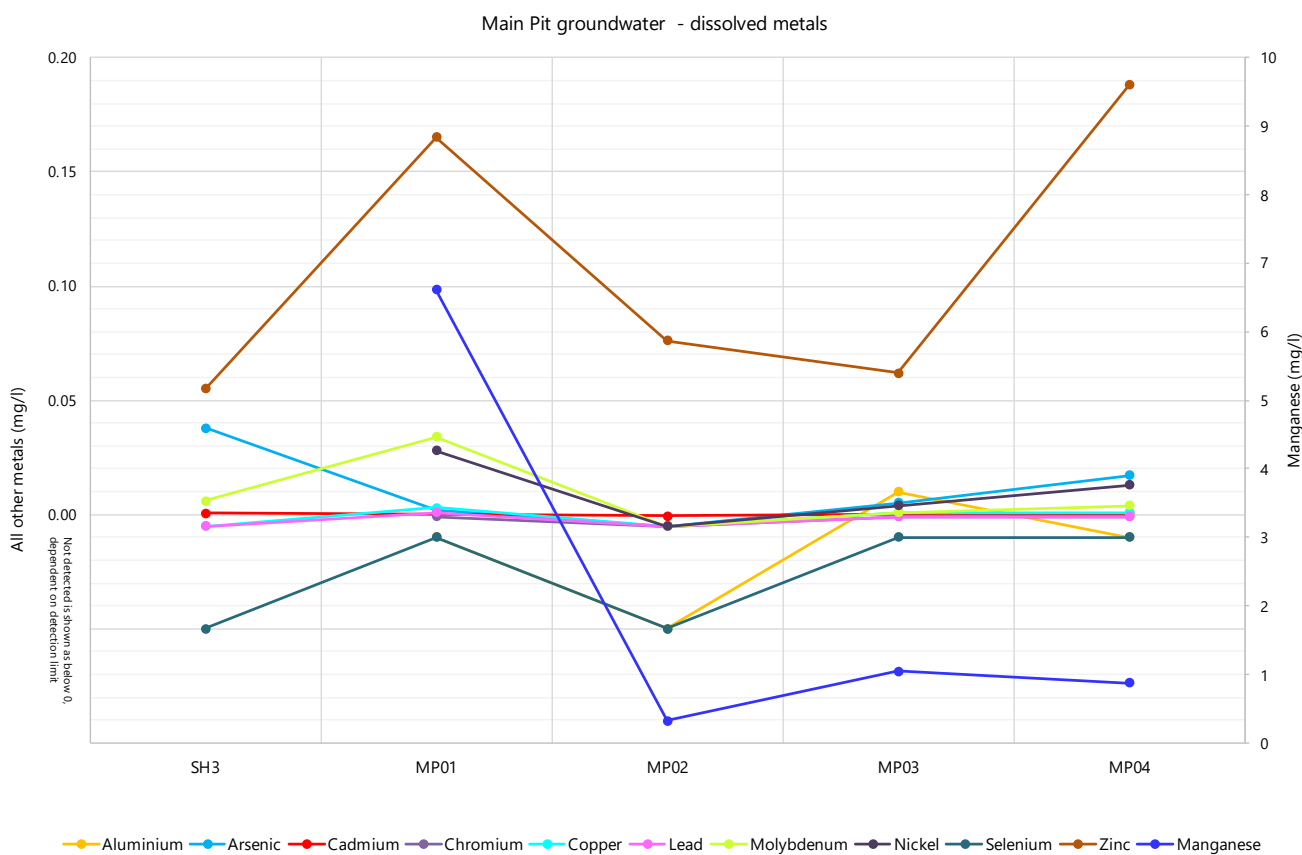
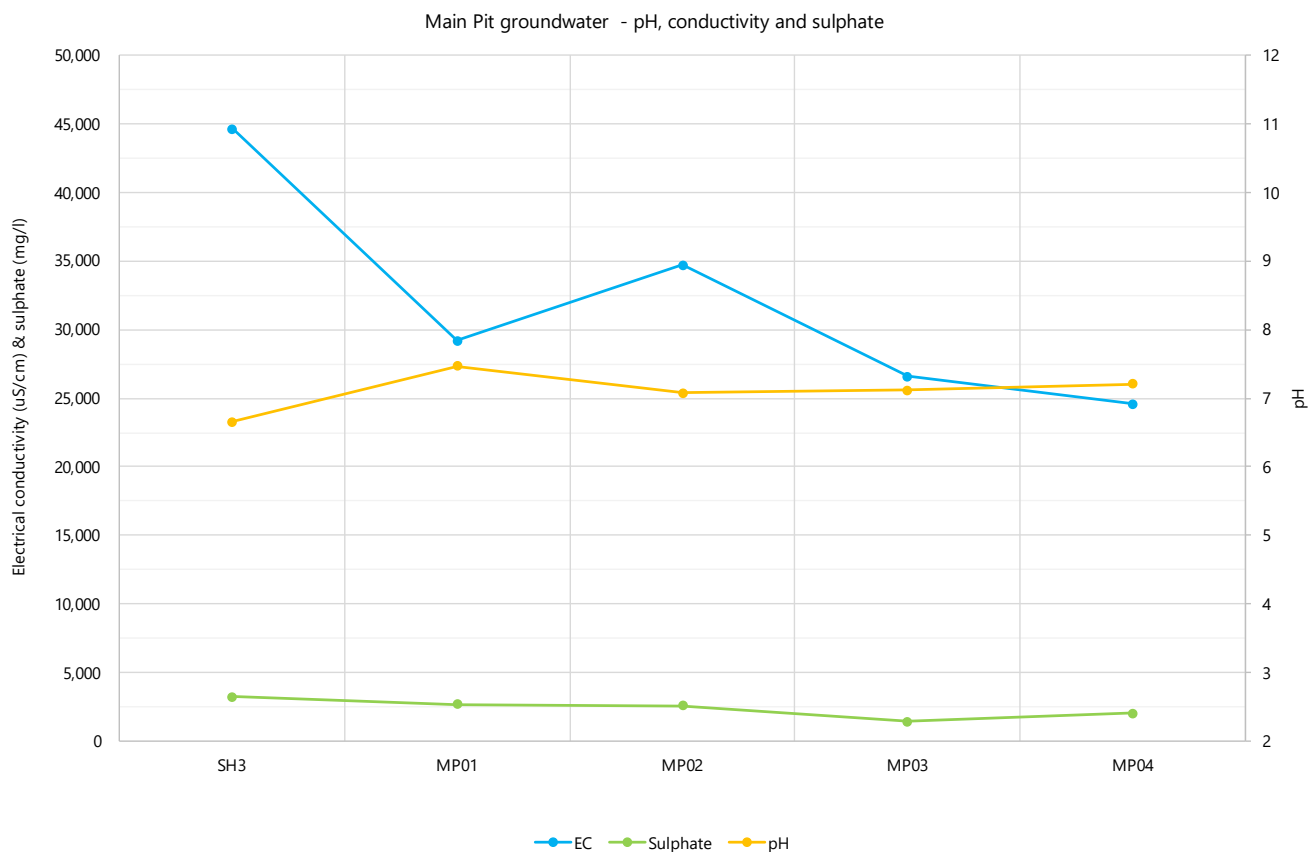


Figure 13 - Initial groundwater sampling event chemistry (may vary)



2.7 Groundwater potentiometric surface

2.7.1 The influence of density on groundwater effective head

As part of constructing a groundwater-surface for Yandan and Main Pit, consideration of effective head differentials given the Main Pit groundwater density is required. As Main Pit groundwater bores' salinity is near or greater than seawater (Table 5), groundwater levels in bores MP01-MP04 and SH3 are substantially denser than fresh waters, including the pit lake. Density, and it's application to head is a representation of the energy per unit weight of fluid: denser the water, the higher the unit weight, and therefore higher effective head. The effect is that groundwater levels in highly saline wells can be measured as lower than their effective hydraulic head compared to fresher (and less dense) waters.

Whilst not a common phenomenon around mining pits; however, it is documented in other relatable environments (Anderson et al 2015). A method to determine equivalent freshwater head from dense water measurements is given by Post and Simmons (2022) from Lusczynski (1961), as shown in Figure 14, and equates to a general rule of 2.5cm/m of freshwater head. If the Main Pit is 30-40m deep of fresh water (assuming connection), this might equate to an approximate 1-1.5m of additional effective head in density flow with saline Main Pit groundwater. Table 6 summarises bore level measurements and the potential effective relative water levels of Main Pit wells.

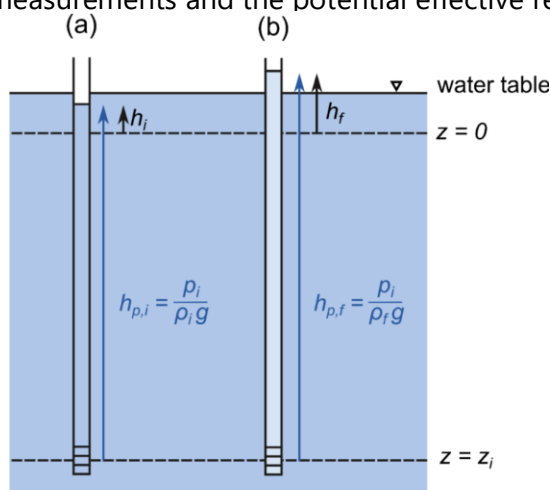


Figure 14 - How density affects effective hydraulic head in groundwater (Post and Simmons (2022))

Note: wells HL1, WSB, TD4, TD5 are excluded given construction in dam embankments or known integrity issues to ensure a representative surface. Note also dry wells – ITD01, ITD02, TD6S, RB1S.

BHID	Type	Measured RWL	Effective RWL
HL1	Heap leach	166.28	
HL3	Heap leach	164.45	
HL4	Heap leach	167.52	
HL5	Heap leach	167.29	
HL6	Heap leach	169.35	
HL7	Heap leach	169.32	
HL8	Heap leach	164.81	
HL9	Heap leach	165.4	
MP02	Main pit	164.89	+1-1.5m
MP03	Main pit	165.25	+1-1.5m
MP04	Main pit	166.24	+1-1.5m
SH3	Main pit	163.07	+1-1.5m
RB2D	Regional	171.4	
RB2S	Regional	171.39	
RB1D	Tailings	178.97	
TD12	Tailings	179.25	
TD13	Tailings	179.85	
TD3	Tailings	176.14	
TD4	Tailings	178.43	
TD7D	Tailings	177.68	
TD7S	Tailings	177.6	
TD8	Tailings	180.45	
TD9	Tailings	173.59	

Table 6 - Summary of groundwater levels used in surface construction

2.7.2 Potentiometric surface

A groundwater potentiometric surface of pressure head for Yandan based on May 2023/February 2024 groundwater levels is shown in Figure 15. A potentiometric surface is more apt as a description to describe relative groundwater head differential across the site rather than flow direction, as groundwater is unlikely to flow in the traditional sense across much of Yandan. The potentiometric surface shows a clear gradient from east to west across the site, mimicking topography in higher-elevation for lower elevations areas, and trending down towards Main Pit and Yandan Creek.

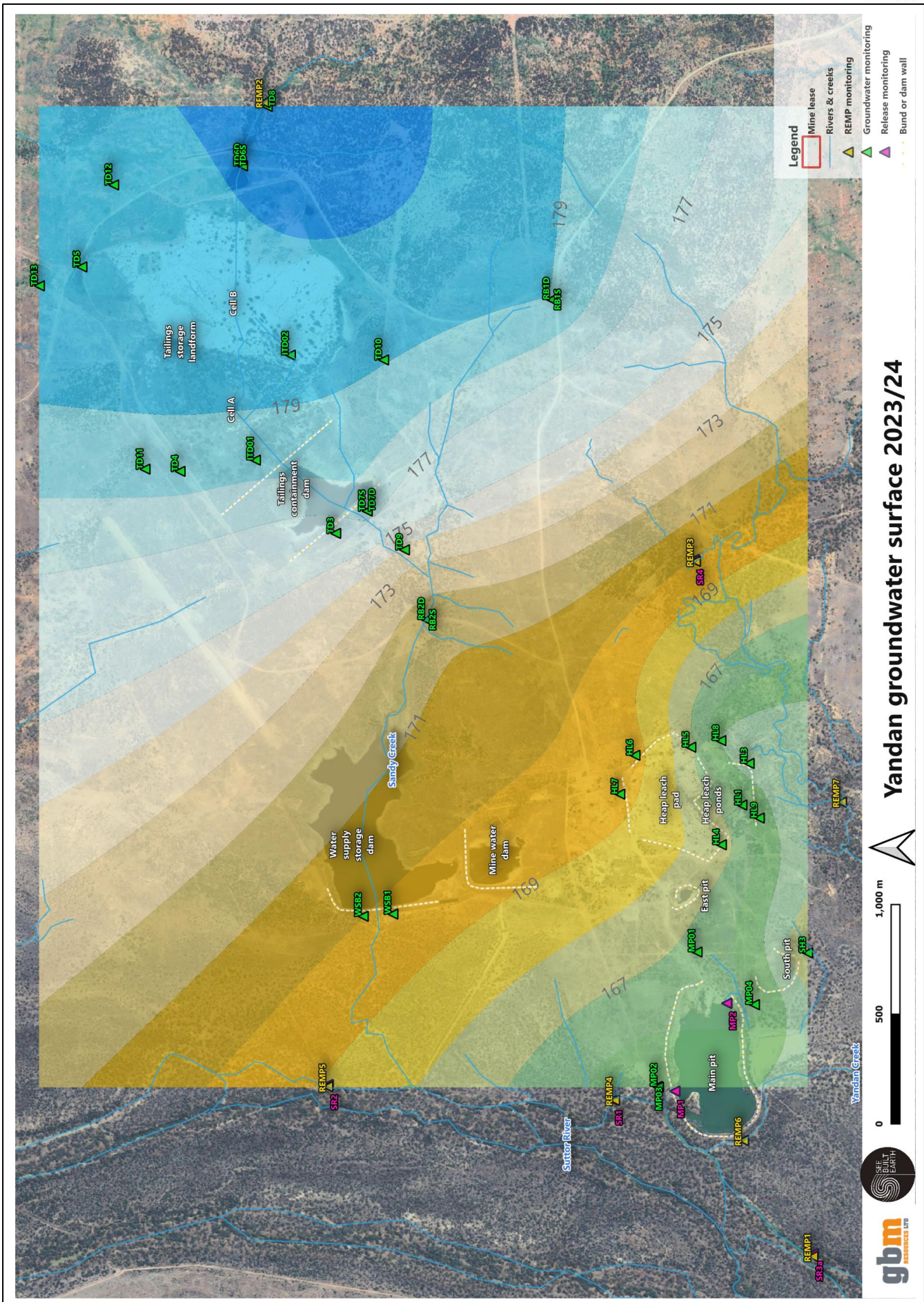


Figure 15 - Groundwater potentiometric surface of Yandan, including Main Pit



2.8 Nature of Suttor River

2.8.1 Flows

The mid-reaches of the Suttor River near the Yandan site are a generally broad, low-gradient and ephemeral river. At Yandan, the Suttor River includes combined flows from the catchments of the Upper Suttor River, Police Creek, Rosetta Creek and Belyando River (refer SBE 2024a for more regional information). The riverbed forms multiple braided channels heavy with alluvium (Figure 2), which flow only after rainfall and constitute a 'losing' stream. Losing streams are not groundwater-fed and instead generally 'lose' water into alluvial aquifers or other connected aquifers (Gordon et al 2004), with flows ebbing away after rainfall to stop flow and dry. Water can settle into small waterholes (where the riverbed has deepened, but are generally isolated, discontinuous and often ephemeral).

Variation and range of Suttor River flow regimes near Yandan can be observed from stream gauge records installed upstream via stream gauge Mount Douglas/Belyando (120301A/B) and Suttor River at St Anns Station (120303A) downstream (note locations in Figure 3). Figure 16 shows flow hydrographs over the past 50 years and a closer view over the last several years to show flow patterns and responses to rain. The ephemeral nature of the river is demonstrated with pulses of flow, retreating to minimal or no river flow for long stretches in between. Analysis of the peaks indicates the system conveys up to 1,000m³/s in regular flow events and up to 4,000m³/s in greater events.

2.8.2 Quality

The natural water quality of the Suttor River is characterised through multiple sources:

- River water quality taken before mine development over five events in 1988 (Figure 17).
- Upstream and downstream receiving environment and release monitoring since 2011 at Yandan eight (8) events of the pit and Suttor River connection (see Figure 18), with multiple samples taken from upstream locations on the Suttor River, Yandan and Sandy Creeks, and downstream on the Suttor River. Table 7 provides results, and the quality ranges in Figure 19.
- Continuous flow and electrical conductivity monitoring at BOM stream gauges of Mount Douglas (Belyando 27km south) and St Anns Station (7km north), shown in Figure 20.

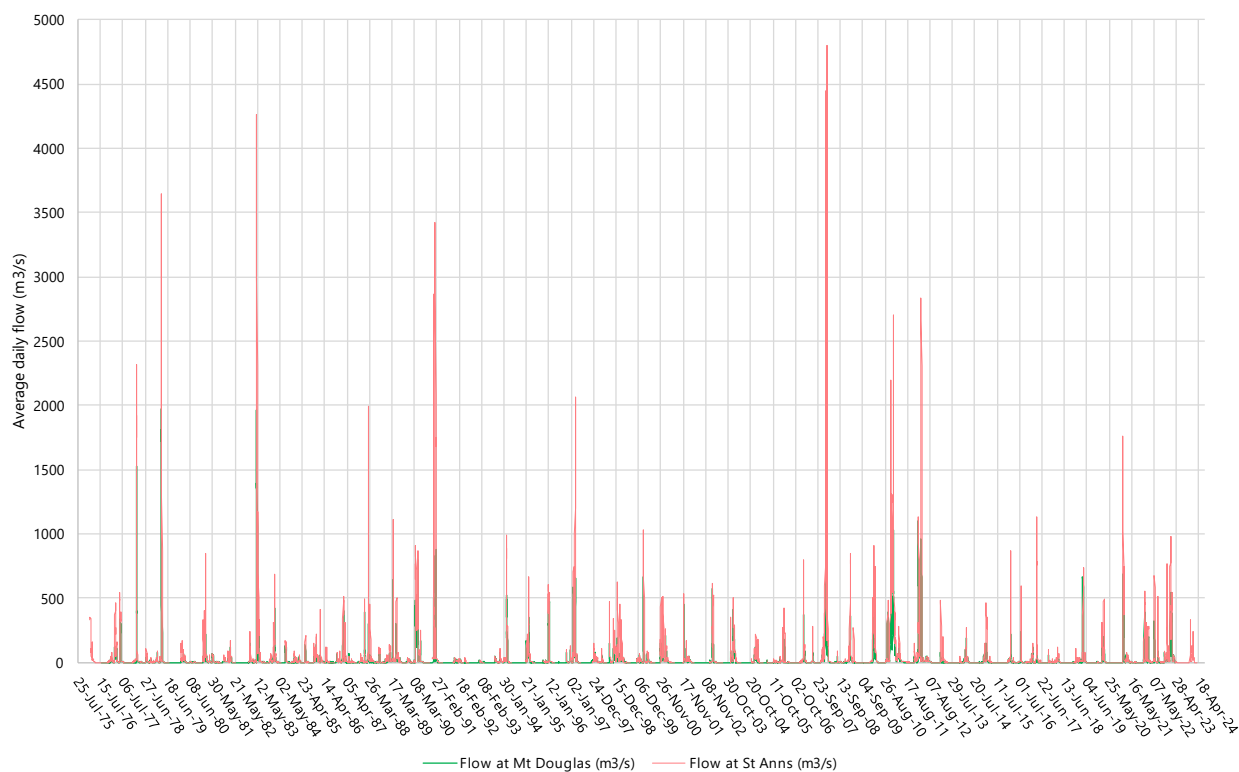
Historical monitoring shows the Suttor River water quality traditionally runs pH neutral (7-8), with minimal sulphate (<50 mg/l) and salinity (<200 uS/cm) and negligible chloride. There is a low presence of metals, including arsenic, copper, nickel and zinc. Mercury is not present. As for background quality in the Suttor River, the presence of metals likely indicates an influence of elevated metals for the river as a natural condition and may result from either draining a mineralised zone upstream or some mineralised materials within alluvium deposits upstream.

In site-specific receiving environment and releases monitoring, upstream and background monitoring of the Suttor River, Yandan and Sandy Creek aligns to historical records: river water is neutral, with electrical conductivity generally less than 300uS/cm, and very low sulphate (<10 mg/l), with the presence of low levels of arsenic, copper, nickel and zinc. Cadmium, lead and mercury are generally not detected. Selenium is present at times, although it is variable and has variable detection limits. Downstream ranges typically align with upstream ranges, indicating that inflows from Yandan do not contribute to a material change in river water quality.

Continuous monitoring at BOM sites (particularly Mt Douglas/Belyando) shows water quality patterns after rainfall in more detail: directly following a flow peak, there is a salinity peak regularly around 1,000EC uS/cm and up to 2,000EC uS/cm. Salinity, like flow, quickly recedes (note the second increase visible in some events is associated with reduced flow conditions and likely represents concentration as water starts to stagnate). The peak is naturally occurring: the first flush and maximum water flow are fresh given the volume of water, and the salinity 'flush' after catchment rainfall comes as flow reduces, and flow subject to throughflow and interflow (add reference) begins draining in the river.



Flows at Mt Douglas (Belyando) & St Anns (Suttor)



Flows at Mt Douglas (Belyando) & St Anns (Suttor)

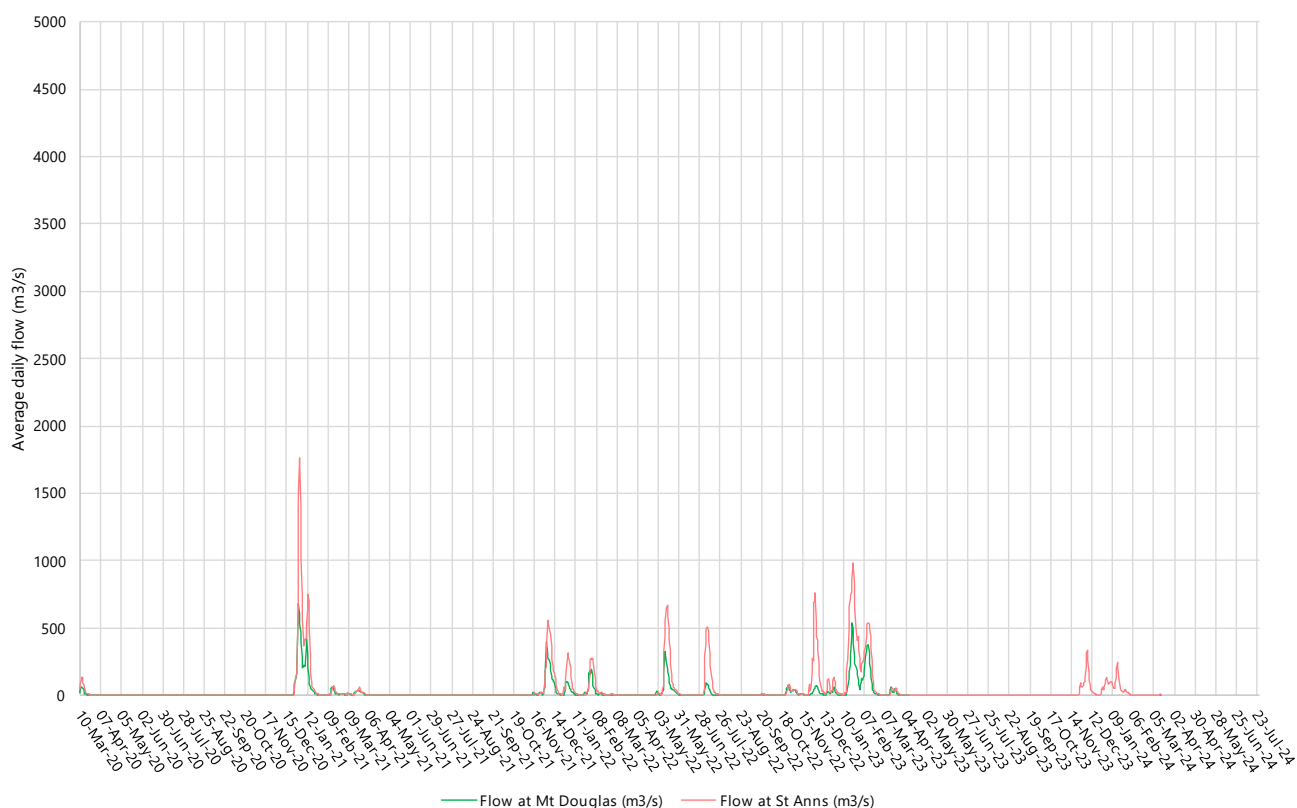


Figure 16 - Flow hydrographs of Mt Douglas (upstream) and St Anns (downstream)



Table 2.5
Summary of Pre-Development Water Quality Results for the Suttor River

Location	Date (1988)	TDS (mg/L)	pH	HCO ₃ (mg/L)	SO ₄ (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Fe (mg/L)	As (mg/L)	Cu (mg/L)	Ni (mg/L)	Zn (mg/L)	Hg (mg/L)
Suttor (Down stream from minesite)	Feb. 3	91	7.4	80.8	5.9	6.4	15.2	5.2	9.6	8.3	19.1	0.003	0.015	0.018	0.05	<0.001
	Mar. 21	100	8.7	55.1	nd	10.9	9.5	4.8	16.1	5.1	12.4	0.003	0.005	0.006	0.008	<0.001
	Mar. 28	12	9.0	68.9	nd	12.2	12.6	6.3	18.4	6.3	11.9	0.003	0.007	0.007	0.009	<0.001
	Apr. 9	59	7.3	39.7	22.2	2.6	3.6	5.1	8.3	4.9	12.1	0.002	0.011	0.016	0.023	<0.001
	May 31	99	7.4	51.1	10.4	5.5	9.0	10.0	9.1	3.9						
Suttor (Up stream from minesite)	Feb. 3	91	7.5	82.1	5.0	7.6	16.2	5.5	9.5	8.1	19.1	0.004	0.015	0.018	0.05	<0.001
	Mar. 21	114	7.1	60.1	2.3	11.5	11.1	5.1	17.0	4.8	13.1	0.003	0.007	0.008	0.01	<0.001
	Mar. 28	119	8.8	67.2	7.2	11.5	12.6	6.4	18.2	6.5	13.0	0.002	0.007	0.006	0.008	<0.001
	Apr. 9															
	May 31	109	7.4	67.5	10.7	5.9	7.5	4.7	9.2	3.6						
Average		88	7.8	63.6	9.1	8.2	10.8	5.9	12.8	5.7	14.4	0.003	0.009	0.011	0.023	<0.001

Figure 17 - Summary of Yandan pre-development water quality (SRK, 1999b)

REMP and release monitoring events with flow records

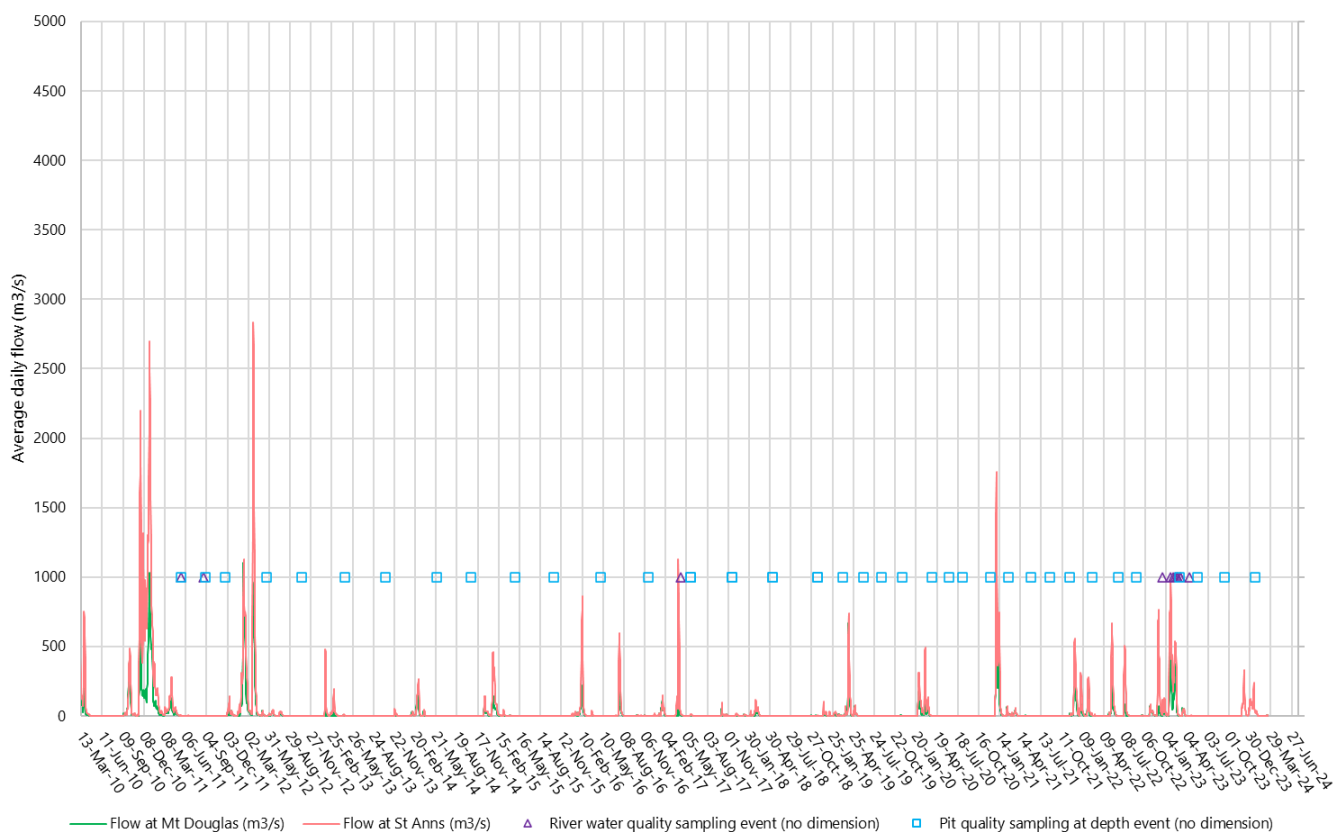


Figure 18 – REMF, release and pit quality monitoring events with flow records



Event Count	Date	Site	Site location	pH	EC	SO4	Aluminium	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Nickel	Zinc
Event 1	18-May-11	REMP4-SR1	Downgradient 1	8.32	1330	22									
	23-Aug-11	REMP4-SR1	Downgradient 1	8.05	1620	5									
Event 2	10-Apr-17	REMP1-SR3a	Background on Suttor	7.36	152	2	0.95			0.004					0.0055
	10-Apr-17	REMP4-SR1	Downgradient 1	7.37	152	4	0.98	0.002		0.004	-0.001			0.003	0.038
Event 3	19-Dec-22	REMP2	Background on Sandy Creek			1	0.218	-0.001	-0.0001	-0.001	-0.002	-0.001	-0.0002	0.003	0.006
	19-Dec-22	REMP3-SR4	Background on Yandan Creek			1	-0.005	0.003	-0.0001	-0.001	-0.001	-0.001	-0.0002	0.004	-0.005
	23-Jan-23	REMP4-SR1	Downgradient 1	7	128	-1		0.001		0.004				-0.002	
	01-Feb-23	REMP4-SR1	Downgradient 1	7.28	177	-1	0.12	0.002	-0.0001	0.001	-0.001	-0.0001	-0.0001	-0.002	-0.005
	10-Feb-23	REMP4-SR1	Downgradient 1	7.13	144	-1	0.11	0.002	-0.0001	0.001	-0.001	-0.0001	-0.0001	-0.002	-0.005
Event 4	16-Feb-23	REMP3-SR4	Background on Yandan Creek	7.42	567	3	0.02	0.001	0.0002	0.002	-0.001	-0.0001	-0.01	-0.002	-0.005
	16-Feb-23	REMP4-SR1	Downgradient 1	7.47	148.4	4	0.04	0.002	-0.0001	0.003	-0.001	-0.0001	-0.01	-0.002	-0.005
Event 5	22-Feb-23	REMP1-SR3a	Background on Suttor	7.66	181.8	-1	0.1	0.003	-0.0001	0.004	0.003	-0.0001	-0.01	-0.002	0.008
	22-Feb-23	REMP3-SR4	Background on Yandan Creek	8.02	620	-1	0.02	0.001	-0.0001	0.001	-0.001	-0.0001	-0.01	0.003	-0.005
	22-Feb-23	REMP4-SR1	Downgradient 1	7.42	185.5	-1									
	22-Feb-23	REMP4-SR1	Downgradient 1	7.42	208.1	2	0.01	0.002	-0.0001	0.001	-0.001	-0.0001	-0.01	-0.002	-0.005
Event 6	05-Mar-23	REMP1-SR3a	Background on Suttor	7.31	220.7	2	0.02	0.002	-0.0001	0.002	-0.001	-0.0001	-0.01	-0.002	0.006
	05-Mar-23	REMP4-SR1	Downgradient 1	7.41	228.4	-1	0.02	0.002	-0.0001	0.001	-0.001	-0.0001	-0.01	-0.002	-0.005
	05-Mar-23	REMP4-SR1	Downgradient 1	7.38	215.5	2	0.02	0.002	-0.0001	0.001	-0.001	-0.0001	-0.01	-0.002	-0.005
	05-Mar-23	REMP5-SR2	Downgradient 2	7.42	230.8	2	0.02	0.002	-0.0001	0.002	-0.001	-0.0001	-0.01	-0.002	-0.005
Event 7	13-Apr-23	REMP1-SR3a	Background on Suttor	7.5	186.2		0.24	0.001	-0.0001	0.002	-0.001	-0.0001	-0.01	-0.002	-0.005
	13-Apr-23	REMP4-SR1	Downgradient 1	7.3	187.4	7	0.01	0.001	-0.0001	0.001	-0.001	-0.0001	-0.01	-0.002	0.007
	13-Apr-23	REMP4-SR1	Downgradient 1	7.45	255.7	3	0.01	0.002	-0.0001	0.002	-0.001	-0.0001	-0.01	-0.002	0.008
	13-Apr-23	REMP5-SR2	Downgradient 2	7.45	238.2	3	0.19	0.002	-0.0001	0.002	-0.001	-0.0001	-0.01	-0.002	0.024
Event 8	15-Apr-23	REMP1-SR3a	Background on Suttor			4	0.379	-0.001	-0.0001	-0.001	0.001	-0.001	0.0006	0.002	0.006
	15-Apr-23	REMP6	Background on Yandan Creek around Main Pit			3	0.007	0.002	-0.0001	-0.001	0.001	-0.001	0.0004	0.002	-0.005
	16-Apr-23	REMP2	Background on Sandy Creek			1	0.024	0.003	-0.0001	-0.001	0.002	-0.001	0.0003	0.004	-0.005
	16-Apr-23	REMP3-SR4	Background on Yandan Creek			6	0.058	0.002	-0.0001	-0.001	-0.001	-0.001	0.0008	0.004	-0.005
	16-Apr-23	REMP4-SR1	Downgradient 1			3	0.264	0.001	-0.0001	-0.001	0.003	-0.001	0.0005	0.002	-0.005
	16-Apr-23	REMP5-SR2	Downgradient 2			3	0.204	0.002	-0.0001	-0.001	0.001	-0.001	0.0003	0.002	-0.005

Table 7 - Release point and REMP monitoring events during pit-Suttor River connection

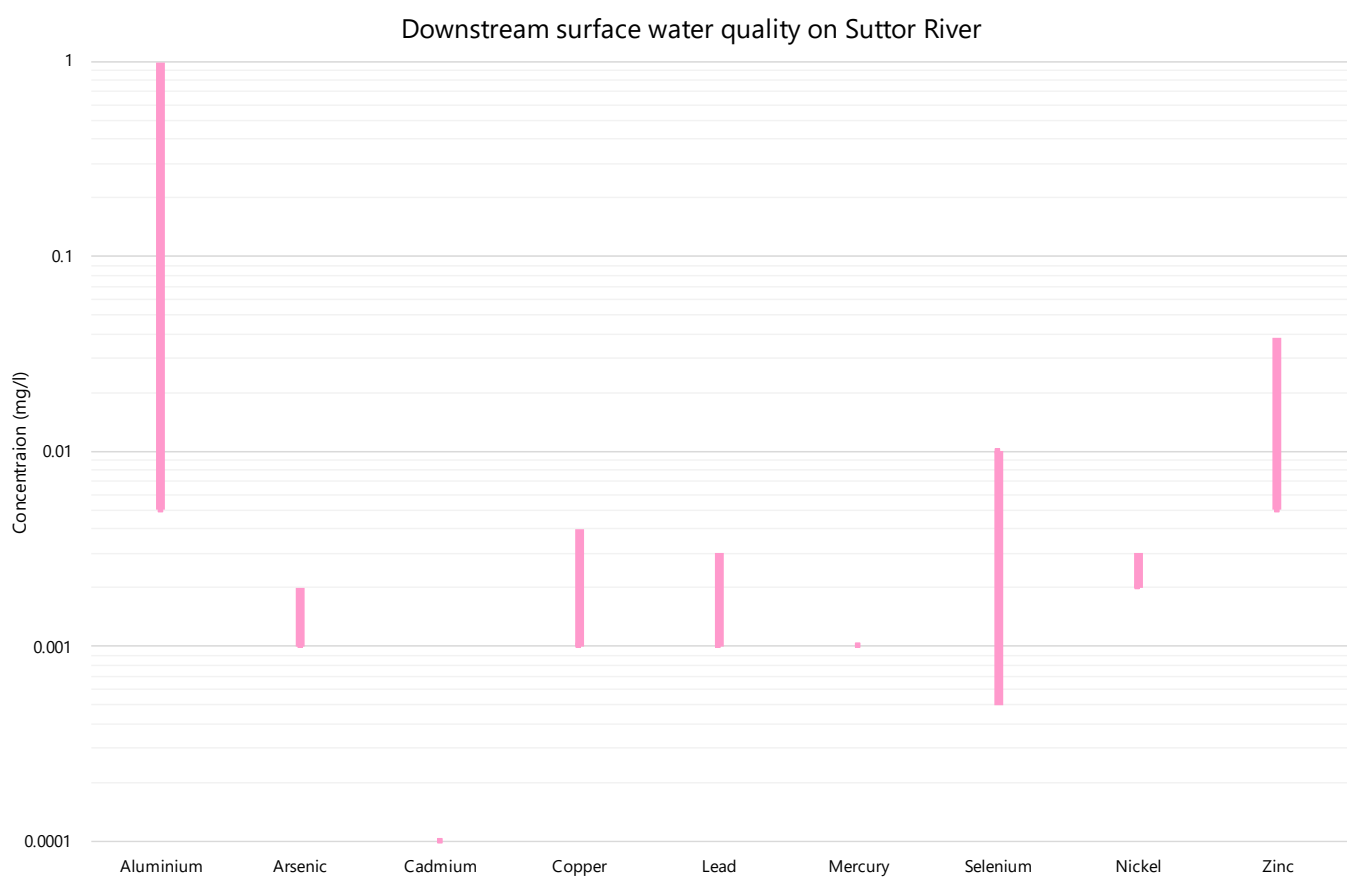
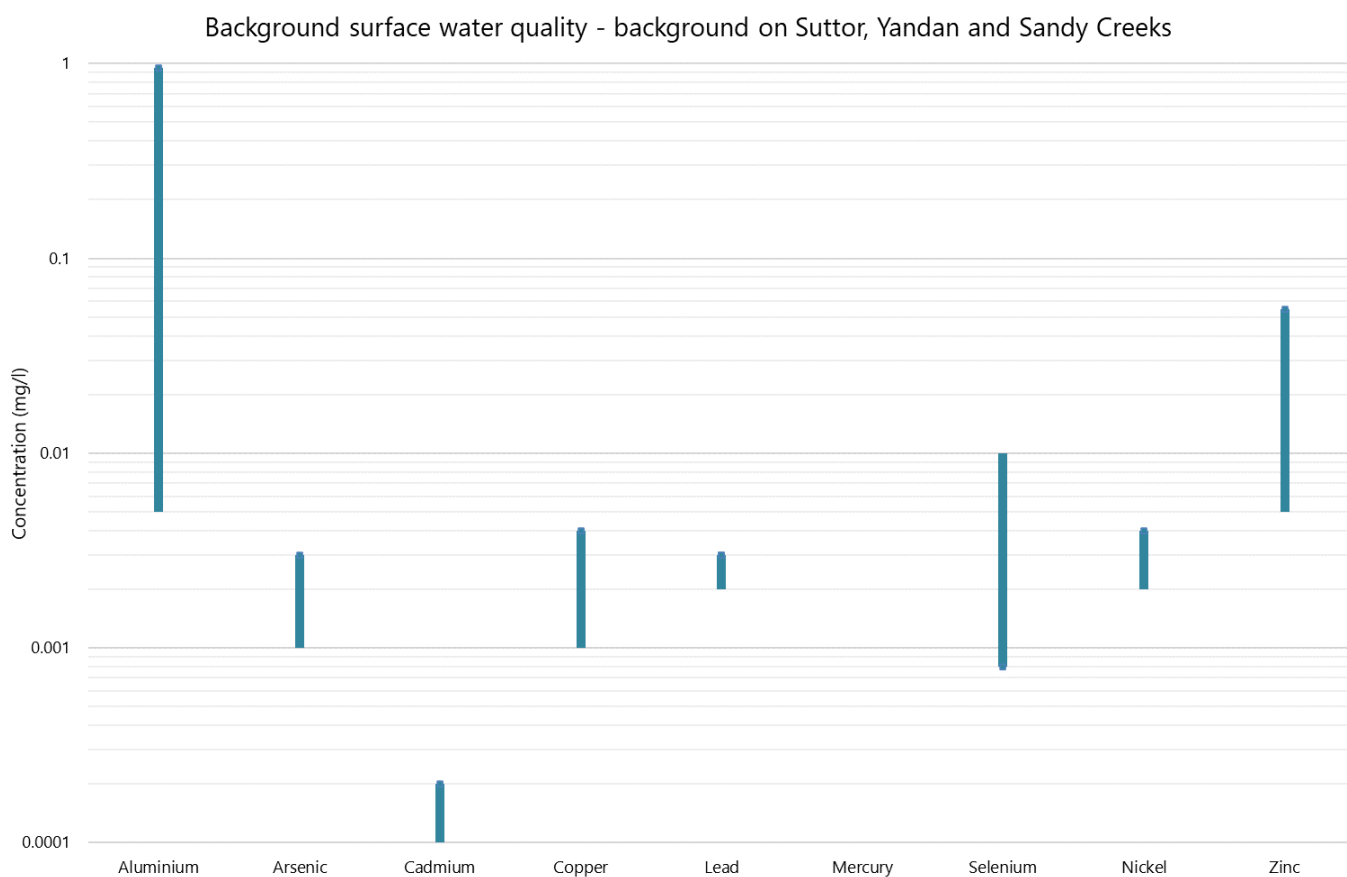
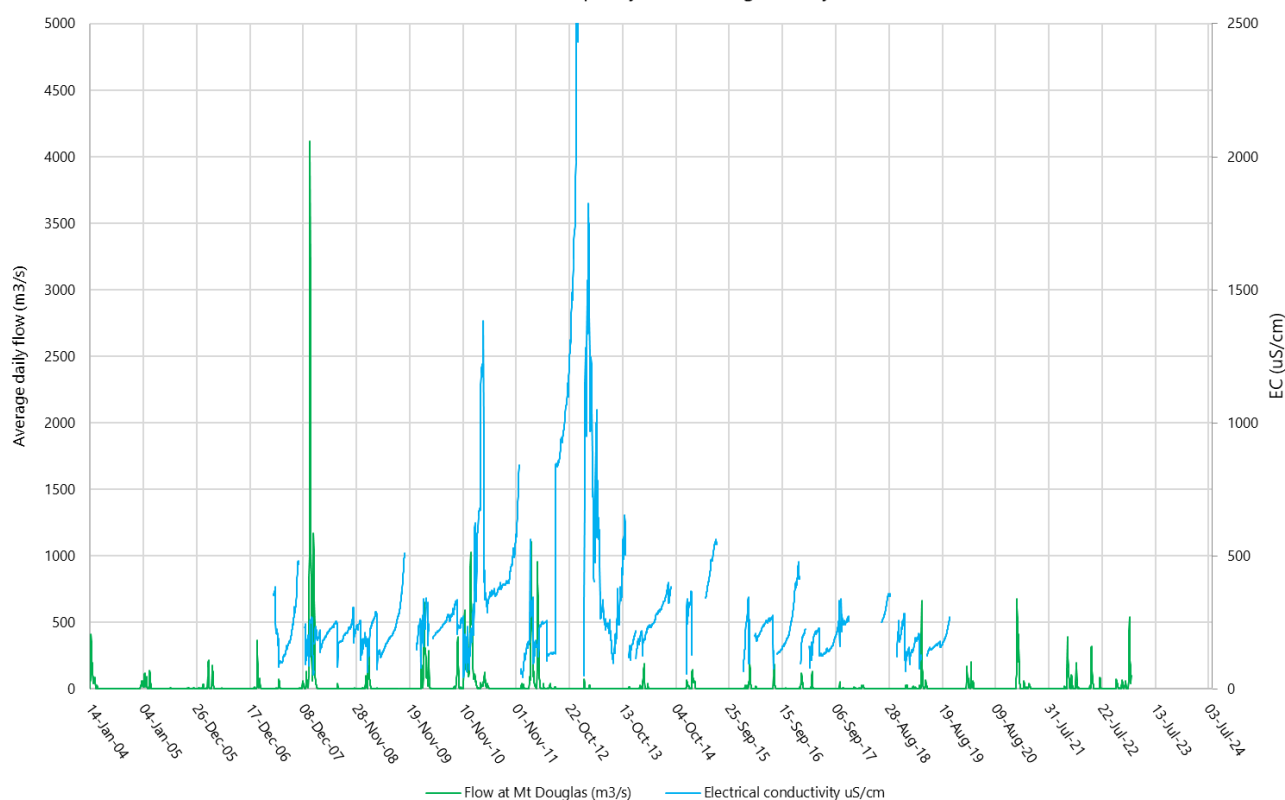


Figure 19 - REMP and water release monitoring quality - upstream (top) and downstream (bottom) of Yandan



Flows and water quality at Mt Douglas (Belyando)



Suttor River electrical conductivity at Mount Douglas and St Anns (uS/cm)

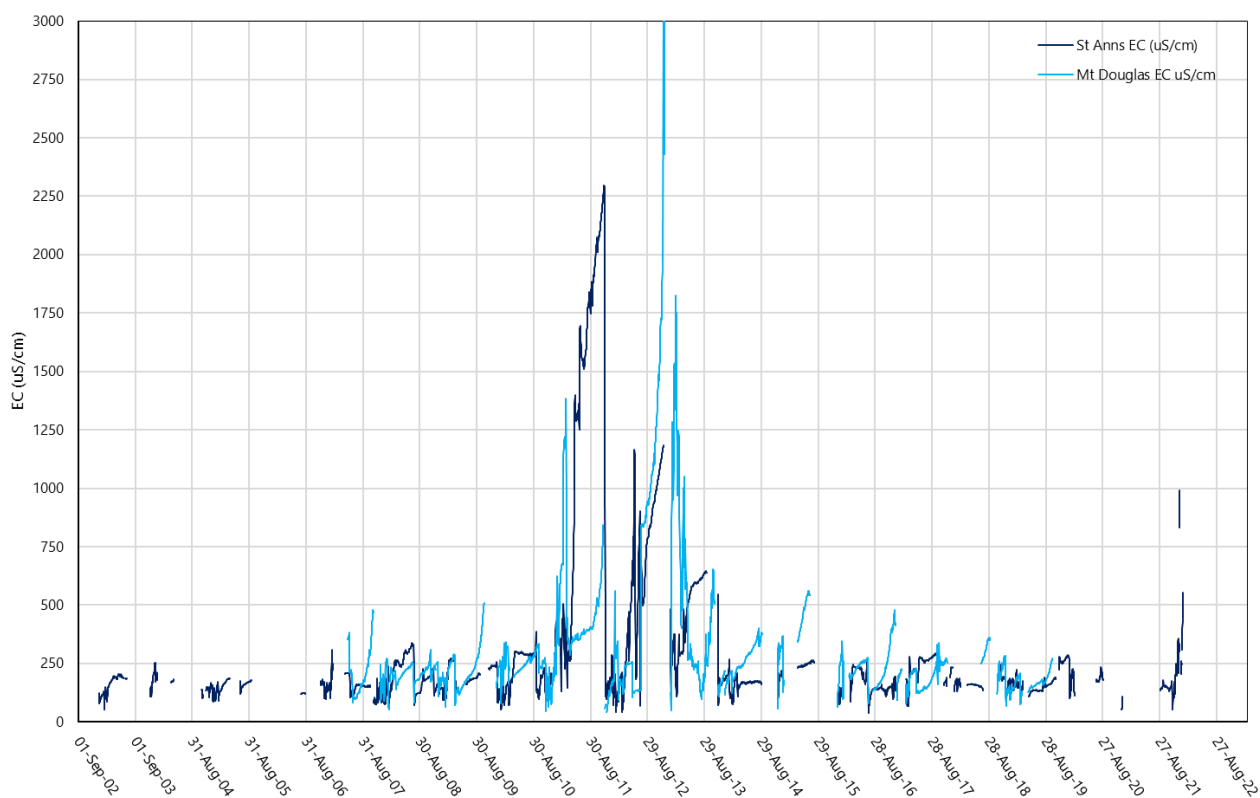


Figure 20 - Comparison of EC Mount Douglas (Belyando) (upstream) and St Anns (downstream)



2.8.3 Flooding profile

Flooding profiles of Yandan are investigated and characterised in detail in the *Water performance of the Yandan Mine landscape at closure* (SBE 2022) and the parallel report of *Yandan mine site flooding profile characterisation* (SBE 2024).

In summary:

- As part of designing flood capacity, AECOMM (2012) calculated reference levels to relate downstream St Ann gauge river levels to when the connection to Yandan Main Pit would occur (where river levels exceed 169mAHD at Yandan and flow into the Main Pit). The work identified the key elevations: a 3.8m river height (or flow elevation of 165.5mAHD) at St Anns gauge, and the Suttor River at Yandan will be at 169.05mAHD. By converting the river stage level to flow rates at St Anns (BOM 2024) (Figure 22), a corresponding flow rate of 500m³/s can be derived. This correlates with earlier work by R&D Environment (1999) which estimated connection to the Main Pit occurs when Suttor River flows reach 850m³/s. As a working guide, the minimum flow range where connection occurs should be considered 500-850m³/s.
- Flooding and Main Pit-Suttor River connection frequency is guided by the duration curve (Figure 21). A flow rate of 500m³/s has an AEP of 7.5%, but may also occur at AEP's of 5% to 25% AEP. This correlates well with observed behaviour: flow records and AECOMM (2012) record eight (8) connection events over the past 25 years, supporting an AEP of ~25%. The closure period since 1999 has included a wetter, drier, and average cycle that represents the longer-term climate history (Section 2.4).

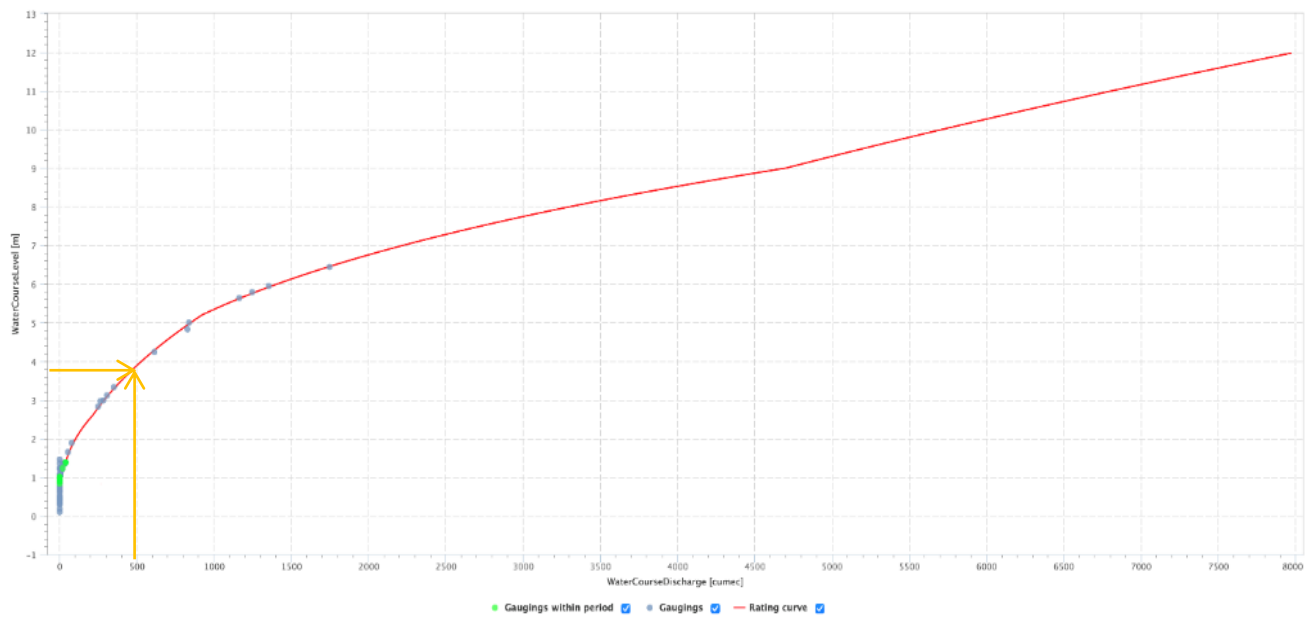


Figure 22 - River gauging curve for St Anns converting river height to flow (BOM 2024)

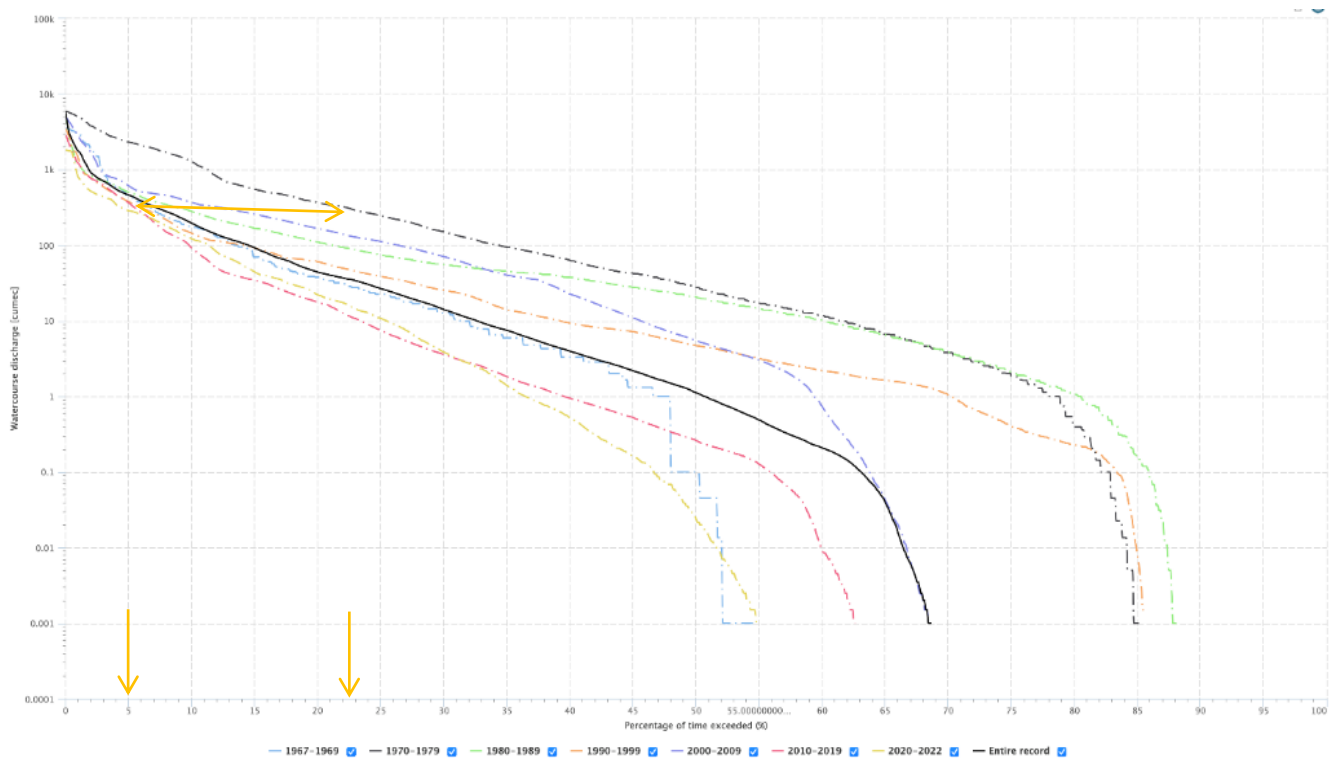


Figure 21 - River flow durations for St Anns gauge (BOM 2024)



2.9 Nature of Main Pit lake water

2.9.1 Monitoring program

Pit lake monitoring has occurred since 2011 and regularly since 2013 to the present quarterly each year, resulting in 40 sampling events. Sampling dates are shown in Figure 19, and locations are shown in Figure 7.

Quality is taken in two locations on either side of the pit lake—MP1 and MP2—from the surface and then each 5-10m to depth as separate samples. Sampling is generally done to 40m depth at both locations.

Pit lake levels have only recently started monitoring, with a continuous level logger (transducer) installed in May 2023. The logger has been comparison surveyed to assign elevation in mAHD of 161.61mAHD and adjusted for atmospheric barometric pressure (10.1m) to be able to relate pit water levels to other parts of the site.

2.9.2 Pit lake water levels

Figure 23 presents the results of Main Pit water level logging with rainfall recorded at St Ann's gauge over nine (9) months between May 2023 and mid-February 2024. Note that no flood connection between the Main Pit and the Suttor River has occurred since installing the level loggers, and the data represents a contained pit lake condition.

Main Pit levels show limited response to rain recorded at St Ann's, which is evidence of the limited catchment and effective containment of Main Pit in non-flood conditions. There is local rainfall variability from event to event, but the limited rainfall response is a consistent feature. The pit lake will not overflow without Yandan Creek or Suttor River inflow.

Throughout observation, Main Pit lake levels declined from 168.2mAHD to 167.1mAHD: 1.1m in decline. On 5 February, when groundwater levels were taken at wells MP01-04), the pit water level was 167.1mAHD, where equivalent groundwater levels (note denser water) range between 166.5-166.8mAHD. The levels are remarkably close, and a confirmation survey is recommended for the Main pit level logger to confirm the level datum of the logger for final details.

The rate of level decline observed in Main Pit is at a lower and slower rate than the other level monitoring at the tailings containment dam and East Hill Pit, further supporting evidence of likely groundwater inflow into Main Pit, which is buffering pit lake level decline in comparison to other storages. Comparative rates of decline are shown in Figure 24 across all records available, and then in Figure 25, through aligning start dates of loggers (noting tailings containment dam shows strong response to rainfall). By the numbers, a comparison of level decline for each site and average monthly evaporation is shown in Table 8.

Whilst it can be expected that evaporation in any given year will vary from the average based on variable conditions, the lower rate of decline at Main Pit in comparison to other storages at Yandan indicates an ongoing groundwater baseflow exists for the pit void.

Table 8 - Summary of average evaporation rates to comparative rates at level loggers

Average BOM evaporation by month													
Station	StationID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MoranbahWaterTreatmentSE	34038	8	7.4	6.8	5.7	4.3	3.5	3.7	4.9	6.6	8	8.5	8.5
TwinHills	SW	36047	7.5	6.5	6.1	5.2	3.6	2.9	3.1	4.2	6.1	7.9	8.7
CollinsvillePostOffice	NE	33013	6.2	5.7	5.2	4.4	3.5	2.9	3.2	4.1	5.3	6.5	6.9
Average evaporation		7.2	6.5	6.0	5.1	3.8	3.1	3.3	4.4	6.0	7.5	8.0	8.0
												Rain	Rain
Observed level decline at level loggers (based on level on 1st of each month)													
Main pit			-1.0	-7.8					-2.3	-1.7	-6.7	-4.6	-7.4
East Hill Pit			-3.2	-10.4									
Tailings containment			2.6	-9.3				-4.3	-3.5	-2.1	-7.9	-6.1	-10.4

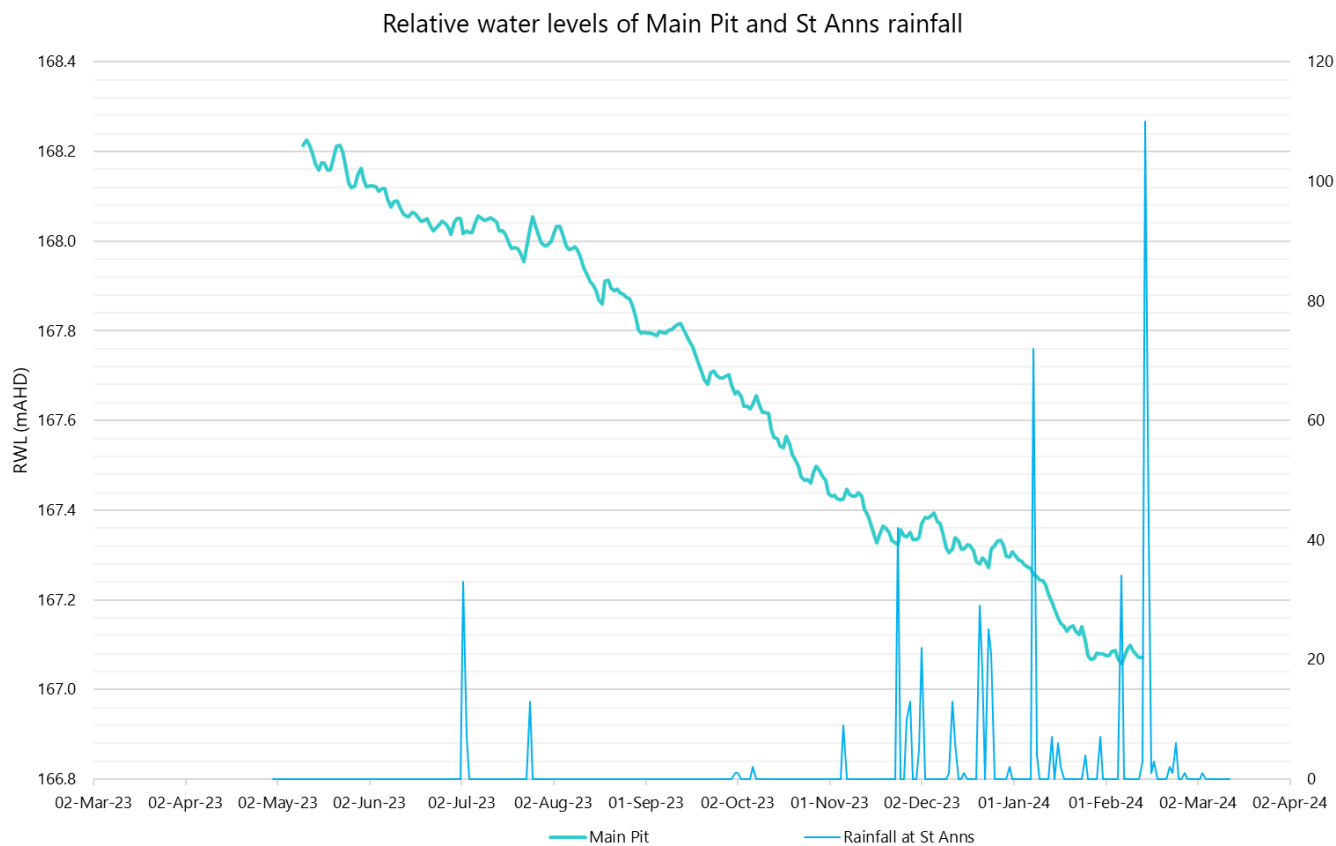


Figure 23 - Main pit level logger and St Anns rainfall

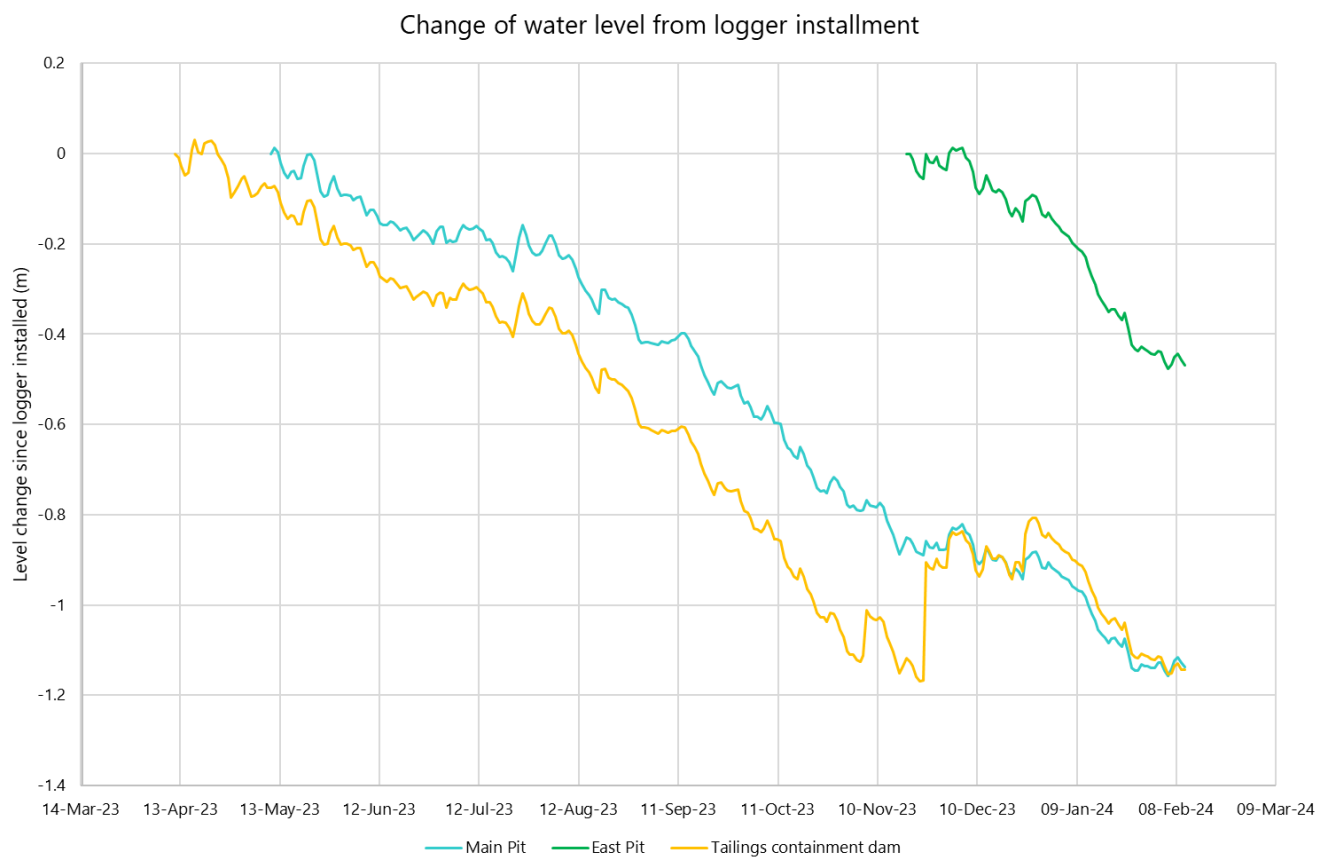


Figure 24 - Comparison of water storages decline rates

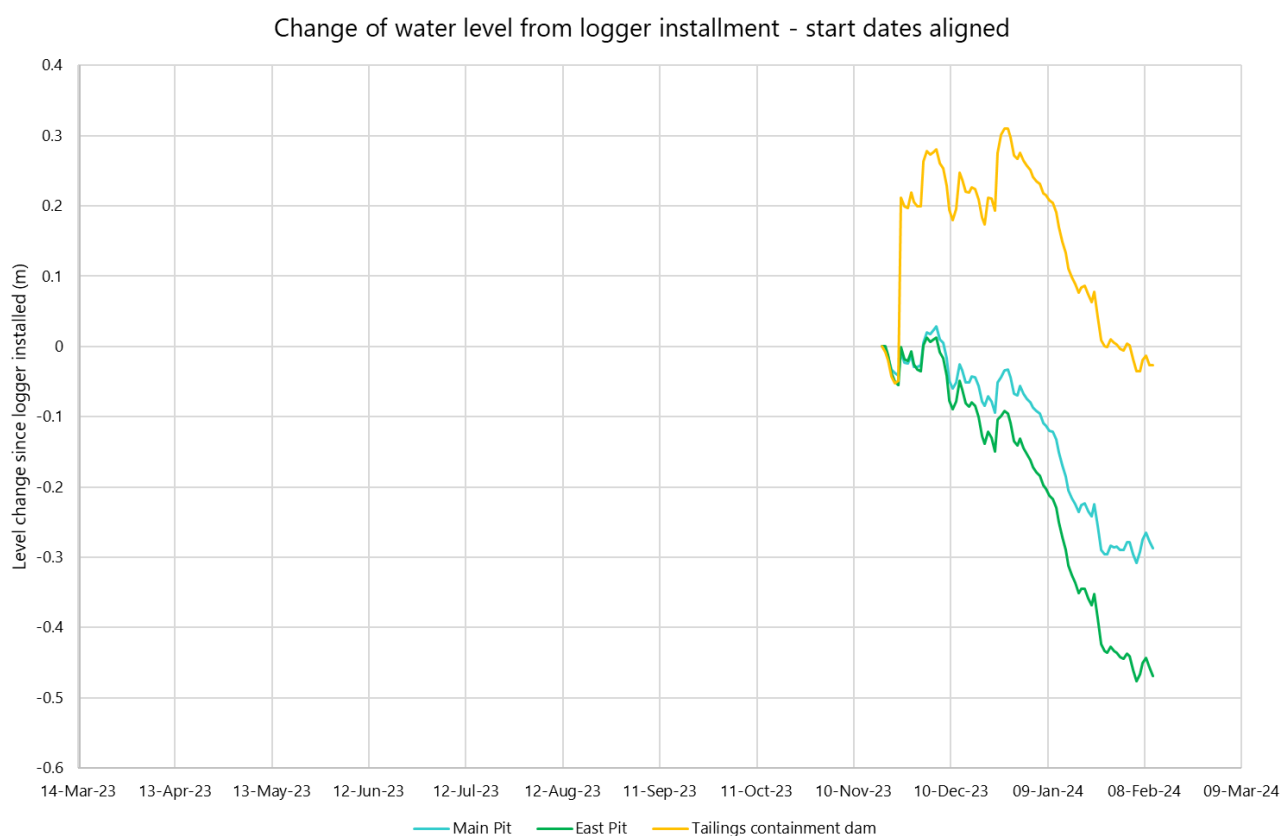
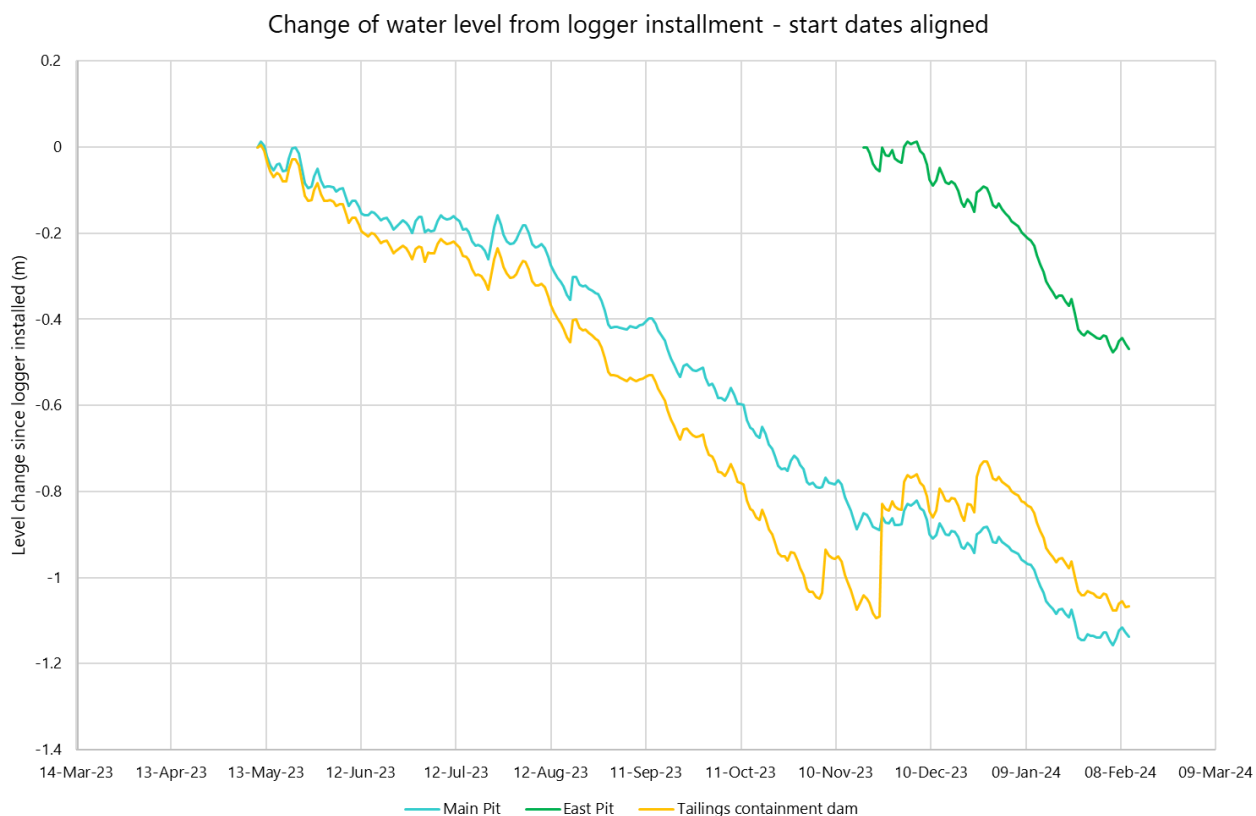


Figure 25 – Comparative decline rates of storages relative to start dates



2.9.3 Pit lake water quality

Pit water quality has been monitored since 2013 in regular quarterly events (40 sampling events) across multiple depths (typically 5-10m increments) in drier, wetter, and average rainfall, flooding and contained conditions, and provides a representative characterisation of pit water quality.

Figure 26 through Figure 32 shows water quality profiles of key parameters (pH, EC, SO₄, DO, As, Cu, Zn) for each monitoring event and over depth. Table 9 provides a summary of trends and observations across all parameters.

Overall, monitoring demonstrates stable pit water quality and indicates a self-sustaining pit lake. Reactive materials in the pit walls and storage are contained within the pit as a water cover; with minimum levels maintained to continue the water cover over the monitoring period. No acid or saline mine drainage occurs, and metals are stable (not increasing) at low levels or undetected. In summary:

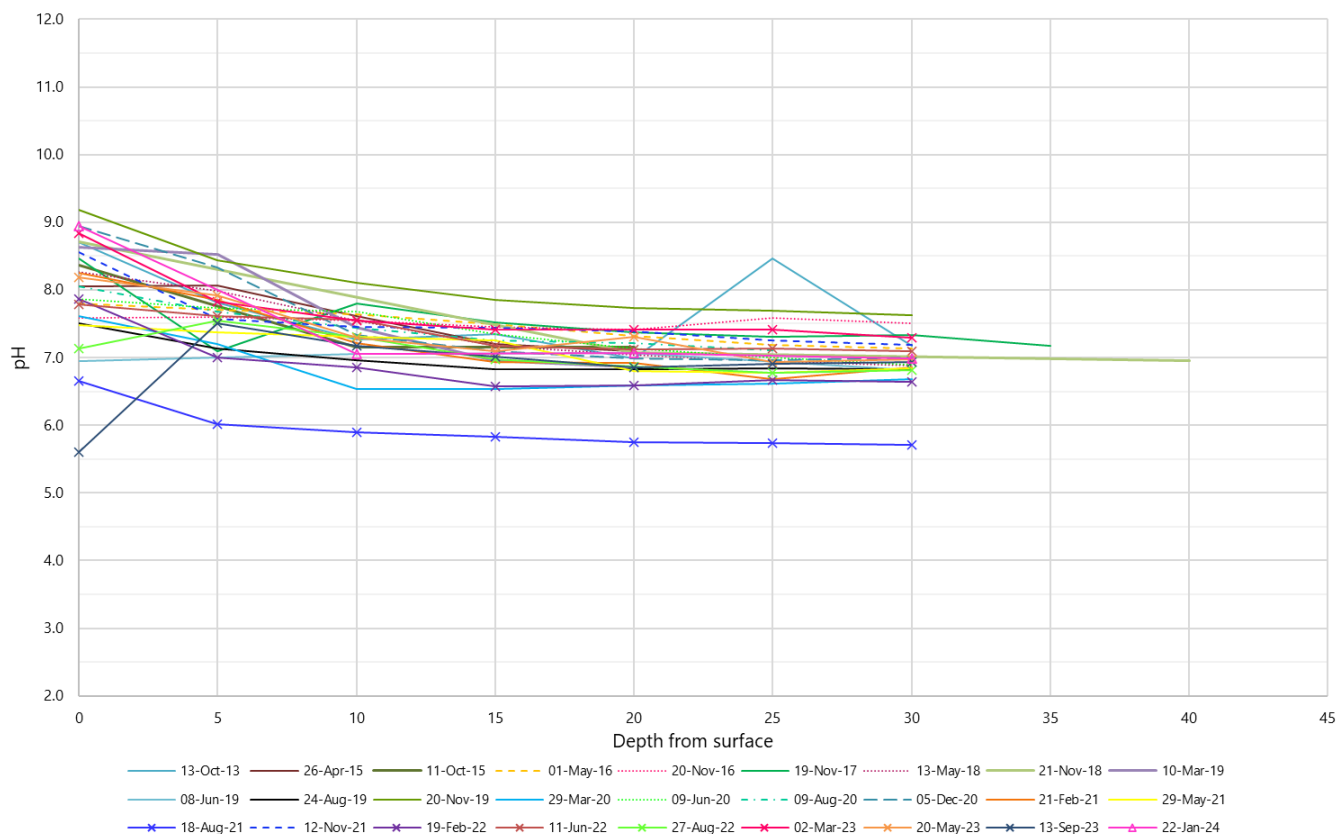
- Water is consistently neutral pH (~6.5-8), with low conductivity (<200EC uS/cm) and low sulphate (<50mg/l), like the background water quality of the Suttor River.
- Dissolved oxygen varies, with an average of >3mg/l across all depths.
- Several metals are absent (Cd, Pb, Hg, Mo, Se), and arsenic, copper and zinc are present. All are stable and demonstrate stability within the pit lake for quality (as with level): not increasing with time, and generally demonstrate improving water quality from 2013 to 2019.
- Arsenic is present at low levels between 0 and 20m depth (0.02mg/l). It steps up with depth and stabilises at 20-40m (0.06mg/l). Copper and zinc demonstrate occasional peaks at a specific depth but are generally at low levels and stable (<0.005mg/l and <0.02mg/l respectively).

Table 9 - Summary of water quality at Main Pit in-pit water & receiving environment

Parameter	Pit water
pH	• Stabilised & neutral to slightly alkaline • Slightly alkaline at the surface • Single event in 2021 with pH of 6, but not repeated in any subsequent events and may be an error or an anomaly
Temperature	• Stable & average
Electrical conductivity (EC)	• <300uS/cm and stable
Sulphate	• <30-40mg/l and stable
Dissolved oxygen (DO)	• Varies, 50th percentile is 3-5mg/l
Arsenic	• Low at surface to 20m depth and stable • Elevated at 20m+ depth <0.07mg/l but stable (not increasing)
Cadmium	• Not detected to around detection
Copper	• Elevated peaks at times to trace levels • Stable - isolated low concentration peaks in 2015, 2019 and recently in 2023, and is stable since and otherwise has stabilised since
Lead	• Not detected to around detection
Mercury	• Not detected
Molybdenum	• Not detected to around detection
Selenium	• Not detected to around detection
Zinc	• Elevated at times to trace levels • Stable - isolated low concentration peaks in 2016, 2017 and recently in 2022, but has stabilised since



Main pit pH with depth - MP1



Main pit pH with depth - MP2

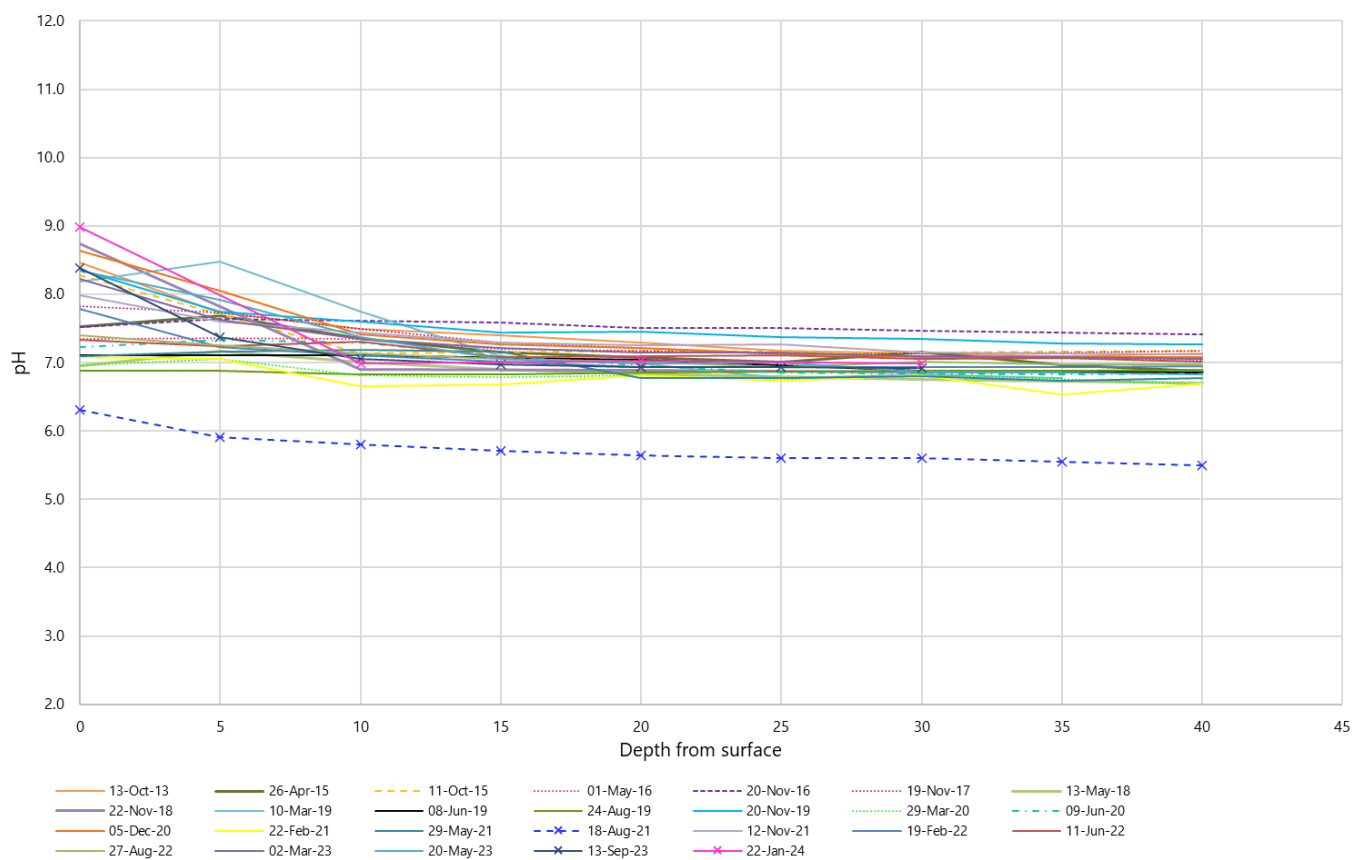
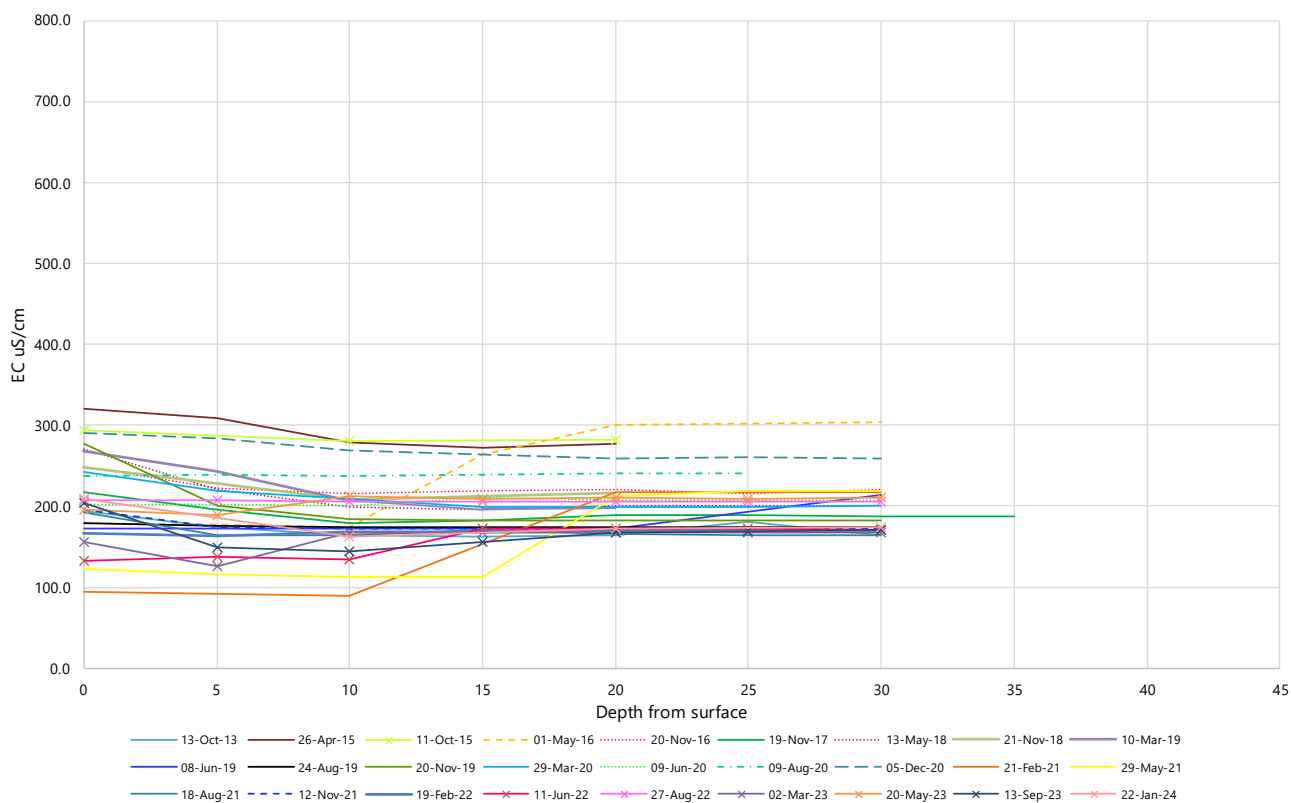


Figure 26 - Main Pit water quality at depth - pH



Main pit conductivity with depth - MP1



Main pit conductivity with depth - MP2

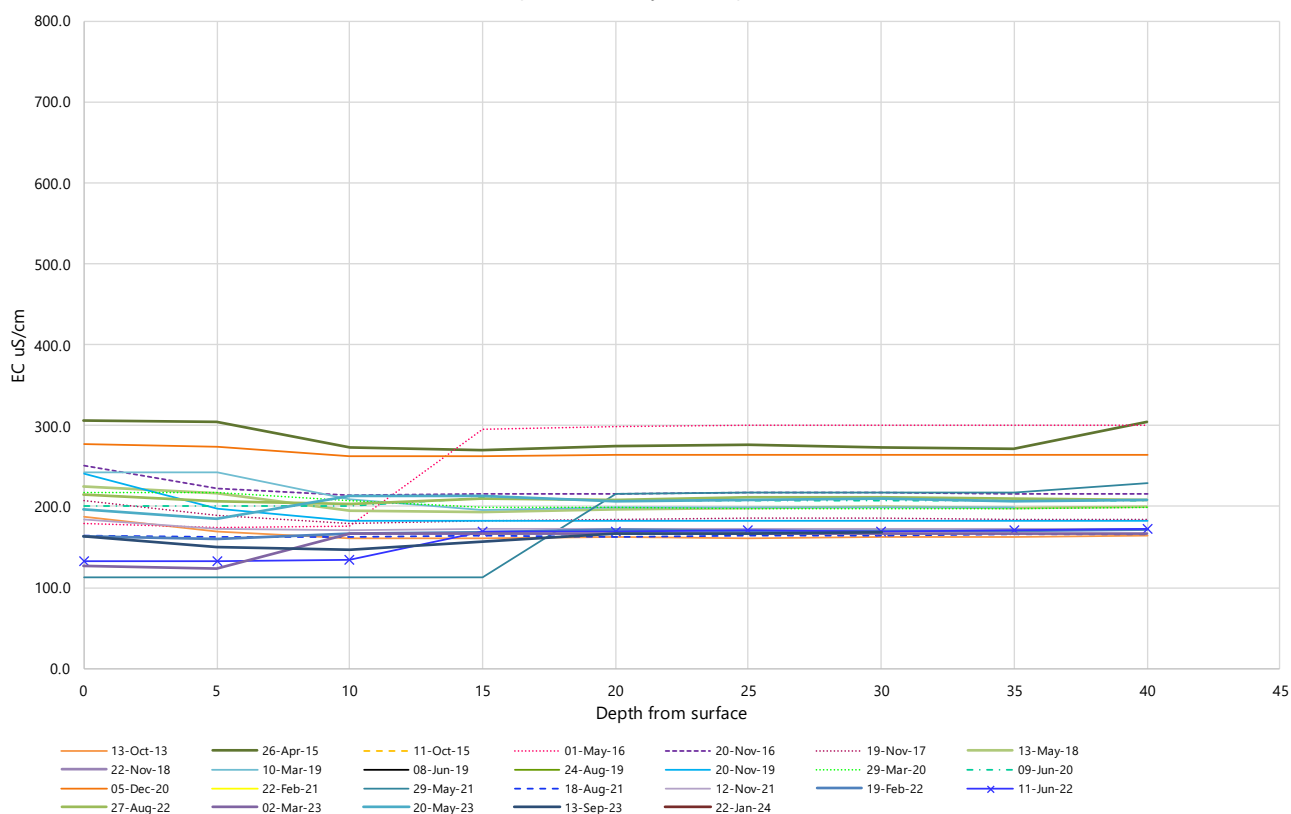
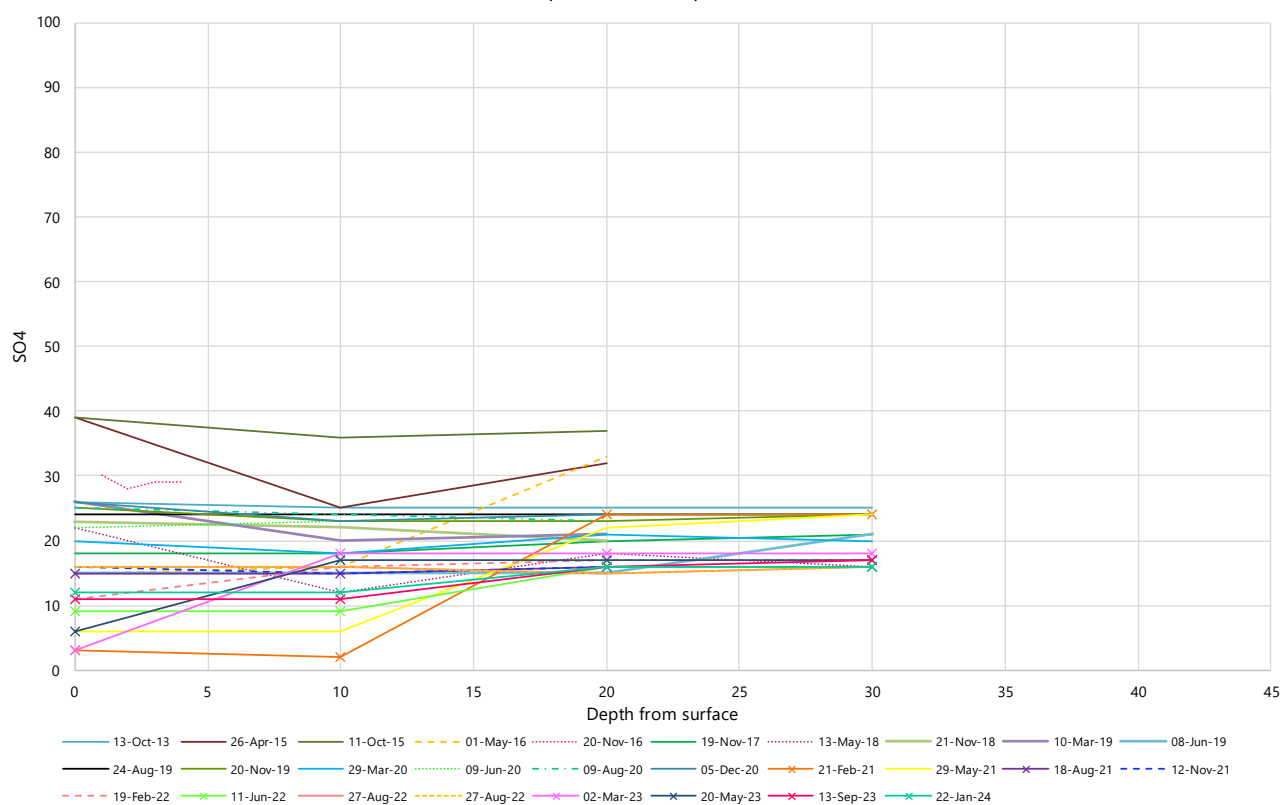


Figure 27 - Main Pit water quality at depth – electrical conductivity



Main pit SO4 with depth - MP1



Main pit SO4 with depth - MP2

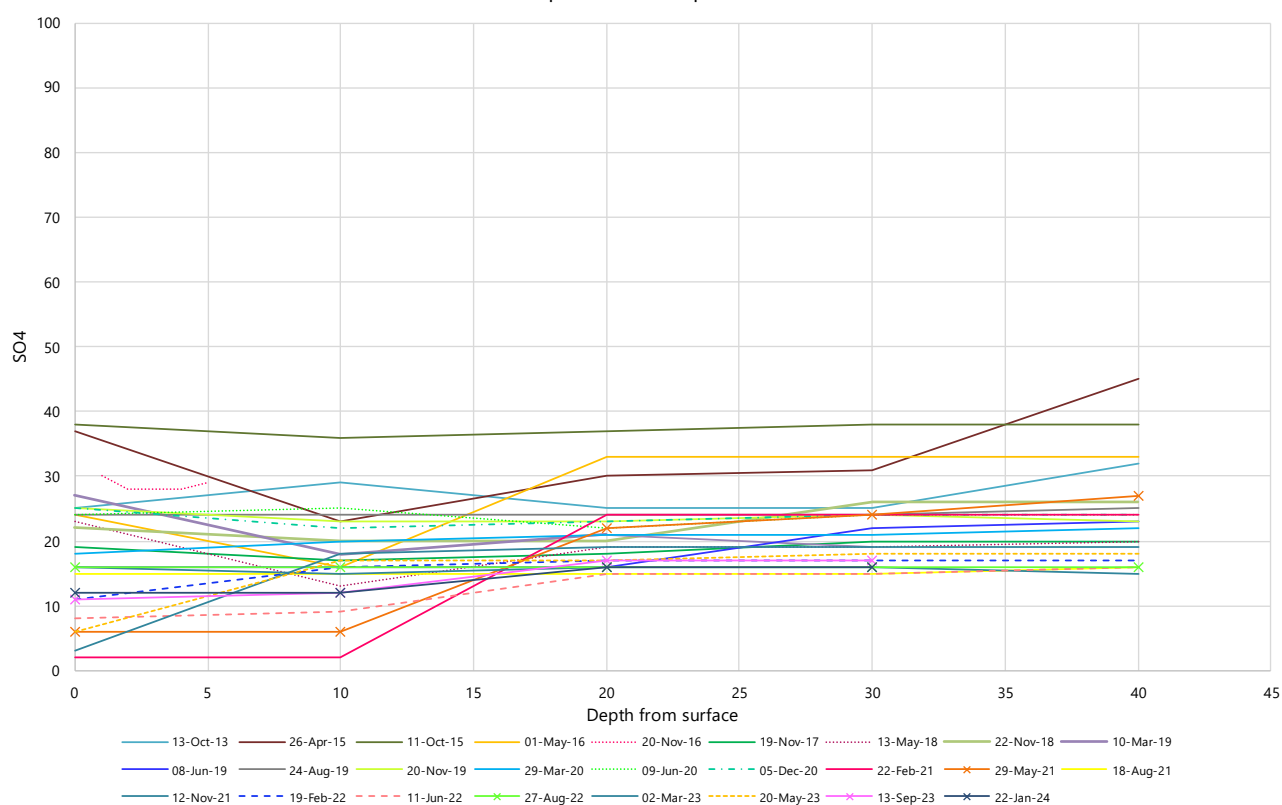
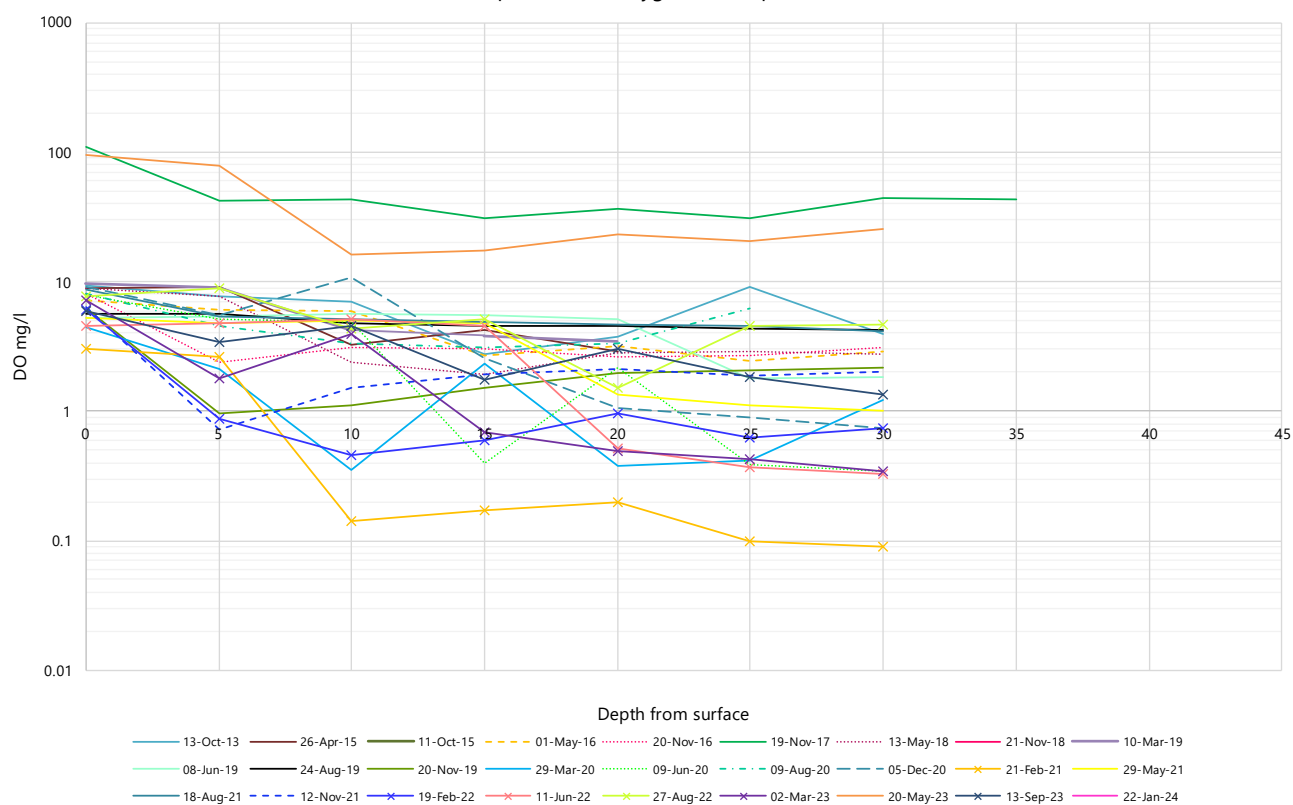


Figure 28 - Main Pit water quality at depth - sulphate



Main pit dissolved oxygen with depth - MP1



Main pit dissolved oxygen with depth - MP2

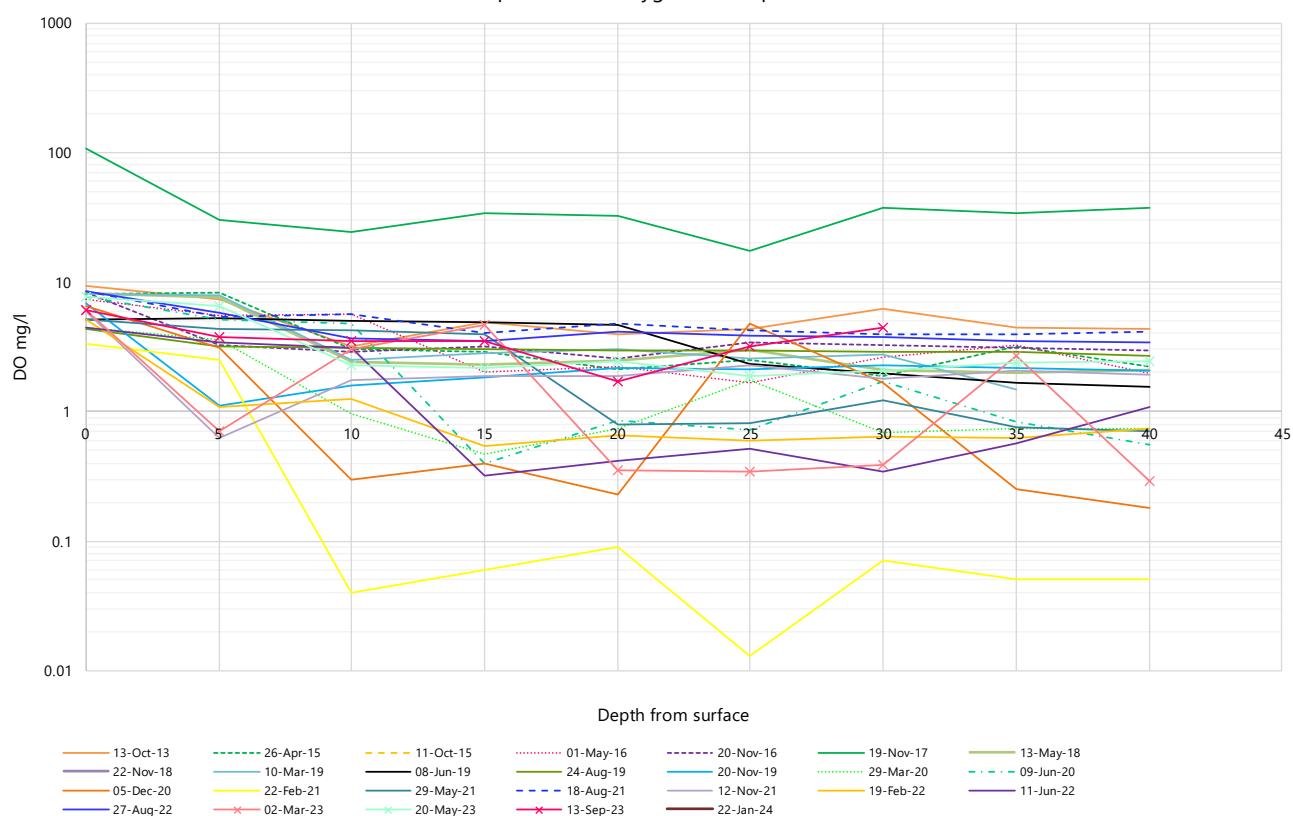
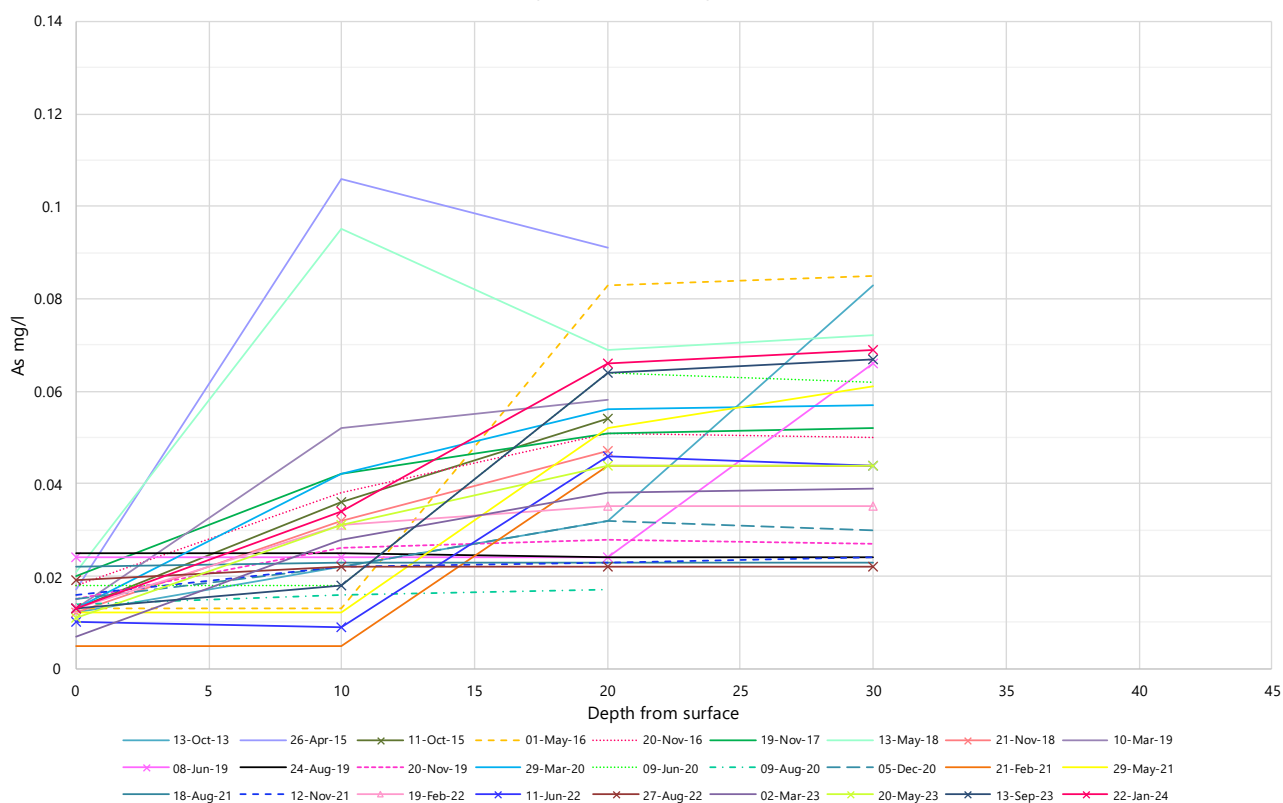


Figure 29 - Main Pit water quality at depth – dissolved oxygen



Main pit arsenic with depth - MP1



Main pit arsenic with depth - MP2

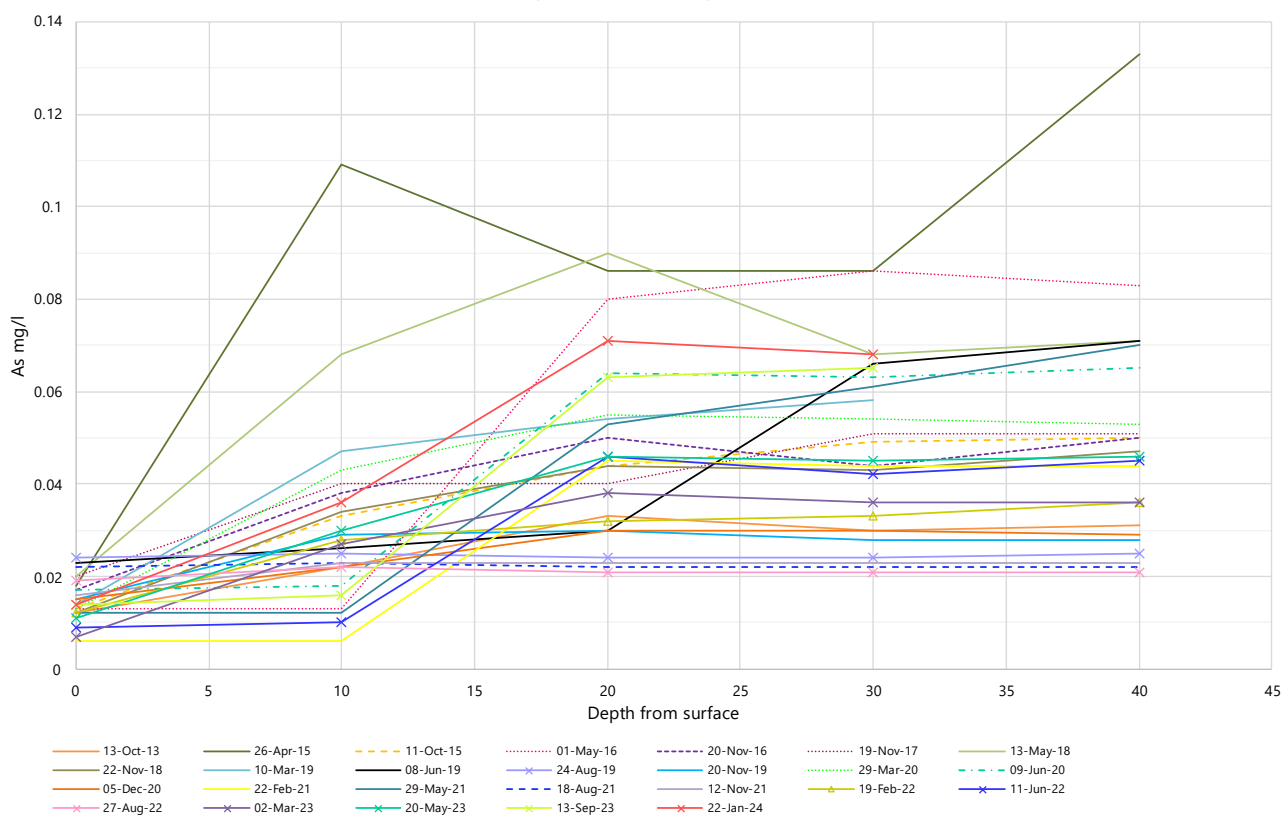
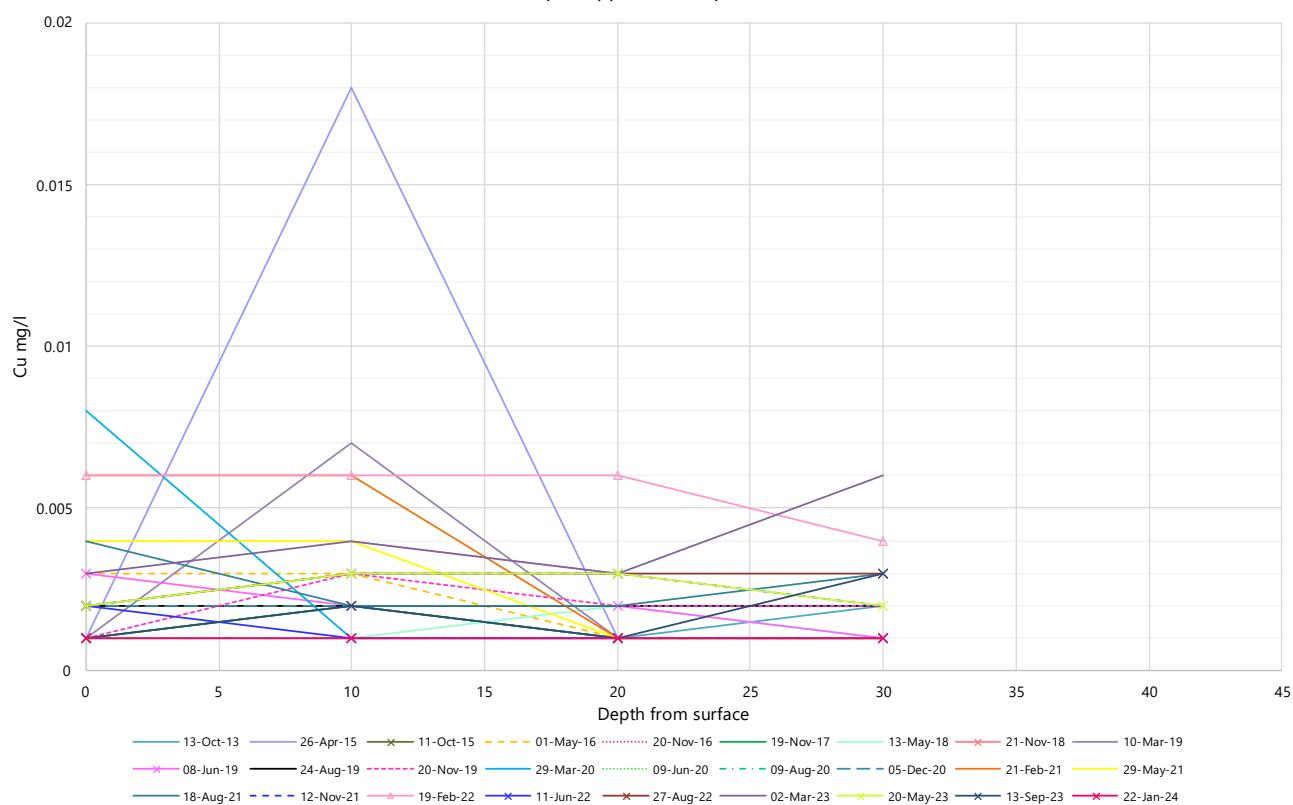


Figure 30 - Main Pit water quality at depth - arsenic



Main pit copper with depth - MP1



Main pit copper with depth - MP2

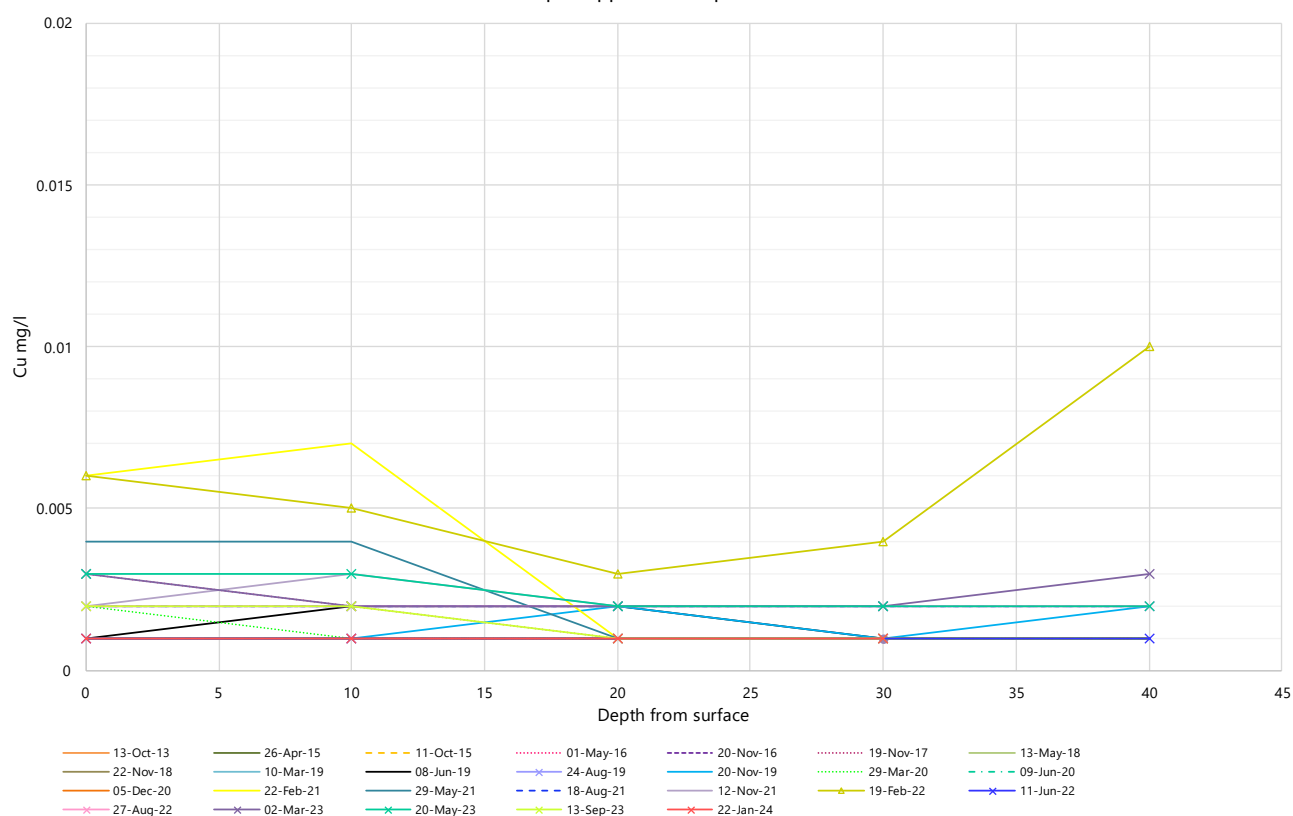


Figure 31 - Main Pit water quality at depth - copper

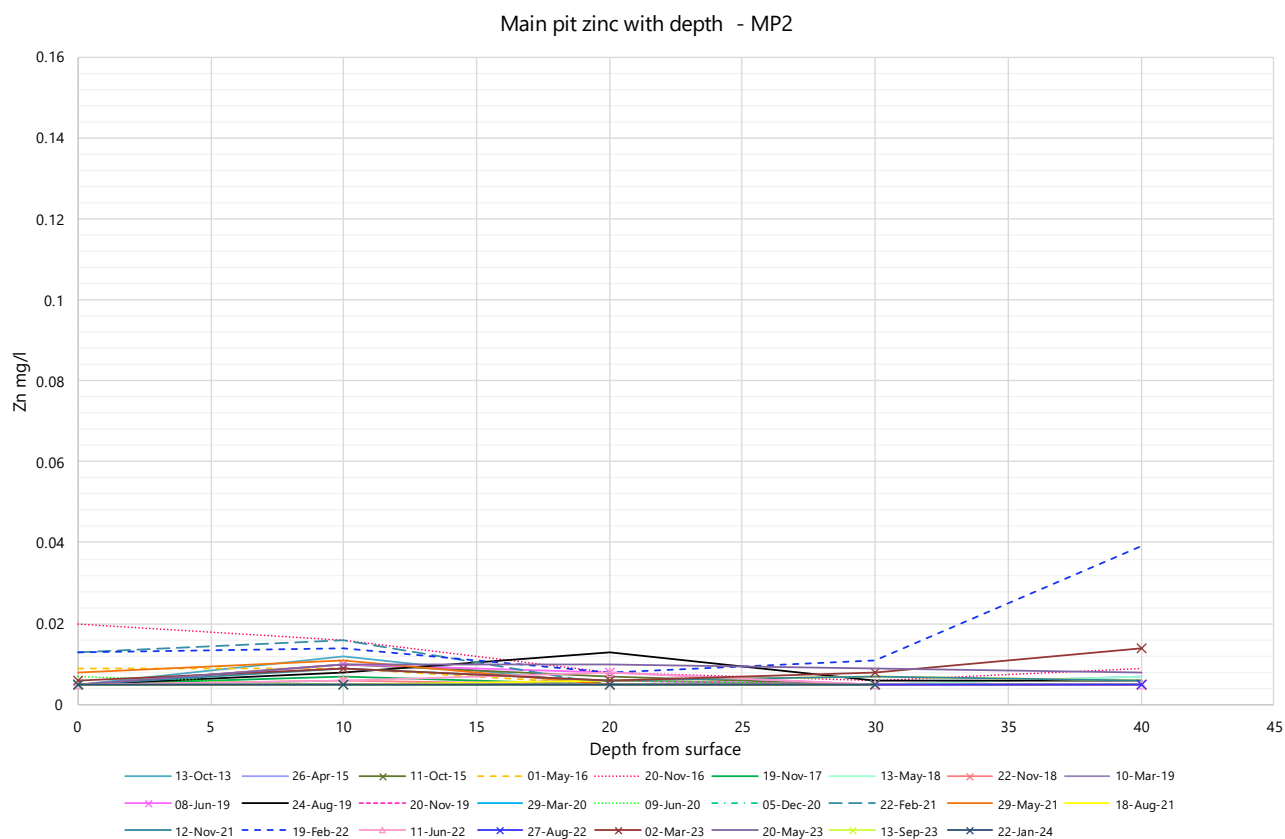
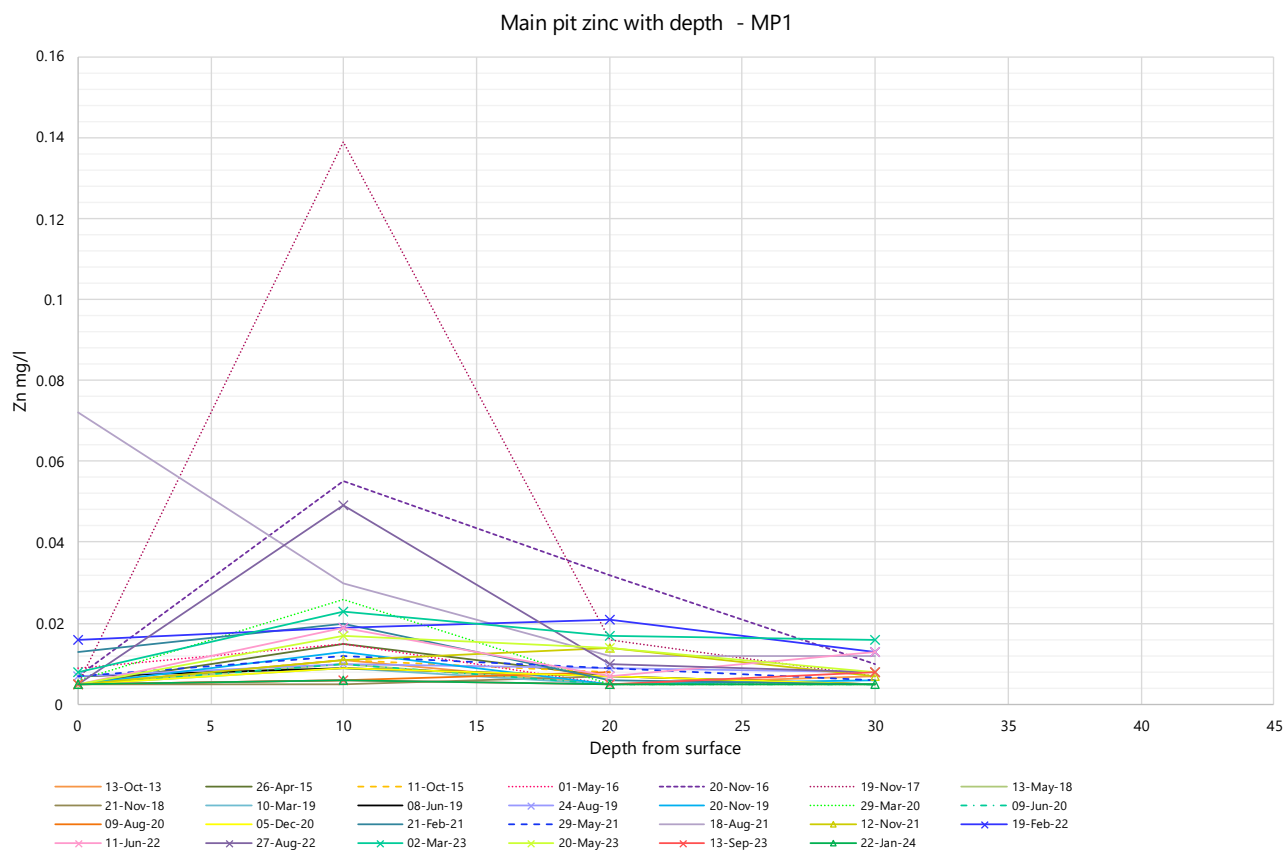


Figure 32 - Main Pit water quality at depth - zinc



3 Water quality of Main Pit and Suttor River mixing

3.1 Direct measurement of connection events since pit lake establishment

Given the Main Pit lake has been established for nearly 25 years, in the current Yandan monitoring database, there are eight (8) events of direct monitoring in periods where the Main Pit and the Suttor River are connected and flowing. These monitoring events provide the opportunity for direct measurement of potential impacts or changes with pit lake mixing.

Figure 33 presents metals concentrations for three (3) connection events over the record as a reconciliation between background and downstream quality. Full disclosure of results is provided earlier in this report: timing of sampling events with flows is shown in Figure 18, and results in Table 7.

Key observations from the reconciliation include:

- Arsenic is generally present in background, and quality downstream is either matched or slightly less after mixing.
- Cadmium, mercury and selenium are generally not present.
- Copper, and zinc are variably present (as we see in pit lake quality) – but when detected can be in background/upstream flow and downgradient flow at similar levels.
- Lead is generally not detected (generally not detected in pit water), but when present is recorded in background and downstream waters.
- Nickel may or may not be present in upstream/background waters, but is generally not detected downstream.

Review of results demonstrates there is no detectable change or impact to water quality for the Suttor River through mixing of Main Pit lake water during periods of connection.

3.2 Mixing model

Resultant water quality as the Suttor River and Main Pit lake water interact can be estimated through generation of the mixing model to compare to water quality objectives (ANZ Guidelines for Fresh and Marine Water Quality).

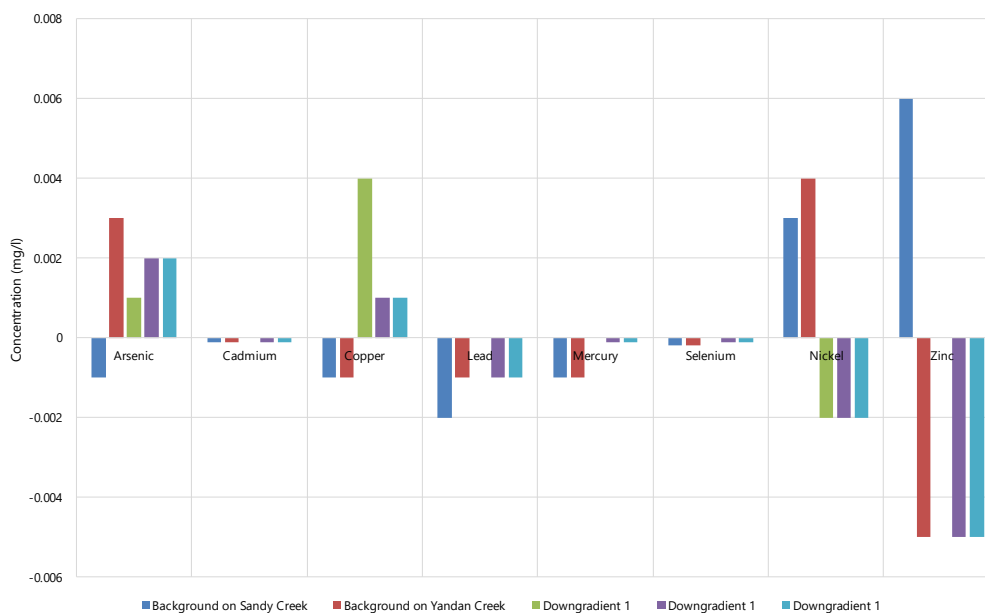
Table 10 lays out a mixing model built to the conditions of minimum connection between Suttor River and Main Pit, and simulating the period of greatest concentration (if higher flows from Main Pit will involve higher flows from the Suttor River). Work adapted from AECOMM (2012) and R&D Environment (1999) provides a river flow volume of 500-850m³/s in the Suttor at connection, and 2.7m³/s from Main Pit at 169.05mAHD. For the mixing model, a flow of 500m³/s is adopted.

The mixing model lays out background quality ranges sourced from the range of sources for the Suttor River: historical background, gauging salinity, and the 99th/1st percentile of upstream/background monitoring upstream/background. Pit water quality is simulated using the 99th/1st percentile of overall pit water monitoring results (all depths and both locations). The mixing model allocates a conservative quality as disclosed, and mixes water at different qualities relative to flow rates and volumes. A comparison to Australian Guidelines for freshwater toxicant limits for freshwater and drinking water (Australian Government 2011, 2023) is provided relative to the mixing model outcome, with commentary on fit to standards.

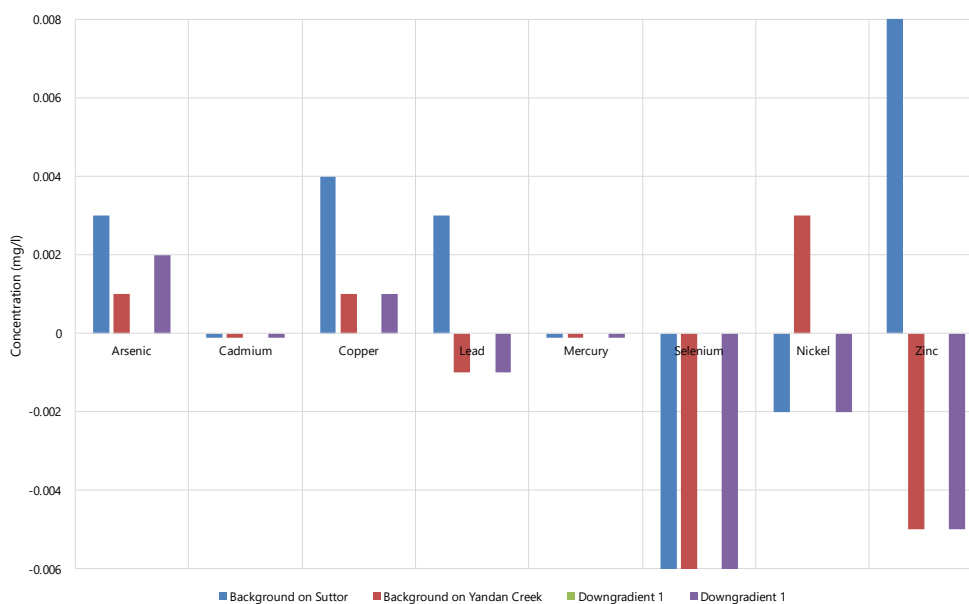
The mixing model confirms even conservative (or worst-case scenario of known concentrations) mixing of Main Pit and Suttor River satisfies or exceeds quality similar to current or historical background flow quality in the Suttor River, meeting water quality objectives for moderately disturbed environments and toxicant limits, and protecting existing aquatic ecosystem values in downstream Suttor River.



Event 3 - Dec 2022 to Jan 2023



Event 5 - Feb 2023



Event 5 - April 2023

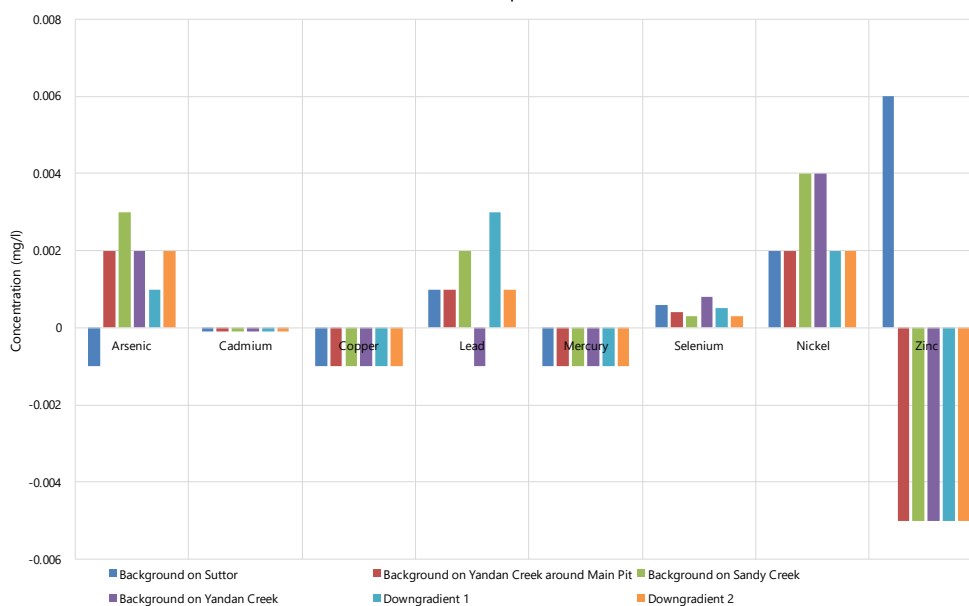


Figure 33 - Reconciliation of 3 connection events - upstream and downstream of Main Pit



Flow in Suttor River at 169.05mAHD									
Flow over spillway from pit to Suttor									
Total flow downstream of Main Pit									
Parameter	Historical background	Gauge background	99th % in event background river quality	1st % in event background river quality	Selected background value for mixing	99th % in lake (all depths)	1st % in pit lake (all depths)	Basic mixing model outcome (for MP/Suttor)	Toxicant limits (95% slightly disturbed) or ADWG* for freshwater $\mu\text{S/cm}$ mg/l
pH	7.1-8.8		8.0	7.3	7.6	8.9	5.6	7.6	6.5-8.5*
Electrical conductivity (EC)	Not detected	<1,000	617	153	10	304	106	11.6	420*
Sulphate	<11		5.8	ND	8	39	2	8.2	250*
Arsenic	0.002-0.004		0.003	ND	0.003	0.103	0.006	0.004	0.024
Cadmium	Not detected		0.0002	ND		ND	ND		Not detected in pit, below background. River background similar to FW toxicant limit
Copper	0.007-0.015		0.004	ND	0.004	0.008	ND	0.004	Above FW toxicant limit, however within historical and river background
Lead	Not detected		0.003	ND	0.003	0.004	ND	0.003	Aligns to background and below FW toxicant limit
Mercury	Not detected		0.0005	ND		ND	ND		Not detected in pit, below background. River background similar to FW toxicant limit
Molybdenum	Not detected		0.009	ND		ND	ND		Not detected in pit, below background. River background well below to FW toxicant limit
Selenium	Not detected		0.004	ND	0.004	0.01	ND	0.004	Aligns to background and below FW toxicant limit
Zinc	0.008-0.05		0.055	ND	0.008	0.053	ND	0.008	Below background and aligns to FW toxicant limit

Table 10 - Mixing model outcome for Main Pit and Suttor River/Yandan (spillways)



3.3 Comparison of expected water quality from original design

At the time of pit lake formation and design, SRK (1999b) modelled expected pit lake water quality after 1 year of flooding and containment (Figure 34). Overall as a comparison of modelled to actual, general parameters have performed as expected (noting pH of the pit is neutral), whilst most metals are much lower than predicted (refer Table 10 for 99th/1st percentile for observed metals), except arsenic. Arsenic is observed at below predicted concentrations at 0.03mg/l in the 50th percentile, however can range from 0.006 to 0.103mg/l at the 99th/1st percentile.

Table 4.5
Effect of Diffusional Transport on Pit Lake Water Quality 1 year After Flooding

Parameter	Units	Guideline	Wall Rock	Waste Rock Cover					
Soil Cover	m			0.2	0.2	0.3	0.4	0.5	0.5
D _{eff}	cm ² /s			1.0E-05	5.0E-06	1.0E-05	1.0E-05	1.0E-05	5.0E-06
pH			5.0	-	-	-	-	-	-
SO ₄	mg/L		15	27	21	23	21	20	17
Cl	mg/L		9	13	11	12	11	10	10
Ca	mg/L		11	13	12	12	12	12	11
Mg	mg/L		6	8	7	7	7	7	6
Na	mg/L		13	18	15	16	15	15	14
K	mg/L		6	6	6	6	6	6	6
Al	mg/L		0.23	2.3	1.2	1.6	1.2	1.04	0.63
Fe	mg/L	Na	16	19	17	18	17	17	16
As	mg/L	0.05	0.040	0.052	0.046	0.048	0.046	0.045	0.042
Cu	mg/L	0.005	0.017	0.055	0.036	0.042	0.036	0.032	0.024
Mn	mg/L	0.1	0.010	0.045	0.027	0.033	0.027	0.024	0.017
Ni	mg/L	0.015-0.15	0.017	0.108	0.063	0.078	0.063	0.054	0.036
Pb	mg/L	0.005	0.000004	0.000012	0.000008	0.000009	0.000008	0.000007	0.000006
Zn	mg/L	0.005-0.05	0.039	0.35	0.19	0.24	0.19	0.16	0.10
Hg	mg/L	0.0001	0.000004	0.000005	0.000004	0.000005	0.000004	0.000004	0.000004

Figure 34 - Summary of expected pit lake water quality at time of design (SRK 1999b)

3.4 Option and impact of a reduced levee bank at closure

The closure fate of the current perimeter levee bank in place around much of Main Pit has been reviewed as to determine the potential for a reduced in height or extent alternative whilst maintaining the minimum 169mAHD elevation constraint of connection from the Main to the Suttor River. The current levee was constructed during operation for water control and safety for operations in the pit, and may not be required for closure. The levee currently provides a hydraulic barrier to elevations of 172-175mAHD. The proposed fate for the levee is to undergo reparation activities to manage erosion, and be retained in the final landform as a flood protection bund, and operate in a similar way as present day.

A cross-section analysis around Main Pit in Figure 35 plots elevations around the pit as a means to determine where an adjusted levee bank would be required to maintain separation to 169mAHD between the Main Pit and Suttor River (outside of natural topography elevation). The analysis is preliminary however indicates potential to have a lower and shorter levee bank and maintain 169mAHD elevation: instead of full coverage around much of the pit, a levee bank may only be required for the western extent, as natural topography provides a barrier for the remainder.

The adjusted levee bank is an estimated 430 metres in length, and would mean that when flooding connection occurs, that instead of having connection only at the spillways, that there would be connection along that 430m extent at 169mAHD. The changed levee bank would not change other parts of the Main Pit water system: the catchment, water level responses and containment would not change, nor the frequency of connection, as the 169mAHD limit is maintained.

From a mixing perspective however, this change would increase the volume of contributing flow from Main Pit into the Suttor River during period of flood. Table 11 provides an updated mixing model, with increased flows of 60m³/s from Main Pit, and using the same process as current state mixing, predicts expected worst case quality. Results of the mixing model with an increased flow from Main Pit reflect an increased concentration of metals where present reporting to the Suttor, but also identifies metals generally meet Australian Guidelines for freshwater toxicant limits for freshwater and drinking water (Australian Guidelines 2011, 2023). Further assessment of the design and function of a changed levee bank is required, however, may provide an alternative to maintaining an extensive and unnecessary high levee in perpetuity.

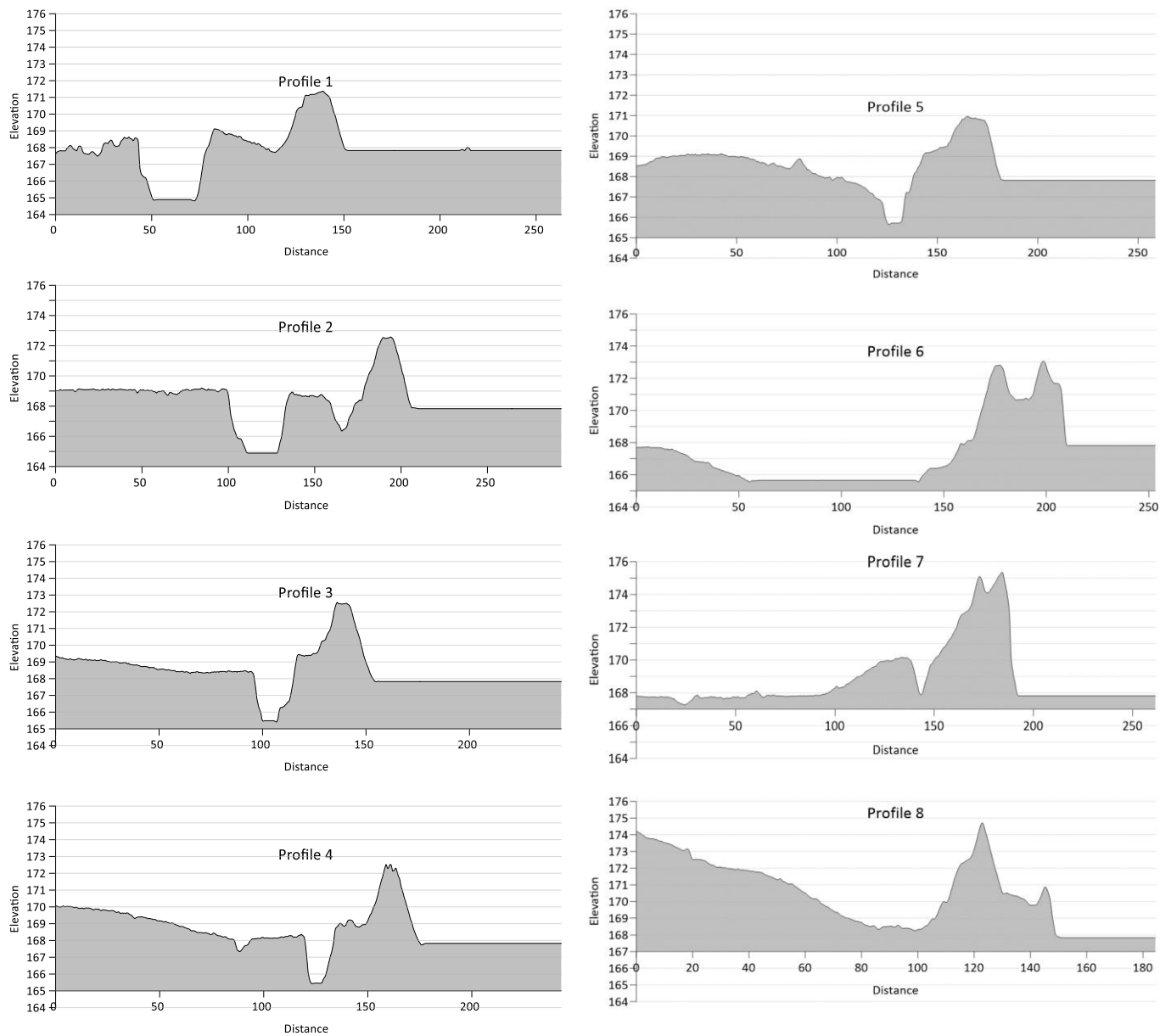
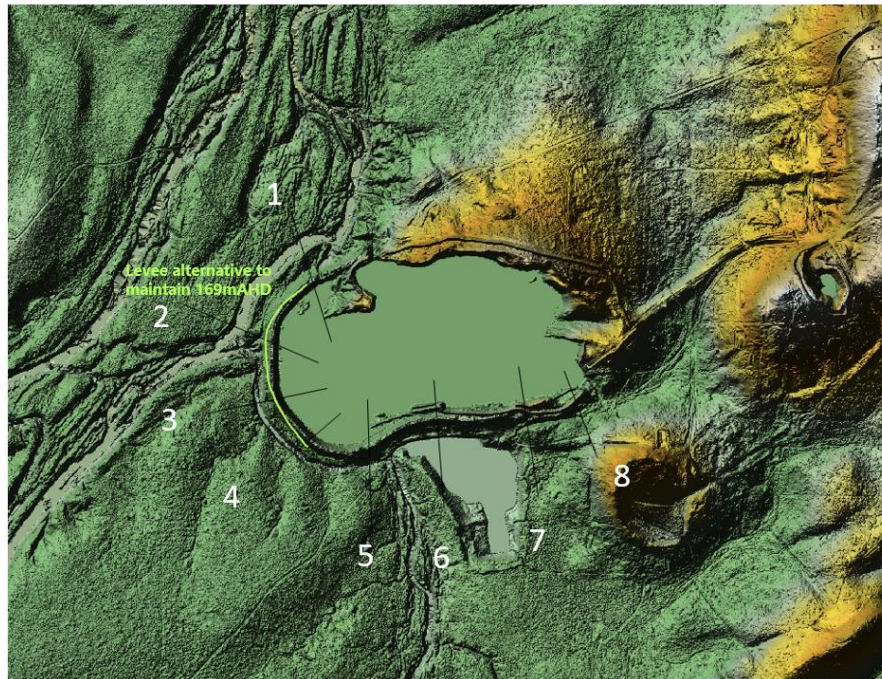


Figure 35 - Representation of potential alternative levee bank at 169m AHD



Flow in Suttor River at 169.05mAHD											
Flow over spillway from pit to Suttor											
Total flow downstream of Main Pit											
Parameter	Historical background	Gauge background	99th % in event background river quality		1st % in event background river quality		Selected background value for mixing	Basic mixing model outcome (for MP/Suttor)		Toxicant limits (95% slightly disturbed) or ADWG* for freshwater uS/cm mg/l	Fit to background water quality
pH	7.1-8.8		8.0	7.3	7.5	8.9	5.6	7.5	6.5-8.5*	Aligns to background and ADWQ	
Electrical conductivity (EC)	Not detected	<1,000	617	153	10	304	106	46.5	420*	Aligns to background and ADWQ	
Sulphate	<11		5.8	ND	8	39	2	12.6	250*	Aligns to background and ADWQ	
Arsenic	0.002-0.004		0.003	ND	0.003	0.103	0.006	0.015	0.024	Aligns to background and underneath FW toxicant limit	
Cadmium	Not detected		0.0002	ND		ND	ND		0.0002	Not detected in pit, below background. River background similar to FW toxicant limit	
Copper	0.007-0.015		0.004	ND	0.004	0.008	ND	0.005	0.0014	Above FW toxicant limit, however within historical background, and near to recent river background	
Lead	Not detected		0.003	ND	0.003	0.004	ND	0.004	0.0034	Aligns to background and FW toxicant limit	
Mercury	Not detected		0.0005	ND		ND	ND		0.00006	Not detected in pit, below background. River background above FW toxicant limit	
Molybdenum	Not detected		0.009	ND		ND	ND		0.034	Not detected in pit, below background. River background well below to FW toxicant limit	
Selenium	Not detected		0.004	ND	0.004	0.01	ND	0.005	0.005	Slightly above background but aligns to FW toxicant limit	
Zinc	0.008-0.05		0.055	ND	0.008	0.053	ND	0.014	0.008	Below background, does not meet FW toxicant limit	

Table 11 - Mixing model outcome for Main Pit and Suttor River/Yandan (adjusted levee bank)



4 Pit lake water level behaviour under climate change

As part of the 2022 original PRCP, a pit void water balance for Yandan Man Pit model was constructed to calibrate water dynamics of the pit and simulate pit water levels for PMF and climate change scenarios (SBE 2022) across 108-year model period. The water balance model recognizes and is supported by the experience of the Main Pit lake being in place for the past 25 years, where relative water levels have been relatively stable, and easily maintained above 160mAHD across dry, wet and average rainfall conditions. Climate change scenarios assessed by the model are sourced from *Queensland Future Climate dashboard* (Queensland Government 2021) (see Table 3) and include:

- Base case – which is used to set systems rates and settings to be applied all scenarios.
- Climate change scenarios based on 50th percentile predictions - 2030, 2050, 2070, 2090
- Climate change scenarios for extreme wet & dry (90th/10th percentile) predictions – 2090

Further details of methodology, construction, and model design settings and parameters are available in SBE (2022), including a fixed allowance for groundwater inflow at 14l/s over the life of the model, and river flooding recurrence AEP of 10%.

Figure 36 presents model outcomes over the range of scenarios, comparing levels with river inflows and without river inflows, noting the key elevation for water levels to remain above is 160mAHD to maintain containment of stored waste materials and potentially reactive pit walls.

The model indicates that with Suttor river inflows, the 160mAHD minimum level is maintained in all scenarios except the 2090 extreme dry scenario. This is a low probability scenario, as the 90th percentile of dry conditions for 2090. There is additional conservatism built into the model as:

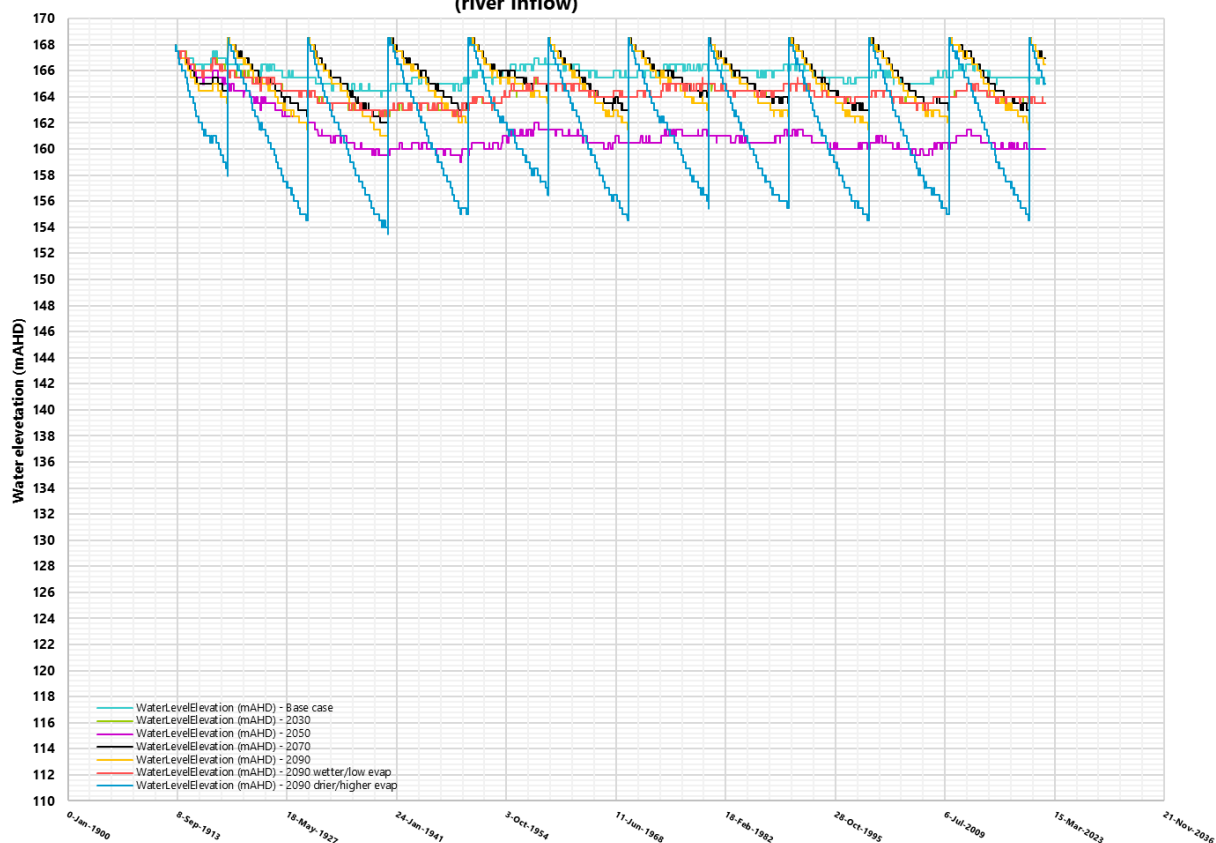
- Groundwater inflow rates are likely to increase as elevation head (water levels) decline within the pit (remembering during mining there was reasonable groundwater inflows for dewatering), rather than being fixed at current inflow rates. An update to pit void modelling is anticipated once adequate monitoring results are available from recently installed groundwater bores and pit water level monitoring to inform an updated approach.
- 10% flooding AEP is conservative compared to the observed AEP of the past 25 years of 25%, and the likelihood of more extreme dry periods with extreme wets with climate change.

In the second scenario where river inflow is excluded however, water levels are not maintained above 160mAHD in the 2070 and 2090 50th percentile, or the 2090 dry 90th percentile scenario. In these situations, potentially reactive pit wall materials might be exposed to air, and part of the rehabilitated cover of the encapsulated waste materials in the base of the pit may be exposed. Model outcomes without river inflow are also conservative given set rates of groundwater inflow (rather than increasing with lowering pit water levels). In extrapolation if conditions where pit walls and stored waste materials were exposed, various factors would influence potential implications:

- The process of metals mobilisation requires exposure to air, and then wet and dry cycles: exposure for oxidation, and then mobilisation to occur in water. This may not which may not be case in severe dry conditions, or equal/combined exposure for the pit wall or waste.
- Exposure of the rehabilitated cover over waste materials within the pit will not necessarily result in exposure of the encapsulated materials to air.
- If metals mobilisation or acid mine drainage occurs within the pit, any impacted water will be contained within the pit and protect river health. As flooding inflow replenishes water levels to the point of overflow within the pit, the resultant water quality will be substantially freshened and further mixed prior to discharge.
- Like when first filled in 1999, if water levels are declined, once flows are restored the pit will fill quickly, re-establish water containment, and we might expect a similar water quality response to that observed to date.



Main pit - 108 year base case pit water levels through climate change scenarios
(river inflow)



Main pit - 108 year base case pit water levels through climate change scenarios
(no river inflow)

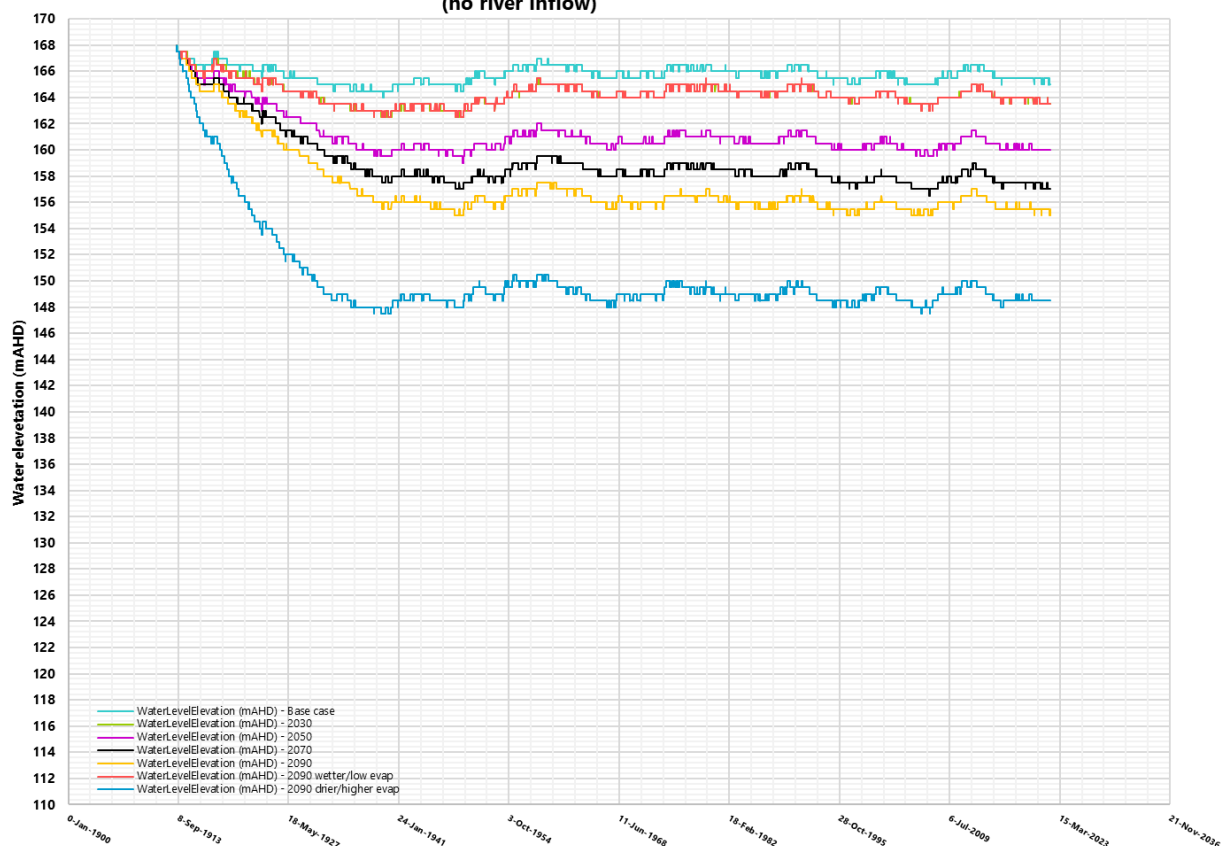


Figure 36 – Predicted response of Main Pit water levels in climate change scenarios



5 Conceptual model of the Main pit and Suttor River

Figure 37 presents a conceptual model diagram of the components and relationship of Main Pit and the Suttor River. A conceptual model is not intended to be at scale, but to show the component and relate different parts of the system to each other for understanding.

Supporting details of the conceptual model are provided in Table 12 below.

Table 12 - Conceptual model descriptions

Area	Description
Climate	Yandan is a strongly water balance negative site where potential evaporation exceeds rainfall. Rainfall is typically 545mm/year but can vary from 220 to 1,200mm. Evaporation potential averages between 1,800 to 2,300mm/year. Future climate scenarios currently extend out to 2090: nearer term climate change expectations are for a slight drying of the climate; scenarios in 2090 range from very dry to very wet.
Geology	Geology directly around Main Pit consists of metasediments and crystalline volcanics which are altered through a history of hydrothermal activity, which also formed the gold mineralisation of the Yandan deposits. There is a bounding fault to the east, and several faults through the pit, known as the Yandan Fault, and several other cross cutting faults. Given the compaction and nature of host rocks, porosity and permeability is generally very low.
Main Pit	The Main Pit is 40-60m deep historical mining pit in place since 1999 and has a water cover pit lake to contain reactive waste rock at the base of the pit, and potential reactive pit walls. The pit lake is relatively contained and does not overflow through direct rainfall but can be connected to the Suttor River and Yandan Creek via two spillways on the western and eastern sides. For water to leave the pit, flood water must be flowing in from either the Suttor or Yandan Creek to lift water levels in the pit, creating mixing conditions before flowing down the Suttor River. The Suttor River connects to Main Pit through the western and/or eastern spillway when flooded at flows of 500m³/s (or a height of 169.05mAHD elevation), with a recurrence interval of around 25%. Groundwater is likely connected into Main Pit given the depth of the pit, presence of the Yandan Fault which is, intersection of groundwater levels in the pit, observed slower evaporation rate than other water storages, and water balances showing a discrepancy. Water in Main Pit will be bound as a groundwater sink – seepage from Main Pit to the river has not been observed over the past 25 years at current elevations. Water balances suggest the Main Pit water cover requires periodic inflow from the river based on rainfall and evaporation rates, with a small groundwater baseflow.
Suttor River and Yandan Creek	The Suttor River in the mid-reaches is a regional ephemeral river which flows only after rainfall. In this area, the Suttor River is a losing river without groundwater baseflow, or there would be permanent flow in the river, or signs of leakage. Water flow is low energy, and extensive alluvials are developed west of the Main Pit (thought to be up to 30m deep in places).



Area	Description
	Yandan Creek is a relatively undisturbed ephemeral creek which drains from the southern part of the lease and diverts around Main Pit unless in flooding conditions, when it will flow into the Pit via the eastern spillway.
Groundwater	Groundwater around Main Pit is highly saline and dense as an ambient condition, and enriched in chloride as a remnant of hydrothermal processes in geological history. The groundwater surface is very low gradient surrounding the pit as a subdued version of the landscape topography, and an indicator the general constrained groundwater environment outside of the pit itself. Groundwater is unlikely to flow into the Suttor River: groundwater levels are unlikely to intersect the river, historical pump tests identified no connection, and after 25 years of observations since the pit lake was constructed, there is no signs of permanent flow, or chemistry signature signifying hydrothermal connections.
Overall performance	Pit water quality is stable, with neutral pH, low salinity and sulphate of fresh water. Pit water has slightly elevated metals of As, Cu and Zn (compared to toxicant levels). Dissolved oxygen averages 3-5mg/l, moderate water quality suitable to support aquatic life. Main Pit lake does not impact surface water quality of the Suttor River. No surface water contamination is identified downstream of the Main Pit during or following connection events: the Main Pit has relatively fresh water, and monitoring of discharges over time shows downstream water meets Suttor River and Yandan Creek background levels, and often meets general toxicant water quality levels for freshwater. This is confirmed with mixing models of worst case scenarios. Inflow into Main Pit from the Suttor River or Yandan Creek does not materially impact flow volumes down the river to alter quantity of water available now or in all scenarios except for the extreme dry 2090 scenario. During periods of flooding, the river hosts excess flow, and the pit generally only requires a top up of volume given the groundwater contribution rather than a significant fill volume before discharge.
Management system	The monitoring system of the Main pit and the Suttor River are well developed with longer term records monitoring of the pit lake quality and levels, river level and quality upstream and downstream of the site, and the installation of recent groundwater bores, there is a substantial dataset which enables a thorough understanding of the pit lake behaviour, and management system to manage into closure and beyond.

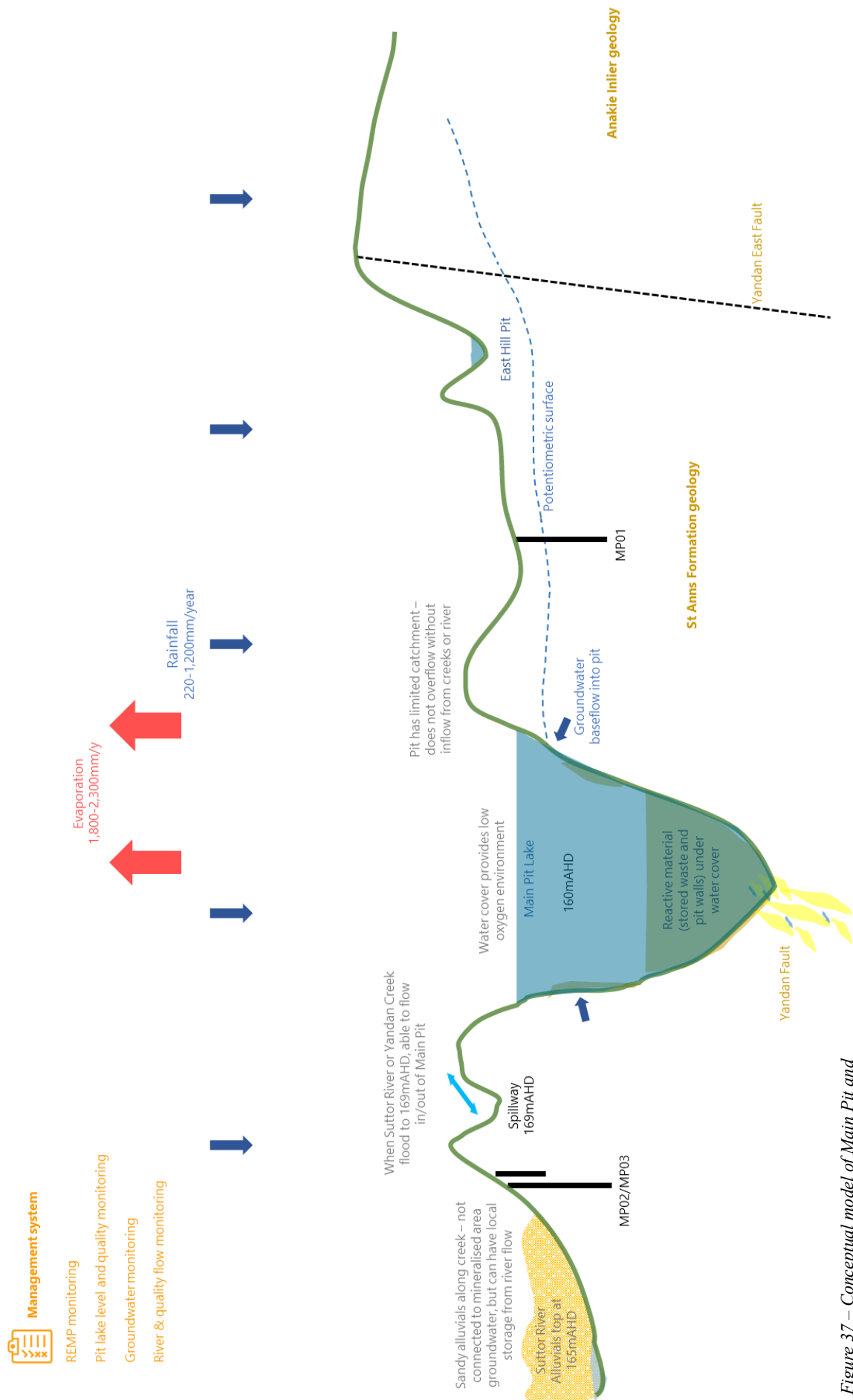


Figure 37 – Conceptual model of Main Pit and Suttor River relationship



6 Risk summary and position

6.1 Principles and benchmarks

Pit lakes continue to be common in the development of closure outcomes for mining pit voids across Australia and the world (Kumar et al 2013). However, the challenge in delivery of a sustainable, stable and water-values supportive pit lake is unique to each void and setting, and factors may not combine to support a stable and non-polluting pit lake as a legacy landform. As a result, many pits host poor water quality, though there are also several highly successful pit lakes such as Lone Pine in Western Australia, or Lake Kepwari in the Collie Region, or the lignite mining areas of Germany (Lund and Blanchette 2023, Johnson and Wright 2003, McCullough et al. 2012, McCullough and Lund 2010).

Water cover as a closure strategy for pit voids can serve multiple purposes: freshwater ecology or recreation services, water supply or management, or like at Yandan as a containment to potentially reactive materials in pit walls or materials stored within. Being under water, the low dissolved oxygen content of water constrains access to oxygen and oxidation and limits leaching capacity, effectively controlling potential for acid or metalliferous drainage potential. The main goal for any reactive waste or materials management on a site for closure is to limit exposure to air and water percolation, and water cover achieves both (Australian Government 2016 a, b).

The ability to deliver a pit lake and water cover as a stable post-mining land use (PMLU) is often unique to each pit void and determines if a PMLU post-closure can be achieved versus the retention as NUMA. Each site has variable geology, geometry, water systems and connections, climate, surrounding environment, community and geometry to consider and bring design to, thus creating unique requirements, constraints, and performance requirements for an acceptable longer-term outcome. In areas of negative water-balances such as Yandan, access to additional inflow from fresher water sources to maintain pit water levels above cover heights, or to freshen water quality is critical (Australian Government 2016 a,b). More water needs to come into the pit lake, as without additional flow evaporation will exceed rainfall rates in water balance of the pit lake, reducing water levels and/or concentrating water quality.

Lake Kepwari, a coal mine pit void in the Collie region in WA demonstrates the role river flow through can have to create and maintain a healthy pit lake, where the pit has been successfully rehabilitated to a recreational lake with a permanent connection to the river system (McCullough et al. 2012). A QMRC commissioners paper (Clay et al 2022) also highlights Kepwari PMLU outcomes *"Lake Kepwari, a Western Australian recreational lake in an old coal mine void, has combated water quality issues through a different approach: riverine flow through. The inputs from the local river system have been recorded to improve water quality in the lake by "adding carbon matter, improving acidity and reducing soluble metal concentrations", at a "low risk to the downstream environment" (Premier Coal, no date).*

Kepwari is not an isolated example: Lone Pine and Harmony mine void relied upon creek diversions to manage potential salinity (Johnson and Wright 2003), and the ex-lignite mines in eastern Germany are now major recreational lakes associated with river flow through (Clay et al 2022, McCullough et al 2012). Other factors for success also include:

- Thinking, design and acceptance of innovative approaches for PMLU through water cover, and other types of values a pit lake might be able to offer (McCullough et al. 2012, Lund and Blanchette 2023).
- The design and placement to contain materials under water over time in stable geotechnical conditions, and use of additional methods such as encapsulation as controls and safeguards for water quality.
- Robust data acquisition and reporting of water quality and levels of voids over time as a test or demonstration that a PMLU is successful (Australian Government 2016a,b).



6.2 Risk assessment summary of Main Pit as a water cover and pit lake

Table 13 – Risk assessment summary for ongoing closure of Main Pit and Suttor River

Risk or opportunity area	Measurement and controls
Technical understanding at appropriate certainty	- Condition of pit lake as established for 25 years - Extensive monitoring history across pit lake chemistry at depth, river flow quality and flow rates (upstream and downstream). Groundwater bore network and water level logger now in place to further advance. <i>Tools</i> - Analysis and relationships of all available monitoring (10+ years), plus background information - Flow regimes and relative levels well understood - Flooding frequency and depths known - Conceptual model updated and a good fit - Reconciliation of river water quality and flow mixing model - Water balance model across various scenarios
Water quality stability and health within pit lake	- Pit lake water quality is broadly stable since 2013 - Neutral pH, low EC and sulphate, metals stable, arsenic, copper and zinc slightly elevated - No interventions required to maintain health recorded
Additional throughflow water to freshen and top up water cover	Regular connection and throughflow from Suttor River and Yandan Creek. Design AEP at around 7-10% over flow records, observed AEP over past 25 years to date at 25%
Potential surface water contamination through discharge	- Quality monitoring upstream and downstream during events shows water quality aligned to background and/or freshwater recreation standards - Mixing model of flow from river and pit confirms adequate mixing to meet background or freshwater standards - Some flexibility in levee heights and extent
Potential groundwater contamination or changes from pit lake	- Groundwater is highly saline around pit given hydrothermal history. Some metals but neutral pH. Flows into pit at low rates (pit is a groundwater sink). - Groundwater unlikely to flow into Suttor River alluvials given hydraulic head and nature of host rock: there is no seepage or evidence of groundwater populations in surface water.
Exposure of reactive materials under climate change scenarios	Water cover persists above 160mAHD in nearly all climate change scenarios except for the 90th percentile dry 2090 scenario. Some conservatism is built into the model for inflows, with other controls such as pit containment and encapsulation of materials at depth to reduce impacts. To review when further groundwater and level information is gained (2-3 years).
Reduced water flow available for creeks	Minimal impact to flow: river inflow occurs only in flooding conditions, and is top up water rather than captured water
Opportunity in pit lake as PMLU used on preliminary analysis (would require further investigation to assess if viable as an outcome)	- Ecology services - Water storage for use in agriculture or other industry



6.3 Water cover for Main Pit

Although not specifically mentioned as an example in published literature to date, Yandan Main Pit lake can credibly be added to the examples of a successful water improvement outcomes using water cover and flushing design.

Water quality in the Pit Lake is demonstrated as self-sustaining and has required no intervention over the 25 years since establishment. The lake acts to effectively encapsulate reactive materials within the pit to protect water quality. Pit lake levels are self-sustaining with flood water flow through to/from Suttor River, and conditions of discharge and mixing meet background and water quality objectives to protect water values.

6.4 Further work recommendations

Table 14 - Further work recommendations

Area	Recommendations
Robust water monitoring and reporting	▪ Ongoing characterisation of groundwater and water levels through bore monitoring and level loggers for 12-24 months (capture at least one flooding event) ▪ Frequency of pit lake depth monitoring could be reduced (as the system is largely stable), recommend move to 2x year and flooding event based ▪ Updates to existing monitoring: ▪ Add cation/anion and dissolved oxygen analysis at SR and REMP sites ▪ Consider taking multiple samples at REMP or release sampling as a trial to identify potential for variability/further test of concept
Monitoring network	▪ Consolidate monitoring sites terminology and sampling regime between release and REMP sites for ease of assessment and clarity of what is monitored when
Advance or further assess PMLU outcomes	▪ Update water balance modelling once groundwater and water level/evaporation rates are able to be quantified, and review 2090 climate change water level scenarios ▪ Undertake biological surveys or reviews of existing studies to determine freshwater ecology services of the pit lake
Advance or further assess final design outcomes	▪ Engineering review to determine feasibility of a reduced levee bank to maintain 169mAHD as an alternative to the current operations levee at 172-175mAHD



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Appendix A – RFI to work package map

	Information Request Matter	Information Request	Response
6	Preliminary flood modelling has identified that some mining domains including the pit and heap leach pad will be inundated or in contact with floodwaters under 1% AEP and PMF events. However, information detailing how flood flow may interact with the final landform has not been included. An understanding of flood depth and velocity across the final landform is required and how this may influence the achievement and maintenance of a safe, stable and sustainable PMLU.	Demonstrate how all final landforms will achieve and maintain a stable condition under 1% AEP and PMF events. This includes investigating the effect that flood depth and velocity may have on the final landform.	Flood characterisation report
8	Section 3.1.6 of the PRC Plan provides some information on groundwater levels and salinity. No detail has been provided on the interactions of the pit, tailings dam and heap leach pad with groundwater. Criteria that demonstrate these structures will be non-polluting has also not been included. Figures 27 and 28 do not provide context on orientation of the pit and river nor depths of strata and pit depth. The Suttor River alluvium mentioned in section 3.1.6 of the PRC Plan is also not represented. Increasing trends in arsenic have been identified in groundwater in the PRC plan and interactions of tailings and heap leach seepage with groundwater may be occurring. The prediction of water quality impacts from mining activities is necessary to determine appropriate measures for the containment and management of contaminants and the	Provide an assessment of the hydrogeology of the site including all landforms and connected strata in accordance with 3.6.1 of the PRCP Guideline. An assessment of the interactions of the tailings and heap leach pad with groundwater must also be included in the PRC Plan. Provide detailed information regarding water quality and how it varies between depths and bores. Provide milestone criteria for groundwater quality to demonstrate all final landforms will be non-polluting.	Original information has been provided in original report.



	potential impacts on environmental values should they be released.		
9	The PRC Plan and EA require that the pit lake level is to remain above 160mAHD. The Plan also considers that the pit will act as a groundwater sink. Figure 32 in the SBE 2022 report indicates that the groundwater levels in the bore SH3 fluctuate above 160mAHD. Figure 26 of the PRC Plan includes an indicative map of the potentiometric surface of the groundwater however the potentiometric surface does not extend to the pit area.	Provide a hydrogeological assessment that encompasses all landforms on the project area. Include supporting evidence that demonstrates how the pit will act as a sink.	Updated Conceptual Model Report
12	The final landform design section of the rehabilitation planning part provides detail surrounding each of the residual voids that will remain as NUMAs on the project. This section of the planning part identifies further investigations that are yet to be completed and are required to inform management area milestone criteria. Main Pit ▪ A geotechnical assessment has not yet conducted on void batter angles, therefore residual void angle requirements are unknown. ▪ The rehabilitation planning part identifies that additional monitoring data (3-5 years) required to improve water balance to then determine a long term bund use. ▪ The expectation is that bunding will be retained within the final landform subject to	Provide further information to demonstrate that both the Main Pit and East Hill Pit will achieve a safe and stable condition as per section 3.6.3 of the PRCP guideline including, but not limited to, a geotechnical assessment and proposed final slope angles. Include all required milestone criteria in the PRCP Schedule to ensure the management of the NUMA's to safe, stable, non-polluting landforms.	Main Pit and Suttor River Characterisation Report



appropriate assessments (i.e. geotechnical investigations).

However, such assessments are incomplete at time of submission.

East Hill Pit

The rehabilitation planning part identifies that the East Hill Pit has a potential to be flooded under a PMF scenario. Given that water quality analysis from within the pit has determined it is of poor quality, this presents a significant environmental contamination risk. The rehabilitation planning part mentions that a small, permanent landform bund will be constructed around the north of the pit, however a design has not been considered in the rehabilitation planning part or supporting technical studies. Nor has this action been included in the PRC Schedule.

14	Various potential risk factors have not been considered in the risk assessment. The following example do not constitute an exhaustive list, but have been provided for reference: • A consideration of how various events may impact the completion time of rehabilitation stages (including potential compliance action as a consequence). • A consideration of risks associated with potential issues arising yet remaining unidentified between monitoring events, with specific links to the monitoring program to justify the selection of specific monitoring frequencies. • A consideration of climatic influence	Please update the risk assessment to include a broader consideration of potential risk factors and their associated mitigation measures to ensure the safe, stable and sustainable PMLU or managed NUMA is achieved. Please refer to section 3.7 of the PRCP guideline for further information.	Main Pit and Suttor River Characterisation Report
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	specific to the pit, for example, the impact that drought conditions may have on maintaining the water cover within the Main pit.		
23	The PRC Plan indicates that the Main Pit is expected to be inundated with flood waters and pass floodwater in to and out of the pit via spillways at certain river heights/flood levels to the Suttor River.	Discuss how the objectives for the Main Pit achieve best practice management of the area and minimises risks to the environment from the passage of flood waters in to and out of the pit. Consideration should be given to the stability of the spillways to achieve the purpose of passing floodwater in to and out of the pit. Completion criteria for water quality must reflect releases from the main pit not causing environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself.	Main Pit and Suttor River Characterisation Report
24	Figures 9 and 10 of the SBE 2022 Report as part of the PRC Plan indicate spikes in Electrical Conductivity (EC) during flow events with an explanation provided as "...with the exception of short-term higher salinity experienced during the major regional flooding event in 2011. Comparison of upstream & downstream salinity would suggest an additional salt load entered the river during this significant event, similar to occurrences across the Queensland region for this event."	Provide commentary on the timing of releases from main pit and how they correlate or not with the peaks in EC in the Suttor River	Addressed in 2022 report Updated Conceptual Model Report



27

The PRC Plan states that “minimal mixing is required with site or river water to meet receiving environment requirements.” However, no detail is included on what dilution is required to meet the receiving environment

requirements or at what flow volumes the minimal mixing will occur.

Provide detail on the minimum mixing requirement to ensure no environment harm will be caused from releases of pit water to the receiving environment

Main Pit and Suttor River Characterisation Report



Appendix B – Bore logs

DataSet	Hole_ID	mFrom	mTo	Lithology	Comments
Yandan	MP01	0	2	Gravel, alluvium, clay	
		2	4	Brown, fine-grained sandstone and silcrete	Minor siliceous material (silcrete?).
		4	6	Tan clay	Minor (rare) calcite crystals.
		6	7	Tan clay, fine-grained sandstone	Minor siliceous material (silcrete?/chert?).
		7	9	Tan-green fine-grained sandstone	Minor clay.
		9	12	Brown sandstone, fine-med- grained	Variable grainsize. Minor clay.
		12	13	Mix of med-gr sandstone and fine siltstone	Minor clay.
		13	16	Khaki clay and med-grained sandstone	
		16	18	Grey-green, fine-med grained sandstone	
		18	19	Green-cream saprolite and fine-gr green sandstone	
		19	25	Med-grained, quartz-rich sandstone	Poorly-sorted sandstone. Minor calcite veins, plus possible sericite alteration.
					A little damp near surface, dry to EOH.
					Most of these tan/brown/green sandstones etc likely to be variably calcareous.
Yandan	MP02	0	1	Soil, alluvium	
		1	7	Green siltstone, very fine sandstone	Probably calcareous. Minor chert and clay.
		7	8	Friable green siltstone	
		8	11	Green very fine-grained sandstone/siltstone	
					Damp at 10m
					Calcareous sequence. Limestone/marl and minor chert outcrop nearby.
Yandan	MP03	0	1	Soil, gravel	
		1	7	Green siltstone, and very fine-gr green sandstone	Minor clay
		7	9	Fine-grained green sandstone and tan limestone	
		9	10	Green siltstone	
		10	11	Green siltstone and tan limestone	
		11	13	Brown siltstone and limestone?	
		13	15	Brown siltstone/limestone, green siltstone	
		15	16	Grey-green siltstone	
		16	17	Dark grey, siliceous, very fine sandstone or chert	
		17	19	Dark grey, siliceous, very fine sandstone	Minor very fine pyrite/marcasite.
		19	24	Green to gray, very fine-gr sandstone/siltstone	Rare small carbonate veins.
		24	32	Grey to pale-green fine sandstone/siltstone	Rare, very fine pyrite/marcasite.
		32	33	Grey siltstone/fine sandstone, clay	Minor cream/grey clay.
		33	41	Grey, very fine sandstone/siltstone	Minor coarse calcite crystals, and rare fine pyrite/marcasite.
					A little damp 22-28m, water at 38m (lifted about 20 litres in 16 seconds in air lift, but not sustained).
					Variably calcareous sequence. Limestone/marl and minor chert outcrop nearby.
Yandan	MP04	0	2	Soil, alluvium	
		2	3	Medium sandstone plus colluvium	
		3	5	Red, med-gr sandstone, plus fine-gr siltstone	
		5	8	Red-grey, med-gr sandstone, plus siltstone	Poorly-sorted sandstone.
		8	9	As above plus grey clay	
		9	10	Fine-gr sandstone/siltstone, plus green clay	
		10	11	Black, siliceous chert/siltstone and clay crusts	Water here?
		11	13	Grey, siliceous siltstone/chert	
		13	14	Fine-grained sandstone	
					Minor water at 10-11m

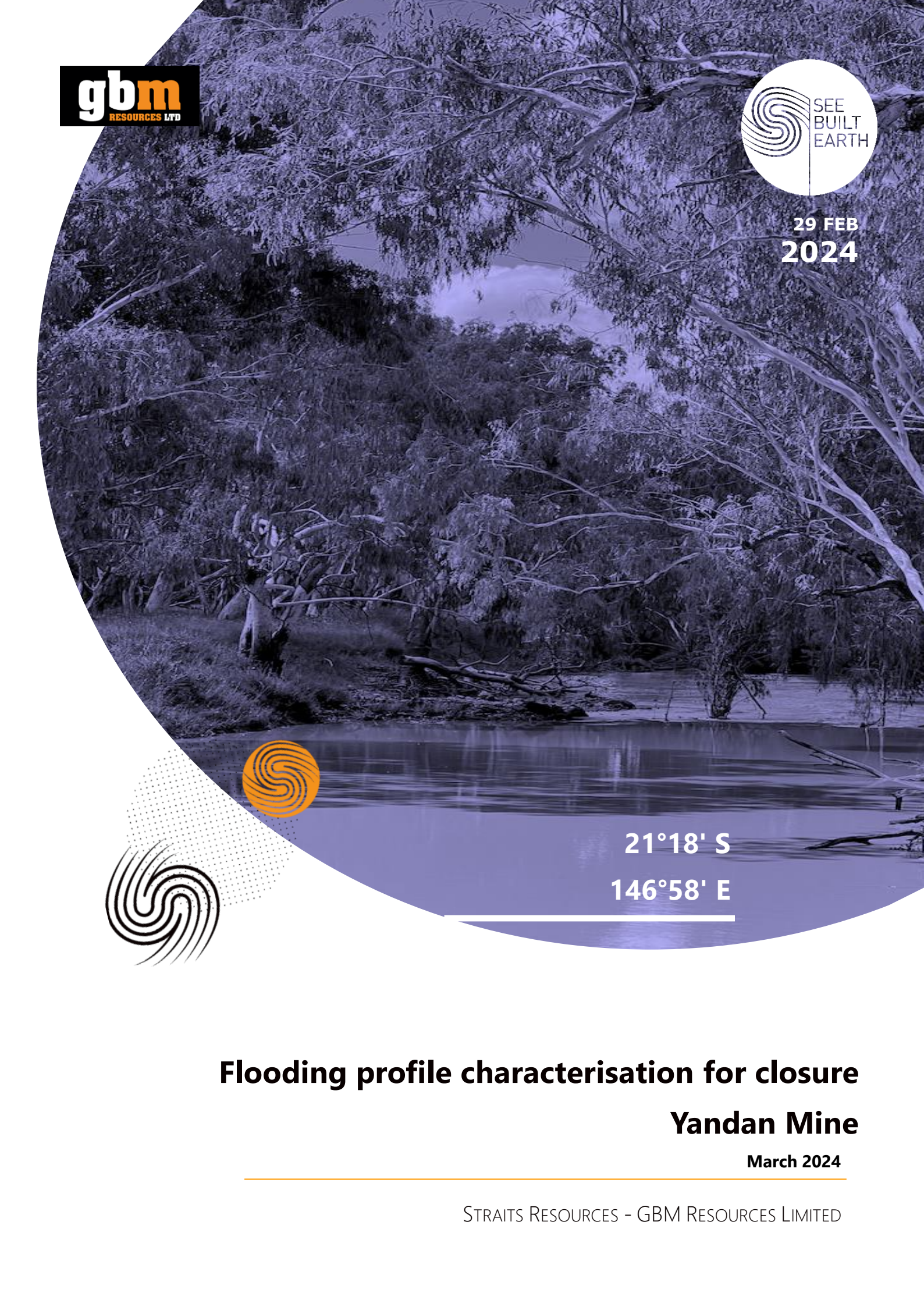


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Flooding profile characterisation for closure

Yandan Mine

March 2024



Document history and status

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1 Introduction

1.1 Background

GBM Resources Limited is currently in the process of a transitional Progressive Rehabilitation and Closure Planning (PRCP) for the Yandan mine with the Department of Environment, Science and Innovation (DESI).

Yandan is a historical mine site with several legacy landforms, including two (2) pit voids (including the Main pit adjacent to the Suttor River and the focus of this assessment), a tailings storage landform, and a heap leach landform. With the initial Yandan PRCP submission early in 2022, subsequently DESI (former DES) issued a request for information (RFI) listing several queries around water-related risk and requests to clarify closure outcomes.

As supplements to SBE (2022), additional packages of work are prepared to respond to the RFI around water-related risk, structured as three separate (3) technical updates:

- Yandan site flooding profile characterisation (this report).
- Main pit and Suttor River water system characterisation.
- Yandan groundwater and conceptual model characterisation.

1.2 Changes since the initial PRCP submission

As core additional information for PRCP and a related program for Estimated Rehabilitation Calculation (ERC), in 2023, GBM embarked on a robust data collection program to obtain representative and seasonal information, including additional groundwater wells and water storage monitoring. The additional data and information obtained over the past year provides a material step change in representative data, understanding and technical confidence of the Yandan water systems, and provides an excellent management tool for the site looking forward. Information and data gained to date is incorporated into this updated assessment.

1.3 Intent of this work package

This report captures, expands, and assesses the flooding nature and risk profile for the Yandan site, including:

- Mapping of Yandan site to elevations and nature of closure landforms.
- Hydrology profile of the mid-Suttor River, including flow regimes, flow durations, and connections with the site, including validation of the working flow model through January 2023 flood observations.
- Flooding profile of the mid-Suttor and Yandan in modelled flooding extents in major floods, including elevations and relationship to closure landforms.
- Risk assessment of Yandan closure landforms in major flooding conditions, including how water will interact with each landform, water flow, quality mixing and contact with engineered structures.

1.4 Scope

The scope of this work is to satisfy reasonable requirements of the Progressive rehabilitation and closure plans (Queensland Government 2023) for a historical site under transitional provisions by addressing and resolving key questions in the 2023 Request for Information (RFI). A map of RFI to responses is provided in Appendix A. This report should supplement SBE (2022) for overall site characterisation and further information.



2 Yandan site profile

2.1 Landscape and drainage setting

The Yandan project lies in central Queensland within the mid-Suttor River catchment and Burdekin River Basin (Figure 1). The Suttor River drains through a landscape of broad valleys towards the north and Burdekin Dam, dotted with isolated low-elevation hills formed through rocky outcrop. Drainage lines are low gradient, ephemeral and alluvial rich, with broad flood plains across much of the basin.

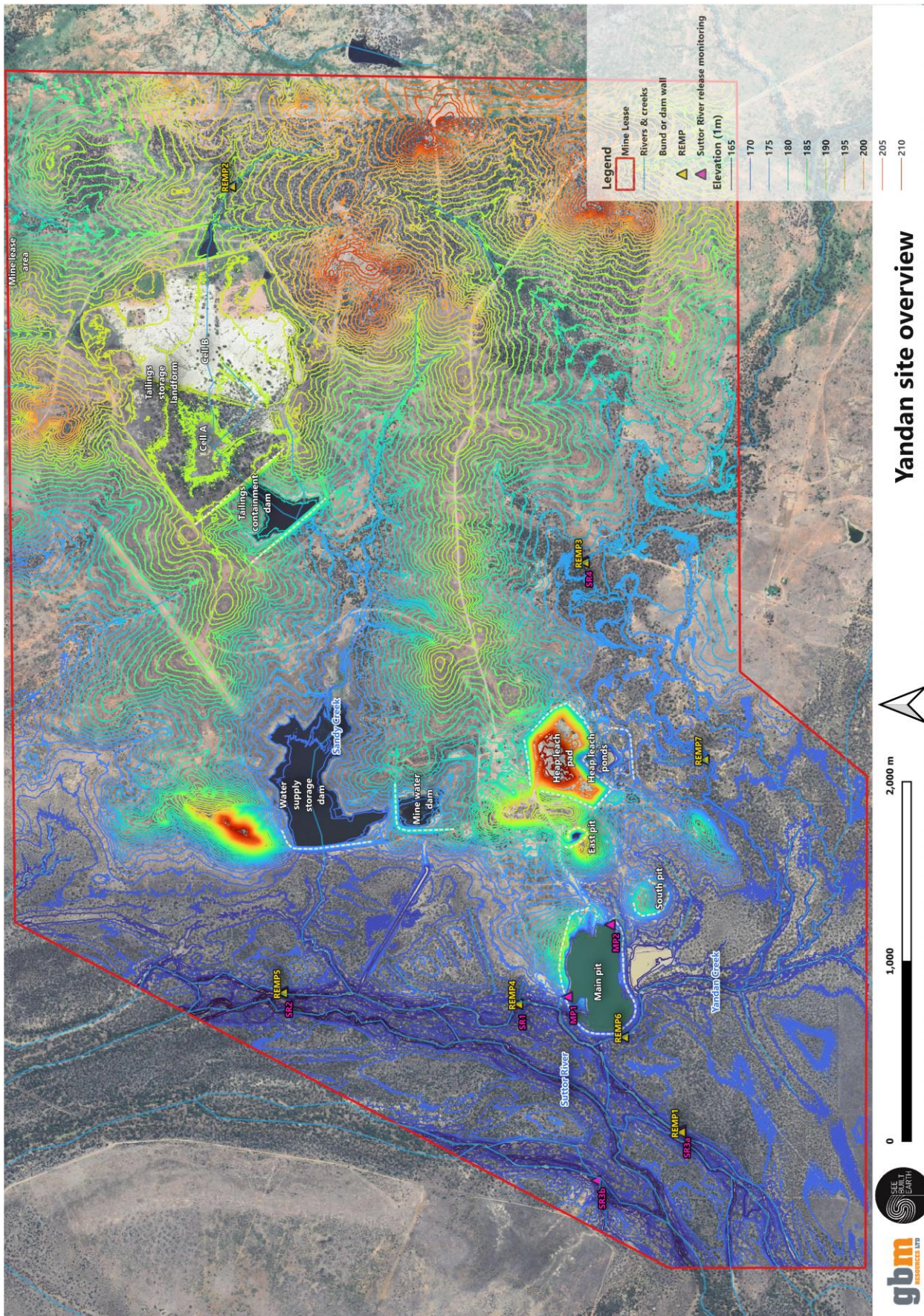
The vegetation zone of the mid-Suttor River is generally classified as eucalypt woodland to grasslands as part of the Brigalow BioZone (Queensland Government 2021a). However, the mid-Suttor catchment is extensively cleared and used for agriculture, including dryland and stock farming with occasional irrigation areas.

As a site, Yandan is gently undulating, rising from the Suttor River at 165mAH and low-lying areas to 191mAH at the tailings area to the east over 3km (a gradient of 0.003) (Figure 2). The Suttor River runs along the west of the Yandan mining tenement, and to the east runs up to low hills which form a sub-watershed boundary. Three (3) naturally occurring small hills are on the site, including one hill as a base to the Heap Leach landform. The site has two local drainage lines generally running draining towards the west towards the Suttor: Yandan Creek, which drains the southern part of the lease, adjacent to the Main Pit, and Sandy Creek which drains the northern part of the lease to the Suttor..

Grasslands cover much of the site, supporting a land use of grazing. The landscape is predominantly stable, including Yandan mining landforms, which have existed for over 25 years.



Figure 1 - Yandan site location within the Burdekin Basin



Yandan site overview

Figure 2 - Yandan site topography and landforms



2.2 Closure landforms profile

A summary of Yandan mining landforms assessed in this report for closure is provided in Table 1, including dimensions, components, and elevations. For locations, please refer to Figure 2.

Table 1 - Summary of Yandan closure landforms with size and elevation details

Landform	Description and details
Main Pit (MP)	The Main Pit (MP) is a pit lake (water storage void) laying directly adjacent to Suttor River, with a maximum 60m depth and surface area of ~ 22 hectares. Engineered levee walls surround the pit: a constructed levee at 172mAHD along the west and south extents and a natural rocky outcrop at 188mAHD along the north. The exception to the levees/barriers are two engineered “spillways” on the western and eastern sides of the pit, set at 169mAHD and 170mAHD, which facilitate flow in and out of the pit on the west and east sides during flooding events from either Suttor River or the local Yandan Creek (undisturbed catchment). The southern levee will likely have been constructed to protect the pit from Yandan Creek flows during operations. Closure outcomes require maintaining water cover of contained historical mining materials at a minimum 160mAHD water level. The quality of pit water is generally good, where mixing with river water during flooding meets receiving environment requirements. The water quality of Main Pit has had several independent reviews, including: • R&D Environment Pty Ltd 1999 • HLA EnviroSciences Pty Ltd 2001 • SeeBuiltEarth 2022
East Hill Pit (EHP)	The East Pit (EP) is a narrow opening pit void with engineered bunds and road access at an elevation of 184mAHD. The pit is situated inland and well elevated above Suttor River, is 0.9ha surface area in diameter, and is a partial pit lake only, with low-lying pit water levels. There is limited historical knowledge of the complete pit void.
Heap leach (HL)	The Heap Leach (HL) is an engineered, historical gold and copper leaching stockpile with a surface area of 17.5 hectares, constructed to a height of 38m and ranging from 212mAHD up to 174mAHD elevation (highest elevation on site). The leach pad is constructed on a low-lying hill in the original landscape, and the final landform design will create a water-shedding landform.
Tailings Storage Facility (TSF)	The Tailings Storage Facility (TSF) is an engineered landform with a containment dam draped across the upper parts of the landscape. The final closure design will create a water-shedding landform. The tailings embankment is generally a low 1-5m around much of the perimeter, extending to 12m height at the highest point at the lower barrier and containment dam, including heights through borrow pit deepening as part of constructing the containment dam. Elevation of access to TSF materials occurs at 189mAHD, which rises to 193mAHD. The tailings containment dam (or returns dam) has a 9m dam to an elevation of 183mAHD.
Landforms not assessed in this study	
South Hill Pit (SHP)	Partially to nearly entirely backfilled pit void.
Water storage dam(s)	• Raw water dam (water supply dam) – wall height of 7.5m, a capacity of 1300m. Downstream of tailings & tailings containment dam. • Mine water (or process water dam) – wall height of 8m, currently raw water, full capacity 450ML. The diversion drain from Suttor River is not in use.



2.3 Elevation profiles

Figure 3 summarises relative elevations for Yandan site across the Suttor River and infrastructure, with geometry across the landscape shown in Figure 6 and Figure 7.

Key elevations and relationships important as a flooding assessment are:

- Main Pit connection to Suttor River and Yandan Creek. The Suttor River base lies at an elevation of 165mAHD, and Yandan Creek is at 165/167.5mAHD, with Main Pit spillways at 169mAHD. The levee running around much of Main Pit is to a height of 172-174mAHD. There is also natural rock outcrop to the east and north of the Main Pit.
- The highest features on site are the Heap Leach and the TSF. The HL base has variable elevation however starting at 177mAHD.
- East pit has an elevation of 183mAHD.

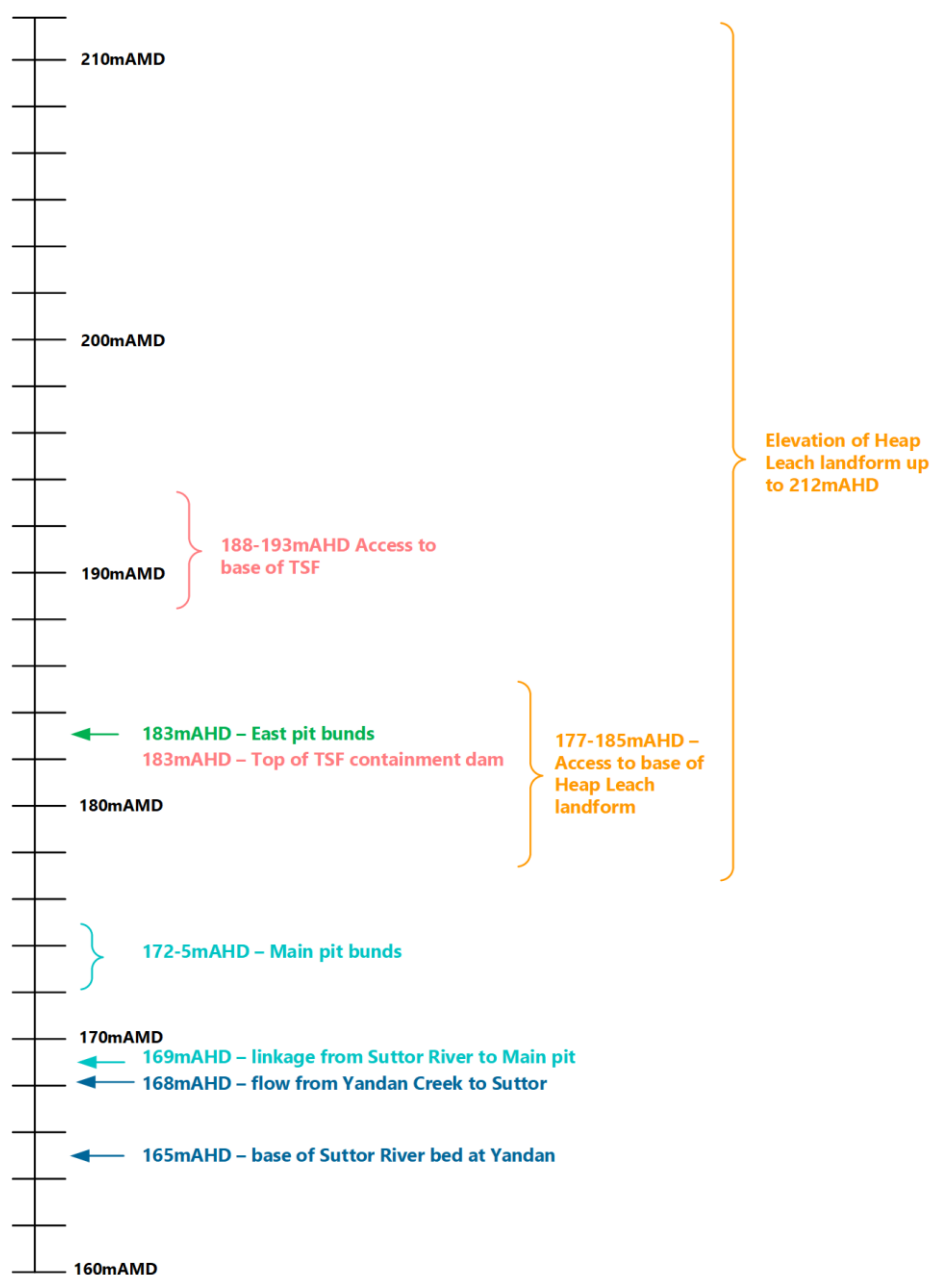


Figure 3 - Elevation profile of Yandan site

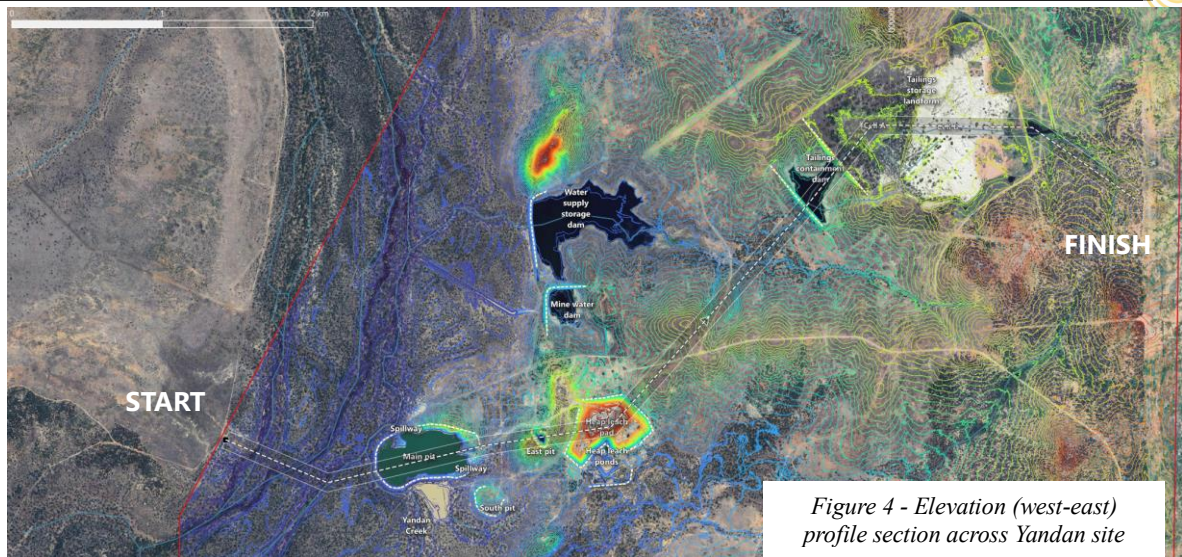


Figure 4 - Elevation (west-east) profile section across Yandan site

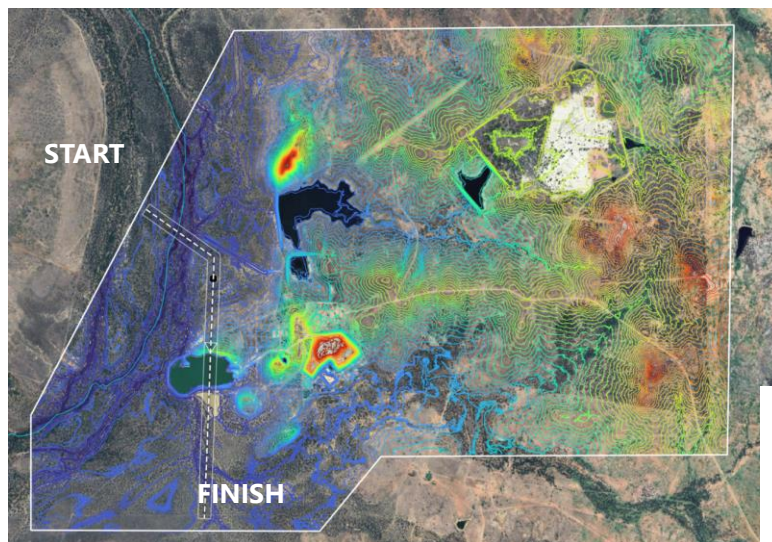
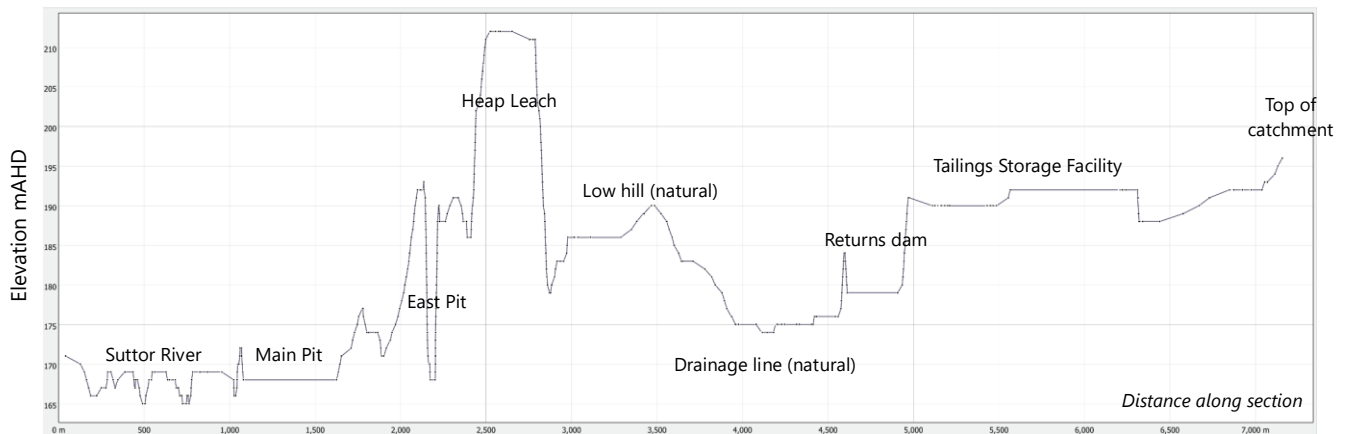


Figure 5 - Elevation (north-south) profile section across Suttor River, Yandan Creek and Main Pit

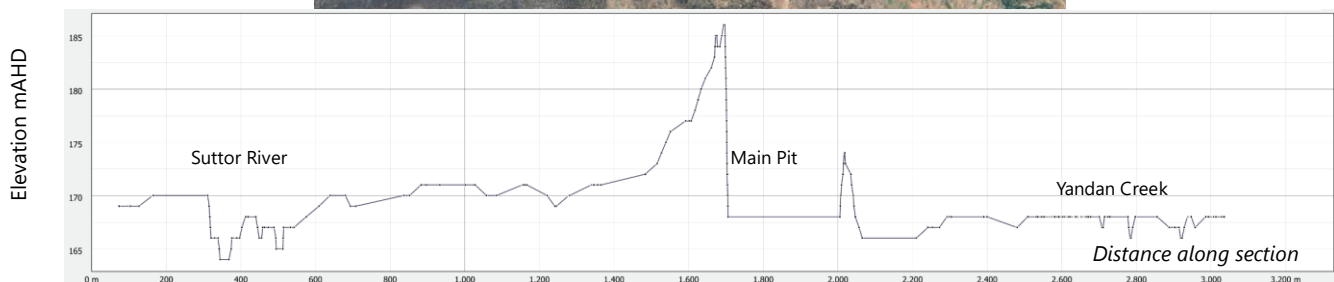
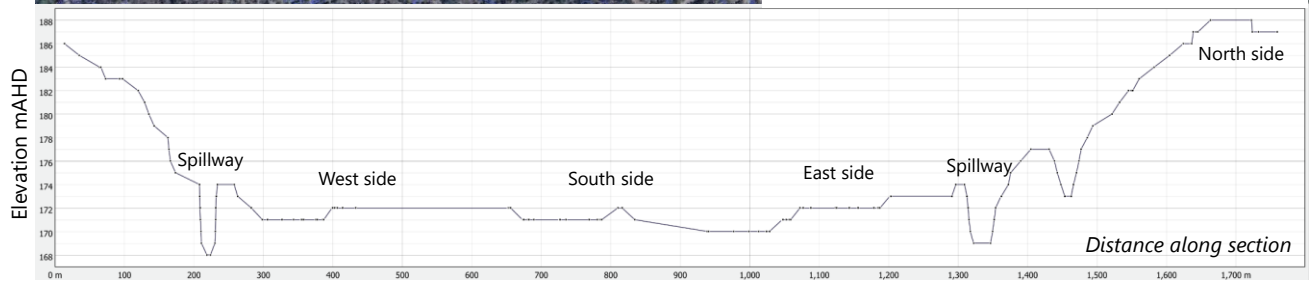




Figure 6 - Elevation profile of Main Pit perimeter





3 Hydrology profile of the Suttor River and Yandan

3.1 Nature of flow

The mid-reaches of the Suttor River near the Yandan site generally form a broad, low-gradient and ephemeral river. The riverbed forms multiple, braided channels heavy with alluvium (Figure 7). Rivers generally only flow after rainfall and are losing streams (not groundwater-fed), generally dry during low rainfall periods or forming non-flowing water holes. By the time the Suttor River reaches Yandan, the river receives flow from the catchments of the Upper Suttor River, Police Creek, Rosetta Creek, and Belyando River (Figure 8).

Rainfall across the region is highly variable from year to year: the catchment sits in a sub-tropical to semi-arid savannah climate, with mild, dry winters and hot summers, which may be very dry or very wet. The area frequently experiences extended dry periods or drought and large wets, with intense rain via tropical low systems and downpours.



Figure 7 - Suttor River near Yandan site

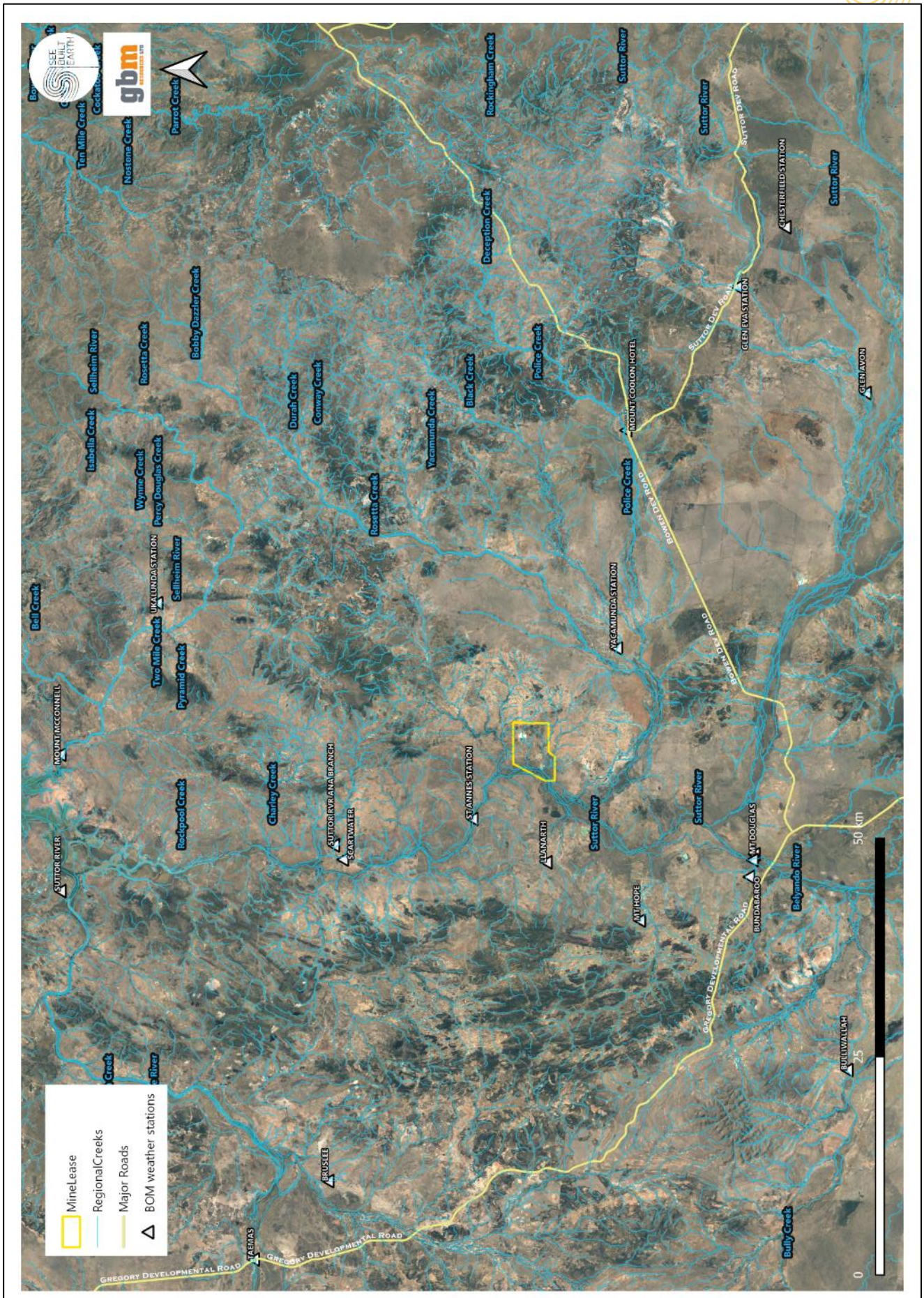


Figure 8 – Yandan site and regional catchments



3.2 Flow regimes and magnitudes

Flow nature of the Suttor River up and downstream of Yandan are available from BOM stream gauges installed since the mid-1970s. For locations refer Figure 8): Mount Douglas (120301A/B) site lays 27km upstream, and St Anns Station (120303A) 7km downstream.

Flow hydrographs of both stations are shown in Figure 9 as a complete record over the past 50 years, as well as a closer view at the past several years. Flow patterns are clearly ephemeral, occurring as rapid flow pulses and retreats with no minimal ongoing flow between. Analysis of the peaks indicates the system conveys up to $1,000\text{m}^3/\text{s}$ in regular flow events, and up to $4,000\text{m}^3/\text{s}$ in periods of larger flooding. In comparison of the gauges, the timing and shape of flow peaks between Belyando and St Anns station show a consistent and linked flow regime. Additional flow is generally observed at St Anns gauge compared to Mount Douglas as a result of the additional catchment flow from Rosetta Creek, Police Creek and the Upper Suttor.

3.3 How connection occurs between the Suttor River system and the Main pit

The Main Pit lies within 80m of the Suttor River, with base of Suttor River at 164-165.5mAHD. Figure 10 shows a detailed map of the main pit with water flow directions, contours and monitoring locations. By design (SRK 1999b & c, Chapman and Dwyer 1999), the water in the Main Pit is expected to connect to the Suttor River and Yandan Creek during minor flood events once river levels reach 169mAHD. Connection and mixing of Main Pit lake water and Suttor River/Yandan Creek water occurs via designed spillways at 169mAHD at the northwest and southeast of the pit.

As an example of connection flow, Figure 11 provides aerial images of the 2020 flooding event, with flows from Yandan Creek into Main Pit and a flooded Suttor River in the background. A review of flow records from stream gauges (refer to Figure 9) shows a peak inflow from December 2019 to January 2020 at $>500\text{m}^3/\text{s}$.

The Main pit does not overflow independently given its very limited catchment: the total catchment directly flowing to the pit without flow from Yandan Creek or Suttor River is 59 hectares. Pit lake water remains contained until the flow height from either the Suttor or Yandan Creek is sufficient to flow into the pit lake and undergo mixing before any pit lake water leaves the site.

3.4 Relationship between river connection at the Main pit to St Anns gauge

AECOMM (2020) calculated reference levels to relate the downstream Suttor River St Ann gauge river levels to Yandan Main Pit to enable ongoing measurement from St Anns as a guide as to when the Suttor River at Yandan was at a height where the hydraulic connection with Main Pit would occur (168mAHD+). The work identified that at 3.8m river height or flow elevation of 165.5m AHD at St Anns gauge, the Suttor River at Yandan will be at 169.05mAHD, at which point the River and Main pit water flow will be linked. Table 2 lays out the relationship as a direct comparison below.

Comparison of river stage gauging to flow rates at St Ann's from the BOM (2024) gauges (Figure 10) gives a corresponding flow rate of $500\text{m}^3/\text{s}$ at 3.8m river height and the minimum flow when connection occurs.

Table 2 - Relational levels between St Ann gauge and river connection to Main Pit

	Suttor at St Anns	Suttor at Yandan
River stage base	161.7mHAD	165mAHD
Connection to Main Pit at Yandan	165.5mAHD (river height of 3.8m)	169.05mAHD (flowing into the pit via spillways)
Flows	$500\text{m}^3/\text{sec}$	

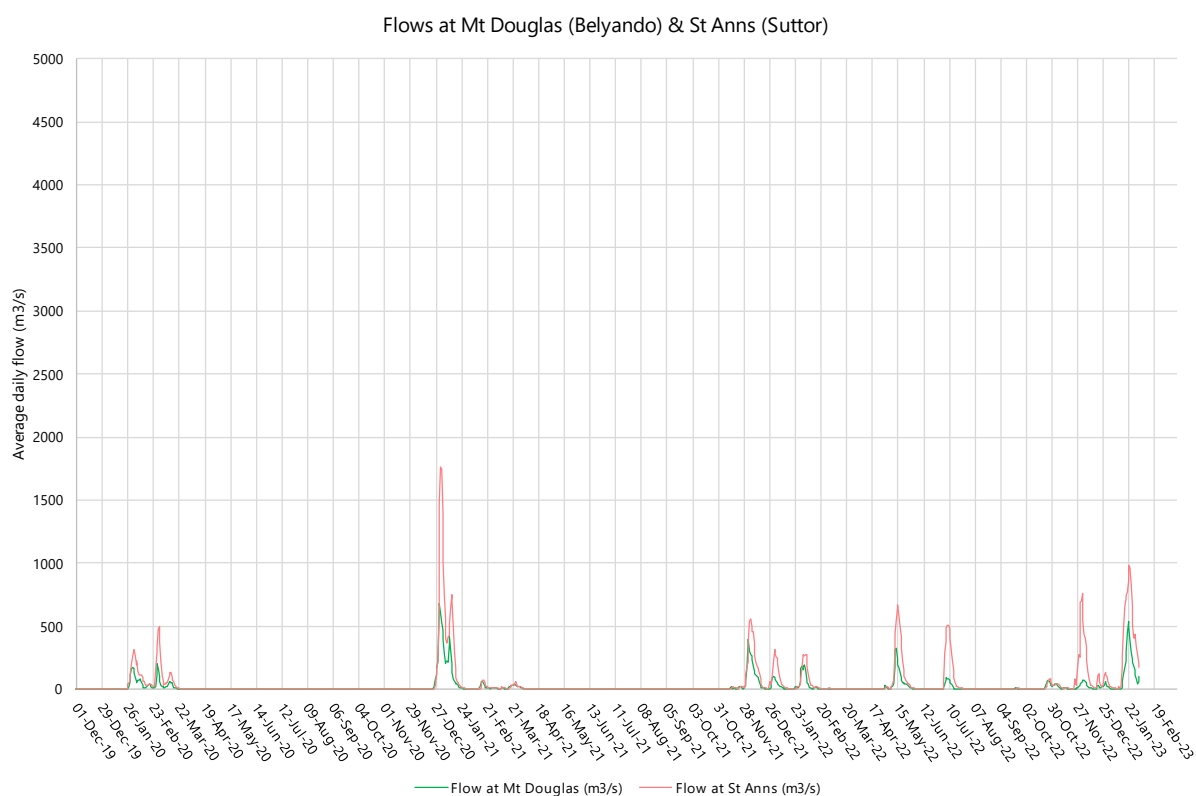
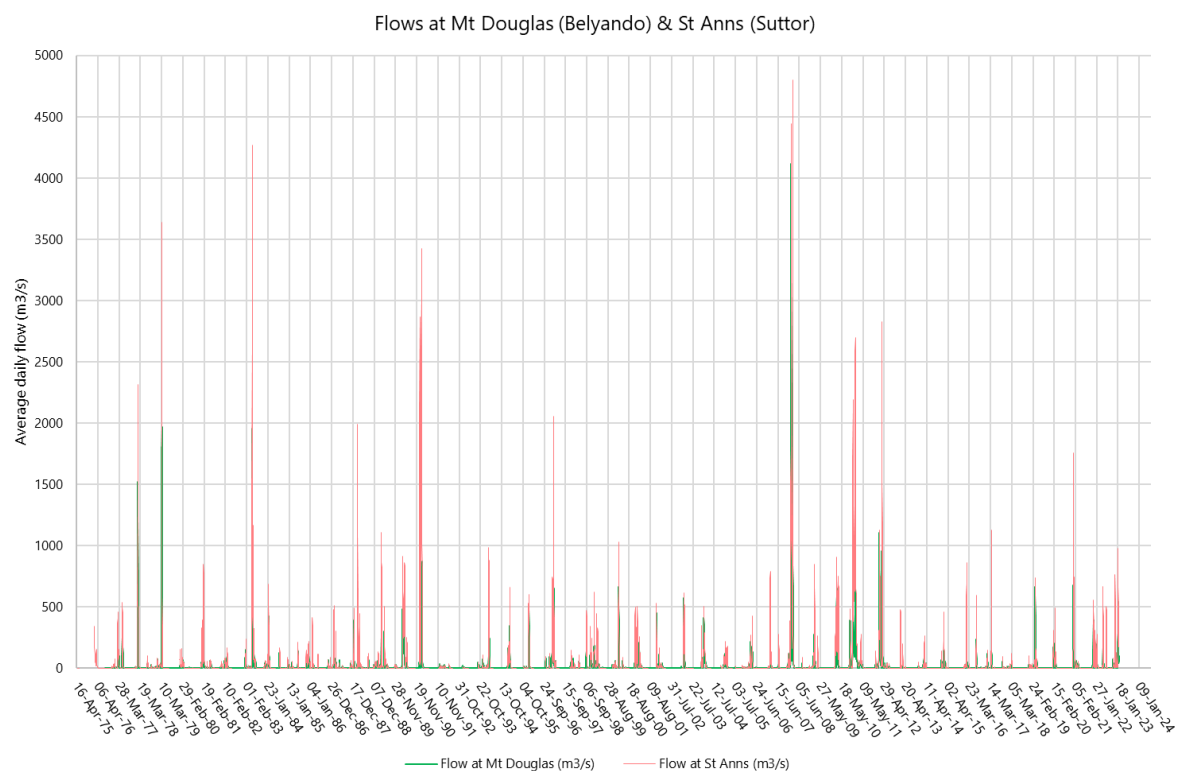


Figure 9 - Flow hydrographs of Mt Douglas (upstream) and St Anns (downstream)

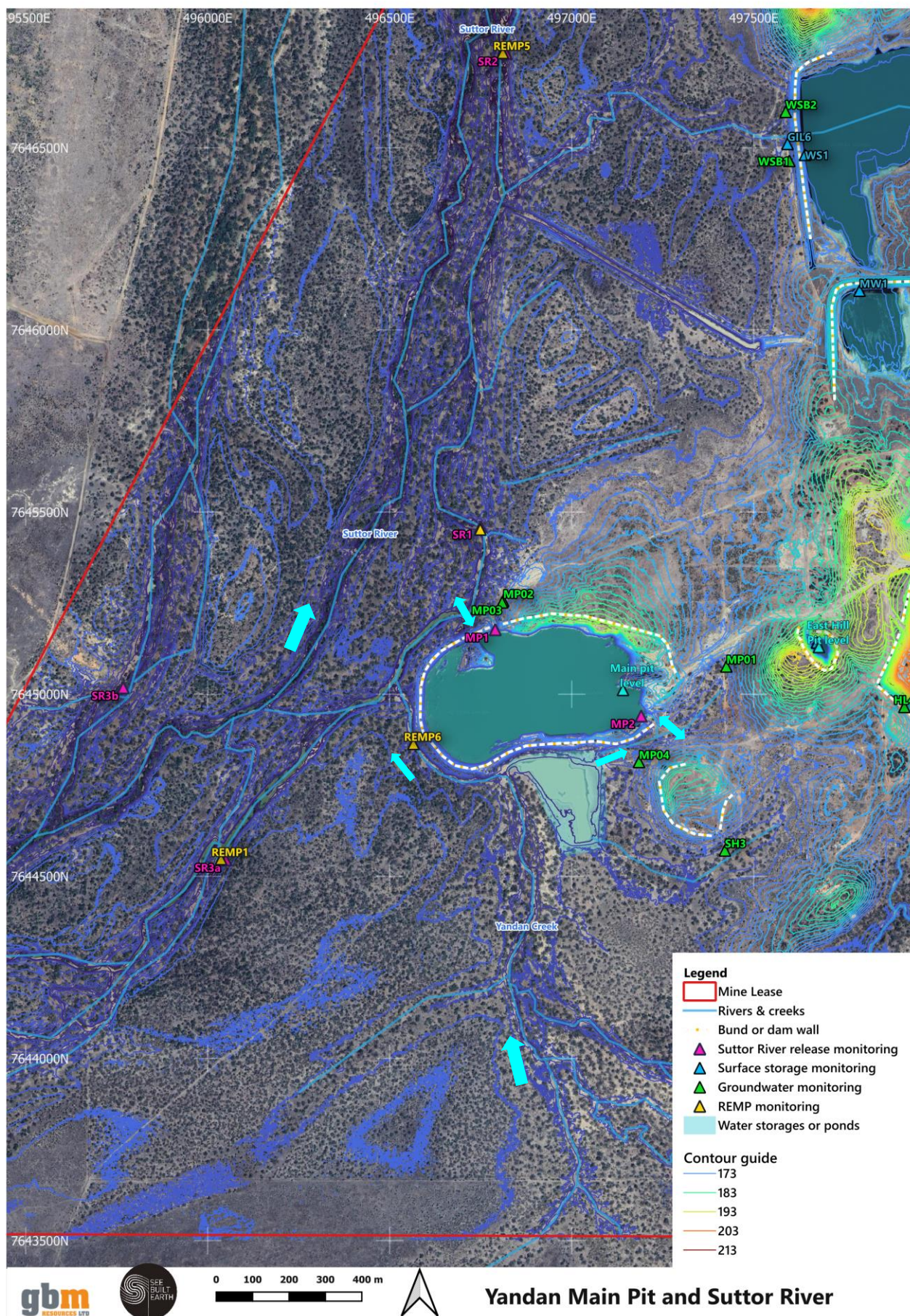


Figure 10 - Main Pit and Sutter River with contours and monitoring network showing direction of flow



Figure 11 - View of Main pit and Suttor River during flood in 2020



3.5 River flow durations

The flow duration curve developed from St Anns gauge flow records is shown in (Figure 12) for different magnitude and frequency of flow events for the entire gauge record, along with flow durations of other notable high flow events since the late 1960's.

The duration curve shows a flow rate of 500m³/s (as the flow rate when the connection is achieved with the Main Pit) with a general AEP of 7.5%, but it can range from 5% to 25% AEP.

AECOMM (2012) also states records of Suttor River and Main pit connection events six times since 1988 (22 years): in 2000 and then in 2001, 2003, 2004, 2007 and 2011. With six (6) events of flows connecting into Main Pit in 22 years, the AEP of 25% is well supported. Since then, connection flow events have also occurred in 2020 and again in 2023 (discussed in the following chapter on flooding profile).

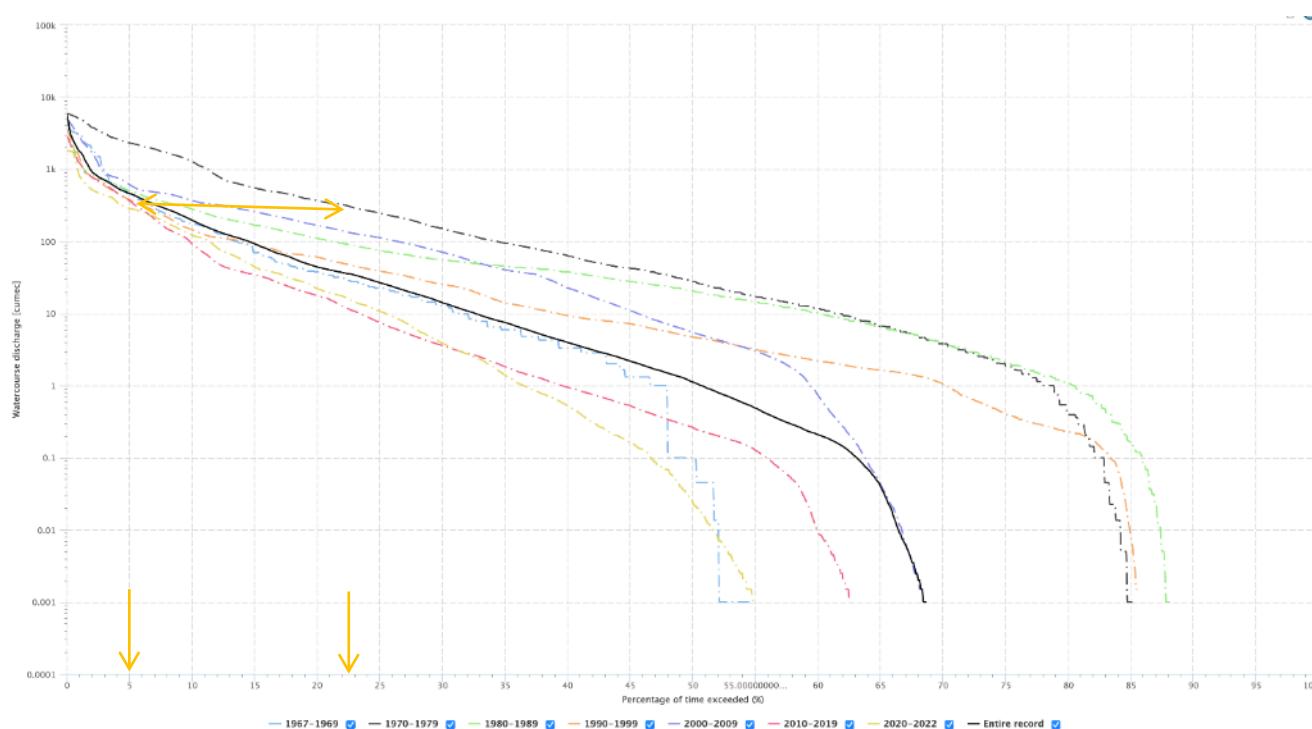


Figure 12 - River flow durations for St Anns gauge (BOM 2024)

3.6 Observation of the 2023 flooding event

In early 2023, the Yandan site experienced a flood event, where the Suttor River began rising on the 14 January, peaked on the 21/22 January, and quickly ebbed back within a week. St Anns gauge on the Suttor River recorded a peak flow rate of 1,000m³/s (or 1ML/s) (refer Figure 9 in January 2023).

Remote imagery using a normalised difference water index was acquired on 19 January 2023 (Figure 13). It clearly shows that the Suttor River and Yandan Creek are in flood and likely connected to the Main Pit (or close to it).

Comparison to the site's contours shows flooding extents fit neatly to 168mAHD elevation (bottom image), which, when cross-checked on the river flow duration curve (Figure 12), suggests an AEP of 2.5-5 years. This elevation, water flow volume, and AEP align with that calculated as a validated observation of when and how often Main Pit receives surface water flow from the Suttor River or Yandan Creek.

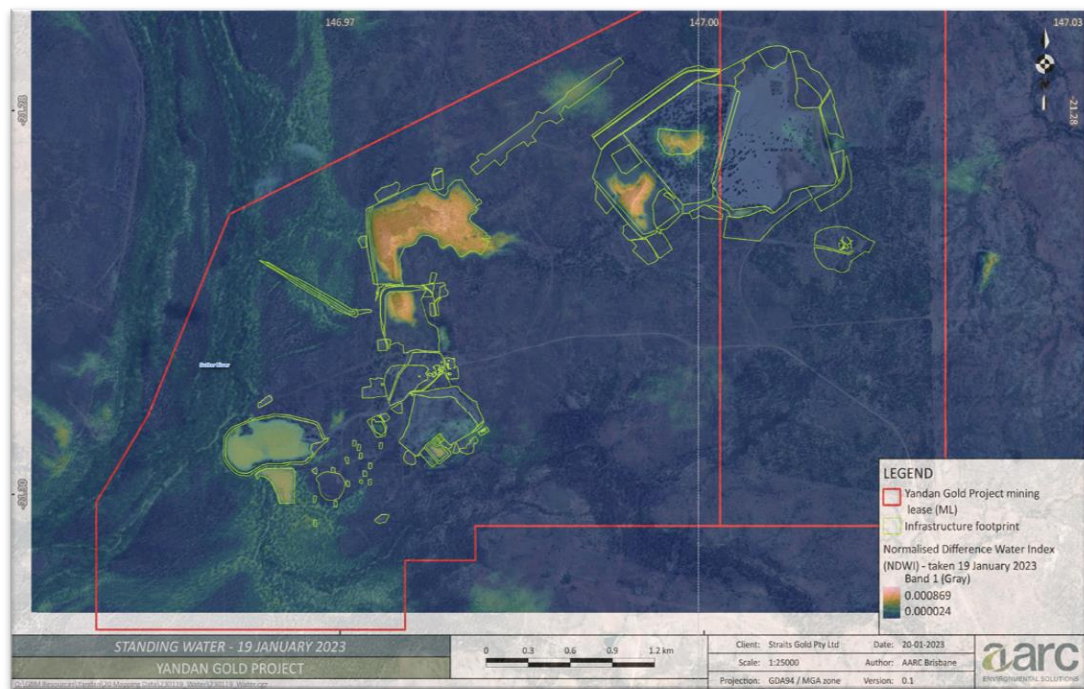
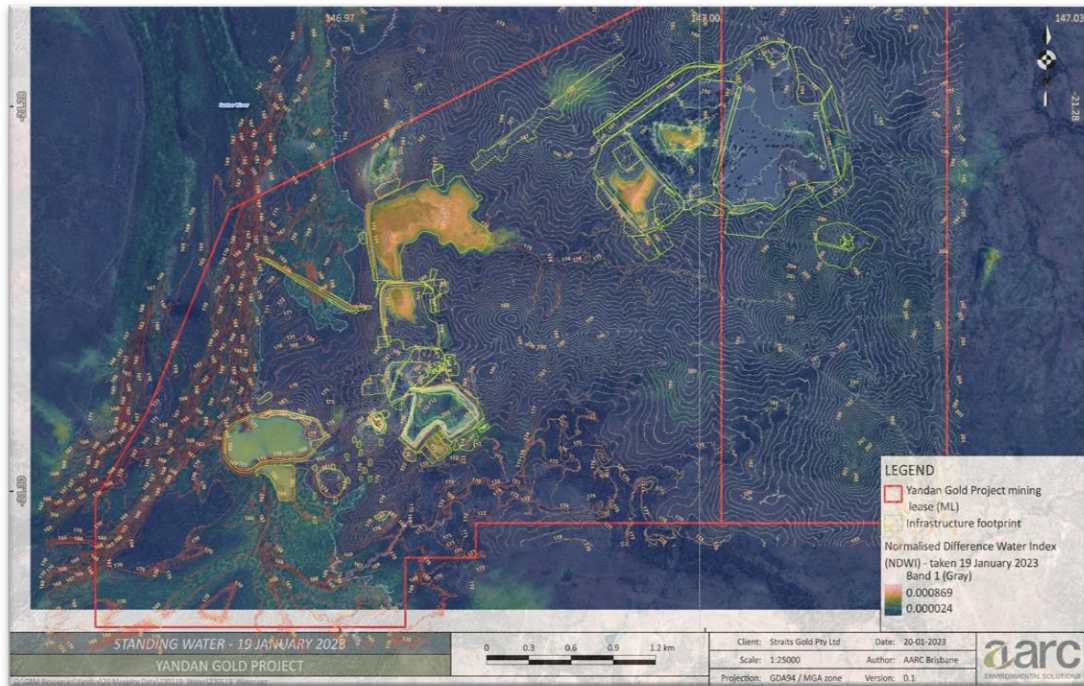


Figure 13 - Normalised difference water index imagery over Yandan during flood January 2023 (from AARC)

4 Flooding profile of the Suttor River and Yandan

4.1 Modelled flooding extents and elevations for 1% AEP and PMF events

Flood extents for the entirety of the Burdekin Basin are published by Queensland Spatial Services and QGlobe (2024).

Figure 14 shows the regional flooding extents for the mid-Suttor River and tributaries in both 1% AEP events and extreme events (PMF). The broad flooding shown occurs given the low gradient drainage and the wide valley topography characteristic of the mid-Suttor River catchment, particularly upstream of the Yandan site.

At the site scale, flood extents and heights at Yandan are shown in Figure 15. As a reference, flooding elevations for major flooding heights (1% AEP and PMF), water depth, flow volumes as rates and flood width are provided in Table 3 below.

Table 3 - Elevations of 1% AEP and PMF events

	1% AEP	PMF
Elevations	179 mAHD	187 mAHD
Suttor water depth at Yandan	14m	22m
Flow rates at St Anns (Extrapolated via Error! R eference source not found.)	Indicative 9,000m3/s	Likely more than 18,000m3/s
Width of flood	~6km	~8km

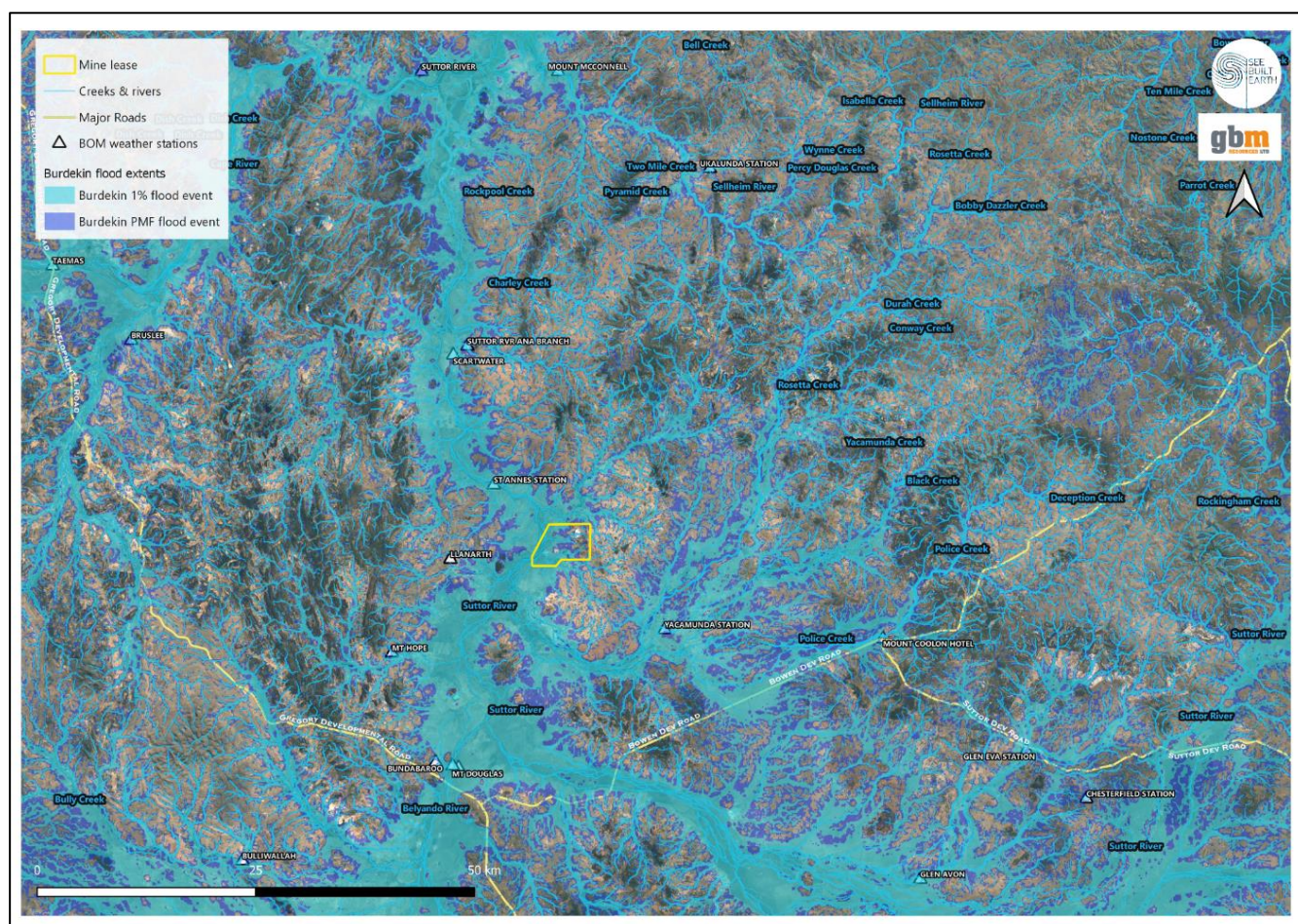


Figure 14 – Mid-reach Suttor River and tributaries flooding profiles – 1% AEP & PMF events

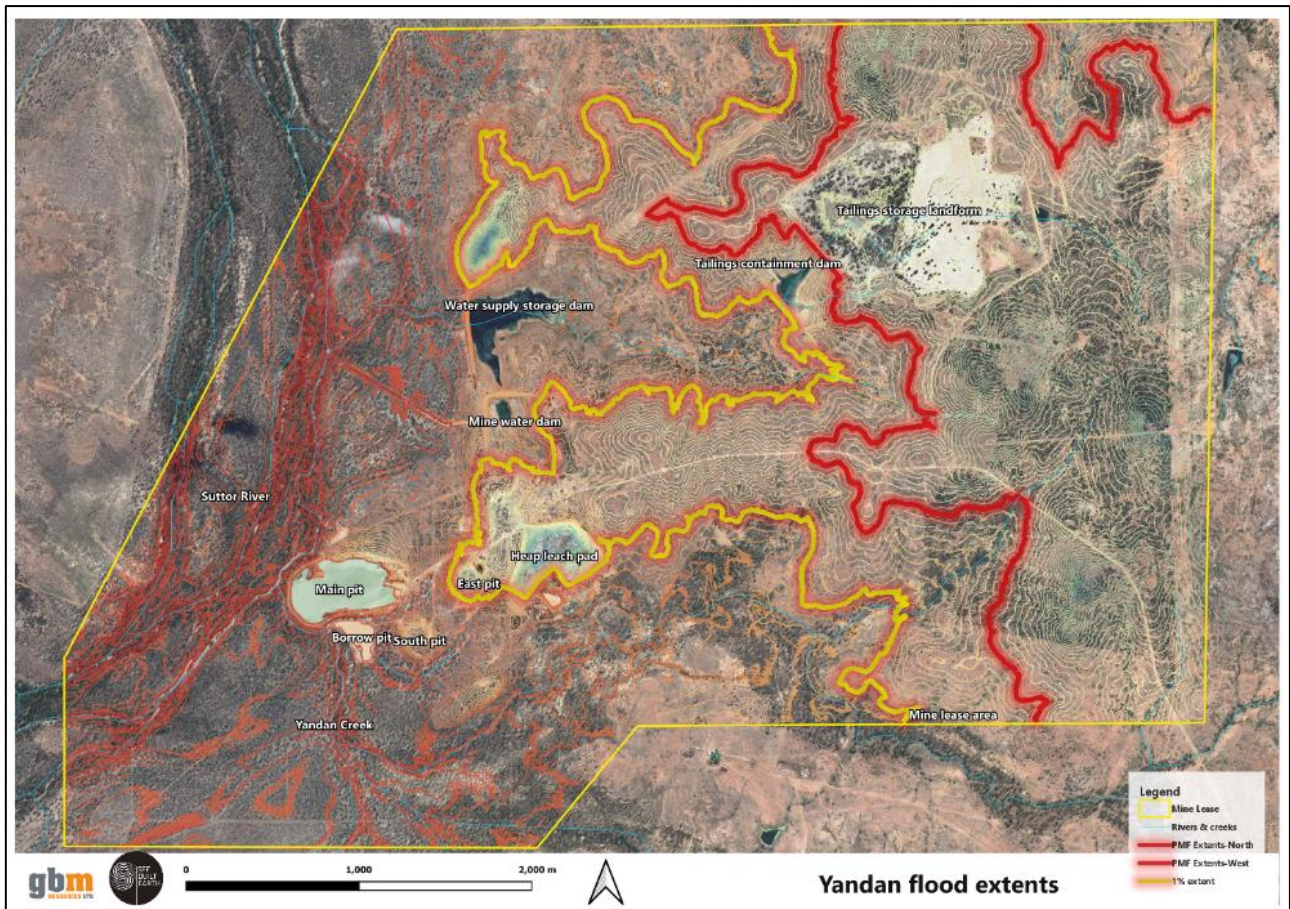
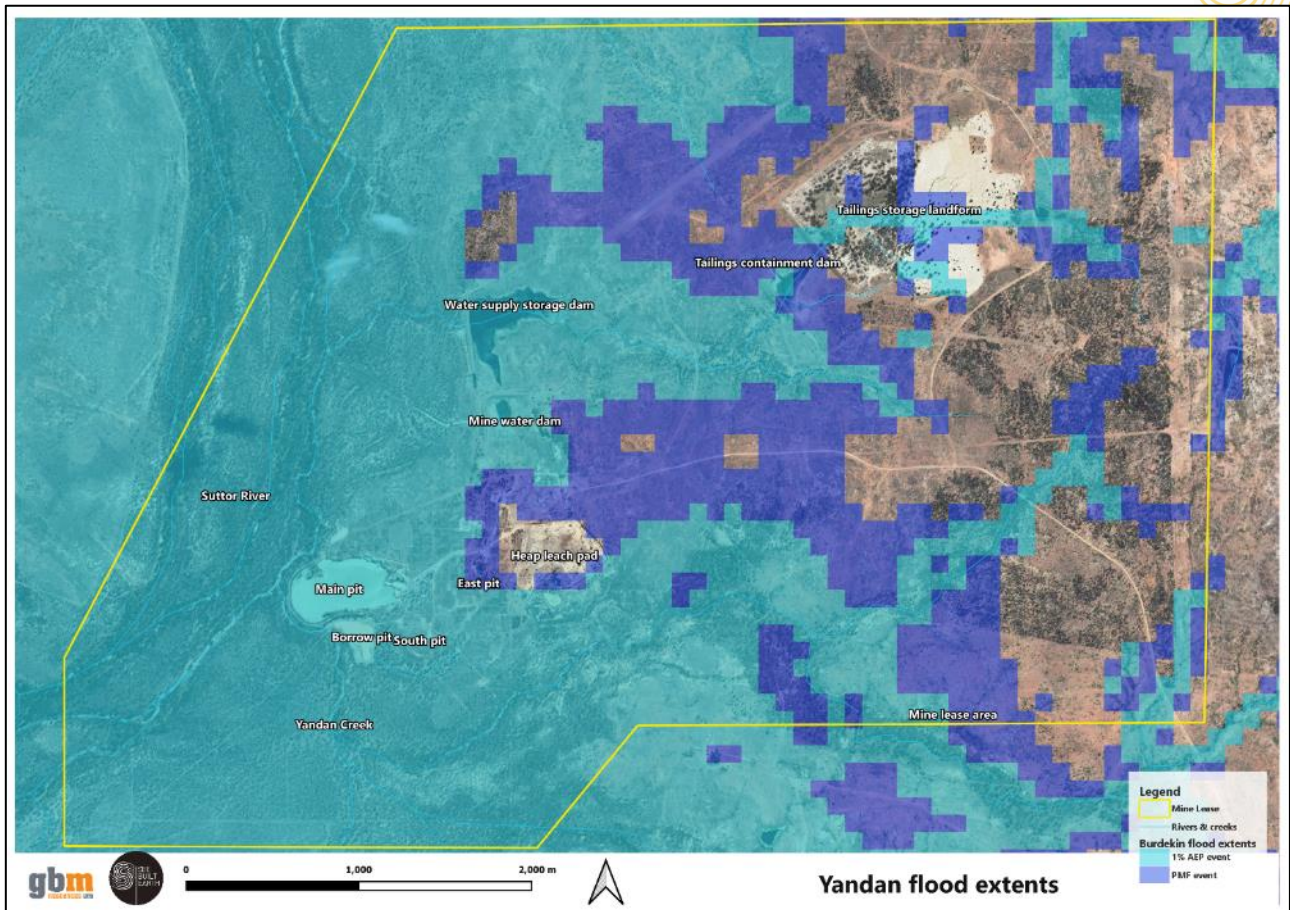


Figure 15 - Flooding extents and elevations for the Yandan site for 1% AEP and PMF events



4.2 Flooding elevation and depths

A summary elevation column and a section for river and flooding heights, with touchpoints across Yandan landforms, are provided in Figure 16 and Figure 17 below.

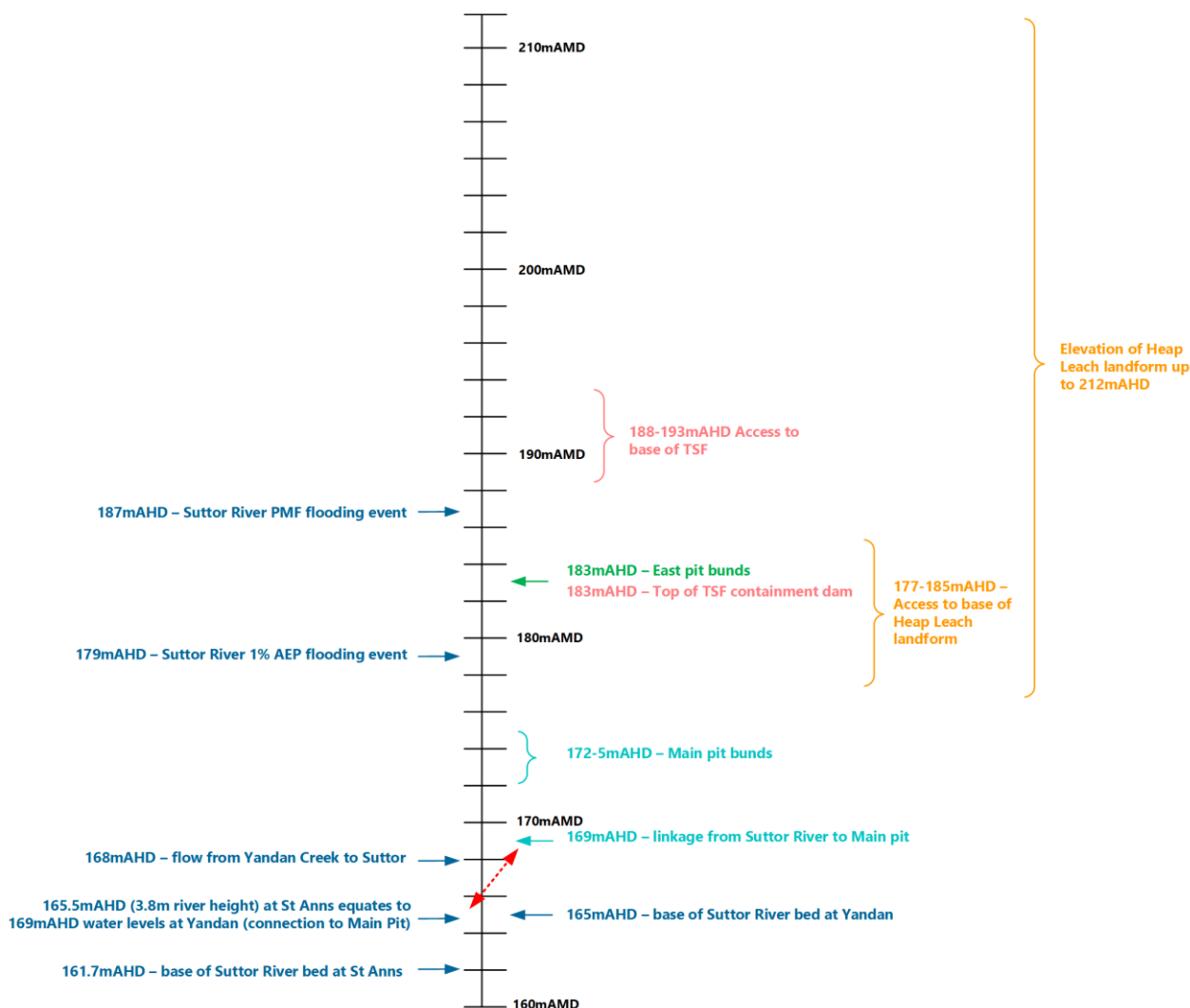


Figure 16 - Reference elevations for Yandan and Suttor River



Figure 17 – Profile of major flood elevations to landforms across Yandan



4.3 Indicative flow velocity profile during floods

Flow velocities for the Suttor near and around Yandan are published Engeny (2011) as part of a regional rail study for Waratah Coal. The flooding model developed a series of models, and specifically three models relevant to Yandan at Belyando River (Model 10) just prior to joining the Suttor River, Mistake Creek (Model 8) as a tributary of Belyando River, and the Suttor River itself (Model 7) south of Mount Coolon township.

Modelling was undertaken by an independent group to industry standards using historical data, data collected for the purposes of the study and desktop assessments. The modelling applied two industry standard modelling packages to determine flood extents and behaviour: XP-Rafts and TUFLOW hydraulic modelling. TUFLOW models were constructed for each major waterway, including those used in the comparative analysis. The XP-Raft model was developed for the Suttor River to cater for higher and more complex flows. Model settings and input information were sourced via:

- Topography - sourced via QGlobe and mining DEM data.
- Catchments - surface roughness and parameters derived from QLUMP and satellite imagery.
- Flood frequency analysis – calculated from multiple gauging stations data along the Suttor River and Mistake Creek.
- Design rainfall intensity frequency durations - derived using procedures in Book 2 of the AR&R 2011 edition, based on 1% AEP.
- Ground truthing of structures within major waterways to confirm details.

Table 4 summarises model outcomes, capturing flood depths, velocities and observed behaviour, and modelling outcomes of Model 7, the lower Suttor are provided in Figure 18. The location and setting of the Yandan project relative to the Energy (2011) modelling study and catchment capture is shown.

Table 4 - Summary of Engeny (2011) TUFLOW and XP-RAFT modelling outcomes

Model	Outcomes
Belyando River (Model 10) upstream of where joins the Suttor River	• Flood depths 7.5 m and 2.5 m/s within the main channel. • Depths of 1.5 m and velocities of 0.9m/s on edges of the flow • 100-yr ARI peak flow at Belyando River 3,267 m³/s
Mistake creek (Model 8), tributary of Belyando River	• Flood depth of 5.5 m in 100 yr ARI, velocities of 0.5 m/s within the channel. • Flat river gradient and thick vegetation. • 100-yr ARI peak flow at Mistake Creek 1,329 m³/s
Suttor River (Model 7), south of Mount Coloon township	• Peak flood depths - 4m in 100 ARI, velocity of up to 1.5m/s in constrained channels but typically 1m/s • Located in a rural/natural area with low flow channels, flat topography adjacent the river at 200 mAHD • 100-yr ARI peak flow at Lower Suttor River of 11,014 m³/s

Modelling outcomes of the study are relevant to Yandan in multiple ways: shared locality, topography and land uses, river and catchment morphology as all being part of the same system. The 1% AEP design river flows at St Anns Gauge just downstream of Yandan and the Belyando model indicate average flows of ~4,000-5,000m³/s (refer Figure 12), similar but slightly higher than the range in Model 10. This is not surprising given Model 10 is simulating flow on the Belyando River, and there is a close relationship between flows as measured between Mount Douglas (Belyando) and St Anns gauges (refer Figure 9). On the upper bounds, Model 7 on the Lower Suttor estimates 1% AEP at ~11,000m³/s. This AEP at St Anns would be higher than design flows.

In velocities, Model 10 estimates peak velocity at 2.5m/s within the channel, grading out to 0.9m/s at the edges of flow. Model 7 estimates peak velocity at 1.5m/s to 1m/s. As Yandan landforms sit predominantly at the edges of expected flooding profiles, a reasonable approximation of expected velocities away from the primary channel and on the extents would be in the range of 0.9-1m/s.

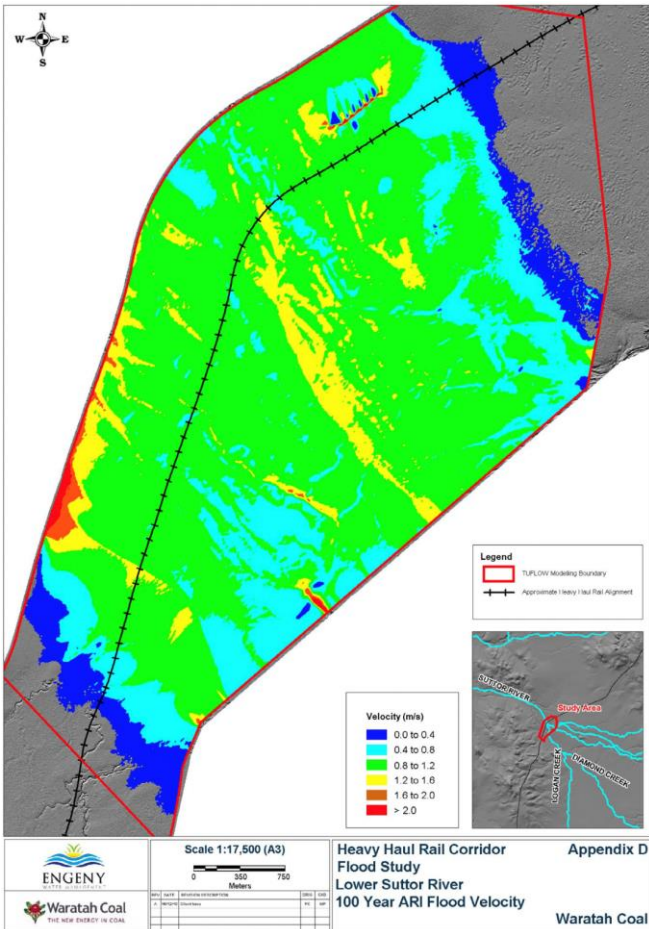
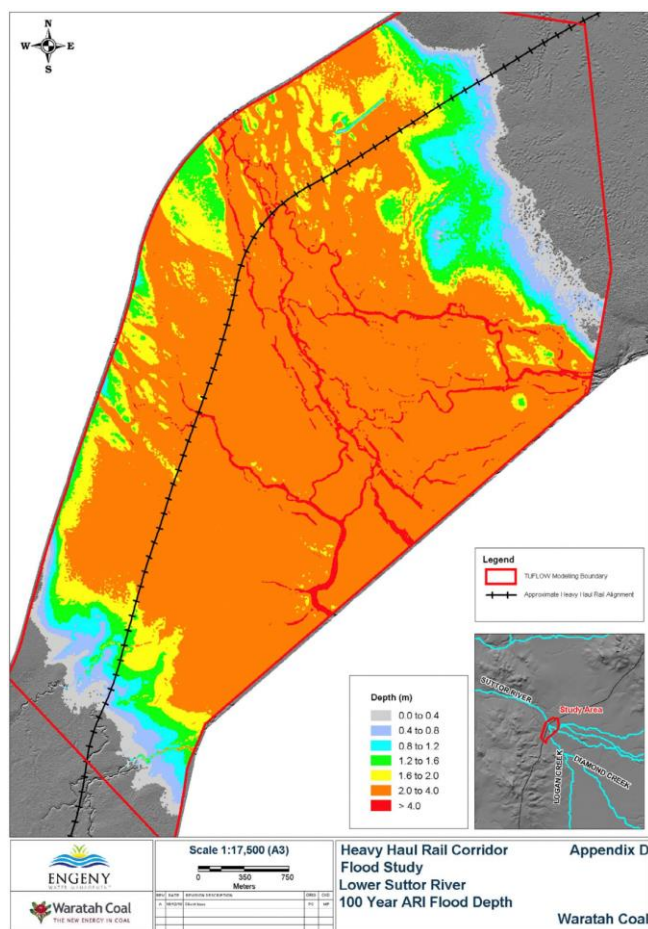
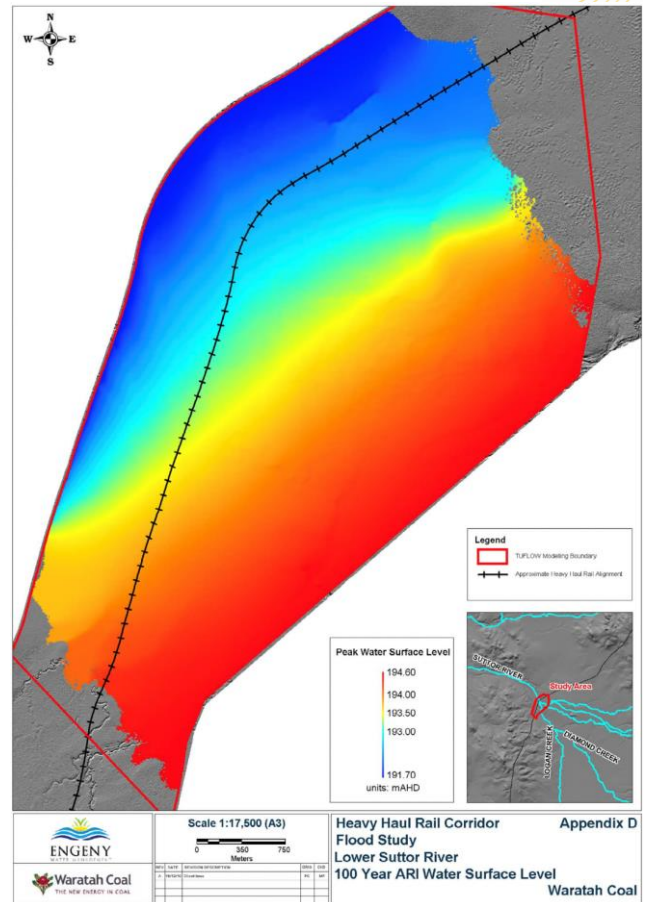
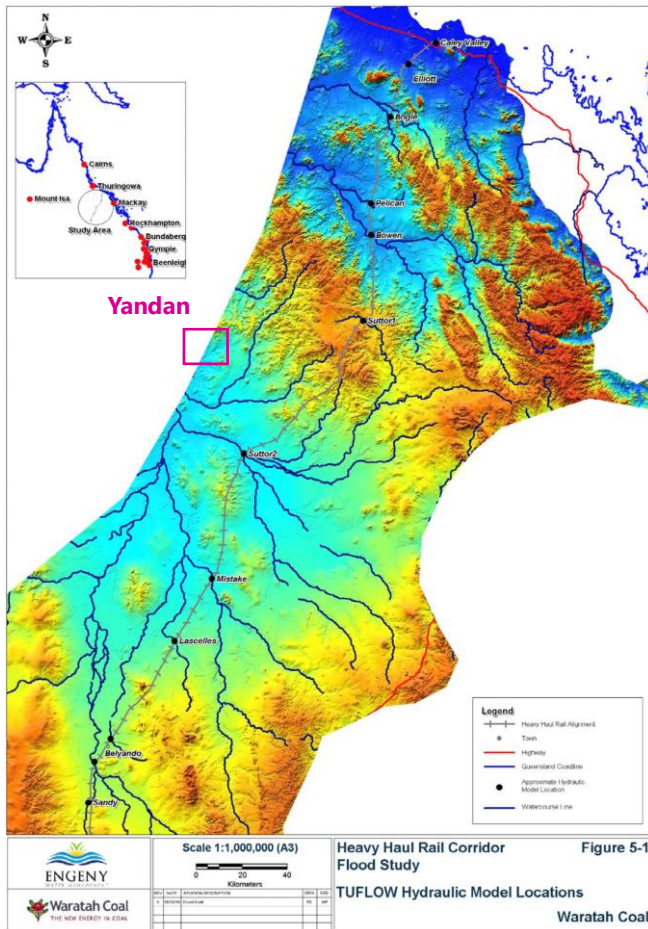


Figure 18- Velocity model location and outputs for Model 7 Lower Suttor (Engeny 2011)



5 Risk assessment for landforms in major flood conditions

Flooding was considered from project design with WMC (1998), which recommended all major infrastructure be constructed above the 1% AEP flood levels, as was considered best practice at the time of construction. As a result, all landforms except the Main Pit (given that it lies in the Suttor River flood plain) are built above the 1% AEP event elevation, and expected flow velocities are up to 1.5m/s at the flood extents (Engeny 2011).

Table 5 summarises major flood risk exposure and expected landform interactions below.

Table 5 - Summary of Yandan landforms risk and interactions with major floods

Landform	1% AEP Event	PMF event
Main Pit (MP)	Full saturation of pit area, with water levels above both constructed levees and natural barrier. Constructed levee will likely become saturated. The current natural outcrop is expected to remain viable. Water in the pit will freshen as flood levels rise from Suttor and Yandan Creek, mixing fresh water with pit water to protect environmental values against potential marginal quality concerns. Suttor River flows are expected to be 8ML/s, against a total pit capacity of 6800ML at full supply level, requiring 10-15 minutes of flow to replace pit volume. Mixing modelling and observed records indicate that under flood conditions water reporting to the receiving environment protects water quality values (SBE 2024).	Full saturation of pit and surrounding area, with water levels above constructed levee and natural barrier. Like 1% AEP event, currently constructed levee will likely become saturated and will require adequate surface cover to manage velocities at the surface and wetting/drying cycles of the materials. The current natural outcrop is expected to remain viable. Water in the pit will freshen as flood levels rise from Suttor and Yandan Creek at the event's start, mixing fresh water with pit water to protect environment values against potential marginal quality concerns. Suttor River flows are expected to be 18ML/s, against a total pit capacity of 6800ML, requiring 5-6 minutes to replace pit volume completely. Mixing modelling and observed records indicate that under flood conditions water reporting to the receiving environment protects water quality values (SBE 2024).
East Hill Pit (EHP)	Remains above flood levels and is contained.	The pit will fill to excavated volume, mixing water from the base of the pit with flood waters and then form part of the flooded landscape, remaining after the flooding event. The pit is excavated into rock in the earth and is unlikely to be an overtopping concern (no embankments). The volume of pit water is unlikely to be material for quality concerns given the volume of impacted stored water, pit volume and magnitude of flows (for volumes and storage curves, refer to SBE 2022). • Pit storage volume (present) – 6.2ML (170mAHD) • Total East Hill Pit void volume to spill – 46.5ML • Flow volume and rate during the event over 18ML/s across 8km reach of flood waters Flood levels will likely flow into the East Hill Pit via the access road (from the north). The current small bund previously planned is likely no longer necessary as inflow during PMF will improve quality and not impact ecosystem health. A small safety bund may still be required.



Landform		1% AEP Event	PMF event
Heap leach (HL)		Largely remains above flood levels, with minor inundation at the base of the landform on the south side only.	Inundation of circumference of landform base to 2m depth. The remainder of the landform remains out of flood waters. A review of the protection and engineering of foundations is recommended with possible solutions ranging from vegetation to rock batters to buttresses as appropriate.
Tailings Storage Facility (TSF)		It remains above flooding levels and is contained.	The TSF remains above flooding levels and is controlled by the tailings dam. A review of the protection and engineering of the downstream dam is recommended.



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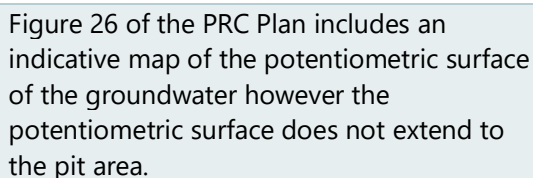
SRK Consulting 1999c, *Yandan pit re-flooding waste rock backfill cover placement specification, RM8030-2*, developed for Ross Mining NL.

Western Mining Corporation (WMC) 1998, *Great Boulder Holdings Limited Yandan Gold Project: Impact assessment study*, self-published.



Appendix A – RFI to work package map

	Information Request Matter	Information Request	Response
6	Preliminary flood modelling has identified that some mining domains including the pit and heap leach pad will be inundated or in contact with floodwaters under 1% AEP and PMF events. However, information detailing how flood flow may interact with the final landform has not been included. An understanding of flood depth and velocity across the final landform is required and how this may influence the achievement and maintenance of a safe, stable and sustainable PMLU.	Demonstrate how all final landforms will achieve and maintain a stable condition under 1% AEP and PMF events. This includes investigating the effect that flood depth and velocity may have on the final landform.	Flood characterisation report
8	Section 3.1.6 of the PRC Plan provides some information on groundwater levels and salinity. No detail has been provided on the interactions of the pit, tailings dam and heap leach pad with groundwater. Criteria that demonstrate these structures will be non-polluting has also not been included. Figures 27 and 28 do not provide context on orientation of the pit and river nor depths of strata and pit depth. The Suttor River alluvium mentioned in section 3.1.6 of the PRC Plan is also not represented. Increasing trends in arsenic have been identified in groundwater in the PRC plan and interactions of tailings and heap leach seepage with groundwater may be occurring. The prediction of water quality impacts from mining activities is necessary to determine appropriate measures for the containment and management of contaminants and the potential impacts on environmental values should they be released.	Provide an assessment of the hydrogeology of the site including all landforms and connected strata in accordance with 3.6.1 of the PRCP Guideline. An assessment of the interactions of the tailings and heap leach pad with groundwater must also be included in the PRC Plan. Provide detailed information regarding water quality and how it varies between depths and bores. Provide milestone criteria for groundwater quality to demonstrate all final landforms will be non-polluting.	Original information has been provided in original report.
9	The PRC Plan and EA require that the pit lake level is to remain above 160mAHD. The Plan also considers that the pit will act as a groundwater sink. Figure 32 in the SBE 2022 report indicates that the groundwater levels in the bore SH3 fluctuate above 160mAHD.	Provide a hydrogeological assessment that encompasses all landforms on the project area. Include supporting evidence that demonstrates how the pit will act as a sink.	Updated Conceptual Model Report



12 The final landform design section of the rehabilitation planning part provides detail surrounding each of the residual voids that will remain as NUMAs on the project. This section of the planning part identifies further investigations that are yet to be completed and are required to inform management area milestone criteria.

Provide further information to demonstrate that both the Main Pit and East Hill Pit will achieve a safe and stable condition as per section 3.6.3 of the PRCP guideline including, but not limited to, a geotechnical assessment and proposed final slope angles.

Main Pit and Suttor River Characterisation Report

Main Pit

- A geotechnical assessment has not yet been conducted on void batter angles, therefore residual void angle requirements are unknown.
- The rehabilitation planning part identifies that additional monitoring data (3-5 years) is required to improve water balance to then determine a long term bund use.
- The expectation is that bunding will be retained within the final landform subject to appropriate assessments (i.e. geotechnical investigations).

However, such assessments are incomplete at time of submission.

Include all required milestone criteria in the PRCP Schedule to ensure the management of the NUMA's to safe, stable, non-polluting landforms.

East Hill Pit

The rehabilitation planning part identifies that the East Hill Pit has a potential to be flooded under a PMF scenario. Given that water quality analysis from within the pit has determined it is of poor quality, this presents a significant environmental contamination risk. The rehabilitation planning part mentions that a small, permanent landform bund will be constructed around the north of the pit, however a design has not been considered in the rehabilitation planning part or supporting technical studies. Nor has this action been included in the PRC Schedule.



14	Various potential risk factors have not been considered in the risk assessment. The following example do not constitute an exhaustive list, but have been provided for reference: • A consideration of how various events may impact the completion time of rehabilitation stages (including potential compliance action as a consequence). • A consideration of risks associated with potential issues arising yet remaining unidentified between monitoring events, with specific links to the monitoring program to justify the selection of specific monitoring frequencies. • A consideration of climatic influence specific to the pit, for example, the impact that drought conditions may have on maintaining the water cover within the Main pit.	Please update the risk assessment to include a broader consideration of potential risk factors and their associated mitigation measures to ensure the safe, stable and sustainable PMLU or managed NUMA is achieved. Please refer to section 3.7 of the PRCP guideline for further information.	Main Pit and Suttor River Characterisation Report
23	The PRC Plan indicates that the Main Pit is expected to be inundated with flood waters and pass floodwater in to and out of the pit via spillways at certain river heights/flood levels to the Suttor River.	Discuss how the objectives for the Main Pit achieve best practice management of the area and minimises risks to the environment from the passage of flood waters in to and out of the pit. Consideration should be given to the stability of the spillways to achieve the purpose of passing floodwater in to and out of the pit. Completion criteria for water quality must reflect releases from the main pit not causing environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself.	Main Pit and Suttor River Characterisation Report
24	Figures 9 and 10 of the SBE 2022 Report as part of the PRC Plan indicate spikes in Electrical Conductivity (EC) during flow events with an explanation provided as "...with the exception of short-term higher salinity experienced during the major regional flooding event in 2011. Comparison of	Provide commentary on the timing of releases from main pit and how they correlate or not with the peaks in EC in the Suttor River	Addressed in 2022 report Updated Conceptual Model Report



upstream & downstream salinity would suggest an additional salt load entered the river during this significant event, similar to occurrences across the Queensland region for this event.”

27	The PRC Plan states that “minimal mixing is required with site or river water to meet receiving environment requirements.” However, no detail is included on what dilution is required to meet the receiving environment requirements or at what flow volumes the minimal mixing will occur.	Provide detail on the minimum mixing requirement to ensure no environment harm will be caused from releases of pit water to the receiving environment	Main Pit and Suttor River Characterisation Report
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Updated conceptual model for water performance Yandan Mine

March 2024



Document history and status

Version	Date	Released by	To	Status
1.0	24 March 2024	Tania Kennedy, SBE	Tom Cooney GBM Resources Natasha Jensen, AARC Hollie Dick, AARC	Draft
1.1	28 March 2024	Tania Kennedy, SBE	Tom Cooney GBM Resources Natasha Jensen, AARC Hollie Dick, AARC	Final

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- Public sources of information.
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- Where possible, data, sources and raw information are separated into application, interpretation and implication assessments.

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1 Introduction

1.1 Background

GBM Resources Limited is currently in the process of a transitional Progressive Rehabilitation and Closure Planning (PRCP) with the Department of Environment, Science and Innovation (DESI) for the Yandan mine, located in north Queensland inland, approximately 40km west of Mount Coolon.

Yandan is a historical mine site with several legacy landforms, including two (2) pit voids (including the Main pit adjacent to the Suttor River and the focus of this assessment), a tailings storage landform, and a heap leach landform. With the initial Yandan PRCP submission early in 2022, DESI (former DES) subsequently requested information (RFI) listing several queries around water-related risk and requests to clarify closure outcomes.

As supplements to SBE (2022), additional packages of work are prepared to respond to the RFI around water-related risk, structured as three separate (3) technical updates:

- Yandan site flooding profile characterisation.
- Main pit and Suttor River water system characterisation.
- Yandan updated groundwater and conceptual model characterisation (this report).

1.2 Changes since the initial PRCP submission

As core additional information for PRCP and a related program for Estimated Rehabilitation Calculation (ERC), in 2023, GBM embarked on a robust data collection program to obtain representative and seasonal information, including additional groundwater wells and water storage monitoring.

The additional data and information obtained over the past year provide a material step change in representative data, understanding, and technical confidence of the Yandan water systems. They also offer an excellent management tool for the site looking forward. Information and data gained to date are incorporated into this updated assessment.

1.3 Intent of this work package

This report captures, expands and assesses the nature of the Yandan water system to identify and characterise water domains as closure landforms, including:

- Summary of new information and implications for the conceptual model.
- Updates to the site setting and water system
- Updated domain conceptual models for the Mineralised zone (Main Pit and East Hill Pit), Regional, Heap Leach and Tailings Storage Facility (TSF).

1.4 Scope

The scope of this work is to satisfy reasonable requirements of the *Progressive rehabilitation and closure plans* (Queensland Government 2023) for a historical site under transitional provisions by addressing and resolving key questions in the 2023 Request for Information (RFI). A map of RFI to responses is provided in Appendix A. This update report should supplement SBE (2022) for overall site characterisation and further information.



2 Summary of new information and learnings

2.1 Map of the overall Yandan water monitoring network

A comprehensive map of the combined water monitoring network across Yandan is shown in Figure 1, including:

- Groundwater wells at the regional background and around each landform (prefix based on landform: MP, TD, HI, RB).
- Surface water monitoring of storages and pit lakes across the site (prefix based on landform: TD, MP, HL, EP).
- Additional to storage monitoring, Main Pit depth quality monitoring (MP prefix within pit lake: MP1 & MP2).
- Level loggers (transducers) are installed at the Main Pit, East Hill Pit, and the Tailings containment dam (the TSF dam includes electrical conductivity to check runoff and quality).
- Receiving environment and releases monitoring sites (REMP and SR prefix).

2.2 Groundwater bores and system

2.2.1 Construction of new groundwater wells

In early 2024, GBM Resources constructed fourteen (14) new groundwater wells around each of the key landforms, including:

- Four (4) wells around the Main Pit/East Pit, including a nested site to test for potential connection to alluvials.
- Two (2) wells downgradient of the Heap Leach
- Eight (8) wells as background and downgradient of the Tailings Storage Facility (TSF).

Borehole design locations were designed to increase the chances of encountering groundwater, such as near geological faults or ephemeral drainage lines.

The bore log and construction details of each well are available in Table 1. Bore logs, including geology, photos, and driller records, are captured in Appendix B-D.

A single sampling event (February 2024) has occurred for the new groundwater wells, including levels and quality. Initial results are discussed in this report; however, findings should be considered preliminary only. Further monitoring events (likely 4-8 recommended to include different seasons) must fully characterise the wells.

2.2.2 Learnings

Groundwater occurrence

Overall, the drilling results of the 14 new wells aligned with and confirmed the previous experience of groundwater occurrence at Yandan: groundwater is poorly developed, has very low hydraulic conductivity, and is isolated across the project. Five wells were completely dry when drilling (see Table 2), two of which could not be sampled in February due to lack of water (TD10, TD11). The two wells constructed within the TSF were damp at ground level (below the tailings) during drilling and could not be sampled, as both presented as dry. Of the remaining wells, most encountered conditions of 'damp' sections only as representative of groundwater. Bore MP03 likely intersected the most water, as a low yield flow from an area of associated mineralisation, likely within a fault at depth.

Geology

Geology encountered during drilling fit within known and expected rock types of:

- MP01-04 – Metasediments and hydrothermal mineralised areas of St Anns Formation.



- TD and HL (all wells) – Metamorphic rocks (phyllites), metasediments and quartzite of the Anakie Inlier.
- ITD – tailings and ground surface of the Anakie Inlier, like hills, surround the TSF landform. Depths of tailings are as expected.

Groundwater level adjustment for Main Pit wells

As an exception and genuine learning for the project, the initial groundwater sampling event identified all bores in the Main Pit area as highly saline (25,000EC uS/cm and above). With no previous wells in the pit domain (only one distal well to the Main Pit previously, SH3), MP01-04 bores were designed to test and inform groundwater quality for the East and Main Pit mineralised areas.

High salinity and high chloride levels are naturally associated with hydrothermal activity and mineralisation events, including high chloride levels. The effect of the salinity is to increase the density of the water, which means the effective head of saline water wells is higher than measured by simple standing water at atmospheric pressure. To compare relative groundwater levels with those of fresher water heads such as Main Pit or other groundwater wells as effective heads, saline well levels require density adjustment. The approach is explained in Appendix E, meaning that an additional 1.5m of the effective head was added to the measured relative water levels for functional purposes.

2.3 Surface water storage and system

2.3.1 Installation of new level monitoring

Water level loggers were installed into three storages between April and November 2023 and continue to present: in Main Pit Lake, East Hill Pit Lake and the Tailings Storage containment dam. Logging aimed to track responses to rainfall and evaporation as a test for runoff factors and potential connection to groundwater. An additional function of logging salinity was installed into the Tailings Containment dam to test for salinity response to rainfall or over a dry season. As a record of installation, the loggers were field surveyed to obtain a relative level (mAHD) and adjusted for barometric pressure, as in Table 1.

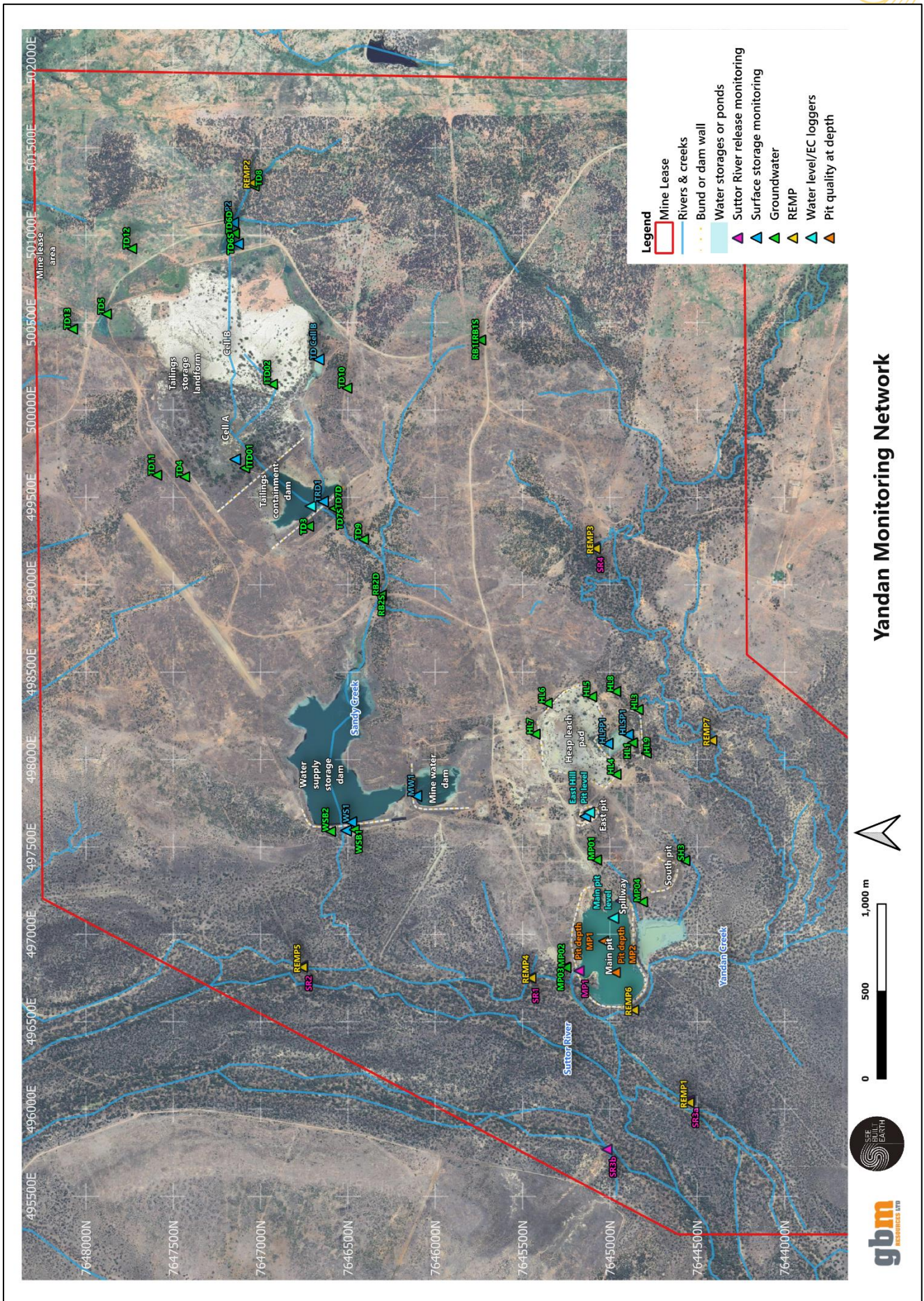
Table 1 - Surface storage logger details

Location	Relative water level installed	Barometric pressure
Main Pit lake	162.21mAHD	10.1m
East Hill Pit lake	163.64mAHD	10.1m
Tailings containment dam	177.29mAHD	10.1m

2.3.2 Learnings

Daily average water storage levels (at relative elevation) from installation through to mid-February 2024 for each storage and rainfall (St Anns River gauge station, BOM) are shown in Figure 2. The general trend shows the Tailings Containment dam as having a strong response to rainfall, whilst the Main Pit and East Hill Pit levels are muted, given limited catchments.

Initial analysis of water level decline rates identifies a split in behaviour between Main Pit and East Hill Pit/Tailings Containment (Figure 3): Main Pit has a substantially lower overall water level loss rate than the other two storages. A comparison of evaporation rates to average (noting each year will differ) in Table 3 shows the magnitude of difference: East Hill Pit lake the Tailings containment decline at a rate more aligned to average expected evaporation rates. The slower rate of decline in the Main Pit suggests and supports the presence of a groundwater baseflow into the Main Pit, similar to those indicated by historical mining investigations (Forbes 1988) and the Main Pit mass water balance (SBE 2022).



Yandan Monitoring Network

Figure 1- Monitoring network in place at Yandan



Table 2 - Summary of new wells constructed

BoreID	Location	Depth	Screen	Water	Geology
Main pit domain (St Anns Formation)					
MP01	Upgradient from Main Pit, between East Pit	25m	20-23m	Largely dry	Tan to green fine-grained sandstones and siltstones, +/- quartz, some saprolite, calcareous and sericite alteration at depth
MP02/03 Nested site	Alluvium and on fault between Main Pit and Suttor River	11m/41m	6.5-9.5m 32-38m	MP02 Damp at 10m MP03 Water at 38m, low yield	Very fine-grained brown to green siltstone, chert and clay, calcareous alteration. At depth, fine pyrite/marcasite, carbonate veining, and minor calcite crystals from 17m.
MP04	South of Main pit	14	10-13m	Minor water at 10-11m	Fine-grained, grey to black metasediment of sandstone and siltstone, clay, clay crusts and chert
Tailings domain (Anakie Inlier)					
TD8	East of TSF, background (near REMP 2)	20	16-19m	Dry to end of hole (EOH)	Fine sandstone and phyllite
TD9	West of TSF, downgradient on Sandy Creek	13	9-12m	Damp at 10-11m	Green-brown phyllite
TD10	South of TSF, downgradient	20	16-19m	Dry to end of hole (EOH)	Very fine grey/brown sandstone, mudstone and phyllite
TD11	North of TSF, downgradient (replace TD4)	20	16-19m	Dry to end of hole (EOH)	Foliated phyllite/siltstone and very fine-grained sandstone
TD12	Northeast of TSF, downgradient	20	16-19m	Dry to end of hole (EOH)	Green mudstone/phyllite to foliated sandstone, buck quartz veins
TD13	North of TSF, downgradient (replace TD5)	20	9-12m	Damp at 10-11m	Khaki to green sandstone, clay and quartz vein
ITD01	Through tailings to natural ground (Cell A)	10.5	6-9m	The natural surface at 9m, some dampness	Fine tailings Phyllite below
ITD02	Through tailings to natural ground (Cell B)	7	3-6m	The natural surface intersection at 5.5m	Fine tailings Coarse gravel at the base (quartz veins)
Heap leach					
HL8	East to southeast	20	13-19m	Damp around 18m	Fine-grained sandstone (moderately oxidised), brown phyllite, muscovite mica
HL9	Downgradient of heap leach	20	13-19m	Damp in places, possibly from 17m	Very fine-grained sandstone, siltstone, buck quartz

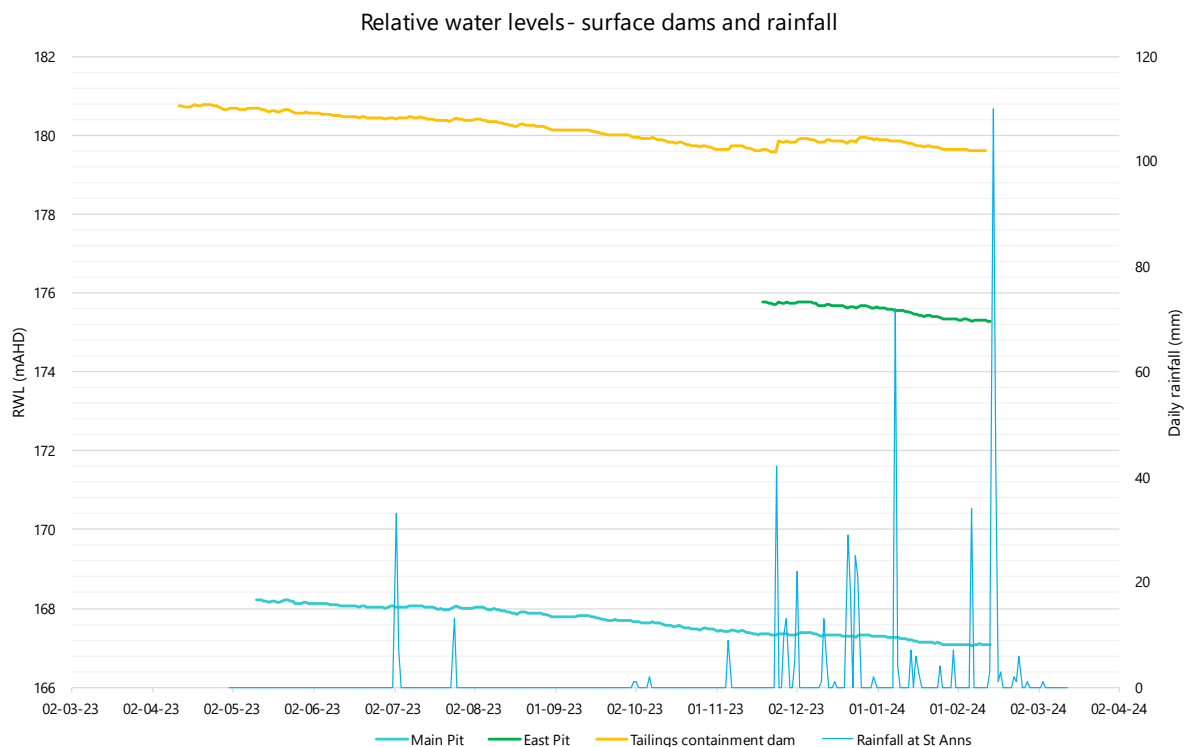


Figure 2 - Surface water storage levels to date via level loggers

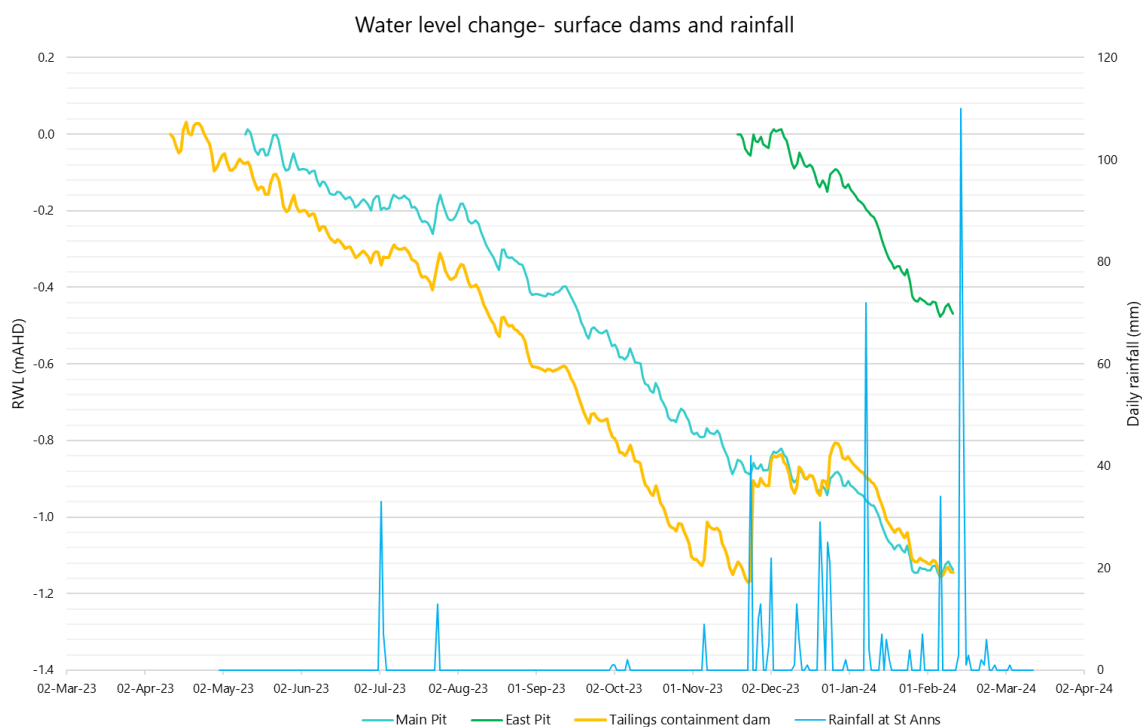


Figure 3 - Surface water storage change in levels and rainfall

Table 3 - Summary of average evaporation rates to comparative rates at level loggers

Average BOM evaporation by month													
Station	StationID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MoranbahWaterTreatmen	SE 34038	8	7.4	6.8	5.7	4.3	3.5	3.7	4.9	6.6	8	8.5	8.5
TwinHills	SW 36047	7.5	6.5	6.1	5.2	3.6	2.9	3.1	4.2	6.1	7.9	8.6	8.7
CollinsvillePostOffice	NE 33013	6.2	5.7	5.2	4.4	3.5	2.9	3.2	4.1	5.3	6.5	6.9	6.9
Average evaporation		7.2	6.5	6.0	5.1	3.8	3.1	3.3	4.4	6.0	7.5	8.0	8.0
Observed level decline at level loggers (based on level on 1st of each month)													
Main pit		-1.0	-7.8					-2.3	-1.7	-6.7	-4.6	-7.4	-3.3
East Hill Pit		-3.2	-10.4										
Tailings containment		2.6	-9.3				-4.3	-3.5	-2.1	-7.9	-6.1	-10.4	6.1



2.4 General influence of rain on water quality

2.4.1 Rainfall

Yandan experienced wetter-than-average rainfall from 2021 through most of 2023, as shown by a Mount Douglas-Belyando residual rainfall trend in Figure 4. The increased rain provides an opportunity to see how rainfall across landforms influences water quality for landform surface water storages (and some bores).

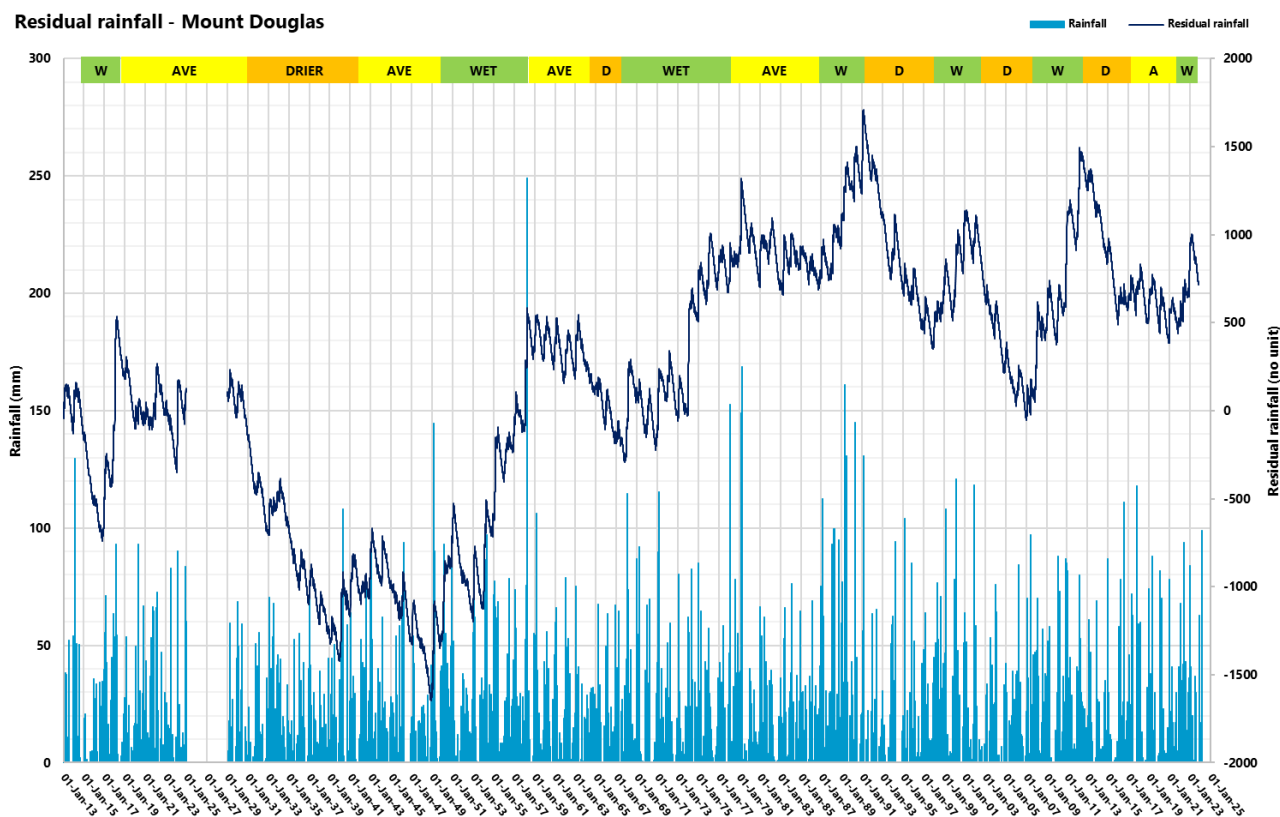


Figure 4 - Residual rainfall - Mount Douglas

2.4.2 Tailings containment storage

Increased rainfall over the past several years has generally demonstrated improved water quality within the tailings storage containment dam and also of TSF water performance (Figure 5, Figure 6):

- pH has remained relatively stable, increasing and becoming alkaline. The latest read shows the pH of the storage at pH 9.5: this is only marginally higher than the pH experienced in 2021. The increased pH is most likely through the dissolution of carbonates or jarosite present in and around the tailings, moving given the saturating rainfall experienced for consecutive wet seasons after the extended dry between 2012 and 2021. Sulphate is also reduced to freshwater levels: to test for potential carbonates, it is recommended to include carbonates and oxidation-reduction potential with the next sampling event.
- Salinity, sulphate, nickel, and zinc have strongly declined and remain stable at freshwater concentrations.
- Arsenic and copper show no response to rainfall and are stable.

At a smaller timescale, the Tailings Containment level and salinity logger results provide an insight into real-time salinity responses (Figure 7), showing slowly increasing salinity concentrations as water levels decline through evaporation concentration. With rainfall, a rapid salinity peak is associated with the first runoff, which rapidly declines to fresher water.

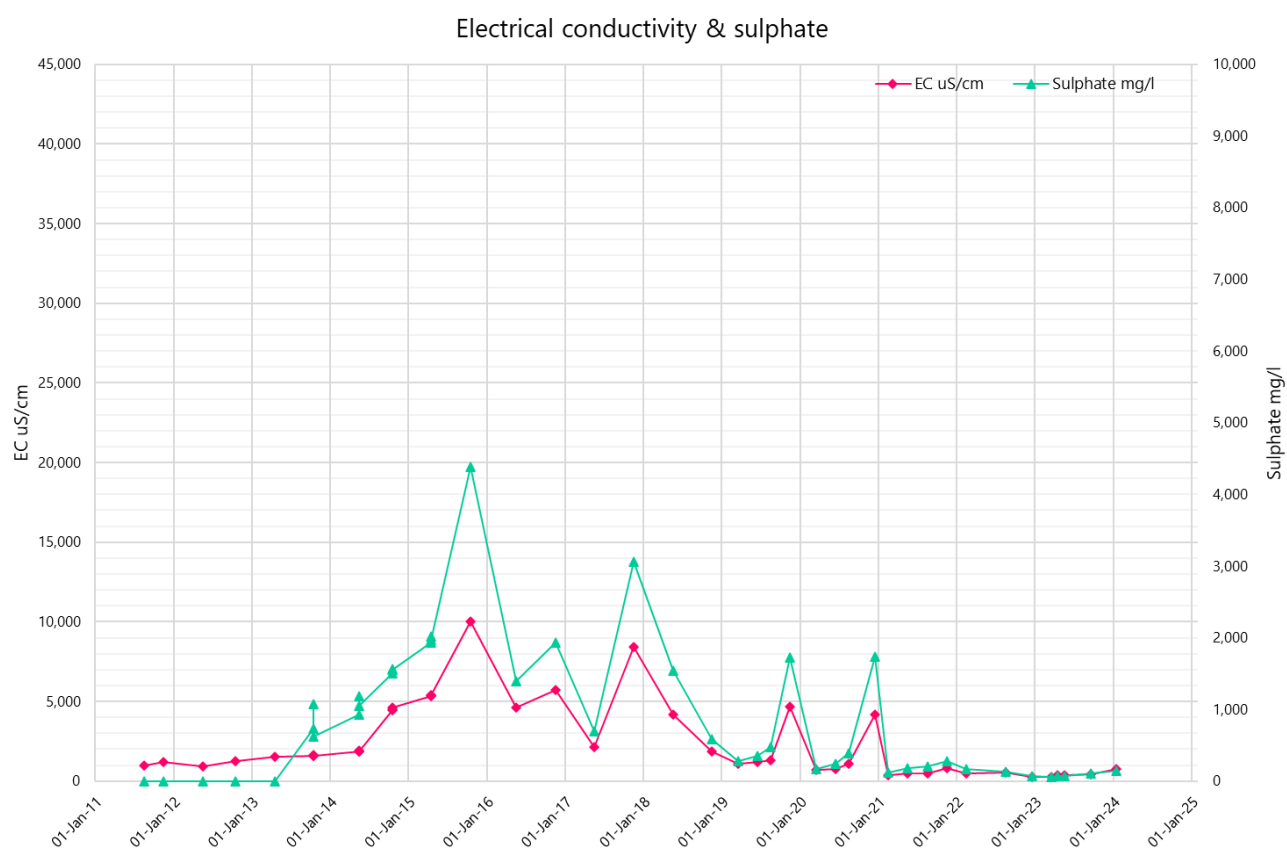
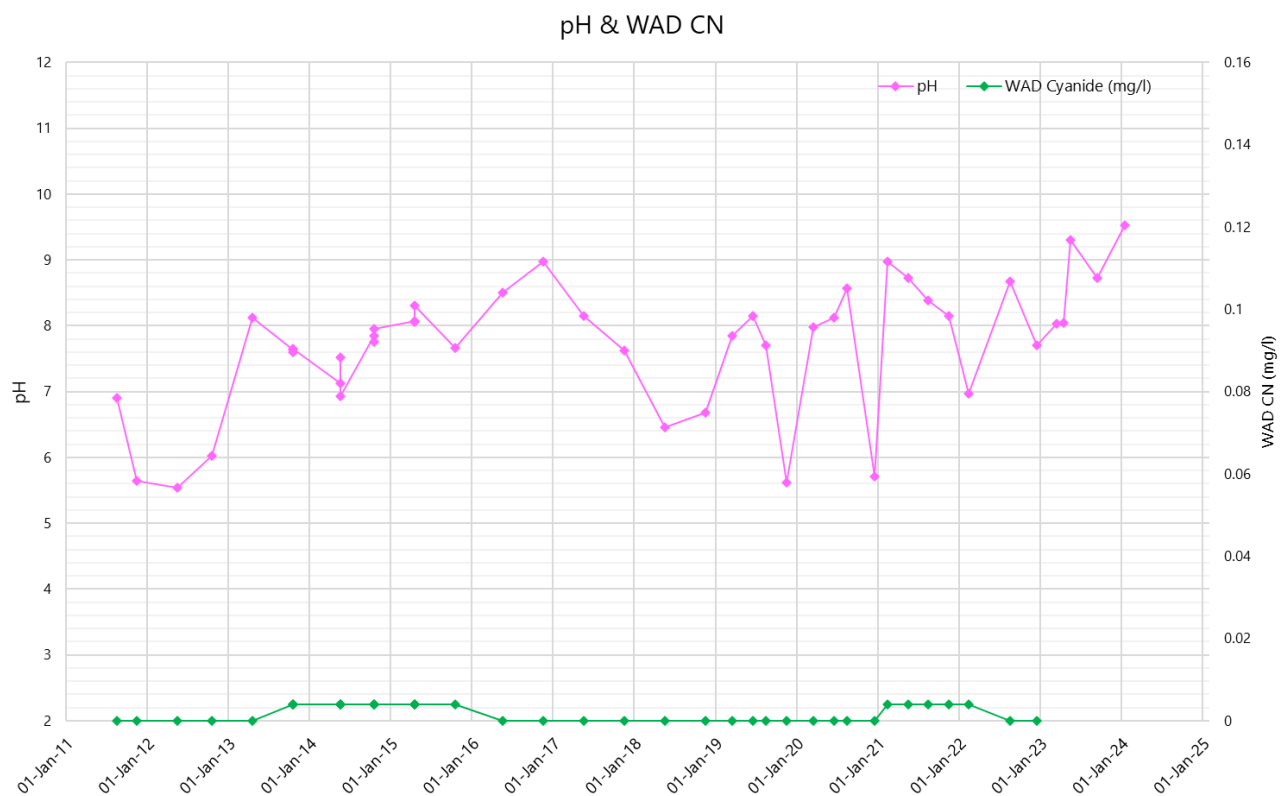


Figure 5 - Tailings containment storage pH, WAD CN, EC and SO4 concentrations



Figure 6 - Tailings containment storage As, Cu, Ni and Zn concentrations

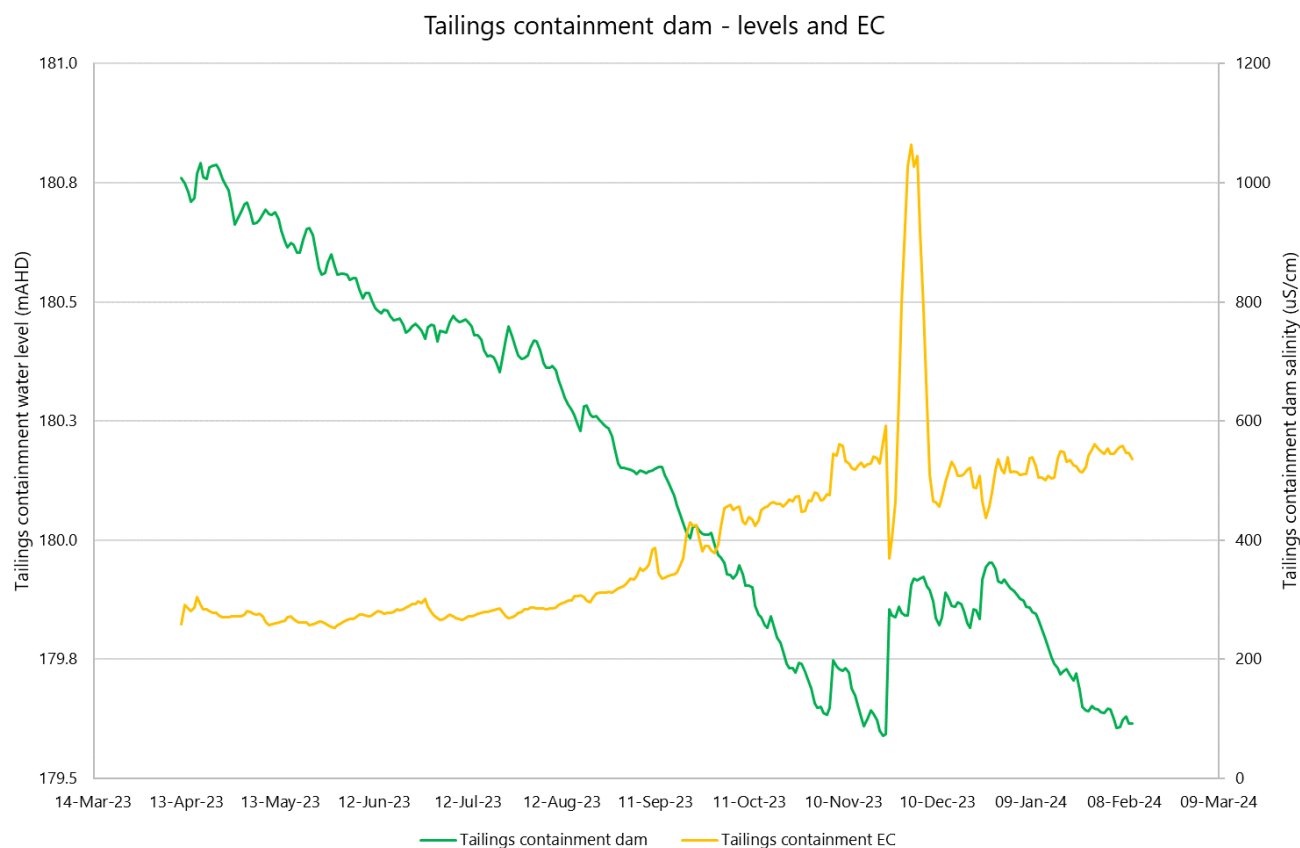


Figure 7 - Tailings containment level and salinity logger over rainfall event

2.4.3 East Hill pit storage

East Hill Pit storage is contained storage and has experienced two introduced water sources since monitoring began: rainfall and a limited amount of water pumping from the Heap Leach ponds (due to the ponds' storage capacity during large rainfall events). The additional volume has lifted relative water levels within the pit storage from 167.6mAHd in July 2021 (from LiDAR survey image) to 175.7mAHd in November 2023 (from level logger), or an estimated additional volume of approximately 47ML.

Mixing of the additional water has dramatically improved water quality (Figure 8, Figure 9):

- pH rising from a relatively constant and acidic 4 to a pH of 7-8.
- A salinity decline from 20,000 to 5,000 EC uS/cm and sulphate reduction of 4,500 to 1,000 mg/l.
- Strong reductions in concentration for arsenic, copper, nickel and zinc.

The change in water quality demonstrates that rainfall or additional water introduction is generally beneficial for the water quality of the East Hill pit. If a PMF flooding event were to occur, the water quality of East Hill Pit lake would be rapidly mixed and not present an additional risk of environmental harm in overflow from the pit into the river.

2.4.4 Main Pit storage

The water quality of Main Pit storage since 2013 and the past several years is discussed in detail in SBE (2024b). Water within the Main Pit storage remains in the pit until flooding from the Suttor River occurs when the river flows into the pit. The estimated AEP of flooding is 7-25%.

Water quality within the pit remains stable across all parameters, and mixing with river inflow during flooding and hydraulic connection to discharge has consistently met environmental performance requirements as a stable and non-polluting landform.

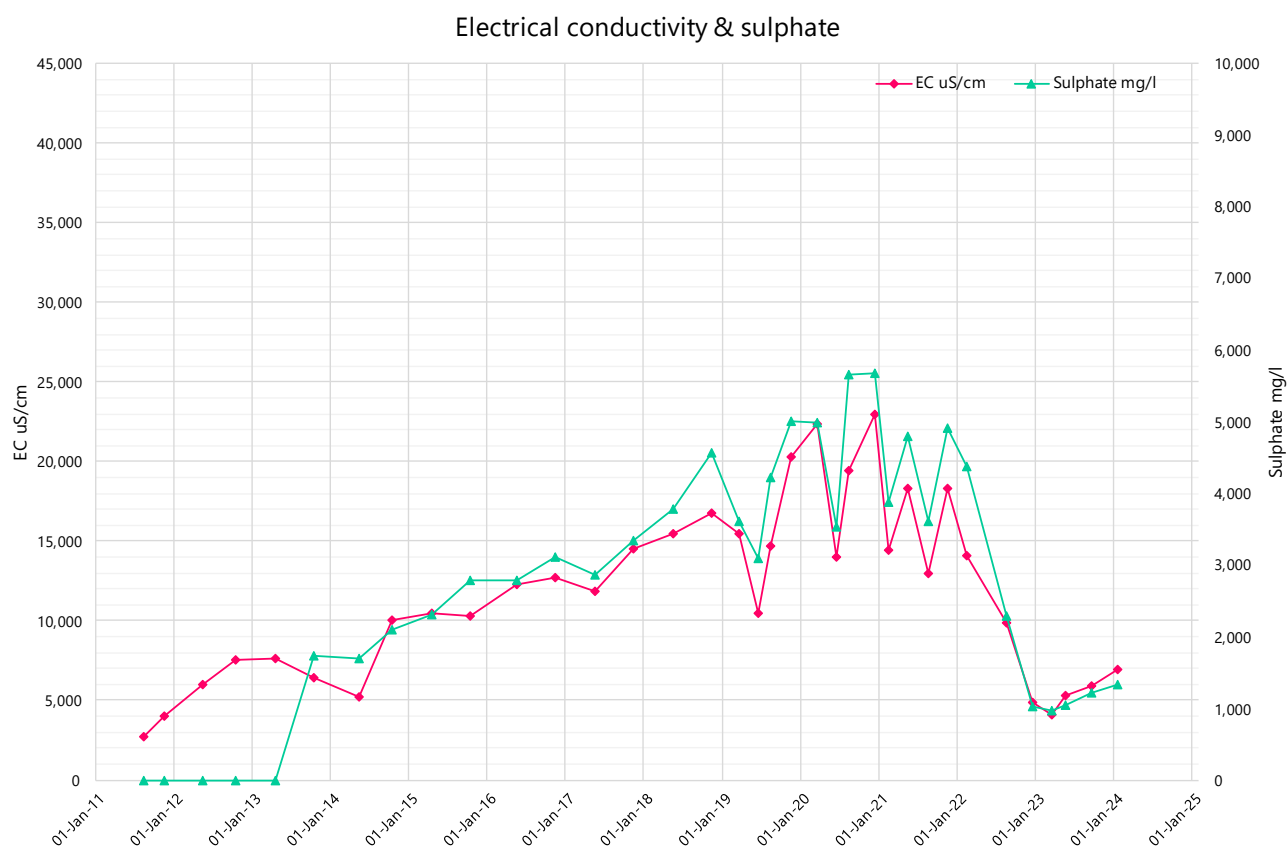
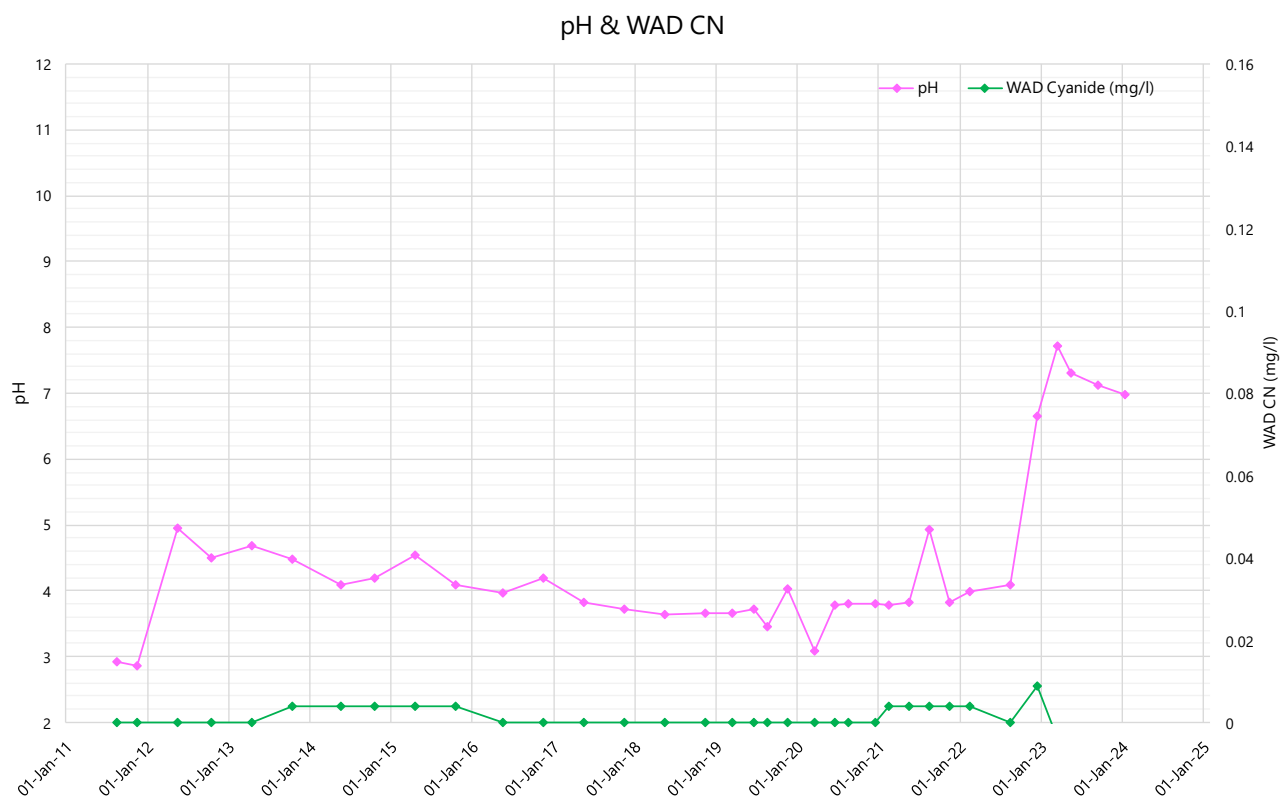


Figure 8 – East Hill Pit storage pH, WAD CN, EC and SO₄ concentrations

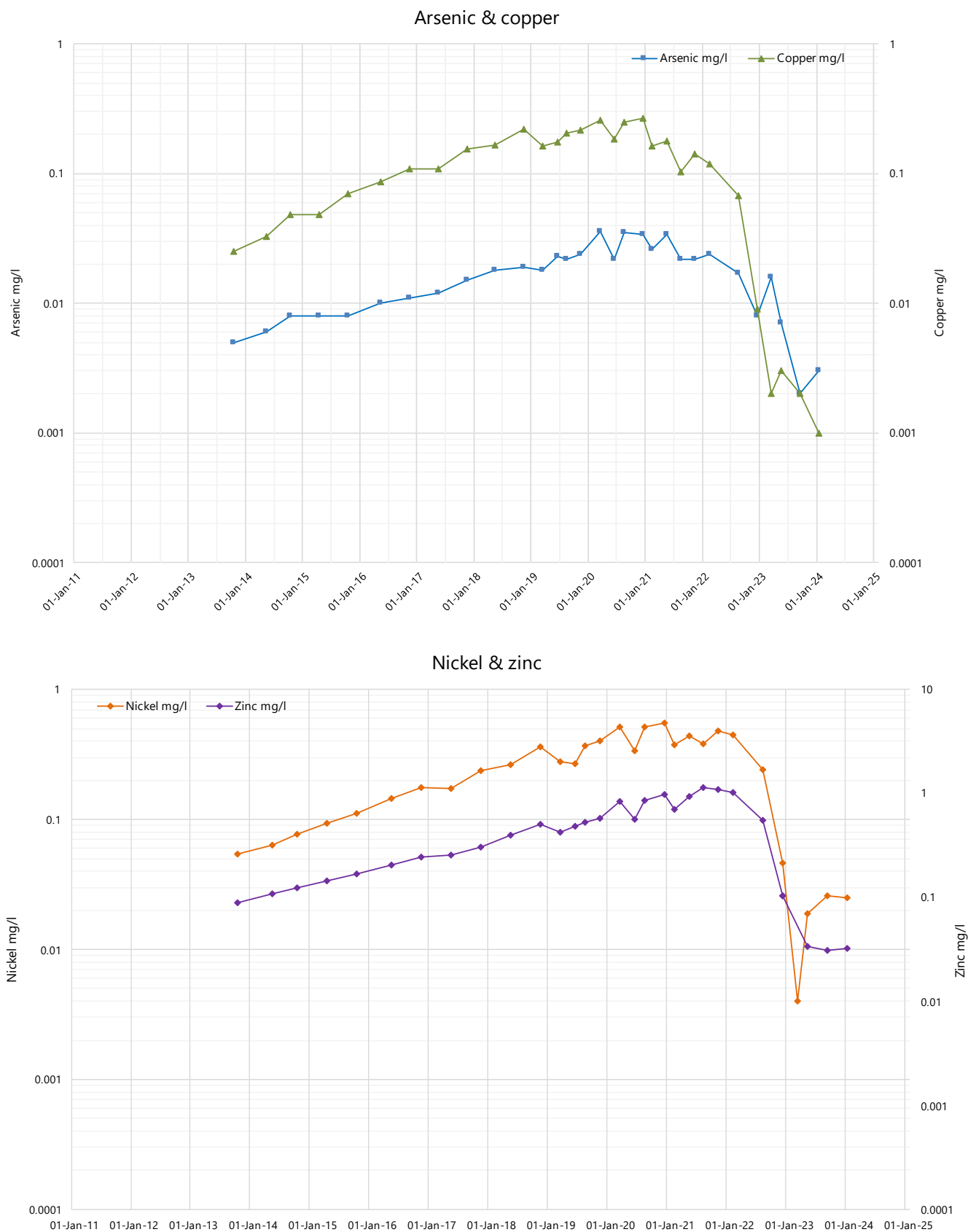


Figure 9 – East Hill Pit storage As, Cu, Ni and Zn concentrations



3 Updated Yandan conceptual model

3.1 Topography and catchments

The topography and catchments of Yandan remain unchanged: the site is bounded to the east by low hills which form a sub-catchment divide, which grades down into a large low-lying area for most of the west part of the lease and the Suttor River braided river.

Figure 10 shows a relief map of the site sourced from a 2021 LiDAR survey with the site location noted:

- The TSF lays back in the hills as a shallow, blanket-type landform across the hills just inside the head of the Sandy Creek tributary. The downgradient is the tailings containment dam, which goes down to the water supply dam and the Suttor River. The catchment of the TSF is the landform itself.
- To the south, the Heap Leach landform is the highest elevation landform of the site (and natural topography). It is constructed on a natural low-lying hill, and directly west is the East Hill pit on the eastern side of an adjoining low-lying hill. The landform is the catchment of the Heap Leach; the East Hill pit has a small catchment to the north and a direct footprint.
- Main Pit lays adjacent to the Suttor River and downstream of Yandan Creek. The pit has a limited catchment, mostly caused by direct rainfall on the pit lake. In non-flood conditions, Yandan Creek deviates around the west of the Main Pit via a levee bank. In flooding conditions, Yandan Creek flows into the eastern spillway and out to the Suttor via the western spillway or, at times, becomes part of a connected system.

Figure 11 shows a map of Yandan site catchments marked with drainage flow directions.

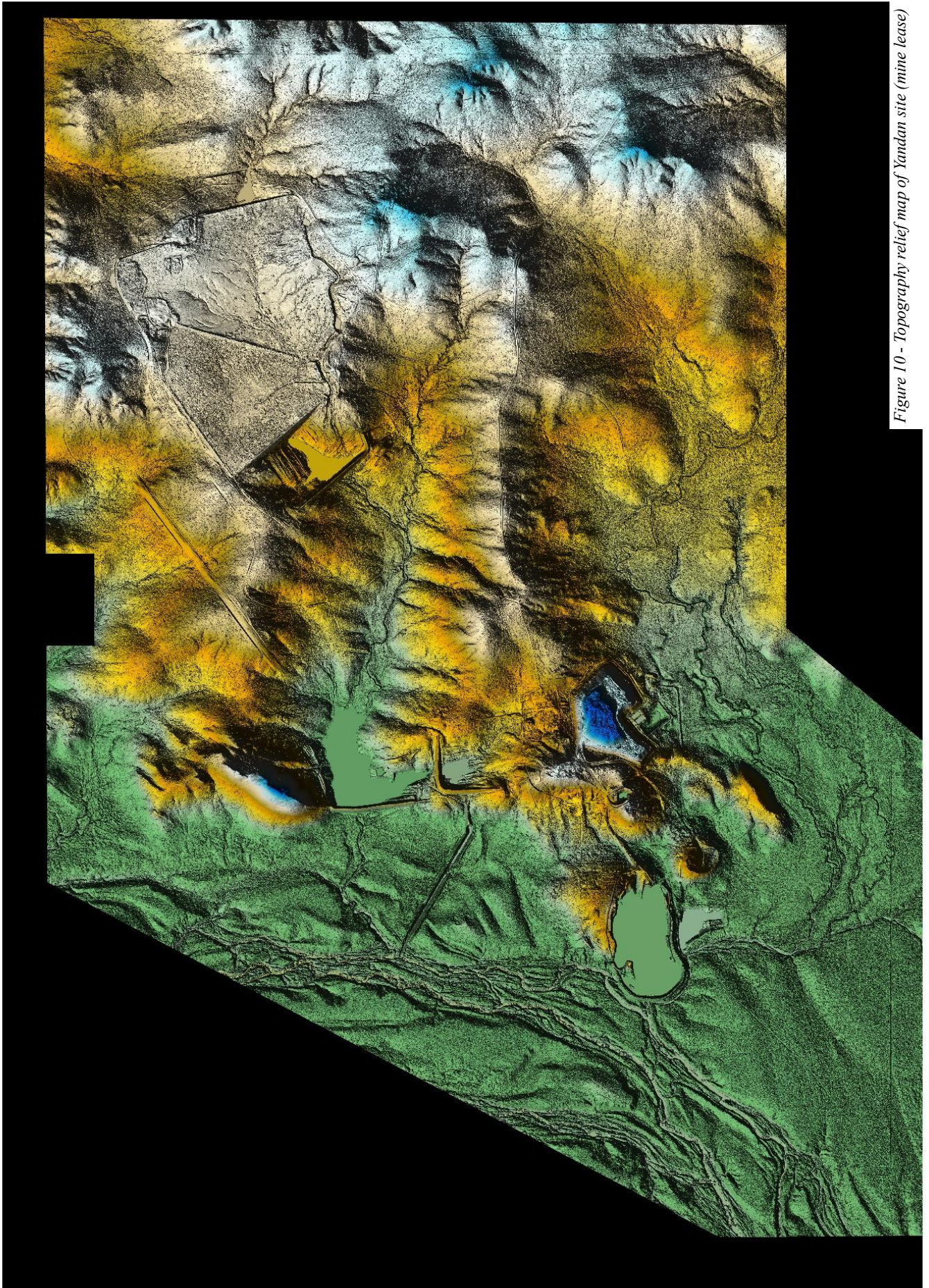


Figure 10 - Topography relief map of Yandan site (mine lease)



3.2 Geology and groundwater framework

3.2.1 Geology

The Yandan deposits are hosted by Middle Devonian to Lower Carboniferous volcanics, clayey limestones and meta-sediments as part of the St Anns Formation in the Drummond Basin (Carver and Chenoweth 2003; Global Ore Discovery 2021). The primary rock material for the Main Pit area is andesite and associated volcanoclastics overlain by metasediments, undifferentiated clastics such as clays, and calcareous (lime-rich and altered) fine siltstones and sandstones. Structures within the Main Pit are well developed, often with calcite and sulphide development. The Yandan Fault strikes east-west along the pit's length, with several cross-cutting faults identified as striking NW-SE and E-W.

To the west, St Anns Formation is overlain by alluvial deposits of the Suttor River. The Suttor River alluvials are considered to range up to 30m depth (Forbes 1988).

The broad geometry of the Yandan project geology comprises two main parts, bounded by the Yandan East fault (Figure 12). The Yandan East fault is a regional and significant fault that separates the St Anns Formation and known mineralised zones on the western side from the Anakie Inlier on the east, which hosts all other landforms. The Anakie Metamorphics are regional basement and are metamorphosed to mid-greenschist facies meta-siltstones, mudstones to phyllites and fine-grained sandstones. Joints and veins through the Anakie are sealed and filled by quartz and silica.

Geology plays a major role in topography, with the Anakie Inlier forming low-lying hills and the St Anns Formation forming low-lying areas over most of the project's western region and the Suttor River. Notably, surface drainage lines broadly align to structural alignments or approximate changes in geology, such as the Suttor River flowing north.

Figure 13 shows a 3D model of geology looking northeast across the Main Pit (MP), East Hill (EHP) and South Hill (SHP) Pits, with the Yandan East fault cutting down between the East Hill pit and the Heap Leach.

3.2.2 Groundwater occurrence

Groundwater generally occurs infrequently across the Yandan site, as the nature of the geology constrains its presence and yield. The prevalence of crystalline volcanics hosting mineralised areas in the west and compacted and metamorphosed meta-sediments in the east strongly restricts hydraulic conductivity, connectivity and effective porosity in most areas.

Poor and restrictive groundwater development has and is consistently experienced: groundwater is rarely developed by local landholders for agriculture unless in alluvials. Yandan site drilling and sampling practices find groundwater at low yields and predominantly dry conditions. Most wells constructed on site are 'damp' wells (Table 2 and Appendix B-D), with groundwater sampling often requiring two days of recharge after purging to allow enough water to return into the bore column (SBE 2022).

There is a limited exception: Main Pit is known to have a groundwater baseflow. Project feasibility studies (Forbes 1988, WMC 1998) identified dewatering demand rates of up to 5,000m³/d to keep Main pit dry, with little to no connection to alluvials despite specific monitoring. However, records of pump tests or dewatering demand have since been lost. According to current water balance estimates, an estimated inflow of 14l/s into the pit as baseflow is most likely sourced from the Yandan Fault across the pit and crosscuts. Further work and investigation are required to define the magnitude and responses of groundwater inflow to pit water levels.

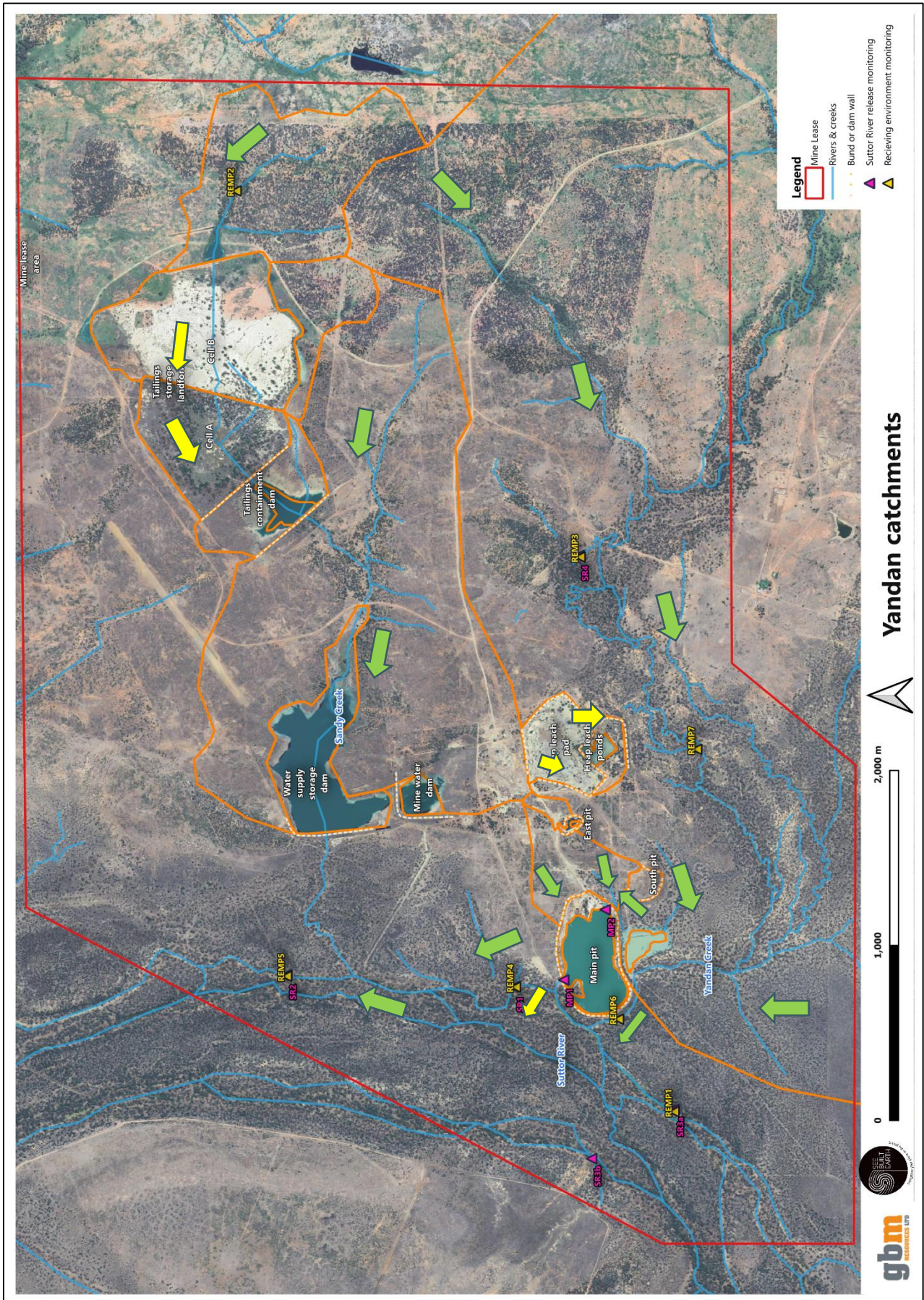


Figure 11 – Surface water framework of Yandan site with catchments & drainage directions

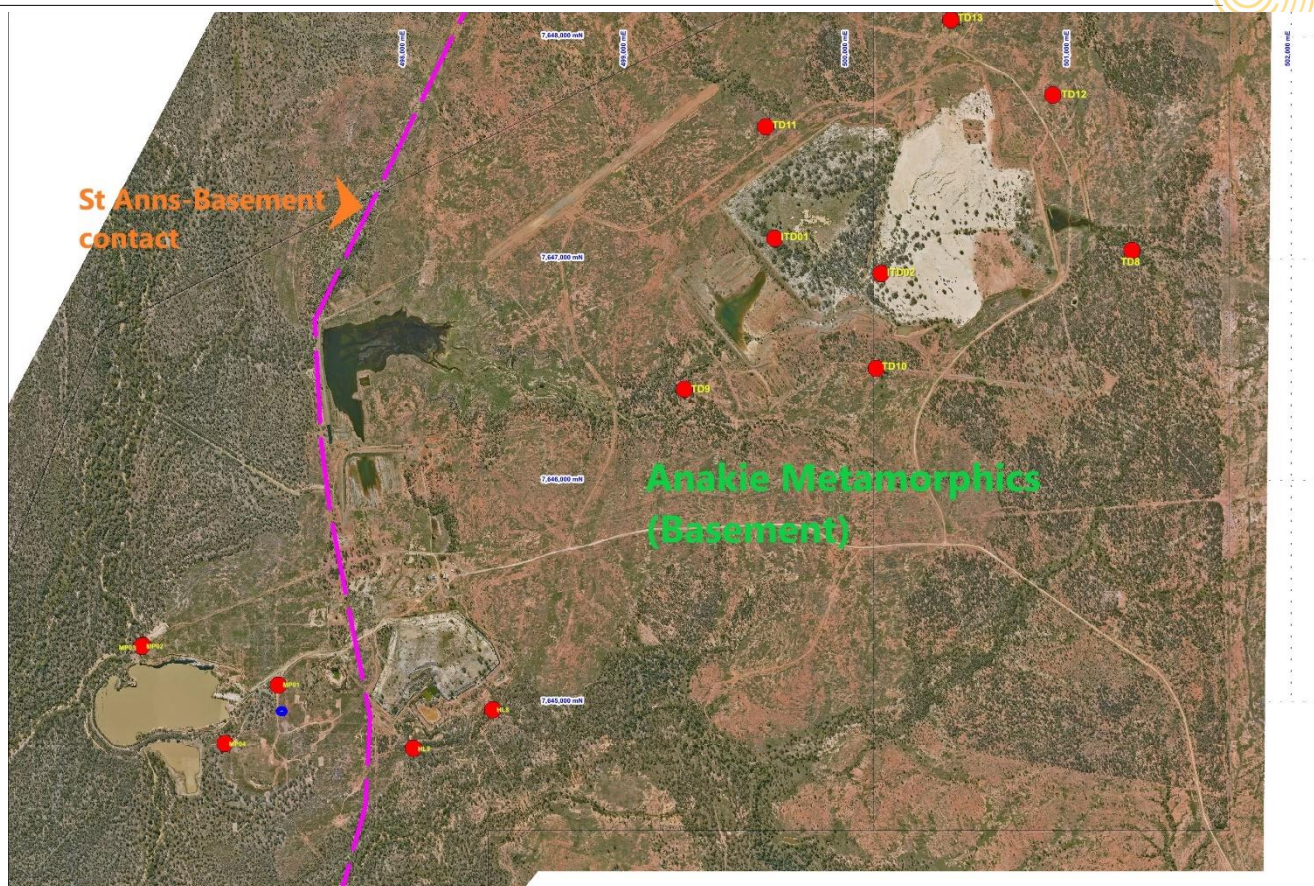


Figure 12 - View of Yandan East bounding fault across the Yandan project (source: GBM Resources)

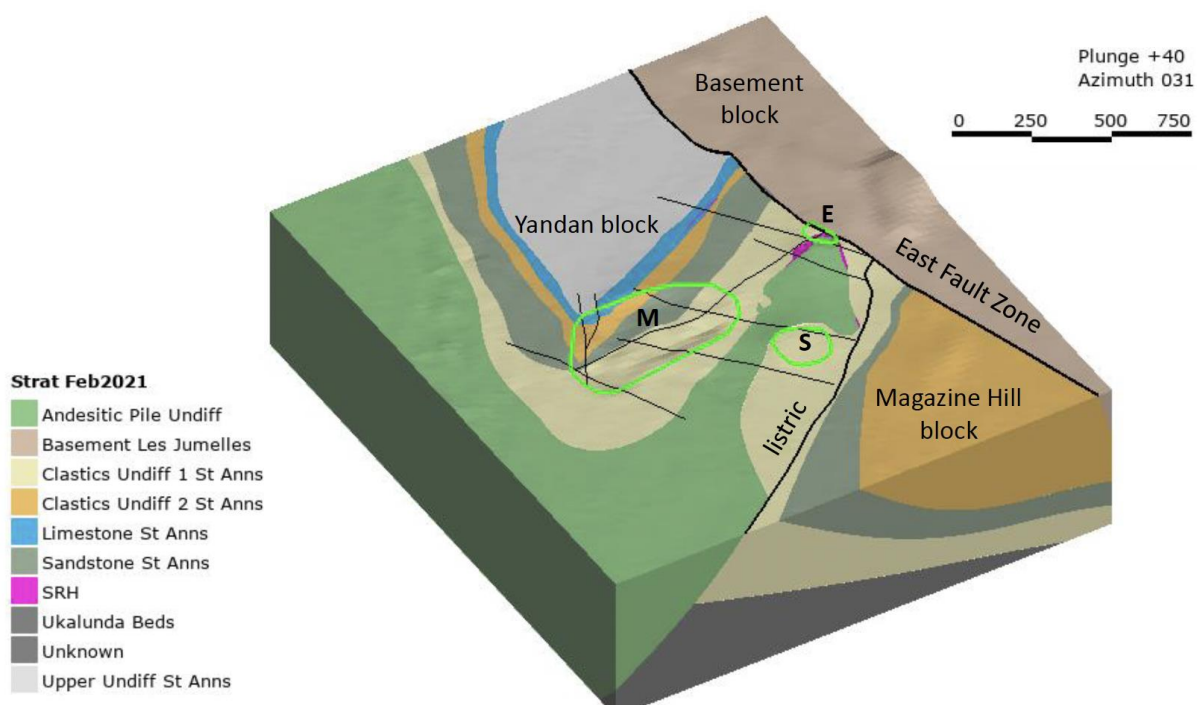


Figure 13 - Main Pit and surrounding area geology, looking southwest (Global Ore Resource 2021)





3.3 Site groundwater characterisation

3.3.1 Groundwater levels over 2023

Groundwater elevations across the project, across the monitoring record, and including the most recent levels are shown in Figure 14 through to Figure 17 as regional, tailings, heap leach, and mineralised area relative water levels. Initial water levels of the recently constructed wells are also shown.

Overall, nearly all groundwater across the project shows a response to rainfall, showing a decline from 2012 through 2020/21, then increasing with higher rainfall to 2022, and beginning to decline again in 2023 with the lower rainfall rates experienced.

The exception is groundwater in the mineralised domain, with SH3 remaining relatively stable throughout. This suggests either less recharge exposure or a deeper source of groundwater that is not dependent on rainfall.

Notably, HL1, situated near the Heap Leach processing pond wall, has responded erratically over the past year and confirms the well is not monitoring groundwater.

The water levels of MP01 will require review moving forward, as relative levels are at a much lower elevation than the surrounding groundwater. This is unusual - the well was predominantly dry when drilled and may be in a fault or separate zone. Given the localised nature of the level compared to the rest of the mineralised domain area, it may be this well does not represent true groundwater pressure head across the field and will require review over time to inform ongoing updates of the conceptual model.

3.3.2 Groundwater potentiometric surface

Figure 18 shows a groundwater potentiometric surface for Yandan based on the groundwater levels of May 2023/February 2024. In constructing the surface, wells HL1, HL6, WSB and TD5 were excluded because they were non-representative of groundwater, either because they were too close to dam embankments or landforms or known to have integrity issues. Wells ITD01, ITD02, TD6S and RB1S were also excluded as these bores were dry and did not record a water level.

Note groundwater is unlikely to “flow” at Yandan in the traditional sense given the disconnected and low hydraulic conductivity of host units (with Main Pit being the exception), and a more apt description to reflect groundwater pressure head across the project would be a groundwater potentiometric surface.

Overall, the groundwater head follows a subdued topography: the pressure head drops towards the west from the highest topography in the east, mimicking topography and trending down towards Main Pit and Yandan Creek.

Near the Main Pit, groundwater potentiometric surfaces are near pit lake water surface levels, which will intersect the void at depth in the lake with some baseflow due to density flow.

From the Main Pit, the direction of the pressure head falls to the west underneath the Suttor River channel or south around the base of Yandan Creek to leave the site.



Reference (regional) groundwater level elevations

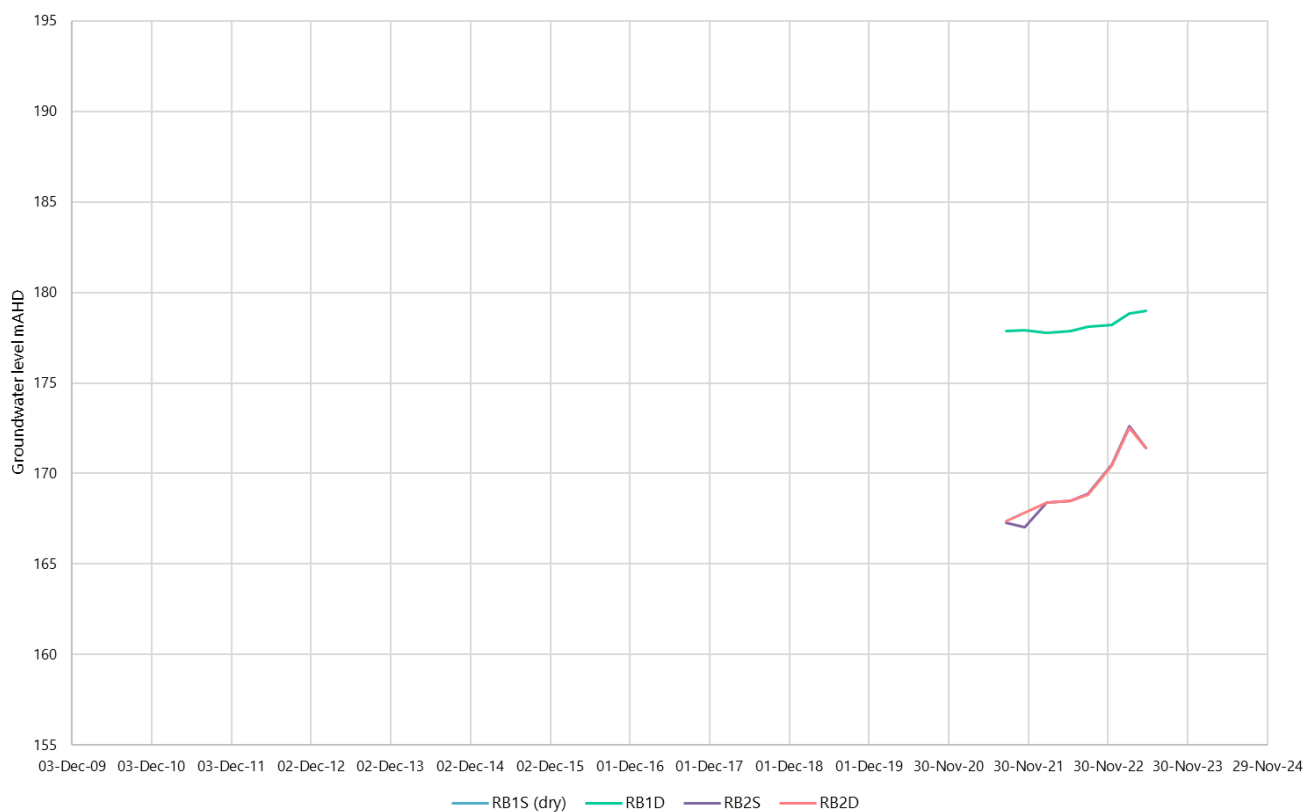


Figure 14 - Regional groundwater elevations

Tailings groundwater elevations

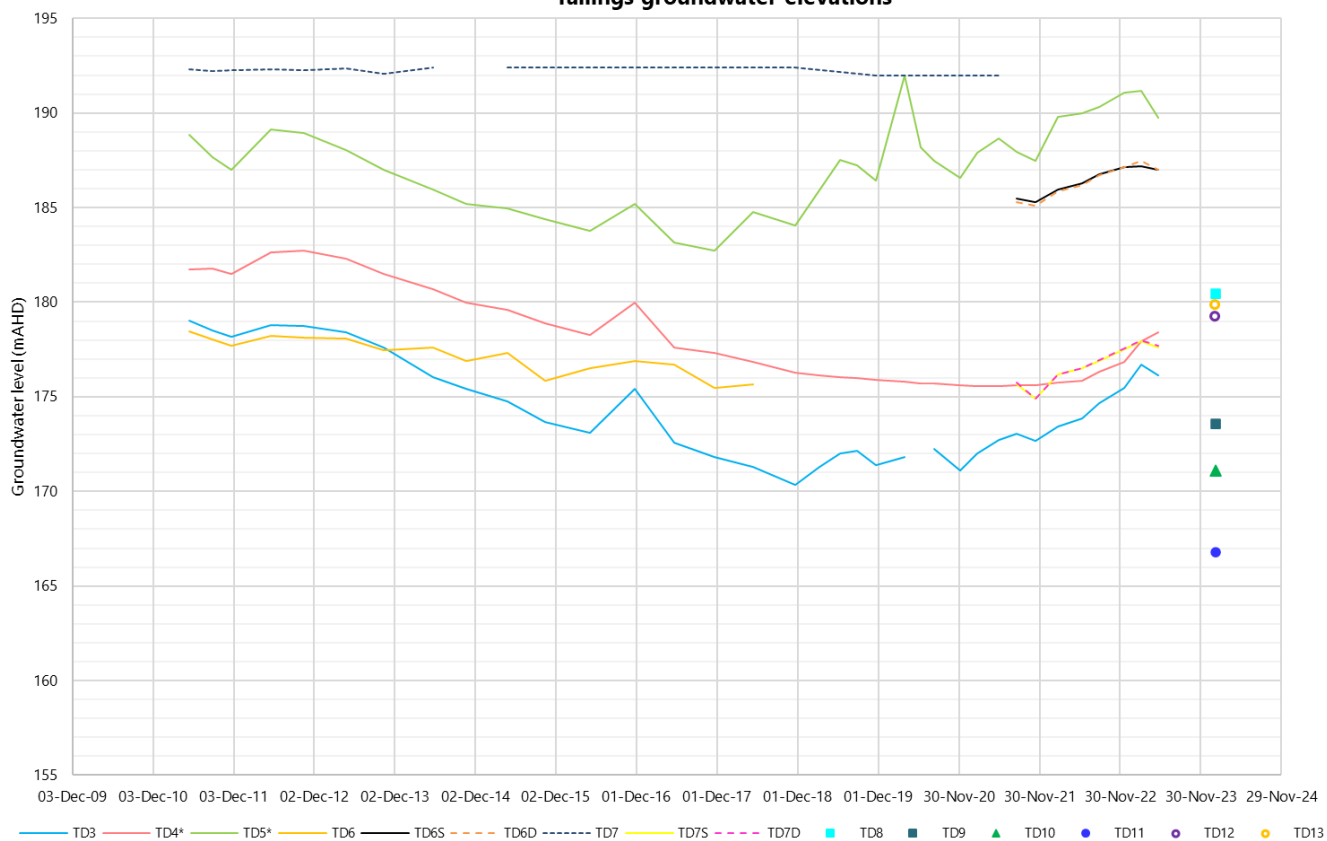


Figure 15 - Tailings area groundwater elevations

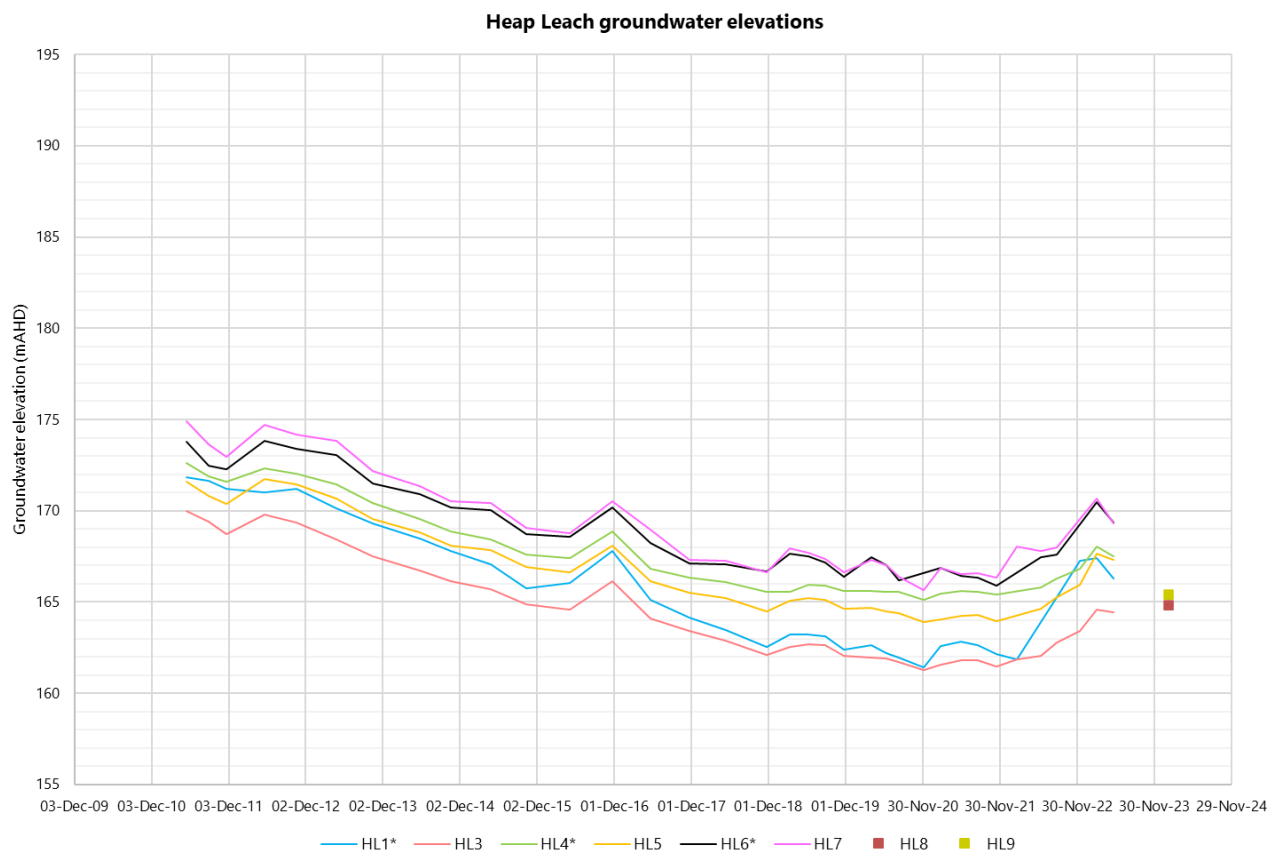


Figure 16 - Heap Leach area groundwater elevations

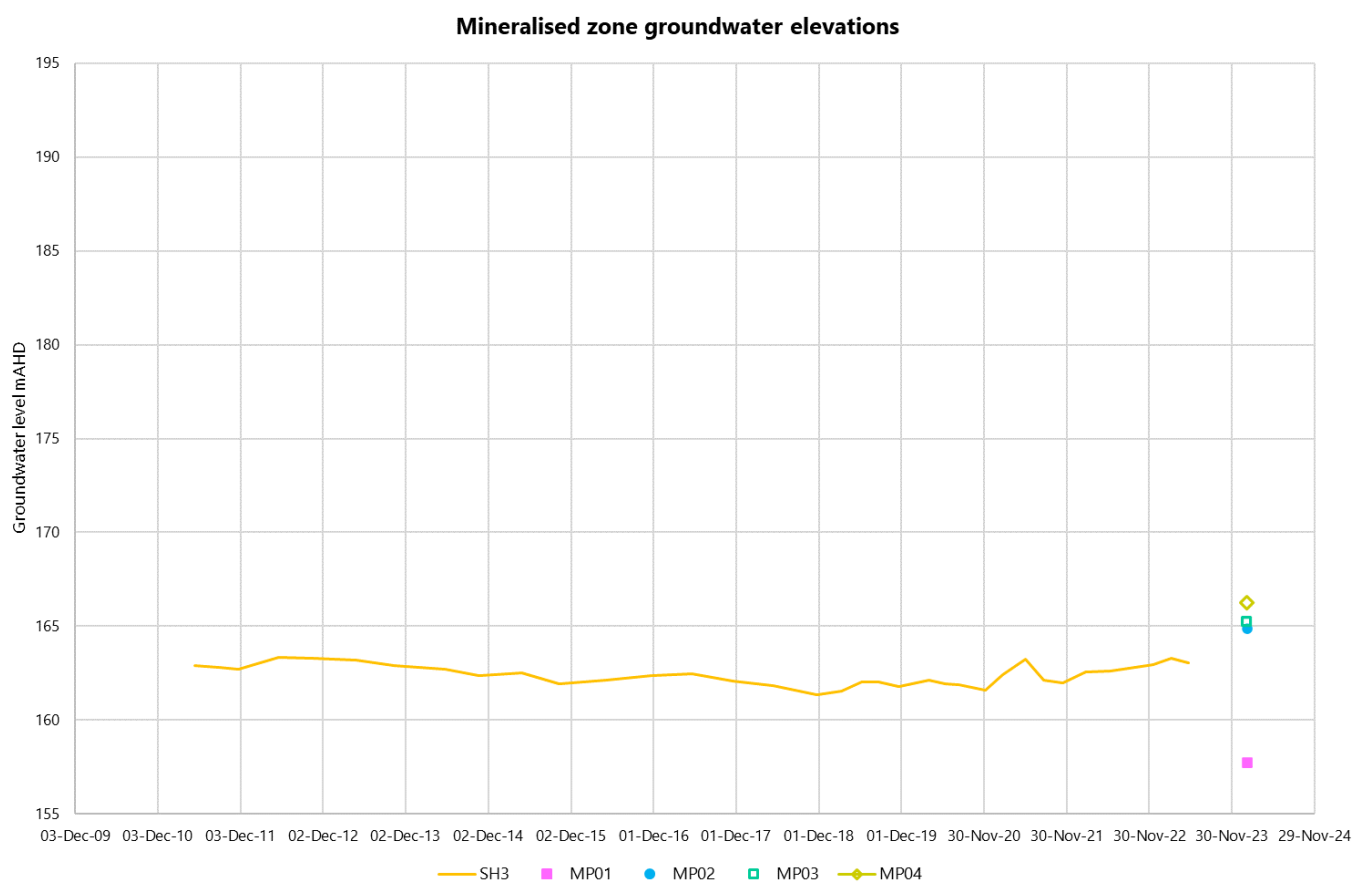


Figure 17 - Mineralised zone groundwater elevations

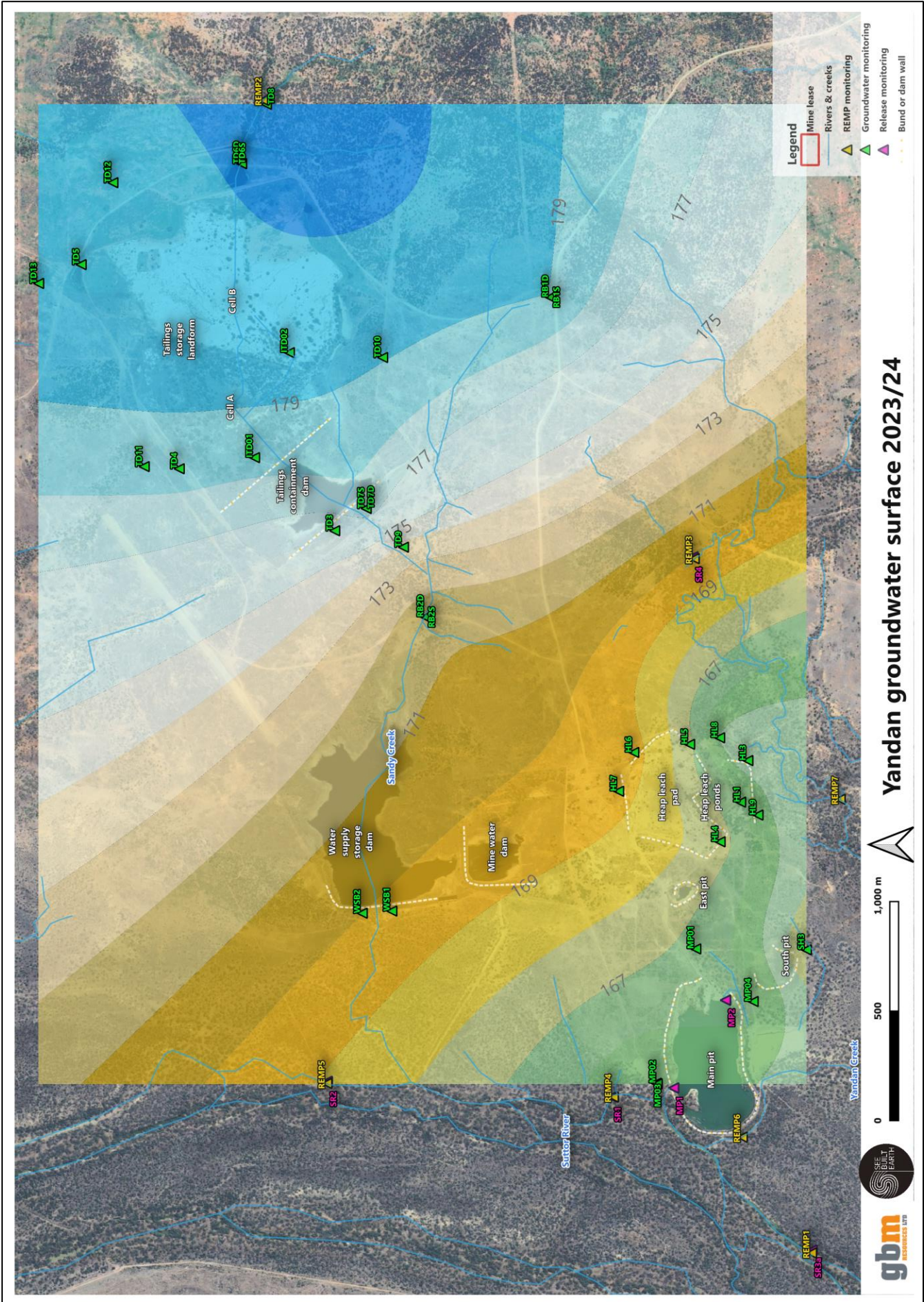


Figure 18 - Groundwater potentiometric surface of Yandan, including Main Pit



3.3.3 Populations by chemistry

Analysis of groundwater nature and populations via ternary (piper) plot is shown in Figure 19 and identifies:

- Main Pit groundwater (all bores – MP01-04, SH3) is a consistent population of sodium-chloride type water. The distribution of similar cations and anions ratios indicates that the main pit wells are subject to similar processes and environments. Given high chloride/elevated salinity, some sulphate and low carbonate – the Main Pit wells indicate groundwater in a hydrothermal, mineralised zone with extended residence time.
- Regional wells RB1D and RB2S wells are of mixed quality, separate from the other groundwater populations, with much lower chloride. This would likely indicate a higher link with rainfall than the other groundwater across the project and perhaps a local groundwater system. Notably, they are closer to HL6 and HL7: HL6 is a known failed well subject to rainfall interference (SBE 2022, 2023); HL7 is an unusual well with a localised signature (and possible interference from rain).
- TSF wells plot in three main populations (noting TD4 and TD5 are excluded as non-representative as per SBE 2022, 2023):
 - Background - TD8, TD6S/D as sodium chloride type.
 - Influenced by embankments – TD3S, TD7S/D as no dominant type (mixed).
 - Influenced by quartz veining and some mineralisation around the tailings as scattered population—TD9, TD12, and heading towards calcium chloride type.
- Heap leach wells plot as similar to and between tailings populations and support the shared lithology and residence time in Anakie Inlier metamorphics:
 - HL8, HL3 and HL9 plot as calcium chloride type, similar and near to TD12
 - HL6, HL7, and HL1 are the exceptions and at a distance:
 - HL1 and HL6 are already identified as not representative (SBE 2022, 2023). As noted above, HL7 is an unusual signature, with some similarities to TD5 and RB1D, and may suggest a link to rainwater.

3.4 Characterisation of groundwater domains

Combining landform catchments, geology, groundwater-surface, ternary populations, and likely residence time, four key domains emerge for Yandan, as summarised in Table 4.

Table 4 - Groundwater bores by domain, fall direction and landform location (* denotes new well)

Domains				
Mineralised zone <i>St Anns Formation</i> Yandan Creek and Suttor River	Heap Leach <i>Anakie Inlier</i> Yandan Creek	TSF <i>Anakie Inlier</i> Sandy Creek	Regional <i>Anakie Inlier</i> Sandy Creek	Type
<i>Extended residence time gw system</i>	<i>Extended residence time gw system</i>	<i>Extended residence time gw system</i>	<i>Local/short-term residence time gw system</i>	
East Hill Pit	HL7	TD8*	RB1D	Groundwater background
MP01* (p.background)	Heap Leach	TSF		
Main Pit	HL4	TD12*		Downgradient
MP02*/03*	HL5	TD13*		Downgradient
MP04*	HL3	TD9*		Downgradient
South Pit	HL8*	RB2D		Downgradient
SH3	HL9*	RB2S		Downgradient

Yandan groundwater ternary

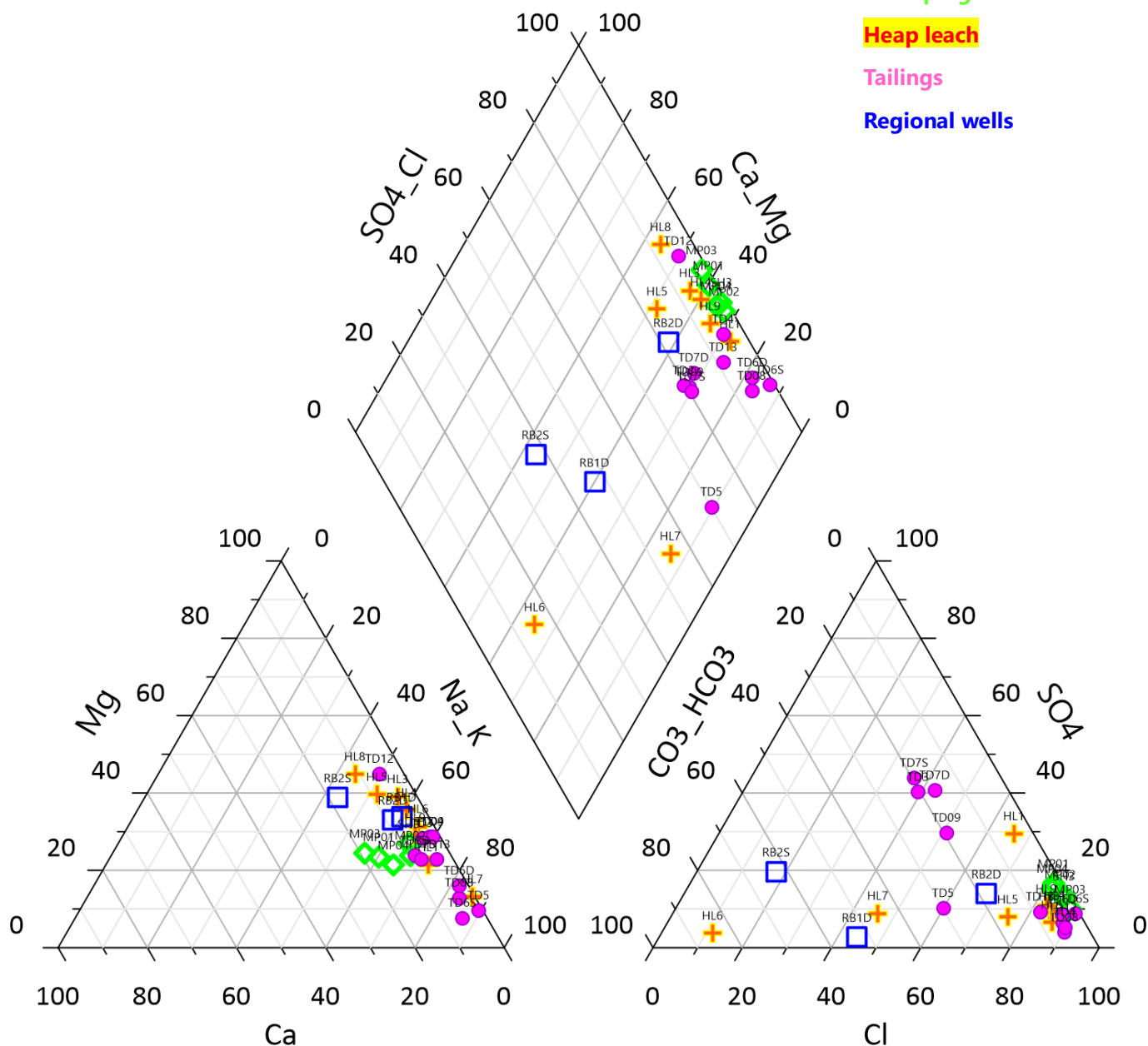


Figure 19 - Piper diagram of groundwater to describe water nature and populations



3.5 Quality profiles across domains

Water quality profiles from 2022/23 across all domains and key groundwater wells are shown in Figure 20 to Figure 23. Profiles show:

- A persistent neutral pH across all groundwater wells.
- There is a clear correlation between chloride and salinity across all wells. As chloride increases, so does salinity, showing that residence time is a key factor in groundwater salinity for the project.
- Regional groundwater (RB1) and Sandy Creek background (TD8) show natural enrichment across the Anakie Inlier in molybdenum, nickel, selenium and zinc before any landforms
- There is a clear domain change with changed chemistry between the mineralised domain and the domains within the Anakie Inlier. The mineralised domain is enriched in salinity, chloride, sulphate, calcium and sodium, as often characterises hydrothermal areas (Stumm and Morgan 2013), and it reduces dramatically with transition to the Heap Leach, TSF or Regional domains.
- In comparison, the Anakie Inlier domains are more enriched in carbonate, with lower sulphate across all Anakie Inlier bores.
- Salinity remains high across much of the Anakie Inlier, except wells previously considered more closely related to rainfall: HL7, TD9, RB2S/D, and RB1D.
- Potassium varies across the domains: elevated in the mineralised domain, TD8 and TD13. TD8 is logged as having high mica content (a mineral enriched in potassium), and TD13 is logged as having high buck quartz.
- Consistently elevated arsenic, molybdenum, nickel, zinc and selenium metals are present in the background, regional bores, and most domains.
 - The mineralised zone shows elevated zinc and nickel, with some arsenic, molybdenum, and selenium (noticeably, copper is not well developed).
 - Heap leach domain demonstrates essentially background metals, except HL8 and HL9 in zinc and nickel, though it is still within the background of TD8.
 - Tailings domain is elevated in nickel, zinc and molybdenum from the background to TD9, which returns to regional background levels.

By quality characterisation, the domain profiles reflect a conceptual model of:

- A relatively stable system, with no detectable acid drainage occurring.
- A natural metal background across both geological domains.
- High residence time groundwater – moving very slowly and having extended contact with old rocks, with limited rainfall influence.
- A hydrothermally influenced area around the pit areas with dense and brine-like groundwater.
- Higher carbonate availability in the Anakie Inlier (compared to the mineralised area).
- There is a similar groundwater environment between the TSF and HL, including occasional quartz and mineralisation as part of the province.
- General position of containment with downgradient wells below the background, except:
 - HL8 and HL9 with elevated zinc compared to the rest of the Heap Leach. This may or may not be representative as only one sampling event has been undertaken. Further monitoring and review are required after sampling over multiple wet and dry seasons.
 - SH3 downgradient of South Hill Pit is elevated compared to other mineralised area wells. The construction of this well is unknown. It may be screened in pit fill or alluvials. It will require ongoing review as the other Main Pit monitoring continues and provides further context. REMP 3 surface water includes a natural background in As, Ni and Se.

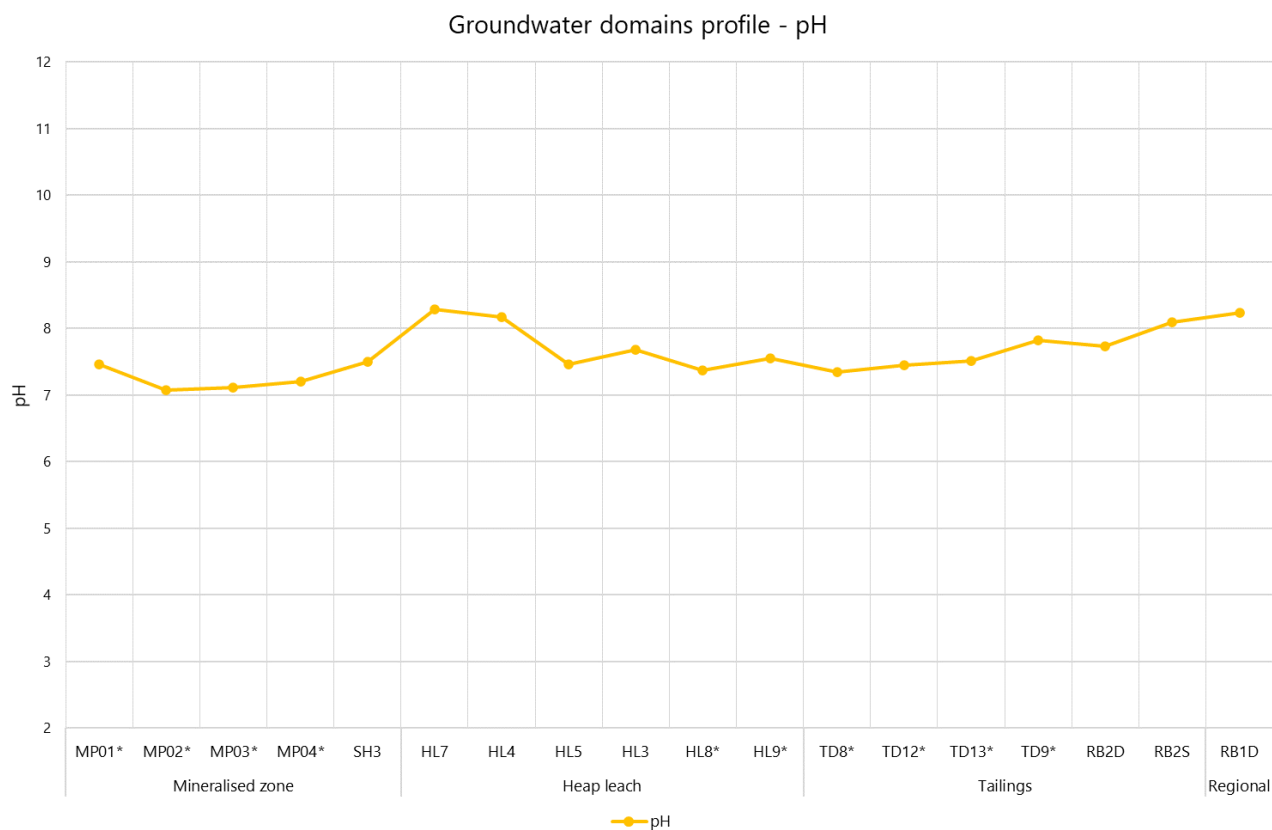


Figure 20 - pH profile by domain

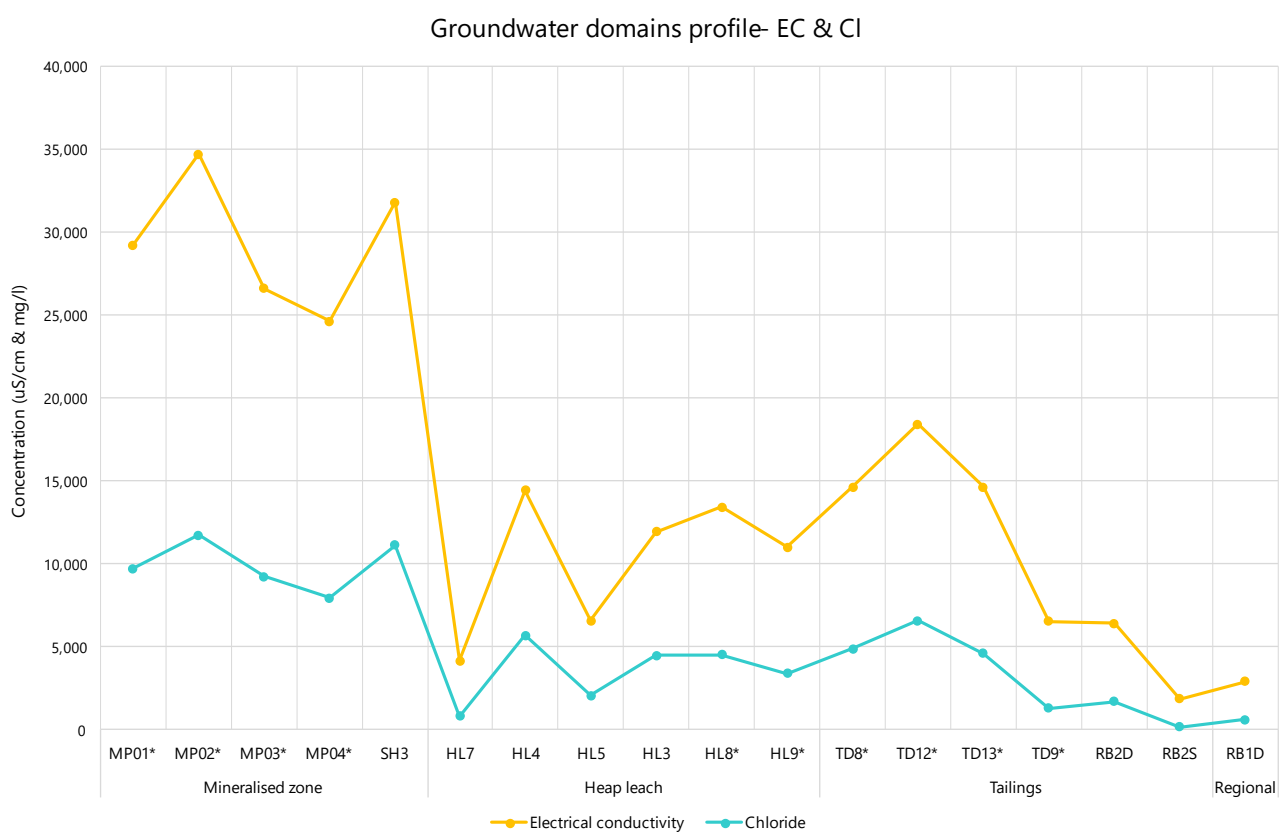
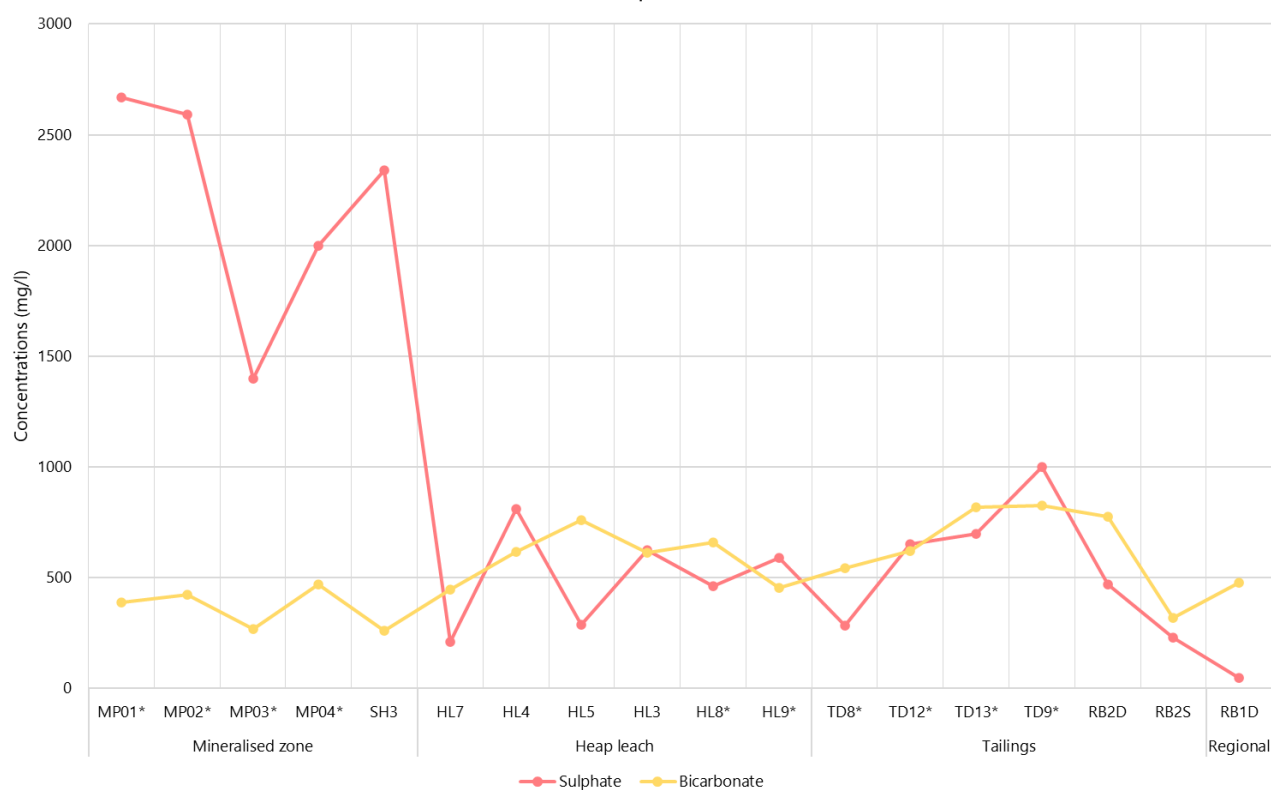


Figure 21 - Electrical conductivity and chloride profile by domain



Groundwater domains profile- SO₄ and HCO₃



Groundwater domains profile - Ca, Mg, Na, K

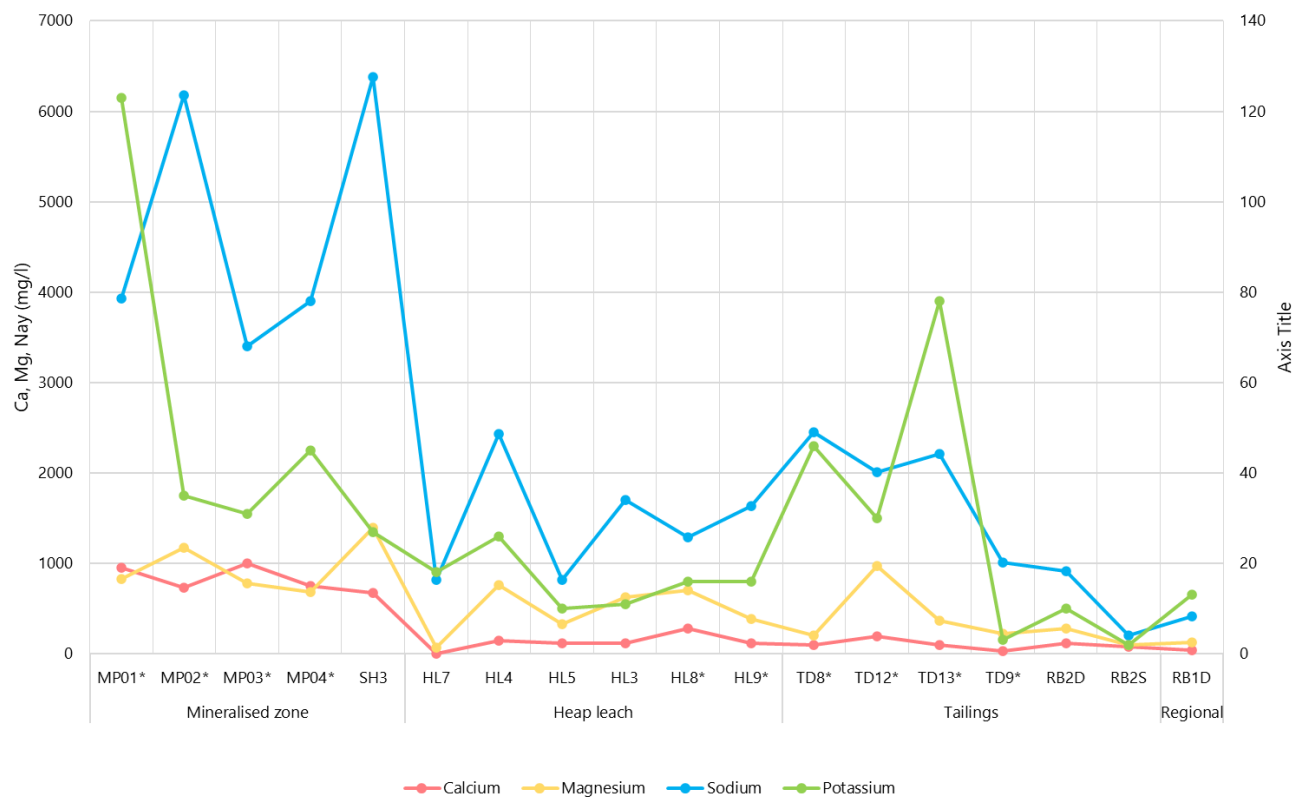
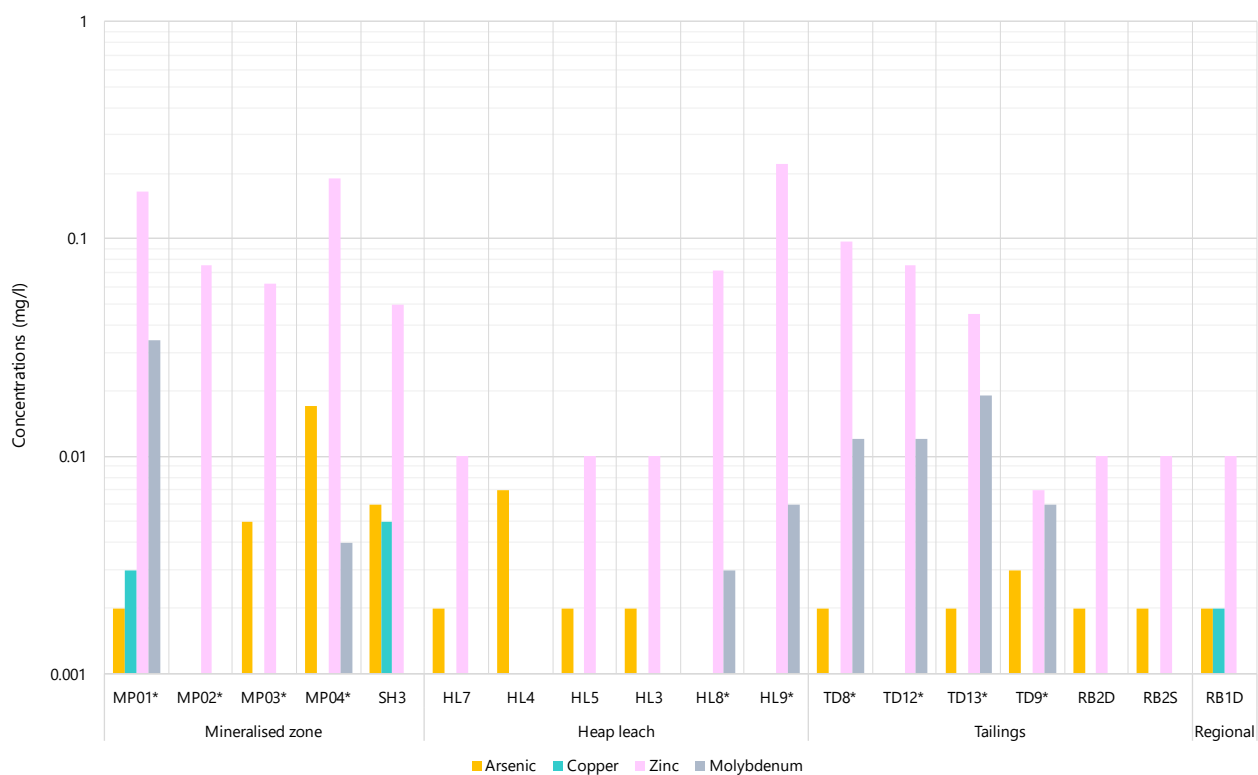


Figure 22 - Cation and anion profile by domain



Groundwater domains profile As, Cu, Zn, Mo



Groundwater domains profile- Cd, Cr, Pb, Ni, Se

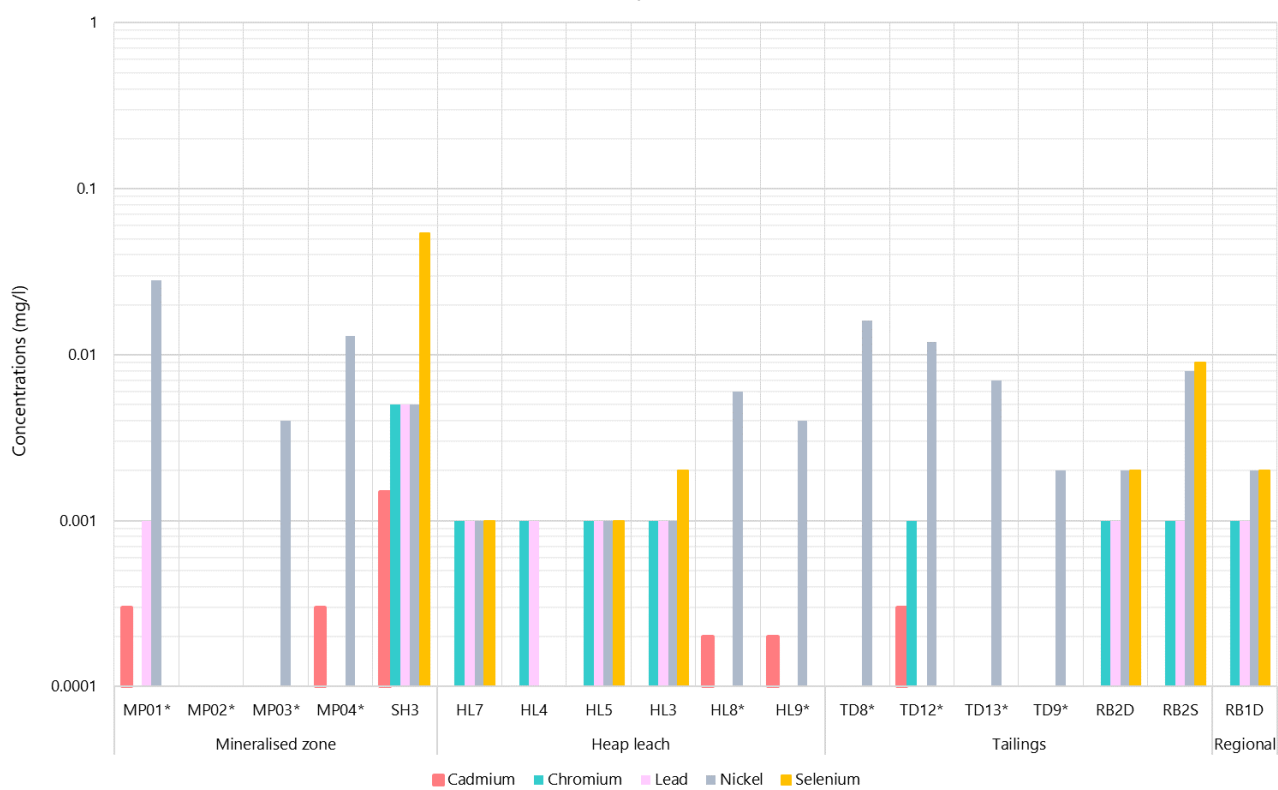


Figure 23 - Metals profile by domain



4 Domain conceptual models

4.1 Overview

Site and groundwater pressure elevation cross-sections across each domain are presented. Elevations are constructed via the 2021 LiDar survey elevation model and the constructed Yandan 2024 groundwater surface (see Figure 18).

The section trace across the field is shown on the map image above each section.

4.2 Sandy Creek and Tailings Storage domain

The Sandy Creek and Tailings Storage domain conceptual model shows groundwater at depth below the TSF passing through to the containment dam. The groundwater gradient then flattens from TD9 down to the water supply dam. Groundwater is close to the surface from below the dam to the Water Supply dam, and there is a strong likelihood of seep development or groundwater baseflow into the Water Supply dam below.

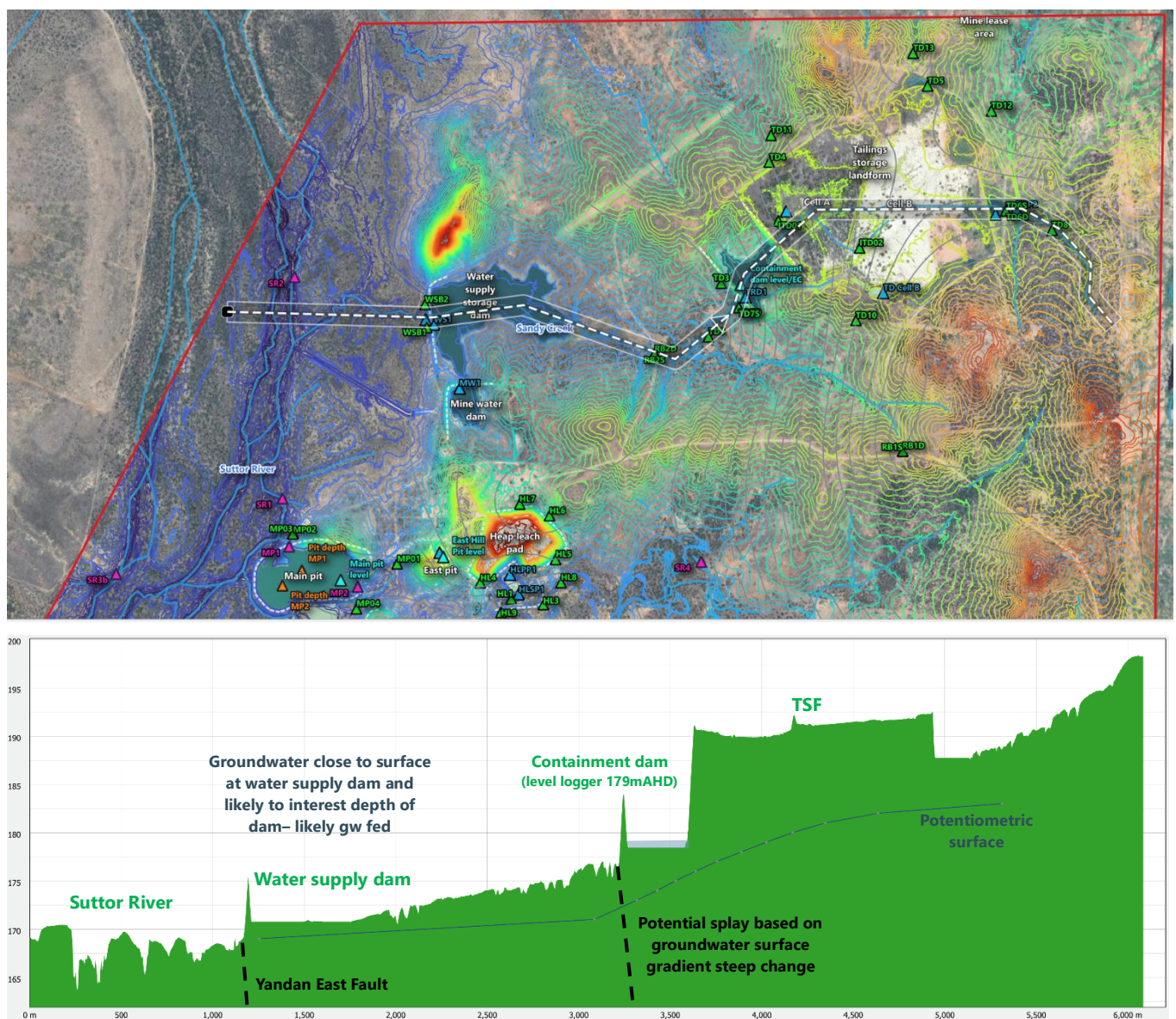


Figure 24 - Profile and groundwater surface with inferred geology - TSF domain



4.3 Heap Leach through Mineralised area domain

From the Heap Leach to the mineralised domain, the groundwater head falls gently west to the inferred Yandan East Fault and then appears to flatten towards a likely intersecting with the Main Pit. The Main Pit void and pit lake depth extend 40-60m from the elevation of the lake surface (and underneath the groundwater potentiometric surface), and through density flow, groundwater is likely to flow into the pit lake.

At East Hill Pit, pit lake water levels are currently higher than during the 2021 LiDar survey (shown by the green elevation), given rainfall and pumping of water from the HL Ponds to the EHP over the 2022/23 season. The initial groundwater surface is shown as intersecting through the EHP at the deepest point. The nature of the potential connection is yet to be defined, given the range of factors:

- There is no evidence of leakage from East Hill Pit (and associated acidic quality) in the quality of downgradient bore MP01.
- Initial level logger decline rates suggest levels are reducing at rates expected in evaporation with no detectable presence of groundwater inflow or outflow.
- The Yandan East Fault might easily offset the groundwater pressure head below the EHP base.
- With the longer-term levels of EHP lake at ~166mAHD (LiDAR), the East Pit may be a groundwater sink with minimal inflow.

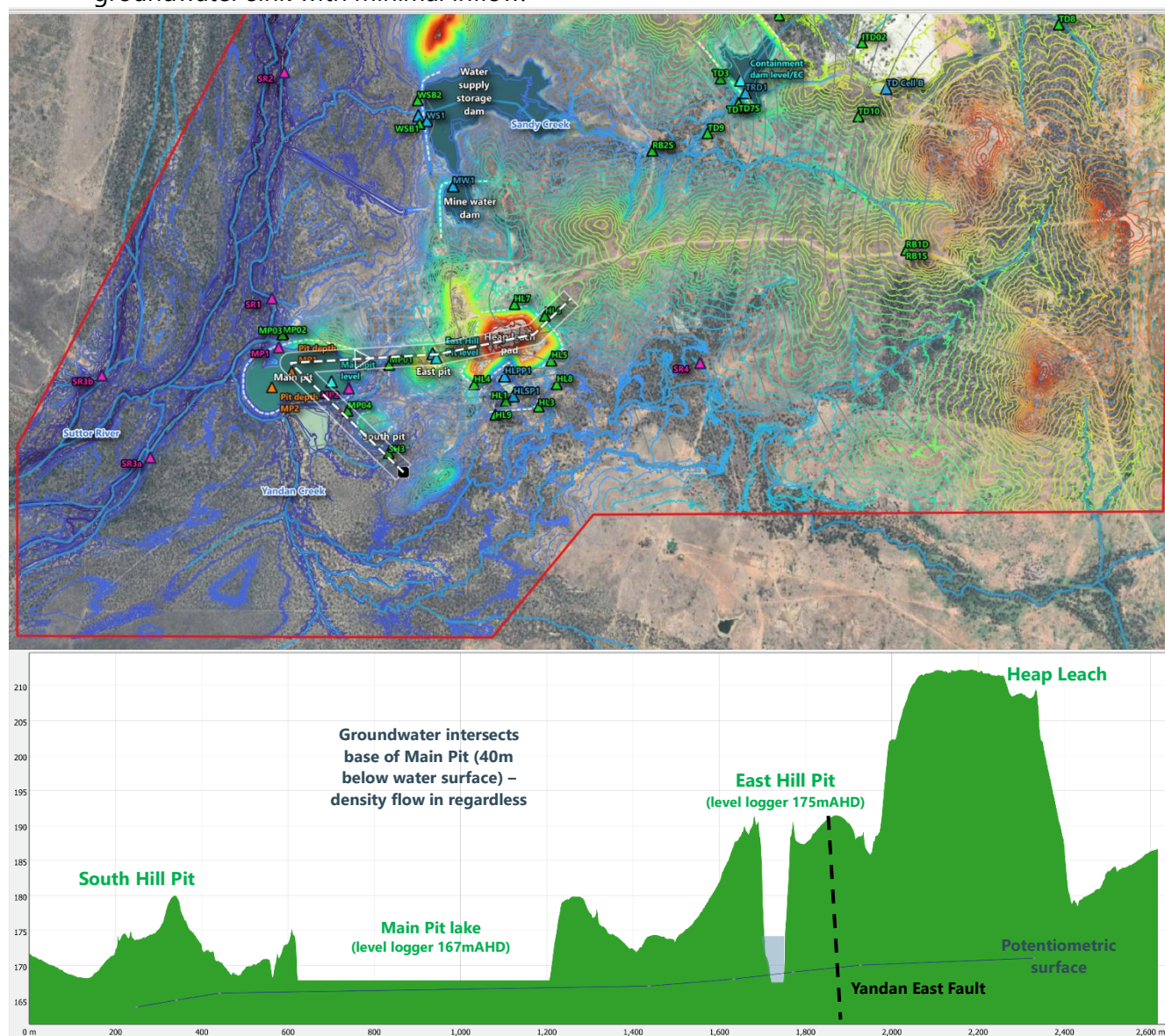


Figure 25 - Profile and groundwater-surface with inferred geology – Mineralised domain



4.4 Regional domain

The regional domain conceptual model shows groundwater well below the surface across the hill, though it does intersect the upper Yandan Creek along the drainage line (not shown). Groundwater follows a subdued version of the topography and appears to flatten again on the western side of the Yandan East Fault.

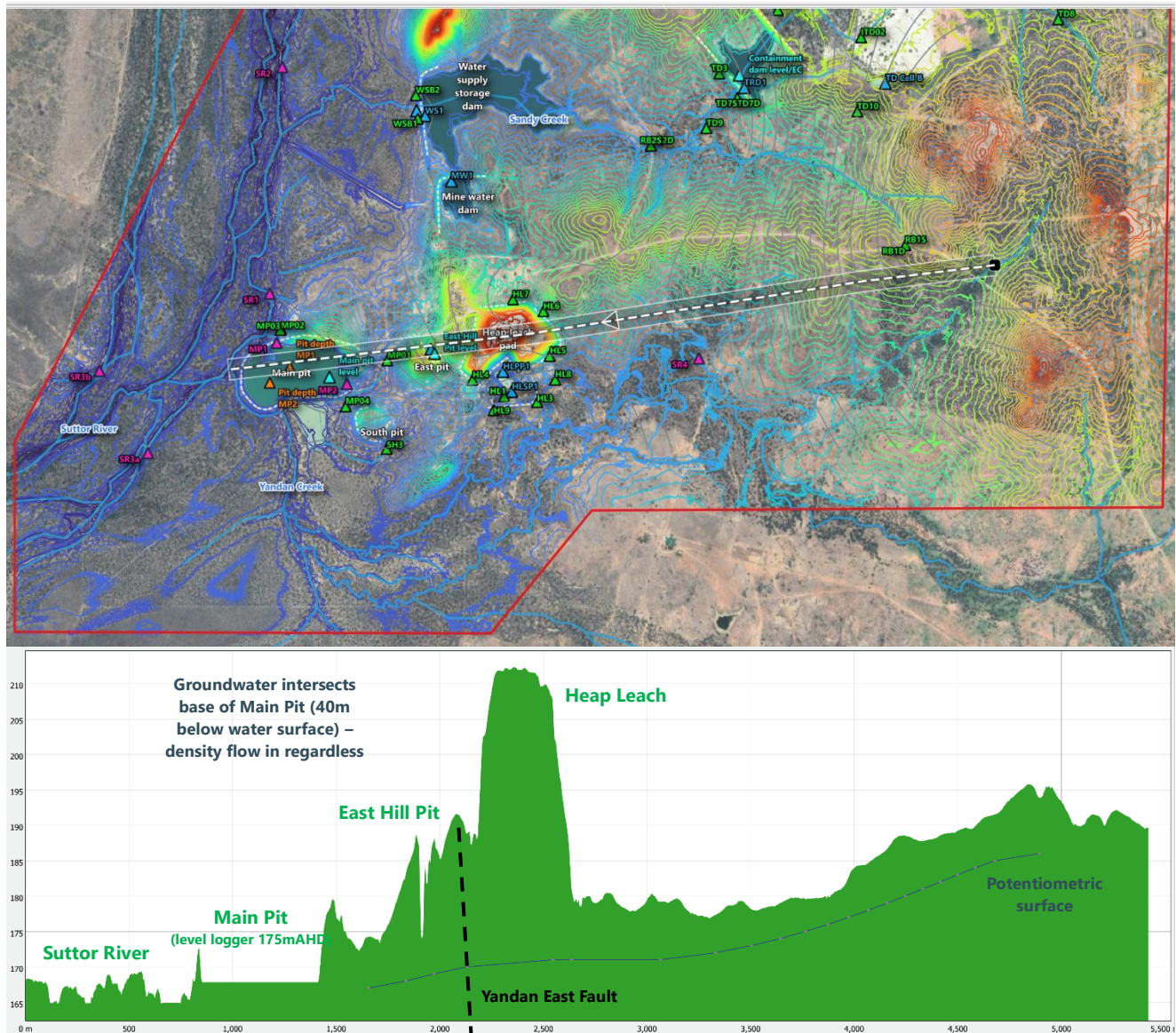


Figure 26 - Profile and groundwater surface with inferred geology – Regional through Yandan Creek domain



4.5 Heap Leach to Yandan Creek domain

The Heap Leach to Yandan Creek section shows the groundwater surface following the topography, moving downgradient from HL7.

The surface suggests the potential for a slight intersection of groundwater with the base of the heap leach processing ponds. The ponds are lined, with several monitoring wells downgradient to detect potential leakage. Notably, the ponds will be fully decommissioned at closure, and the topography will be re-established.

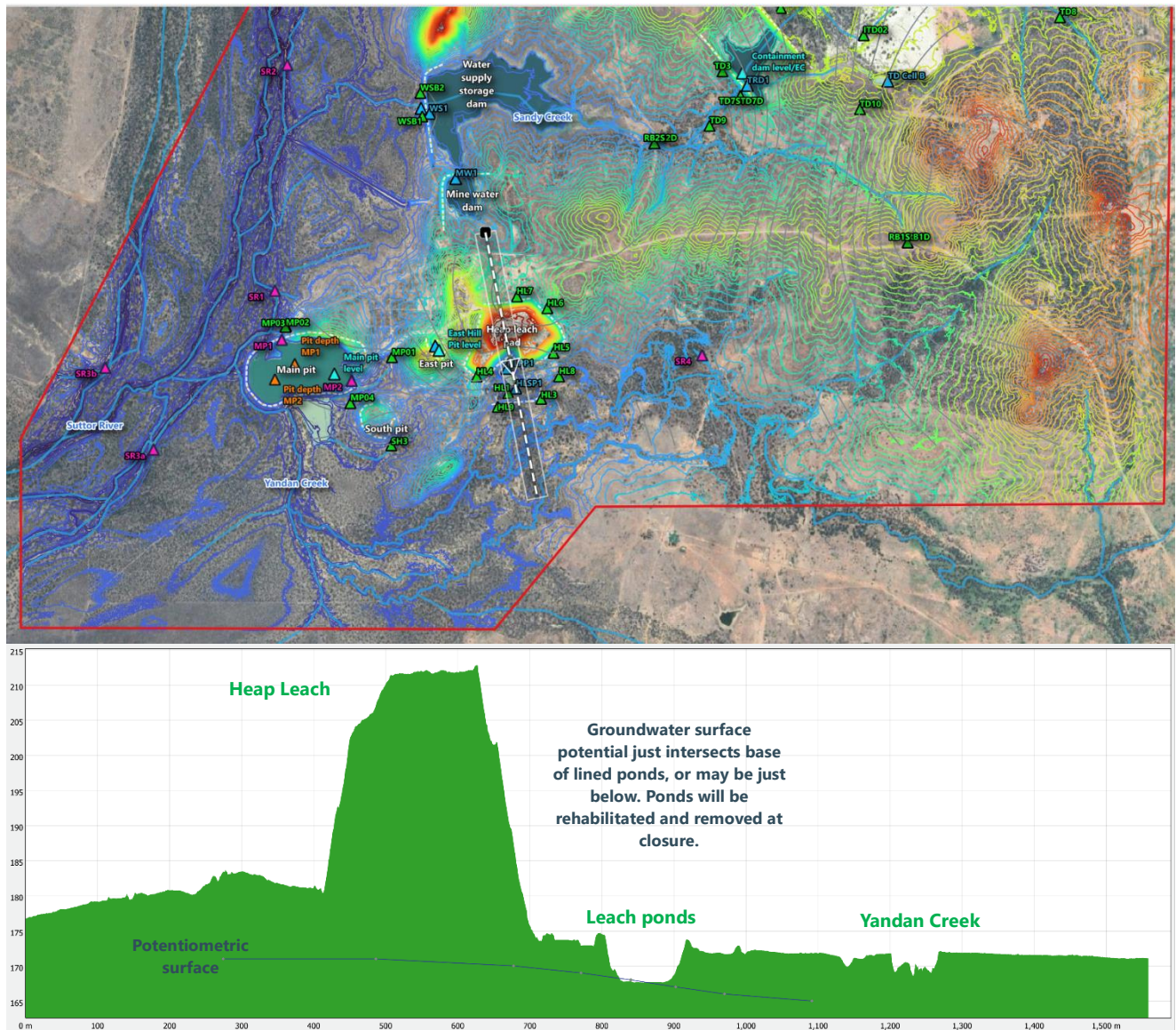


Figure 27 - Profile and groundwater surface with inferred geology - Heap Leach domain



5 Findings and recommendations

5.1 Technical confidence

Understanding and characterising the Yandan water system environment has matured significantly over the past two years and is now moving towards a measured definition. Key geometries and drivers are known and benchmarked across different seasons, groundwater is representative and mapped across all domains, and sufficient management tools, such as monitoring and benchmarking, exist to define and detect groundwater responses and inform closure outcomes.

5.2 Characterisation of domains

A bore construction program installing 14 new wells has confirmed that the Yandan site hosts poor groundwater development given the nature of tightly compacted and low porosity geology, with limited hydraulic conductivity and connectivity. The updated conceptual model has identified two domains:

- Mineralised zone around the Yandan deposits within the St Anns Formation, consisting of metasediments and volcanics. Groundwater in this area is dense with naturally elevated salinity and chloride through the similar hydrothermal processes that formed the Yandan gold deposits. There is also naturally elevated sulphate and some metals, particularly arsenic, molybdenum, nickel, selenium, and zinc.
- On the eastern side of the fault, the Anakie Inlier is characterised by metamorphosed rocks of phyllites and fine meta-sandstones. Background metals and salinity exist in the Anakie Inlier, particularly nickel, selenium and zinc.

Groundwater is responsive to rainfall across most of the site. The exception is the mineralised zone, where groundwater levels hold steady despite changing rainfall.

An updated and extended groundwater surface indicates that the groundwater pressure head generally falls from the east to the west. Together with topography, geology and groundwater chemistry populations, a series of four domains have been defined, with supporting critical monitoring bores:

- Sandy Creek and Tailings Storage domain – consisting of groundwater at depth in the hills and around the TSF, and likely emerging downgradient near the Water Storage Dam as seeps.
- Heap Leach and Yandan Creek domain – where groundwater is generally deep and follows the topography south towards Yandan Creek.
- Mineralised zone domain – consisting of highly saline, dense groundwater influenced by hydrothermal mineralisation processes and likely connected to the Main Pit.
- Regional domain – which demonstrates a natural background of salinity and some background of dissolved metals, particularly zinc.

5.3 Characterisation of quality

Groundwater quality and levels are relatively stable across the site: neutral to slightly alkaline pH prevails, and metals present are below background concentrations across each domain. There are some elevated metals at HL8, HL9 and SH3; however, further groundwater sampling of the new wells is required to assess variability before forming a view for closure.



5.4 Conceptual model water system interactions and processes

The process of conceptual model construction has also demonstrated the following:

- The connection of groundwater with the Main Pit through observation of relative water level decline rates and intersection of groundwater surfaces. The main pit is likely a groundwater sink (historical studies found no connection between it and the Suttor River).
- Likelihood of the Water Supply Dam being groundwater-fed.
- Potential connection of East Hill pit with groundwater: Currently, interpolated levels intersect with the pit void; however, countering evidence suggests that this is not the case, particularly since MP01 does not show similar quality to the pit.
- The extended wet seasons over 2021-2023 improved water quality at both East Hill Pit and the Tailings Storage containment dam, providing evidence of tailings drainage stability and insight into how the storages will interact with rainfall and flooding events over time at closure.

5.5 Next steps

The recommended way forward is:

- Continue monitoring of new groundwater wells (with existing) and storage water level loggers to ensure quality characterisation is representative and to see if there are any seasonal trends.
- Review queries relating to:
 - The quality profile and processes for HL8, HL9 and SH3
 - Relationship of East Hill Pit with groundwater
 - Nature and magnitude of groundwater flow into Main Pit.
 - Nature and connection of groundwater within MP01.
- Look to determine closure criteria as a milestone in 2-3 years to allow sufficient monitoring of new wells and level loggers to provide further insight into the nature of how water systems move and interact with landforms across the domains of Yandan.



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Appendix A – RFI to work package map

	Information Request Matter	Information Request	Response
6	Preliminary flood modelling has identified that some mining domains, including the pit and heap leach pad, will be inundated or in contact with floodwaters under 1% AEP and PMF events. However, information detailing how flood flow may interact with the final landform has not been included. Understanding flood depth and velocity across the final landform is required, as well as how this may influence achieving and maintaining a safe, stable, and sustainable PMLU.	Demonstrate how all final landforms will achieve and maintain a stable condition under 1% AEP and PMF events. This includes investigating the effect that flood depth and velocity may have an impact on the final landform.	Flood characterisation report
8	Section 3.1.6 of the PRC Plan provides information on groundwater levels and salinity. However, no detail has been provided on the interactions of the pit, tailings dam, and heap leach pad with groundwater. Criteria that demonstrate these structures will be non-polluting have also not been included. Figures 27 and 28 do not provide context on orientation of the pit and river nor depths of strata and pit depth. The Suttor River alluvium mentioned in section 3.1.6 of the PRC Plan is also not represented. Increasing trends in arsenic have been identified in groundwater in the PRC plan and interactions of tailings and heap leach seepage with groundwater may be occurring. The prediction of water quality impacts from mining activities is necessary to determine appropriate measures for the containment and management of contaminants and the potential impacts on environmental values should they be released.	Provide an assessment of the hydrogeology of the site including all landforms and connected strata in accordance with 3.6.1 of the PRCP Guideline. An assessment of the interactions of the tailings and heap leach pad with groundwater must also be included in the PRC Plan. Provide detailed information regarding water quality and how it varies between depths and bores. Provide milestone criteria for groundwater quality to demonstrate all final landforms will be non-polluting.	Original information has been provided in original report.
9	The PRC Plan and EA require that the pit lake level is to remain above 160mAHD. The Plan also considers that the pit will act as a groundwater sink. Figure 32 in the SBE 2022 report indicates that the groundwater levels in the bore SH3 fluctuate above 160mAHD.	Provide a hydrogeological assessment that encompasses all landforms on the project area. Include supporting evidence that demonstrates how the pit will act as a sink.	Updated Conceptual Model Report



Figure 26 of the PRC Plan includes an indicative map of the potentiometric surface of the groundwater however the potentiometric surface does not extend to the pit area.

12	The final landform design section of the rehabilitation planning part provides detail surrounding each of the residual voids that will remain as NUMAs on the project. This section of the planning part identifies further investigations that are yet to be completed and are required to inform management area milestone criteria.	Provide further information to demonstrate that both the Main Pit and East Hill Pit will achieve a safe and stable condition as per section 3.6.3 of the PRCP guideline including, but not limited to, a geotechnical assessment and proposed final slope angles.	Main Pit and Suttor River Characterisation Report
	Main Pit ▪ A geotechnical assessment has not yet conducted on void batter angles, therefore residual void angle requirements are unknown. ▪ The rehabilitation planning part identifies that additional monitoring data (3-5 years) required to improve water balance to then determine a long term bund use. ▪ The expectation is that bunding will be retained within the final landform subject to appropriate assessments (i.e. geotechnical investigations). However, such assessments are incomplete at time of submission.	Include all required milestone criteria in the PRCP Schedule to ensure the management of the NUMA's to safe, stable, non-polluting landforms.	
	East Hill Pit The rehabilitation planning part identifies that the East Hill Pit has a potential to be flooded under a PMF scenario. Given that water quality analysis from within the pit has determined it is of poor quality, this presents a significant environmental contamination risk. The rehabilitation planning part mentions that a small, permanent landform bund will be constructed around the north of the pit, however a design has not been considered in the rehabilitation planning part or supporting technical studies. Nor has this action been included in the PRC Schedule.		



14	Various potential risk factors have not been considered in the risk assessment. The following example do not constitute an exhaustive list, but have been provided for reference: • A consideration of how various events may impact the completion time of rehabilitation stages (including potential compliance action as a consequence). • A consideration of risks associated with potential issues arising yet remaining unidentified between monitoring events, with specific links to the monitoring program to justify the selection of specific monitoring frequencies. • A consideration of climatic influence specific to the pit, for example, the impact that drought conditions may have on maintaining the water cover within the Main pit.	Please update the risk assessment to include a broader consideration of potential risk factors and their associated mitigation measures to ensure the safe, stable and sustainable PMLU or managed NUMA is achieved. Please refer to section 3.7 of the PRCP guideline for further information.	Main Pit and Suttor River Characterisation Report
23	The PRC Plan indicates that the Main Pit is expected to be inundated with flood waters and pass floodwater in to and out of the pit via spillways at certain river heights/flood levels to the Suttor River.	Discuss how the objectives for the Main Pit achieve best practice management of the area and minimises risks to the environment from the passage of flood waters in to and out of the pit. Consideration should be given to the stability of the spillways to achieve the purpose of passing floodwater in to and out of the pit. Completion criteria for water quality must reflect releases from the main pit not causing environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself.	Main Pit and Suttor River Characterisation Report
24	Figures 9 and 10 of the SBE 2022 Report as part of the PRC Plan indicate spikes in Electrical Conductivity (EC) during flow events with an explanation provided as "...with the exception of short-term higher salinity experienced during the major regional flooding event in 2011. Comparison of	Provide commentary on the timing of releases from main pit and how they correlate or not with the peaks in EC in the Suttor River	Addressed in 2022 report Updated Conceptual Model Report



upstream & downstream salinity would suggest an additional salt load entered the river during this significant event, similar to occurrences across the Queensland region for this event.”

27	The PRC Plan states that “minimal mixing is required with site or river water to meet receiving environment requirements.” However, no detail is included on what dilution is required to meet the receiving environment requirements or at what flow volumes the minimal mixing will occur.	Provide detail on the minimum mixing requirement to ensure no environment harm will be caused from releases of pit water to the receiving environment	Main Pit and Suttor River Characterisation Report
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Appendix B – Bore logs

Hole_I D	mFrom	mTo	Lithology	Comments
MP01	0	2	Gravel, alluvium, clay	
	2	4	Brown, fine-grained sandstone and silcrete	Minor siliceous material (silcrete?).
	4	6	Tan clay	Minor (rare) calcite crystals.
	6	7	Tan clay, fine-grained sandstone	Minor siliceous material (silcrete?/chert?).
	7	9	Tan-green fine-grained sandstone	Minor clay.
	9	12	Brown sandstone, fine-med- grained	Variable grain size. Minor clay.
	12	13	Mix of med-gr sandstone and fine siltstone	Minor clay.
	13	16	Khaki clay and med-grained sandstone	
	16	18	Grey-green, fine-med grained sandstone	
			Green-cream saprolite and fine-gr green sandstone	
	18	19		
	19	25	Med-grained, quartz-rich sandstone	Poorly-sorted sandstone. Minor calcite veins, plus possible sericite alteration. A little damp near surface, dry to EOH.
Most of these tan/brown/green sandstones etc likely to be variably calcareous.				
MP02	0	1	Soil, alluvium	
	1	7	Green siltstone, very fine sandstone	Probably calcareous. Minor chert and clay.
	7	8	Friable green siltstone	
	8	11	Green very fine-grained sandstone/siltstone	
Damp at 10m				
Calcareous sequence. Limestone/marl and minor chert outcrop nearby.				
MP03	0	1	Soil, gravel	
	1	7	Green siltstone and very fine-gr green sandstone	Minor clay
	7	9	Fine-grained green sandstone and tan limestone	
	9	10	Green siltstone	
	10	11	Green siltstone and tan limestone	
	11	13	Brown siltstone and limestone?	
	13	15	Brown siltstone/limestone, green siltstone	
	15	16	Grey-green siltstone	
	16	17	Dark grey, siliceous, very fine sandstone or chert	
	17	19	Dark grey, siliceous, very fine sandstone	Minor, very fine pyrite/marcasite.
	19	24	Green to grey, very fine-gr sandstone/siltstone	Rare small carbonate veins.
	24	32	Grey to pale-green fine sandstone/siltstone	Rare, very fine pyrite/marcasite.
	32	33	Grey siltstone/fine sandstone, clay	Minor cream/grey clay.
				Minor coarse calcite crystals and rare fine pyrite/marcasite.
	33	41	Grey, very fine sandstone/siltstone	A little damp 22-28m, water at 38m (lifted about 20 litres in 16 seconds in airlift, but not sustained).
Variably calcareous sequence—limestone/marl and minor chert outcrop nearby.				
MP04	0	2	Soil, alluvium	
	2	3	Medium sandstone plus colluvium	
	3	5	Red, med-gr sandstone, plus fine-gr siltstone	
	5	8	Red-grey, med-gr sandstone, plus siltstone	Poorly-sorted sandstone.
	8	9	As above, plus grey clay	
	9	10	Fine-gr sandstone/siltstone, plus green clay	
	10	11	Black, siliceous chert/siltstone and clay crusts	Water here?
	11	13	Grey, siliceous siltstone/chert	
	13	14	Fine-grained sandstone	
Minor water at 10-11m				



Hole_ID	from	mTo	Lithology	Comments
HL8	0	2	Soil, clay, alluvium	
	2	4	White to tan saprolite/clay	
	4	6	Fine sandstone/siltstone and clay	Oxidised
	6	12	Fine-grained sandstone	Moderately oxidised
	12	20	Brown Phyllite	Partly oxidised. Weakly foliated with rare, very fine muscovite crystals.
<i>A little damp from 18m, possibly from higher in the hole?</i>				
Basement sequence throughout (Anakie Metamorphics)				
HL9	0	2	Soil, clay, alluvium	
	2	4	Gravel, clay, minor sandstone	Coarse quartz fragments in brown clay. Weathered qtz vn? Or qtz lag surface?
	4	7	Phyllite, clay, siltstone	Very weathered, lot of orange clay.
	7	9	Very fine-gr khaki sandstone, green siltstone	
	9	10	Khaki phyllite	Weathered, minor coarse-gr quartz-vein fragments
	10	11	Grey-green clay, minor siltstone	
	11	12	Mix of clay and grey-green fine-gr sandstone	
	12	14	Fine-gr sandstone and 40% buck quartz vein	
	14	15	Very fine-gr sandstone to siltstone	Weakly foliated, very small muscovite crystals.
	15	17	As mentioned above with 5% buck quartz vein fragments	
	17	20	Green-grey phyllite	
<i>A little damp from 17m, a bit of water after, sitting-possibly from higher in the hole</i>				
Basement sequence throughout (Anakie Metamorphics)				
Steeply-dipping, deformed quartz veins cutting phyllite here are part of basement.				



Hole_ID	mFrom	mTo	Lithology	Comments
TD8	0	1	Quartz gravel, soil	A lot of quartz lag or insitu, weathered buck quartz vein.
	1	3	Clay, siltstone	
	3	4	Saprolite	White clay.
	4	9	Pink-brown very fine-gr sandstone/siltstone	Micaceous sandstone, minor buck quartz vein fragments.
	9	10	Deformed buck quartz vein, plus phyllite	
	10	13	Fine-gr sandstone and phyllite	
	13	16	Tan clay and phyllite/siltstone	
	16	20	Fine-grained khaki sandstone, clay	
Dry to EOH				
Basement sequence throughout (Anakie Metamorphics)				
TD9	0	1	Soil, gravel, alluvium	Mostly quartz gravel.
	1	3	Quartz vein, phyllite	Deformed buck quartz veins.
	3	4	Quartz vein, minor phyllite	Minor pyrite/marcasite in quartz.
	4	7	Grey-green phyllite, lesser quartz vein fragments	
	7	8	Quartz vein, plus silicified/altered phyllite	Deformed buck quartz vein.
	8	11	Green-brown phyllite	Foliated.
	11	12	As mentioned above plus lesser quartz vein fragments	
	12	13	Green-brown phyllite	
Moisture at 10-11m				
Basement sequence throughout (Anakie Metamorphics)				
TD10	0	1	Soil, alluvium	
	1	4	Grey-green mudstone	
	4	8	Pink-brown fine-grained sandstone	
	8	13	Green-grey phyllite	Foliated.
	13	20	Very fine-gr green-grey-brown sandstone	Plus minor mudstone/phyllite.
Dry to EOH				
Basement sequence throughout (Anakie Metamorphics)				
TD11	0	1	Fine-grained sandstone	Very siliceous. Slightly weathered.
	1	8	Grey-green quartz-rich sandstone/quartzite	Fresh.
	8	11	As above plus siltstone	
	11	14	Grey-green phyllite/mudstone	Foliated.
	14	18	Siltstone	Weakly foliated.
	18	20	Fine-grained sandstone	
Dry to EOH				
Basement sequence throughout (Anakie Metamorphics)				
Fresh rock throughout.				

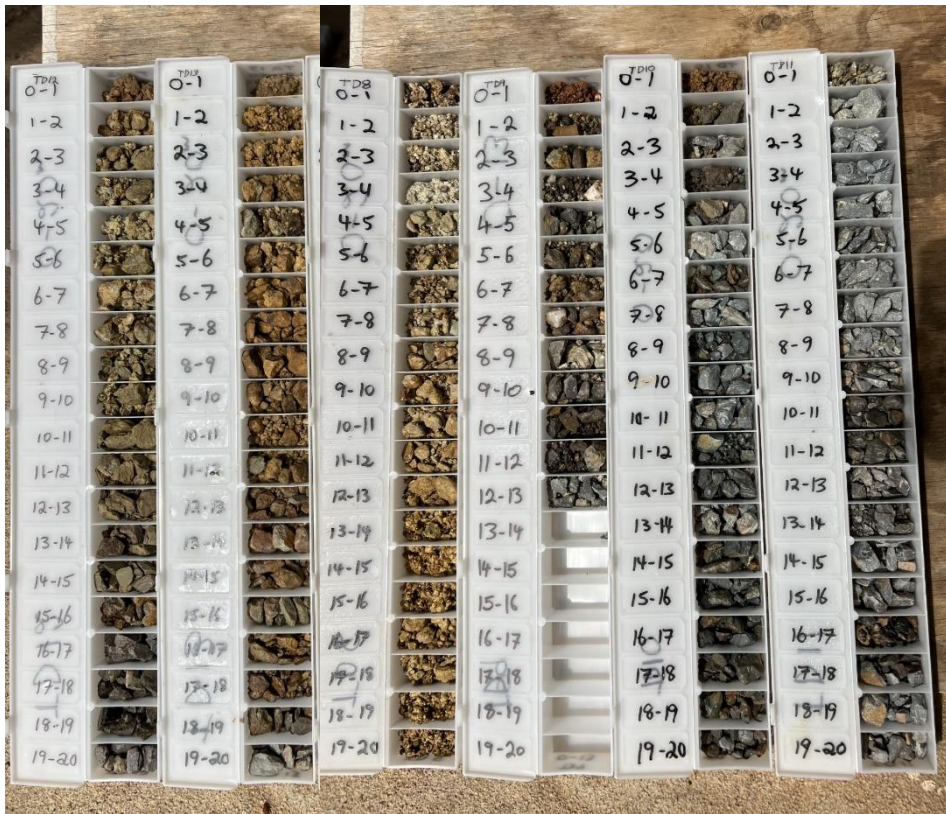


Hole_ID	mFrom	mTo	Lithology	Comments
TD12	0	1	Soil, gravel, clay	
	1	4	Fine-grained sandstone	Quartz-rich sandstone.
	4	5	Saprolite/clay and sandstone	
	5	12	Fine-grained sandstone	Micaceous, weakly foliated.
	12	15	Khaki to green mudstone/phyllite	Well foliated.
	15	20	Fine-gr sandstone and mudstone	Foliated. Minor buck quartz veins.
			Dry to EOH	
			Basement sequence throughout (Anakie Metamorphics)	
TD13	0	1	Soil and tan clay	
	1	3	Tan clay and siltstone	
	3	10	Fine- to medium-grained, khaki sandstone	
	10	11	As above plus clay	Water?
	11	12	Fine-gr sandstone plus quartz vein	
	12	19	Medium-grained, green-grey sandstone	Quartz-rich sandstone.
	19	20	Phyllite	Foliated
			Damp 10-11m	
			Basement sequence throughout (Anakie Metamorphics)	
ITD01	0	9	Fine tailings	
	9	10.5	Phyllite	Foliated green phyllite with very-fine muscovite crystals.
			Natural surface intersected ca 9m. Damp at ca 9m.	
			Natural surface is basement Anakie Metamorphics	
ITD02	0	5	Fine tailings	
	5	6	Fine tailings and Quartz gravel	
	6	7	Quartz gravel	Quartz lag or weathered buck quartz vein and adj alteration in basement.
			Natural surface intersected ca 5.5m. Gravel made up of quartz lag	
			Natural surface is buck quartz vein material from basement Anakie Metamorphics.	



Appendix C – Bore chip photos

Tailings wells



Main pit





Heap Leach





Appendix D – Driller logs

Water bore drilling log

Authorisation details Registered number <u>MPO1</u> Development permit number _____ Works reference number _____		Queensland Government 2006763	
SECTION A—LOCATION DETAILS Name of landholder <u>STRAITS GOLD PTY LTD.</u> Phone No. <u>0402109833</u> Postal address <u>22 BUNOWANIS ST BALMORAL QLD</u> Postcode <u>4171</u> Real property address <u>L1, M16 1096 MACAMUNDA RD Mt COOLON</u> Postcode _____ Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____ Easting <u>497425</u> Northing <u>7645076</u> Zone _____		SECTION B—BORE COMPLETION DETAILS Date commenced <u>18/01/2024</u> Date completed <u>19/01/2024</u> SECTION C—DRILLING METHOD ☐ Rotary mud ☐ Cable tool ☐ Auger ☒ Rotary air ☐ Other _____	
SECTION D—HOLE SIZE Diameter (mm) <u>190</u> <u>140</u> Location (metres) From <u>0</u> To <u>4.6</u> <u>25</u>		SECTION I—BORE PURPOSE ☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial Other (please specify) <u>RECHARGING BORE</u>	
SECTION E—CASING DETAILS Type (PVC, steel etc) <u>PVC</u> Size O.D. (mm) <u>60.5</u> Wall thickness (mm) <u>2.8</u> Location (metres) From <u>0</u> To <u>25</u>		SECTION J—PARTICULARS OF STRATA From (metres) To (metres) Strata description (use more than one line if required) Water bed (thus*) <u>0</u> <u>2</u> <u>GRAVEL - ALLUVIUM - CLAY</u> <u>2</u> <u>4</u> <u>FINE SAND STONE - SILTSTONE</u> <u>4</u> <u>6</u> <u>CLAY</u> <u>6</u> <u>9</u> <u>FINE SAND STONE - SILTSTONE</u> <u>9</u> <u>13</u> <u>MEDIUM-COURSE SAND STONE</u> <u>13</u> <u>16</u> <u>KHAKI CLAY - SAND STONE</u> <u>16</u> <u>18</u> <u>MEDIUM GRAINED SAND STONE</u> <u>18</u> <u>19</u> <u>SAPROLITE FINE SAND STONE</u> <u>19</u> <u>25</u> <u>MEDIUM GRAINED SAND STONE</u>	
SECTION F—CENTRALISERS Type <u>KWIK-ZIP</u> Location (metres) From <u>23</u> To <u>0</u>		SECTION K—WATER BEARING BEDS Depth struck (metres) _____ Water rose to (metres) _____ Supply (litres/second) _____ Quality (e.g. potable, brackish, salty) _____	
SECTION G—PERFORATIONS/ SLOTS/ SCREENS Type <u>PVC</u> Size O.D. (mm) <u>60.5</u> Aperture (mm) <u>1</u> Location (metres) From <u>23m</u> To <u>20m</u>		SECTION L—SUB ARTESIAN BORE ON COMPLETION Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____ Type of test used ☐ Air ☐ Bail ☐ Pump Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____	
SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS Type & material size Hole diameter (mm) Casing diameter (mm O.D.) Location (metres) From To <u>CEMENT 190</u> <u>160.5</u> <u>0</u> <u>4.6</u> <u>CEMENT 140</u> <u>60.5</u> <u>0</u> <u>5</u> <u>PACK FILL 140</u> <u>60.5</u> <u>5</u> <u>16</u> <u>BENTONITE 140</u> <u>60.5</u> <u>16</u> <u>17</u> <u>GRAVEL 140</u> <u>60.5</u> <u>17</u> <u>25</u>		SECTION M—ARTESIAN BORE ON COMPLETION Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____	
SECTION N—REMARKS <u>DRY HOLE</u>		SECTION O—CERTIFICATION I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate. Driller <u>DALE GROTH</u> Driller's licence no. <u>3555</u> Trainee driller <u>DAVID FOX</u> Driller's licence no. _____ Signature of driller <u>[Signature]</u> Date <u>04/12/2024</u> Contractor _____	

Department of Natural Resources and Mines White — forward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain
The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au

Water bore drilling log

Authorisation details Registered number <u>MPO2</u> Development permit number _____ Works reference number _____		Queensland Government 2006762	
SECTION A—LOCATION DETAILS Name of landholder <u>STRAITS GOLD PTY LTD.</u> Phone No. <u>0402109833</u> Postal address <u>22 BUNOWANIS ST BALMORAL QLD</u> Postcode <u>4171</u> Real property address <u>L1, M16 1096 MACAMUNDA RD Mt COOLON</u> Postcode _____ Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____ Easting <u>496812</u> Northing <u>7645256</u> Zone _____		SECTION B—BORE COMPLETION DETAILS Date commenced <u>18/01/2024</u> Date completed <u>18/01/2024</u> SECTION C—DRILLING METHOD ☐ Rotary mud ☐ Cable tool ☐ Auger ☒ Rotary air ☐ Other _____	
SECTION D—HOLE SIZE Diameter (mm) <u>190</u> <u>140</u> Location (metres) From <u>0</u> To <u>1.4</u> <u>10.5</u>		SECTION I—BORE PURPOSE ☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☒ Industrial Other (please specify) <u>RECHARGING BORE</u>	
SECTION E—CASING DETAILS Type (PVC, steel etc) <u>PVC</u> Size O.D. (mm) <u>60.5</u> Wall thickness (mm) <u>2.8</u> Location (metres) From <u>0</u> To <u>1.4</u> <u>10.5</u>		SECTION J—PARTICULARS OF STRATA From (metres) To (metres) Strata description (use more than one line if required) Water bed (thus*) <u>0</u> <u>1</u> <u>SAND ALLUVIUM</u> <u>1</u> <u>7</u> <u>SILTSTONE FINE SANDSTONE</u> <u>7</u> <u>11</u> <u>BREKEN FINE SANDSTONE</u> <u>11</u> <u>11</u> <u>SILTSTONE</u>	
SECTION F—CENTRALISERS Type <u>KWIK-ZIP</u> Location (metres) From <u>9.5</u> To <u>0</u>		SECTION K—WATER BEARING BEDS Depth struck (metres) _____ Water rose to (metres) _____ Supply (litres/second) _____ Quality (e.g. potable, brackish, salty) _____	
SECTION G—PERFORATIONS/ SLOTS/ SCREENS Type <u>PVC</u> Size O.D. (mm) <u>60.5</u> Aperture (mm) <u>1</u> Location (metres) From <u>6.5</u> To <u>9.5</u>		SECTION L—SUB ARTESIAN BORE ON COMPLETION Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____ Type of test used ☒ Air ☐ Bail ☐ Pump Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____	
SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS Type & material size Hole diameter (mm) Casing diameter (mm O.D.) Location (metres) From To <u>CEMENT 190</u> <u>160.5</u> <u>0</u> <u>1.4</u> <u>CEMENT 140</u> <u>60.5</u> <u>0</u> <u>5.5</u> <u>BENTONITE 140</u> <u>60.5</u> <u>5.5</u> <u>6.5</u> <u>GRAVEL 140</u> <u>60.5</u> <u>6.5</u> <u>10.5</u>		SECTION M—ARTESIAN BORE ON COMPLETION Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____	
SECTION N—REMARKS <u>DRY HOLE RETURN 9.5m</u>		SECTION O—CERTIFICATION I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate. Driller <u>DALE GROTH</u> Driller's licence no. <u>3555</u> Trainee driller <u>DAVID FOX</u> Driller's licence no. _____ Signature of driller <u>[Signature]</u> Date <u>06/12/2024</u> Contractor _____	

Department of Natural Resources and Mines White — forward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain
The information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au





Water bore drilling log

Authorisation details
Registered number MP03 Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder STRAITS GOLD PTY LTD Phone No. 0402109833
Postal address 22 BUNDWANG ST BARMORAH QLD Postcode 4171
Real property address L1 M19 1096 YACAMUNDA RD Mt Coolon Postcode _____
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 496809 Northing 7645252 Zone _____



2006761

SECTION D—HOLE SIZE				SECTION I—BORE PURPOSE				SECTION K—WATER BEARING BEDS			
Diameter (mm)	Location (metres) From	To		☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial	☐ Urban ☒ Industrial ☐ Other (please specify) <u>Monitoring Bore</u>	Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)		
<u>190</u> <u>140</u>	<u>0</u> <u>4.8</u>	<u>4.8</u> <u>41</u>				<u>38</u>		<u>1.25</u>	<u>POTABLE</u>		
SECTION E—CASING DETAILS				SECTION J—PARTICULARS OF STRATA				SECTION L—SUB ARTESIAN BORE ON COMPLETION			
Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To	Strata description (use more than one line if required)	Water bed thus(*)	Conductivity (uS/cm)	pH	Depth to standing water level from ground level (metres)	Depth to pump suction or bottom of drill stem (metres)	
<u>PVC</u> <u>PVC</u>	<u>160.5</u> <u>60.5</u>	<u>6.3</u> <u>2.8</u>	<u>0</u> <u>0</u>	<u>4.8</u> <u>41</u>	<u>SOIL GRAVEL</u> <u>SILTSTONE FINE SANDSTONE</u> <u>CLAY</u> <u>7</u> <u>11</u> <u>13</u> <u>16</u> <u>17</u> <u>32</u> <u>33</u> <u>41</u>						
SECTION F—CENTRALISERS				SECTION M—ARTESIAN BORE ON COMPLETION				SECTION N—REMARKS			
Type	Location (metres) From	To		Shut-in pressure (kPa)	Free flow (litres/second)	Temperature (°C)	<u>BRIGHT Damp Between 22-29m</u>				
<u>KWIK-ZIP</u>	<u>38</u>	<u>0</u>									
SECTION G—PERFORATIONS/ SLOTS/ SCREENS				SECTION O—CERTIFICATION							
Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To	I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.						
<u>PVC</u>	<u>60.5</u>	<u>1</u>	<u>32</u>	<u>38</u>	Driller <u>DALE GROTH</u> Driller's licence no. <u>3555</u>						
SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS				Trainee driller <u>SAVIN FOX</u> Driller's licence no. _____							
Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To	Signature of driller <u>[Signature]</u> Date <u>04/2/2024</u>						
<u>CEMENT</u> <u>CEMENT</u> <u>BACK FILL</u> <u>RESINANT</u> <u>GRAVEL</u>	<u>160.5</u> <u>140</u> <u>140</u> <u>140</u> <u>140</u>	<u>160.5</u> <u>60.5</u> <u>60.5</u> <u>60.5</u> <u>60.5</u>	<u>0</u> <u>0</u> <u>0</u> <u>27</u> <u>30</u>	<u>4.8</u> <u>6</u> <u>29</u> <u>30</u> <u>41</u>	Contractor _____						

Department of Natural Resources and Mines White — forward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain
Information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au.

Water bore drilling log

Authorisation details
Registered number MP04 Development permit number _____ Works reference number _____

SECTION A—LOCATION DETAILS
Name of landholder STRAITS GOLD PTY LTD Phone No. 0402109833
Postal address 22 BUNDWANG ST BARMORAH QLD Postcode 4171
Real property address L1 M19 1096 YACAMUNDA RD Mt Coolon Postcode _____
Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____
Easting 497185 Northing 7644814 Zone _____



2006769

SECTION D—HOLE SIZE				SECTION I—BORE PURPOSE				SECTION K—WATER BEARING BEDS			
Diameter (mm)	Location (metres) From	To		☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial	☐ Urban ☒ Industrial ☐ Other (please specify) <u>Monitoring Bore</u>	Depth struck (metres)	Water rose to (metres)	Supply (litres/second)	Quality (e.g. potable, brackish, salty)		
<u>190</u> <u>140</u>	<u>0</u> <u>3</u>	<u>3</u> <u>14</u>									
SECTION E—CASING DETAILS				SECTION J—PARTICULARS OF STRATA				SECTION L—SUB ARTESIAN BORE ON COMPLETION			
Type (PVC, steel etc)	Size O.D. (mm)	Wall thickness (mm)	Location (metres) From	To	Strata description (use more than one line if required)	Water bed thus(*)	Conductivity (uS/cm)	pH	Depth to standing water level from ground level (metres)	Depth to pump suction or bottom of drill stem (metres)	
<u>PVC</u> <u>PVC</u>	<u>160.5</u> <u>60.5</u>	<u>6.3</u> <u>2.8</u>	<u>0</u> <u>0</u>	<u>3</u> <u>14</u>	<u>SOIL - ARGILLUM</u> <u>MEDIUM SANDSTONE - SILTSTONE</u> <u>MEDIUM SANDSTONE SILTSTONE</u> <u>CLAY</u> <u>9</u> <u>10</u> <u>11</u> <u>13</u> <u>14</u>						
SECTION F—CENTRALISERS				SECTION M—ARTESIAN BORE ON COMPLETION				SECTION N—REMARKS			
Type	Location (metres) From	To		Shut-in pressure (kPa)	Free flow (litres/second)	Temperature (°C)	<u>Damp in Places - Due Hole</u>				
<u>KWIK ZIP</u>	<u>14</u>	<u>0</u>									
SECTION G—PERFORATIONS/ SLOTS/ SCREENS				SECTION O—CERTIFICATION							
Type	Size O.D. (mm)	Aperture (mm)	Location (metres) From	To	I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.						
<u>PVC</u>	<u>60.5</u>	<u>1</u>	<u>10</u>	<u>13</u>	Driller <u>D GROTH</u> Driller's licence no. <u>3555</u>						
SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS				Trainee driller <u>S FOX</u> Driller's licence no. _____							
Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From	To	Signature of driller <u>[Signature]</u> Date <u>04/02/2024</u>						
<u>CEMENT</u> <u>CEMENT</u> <u>RESINANT</u> <u>GRAVEL</u>	<u>190</u> <u>140</u> <u>140</u> <u>140</u>	<u>160.5</u> <u>60.5</u> <u>60.5</u> <u>60.5</u>	<u>0</u> <u>0</u> <u>6</u> <u>7</u>	<u>3</u> <u>9</u> <u>7</u> <u>14</u>	Contractor _____						

Department of Natural Resources and Mines White — forward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain
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Water bore drilling log

Authorisation details Registered number HL8		Development permit number		Works reference number	
SECTION A—LOCATION DETAILS					
Name of landholder STRATS GOLD PT LTD		Phone No. 0402109833			
Postal address 22 BUNQUANG ST BALMORAL QLD		Postcode 4171			
Real property address 11 M19 1096 YACAMUNDA RD Mt COXON		Postcode			
Real property description Lot		Plan		or Bore location GPS. Latitude Easting 498393 Northing 7644967 Datum Zone	
SECTION D—HOLE SIZE		SECTION I—BORE PURPOSE		SECTION K—WATER BEARING BEDS	
Diameter (mm) Location (metres) From To		☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial Other (please specify) MONITORING BORE		Depth struck (metres) Water rose to (metres) Supply (litres/second) Quality (e.g. potable, brackish, salty)	
170 0 3 140 3 20		SECTION J—PARTICULARS OF STRATA		Conductivity (uS/cm) pH	
SECTION E—CASING DETAILS		From (metres) To (metres) Strata description (use more than one line if required) Water bed thus(*)		SECTION L—SUB ARTESIAN BORE ON COMPLETION	
Type (PVC, steel etc) Size O.D. (mm) Wall thickness (mm) Location (metres) From To		0 2 Soil - CLAY - ALLUVIUM 2 4 SAPROLITE 4 6 FINE SANDSTONE - SILTSTONE - CLAY 6 10 FINE SANDSTONE 12 20 PHYLLITE		Depth to standing water level from ground level (metres) Depth to pump suction or bottom of drill stem (metres)	
PVC 160-S 6-3 0 3 PVC 60-S 2-8 0 20				Type of test used ☐ Air ☐ Bail ☐ Pump	
SECTION F—CENTRALISERS				Estimated supply (litres/second) Duration of test (hours) Drawdown level from surface (metres)	
Type Location (metres) From To				SECTION M—ARTESIAN BORE ON COMPLETION	
Kwik-ZIP 19 0				Shut-in pressure (kPa) Free flow (litres/second) Temperature (°C)	
SECTION G—PERFORATIONS/ SLOTS/ SCREENS				SECTION N—REMARKS	
Type Size O.D. (mm) Aperture (mm) Location (metres) From To				Damo Sample Around 18m	
PVC 60-S 1 19 13				SECTION O—CERTIFICATION	
SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS				I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.	
Type & material size Hole diameter (mm) Casing diameter (mm O.D.) Location (metres) From To				Driller DALE GROTH Driller's licence no. 3555	
CEMENT 170 160-S 0 3 CEMENT 140 60-S 0 3 GRAVEL 140 60-S 5 10 CEMENT 140 60-S 10 11 GRAVEL 140 60-S 11 20				Trainee driller SAVIN FOX Driller's licence no.	
				Signature of driller [Signature] Date 04/2/2024	
				Contractor	

Department of Natural Resources and Mines

Information being collected in this form will be used by this department for the purpose of processing your drill log form to record your water bore drilling activity under the authority of section 313 of the Water Act 2000. Your personal details will be accessed only by authorised officers within this department and will not be disclosed to any other third party without your consent except where required by law. The information collected will be retained as required by the Public Records Act 2002 (Qld) and may be stored in a departmental database. For more information on the department's privacy commitment, please visit www.dnrm.qld.gov.au.

White — forward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain

Water bore drilling log

Authorisation details Registered number HL9		Development permit number		Works reference number	
SECTION A—LOCATION DETAILS					
Name of landholder STRATS GOLD PT LTD		Phone No. 0402109833			
Postal address 22 BUNQUANG ST BALMORAL QLD		Postcode 4171			
Real property address 11 M19 1096 YACAMUNDA RD Mt COXON		Postcode			
Real property description Lot		Plan		or Bore location GPS. Latitude Easting 498036 Northing 7644792 Datum Zone	
SECTION D—HOLE SIZE		SECTION I—BORE PURPOSE		SECTION K—WATER BEARING BEDS	
Diameter (mm) Location (metres) From To		☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial Other (please specify) MONITORING BORE		Depth struck (metres) Water rose to (metres) Supply (litres/second) Quality (e.g. potable, brackish, salty)	
170 0 3 140 3 20		SECTION J—PARTICULARS OF STRATA		Conductivity (uS/cm) pH	
SECTION E—CASING DETAILS		From (metres) To (metres) Strata description (use more than one line if required) Water bed thus(*)		SECTION L—SUB ARTESIAN BORE ON COMPLETION	
Type (PVC, steel etc) Size O.D. (mm) Wall thickness (mm) Location (metres) From To		0 2 Soil - CLAY - ALLUVIUM 2 4 GRAVEL 4 7 PHYLLITE - CLAY 7 10 FINE SANDSTONE - SILTSTONE 10 12 CLAY - FINE SANDSTONE 12 17 FINE SANDSTONE - QUARTZ VEIN 17 20 PHYLLITE		Depth to standing water level from ground level (metres) Depth to pump suction or bottom of drill stem (metres)	
PVC 160-S 6-3 0 3 PVC 60-S 2-8 0 20				Type of test used ☐ Air ☐ Bail ☐ Pump	
SECTION F—CENTRALISERS				Estimated supply (litres/second) Duration of test (hours) Drawdown level from surface (metres)	
Type Location (metres) From To				SECTION M—ARTESIAN BORE ON COMPLETION	
Kwik ZIP 19 0				Shut-in pressure (kPa) Free flow (litres/second) Temperature (°C)	
SECTION G—PERFORATIONS/ SLOTS/ SCREENS				SECTION N—REMARKS	
Type Size O.D. (mm) Aperture (mm) Location (metres) From To				Damo Cuts in Places (No Water)	
PVC 60-S 1 13 19				SECTION O—CERTIFICATION	
SECTION H—CEMENTING/ GRAVEL PACK/ ANNULAR FILL DETAILS				I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate.	
Type & material size Hole diameter (mm) Casing diameter (mm O.D.) Location (metres) From To				Driller DALE GROTH Driller's licence no. 3555	
CEMENT 170 160-S 0 3 CEMENT 140 60-S 0 3 GRAVEL 140 60-S 5 10 CEMENT 140 60-S 10 11 GRAVEL 140 60-S 11 20				Trainee driller SAVIN FOX Driller's licence no.	
				Signature of driller [Signature] Date 04/2/2024	
				Contractor	

Department of Natural Resources and Mines

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White — forward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain



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Water bore drilling log

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Authorisation details Registered number _____ Development permit number _____ Works reference number TD08		Log ID # 87724374
SECTION A—LOCATION DETAILS Name of landholder straits gold ply ltd Phone No. 0402109833 Postal address 22 bunowang st, balmoral qld Postcode 4171 Real property address 11, mlg 1096, yacamunda rd, mt coolon - yandan gold mine Postcode _____ Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____ Easting 501281 Northing 7647037 Zone _____		SECTION B—BORE COMPLETION DETAILS Date commenced 23/1/24 Date completed 23/1/24 SECTION C—DRILLING METHOD ☐ Rotary mud ☐ Cable tool ☐ Auger ☒ Rotary air ☐ Other
SECTION D—HOLE SIZE Diameter (mm) _____ Location (metres) From _____ To _____ 190 0 3 140 3 20		SECTION I—BORE PURPOSE ☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial ☐ Other (please specify) monitoring bore
SECTION E—CASING DETAILS Type (PVC, steel etc) _____ Size O.D. (mm) _____ Wall thickness (mm) _____ Location (metres) From _____ To _____ PVC 150 6.3 0 3 PVC 50 2.4 0 20		SECTION J—PARTICULARS OF STRATA From (metres) To (metres) Strata description (use more than one line if required) Water bed thus(*) 0 1 quartz gravel 1 3 clay siltstone 3 4 saprolite 4 8 fine sandstone 8 13 phyllite 13 20 fine sandstone, minor phyllite
SECTION F—CENTRALISERS Type _____ Location (metres) From _____ To _____ plastic 20 1		SECTION K—WATER BEARING BEDS Depth struck (metres) _____ Water rose to (metres) _____ Supply (litres/second) _____ Conductivity (µS/cm)* _____ pH _____ dry
SECTION G—PERFORATIONS/ SLOTS/ SCREENS Type _____ Size O.D. (mm) _____ Aperture (mm) _____ Location (metres) From _____ To _____ PVC 50 1 16 19		SECTION L—SUB ARTESIAN BORE ON COMPLETION Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____ Type of test used ☐ Air ☐ Bail ☐ Pump Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____
SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS Type & material size _____ Hole diameter (mm) _____ Casing diameter (mm O.D.) _____ Location (metres) From _____ To _____ cement 190 150 0 3 cement/ben 140 50 0 5 sample 140 50 5 14 bednite 140 50 14 15 3-5 gravel 140 50 15 20		SECTION M—ARTESIAN BORE ON COMPLETION Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____
		SECTION N—REMARKS
SECTION O—CERTIFICATION I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate. Driller name Timothy Schonknecht Driller's licence no. 3538 Trainee Driller name Gavin Fox Driller's licence no. _____ Signature of driller [Signature] Date 6/2/2024 Contractor name Eagle Drilling NQ		

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Collection of information on this form is authorised by section 983L of the Water Act 2000 and will be used by the Department for the purpose of processing your application. For these purposes disclosure to other third parties may be required by or of the Department. The information may be accessible, disclosed to and used by the public as allowed, authorised or required by legislation. A copy of the completed log must be provided to the Department. It is recommended that a copy be retained by the landholder.

Water bore drilling log



2006768

Authorisation details Registered number TD9 Development permit number _____ Works reference number _____		Log ID # 2006768
SECTION A—LOCATION DETAILS Name of landholder STRAITS GOLD PLY LTD Phone No. 0402109833 Postal address 22 BUNOWANG ST BALMORAL QLD Postcode 4171 Real property address 11 MLG 1096 YACAMUNDA RD MT COOLON Postcode _____ Real property description Lot _____ Plan _____ or Bore location GPS. Latitude _____ Longitude _____ Datum _____ Easting 499259 Northing 7646411 Zone _____		SECTION B—BORE COMPLETION DETAILS Date commenced 20/1/2024 Date completed 20/1/2024 SECTION C—DRILLING METHOD ☐ Rotary mud ☐ Cable tool ☐ Auger ☒ Rotary air ☐ Other
SECTION D—HOLE SIZE Diameter (mm) _____ Location (metres) From _____ To _____ 190 0 3 140 3 13		SECTION I—BORE PURPOSE ☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial ☐ Other (please specify) Monitoring Bore
SECTION E—CASING DETAILS Type (PVC, steel etc) _____ Size O.D. (mm) _____ Wall thickness (mm) _____ Location (metres) From _____ To _____ PVC 160.5 6.3 0 3 PVC 60.5 2.4 0 13		SECTION J—PARTICULARS OF STRATA From (metres) To (metres) Strata description (use more than one line if required) Water bed thus(*) 0 1 SOIL-GRAVEL-ALUMINIUM 1 4 QUARTZ VEIN-PHYLLITE 4 7 PHYLITE 7 8 QUARTZ VEIN-PHYLLITE 8 11 PHYLITE 11 12 PHYLITE QUARTZ VEIN 12 13 PHYLITE
SECTION F—CENTRALISERS Type _____ Location (metres) From _____ To _____ Kwik-Zip 12 0		SECTION K—WATER BEARING BEDS Depth struck (metres) _____ Water rose to (metres) _____ Supply (litres/second) _____ Quality (e.g. potable, brackish, salty) _____ Conductivity (µS/cm) _____ pH _____
SECTION G—PERFORATIONS/ SLOTS/ SCREENS Type _____ Size O.D. (mm) _____ Aperture (mm) _____ Location (metres) From _____ To _____ PVC 60.5 1 12 9		SECTION L—SUB ARTESIAN BORE ON COMPLETION Depth to standing water level from ground level (metres) _____ Depth to pump suction or bottom of drill stem (metres) _____ Type of test used ☐ Air ☐ Bail ☐ Pump Estimated supply (litres/second) _____ Duration of test (hours) _____ Drawdown level from surface (metres) _____
SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS Type & material size _____ Hole diameter (mm) _____ Casing diameter (mm O.D.) _____ Location (metres) From _____ To _____ CEMENT 190 160.5 0 3 CEMENT 140 60.5 0 6 CEMENT 140 60.5 6 7 GRAVEL 140 60.5 7 13		SECTION M—ARTESIAN BORE ON COMPLETION Shut-in pressure (kPa) _____ Free flow (litres/second) _____ Temperature (°C) _____
		SECTION N—REMARKS DAMP SAMPLE AROUND 10-11m
SECTION O—CERTIFICATION I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate. Driller DALE GROTH Driller's licence no. 3555 Trainee driller Gavin Fox Driller's licence no. _____ Signature of driller [Signature] Date 4/2/2024 Contractor _____		

Department of Natural Resources and Mines White — forward to the Department of Natural Resources and Mines Pink — provide to landholder Blue — Driller to retain
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Water bore drilling log

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Authorisation details Registered number.....Development permit number.....Works reference number TD10		Log ID # 96937995
SECTION A—LOCATION DETAILS Name of landholder straits gold pty ltd Phone No. 0402109833 Postal address 22 bunowang st, balmoral qld Postcode 4171 Real property address 11, mlg 1096, yacamunda rd, mt coolon - yandan gold mine Postcode..... Real property description Lot.....Plan.....or Bore location GPS. Latitude.....Longitude.....Datum..... Easting 500125 Northing 7646506 Zone.....		SECTION B—BORE COMPLETION DETAILS Date commenced 23/1/24 Date completed 23/1/24 SECTION C—DRILLING METHOD ☐ Rotary mud ☐ Cable tool ☐ Auger ☒ Rotary air ☐ Other
SECTION D—HOLE SIZE Diameter (mm) Location (metres) From To 190 0 3 140 3 20	SECTION I—BORE PURPOSE ☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial ☐ Other (please specify) monitoring bore	SECTION K—WATER BEARING BEDS Depth struck (metres) Water rose to (metres) Supply (litres/second) Conductivity (µS/cm)* pH dry
SECTION E—CASING DETAILS Type (PVC, steel etc) Size O.D. (mm) Wall thickness (mm) Location (metres) From To PVC 150 6.3 0 3 PVC 50 2.4 0 20	SECTION J—PARTICULARS OF STRATA From (metres) To (metres) Strata description (use more than one line if required) Water bed thus (*) 0 1 soil alluvium 1 4 mudstone 4 8 fine sandstone 8 13 phyllite 13 20 very fine sandstone	Final Conductivity (µS/cm): Final pH: *Fresh, brackish or salty. Laboratory testing is recommended before human consumption.
SECTION F—CENTRALISERS Type Location (metres) From To plastic 20 1	SECTION L—SUB ARTESIAN BORE ON COMPLETION Depth to standing water level from ground level (metres) Depth to pump suction or bottom of drill stem (metres) Type of test used ☐ Air ☐ Bail ☐ Pump Estimated supply (litres/second) Duration of test (hours) Drawdown level from surface (metres)	SECTION M—ARTESIAN BORE ON COMPLETION Shut-in pressure (kPa) Free flow (litres/second) Temperature (°C)
SECTION G—PERFORATIONS/ SLOTS/ SCREENS Type Size O.D. (mm) Aperture (mm) Location (metres) From To PVC 50 1 16 19	SECTION N—REMARKS	
SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS Type & material size Hole diameter (mm) Casing diameter (mm O.D.) Location (metres) From To cement 190 150 0 3 cement/ben 140 50 0 5 sample 140 50 5 14 bednite 140 50 14 15 3-5 gravel 140 50 15 20	SECTION O—CERTIFICATION I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate. Driller name Timothy Schonknecht Driller's licence no. 3538 Trainee Driller name Gavin Fox Driller's licence no. Signature of driller Date 6/2/2024 Contractor name Eagle Drilling NQ	

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Water bore drilling log

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Authorisation details Registered number.....Development permit number.....Works reference number TD11		Log ID # 74277464
SECTION A—LOCATION DETAILS Name of landholder straits gold pty ltd Phone No. 0402109833 Postal address 22 bunowang st, balmoral qld Postcode 4171 Real property address 11, mlg 1096, yacamunda rd, mt coolon - yandan gold mine Postcode..... Real property description Lot.....Plan.....or Bore location GPS. Latitude.....Longitude.....Datum..... Easting 499627 Northing 7647595 Zone.....		SECTION B—BORE COMPLETION DETAILS Date commenced 23/1/24 Date completed 23/1/24 SECTION C—DRILLING METHOD ☐ Rotary mud ☐ Cable tool ☐ Auger ☒ Rotary air ☐ Other
SECTION D—HOLE SIZE Diameter (mm) Location (metres) From To 190 0 3 140 3 20	SECTION I—BORE PURPOSE ☐ Domestic ☐ Stock ☐ Irrigation ☐ Commercial ☐ Urban ☐ Industrial ☐ Other (please specify) monitoring bore	SECTION K—WATER BEARING BEDS Depth struck (metres) Water rose to (metres) Supply (litres/second) Conductivity (µS/cm)* pH dry
SECTION E—CASING DETAILS Type (PVC, steel etc) Size O.D. (mm) Wall thickness (mm) Location (metres) From To PVC 150 6.3 0 3 PVC 50 2.4 0 20	SECTION J—PARTICULARS OF STRATA From (metres) To (metres) Strata description (use more than one line if required) Water bed thus (*) 0 1 fine/medium sandstone 1 8 sandstone quartzite 8 11 siltstone 11 18 phyllite/mudstone 18 20 fine sandstone	Final Conductivity (µS/cm): Final pH: *Fresh, brackish or salty. Laboratory testing is recommended before human consumption.
SECTION F—CENTRALISERS Type Location (metres) From To plastic 20 1	SECTION L—SUB ARTESIAN BORE ON COMPLETION Depth to standing water level from ground level (metres) Depth to pump suction or bottom of drill stem (metres) Type of test used ☐ Air ☐ Bail ☐ Pump Estimated supply (litres/second) Duration of test (hours) Drawdown level from surface (metres)	SECTION M—ARTESIAN BORE ON COMPLETION Shut-in pressure (kPa) Free flow (litres/second) Temperature (°C)
SECTION G—PERFORATIONS/ SLOTS/ SCREENS Type Size O.D. (mm) Aperture (mm) Location (metres) From To PVC 50 1 16 19	SECTION N—REMARKS	
SECTION H—CEMENTING/GRAVEL PACK/ANNULAR FILL DETAILS Type & material size Hole diameter (mm) Casing diameter (mm O.D.) Location (metres) From To cement 190 150 0 3 cement/ben 140 50 0 5 sample 140 50 5 14 bednite 140 50 14 15 3-5 gravel 140 50 15 20	SECTION O—CERTIFICATION I hereby certify that the bore is drilled and constructed according to the conditions of my driller's licence and the information provided is true and accurate. Driller name Timothy Schonknecht Driller's licence no. 3538 Trainee Driller name Gavin Fox Driller's licence no. Signature of driller Date 6/2/2024 Contractor name Eagle Drilling NQ	

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Water bore drilling log

Ensure you have generated a Log ID number prior to submitting >

Click to generate log ID

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203



Water bore drilling log

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Water bore drilling log

Ensure you have generated a Log ID number prior to submitting a

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Authorisation details Registered number _____		Development permit number _____		Works reference number _____		ITD01		Log ID # 39156553									
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SECTION D—HOLE SIZE						SECTION E—CASING DETAILS											
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PVC	50	1	9 6														
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Type & material size	Hole diameter (mm)	Casing diameter (mm O.D.)	Location (metres) From To				hole caved in, case base set at 9.5										
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I hereby certify that the bore is drilled and constructed according to the conditions of m driller's licence and the information provided is true and accurate.						Drilliner name <u>Timothy Schonknecht</u> Driller's licence no. <u>3538</u>											
						Trainee Driller name <u>Gavin Fox</u> Driller's licence no. _____											
						Signature of driller <u>[Signature]</u> Date <u>6/2/2024</u>											
						Contractor name <u>Eagle Drilling NQ</u>											



Water bore drilling log

Ensure you have generated a Log ID number prior to submitting >

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Appendix E – Influence of density on groundwater effective head

As part of constructing a groundwater-surface for Yandan and Main Pit, consideration of effective head differentials given the Main Pit groundwater density is required. As Main Pit groundwater bores' salinity is near or greater than seawater, groundwater levels in bores MP01-MP04 and SH3 are substantially denser than fresh waters, including the pit lake. Density, and its application to head, represents the energy per unit weight of fluid: denser the water, the higher the unit weight, and therefore higher effective head. The effect is that groundwater levels in highly saline wells can be measured as lower than their effective hydraulic head compared to fresher (and less dense) waters.

Whilst not a common phenomenon around mining pits; however, it is documented in other relatable environments (Anderson et al 2015). A method to determine equivalent freshwater head from dense water measurements is given by Post and Simmons (2022) from Luszczynski (1961), as shown in Figure 14, and equates to a general rule of 2.5cm/m of freshwater head. If the Main Pit is 30-40m deep of fresh water (assuming connection), this might equate to an approximate 1-1.5m of additional effective head in density flow with saline Main Pit groundwater.

Table 5 - Summary of groundwater levels used in potentiometric surface

BHID	Type	RWL
HL1	Heap leach	166.28
HL3	Heap leach	164.45
HL4	Heap leach	167.52
HL5	Heap leach	167.29
HL6	Heap leach	169.35
HL7	Heap leach	169.32
HL8	Heap leach	164.81
HL9	Heap leach	165.4
MP02	Main pit	164.89
MP03	Main pit	165.25
MP04	Main pit	166.24
SH3	Main pit	163.07
RB2D	Regional	171.4
RB2S	Regional	171.39
RB1D	Tailings	178.97
TD12	Tailings	179.25
TD13	Tailings	179.85
TD3	Tailings	176.14
TD4	Tailings	178.43
TD7D	Tailings	177.68
TD7S	Tailings	177.6
TD8	Tailings	180.45
TD9	Tailings	173.59

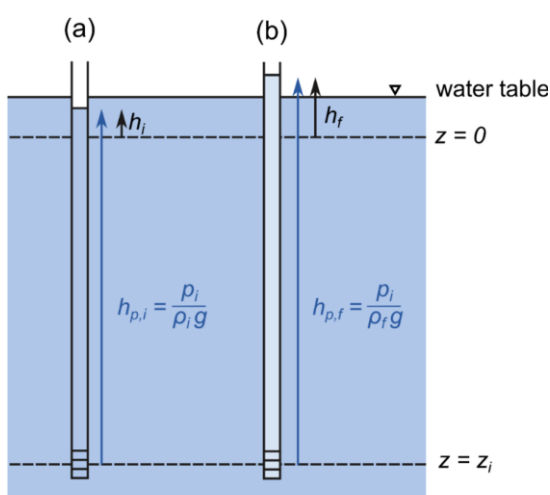


Figure 6 – a) Point water head for a system with water density greater than freshwater density and b) equivalent freshwater head for the piezometer located at (a). The pressure and density at elevation z_i are p_i and ρ_i .

Figure 28 - Changes to effective head with salinity (Post and Simmons 2022)

Note: wells HL1, WSB, TD4, TD5 are excluded given construction in dam embankments or known integrity issues to ensure a representative surface. Note also dry wells – ITD01, ITD02, TD6S, RB1S.



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ROSS MINING NL

YANDAN PIT REFLOODING WASTE ROCK BACKFILL COVER PLACEMENT SPECIFICATION

RM803 - 2

FEBRUARY 1999

Compiled by:

Principal Engineer

Endorsed by:

N.M. Netherway
per Com Scott

Principal

The conclusions and recommendations expressed in this report represent the opinions of the authors based on the data available to them. The opinions and recommendations provided from this information are in response to a request from the client and no liability is accepted for commercial decisions or actions resulting from them.

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Figure 1 Waste Rock Backfill Areas

1. Introduction

The assessment completed on the Yandan Gold Mine pit lake water quality (“Yandan Gold Mine Pit Water Quality Prediction”, SRK 1999), identified the sulphidic waste rock within the pit as the largest potential source for contaminant release to the pit lake. As determined in that study, the rate of contaminant release from the waste rock may be controlled by covering the sulphidic backfill with a soil cover. Further control on solute release may be affected with a lime application to the waste rock prior to the placement of the soil cover. The purpose of the soil cover will be to limit interaction between the pore water in the waste rock and the pit lake. The purpose of the lime application is to provide limited solubility controls on solute concentrations within the immediate vicinity of the waste rock.

The areas where waste rock has been backfilled are illustrated in Figure 1. This report briefly summarises the recommended requirements for the placement of the soil cover to achieve the stated objective. However, as typical with geotechnical engineering projects, the material properties may vary, and placement requirements may be dictated by the material available at the site. We understand that a stockpile containing a sufficient quantity of material to complete the cover is currently available on site. The stockpiled material is described as a cohesive clayey soil. In addition, it is understood that the moisture content and handlability of the clayey soil is appropriate for the intended use.

2. Cover Description and Placement

2.1 Lime Application and Cover Thickness

Lime application to the waste rock prior to the placement of the soil cover is recommended. The lime should be spread evenly over all faces of the waste rock prior to the placement of the cover, at an application rate of approximately 1 kg per square meter. The lime should be applied and covered under dry conditions to prevent the lime from being flushed away. In order to avoid losses due to wind or rain, the lime application should be staged so that limed areas are not left uncovered for extended periods.

It is recommended that a soil cover with a minimum thickness of 0.3 m be placed over the waste rock. It will be necessary to increase the cover thickness in areas where the waste rock is very porous, e.g. from segregation, to prevent the cover material from being 'washed' into the waste rock during flooding. This will need to be judged by the site engineer.

2.2 Material Properties

Based on the recommended minimum cover thickness of 300 mm, all oversize particles in excess of 75 mm, should be removed from the soil before placement. Should it be impractical to remove oversize material, the cover thickness may be increased proportionately to the maximum particle size.

Since the material that will be used in the cover construction has already been stockpiled, it is recommended that five bulk samples be obtained randomly from the stockpile to characterise the size distribution and obtain soil descriptions (i.e. size gradations, moisture contents and Atterburg Limits).

2.3 Cover Placement

In preparation for the placement of the soil cover, all sideslopes of the backfilled waste rock should be contoured to a maximum slope of 3:1 (H:V). All horizontal areas should be graded smooth to present a suitable bedding surface for placement of the soil cover. Care should be taken to remove extraneous rocks that may protrude from the bedding surface. Obvious zones of porous waste rock, resulting from for example segregation, should be filled where

possible with a sandy soil or suitable material in preparation for the placement of the cover, or the cover thickness may be increased.

The cover may be constructed by free dumping soil, and spreading it with a dozer on horizontal surfaces. Trafficking of sloped surfaces should be minimized to preserve the cover thickness. It is recommended where possible that material on side slopes be spread with a backhoe working from the crest and the toe respectively, or as is practical.

While compaction of the soil cover will be beneficial to the purpose of the cover, it is not essential to the cover performance. However, compaction of the cover can be achieved by traversing with the soil cover with rubber wheeled vehicles during cover construction.

In Area 2, as shown in Figure 1, waste rock has been dumped up to the edge of an internal bench within the pit, with a height of about 15 m. Within this area it may not be practical to contour the sideslopes to the recommended slope. It is recommended that the slope in this area be flattened as much as is practical, to reduce it from the angle of repose. Since it will be difficult to place the cohesive clayey soil on these slopes, the soil cover may be replaced with fine grained oxide material that is sized to less than 75 mm, and placed to a minimum thickness of 0.45 m.

2.4 Erosion Protection

As shown in Figure 1, there are four areas in which backfill has been placed. In the long term, all areas are expected to be well below the surface of the pit lake (in excess of 5 m) and therefore wave action is not expected to cause cover erosion. In the short term, prior to flooding of the pit, extreme rainfall events may result in cover erosion. Flooding of the pit is expected to be relatively rapid. Therefore, during the flooding period, the erosion protection will vary according to the location within the pit.

Areas 1 and 2 in Figure 1, will be located some distance from the influent point, and are at an elevation at which a comparatively stable lake will have been established. Therefore, these areas will require erosion protection from wave action for the short time during the flooding period until these are submerged. The sideslopes of these areas are likely to be most susceptible to wave action, and therefore, erosion protection will be required on all side slopes.

It is recommended that coarse gravel to cobble size material (approximately 5 mm to 50 mm) be spread to a thickness of 75 to 100 mm on all sideslopes of Areas 1 and 2.

Area 3 will receive water cascading down the pit wall and will require rip rap on all surfaces to provide erosion protection for the soil cover. As well, to prevent washout of the soil from below the rip rap, filter cloth should be placed to separate the soil cover from the rip rap.

It is recommended that the rip rap should consist of competent cobble to boulder size (150 mm to 300 mm) material, placed to a thickness of about 500 mm. The rock can be obtained from the competent oxide waste rock that has been backfilled to the pit. The tensile strength will be key to the performance of the filter cloth. A nonwoven geotextile with the following minimum specifications is recommended:

Grab Tensile Strength (ATSM-D 4632)	1.3 kN
Mullen Burst (ATSM-D 3786)	5 100 kPa
Puncture (ATSM-D 4833)	1.0 kN

Cover placement should be planned in advance to eliminate trafficking of the rip rap/geotextile to prevent unnecessary damage to the geotextile.

Area 4 is removed (approximately 75 m) and somewhat protected from the area where water is expected to cascade down the pit walls. This is also the lowest area in the pit, and will flood rapidly. However, initial flows into this area could cause some erosion of the cover. Therefore, it is recommended that erosion protection, consisting of a 0.15 m layer of cobble sized oxide rock (50 to 75 mm), be placed over the soil cover in this area.

2.5 QA/QC of the Cover Placement

Spot elevations should be obtained for all waste rock backfill areas after final surface dressing. Spot elevations should be repeated after final cover placement to document the cover thickness. In addition, it is recommended that test pits be excavated by hand at regular grid spacing of about 25 to 30 m square, to document the soil cover thickness and soil description. The test pits should be backfilled after the necessary information had been documented. Similar checks should be completed for the erosion protection.

3. Schedule

Current estimates of the rainfall conditions for 1999 at the site suggest a typical to wet season. However, it is difficult to project climatic conditions. Therefore, conservatively also considering median flow conditions in the Suttor River, it is therefore recommended that that flooding of the pit should commence no later than April of 1999.

Please note that the above recommendations are based on a controlled flooding of the pit. It was assumed that the rate of flooding would be controlled, by breaching of the bund and constructing a suitable spillway to limit the rate of flow into the pit.

4. References

SRK, 1999. "Yandan Gold Mine Pit Water Quality Prediction", SRK Report Number RM803/1, February 1999



Steffen, Robertson and Kirsten (Australasia) Pty Ltd; ACN 074 271 720, trading as SRK Consulting

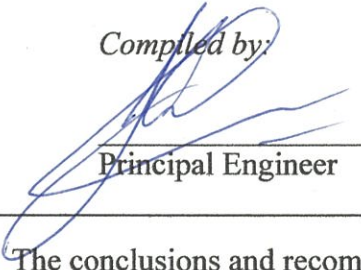
ROSS MINING NL

YANDAN GOLD MINE PIT WATER QUALITY PREDICTION

RM803 - 1

FEBRUARY 1999

Compiled by:


Principal Engineer

Endorsed by:

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Technical Director

The conclusions and recommendations expressed in this report represent the opinions of the authors based on the data available to them. The opinions and recommendations provided from this information are in response to a request from the client and no liability is accepted for commercial decisions or actions resulting from them

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1. INTRODUCTION

1.1 *Background*

The Yandan Gold Mine is located approximately 180 km SSE of Charters Towers, on the eastern bank of the Suttor River, at the confluence with Yandan Creek. The Yandan pit is separated from the Suttor River by an earthen bund.

The mine was commissioned in September of 1993. Increasing sulphide rich ore and waste was encountered as mining of the open pit progressed. Sulphide rich waste rock has been deposited within limited areas of the open pit.

Upon completion of mining, the pit will be allowed to flood. As part of the reclamation objective, Ross Mining NL proposes to breach the earthen bund such that the pit lake becomes a backwater to the Suttor River.

1.2 *Terms of Reference and Study Objectives*

Ross Mining NL retained SRK Consulting to assess the potential impact on surface water quality that may result from flooding of the Yandan Gold Mine open pit.

The specific objectives of the scoping investigation were to:

- predict short and long term water quality for the pit,
- assess the requirements for controlled flooding of the pit, including the need for pH modification of the pit lake water during the flooding process; and,
- assess the need for capping of sulphidic wall rock that may remain above the pit lake level, or any other remediation measures, to achieve acceptable water quality in the pit lake and downstream in the Suttor River.

The scope of work is limited to assessing surface water quality and impacts, and does not include an assessment of the hydrogeology.

1.3 Approach

Briefly, a simple three step approach was followed to assess the water quality within the pit during flooding, and the potential impacts downstream. These steps were as follows:

- i) A geological map of the exposed pit wall rocks, with particular emphasis on the presence of sulphide minerals, was prepared. The map included the area and volume of waste rock that has been placed within the confines of the pit.
- ii) A field sampling program was then undertaken. The map prepared in Step (i) was used to select appropriate sampling locations to represent each of the rock types exposed in the pit wall rocks. These samples were tested to determine their potential for solute release upon flooding, using leach extraction test procedures.
- iii) A simple dilution model was then developed (as an Excel spreadsheet) to calculate solute concentrations in the pit lake based on the solute release rates determined from the leach extraction tests.

This report is arranged as follows. Section 2 contains a summary of relevant regional and site specific information. Section 3 presents the geological map and discusses the results of the field and laboratory testing program. The results of the dilution calculations are presented in Section 4. Conclusions and recommendations are summarized in Section 5.

2. RELEVANT SITE INFORMATION

2.1 *Geological Setting*

The brief summary of the geology of the Yandan deposit was taken from Doherty (1997a, b).

The Yandan deposit is hosted in a downfaulted block of Lower St. Anns Formation sediments, bounded by ENE and NNW-striking faults. The sediments comprise regular thick limestone interbedded with arenaceous and tuffaceous units. The sediments contain abundant carbonaceous material and some chert. Within the sedimentary block, the structure is dominated by a series of closely spaced E-W to ENE subvertical faults, which appear to have undergone several episodes of movement. The two most significant structures, the Yandan Feeder Zone and the Stage 3 Feeder Zone, are believed to be the main controls on mineralization. Breccias are associated with the two feeder zones but whether these are tectonic or sedimentary in origin is unclear.

The Yandan deposit is a disseminated epithermal gold-silver deposit with economic minerals found in both veins and the host rock. There are three main alteration events within the pit: (1) an early quartz-adularia $\pm$ pyrite alteration (2) pervasive silicification and quartz veining, and (3) pyrite veining. Economic minerals are found associated with the first two alteration types, indicating that gold deposition occurred during several stages of epithermal activity.

Abundant pervasive silicification and quartz veining is associated with the feeder zones. Very fine-grained pyrite is found throughout the deposit, but is highly concentrated in some “high sulfide” areas of the pit. Mineralization at Yandan has been dated at approximately 346 ± 4 Ma (Perkins et al 1995).

2.2 *Rainfall*

Rainfall data have been gathered at the minesite and at the mine village since 1993 and 1994, respectively. The average monthly rainfall data are summarized in Table 2.1. Monthly data are provided in Appendix A.

Table 2.1
Summary of Monthly Average Rainfall

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Village	85	85	41	19	27	15	1	41	6	35	35	51
Minesite	97	117	67	57	35	19	9	27	6	29	45	61

2.3 *Lake Evaporation*

Estimated pan evaporation rates for the study area are summarised in Table 2.2. These estimates were derived from observations over a 15 year period at the Bureau of Meteorology Twin Hills station. These pan evaporation rates were corrected by a factor of 0.8 to provide estimates of lake evaporation (Weeks, 1983).

Table 2.2
Pan Evaporation Rates

Month	Evaporation (mm)
January	240
February	190
March	190
April	140
May	110
June	90
July	110
August	140
September	190
October	270
November	270
December	270

2.4 *Surface Water*

2.4.1 *Streamflow Data*

As shown on the location map (Figure 2.1), the minesite is located on the eastern bank of the Suttor River. Plate 1 shows an aerial photograph of the minesite taken in 1996. The Suttor River has a braided streambed, with a major channel that has been diverted around the western end of the pit. Similarly, the lower section of Yandan Creek has also been diverted.

No flow data are available for the Suttor River at the mine site, however, streamflow data have historically been collected at St. Anns. The catchment for the Suttor River at St. Anns is about 49 820 km². This is reduced by about 500 km² at the minesite. This reduction represents just over 1 percent of the total catchment and, consequently, the flows at the minesite are assumed to be approximately the same as those measured at St. Anns.

Monthly streamflow data for the Suttor River were obtained from the Department of Natural Resources. The raw data are provided in Appendix B, and are summarized in Table 2.3.

Table 2.3
Streamflow Data for the Suttor River
(Summary of data for 1967 through 1998 at St. Anns)

Month	Monthly Average (ML)	Monthly Median (ML)
January	439230	66869
February	634517	152340
March	269887	63188
April	80572	2970
May	162009	70
June	26431	184
July	5356	0
August	7046	0
September	4441	0
October	9109	0
November	15254	5592
December	78399	45351

2.4.2 Water Quality

The 1998 quarterly water quality monitoring (undertaken by Yandan Gold Mine) results for the Suttor River are summarized in Table 2.4. Sampling location (SW1) is located at the harvesting channel downstream from the minesite (see Plate 1) and thus includes impacts, if any, from the minesite. No background or upstream data were available for the same period, however, pre-development water quality for the Suttor River are presented in Table 2.5. These data show that the Suttor River water is characterised by low sulphate and salinity, and has some bicarbonate alkalinity.

Table 2.4
Water Quality in the Suttor River at Sampling Location SW1

Site	Date Sample collection	Parameter						
		pH mg/L	TDS mg/L	Cu mg/L	Zn mg/L	As mg/L	Pb mg/L	Fe mg/L
SW1	22/03/98	7.5	884	< 0.01	< 0.01	0.007	0.02	3.0
SW1	12/05/98	7.5	448	< 0.01	< 0.01	< 0.001	< 0.001	2.2
SW1	7/07/98	7.5	424	< 0.01	0.01	0.001	0.002	1.9
SW1	15/09/98	7.4	484	< 0.01	< 0.01	0.002	0.004	2.2
Average		7.5	560	< 0.01	< 0.01	0.003	0.009	2.3

Table 2.5
Summary of Pre-Development Water Quality Results for the Suttor River

Location	Date (1988)	TDS (mg/L)	pH	HCO ₃ mg/L	SO ₄ mg/L	Cl mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Fe mg/L	As mg/L	Cu mg/L	Ni mg/L	Zn mg/L	Hg mg/L
Suttor (Down stream from minesite)	Feb. 3	91	7.4	80.8	5.9	6.4	15.2	5.2	9.6	8.3	19.1	0.003	0.015	0.018	0.05	<0.001
	Mar. 21	100	8.7	55.1	nd	10.9	9.5	4.8	16.1	5.1	12.4	0.003	0.005	0.006	0.008	<0.001
	Mar. 28	12	9.0	68.9	nd	12.2	12.6	6.3	18.4	6.3	11.9	0.003	0.007	0.007	0.009	<0.001
	Apr. 9	59	7.3	39.7	22.2	2.6	3.6	5.1	8.3	4.9	12.1	0.002	0.011	0.016	0.023	<0.001
	May 31	99	7.4	51.1	10.4	5.5	9.0	10.0	9.1	3.9						
Suttor (Up stream from minesite)	Feb. 3	91	7.5	82.1	5.0	7.6	16.2	5.5	9.5	8.1	19.1	0.004	0.015	0.018	0.05	<0.001
	Mar. 21	114	7.1	60.1	2.3	11.5	11.1	5.1	17.0	4.8	13.1	0.003	0.007	0.008	0.01	<0.001
	Mar. 28	119	8.8	67.2	7.2	11.5	12.6	6.4	18.2	6.5	13.0	0.002	0.007	0.006	0.008	<0.001
	Apr. 9															
	May 31	109	7.4	67.5	10.7	5.9	7.5	4.7	9.2	3.6						
Average		88	7.8	63.6	9.1	8.2	10.8	5.9	12.8	5.7	14.4	0.003	0.009	0.011	0.023	<0.001

2.5 Yandan Pit Volume

A survey model of the open pit was created by the Yandan Gold Mine Contract Surveyor from the end of November 1998 model and survey pick ups done up to the 4th of December 1998. The planimetric surface areas and volumes were calculated for each 1-m increment in elevation. As mining continued into mid December, it was estimated that approximately 15000 BCM would be mined from 113 R.L. to the 101 R.L. in the western part of the pit. The pit volume calculations were also adjusted for approximate waste volumes that have been placed within the pit, as follows (pers. com. Alistair Watts, Yandan Gold Mine):

113-115 R.L. 2500 BCM waste

130-140 R.L. 25000 BCM waste

134-154 R.L. 86400 BCM waste

The “full” water level seems to be about 164.6 R.L., which corresponds approximately with the river bed elevation.

The calculated elevation – volume curve is illustrated in Figure 2.2. It is worth noting that there may be some areas in the pit which are below 164m R.L. which may be isolated from the main pit lake. The volume contained in these areas is only about 3000 BCM with a surface area of about 1000 square metres, and are considered insignificant for the purposes of this study.

3. FIELD AND LABORATORY ASSESSMENT

3.1 Geological Mapping

A map of the pit walls was prepared, in conjunction with the Yandan Gold Mine Mine Geologist, to reflect sulphide alteration of the pit wall rocks, as shown in Figure 3.1. In addition to visual methods, results from ore control sampling were used to identify the respective areas. Based on the mapping and a digital terrain model of the open pit, the actual wall rock surface area (m²) was determined for each alteration type identified. The estimated wall rock surface areas, as a function of elevation, are summarised in Table 3.1 for each alteration type.

Table 3.1
Summary of Estimated Wall Rock Surface Exposure for Each Alteration Type

Elev. (RL) (m)	Siliceous Oxide (m ²)	Siliceous Fresh High Sulphide (m ²)	Siliceous Carbonate (m ²)	Mod. clay and Siliceous / Moderate to Strong Sulphide (m ²)	Moderate to Strong Siliceous / Sulphide (m ²)	Strong Clay Alt. Oxide (m ²)
110	0	0	0	0	0	0
115	0	1937	0	0	532	0
120	679	4467	0	0	1135	0
125	2676	8366	0	0	3370	0
130	6282	10677	0	0	5498	0
135	10141	12329	0	0	12556	2738
140	13011	12729	860	41	22346	6845
145	15260	12910	2150	459	30469	11225
150	16365	12910	3440	2936	33980	16884
155	18711	12910	3870	6169	35115	25280
160	19390	12910	4300	8687	35470	34224
165	19390	12910	4300	10196	35470	47457

The map also includes estimates of the areas and volumes of waste rock (in BCM) that was backfilled within the confines of the pit. The waste rock has been placed in two locations. The waste placed in Area 1 (Plate 6) comprises a mixture of sulphidic and oxide material, which originated from various locations within the pit. Area 2 contains predominantly fresh high-sulphide material that has been mined from the western, deeper section of the pit (Plate 7). Area 1 was developed before Area 2, and consequently has been oxidizing for a longer time. For the purposes of this evaluation, the volume estimates for the two sulphide waste rock dumps (Areas 1 and 2) have been combined, and are summarised in Table 3.2.

Table 3.2
Summary Cumulative Volume of Waste Rock Backfill

Elevation RL (m)	Sulphide Dumps (m³)	Oxide Dumps (m³)
110	0	0
115	2278	0
120	2278	0
125	2278	0
130	2278	0
135	25058	0
140	56950	0
145	85425	0
150	96815	0
155	113900	0
160	113900	2770
165	113900	5540

3.2 *Field Sampling Program*

3.2.1 *Sample Locations*

Locations for sampling were distributed to represent each alteration type. A comparison of the proportion of samples to the relative proportion of wall rock exposure (as percentages) is provided in Table 3.3. The sample distribution approximates the surficial distribution, with the exception of the oxide dump. This material is similar to oxide wall rock and is represented by those samples.

The sample locations were further restricted, where possible, to the upper benches within each alteration type. The upper benches have been in place since the early stages of mining and have oxidized for the longest time period. Therefore, samples from the upper benches are likely to provide above average estimates of solute release, which will result in conservative estimates of solute release during flooding.

The sample locations are illustrated in Figure 3.2.

Table 3.3
Comparison of Sample and Wall Rock Area Distribution

Alteration Description	Area m2	Volume m3	Area Distrib. (%)	Samples (#)	Distrib. (%)
Siliceous Oxide	19390	-	9.3	5	15.6
Siliceous Fresh High Sulphide	12910	-	6.2	2	6.3
Siliceous Carbonate Alteration	4300	-	2.1	2	6.3
Soft. Moderate Siliceous Alteration and Moderate to Strong Sulphide	10196	-	4.9	3	9.4
Moderate to Strong Siliceous and Sulphide Alteration	35470	-	17.1	6	18.8
Strong Clay Altered Oxide	91264	-	44.0	7	21.9
Sulphide Waste Dump	19570	113900	9.4	6	18.8
Oxide Waste Dump	14500	55400	7.0	1	3.1
Total	207600	169300	100.0	32	100.0

3.2.2 Sampling

Samples representing the alteration types exposed on the wall rocks were taken from loose rubble and fines that had accumulated on the pit benches. The samples representing the waste rock dumps are composites that were prepared from grab samples taken approximately evenly distributed over set areas of the dumps, such that the composite samples together represent the entire dump area. The grab samples were composited on an equal weight basis.

Samples were prepared in the field by removing obvious oversize material, and hand screening to less than 8 mm. Approximately 2 kg of the less than 8 mm material was retained for further testing.

3.3 Testing

3.3.1 Field Testing

Field Testing comprised paste pH and conductivity measurements. The paste parameters were obtained by combining a representative sub-sample of the less than 8 mm size fraction material with distilled water. The paste was prepared by mixing approximately 65 mL (approximately 100 g) of the solids with 100 mL of distilled water to give a solid:liquid ratio of about 1:1. The slurry was well mixed, and then the solids were allowed to settle. The supernatant pH and conductivity measurements were obtained with handheld field equipment.

3.3.2 Laboratory Testing

Laboratory testing included leach extraction tests, and size distributions, were obtained for each of the samples. In addition, sulphur, sulphate and carbonate analyses of the solids were completed for selected samples. Testing methods are summarized below.

3.3.3 Leach Extraction Tests

The leach extraction tests were completed on representative sub-samples of 750 g. The solids were placed in a 5 litre roll bottle, 1 500 mL distilled water was added, and the slurry was agitated on rollers for 24 hours. The roll bottles were then removed from the rollers, and the solids were allowed to settle. The supernatant pH and conductivity were measured and recorded. Clear supernatant was decanted and analyzed for the total concentrations of the solute parameters given in Table 3.4

The leach extraction tests were completed at the Yandan Mine. Sulphate, chloride calcium, magnesium, total alkalinity and acidity analyses were completed on site while analysis of the remainder of the solutes was contracted to Australian Laboratory Services (ALS) in Brisbane.

Table 3.4
Leach Extraction Test Parameters

Leachate Solute Parameters	
Acidity	Al
Alkalinity	Fe
SO ₄	As
Cl	Cu
Ca	Mn
Mg	Ni
	Pb
	Zn
	Hg
	Na
	K

3.3.4 *Size Distributions*

Standard sieving procedures were followed to determine the size distribution for each sample. Screen sizes that were selected included 3.35 mm, 1.7 mm, 0.85 mm, 0.425 mm, and 0.212 mm.

3.4 *Results*

3.4.1 *Field Paste Parameters*

The field parameters are summarised in Table 3.5 according to the alteration type. A good correlation is observed between the field parameters and alteration. Lower pH values tend to be associated with strong sulphide alteration, while near neutral conditions are observed for the oxides. The sulphide waste rock placed in Area 1 exhibited lower paste pH values than were observed for Area 2. This is consistent with relative duration of oxidation in the respective areas.

3.4.2 *Size Distributions*

Detailed results for the grain size distributions of each sample are presented in Appendix C. The grain size distributions were used for specific surface area calculations, as discussed below.

3.4.3 *Leach Extraction Test Results*

The leach extraction test results are summarized in Table 3.6. Detailed results are provided in Appendix D.

As the detailed results show, with respect to leachant pH, samples within the same alteration type showed little variation. However, this is not always the case with respect to leachant solute concentrations. Variability is most evident in samples from the siliceous oxide alteration and the moderate to strong siliceous oxide / sulphide alteration groups. For example, sulphate concentrations range from less than 1000 mg/L to several 1000 mg/L within the same group. Similar variability is also seen in some of the trace metal concentrations for these alteration types. For the remainder of the alteration groups variability in solute concentrations is limited, as is apparent from the similarity between the average and maximum concentrations.

Table 3.5
Summary of Field Parameters

Alteration	Sample #	Paste Parameters	
		pH	Conductivity mS/cm
Siliceous Oxide	YD-11	3.9	0.8
	YD-15	1.1	3.3
	YD-16	4.5	0.1
	YD-18	2.4	1.3
	YD-20	3.9	0.2
Siliceous Fresh High Sulphide	YD-12	1.8	5.2
	YD-17	1.1	5.3
Siliceous Carbonate	YD-13	5.9	0.1
	YD-14	4.9	0.3
Mod. clay and Siliceous / Moderate to Strong Sulphide	YD-4	2.1	7.9
	YD-5	2.2	13.2
	YD-26	0.9	4.0
Moderate to Strong Siliceous / Sulphide	YD-6	1.8	3.4
	YD-8	3.1	0.4
	YD-9	2.6	1.9
	YD-10	1.8	4.8
	YD-19	0.5	5.5
	YD-21	5.2	0.4
Strong Clay Altered Oxide	YD-1	5.9	2.4
	YD-2	6.8	6.3
	YD-3	6.3	2.2
	YD-23	5.8	0.1
	YD-25	5.2	0.1
	YD-28	5.2	1.6
	YD-29	5.3	0.6
Sulphide Dump - Area 1	YD-22	1.5	4.5
	YD-24	1.5	3.7
	YD-27	1.2	2.8
Sulphide Dump - Area 2	YD-7	2.5	2.8
	YD-31	2.7	2.1
Oxide Dump	YD-30	5.8	0.8

Concentrations of arsenic, copper, nickel, and zinc were elevated in several alteration types. Arsenic concentrations were elevated in leachates from the moderate to strong sulphide alteration types, but, in contrast, were not elevated for the sulphide waste rock dumps. Zinc concentrations, similar to iron and copper, were elevated in all but the oxide and siliceous carbonate alteration types.

Leach extraction tests are reasonably accurate for estimating the potential for solute release from rock samples, provided solubility controls do not limit the dissolution of potentially soluble secondary mineral phases. Therefore, to assess the potential for solubility controls, saturation indices were calculated for selected tests, using the US EPA speciation model, MINTEQA2. Calculated saturation indices can be used to determine if an aqueous phase is in

equilibrium with a secondary mineral phase, or alternatively, assess the potential for a secondary mineral phase to precipitate from solution. A negative saturation index for a secondary mineral phase indicates that the solution is not in equilibrium with the secondary mineral phase. A positive value indicates that the aqueous solution is supersaturated with respect to that mineral phase and, therefore, that the secondary mineral phase may be precipitated from solution. A saturation index equal to zero suggests that the aqueous phase is in equilibrium with that mineral phase.

Abbreviated MINTEQA2 input and output files are provided in Appendix E. The results are summarized in Table 3.7. Leachant compositions assessed with the MINTEQA2 model, were selected from the leach extraction tests to represent the alteration types that are likely to dominate the pit lake water quality, i.e. the alterations with the highest wall exposure and/or highest solute concentrations. It should be noted that the MINTEQA2 model calculates saturation indices for all the secondary mineral phases that are contained in its database. However, not all these phases may be formed under ambient conditions. The summary presented in Table 3.4, therefore, contains a selection of phases that are considered applicable to the system under consideration.

The results show that the calculated saturation indices are below zero for all phases for acidic leachates associated with the sulphide altered materials (YD10 and YD24) as well as the siliceous oxide (YD18). This indicates that, for these materials, solute concentrations are not solubility controlled and that the leach extraction tests are effective in indicating the potential for solute release. In contrast, calculated saturation indices suggest that the strong clay altered oxide (YD23) and oxide dump (YD30) materials exhibit solubility controls with respect to aluminium and iron, predominantly as hydroxide and oxy-hydroxide phases. These samples generated leachates at circumneutral pH conditions. The implications of these results are discussed further in Section 4.

3.4.4 Solids Analysis

Solids analyses for selected samples are summarised in Table 3.8. All but YD04 represent strong clay altered oxide samples taken from the upper benches of the pit.

The results confirm the field observations and leach extraction test results in that these samples do not exhibit a potential for net acid generation. Therefore, acid generation and solute release from the strong clay altered oxide pit wall rocks that will remain above the pit lake, do not represent a concern.

Sample YD04 represents the sulphide altered wall rock (Mod. Clay and Siliceous / Moderate to Strong Sulphide Altered Unit) that could be exposed to oxidizing conditions for short periods, as discussed in Section 4.6. As indicated by the leach extraction tests, the neutralization potential (NP) of the material has been depleted, and it has a significant potential for acid generation (AP). The magnitude of the net neutralization potential (NNP), which is the difference between the NP and the AP, is comparatively small and may only result in short term impacts, should exposure of this rock pose a problem.

3.4.5 *Quality Assurance and Control*

As part of the analytical program, a blank was prepared and analyzed, and duplicate analyses of 4 tests were completed. A comparison of the results is provided in Appendix F. The blank sample showed no appreciable solute concentrations and duplicate analyses were found to correlate well.

Table 3.6

Summary of Leach Extraction Test Results – Solute Analyses of Leachates

Alteration		pH*	Cond. (mS/cm)	Acidity	Alkalinity	SO4 mg/L	Cl mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Al mg/L	Fe mg/L	As mg/L	Cu mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L	Hg mg/L
Siliceous Oxide	Average	3.6	2.43	854	6	2008	57	192	122	49	16	55	324	3.9	4.7	35	2.2	<0.002	4.0	0.0005
	Maximum	2.2	6.12	3178	6	7366	172	506	382	115	32	195	1580	19.2	20.8	141	8.4	<0.002	16.4	0.0012
Siliceous Fresh High Sulphide	Average	1.9	8.85	4101		6730	32	108	58	43	11	223	1925	57.7	1.9	2.1	7.2	0.003	18.0	0.0015
	Maximum	1.8	9.17	4434		7351	52	170	85	60	20	261	1980	65.3	2.1	3.0	7.4	0.005	20.6	0.0016
Siliceous Carbonate	Average	6.3	0.89		49	396	64	73	30	54	22	<0.10	0.4	0.03	0.004	0.9	0.04	0.002	0.1	<0.0003
	Maximum	5.0	1.17		96	617	107	82	39	91	26	<0.10	0.6	0.04	0.005	1.6	0.08	0.003	0.1	0.0005
Mod. clay and Siliceous / Moderate to Strong Sulphide	Average	1.9	11.81	3518		9172	1137	267	276	1124	7	305	1787	50.8	25.1	13	18	0.006	46.8	0.0034
	Maximum	1.9	13.39	5372		11895	1734	452	417	1690	11	383	2460	73.4	58.5	31	22	0.010	82.1	0.0066
Moderate to Strong Siliceous / Sulphide	Average	2.9	5.72	3004	5	4242	32	87	47	39	23	<173	<1050	32.6	4.9	3.7	3.2	0.002	8.7	<0.0040
	Maximum	1.6	12.02	6042	5	8479	59	293	101	103	56	419	2570	70.6	15.8	17	5.6	0.003	19.0	0.0150
Strong clay altered oxide	Average	7.6	2.50		43	185	655	107	57	358	18	0.3	<0.13	0.02	0.01	0.1	0.0	0.002	0.1	<0.0008
	Maximum	6.5	5.82		81	469	1751	347	139	778	39	1.1	0.50	0.05	0.01	0.2	0.0	0.003	0.1	0.0040
Sulphide Dump – Area 1	Average	2.3	6.72	1398		3582	532	266	145	340	21	163	526	2.6	8.6	7.4	14	0.004	68.9	<0.0001
	Maximum	2.2	7.27	1550		4206	961	353	182	577	39	215	715	4.6	11.1	15	18	0.006	86.1	0.0001
Sulphide Dump – Area 2	Average	2.3	4.05	988		1762	128	127	49	103	39	87	392	1.9	1.7	0.4	11	0.003	17.8	0.0019
	Maximum	2.3	4.23	1080		2161	168	131	54	135	46	101	417	2.5	3.3	0.5	12	0.004	33.3	0.0022
Oxide Dump		8.4	1.27		86	95	276	22	22	206	16	<0.1	<0.01	0.057	0.005	0.003	<0.001	0.003	0.044	<0.0001

Note: Average = arithmetic average.

* Minimum values reported in rows designated as maximum;

Acidity and Alkalinity in units of mg CaCO₃ eq/L

Table 3.7
Summary of Calculated Saturation Indices

Phase	Saturation Index				
	YD-10	YD-18	YD-23	YD24	YD-30
$\text{Al}_4(\text{OH})_{10}\text{SO}_4$			6.524		
$\text{Al}(\text{OH})_3$ (A)		-6.143	1.020		-1.616
$\text{Al}(\text{OH})\text{SO}_4$	-0.532	-0.211	-1.746	-0.244	
Alunite	-5.726	-2.18	5.699	-3.891	
Anglesite	-3.198	-3.259	-3.926	-2.763	
Anhydrite	-1.558	-0.486	-2.589	-0.375	-2.117
$\text{Cu}(\text{OH})_2$			-2.635		-2.064
Diaspore	-4.862	-2.636	4.527	-3.868	1.891
$\text{Fe}_3(\text{OH})_8$					0.186
Ferrihydrite			-2.067		0.947
Gibbsite (C)		-4.533	2.63	-5.766	-0.006
Goethite			2.325		5.339
Gypsum	-1.349	-0.275	-2.378	-0.165	-1.906
Jarosite K					-2.967
Lepidocrocite			1.454		4.468
$\text{Ni}(\text{OH})_2$			-4.437		-2.239
$\text{Pb}(\text{OH})_2$ (C)			-3.49		-0.055
Tenorite			-1.615		-1.044
$\text{Zn}(\text{OH})_2$ (A)			-5.402		-2.234

Table 3.8
Summary of Solids Analyses and Calculated Potential for Acid Generation

Sample	Analysis					Calculated			
	SO4 - Total	S - Total	TOC	TIC	TC	AP	NP	NNP	NP:AP
	ED-040T (%)	ED-042T (%)	EP-005 (%)	EP-006 (%)	EP-007 (%)				
YD02	0.11	0.04	<0.01	<0.01	<0.01	0.1	0.2	0.1	1.60
YD03	0.13	0.05	0.02	<0.01	0.02	0.2	0.2	0.0	0.80
YD04	3.04	2.04	0.03	0.02	0.05	32.1	0.3	-31.8	0.01
YD29	0.09	0.02	0.01	0.04	0.05	(0.3)	0.7	0.7	-
YD30	0.05	0.03	0.03	0.18	0.21	0.4	3.0	2.6	7.20

Note: units of NP, AP, and NNP in kg $\text{CaCO}_3\text{eq/tonne}$

4. PIT LAKE WATER QUALITY

4.1 *Estimation of Solute Release During flooding*

The leach extraction tests provide a measure of the potential for solute release from each of the alteration units exposed in the wall rocks, and from the waste rock backfill. The leach extraction test results were used to first calculate solute release from the waste rock backfill and the wall rocks respectively, and then combined to calculate solute concentrations in the pit lake during flooding, as described in Appendix G.

4.2 *Estimated Solute Release*

4.2.1 *Waste Rock Backfill*

For ease of calculation, the leach extraction test results for both Area 1 and Area 2 of the waste rock backfill were averaged to provide a single release rate that was applied to both areas. This approach clearly is conservative for Area 2. It should be noted that the composite samples for testing were obtained from the surface of the waste rock dumps. Experience elsewhere has shown that waste rock on the surfaces of dumps tend to oxidize more rapidly than the bulk of the material within the dump (e.g. Ritchie 1994), and as little as 20 percent of the waste rock may have oxidized. Therefore, using the slightly lower estimate that results from all the samples, to reflect average conditions, is considered reasonable.

The solute release rates for the waste rock, calculated from the leach extraction tests are summarised in Table 4.1, which shows the average and the maximum calculated values. The results for the strong clay altered oxide materials have also been included in this table to enable a comparison with the sole sample representing the oxide waste rock backfill. Detailed results are provided in Appendix H.

4.2.2 *Wall Rocks*

The specific solute release rates calculated from the leach extraction test results are summarised in Table 4.2. The table shows the average and maximum specific release rate for each alteration type. Detailed results are provided in Appendix H.

4.3 *Flood Elevation*

A monthly water balance calculations were completed for the flooding of the pit as follows:

$$PLV_t = SRS_t + PPT_t - EVP_t \quad (9)$$

Where PLV = Pit lake volume (m^3);

SRS = Volume of water scavenged from the Suttor River (m^3);

PPT = Volume of water contributed by direct precipitation (m^3);

EVP = Evaporative losses (m^3); and,

Subscript t refers to the end of the applicable month.

As stated before, the scope of work did not include a hydrogeological assessment, and hence any groundwater recharge / discharge was not considered in this assessment. Groundwater recharge will contribute to reflooding during the initial stages.

To estimate the evaporative losses, the pit lake surface area was determined from the volume of the water in the pit lake for the preceding month. It was further assumed that all of the precipitation that fell within the pit perimeter would enter the lake. No additional runoff was allowed, since there are no incremental catchments that may contribute inflow, and since upon decommissioning of the site a diversion berm will be constructed to prevent runoff entering along the access ramp.

Table 4.1
Summary of Solute Release Rates Estimated for Waste Rock Backfill

Rock Type	H ⁺ Mol/kg	Acidity mg/kg	Alkalinity mg/kg	SO ₄ mg/kg	Cl mg/kg	Al mg/kg	Fe mg/kg	As mg/kg	Cu mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg
Strong clay Ave	0.000		85	371	1309	0.51	0.26	0.05	0.02	0.12	0.02	0.00	0.10	0.002
altered oxide Max	0.000		162	938	3502	2.20	1.00	0.10	0.03	0.45	0.05	0.01	0.26	0.008
Sulphide Ave	0.010	2467		5707	740	265	944	4.59	11	9.19	258	0.01	97	0.002
Backfill Max	0.013	3100		8412	1922	430	1430	9.24	22	30.80	36	0.01	172	0.004
Oxide Backfill (YD-30)	0.000		172	190	552	0.20	0.02	0.11	0.01	0.01	0.002	0.01	0.09	0.0002

Table 4.2
Calculated Specific Solute Release Rates

Rock Type	H ⁺ mol/m ²	Acidity mg/m ²	Alkalinity mg/m ²	SO ₄ mg/m ²	Cl mg/m ²	Al Mg/m ²	Fe mg/m ²	As mg/m ²	Cu mg/m ²	Mn mg/m ²	Ni mg/m ²	Pb mg/m ²	Zn mg/m ²	Hg mg/m ²
Siliceous Oxide Ave	0.0003	108	0.2	399	19	10	49	0.59	0.78	6.6	0.42	0.0004	0.72	0.0001
Max	0.0009	477	1	1106	62	29	237	2.8	3.12	21	1.3	0.0006	2.5	0.0004
Siliceous Fresh High Ave	0.004	1411		2310	10	75	669	19	0.69	0.66	2.5	0.0009	6.1	0.0005
Sulphide Max	0.004	1596		2587	14	78	792	21	0.89	0.83	3.1	0.0014	6.52	0.0006
Siliceous Carbonate Ave	0.000		27	148	23	0.04	0.20	0.01	0.001	0.33	0.01	0.0008	0.02	0.0002
Alteration Max	0.000		53	201	35	0.06	0.33	0.02	0.002	0.52	0.03	0.0010	0.03	0.0003
Soft. Mod. Siliceous Ave	0.002	657		1714	205	57	334	9.3	4.3	2.4	3.4	0.0012	9.6	0.0006
and Mod. to Strong Max	0.003	849		2040	274	69	388	12	9.3	6.1	4.3	0.0020	19	0.0010
Sulphide														
Mod. Strong Siliceous Ave	0.003	808	0.4	1517	13	77	335	10	2.1	0.99	1.2	0.0008	3.7	0.0014
and Sulphide Alt. Max	0.005	1603	3	2505	23	248	668	27	6.6	3.4	3.3	0.0013	11	0.0050
Strong clay altered Ave	0.000		12	37	122	0.10	0.05	0.01	0.003	0.02	0.003	0.0005	0.02	0.0001
oxide Max	0.000		22	101	368	0.52	0.24	0.01	0.006	0.05	0.011	0.0013	0.06	0.0006

In order to limit continued oxidation of the sulphide alterations, pit flooding should be completed as soon as possible, to the maximum possible level. Similarly, to prevent long term solute release, the pit lake level should be sustained at the maximum level possible. Therefore, in the pit water balance assessment, the following issues were addressed:

- 1) How long the flooding may be delayed for this year (1999), and what proportion of the flow in the Suttor would need to be scavenged to still achieve a reasonable flood level to limit oxidation of the sulphide alteration zones.
- 2) Potential pit lake level fluctuation in the long term.
- 3) Potential pit wall exposure of sulphide alteration zones above the lake level, and the associated requirement for capping, if any, for such zones.

Estimated Maximum Delay

Water balance calculations were completed for both median and average flow conditions in the Suttor River. The results are summarized in Table 4.3. Based on recent rainfall data, these estimates may be used to evaluate the flooding requirements.

As indicated in the table, for median flow conditions approximately 70 percent of the flow in the Suttor would need to be diverted to the pit if the flooding is delayed to the beginning of April. This would not be acceptable. Conditions are more favourable if flooding commences at the beginning of March, and as little as 4 percent of the flow in the Suttor would need to be scavenged to achieve flooding. For average flow conditions, flooding could be postponed to as late as June, while only 10 percent of the flow in the Suttor would need to be scavenged.

It should be noted that these flooding rate estimates considered only the volume of the pit. Porevolume within the desaturated wallrocks may be significant (as indicated by vugs observed in the host rocks) and could significantly impact on the rate of flooding.

Estimated Long Term Fluctuations

It is assumed that once flooding of the pit has been achieved, any isolating structure would be removed such that the pit lake becomes part of the Suttor River. This means that the channel

nearest the pit may flow directly into the pit to make up evaporative losses, and any potential discharge to groundwater. (It is uncertain where the pre-development water table was located, and the development of the pit may have resulted in a draw-down area.)

Assuming conservatively that the channel nearest the pit carries only 30 percent of the total flow in the Suttor River, water balance calculations for average flow conditions indicate that the pit lake will remain at its maximum level year round. However, under median flow conditions, no flow is expected for the months of July through October. Under these conditions the lake level may drop by about 0.5 to 1 meter. The corresponding total volume change is small and the lake level will recover rapidly at the onset of the wet season. For example, a decrease in the pit lake level of 1 m during the dry period (to the end of October) represents about 126 000 m³, which equals less than 1 percent of the average monthly flow in the Suttor River for November. This demonstrates that once the pit is filled, the volume of water required to sustain the lake, thereafter, is small.

Under drought conditions the pit lake level is likely to drop below the above estimate.

Pit Wall Exposure

The long term water balance suggests that under average conditions the pit lake will be sustained at about 164.6 m RL. For median flow conditions, the pit lake level may decrease by about 0.5 to 1 m. Within this range, only strong clay altered oxide pit wall rocks will be exposed, and continued oxidation is not a concern.

Under severe drought conditions, the pit lake level may drop by several meters. However, based on the pit alteration type exposure on the pit walls, a decrease in excess of 5 m has to occur before any significant surface areas of sulphide alteration will be exposed. The alteration that will be exposed is the Moderate Clay and Siliceous – Moderate to Strong Sulphide Alteration type, which is acid generating. The potential impact from this exposure is discussed in Section 4.6.

Table 4.3
Summary of Estimated Monthly Water Balance and Flood Elevaion

Month	Fraction Scavenged (m ³)	Inflow from Suttor (m ³)	Evaporation (m ³)	Precipitation (m ³)	Cummulative Volume (m ³)	Flood Elevation (m RL)
MEDIAN FLOW CONDITIONS						
January						
February						
March	0.04	2497068	-4049	13879	2506898	163
April	0.04	117369	-14278	11790	2582675	164
May	0.04	2766	-11394	7169	2581216	164
June	0.04	7271	-9320	3955	2582675	164
July	0.04	0	-11394	1811	2573092	164
August	0.04	0	-14474	5600	2564218	164
September	0.04	0	-19608	1277	2545887	164
October	0.04	0	-27760	6043	2524170	163
November	0.04	220985	-27636	9388	2582675	164
December	0.04	1792184	-27968	12577	2582675	164
January						
February						
March						
April	0.70	2053952	-2983	11790	2062758	160
May	0.70	48410	-10082	7169	2108256	160
June	0.70	127248	-8352	3955	2231107	161
July	0.70	0	-10536	1811	2222382	161
August	0.70	0	-13380	5600	2214602	161
September	0.70	0	-18124	1277	2197754	161
October	0.70	0	-25646	6043	2178152	161
November	0.70	3867239	-25519	9388	2582675	164
December	0.70	31363222	-27968	12577	2582675	164
AVERAGE FLOW CONDITIONS						
January						
February						
March						
April						
May						
June	0.10	2611255	-1918	3955	2582675	164
July	0.10	529147	-11394	1811	2582675	164
August	0.10	696111	-14502	5600	2582675	164
September	0.10	438749	-19681	1277	2582675	164
October	0.10	899925	-27968	6043	2582675	164
November	0.10	1507022	-27968	9388	2582675	164
December	0.10	7745443	-27968	12577	2582675	164

4.4 Calculated Pit Lake Water Quality

*Subsided
backfill
2000m long
2000m wide
plate*

4.4.1 Calculation Inputs

The primary inputs to the calculation of solute release from the pit wall rocks comprise the specific solute release rates estimated from the leach extraction tests, and the ratio between the pit wall exposure and reactive surface area. As discussed in Section 3.4.3, solubility controls were not indicated for the different alteration types that are likely to determine the pit lake water quality, indicating that the leach extraction tests provide reasonable estimates of solute releases.

The ratio of the reactive surface area to the wall exposure area however is not that easily determined. A study carried out in three open pits measured ratios of reactive surface area to pit wall area ranging from 27:1 to 161:1 (Morin and Hutt, 1995). While the pit benches at Yandan are relatively free of accumulated rubble and fines, the wall rocks generally are very fractured, as shown in Plates 2 to 6 (representing each of the alteration areas). Therefore, it is anticipated that the ratio for Yandan would fall in the upper quartile of this range. For simplicity, a ratio of 130 was adopted for all of the alteration types.

The primary input for the calculation of solute release from the backfilled waste rock is the solute release rates, which are estimated directly from the leach extraction tests. However, it is important to note that the solute release rates have been obtained from leach extraction tests completed on the less than 8 mm fraction of the waste rock. Based on field observations, and the hand screening completed in the field, it is estimated that the waste rock backfill has a size distribution of about 25 to 35 percent less than 8 mm, and 100 percent less than 600 mm. The specific surface area of the oversize material is small in comparison, and it is estimated that the plus 8 mm size fraction represents less than 1 percent of the reactive surface area. The solute release rates obtained from the leach extraction tests were therefore corrected, assuming an upper bound size distribution of 40 percent less than 8 mm for all samples.

4.4.2 *Estimated Pit Lake Water Quality*

The estimated water quality in the pit lake as the flood level rises is summarised in Table 4.4. The results are also illustrated in Figures 4.1 (pH), 4.2 (sulphate and iron) and 4.3 (selected trace metals). These calculations assume that the pit water will be fully mixed as the level rises, and represent the average solute concentrations in the entire water body. This assumption is reasonable for at least the initial stages of flooding since large volumes of water from the Suttor River will be cascading down the pit walls, causing mixing of the water body. As the level rises, the energy for mixing will decrease due to the reduced elevation difference, and the impact on the larger water body will decrease.

The results show that solute concentrations are expected to increase rapidly during the initial flooding period. This is as a result of a high solute loading from the fresh sulphides at the base of the pit, and a comparatively low dilution from the flooding waters. After this initial increase, concentrations are expected to decrease as additional dilution is provided by the flooding waters. Once an elevation of about 130 m RL is reached, however, concentrations are expected to increase again as a result of the relatively high solute release expected from the oxidized waste rock present at about this elevation. As the flood level rises above this level, the ratio of flood water to solute release increases, resulting in decreasing concentrations. Concurrently, the relative surface area of the sulphide alterations decrease, and that of the oxides (low solute release) increases. Thus a decrease in solute concentrations results.

As discussed above, the physical mechanism for mixing decreases as the flood level rises. Furthermore, it is estimated that the majority of the solute release occurs at lower elevations. Therefore, it is considered possible that a chemocline may develop in the pit lake. However, assuming fully mixed conditions, the pit lake water quality immediately before reaching the spill elevation (i.e. estimated water quality provided for 164 m R.L. in table 4.4) is expected to exhibit an acidic pH of about 3.5 and contain trace metal concentrations elevated above those observed in the Suttor River.

4.4.3 Discussion of Results

Approximately 95 percent of the solute release to the pit lake originates from the sulphide waste rock backfill. This means that the calculation of solute concentrations in the pit lake is insensitive to the estimated ratio of reactive surface area to exposed surface area for the wall rock. For example, increasing the ratio from 130 to 160 results in the estimated sulphate concentration increasing from 211 to 213 mg/L, which is negligible.

Since the estimated water quality is dominated by solute release from the waste rock, it is conservative for the following reasons:

- Leach extraction tests were completed on samples taken from the surface of the waste rock backfill and, consequently, the bulk of the waste rock is likely to exhibit lower solute release rates.
- As shown on Plates 6 and 7, the waste rock backfill surface is dressed as each lift is placed, and the surface is compacted due to heavy vehicle traffic. (There is however a portion of Area 1 that has been end dumped without surface dressing). Compaction will result in decreased permeability, and the free movement between pore and lake water will be restricted such that not all of the solutes available for dissolution will be released to the pit lake.
- The water quality estimates do not consider the effects of alkalinity that may be associated with the flooding waters. The alkalinity will result in partial neutralization of acidity, and may even lead to precipitation reactions within the pore space of the waste rock, which may further “seal off” pore water from lake water.

A comparison of the estimated pit lake water quality when the pit is fully flooded (Table 4.3) with the background water quality in the Suttor River (Table 2.5) suggests that if no remediation is undertaken, the pit lake water could adversely impact the water quality in the Suttor River. However, to accurately estimate the impacts from pit lake discharge on water quality in the Suttor River would require accurate estimates of typical rates of change in water level and corresponding flow volumes in the Suttor River at the minesite. These data are not available. Therefore, various control options have been identified and evaluated as follows.

i) *Controlled Discharge*

The first option is to increase the channel invert above the river level to increase the base flow in the river for which discharge could occur. This would also decrease volume of exchange with the river, and thus the volume of discharge that might occur from the pit. This 'spillway' would need to be maintained until such time that solute concentrations in the pit lake had decreased to acceptable levels. However, accurate prediction of the rate of discharge as a function of the flow in the Suttor River will require streamflow and flood elevation data for the Suttor at the site, which currently are not available.

ii) *Control of Solute Release from Sulphide Waste Rock Backfill*

Since more than 95 percent of the solute loading is expected from the sulphide waste dumps, solute release can most effectively be controlled if the waste rock pore water can be restricted from interacting with the pit lake.

Compacting the outer surface of the waste rock will reduce the permeability of the outer layer, thus decreasing the pore – pit lake water interaction, provided there are no hydraulic gradients that will displace pore water from the waste rock. However, considering the size distribution of the backfill, and segregation of rock during placement, compaction will likely have a limited effect on the rate of solute release from the waste rock.

Alternatively, a cover can be placed to control solute release. The purpose of the cover would not necessarily be to hydraulically isolate the rock from the pit lake, but rather to restrict solute release rates equivalent to molecular diffusion rates. This can be achieved by placing a simple soil cover, provided that it covers the whole dump, including sideslopes. While compaction of the soil cover will not be essential, some protection against erosion may be required.

The potential solute release rates were estimated for different soil cover thicknesses, as follows:

$$N_A = D \frac{dC}{dx} \quad (10)$$

Where N_A = rate of flux (moles / cm² / s)

D = diffusion coefficient (cm²/s)

C = concentration (mole / cm³)

x = distance in the direction of flux (cm), i.e. cover thickness.

The effective diffusion coefficient will depend on the properties of the soil cover (tortuosity), and may be an order of magnitude or more lower than the diffusivity of an electrolyte in water. Typically, the diffusion coefficient of strong electrolytes in water range from 1×10^{-5} to

$3 \times 10^{-5} \text{ cm}^2/\text{s}$. The solute concentrations within the pore water of the waste rock were estimated from the leach extraction test results by correcting for the difference in liquid to solid ratio. For this calculation it was assumed that the waste rock has a porosity of about 30 percent. Furthermore, it was conservatively assumed that the solute concentrations in the pit lake were zero, resulting in a maximum solute concentration gradient. Total solute release was estimated by multiplying the flux (from Eq. 10) with the total surface area of the sulphide waste dumps. The calculations also assume complete mixing. The results from these calculations are summarized in Table 4.5.

Table 4.5

Effect of Diffusional Transport on Pit Lake Water Quality 1 year After Flooding

Parameter	Units	Guideline	Wall Rock	Waste Rock Cover					
Soil Cover	m			0.2	0.2	0.3	0.4	0.5	0.5
D_{eff}	cm^2/s			$1.0\text{E-}05$	$5.0\text{E-}06$	$1.0\text{E-}05$	$1.0\text{E-}05$	$1.0\text{E-}05$	$5.0\text{E-}06$
pH			5.0	-	-	-	-	-	-
SO_4	mg/L		15	27	21	23	21	20	17
Cl	mg/L		9	13	11	12	11	10	10
Ca	mg/L		11	13	12	12	12	12	11
Mg	mg/L		6	8	7	7	7	7	6
Na	mg/L		13	18	15	16	15	15	14
K	mg/L		6	6	6	6	6	6	6
Al	mg/L		0.23	2.3	1.2	1.6	1.2	1.04	0.63
Fe	mg/L	Na	16	19	17	18	17	17	16
As	mg/L	0.05	0.040	0.052	0.046	0.048	0.046	0.045	0.042
Cu	mg/L	0.005	0.017	0.055	0.036	0.042	0.036	0.032	0.024
Mn	mg/L	0.1	0.010	0.045	0.027	0.033	0.027	0.024	0.017
Ni	mg/L	0.015-0.15	0.017	0.108	0.063	0.078	0.063	0.054	0.036
Pb	mg/L	0.005	0.000004	0.000012	0.000008	0.000009	0.000008	0.000007	0.000006
Zn	mg/L	0.005-0.05	0.039	0.35	0.19	0.24	0.19	0.16	0.10
Hg	mg/L	0.0001	0.000004	0.000005	0.000004	0.000005	0.000004	0.000004	0.000004

The column "Wall Rock" in Table 4.5 represents the pit lake water quality immediately after flooding when a suitable cover is placed on the waste rock, and solute release occurs only from the wall rocks. As shown, the water quality in general would meet guidelines for the protection of fresh water aquatic life, with the exception of copper. Copper is approximately 3 times higher than the guideline, however, at this concentration is unlikely that sufficient release of the pit lake water could occur to impact the water quality in the Suttor. Iron concentrations are similar to those observed in the Suttor.

The next two columns in the table consider the placement of a 0.2 m cover, with first an effective diffusion coefficient of $1 \times 10^{-5} \text{ cm}^2/\text{s}$. The second calculation was performed at a lower effective diffusion coefficient. These calculations consider the total solute release after one year, but do not allow for any exchange of water between the pit lake and the river, i.e. dilution of the pit lake is not factored into the calculations. Furthermore, the calculations

were completed at a fixed rate of flux. In reality, as solutes are depleted from the outer zones of the waste rock, the rate of flux will slow with time.

As shown, the copper concentration would increase to in excess of ten times the guidelines value, and that of zinc about seven times. Using, a lower effective diffusion coefficient, which is considered more appropriate, clearly results in a lower impact. At a cover thickness of about 0.5 m, the incremental solute loadings to the pit lake would be limited substantially. Further control of these solutes can be achieved by mixing small amounts of lime with the soil, or spreading a thin layer of lime over the waste rock before the soil cover is placed. This will result in localized areas of high pH, which will result in the precipitation of both zinc and copper, and other secondary mineral phases. Thus solute release will effectively be limited.

Other options that were considered included alkali addition to the inflow during flooding. However, this option was discounted because of i) the inefficiency in alkali utilization for the uncontrolled conditions that will exist during flooding, ii) the potential risk in overdosing, if lime is used as an alkali, that may result in unacceptable elevated pH conditions, iii) the limited efficiency of limestone to control some solute concentrations, and, iv) practical considerations for controlling alkali addition during flooding.

In conclusion, the placement of an appropriate soil cover to limit solute release from the backfilled waste rock is expected to result in solute concentrations in the pit lake that should not impact the water quality in the Suttor River adversely.

4.5 Potential Long Term Impacts

In the long term, repeated displacement of pit lake water during flood events will result in a decrease of solute concentrations. However, continued solute generation from pit wall rocks may contribute to solute concentrations.

Water balance calculations suggest that for average flow conditions, pit wall rock exposure will be limited to oxides only. Solute release from the oxides, as indicated by the leach extraction tests, is insignificant and is at a neutral pH. As indicated by the solids analyses, no acid generation is expected from these rocks.

Extreme drought conditions, however, may result in significantly lower pit lake levels. This may result in the exposure of a small area of the 'Moderate Clay and Siliceous and Moderate to Strong Sulphide' alteration wall rocks. Assuming that, under extreme drought conditions, the pit lake level decreases by up to 5 m in elevation, approximately 2 000 m² of potentially

acid generation wall rock might be exposed. Using the estimated solute release for this material, a reactive to exposed surface area ratio of 130, and assuming all the solutes were generated over a 1 year period (which is conservative), then the solute release from this can be calculated as summarized in Table 4.6. This table shows the expected incremental concentrations over the same time period, assuming fully mixed conditions and all the solutes are release to the pit lake. From these estimates, and since oxidation will be limited to extreme drought conditions, it is concluded that the effect of the exposed wall rock is insignificant, and capping of the areas is not required.

Table 4.6
Summary of Estimated Incremental Annual Solute Concentrations
from Exposed Sulphide and Oxide Wall Rocks for Severe Drought Conditions

SO4	Cl	Ca	Mg	Na	K	Al	Fe	As	Cu	Mn	Ni	Zn
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
9	8.5	10	5.9	13	5.7	0.008	14	0.004	0.01	0.0004	0.01	0.02

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 *Conclusions*

The conclusions from this investigation can be summarized as follows:

- Solute release from the sulphidic waste rock backfill is expected to dictate water quality in the pit lake if no remediation is undertaken;
- Solute release will occur predominantly at lower elevations within the pit, and, potentially, a chemocline may develop;
- If no remediation is undertaken, estimates of solute concentrations indicate that the pit lake is likely to be acidic, and will contain elevated concentrations of some solutes;
- Pit lake water balance calculations suggest that the pit lake level, annually, will fluctuate by less than 1 m for average flow and rainfall conditions;
- Based on the estimated fluctuation in pit lake level, sulphide wall rock alterations are expected to be fully submerged for average flow and rainfall conditions; and,
- Extreme drought conditions could lead to larger decreases in pit lake elevation, however, the incremental exposure of sulphidic wall rock is not expected to result in a significant impact on solute concentrations in the pit lake.
- Placement of a soil cover to limit solute release from the backfilled waste rock represents an effective control measure.

5.2 *Recommendations*

The water quality estimates derived herein are conservative. However, the indicated potential for adverse impacts on the water quality in the Suttor River suggests that remediation comprising the placement of a soil cover should be undertaken. The recommended remediation activities are summarized below.

Recommended Remediation

The investigation has shown that the waste rock represents the primary source for solute release to the pit lake. Solute release from the waste rock can be limited by placing a soil cover over the backfill to restrict interaction between the waste rock pore water and the pit lake during and after flooding. Additional control of solute release from the waste rock can be achieved by either amending the soil used in the construction of the cover with lime, or by spreading a thin layer of lime directly on the waste rock before the soil cover is placed.

Based on the conservative estimates of potential solute release by diffusion, it is recommended that a soil cover with a minimum thickness of 0.3 m be placed homogeneously over the waste rock, including the sideslopes. It is also recommended that lime should be spread on the waste rock at a ratio of about 1 kg/m². Erosion protection of the soil cover will also be required prior to and during flooding.

Since this remediation approach directly targets the primary source for solute release, the associated risk is considered to be low. However, it is recommended that provision should be made for the implementation of the following contingencies.

Contingencies

It is recommended that the pit be flooded in a controlled manner, until such time that it can be shown that free movement of water between the pit lake and the river will not adversely impact the river water quality. This can be done by breaching the bund to provide a spillway at 165 m R.L. The breach should be performed in such a way that the channel could readily be sealed to prevent any discharge from the pit lake, if required. During the flooding, water quality in the lake should be monitored continuously at the lake surface and at depth. Once the water quality in the flooded lake has been established, the potential impact on the river can be assessed. If the water quality is acceptable, then the bund can be fully breached and no additional control is required. However, if solute concentrations are unacceptable, a new spillway design may be developed to provide controlled release of pit lake water.

In the event that the pit lake water quality after flooding is unacceptable, the potential for adverse impacts on the Suttor River depends on the interaction between the pit lake and the river. To assess this interaction requires detailed data of the river level at the minesite, the rate of change of the water level during flood events, and the corresponding flows in the river. It is therefore recommended that, should the pit lake water be unacceptable, the necessary information be gathered at site while the pit is isolated from the river by sealing the spillway.

6. REFERENCES

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- Weeks, W.D. 1983. The Calculation of Evaporation in Queensland, *Queensland Division Technical Papers, Institution of Engineers Australia* Vol. 24 No. 4, March 1983.

PLATES

PLATES

Plate 1	Aerial photograph of the Yandan Mine Site and adjacent Suttor River.
Plate 2	Siliceous oxide sample location adjacent to zone of siliceous fresh high sulphide alteration.
Plate 3	Moderate to strong siliceous / moderate to strong sulphide alteration (sample YD 06).
Plate 4	Siliceous carbonate alteration (area of sample YD 13).
Plate 5	Transition between moderate to strong siliceous / moderate to strong sulphide alteration (lower) and siliceous oxide (upper) alteration.
Plate 6	Area 1 sulphide waste rock backfill.
Plate 7	Area 2 sulphide waste rock backfill.

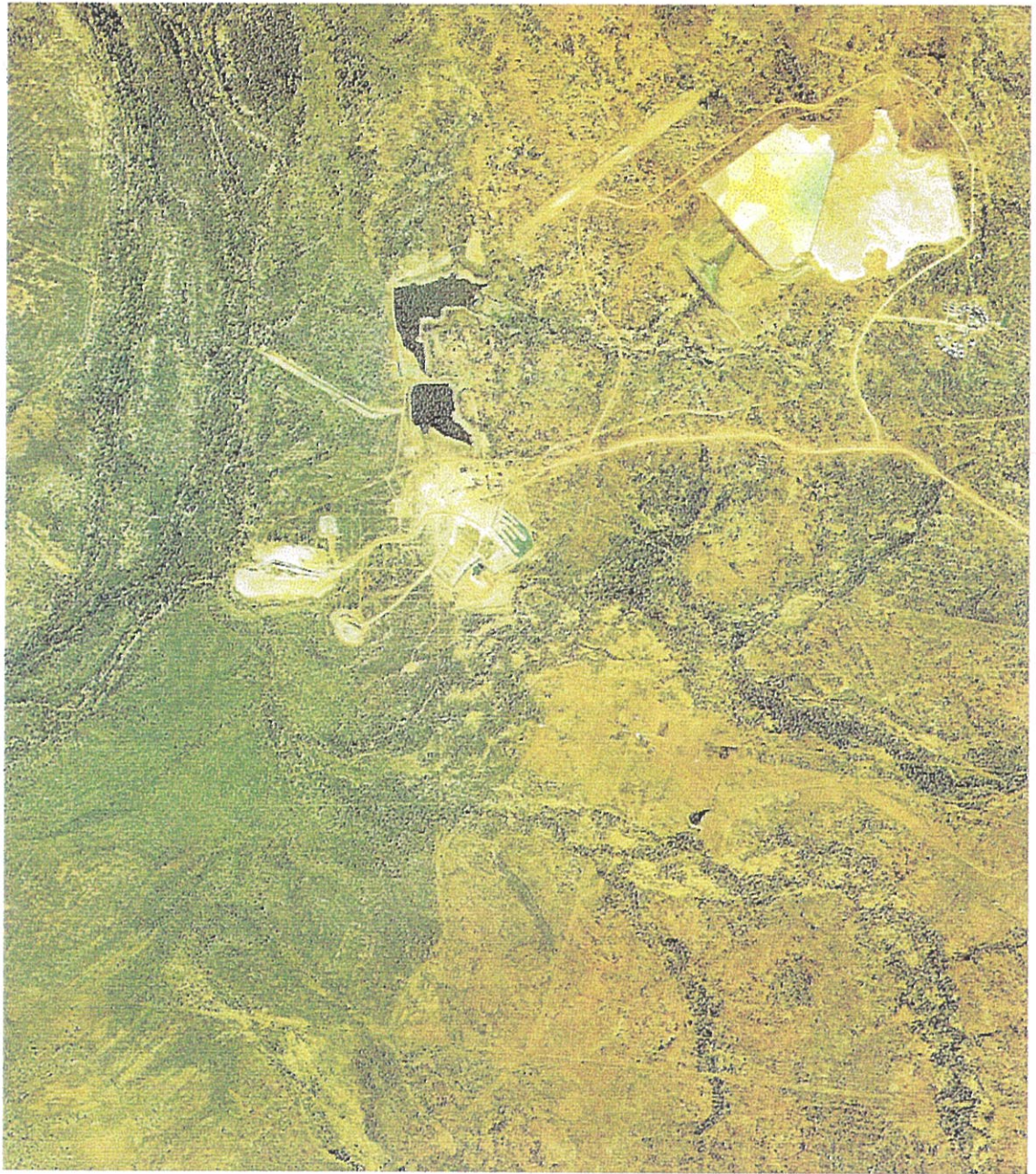


PLATE 1



PLATE 2

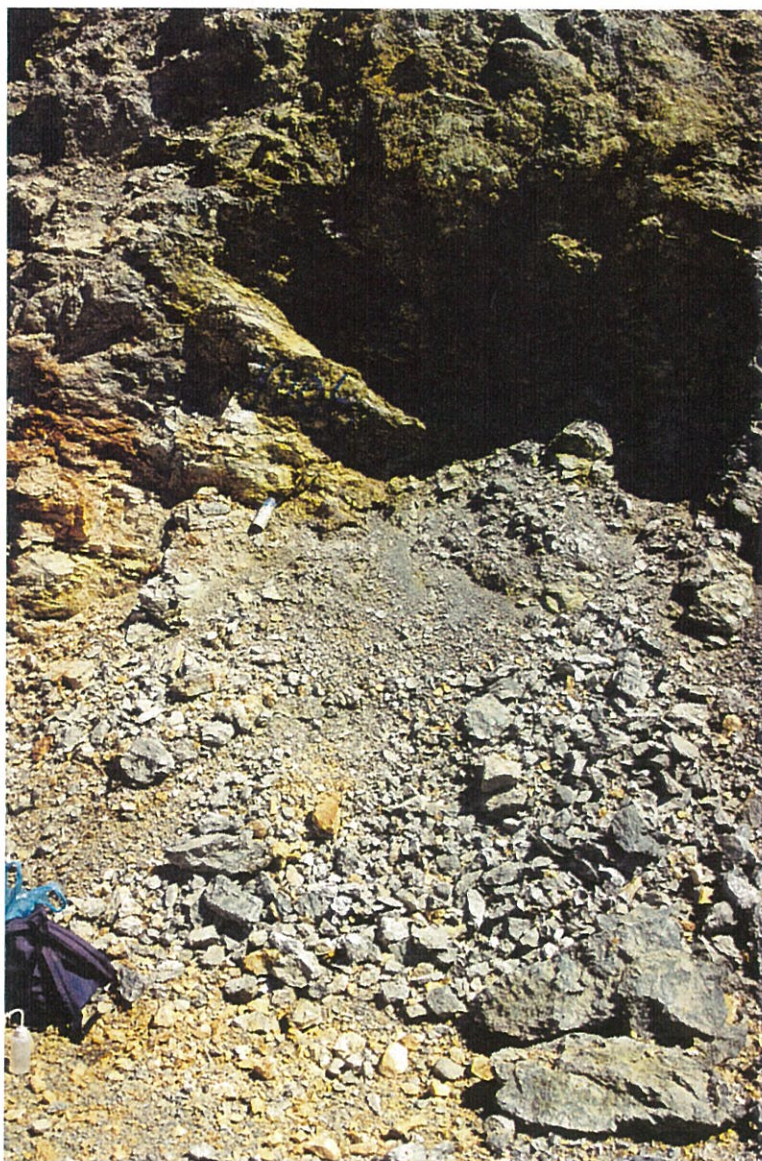


PLATE 3



PLATE 4



PLATE 5

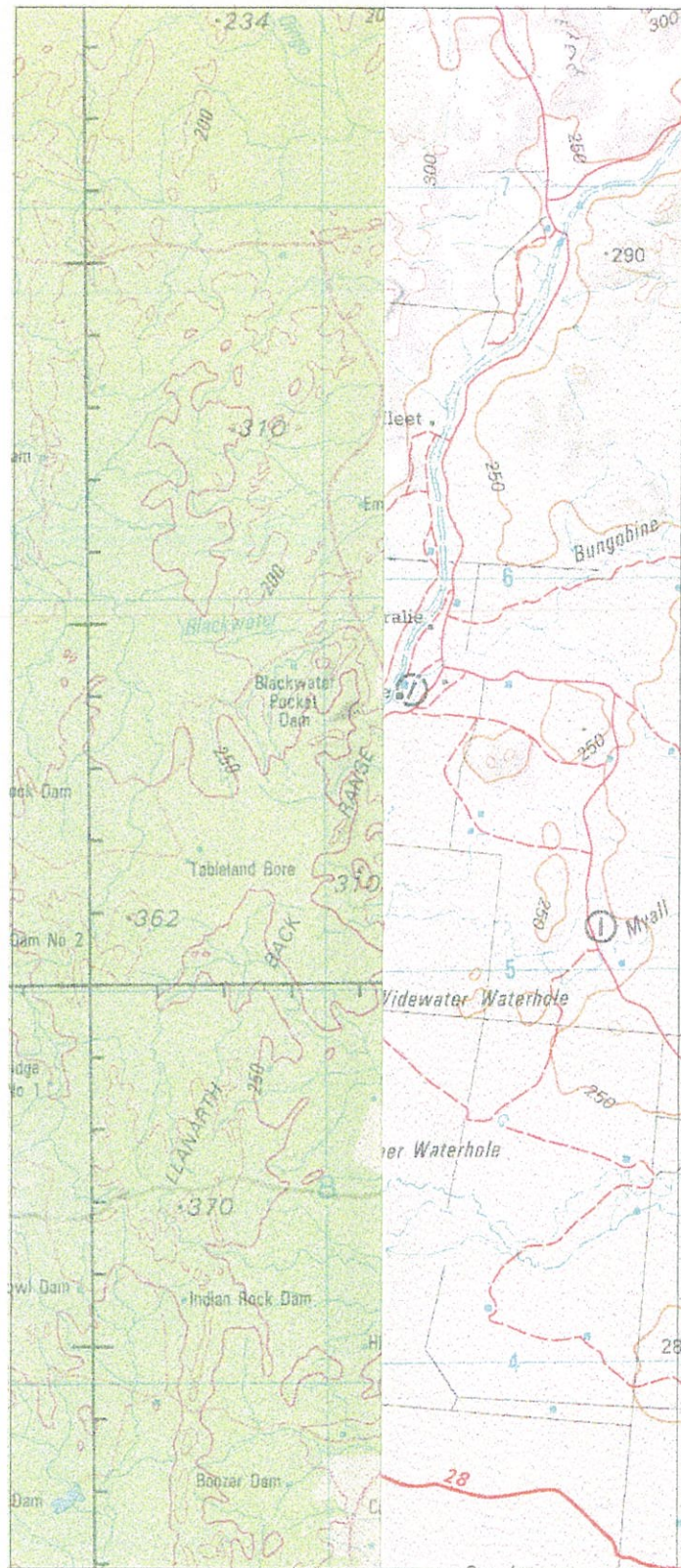


PLATE 6



PLATE 7

FIGURES



Yandan Gold Mine

Project Location Map

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03	18/1/99		2.1

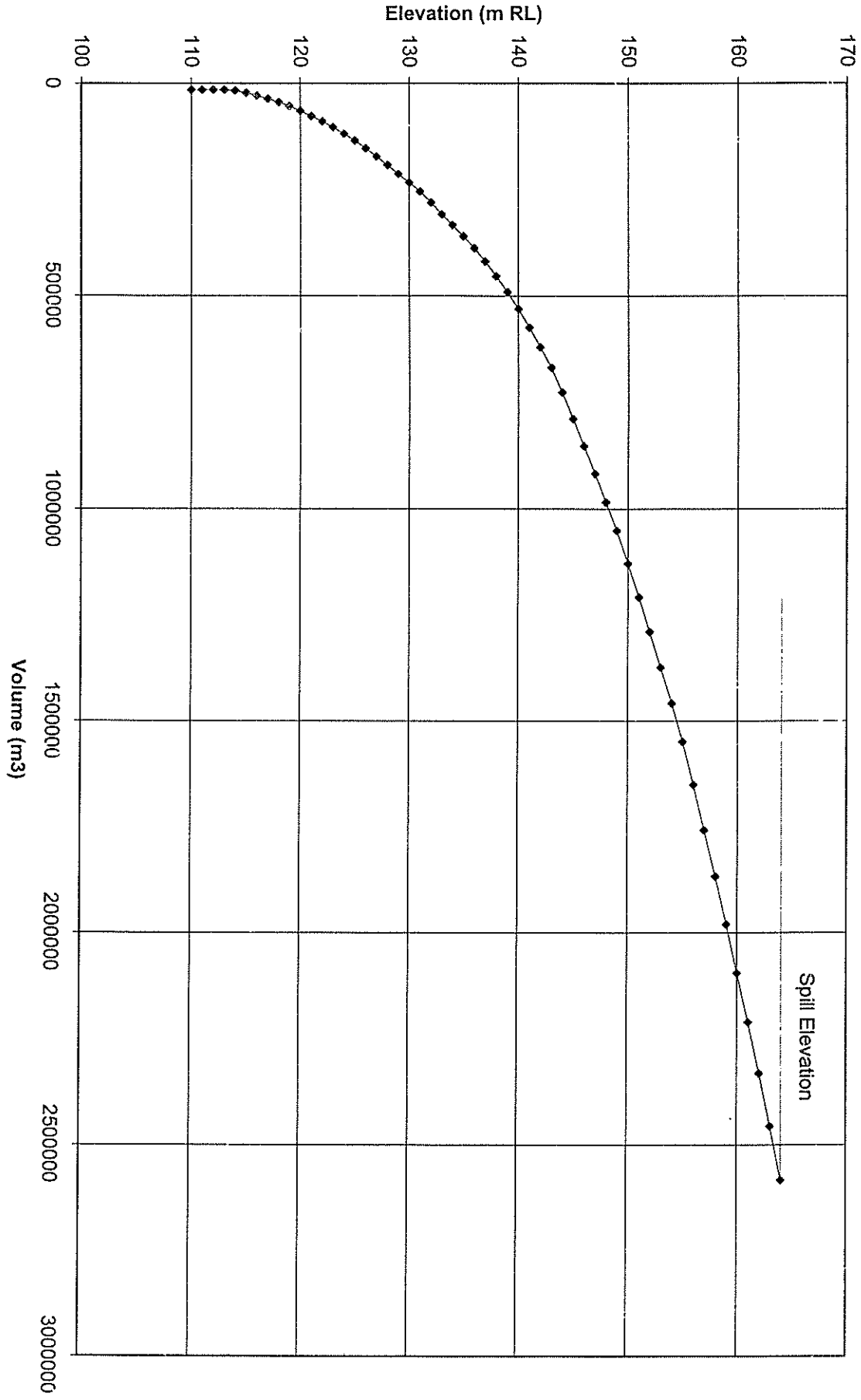
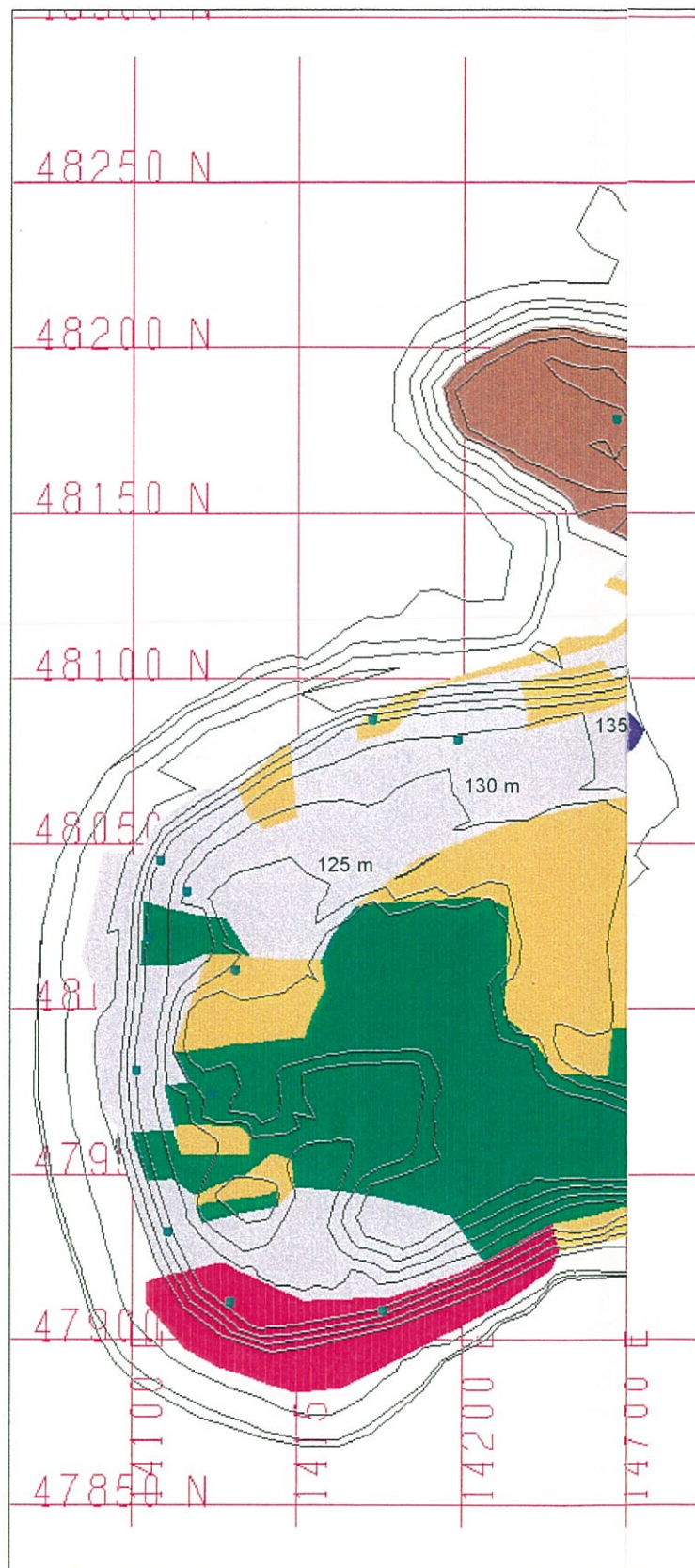


Figure 2.2 Elevation - Pit Volume Relationship



Not to scale.

LEGEND

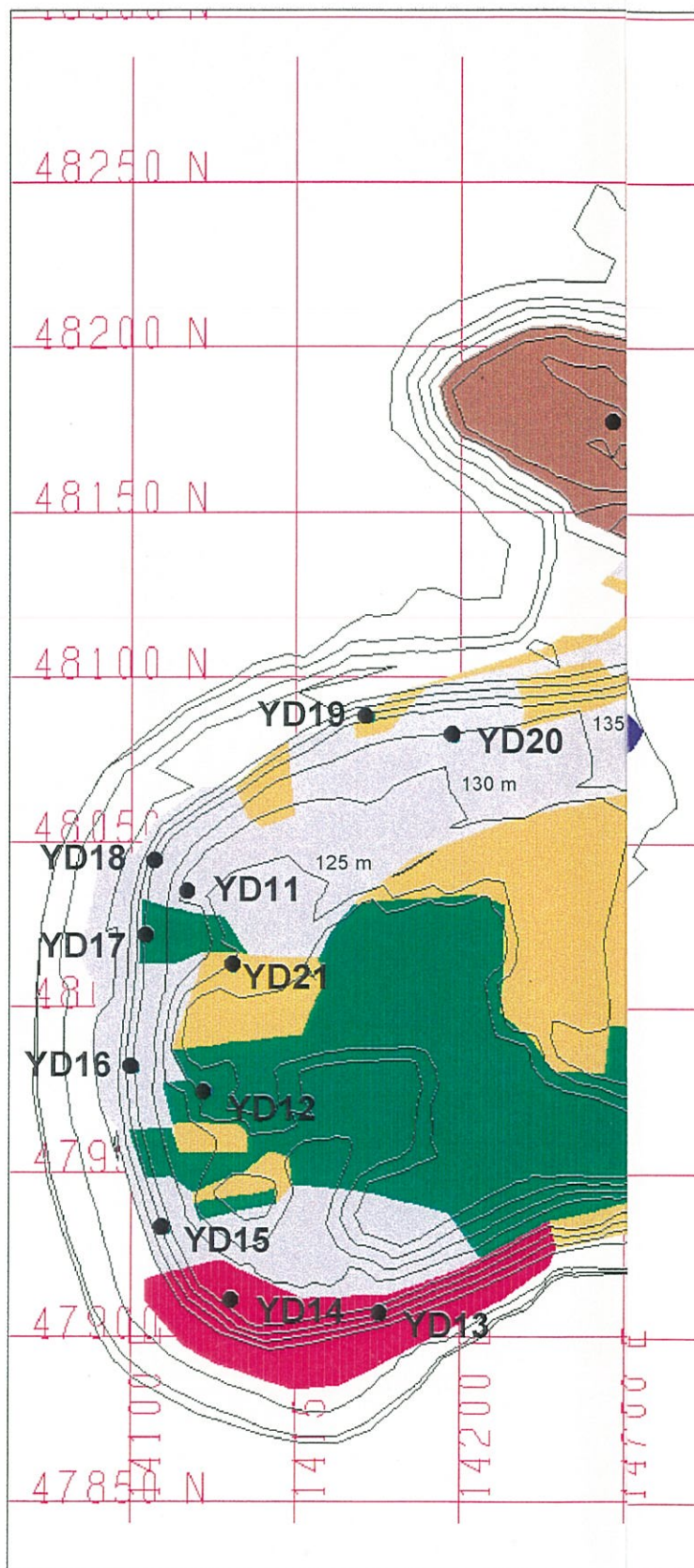
Siliceous Oxide (19,390 m ²)	
Siliceous Fresh High Sulphide (12,910 m ²)	
Siliceous Carbonate (4,300 m ²)	
Moderate Clay and Siliceous and Moderate to Strong Sulphide (10,196 m ²)	
Moderate to Strong Siliceous and Sulphide (35,470 m ²)	
Strong Clay Altered Oxide (91,264 m ²)	
Sulphide Waste Dump (19,570 m ²)	
Oxide Waste Dump (14,500 m ²)	



Yandan Gold Mine Open Pit

WASTE ROCK BACKFILL AREAS

PROJECT RM803	DATE 08/02/99	APPROVED D	FIGURE: 3.1
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Not to scale.

LEGEND

Siliceous Oxide
(19,390 m²)



Siliceous Fresh High
Sulphide
(12,910 m²)



Siliceous Carbonate
(4,300 m²)



Moderate Clay and
Siliceous and Moderate
to Strong Sulphide
(10,196 m²)



Moderate to Strong
Siliceous and Sulphide
(35,470 m²)



Strong Clay Altered
Oxide
(91,264 m²)



Sulphide Waste Dump
(19,570 m²)



Oxide Waste Dump
(14,500 m²)



● **YD04** Sample Location



Yandan Gold Mine Open Pit

SAMPLE LOCATIONS

OBJECT
RM803

DATE
14/1/99

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FIGURE:
3.2

0749835534

WESTERN MINING CORPORATION

GEOCHEMISTRY OF WASTE ROCK, ORE AND TAILINGS

AND

IMPLICATIONS FOR WASTE MANAGEMENT

YANDAN GOLD PROJECT

Prepared by:

STUART MILLER & ASSOCIATES PTY LTD

for:

Kinhill Engineers Pty Ltd

July 1988

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Multi-Element Composition of Rock and Tailings Samples	

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0749835534

4

1.0 INTRODUCTION

Western Mining Corporation (WMC) propose to develop a mine and gold processing operation at Yandan in northern Queensland. The project is based on mining and milling approximately 1 million tonnes of ore per year for a project life of 6 or 7 years. 2.8 million tonnes of waste rock and 2.5 million tonnes of low grade ore will be generated by the mining operation. The low grade ore is expected to be processed.

The ore will be mined by open cut methods and the waste rock will be placed in constructed emplacements or, where suitable, used for engineering works. The waste rock emplacements will be rehabilitated and the drainage controlled to prevent adverse environmental impact.

Processing will be by the carbon-in-leach method and a total of approximately 10 million tonnes of tailings will be produced. The tailings will be stored in an engineered tailings dam on site. It will be necessary to ensure that the design of the tailings disposal system is environmentally sound with minimal or nil post-decommissioning maintenance requirements.

The investigations outlined in this report address the geochemical characteristics of waste rock, ore and tailings and provide the preliminary implications of the waste geochemistry for engineering design and management.

2.0 STUDY APPROACH

The overall objective of this investigation was to determine the geochemical characteristics of waste rock, ore and tailings. This information provides the necessary design criteria for waste rock and tailings management, pollution control and rehabilitation. The major geochemical concerns addressed are:

1. Potential for acid generation in waste rock and tailings;
2. Total element composition of ore, waste rock and tailings and the potential for element leaching;
3. Composition of tailings liquor and tailings seepage;
4. Fate of cyanide in tailings;
5. Attenuation characteristics of soil from the tailings disposal area.

This investigation involved laboratory testing of samples of ore, waste rock and tailings. Details of the sampling and testing programmes are outlined in this section.

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2.1 Sample Selection and Preparation

Waste rock and ore samples from drill hole material were collected by WMC personnel. Individual depth profile samples and composite waste rock type samples were collected. Samples were selected to represent the types of mine rock to be excavated from the open pit. The description of mine rock samples are given in Table 1.

TABLE 1 SAMPLE DESCRIPTIONS

Sample Code	Sample Depth (metres)	Sample Description
INDIVIDUAL DEPTH SAMPLES		
YN73/1	1 - 5	Oxidised
YN73/2	6 - 10	Oxidised
YN73/3	11 - 15	Oxidised
YN73/4	16 - 20	Oxidised
YN73/5	21 - 25	Oxidised
YN73/6	25 - 30	Oxidised
YN73/7	31 - 35	Oxidised
YN73/8	36 - 40	Oxidised
YN73/9	41 - 45	Oxidised
YN73/10	46 - 50	Oxidised
YN73/11	51 - 55	Oxidised
YN73/12	56 - 60	Unoxidised Primary
YN73/13	61 - 65	Unoxidised Primary
YN73/14	66 - 70	Unoxidised Primary
YN73/15	71 - 75	Unoxidised Primary
COMPOSITE SAMPLES		
YN/PW-SS (YND 64)		Primary Waste-Sandstone
YN/PA (YND 87)		Unaltered Andesite*
YN/PW-SS/SL (YND 72)		Primary Waste-Sandstone/Siltstone
YN/W (YND 43)		Fresh altered andesite waste

* Potential construction aggregate material

Samples of Yandan cyanidation tailings pulp were prepared by Roxby Management Services in South Australia. The ore was crushed and cyanide leached according to the likely process to be adopted at Yandan. The leaching conditions were as follows:

Grind size: 80% passing 106um
 Leach time: 24 hours
 Cyanide Addition: to a solution strength of
 0.05% NaCN excess.
 Lime Addition: to pH 10-11
 Leach density: 45% Solids

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The tailings were sent to Stuart Miller & Associates as a slurry at 45% solids with approximately 5 kg of solids. The sample was sent in a sealed container immediately after completion of the cyanide leaching. Two tailings samples were supplied. The initial sample was prepared using synthetic bore water with a high level of dissolved salts. Subsequently, a second tailings sample was prepared using demineralised water to simulate surface water from the site. The initial tailings sample is referred to as the 'High TDS Tailings' and the second sample as the 'Low TDS Tailings'.

A sample of soil from the vicinity of the proposed tailings storage was provided by D.J. Douglas & Partners Pty Ltd for the seepage attenuation tests.

2.2 Testing Programme

2.2.1 Waste Rock and Ore

All samples were analysed for total sulphur, acid neutralising capacity (ANC) and paste pH and electrical conductivity (EC). The net acid producing potential (NAPP) was calculated from the total sulphur content and ANC. This determines the potential for a solid waste from mining operations to generate acid.

Accelerated oxidation tests were carried out on primary waste which was identified as potentially acid forming by the NAPP assessment. These tests were carried out to determine if primary waste was acid producing and to better define the geochemical mechanisms. Samples of primary waste were placed in flasks and subjected to accelerated oxidised leaching. Two tests were carried out; one at natural pH and the other under acid conditions. In the acidified test the inherent ANC was consumed by addition of acid and the pH was maintained at less than 3 by further additions of acid as required. The samples were inoculated with Thiobacillus sp. bacteria culture and the oxidation and leaching products were extracted at regular intervals and analysed for pH, electrical conductivity, acidity and sulphate. The tests are continuing and the preliminary results are presented in this report.

Saturation extracts were prepared on all samples and the extracts were analysed for pH, EC, Ca, Mg, Na, K, SO₄, Cl, Al, Fe, Mn, Cu, Zn, Ni, Pb, Co, Mo, Cd, Cr, B, Ba, Sr, As, Hg, Sb, Se, Te, Bi, Be, V, Zr and W using ICP techniques by Australian Laboratory Services Pty Ltd.

The total element content of all waste rock and ore samples was determined by a combination of Atomic Adsorption, Optical Emission Plasma Spectrometry and Inductively Coupled Plasma-Mass Spectrometry by Analytical Services (W.A.) Pty Ltd. Total mercury determinations were carried out on these samples by SGS Australia.

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2.2.2 Tailings

The tailings solids from the initial sample (high TDS tailings) were analysed for total sulphur, acid neutralising capacity and multi-element content. The second sample (low TDS tailings) was analysed for Hg, totals S and total CN.

The tailings liquor from both samples were analysed for total cyanide (CNT), weak acid dissociable cyanide (CN-wad), thiocyanate, pH, electrical conductivity, SO₄, Cl, Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Sr, V, W, Zn, Zr, Hg, As, Bi, Se, Te and Sb. The cyanide forms were determined by SGS Australia Pty Ltd and the metals and specific ions were determined by Australian Laboratory Services Pty Ltd using ICP methods.

Leaching tests were carried out on the high TDS tailings to determine the leaching behaviour of metals and cyanide. Tailings slurry, at 40% solids, was placed into a large diameter buchner funnel and allowed to drain. Sufficient slurry was added so that approximately 2 kg of tailings pulp remained in the column. After the tailings liquor had drained approximately 300 mls of deionised water was added to the column and continually topped-up to maintain a cover of approximately 30mm. Leachate was collected at approximately 1 pore volume intervals over 7 days. A total of 6 pore volumes were passed through the column.

The leachates were analysed for pH, EC, Ca, Na, total CN, Cu, Fe, Ni, Zn, Cd, Hg and As. The hydraulic conductivity of the tailings was also measured in the column.

Cyanide decay tests were carried out on both the high TDS and low TDS tailings samples to determine the rate of loss of cyanide from supernatant (or decant) and from entrained liquor within the tailings mass.

To determine the cyanide decay from the decant, 2 kg of tailings pulp was placed in an open lysimeter exposed to sunlight with supernatant samples collected after 0, 1, 3, 6, 15 and 47 days for the high TDS sample and after 0, 1, 4, 8, 19 and 32 days for the low TDS sample. The samples were analysed for pH, EC and total CN.

To determine the nature of cyanide decay within the tailings mass, 1 kg samples of tailings slurry were placed in each of 2 containers. The supernatant was discarded after 1 day and the entrained liquor sampled for analysis after 10 and 26 days for the high TDS sample and after 19 and 32 days for the low TDS tailings. The extracted liquor was analysed for pH, EC and total cyanide.

The test on the low TDS tailings were carried out after all test had been completed on the high TDS tailings.

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2.2.3 Soil Attenuation

The soil pH and EC were determined on the soil sample provided.

Approximately 1.5 kgs of soil was placed in a large diameter buchner funnel. A filter paper was placed on the surface of the soil and tailings pulp added to the surface of the soil layer. Tailings liquor was then added to the column at regular intervals to maintain a liquor cover over the settled tailings. The column was covered to minimise evaporation and cyanide decay. Leachates were collected regularly and a total of 4 pore volumes was passed through the soil. The leachates were analysed for pH, EC, total CN, Ni, Cu, As and Na.

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3.0 RESULTS AND DISCUSSION

This section presents and discusses the results of the preliminary laboratory investigations. The results are presented in Tables 2 to 6 and Appendix A.

3.1 Waste Rock and Ore

The waste rock is primarily a kaolin and silica altered sandstone and tuffaceous siltstone rock type. Some fresh altered andesite also occurs as waste. The ore is within the altered sandstone/siltstone rock types.

3.1.1 Acid Producing Potential

Table 2 presents the total sulphur content (% S), acid neutralising capacity (ANC), net acid producing potential (NAPP), saturation moisture ratio and saturated paste pH and electrical conductivity (EC) for the 15 profile samples from drill hole YN73, the 3 composite waste types and the composite weathered andesite which is a potential aggregate material.

The acid generating potential of geological material is a function of the total S content and the inherent ANC which are used to derive the NAPP. A negative NAPP indicates there is an excess of neutralising capacity and the material is unlikely to generate acid. Whereas a positive value suggests that the material is acid or may generate acid upon exposure.

The results show that in drill hole YN73 the level of sulphur was less than 0.1% S from the surface down to 55 metres. Below this depth the level of sulphur increased to a maximum of 0.57% S. Figure 1 is a profile plot of the major parameters used to assess the acid forming potential of waste rock. This indicates that potentially acid forming material occurs below a depth of 56 metres. The samples from the surface to 56 metres are essentially devoid of sulphur and ANC and are classified as barren. This material is also non-acid forming.

The sulphur content of selected profile samples were also determined by WMC in conjunction with exploration activities. The results of these results are presented in Table 7 for the drill holes YNDC2, YNDC5, YNDC7 and YNDC8. The results are generally consistent with those reported above for YN73 and confirm that material from the surface to a depth of 50 to 60 metres is low in sulphur and unlikely to be non-acid forming. However, below this depth the material is classified as primary unoxidised rock and the sulphur content approaches 1 to 1.5 % S. This material is potentially acid forming except where carbonate veining occurs and the rock has a high ANC.

The results of the composite samples are consistent with the individual drill hole samples and also confirm the presence of high ANC in some waste rock (composite primary waste sample YN/PW-SS/SL). The significance of carbonate zones

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should be considered for waste rock management since the carbonate provides a natural acid neutralising capacity which will prevent acid formation.

The fresh altered andesite waste rock sample (YN/W) is acid forming. The partially weathered andesite sample (YN/PA) is classified as non-acid forming.

The paste pH and EC values are given on Table 2 and the profile samples for YN73 are plotted on Figure 1. The results show that the waste rock is generally neutral to slightly acid. However, the composite altered andesite is acid with a pH of 4.3. The EC indicates that much of the waste rock is saline with an EC greater than 4mS/cm.

This preliminary investigation identified 4 geochemical waste rock types at Yandan as follows:

- Barren;
- Non-Acid Forming;
- Acid Forming; and
- Potentially Acid Forming.

All oxidised waste rock is barren and non-acid forming. The fresh primary waste rock is potentially acid forming however some non-acid forming material will occur where significant carbonate veining occurs. The fresh altered andesite is acid forming but only small quantities of this material will be mined (less than 5% of the total waste rock).

Acid generation in the potentially acid forming primary waste is currently being assessed by laboratory oxidation tests. The interim results for primary waste with approximately 0.5%S are shown on Figures 7 and 8 which show the pH and sulphate concentration of sequential extractions from the 'natural' and 'acidified' tests, respectively. Figure 7 shows that the natural pH of the primary waste is approximately 7. In the acidified test, regular additions of acid were required to maintain a pH less than 3 which confirms the presence of an effective acid neutralising capacity. The acid was neutralised by the sample and with leaching the pH steadily increased. Figure 8 indicates that the rate of sulphate release under natural pH conditions is very slow and there is no evidence of sulphide oxidation.

Under acid conditions sulphate generation is also minimal and there is no indication of the establishment of bacterially catalysed oxidation. These preliminary test results demonstrate that primary waste with less than 0.5%S is not acid forming and is unlikely to be a problem. Test work will be carried out on primary waste rock with greater than 0.5%S to confirm if this material is acid generating and if any selective handling is required. These additional investigations will be carried out at a later stage of project development since it is anticipated that control will involve only limited changes to dumping scheduling and placement strategies that will have minimal impact of the overall mining and waste management plan.

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3.1.2 Total Element Composition

The results of the total element analysis are given in Appendix A. The results indicate that As and S are the only elements occurring at elevated levels. All other environmentally important metals and specific elements are below toxicity trigger levels or in the normal range for non-mineralised rocks and soils.

3.1.3 Element Solubility and Leaching Potential

The composition of saturation extracts of the 4 composite samples are given in Table 3. The results confirm that the fresh smectite altered andesite waste (YN/W) is acid and water extracts contain high levels of a number of environmentally important elements such as Al, Fe, Ni, Mn, Zn, and As. The weathered andesite sample (YN/PA) contains low levels of soluble constituents.

The two composite primary waste samples have a neutral pH but are saline. The salinity is due to both sulphate and chloride salts but the level of soluble metals is generally low except for a slightly elevated level of As in sample PW-SS

The level of Hg was below the analytical detection limit of 0.001 mg/l in all samples.

These results suggest that drainage from the altered andesite waste rock could contain environmentally significant levels of some metals. Drainage from the primary waste rock is unlikely to be a concern provided acid generation does not occur.

The partially weathered andesite (YN/PA) is non-acid forming and contains low levels of soluble elements. This rock type is expected to be chemically suitable for engineering works.

3.2 Tailings

The chemical composition of the tailings is determined by the composition of the ore and the chemicals added during processing. Cyanide and lime are the main reagents added during processing and will have a major impact on the short term geochemistry of the tailings.

In the short term the residual CN and lime are likely to be significant factors in determining leachate quality and the quality of decant water. In the longer term, the geochemical characteristics of the tailings will become important.

3.2.1 Acid Producing Potential

The two tailings sample provided had a total sulphur content of 0.04%S and 0.034%S for the high TDS and low TDS samples, respectively. The ANC was approximately 0.06 %CaCO₃ and the

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resulting NAPP approximately +0.07 % CaCO₃. These tailings samples are classified as non-acid forming.

This result suggests that the tailings samples provided are composite oxide ore tailings. The primary ore will contain a higher level of sulphur and may be potentially acid forming. This should be confirmed by analysis of additional ore and tailings samples.

3.2.2 Composition of Tailings

i) Tailings Solids

In relation to tentative toxicity trigger level criteria for environmentally important elements (ICRCL, 1987) and the average value for non-mineralised rocks and soils (Bowen, 1979, Bresler et al, 1982 and Lindsay, 1979), the Yandan tailings sample contains a slightly elevated level of As. The content of Hg in the composite tailings samples was 0.062 mg/kg and 0.11 mg/kg for the low TDS tailings and high TDS tailings, respectively. This is below the toxicity trigger level criteria. On a mass basis, the content of cyanide, as CN, in the tailings was only 16.9 mg/kg and 2.5mg/kg for the low TDS tailings and high TDS tailings, respectively. This is well below the trigger level criteria of 50 mg/kg (ICRCL, 1987).

The results of the multi-element analysis of the tailings, as well as the results from the waste rock testing, suggest that the tailings solids will contain relatively low levels of most environmentally important metals and specific elements.

ii) Tailings Liquor

The composition of the liquor in both the low TDS tailings and high TDS tailings samples is given in Table 4. The results show that the tailings liquor will have a pH of approximately 10.5 to 11. Table 4 confirms that the low TDS tailings has a significantly lower level of salinity than the high TDS tailings with an EC of 1.74mS/cm compared to 6.03mS/cm for the high TDS tailings.

Although there is significant analytical error in the values reported for total CN and weak acid dissociable cyanide (CNwad), the results suggest that the initial concentration is likely to be about 150 to 175 mg/l total CN occurring as CNwad. The concentration of strong iron complexes is expected to be low.

The results of the dissolved metal analyses indicate that the complexed CN will be associated primarily with copper and zinc. Only a small amount will be present as Fe and Ni complexes.

The high level of dissolved copper in the tailings liquor supplied is not considered representative of tailings to be produced from the current operation. Ore from outside the

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current pit limit was included in the sample. This ore was from a different deposit and contained a high level of copper. The level of copper in material from the proposed pit is indicated by the assay results given in Table 7. These results confirm that the level of copper will be low and in the range for non-mineralised rocks and soils and therefore the level of copper-cyanide complexes is also expected to be far lower than observed in the current sample. This will be confirmed when representative tailings samples are available. The conclusions and recommendations presented in this report are based on the high Cu tailings and are therefore 'worst case' since natural cyanide decay will be more effective with the anticipated lower level of complexed cyanide.

In summary, the results indicate that the tailings liquor, as it reports to the disposal area, will be highly alkaline (pH 10.5-11) and will contain a maximum of approximately 35 to 60 mg/l moderate and weak cyanide complex (Cu, Zn and Ni) and 100 to 150mg/l free cyanide.

3.2.3 Nature of Tailings Leachate

As indicated above, the composition of tailings leachate is determined by the geochemistry of the ore, the process chemicals added and the disposal operation. Cyanide and lime are the main reagents added and will have a major impact on the short term geochemistry of the tailings. The method of disposal has a major impact on the concentration and form of residual cyanide in entrained water which determines the quality of potential leachate.

A column leaching test was carried out on the high TDS tailings to determine the leaching characteristics of the tailings. No attempt was made during this test to promote cyanide decay and the results represent a worst case situation. The results are given in Table 5 and are plotted on Figures 2 and 3.

The results show that as leaching proceeds the pH of leachates remains at approximately 10 to 10.5. The content of soluble salts (as indicated by the EC results) falls rapidly to a very low level as the tailings liquor is flushed from the column. The rapid removal of dissolved constituents indicates that the tailings solids are relatively un-reactive.

Figure 2 shows the leaching behaviour of CN and Fe and Figure 3 shows the leaching behaviour of Cu, Fe, Ni, Zn, Hg, Cd and As. The trends for each constituent are similar except for As and Fe. During liquor drainage the concentration of each constituent remained constant but decreased rapidly after 1 pore volume of deionised water was passed. Arsenic initially decreased but with leaching the concentration increased to about 0.08mg/l. Iron remained relatively steady through out the test period at approximately 2 to 2.5 mg/l. Further reduction in the metal concentrations will occur as metallo-cyanide complexes dissociate and the metals precipitate as

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insoluble hydroxides. In a properly managed disposal operation, this process will greatly reduce the potential for metal migration from the tailings site.

After 3 pore volumes were leached, the concentration of CN fell to less than 10 mg/l and continued to fall with further leaching. Therefore, approximately 95% reduction occurs in the CN concentration after 3 pore volumes were leached. Similar reductions in the other constituents were also observed (except for As and Fe).

The hydraulic conductivity of the tailings column was approximately 2×10^{-7} m/sec for the duration of the leaching test

3.2.4 Fate of Cyanide

The composition of the tailings liquor indicates that as tailings reports to the disposal dam, the content of total CN is expected to be approximately 150-175 mg/l.

Figures 4 and 5 show the results of the cyanide decay tests for decant water and entrained liquor within the tailings. The results for both the low TDS tailings and high TDS tailings are given. Duplicate decant tests were carried out for the low TDS sample and are indicated by replicates 'R/1' and 'R/2' on Figures 4 and 5. The high TDS sample results are indicated by 'I'. 'Decant' refers to the decant tests and 'EL' refers to the entrained liquor tests.

The results indicate that the free cyanide is readily lost from the liquor within 150 to 200 hours. The rate of further cyanide loss is slow with a calculated rate constant of 0.0005 hr^{-1} in the low TDS tailings. At this rate it would take at least an additional 40 days for the cyanide level in the decant to fall to below 10mg/l.

The high level of residual cyanide in the high TDS tailings and the slow rate of decay was most likely due to both the high level of complex cyanide and the formation of a scum on the surface of the tailings liquor. Although a scum also formed on the low TDS sample, it was significantly weaker and easily broke up and was unlikely to affect volatilisation of cyanide from solution.

The rate of cyanide decay in the entrained liquor is significantly slower than in decant with similar trends observed in the high TDS and low TDS samples. After 30 days the concentration of cyanide remained greater than 100mg/l. This rate of decay is an order of magnitude slower than observed in the decant.

These results suggest that natural cyanide decay in the decant and in the entrained liquor is relatively slow in the Yandan tailings samples supplied. With the high TDS tailings a total exposure time of at least 50 days would be required to reduce the residual cyanide level to 20mg/l. With the low

TDS tailings, a 20mg/l residual is achieved within 10 to 12 days. However, further reduction to less than 10mg/l would require an additional 40 days. Similar test carried out on tailings decant from other operations indicates that 10 mg/l residual CN can be achieved in only 7 to 10 days. This highlights the very slow rate of decay observed in the Yandan tailings. However, as indicated previously, the actual tailings are expected to have a much lower content of complexed cyanide. The rate of decay will be significantly faster and the overall decay will be more complete.

The results of these preliminary tests indicate that with the high TDS tailings and high Cu-CN content, a very high residual cyanide level could be expected and cyanide seepage would be a real concern. With the low TDS tailings the residual cyanide level will be significantly less and can be maintained at less than 20mg/l in the entrained liquor. To achieve a residual cyanide level of less than 20 mg/l the tailings must be deposited by sub-aerial techniques with beaches no more than 150mm thick with a recycle time of at least 10 days. If the recycle time can be extended to approximately 50 days, a residual level of less than 10mg/l would be expected and cyanide seepage problems essentially eliminated. Since entrained liquor decay is very slow in the Yandan tailings, it is essential that full exposure on the beaches be achieved. It is therefore recommended that the decant pond is maintained as small as possible at all times and that water is not stored on the tailings. Prior to detailed design it is recommended that decay test are carried out on representative oxide and primary ore tailings to confirm the absence of Cu-CN and define the decay characteristics for operational management.

The results of the soil attenuation tests are given in Table 6 and Figure 6. Figure 6 shows the concentration of constituents in the leachates relative to the initial concentration. The results show that the pH of tailings seepage is effectively buffered by the soil at approximately 7.8. Arsenic is strongly attenuated. CN and Cu are initially attenuated but the concentration in leachates returns to the initial level with continued leaching. Nickel is eluted from the soil with the concentration in leachates significantly greater than in the tailings liquor. The level of dissolved salts is also greater in the leachates than in the initial tailings liquor. The natural soil was observed to be saline and therefore the source of the additional dissolved salts. These results suggest that the tailings basement soils, represented by the sample tested, are not effective at attenuating dissolved constituents from tailings seepage.

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4.0 CONCLUSIONS AND GEOCHEMICAL IMPLICATIONS FOR ENGINEERING DESIGN, POLLUTION CONTROL AND REHABILITATION

The section summarises the findings of the preliminary geochemical test work and highlights the engineering implications for waste management, pollution control and rehabilitation.

4.1 General Conclusions and Summary of Findings

4.1.1 Waste Rock and Ore

The results of the preliminary test work demonstrate that the oxide waste rock is very low in sulphur and is non-acid forming. The fresh primary waste containing approximately 0.5%S or less is also likely to be non-acid forming. Primary waste containing greater than 0.5%S is potentially acid forming except in areas where significant carbonate veining occurs. Test work will be carried out to confirm if this material will generate acid so that any need for special handling is identified.

Fresh altered andesite waste rock is acid forming and leachates from this material will be contaminated. This material will require special handling to ensure that it is not exposed on or near the surface of dumps.

The level of environmentally important elements are generally low except for slightly elevated levels of arsenic. Leachates and drainage from exposed areas may contain slightly elevated levels of As.

4.1.2 Tailings

The oxide tailings are non-acid forming whereas the primary tailings may have a long term potential to produce acid.

The tailings liquor is expected to contain approximately 150 to 175 mg/l total CN. The rate of decay of the free cyanide is rapid but the rate of decay of the complex forms is relatively slow.

4.2 Implications for Engineering Design

The implications of the waste geochemistry for engineering design and management are presented below. These are based on the results of this preliminary investigation and should be confirmed by testing additional samples at a later stage of project development.

WASTE ROCK

1. The results of test work to date demonstrate that all oxide waste rock and primary waste with less than 0.5%S is likely to be non-acid forming and can be disposed of without special handling needs.

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2. Primary waste with greater than 0.5% S is naturally non-acid but is potentially acid forming. As a precautionary measure, pending the results of confirmation tests, this material should not be placed within 1 metre of the final surface of dumps. Where carbonate veining occurs the primary waste is likely to be non-acid forming and controlled placement will not be required.
3. Fresh altered andesite waste rock must be buried and compacted within the core of dumps.
4. Unaltered andesite is non-acid forming and is geochemically suitable for construction and engineering purposes.
5. The waste rock should be monitored during excavation to confirm the geochemical characteristics.
6. All drainage from active dumping areas must be contained and, if necessary, treated before discharge. Drainage from completed dumping areas that have been rehabilitated can most likely be discharged directly.
7. All available top soil should be stripped and stockpiled for rehabilitation purposes.

ORE

1. Low grade ore stockpiles that are to remain for a long period should be constructed with oxide material on the outer slopes and surfaces. This will minimise decommissioning and rehabilitation costs.
2. Drainage from ore stockpiles is likely to be contaminated. This should be collected and treated or reused.

TAILINGS

An objective of the tailings disposal operation at Yandan is to ensure that the level of CNwad in the entrained liquor within the tailings storage is less than 10 mg/l. At this level of residual cyanide and since on-going decay occurs within the tailings mass, the likelihood of seepage problems is minimal.

The results suggest that an exposure period of approximately 50 days would be required to achieve the desired residual cyanide level with the unrealistically high Cu-CN tailings which was tested in the current investigations. With the expected low Cu-CN tailings it is anticipated that an exposure period of 10 to 12 days would be sufficient. This will be confirmed when representative tailings samples are available.

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~~The current tailings disposal plan is sufficiently flexible~~
to accommodate a 50 day recycle time. Therefore even with
the 'worst case' tailings sufficient time is available to
provide adequate cyanide decay. It is recommended that this
level of flexibility be retained at least until the low Cu-CN
tailings has been confirmed.

In addition to providing the required exposure or recycle
time, it is recommended that the tailings are deposited sub-
aerially with a beach thickness of no more than 150mm. Also,
the decant pond must be minimised in area and water must not
be stored on the tailings.

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Table 2: Acid-Base Analysis

Saturation		Sample Code	Sample Interval	Sample Description	Total S %	ANC gCaCO3	NAPP gCaCO3	Sat, Paste Moisture Ratio	pH	E.C. (dS/m)
Sample	Interval									
INDIVIDUAL PROFILE SAMPLES										
YN73/1	1-5			Oxide	0.02	0.06	0.00	0.29	5.7	1.92
YN73/2	6-10			Oxide	0.02	0.04	0.02	0.34	6.3	0.91
YN73/3	11-15			Oxide	0.02	0.04	0.02	0.41	6.4	0.29
YN73/4	16-20			Oxide	0.02	0.05	0.01	0.26	6.2	1.44
YN73/5	21-25			Oxide	0.04	0.01	0.12	0.35	6.3	4.02
YN73/6	26-30			Oxide	0.03	0.06	0.03	0.28	6.6	0.42
YN73/7	31-35			Oxide	0.04	0.04	0.09	0.28	6.7	0.53
YN73/8	36-40			Oxide	0.05	0.05	0.11	0.27	6.4	1.99
YN73/9	41-45			Oxide	0.08	0.06	0.19	0.27	6.7	0.67
YN73/10	46-50			Oxide	0.05	0.11	0.05	0.35	5.5	3.59
YN73/11	51-55			Oxide	0.07	0.11	0.11	0.36	5.6	3.82
YN73/12	56-60			Primary	0.38	0.05	1.14	0.36	5.6	4.59
YN73/13	61-65			Primary	0.54	0.11	1.58	0.35	6.3	4.59
YN73/14	66-70			Primary	0.57	0.12	1.66	0.37	6.9	4.49
YN73/15	71-75			Primary	0.38	0.07	1.12	0.37	6.1	4.86
COMPOSITE SAMPLES										
YN / PW-SS				Primary waste-sandstone	0.88	0.31	2.44	0.38	7.4	5.64
YN / PA				Unaltered andesite	0.09	0.07	0.21	0.35	6.2	1.04
YN / PW-SS/SL				Primary waste-sandst/siltstone	0.96	14.96	-11.96	0.32	7.1	5.22
YN / W				Fresh altered andesite	0.81	0.11	2.42	0.34	4.3	5.30

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TABLE 4: TAILINGS LIQUOR COMPOSITION

(all results in mg/l except pH and EC mS/cm)

Parameter	Tailings Liquor		Entrained Liquor
	High TDS	Low TDS	High TDS
pH	10.6	10.9	10.2
EC	6.03	1.74	5.23
CN total	174	156	159
CN WAD	201	90	207
SCN	1.3	27	1.3
Fe	1.56	0.3	2.56
Cu*	35.4	16.6	37.2
Zn	7.14	8.8	9.08
Ni	0.64	0.7	0.84
As	0.052	0.13	0.098
Hg	0.024	<0.001	0.036
Cd	0.06	0.02	0.07
Pb	<0.01	<0.01	<0.01
Sr	2.79	0.5	2.85
CO		0.01	
SO4	199	32	203
Na	1260	296	1260
Cl	2670	361	2640
Ca	646	93	645
K	102	23	102
Mg	0.32	<0.01	0.39

* The observed Cu concentration in these samples is due to contamination from unrepresentative high copper ore. The actual copper concentration in the tailings is expected to be significantly lower.

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TABLE 5 : TAILINGS COLUMN LEACHING TEST RESULTS

Parameter/ Element	Solution Concentration (mg/l)						
	YN/LC1	YN/LC1	YN/LC2	YN/LC3	YN/LC4	YN/LC5	YN/LC6
Pore Volume leached:	1.8	2.5	3.3	4.1	4.9	5.6	6.2
pH	10.1	9.9	10.5	10.3	10.6	10.3	10.3
EC(dS/m)	5.50	6.22	5.35	2.23	0.89	0.51	0.37
CN	170	149	110	32.0	7.2	2.1	1.0
Fe	2.27	2.34	2.15	1.99	2.57	2.40	2.15
Cu	37.2	41.3	38.9	13.5	2.93	1.18	0.69
Zn	8.86	7.40	4.74	0.18	<0.01	<0.01	<0.01
Ni	0.80	0.76	0.69	0.12	<0.01	<0.01	<0.01
Cd	0.06	0.063	0.049	0.001	<0.01	<0.01	<0.01
As	0.106	0.029	0.022	0.049	0.115	0.083	0.078
Hg	0.038	0.017	0.016	0.009	0.007	0.006	0.006

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TABLE 6 SOIL ATTENUATION TEST RESULTS

(all results in mg/l except pH and EC: mS/cm)

Sample code	Pore Volume	pH	EC	CNT	Na	Cu	Ni	As
Co	initial	10.6	6.03	174	1260	35.4	0.64	0.052
YN/AT1	0.25	7.6	11.65	42	1820	23.1	4.7	<0.005
YN/AT2	0.87	8.0	9.93	65	1370	37.1	3.6	<0.005
YN/AT3	1.38	7.8	6.43	91	1190	39.6	2.54	<0.005
YN/AT4	1.98	7.9	6.68	110	1080	39	2.05	<0.005
YN/AT5	2.5	7.8	7.24	136	1070	38.4	1.98	<0.005
YN/AT6	3.2	8.0	6.89	149	1000	31.7	1.64	<0.005
YN/AT7	3.5	7.8	7.17	156	930	26.4	1.40	<0.005
YN/AT8	4.0	7.8	6.90	136	950	23.3	1.32	<0.005
Soil Sample		7.8	4.33					

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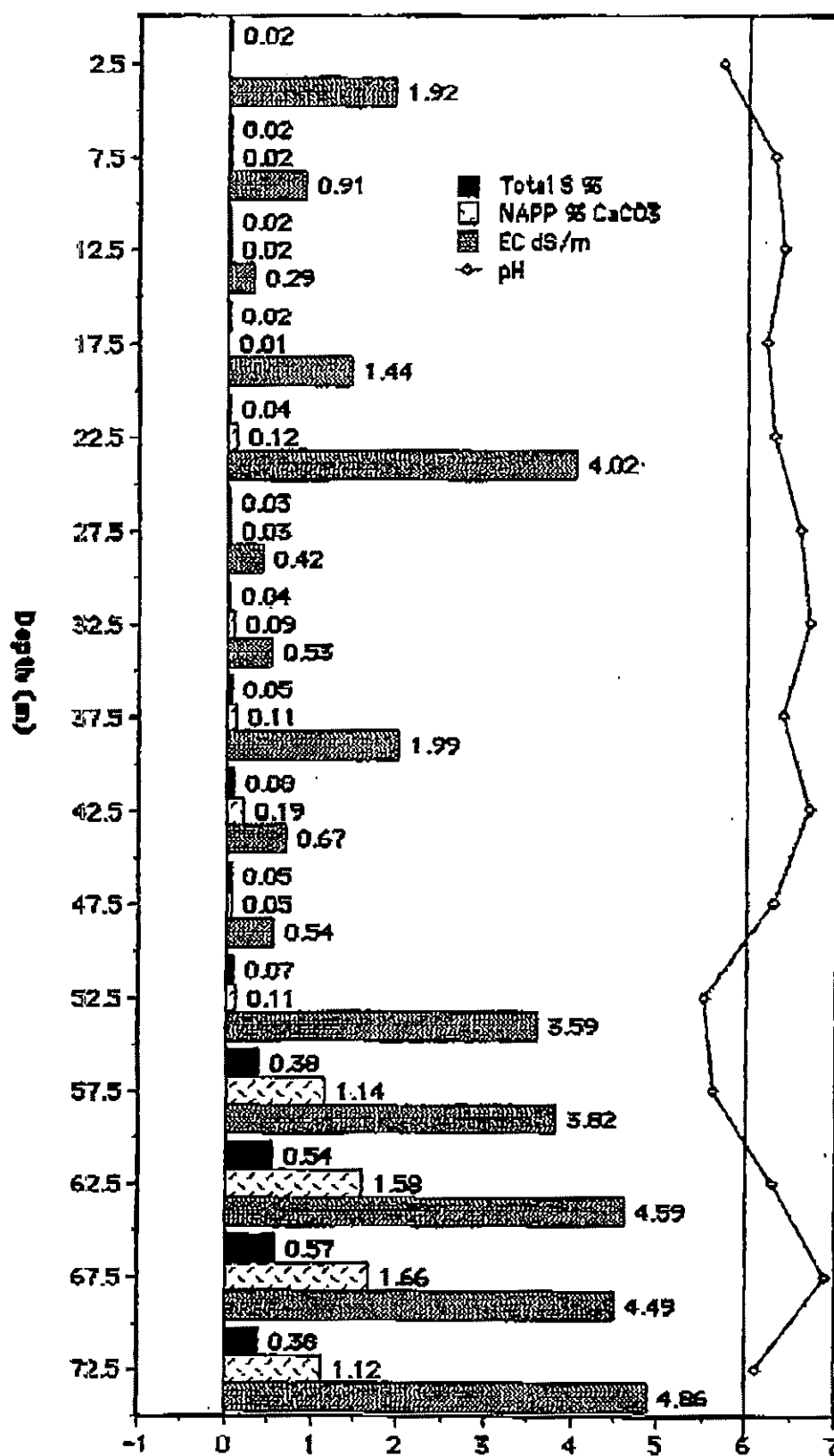
TABLE 7 ASSAY DATA FOR TOTAL SULPHUR AND COPPER

DEPTH (metres)	YND02		YND05		YND07		YND08	
	S*	Cu*	S	Cu	S	Cu	S	Cu
0-1	0.03	10			0.02	5	0.03	5
5-6	0.06	30			0.04	5	0.04	5
10-11	0.03	10			0.04	5	0.04	5
15-16	0.02	10	0.01	5	0.03	5	0.01	5
20-21	0.03	25	0.10	15	0.01	5	0.02	5
25-26	0.02	5	0.04	10	0.03	5	0.03	15
30-31	0.04	15	0.08	15	0.02	15	0.01	10
35-36	0.06	20	0.01	10	0.02	20	0.01	10
40-41	0.08	30	0.01	20	0.02	15	0.01	20
45-46	0.10	30	0.01	30	0.04	15	0.02	10
50-51	0.04	10	0.02	90	0.03	20	0.01	5
55-56	0.05	10	0.02	55	0.01	20	0.96	15
58-59	0.06	10	0.01	30			1.15	15
60-61					0.01	10		
65-66					1.04	15		
70-71					1.26	10		
75-76					1.21	15		
76-77					1.40	10		

* Sulphur in % and Copper in mg/kg

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FIGURE 1: Yandan Acid-Base Analysis



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FIGURE 2: COLUMN LEACHING TEST RESULTS - CN AND CU

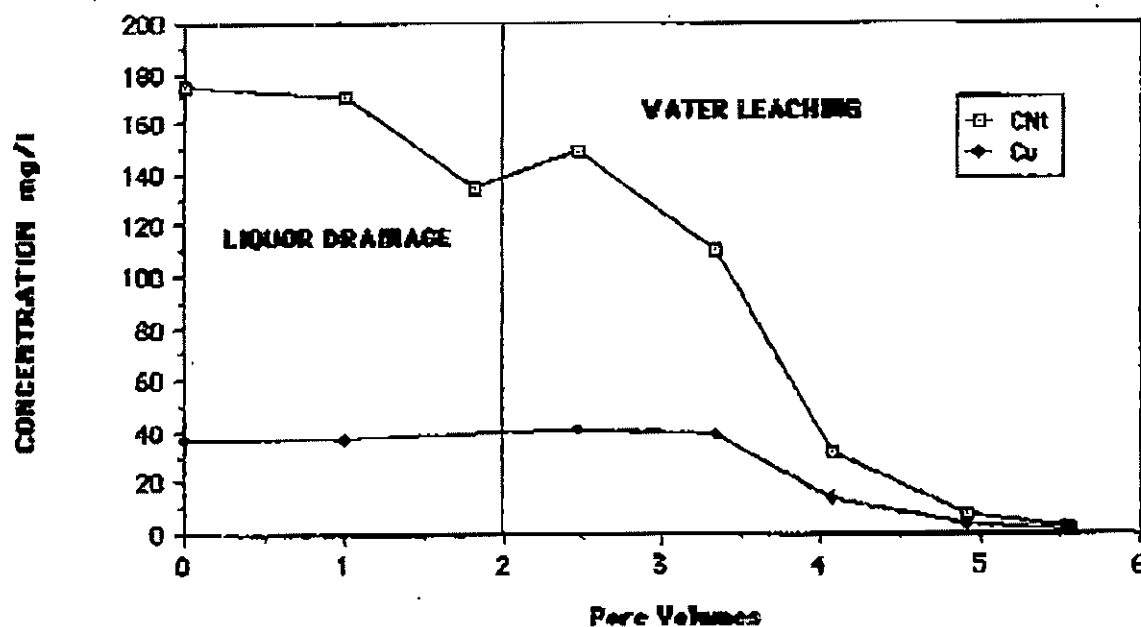
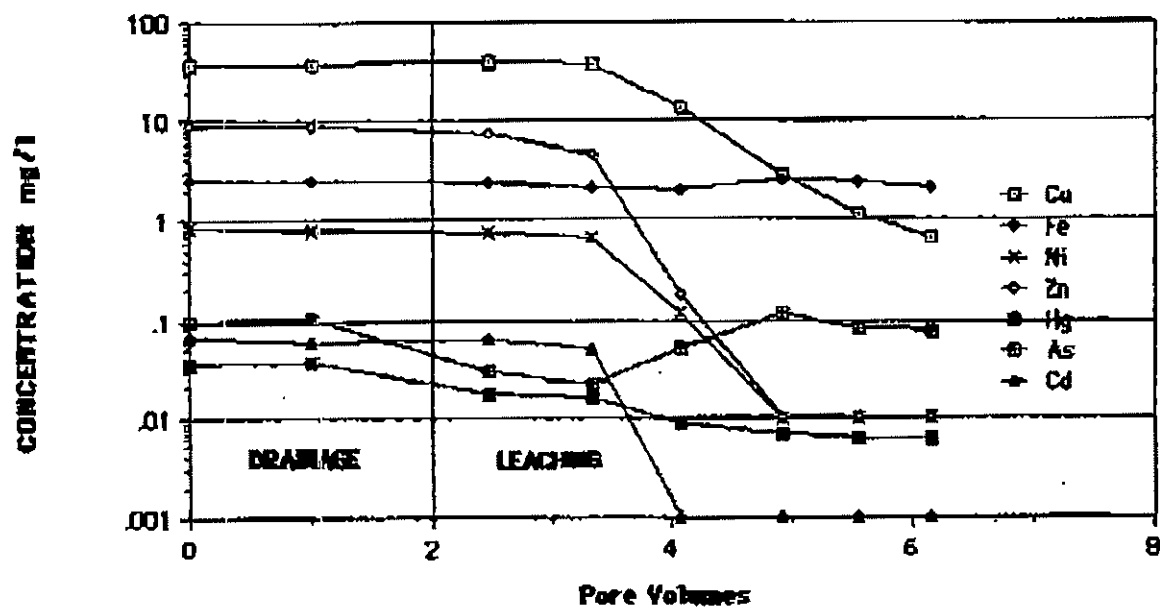


FIGURE 3: COLUMN LEACHING RESULTS -METALS



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FIGURE 4: CYANIDE DECAY IN DECANT AND ENTRAINED LIQUOR

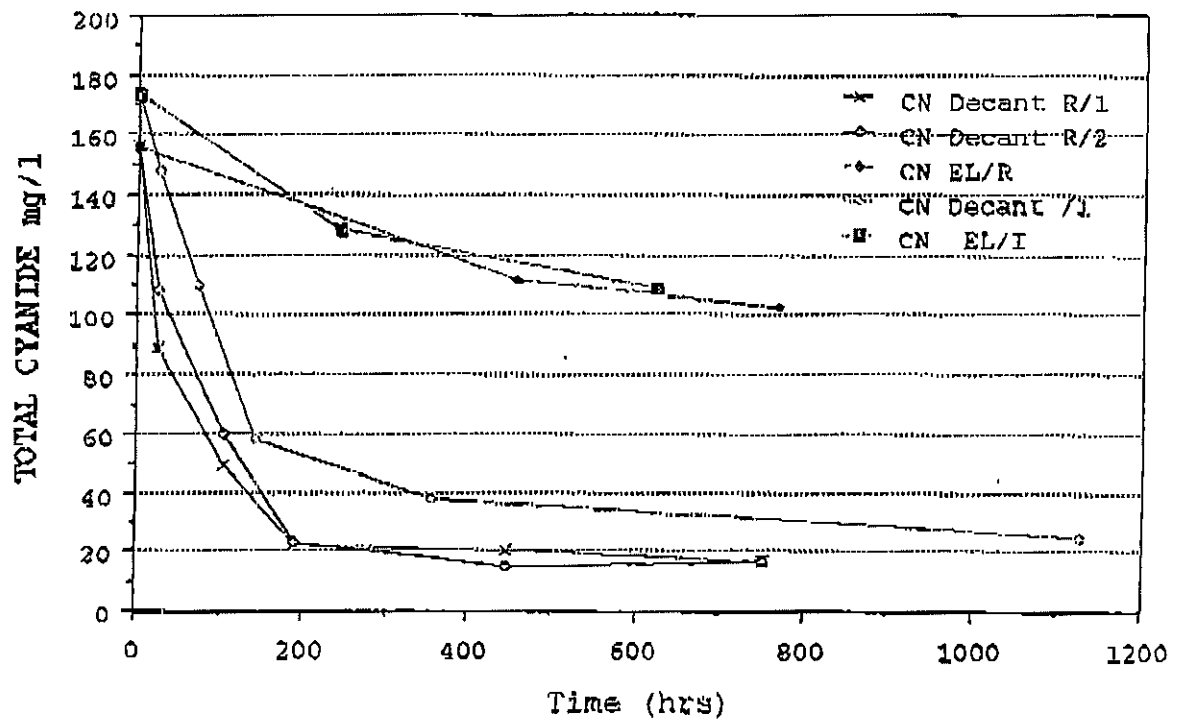
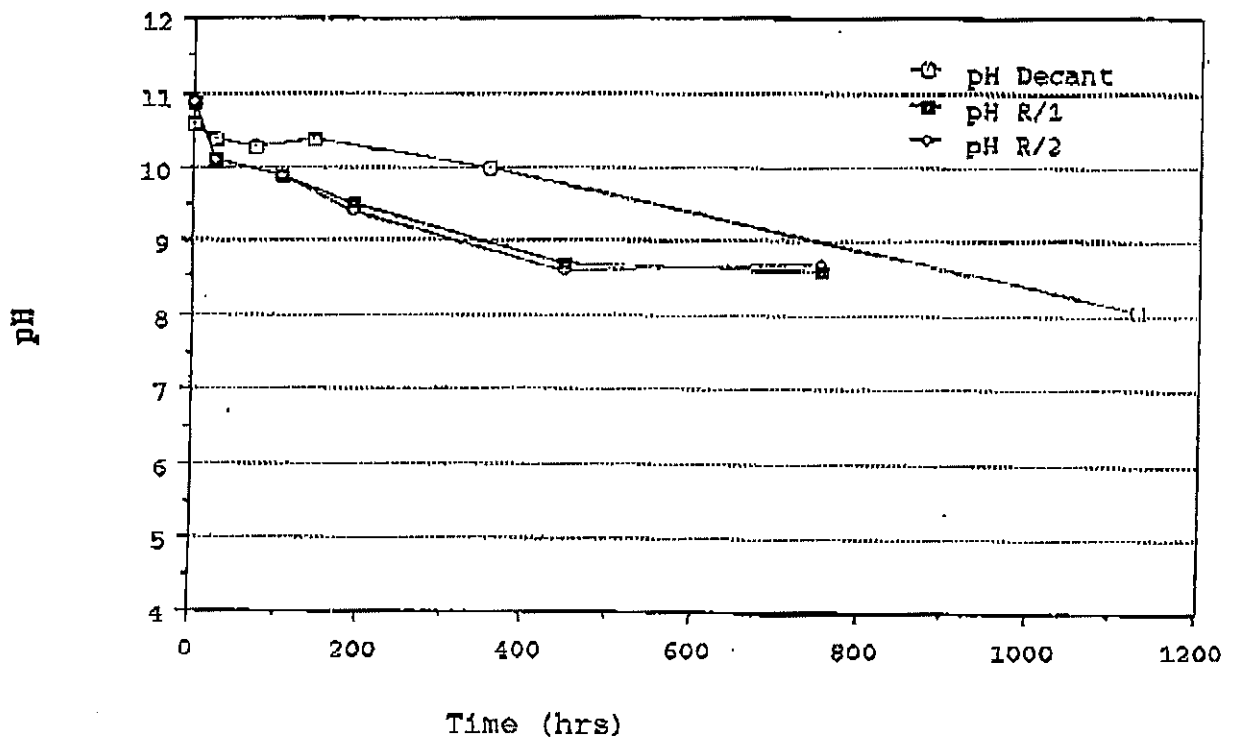
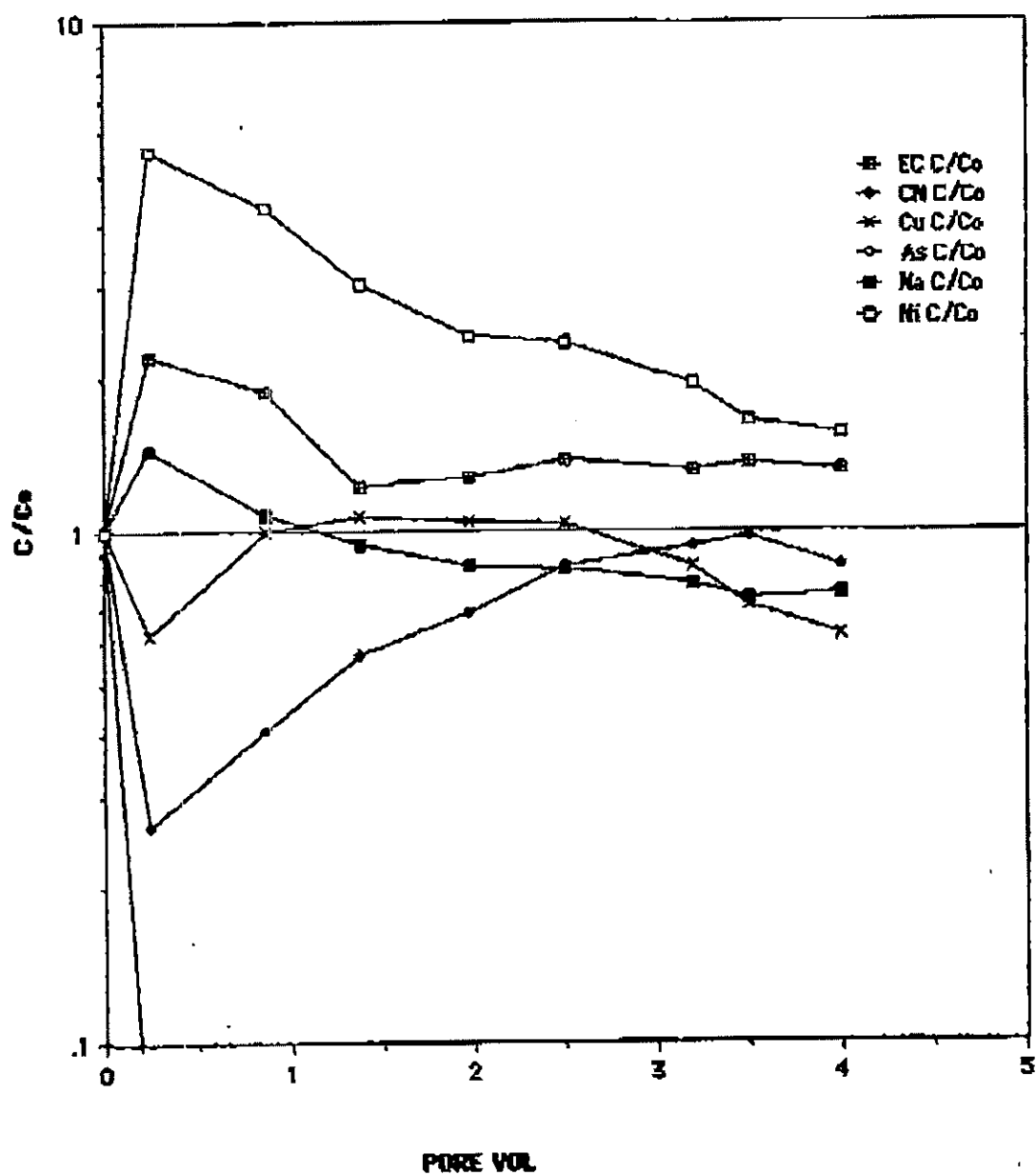


FIGURE 5: pH IN DECANT AND ENTRAINED LIQUOR



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FIGURE 6: SOIL ATTENUATION TEST RESULTS



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Figure 7: Accelerated Leaching Test Results - Slurry pH

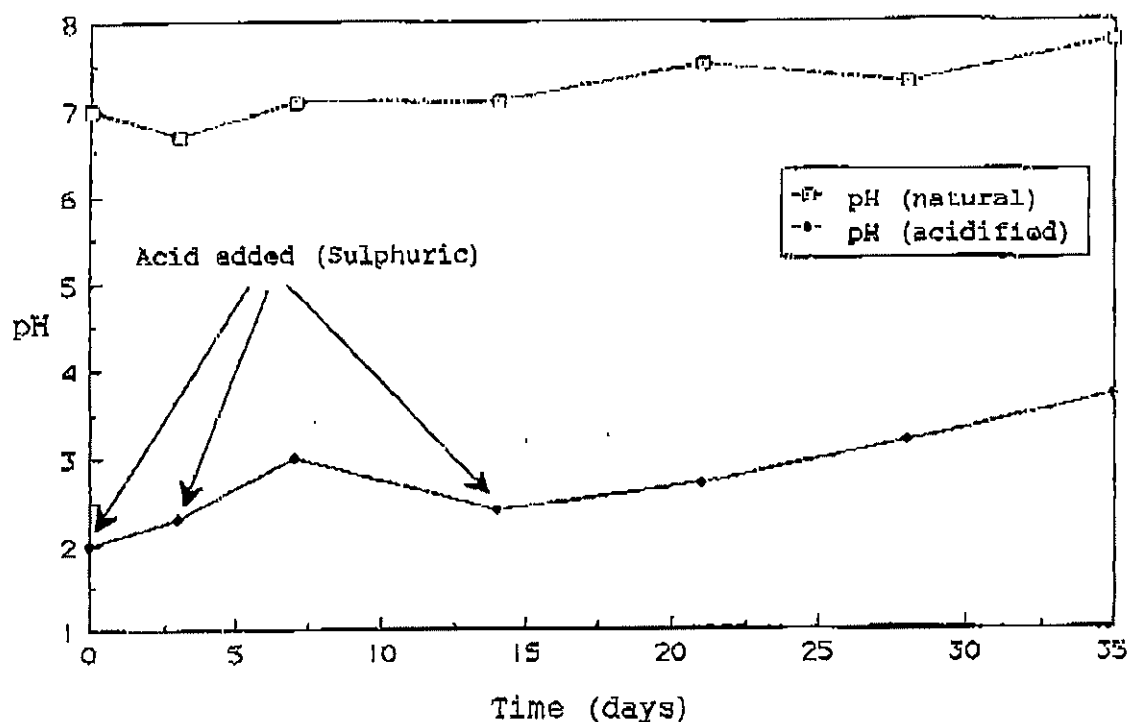
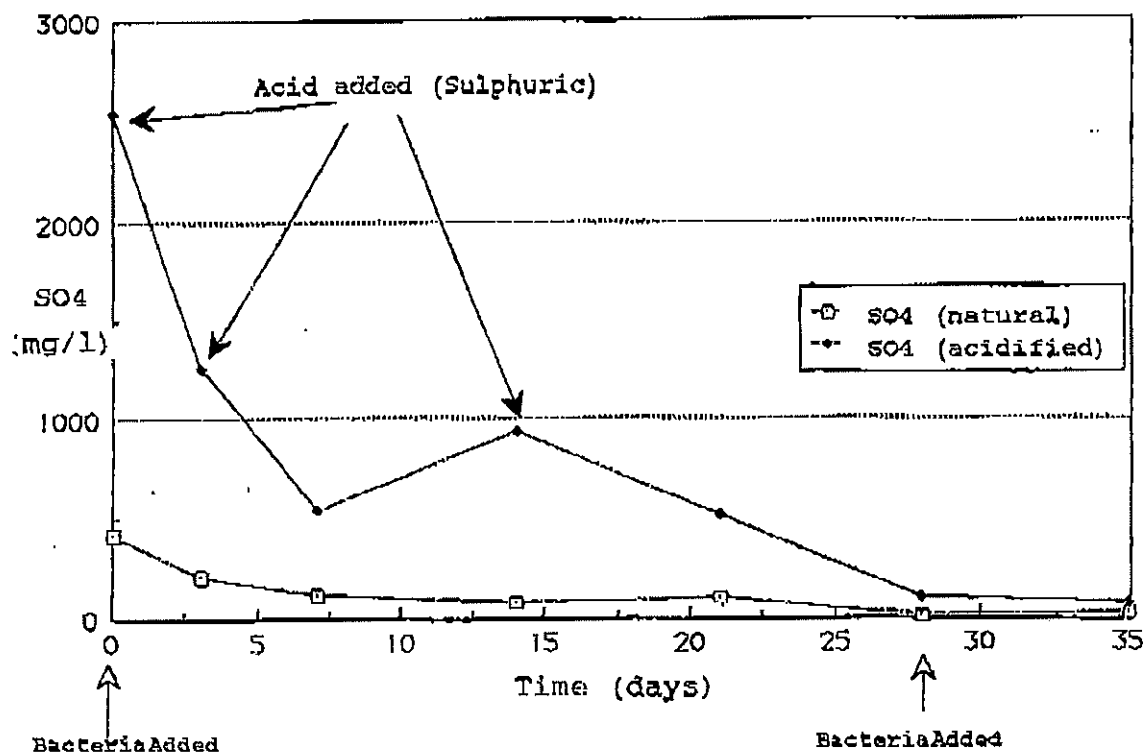


Figure 8: Accelerated Leaching Test Results - Solution SO4



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APPENDIX A

MULTI-ELEMENT COMPOSITION
OF
ROCK AND TAILINGS SAMPLES

ANALYTICAL SERVICES (W.A.) PTY LTD.
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REFERENCE NUMBER 36798

Order No 6301

Page 1

Sample Det Limit

Li = <200	Be = <500	Na = < 10	Mg = < 50	Al = < 50
P = < 20	S = < 50	K = < 10	Ca = <100	Ti = < 1
V = < 1	Cr = < 1	Mn = < 1	Fe = <100	Ni = < 10
Co = < 10	Cu = < 1	Zn = < 1	Ga = <200	Ge = < 10
As = < 2	Se = < 10	Rb = < 1	Sr = < 5	Y = <100
Zr = < 1	Nb = <200	Mo = < 1	Pd = <500	Ag = < 1
Cd = < 1	In = < 50	Sn = < 20	Sb = < 1	Te = <200
Cs = < 10	Ba = < 10	La = < 20	Ce = <100	Pr = < 20
Nd = <200	Sm = <100	Eu = <100	Gd = <100	Tb = < 50
Dy = <100	Ho = < 50	Er = <100	Tm = <200	Yb = <100
Lu = < 50	Hf = < 1	Ta = <100	W = <500	Re = < 50
Pt = <200	Au = < 2	Tl = < 50	Pb = < 20	Bi = <100
Th = < 50	U = < 50			

Sample W/R YN/PA

Li = 19	Be = 4.8	Na = 590	Mg = 850	Al = 9.4
P = 180	S = 1600	K = 5.4	Ca = 500	Ti = 1400
V = 58	Cr = 41	Mn = 19	Fe = 1.4	Ni = 50
Co = 2.2	Cu = 11	Zn = 12	Ga = 7.3	Ge = 19
As = 420	Se = < 10	Rb = 320	Sr = 250	Y = 18
Zr = 120	Nb = 6.8	Mo = < 1	Pd = <500	Ag = < 1
Cd = < 1	In = 41	Sn = < 20	Sb = 67	Te = 410
Cs = < 10	Ba = 780	La = 24	Ce = 56	Pr = 5.9
Nd = 20	Sm = <100	Eu = 600	Gd = 4.3	Tb = 550
Dy = 3.4	Ho = 660	Er = 1.9	Tm = <200	Yb = 2.5
Lu = 450	Hf = 1.9	Ta = 5.1	W = 6.6	Re = 66
Pt = <200	Au = < 2	Tl = 4.7	Pb = 6.6	Bi = 530
Th = 11	U = 2.1	Hg = 15 ppb		

Sample W/R YN/W

Li = 59	Be = 5.4	Na = 740	Mg = 1500	Al = 6.9
P = 160	S = 8800	K = 3.3	Ca = 700	Ti = 1200
V = 71	Cr = 69	Mn = 23	Fe = 1.2	Ni = 50
Co = 18	Cu = 19	Zn = 74	Ga = 5.1	Ge = < 10
As = 140	Se = 1.2	Rb = 210	Sr = 75	Y = 29
Zr = 76	Nb = 6.1	Mo = < 1	Pd = <500	Ag = < 1
Cd = < 1	In = 69	Sn = < 20	Sb = 20	Te = <200
Cs = 20	Ba = 680	La = 17	Ce = 41	Pr = 4.2
Nd = 16	Sm = <100	Eu = 530	Gd = 5.0	Tb = 700
Dy = 4.6	Ho = 940	Er = 3.1	Tm = <200	Yb = 3.4
Lu = 450	Hf = < 1	Ta = 1.7	W = 11	Re = 57
Pt = <200	Au = < 2	Tl = 7.3	Pb = 3.2	Bi = 120
Th = 7.5	U = 4.7	Hg = 260 ppb		

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Order No 6301

Page 2

Sample W/R YN/PW

Li = 52	Be = 4.2	Na = 5400	Mg = 6600	Al = 7.4
P = 360	S = 9700	K = 4.3	Ca = 3.8	Ti = 1100
V = 27	Cr = 42	Mn = 630	Fe = 2.2	Ni = 20
Co = 10	Cu = 18	Zn = 48	Ga = 3.4	Ge = < 10
As = 60	Se = < 10	Rb = 220	Sr = 350	Y = 21
Zr = 94	Nb = 5.1	Mo = < 1	Pd = < 500	Ag = < 1
Cd = < 1	In = < 0.1	Sn = < 20	Sb = 7.6	Te = < 200
Cs = < 10	Ba = 520	La = 18	Ce = 44	Pr = 4.9
Nd = 17	Sm = 140	Eu = 760	Gd = 4.3	Tb = 570
Dy = 3.7	Ho = 690	Er = 2.4	Tm = < 200	Yb = 2.7
Lu = 420	Hf = 1.4	Ta = 3.6	W = 4.8	Re = < 50
Pt = < 200	Au = < 2	Tl = 3.3	Pb = 9.4	Bi = 190
Th = 7.9	U = 2.4	Hg = 88 ppb		

Sample W/R YN/OW

Li = 46	Be = 4.2	Na = 1500	Mg = 2500	Al = 8.8
P = 300	S = 9000	K = 4.1	Ca = 2200	Ti = 870
V = 36	Cr = 56	Mn = 250	Fe = 1.8	Ni = 30
Co = 15	Cu = 19	Zn = 78	Ga = 4.5	Ge = < 10
As = 70	Se = 2.6	Rb = 280	Sr = 74	Y = 24
Zr = 71	Nb = 4.3	Mo = 2.1	Pd = < 500	Ag = < 1
Cd = < 1	In = 26	Sn = < 20	Sb = 12	Te = < 200
Cs = < 10	Ba = 720	La = 22	Ce = 54	Pr = 5.4
Nd = 20	Sm = < 100	Eu = 670	Gd = 5.3	Tb = 730
Dy = 4.5	Ho = 890	Er = 2.6	Tm = < 200	Yb = 2.5
Lu = 410	Hf = < 1	Ta = 1.3	W = 3.4	Re = < 50
Pt = < 200	Au = < 2	Tl = 4.2	Pb = 9.2	Bi = 230
Th = 9.2	U = 4.0	Hg = 418 ppb		

Sample TAIL YN/TS

Li = 69	Be = 5.6	Na = 480	Mg = 600	Al = 6.0
P = 800	S = 400	K = 2.0	Ca = 2700	Ti = 620
V = 21	Cr = 280	Mn = 72	Fe = 6600	Ni = 180
Co = 4.5	Cu = 27	Zn = 25	Ga = 2.4	Ge = < 10
As = 50	Se = < 10	Rb = 120	Sr = 470	Y = 37
Zr = 54	Nb = 2.5	Mo = 38	Pd = < 500	Ag = < 1
Cd = < 1	In = 51	Sn = < 20	Sb = 21	Te = < 0.1
Cs = < 10	Ba = 650	La = 24	Ce = 72	Pr = 9.3
Nd = 39	Sm = 4.3	Eu = 1.9	Gd = 9.5	Tb = 1.2
Dy = 7.9	Ho = 1.4	Er = 4.0	Tm = 220	Yb = 3.3
Lu = 630	Hf = < 1	Ta = 420	W = 5.2	Re = 58
Pt = < 200	Au = < 2	Tl = 1.4	Pb = 9.2	Bi = 430
Th = 5.8	U = 5.4	Hg = 62 ppb		

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PAGE 3

Sample Preparation

Sample preparation as instructed on submission form .

Sample Analysis

These elements have been determined on the sample after digestion with Nitric, Hydrofluoric and Perchloric acids to fumes. The digest has then been taken up in Nitric and Hydrochloric acids. This digest approaches total extraction for many elements; however some minerals, particularly Chromite and Cassiterite and high levels of some of the refractory minerals, may not be recovered in total. Although reported, Zirconium, Hafnium and Titanium results via this digestion will probably be low. The elements Na and K have been determined by Atomic Absorption. The elements Mg, Cr, V, Ni, As, Fe, Ti, Ca, Al, Zn, Cu, P and S have been determined by Optical Emission Plasma Spectrometry. All other elements have been determined by Inductively Coupled Plasma - Mass Spectrometry. Since short integration times have been used in assessing element concentrations, these results should be considered SEMI-QUANTITATIVE. The element detection limits for this analytical run have been reported, and consideration should be given to them in relation to low level positive results on samples.

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INDEPENDENT DESKTOP REVIEW OF RISK LEVEL AND APPROPRIATE CAPPING STRATEGY FOR TSF CELL B AT YANDAN GOLD MINE



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David Williams

2 June 2021

EXECUTIVE SUMMARY

Dr David Williams was commissioned by Mr Peter Rohner of GBM Resources Ltd, to carry out an Independent Desktop Review of the risk level and appropriate capping strategy for TSF Cell B at Yandan Gold Mine in Central Queensland.

Based on the available information, TSF Cell B satisfies Table 6-1 in the ERC User Guide (2009) for a Low Risk Category, and grass on a 400 to 600 mm gravelly topsoil cover is recommended. This is supported by the sulfide minerals in the Cell B tailings having completely oxidised to at least 600 mm depth, and revegetation of the trial 400 to 600 mm of gravelly topsoil placed on the Cell B tailings achieving similar success to reference sites, with similar minor erosion, over a 7-year period. The available information does not support a High Risk Category as considered by the Queensland Department of Environment and Science (DES).

Consideration could be given to compacting the surface tailings to form a low permeability layer to enhance the store and release function of a revegetated gravelly topsoil cover on TSF Cell B. This would better hold-up moisture to be available to support revegetation, limit net percolation and seepage, and limit potential salt uptake into the cover. Surface salinity is most likely related to evaporative concentration in ponded surface water rather than to uptake from the tailings.

O'Kane did not consider a revegetated gravelly topsoil cover, as has been demonstrated to be successful on TSF Cell B tailings. O'Kane considered a deficient and limited thickness store and release cover design, with a capillary break (or drain), and with no low permeability layer to hold-up rainfall infiltration, limit net percolation and limit salt uptake. O'Kane focussed on much thicker cover system designs incorporating capillary break(s) of unspecified coarse rock and a low permeability layer of compacted clay.

O'Kane's inclusion of a capillary break in their Base Case and an upper capillary break in their Case 2 is counter-productive, since they would act as a drain to increase net percolation into the underlying tailings. Capillary breaks need to exclude fines to be effective and are considered prone to failure in the longer-term due to settlement and fines migration. Further, given the absence of residual sulfide minerals in the upper Cell B tailings and their low permeability, a capillary break is not needed.

Excessive thickness of the combined topsoil and growth medium in some of the O'Kane cover system designs would lead to deep drainage beyond the rooting zone of the proposed grass cover.

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1 INTRODUCTION

Dr David Williams was commissioned by Mr Peter Rohner of GBM Resources Ltd, to carry out an Independent Desktop Review of the risk level and appropriate capping strategy for TSF Cell B at Yandan Gold Mine (Yandan) in Central Queensland. Reference was made to:

- Information on the mineralogy of the ore and hence the tailings in Cell B.
- RGS Letter Report R001-C on Yandan Cell B Soil, Oxide and Sulfide Tailings Assessment, dated 31 July 2015.
- Monitoring of ongoing capping trials on Cell B from 2014 to 2021, including an AARC Yandan Gold Mine Rehabilitation Monitoring Report, dated 22 January 2021.
- Report by O'Kane Consultants Pty Ltd (O'Kane) on Yandan Gold Mine TSF Cell B Conceptual Cover System Design Update, dated 1 December 2019.
- Various correspondence from meetings with the Queensland Department of Environment and Science (DES).

2 REVIEW OF RISK AND APPROPRIATE CAPPING

Review comments are highlighted in ***bold italics***.

2.1 Background

The Yandan orebody comprises generally very fine-grained gold within two-stage bleaching around the ore of quartz, illite, K-feldspar and pyrite, overprinted by intense kaolin alteration. The composition of the ore suggests clay-dominated tailings.

The Yandan TSF comprises two cells. Cell A was revegetated directly on tailings and was considered in Straits Gold's Rehabilitation Review in 2013 to have been largely effective in terms of revegetation and surface drainage, apart from limited central ponding and lack of revegetation (see Figure 1, Figure 2.2 in the O'Kane Report). ***No comment is offered in the O'Kane Report, although the bare patch in the middle of Cell A may be related to consolidation of the tailings producing a low spot prone to ponding. Salinity at this location is most likely related to evaporative concentration rather than to uptake from the tailings.***



Figure 1 Revegetated TSF Cell A and largely unvegetated Cell B

2.2 Geochemical Assessment of Soil and Cell B Tailings

RGS sampled 85 soil, oxide tailings, sulfidic tailings and mixed tailings to a depth of 600 mm, at the locations shown in Figure 2 (Figure 2-2 in the RGS Report). ***Note the partial revegetation seen directly on the tailings in Figure 2.*** The measured soil 1(solids):5(deionised water) paste pH varied from 3.9 to 7.0, the oxide tailings paste pH varied from 4.1 to 6.5, the sulfidic tailings paste pH varied from 4.0 to 6.1, and the mixed tailings paste pH varied from 4.0 to 6.6. There was no measured alkalinity. The tailings samples did not generally produce acidity, with only nine tailings samples producing acidity ranging from 6 to 35 mg/L, averaging 17 mg/L.

The soil 1(solids):5(deionised water) paste electrical conductivity (EC) varied from 100 to 2,000 $\mu\text{S}/\text{cm}$, the oxide tailings paste EC varied from 600 to 2,950 $\mu\text{S}/\text{cm}$, the sulfidic tailings paste EC varied from 600 to 2,400 $\mu\text{S}/\text{cm}$, and the mixed tailings paste EC varied from 650 to 2,350 $\mu\text{S}/\text{cm}$. ***It is noted that the paste EC is not a true measure of the EC of the pore water, which can only be determined by extracting pore water. For relatively dry samples, producing a paste results in crystallised salts being dissolved, which over-estimates the salinity of the pore water (Indrawan et al. 2012¹).*** The dominant anion is sulfate and the majority of the samples produced water with an EC suitable for irrigation purposes.

All 85 samples were classified as “barren” (containing essentially no residual sulfide minerals) based on the Acid Base Accounting. The sulfide minerals present in the tailings were completely oxidised to a depth of 600 mm, and any future very low acid forming potential would come from the pore water or secondary minerals such as Jarosite. Metals, such as aluminium, iron and manganese, were low compared with average crustal abundance, and other metals, such as arsenic and mercury, were sparingly soluble. RGS suggested that any residual acid generation could be mitigated by adding alkaline minerals such as lime, provided that elevating the pH did not cause the release of metals from secondary minerals such as Jarosite.

RGS considered that the revegetation of the Cell B tailings, apart from along drainage lines (as seen in Figure 2), is likely limited by the availability of water. The tailings in Cell B were considered by RGS to have low permeability, particularly if compacted, limiting deep drainage. There was no apparent accumulation of soluble salts in the trial cover on Cell B due to capillary action, obviating the need for a capillary break in the cover system, which in any case is prone to failure over time due to settlement and fines migration. Further, there was no accumulation of tailings in the surface soils due to wind erosion. RGS recommended a soil cover 0.5 to 1.0 m thick.

¹ Indrawan, I.G.B., Williams, D.J. and Scheuermann, A. (2012). Determination of the true electrical conductivity of a saline clay. *Proceedings of Eleventh Australia-New Zealand Conference on Geomechanics, Melbourne, Australia, 15-18 July 2012*, 92-95.

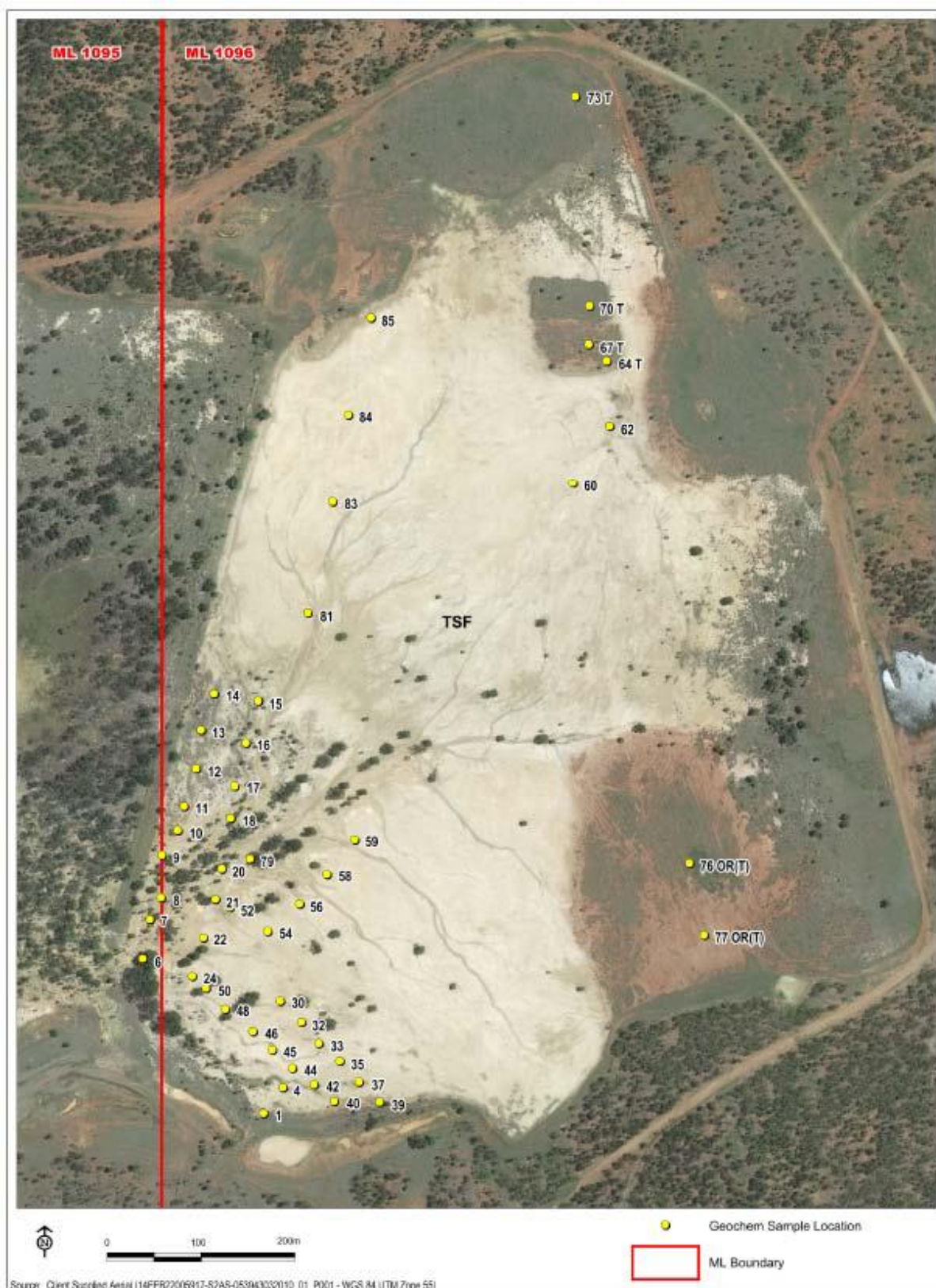


Figure 2 RGS sample locations on TSF Cell B

2.3 Monitoring of Ongoing Capping Trials on Cell B

AARC reported in 2021 on rehabilitation monitoring as summarised in Table 1 and 2 (from Tables 1 and 2 of AARC Report, and a supplied spreadsheet for revegetation towards the end of the dry season on 24-26 August 2020), with the rehabilitation sites shown in Figure 3 (Figure 2 in the AARC Report). The revegetation was dominated by grasses, with some forbs (flowering plants) and occasional shrubs. It is clear from Table 2 that direct revegetation of Cell A oxide tailings, and revegetation of 400 to 600 mm of gravelly topsoil on Cell B sulfide tailings that had completely oxidised to a depth of at least 600 mm depth, achieved similar success to the reference sites. Revegetation of thin topsoil on Cell B tailings was somewhat less successful compared with the reference site. Vegetation cover on all sites is greener, and tends to be taller and at a higher percentage, during and following the wet season. Erosion of the reference sites and revegetated covers was generally minor.

Table 1 Rehabilitation monitoring

NUMBER	DATES	SEASON
1	8-9 October 2014	Pre-wet
2	25-26 March 2015	Wet
3	10-11 June 2015	Post-wet
4	13-14 August 2015	Dry
5	17-18 May 2016	Post-wet
6	22-22 July 2017	Post-wet
7	28-29 May 2018	Post-wet
8	25-26 February 2019	Post-wet
9	24-26 August 2020	Dry

Table 2 Revegetation at end of dry season on 19 September 2020

SITES	YEAR ESTABLISHED	% COVER AUG 20
Reference (R1 to R3)	2014	20, 24 & 71
Cell A directly on oxide tailings (A1 & A2)	2014	42 & 39
Cell B 300 mm topsoil (B1 & B2)	2014	18 & 12
Cell B 450 mm topsoil (B3 & B4)	2014	28 & 23
Cell B 400 to 600 mm gravelly topsoil (B5 & B6)	2014	31 & 57

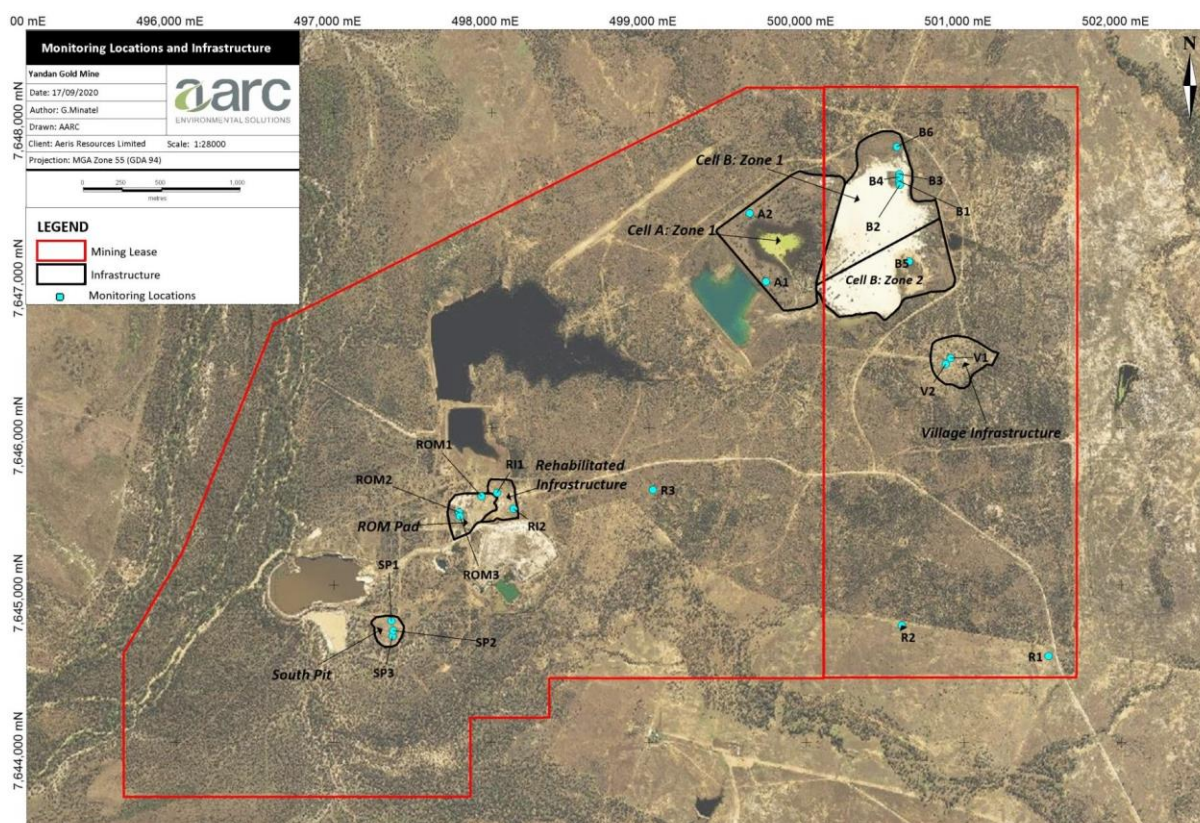


Figure 3 Locations of rehabilitation monitoring sites

2.4 Assessment of Risk Category for TSF Cell B

According to the ERC User Guide (2019)², the key entry for review by the DES is the Risk Category selected by the User, which should reflect the risk that TSF Cell B poses to the environment. Table 6-1 in the ERC User Guide (2019) provides Risk Category characteristics to inform the selection of the Risk Category. For TSFs, these are reproduced in Table 3.

On the basis of the available information, TSF Cell B has the following characteristics:

- ***Sulfide minerals in the tailings are completely oxidised to a depth of at least 600 mm.***
- ***Metals, such as aluminium, iron and manganese, are low compared with average crustal abundance, and other metals, such as arsenic and mercury, are sparingly soluble; hence salinity is low.***
- ***The tailings support traffic.***
- ***The TSF embankments are <15 m high.***

² DES. (2019). User Guide for Estimated Rehabilitation Cost Calculator for Mining. Operational Support, Department of Environment and Science, State of Queensland. (https://environment.des.qld.gov.au/_data/assets/pdf_file/0029/89615/rs-gl-user-guide-erc-calculator-mining.pdf).

- *The compacted tailings are of low permeability; that is, suitable as a low permeability layer to hold-up rainfall infiltration, limit net percolation into the underlying tailings and hence limit seepage to the environment, and limit potential uptake of salts into the cover.*
- *Revegetation of 400 to 600 mm of gravelly topsoil placed on the Cell B tailings achieved similar success to reference sites, with similar minor erosion, over a 7-year period.*

On this basis, TSF Cell B satisfies Table 6-1 in the ERC User Guide (2009) for a Low Risk Category, for which a revegetated cover is required. DES considers the TSF Cell B to be High Risk due to the presence of sulfidic tailings, which is inconsistent with the available information, including the successful revegetation of 400 to 600 mm of gravelly topsoil placed on the Cell B tailings.

Table 3 Risk Category characteristics for TSFs

RISK CATEGORY	CHARACTERISTICS FOR TSFS
High	Potentially acid forming (PAF) material Other highly reactive materials including (ARD/AMD/NMD) Poor consolidation and low shear strength tailings Requiring composite liners (e.g., HDPE) Embankments >30 m high Observed contaminated seepage capable of causing environmental harm
Medium	Moderately reactive materials (ARD/AMD/NMD) Hypersaline tailings that could impact on the proposed end land use objectives for the facility Low strength consolidated tailings Embankments 15 to 30 m high
Low	Low reactive materials (ARD/AMD/NMD) Moderate to low salinity Moderate strength consolidated tailings Embankments <15 m high
Very Low	Zero reactive materials (ARD/AMD/NMD) Low salinity Moderate strength consolidated tailings Embankments <15 m high

2.5 TSF Cell B Cover System Design by O’Kane

A store and release cover system was originally proposed by O’Kane as a conceptual cover system design for Cell B in 2015, but without a “low permeability layer”. **The selection of a store and release cover system is consistent with the GARD Guide (2011), as shown in Figure 4 (Figure 4.3 in the O’Kane Report).** All covers have some “store and release” function, including direct revegetation of inert tailings underlain by low permeability tailings, as was largely successfully applied to Cell A. The vital components of a store and release cover are an underlying low permeability layer to “hold-up” rainfall infiltration, limit net percolation into the underlying tailings, and limit potential uptake of salts into the cover, and a growth medium to sustain revegetation. Where it is desirable to limit rainfall runoff and erosion, the upper surface may be hummocked.

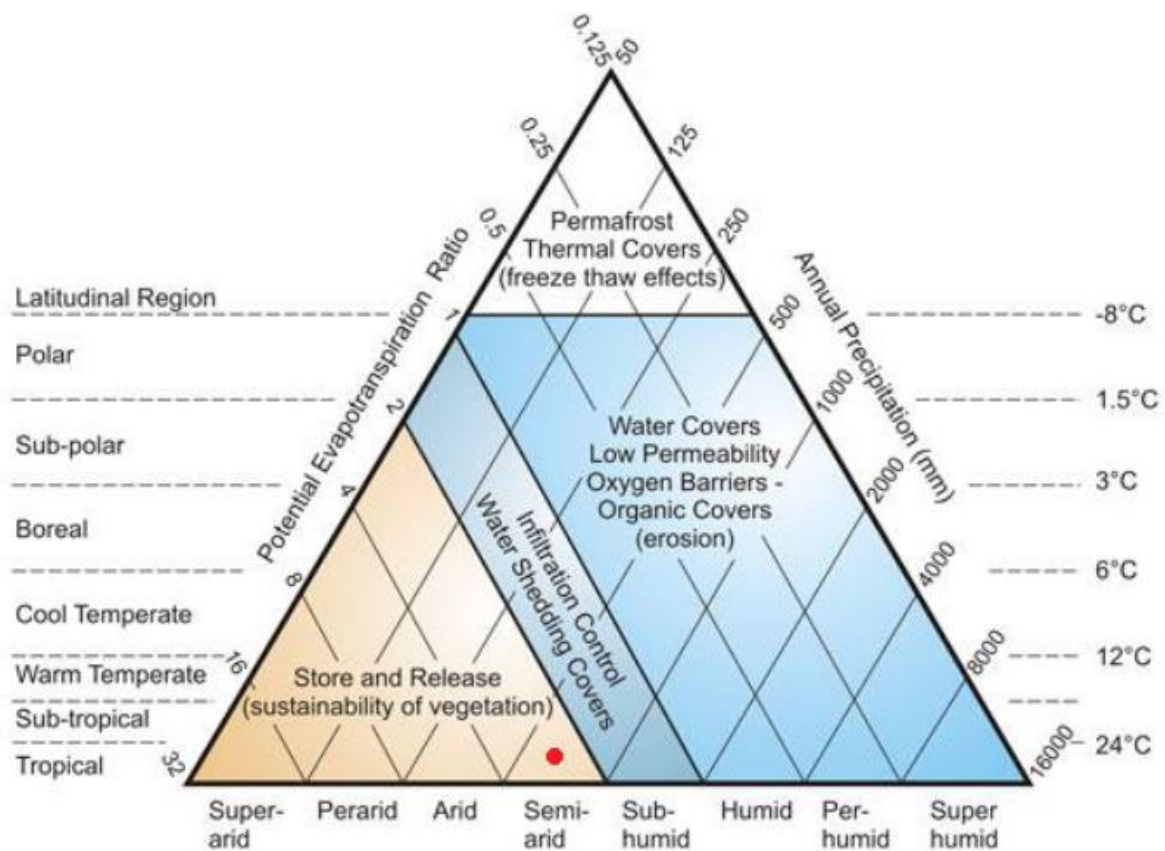


Figure 4 Recommended cover system for Yandan TSF Cell B (indicated by red dot)

DES required a cover on Cell B that limits the potential for acid and metalliferous drainage (AMD), through a low permeability layer over the sulfidic tailings. **In fact the upper 600 mm depth of tailings, at least, are oxidised. DES did not require a capillary break layer.**

Subsequently, DES was prepared to consider an alternative capping design (Case 4 in Figure 5), supported by the results of a trial cover established on representative tailings. The alternative cover system design and trial would need to be certified by a suitably qualified, independent, third party reviewer. There is no mention of the need for cover trials in the ERC User Guide (2019).

The objectives of the cover system are to ensure clean surface runoff and limit surface erosion, limit potential salt uptake into the cover, limit net percolation into the sulfide tailings and the seepage of AMD, and support future cattle grazing while avoiding deep-rooted trees.

2.5.1 Cover System Designs Considered by O’Kane

O’Kane assessed the suitability of available cover materials, including Topsoil, Growth Medium, Coarse Rock, and Clay from an offsite borrow location. O’Kane considered four cover system designs:

1. The previously proposed store-and-release cover system design;
2. Incorporating a double capillary break to the DES default thickness;
3. Incorporating a single capillary break to the DES default thickness; and
4. Incorporating an alternative single capillary break thickness.

The cover system designs are compared in Figure 5 (Figure 5.1 in the O’Kane Report). ***It is noted that O’Kane did not include among their cover system designs a store and release cover with an underlying low permeability layer, as is normally required to hold-up rainfall infiltration and limit net percolation and salt uptake. This is despite all of the other three designs incorporating a low permeability (Barrier) layer. Their Base Case included a capillary break (of Coarse Rock), which is essentially a “drain” in the absence of an overlying low permeability layer. It is further noted that the thickness of the Base Case is much less than that of the other designs considered, with the Growth Medium absent. These deficiencies make comparisons between the cover system designs somewhat meaningless, and the results biased against a store and release cover system. It is also not clear how O’Kane determined the representative dimension of the “variable” thickness of Oxide Tailings to be 0.4 m, given that RGS found oxidised tailings to at least 0.6 m depth, nor the rationale for the variable thickness of Topsoil between the alternative cover system designs. Further, the O’Kane Report did not consider compacted tailings as a possible low permeability layer, as suggested by RGS (see Section 2.2).***

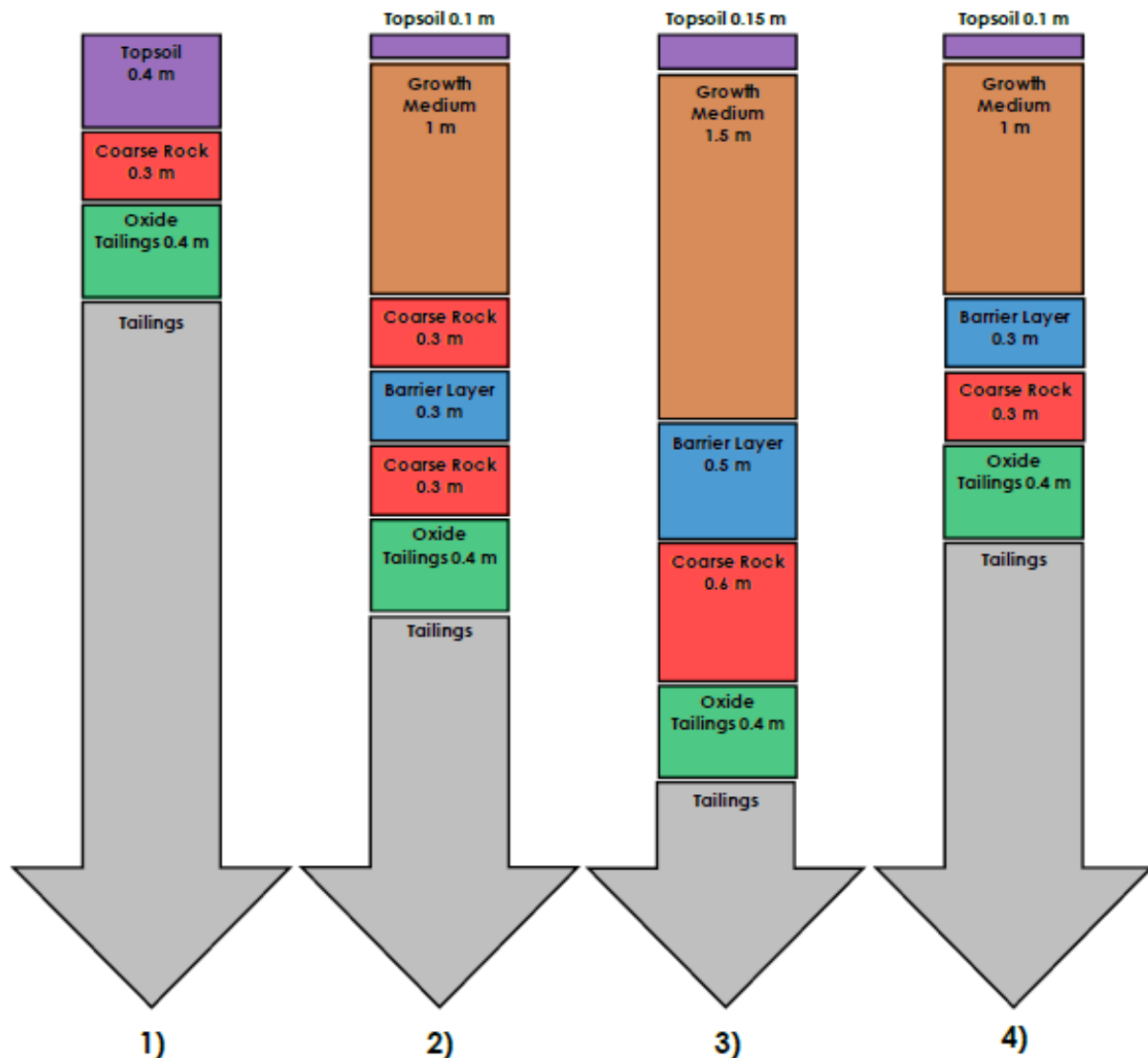


Figure 5 Four cover system designs considered by O’Kane

2.5.2 Available Cover Materials and Their Geotechnical Parameters

The available cover materials identified by O’Kane include Topsoil, Growth Medium, Coarse Rock, and Clay from an offsite borrow location, plus the Oxide Tailings. **Figure 3.16 of the O’Kane Report indicates a laboratory-measured Air Entry Value (AEV) for the Compacted Clay (Barrier Layer) of about 8 kPa. Figure 5.2 in the O’Kane Report indicates that all of the cover materials were presumed to have a similar, low AEV of 1 to 3 kPa, which is more representative of Coarse Rock. The Topsoil, Growth Medium and Coarse Rock all have a very much higher inferred dry density (ρ_{dry}) than would be expected, averaging about 2.1 t/m³ (for a very low porosity n of about 0.2 and a very low saturated gravimetric moisture content w_{sat} of about 9%). These materials would be placed loose in practice, Topsoil and Growth Medium being intended to promote and sustain revegetation, and the Coarse Rock (capillary break) being loose by virtue of its lack of fines.**

Figure 3.16 of the O’Kane Report indicates for the Compacted Clay a low ρ_{dry} of about 1.54 t/m^3 (for n of about 0.42 and w_{sat} of about 27%). Figure 5.2 of the O’Kane Report presumes for the Compacted Clay a more reasonable ρ_{dry} of about 1.78 t/m^3 (for n of about 0.33 and w_{sat} of about 19%). The Modified maximum dry densities were much higher, ranging from 2.05 to 2.22 t/m^3 , at very much lower optimum gravimetric moisture contents ranging from 10 to 7%, which are considered unrepresentative of field conditions.

The Oxide Tailings were presumed to have a ρ_{dry} of only about 1.57 t/m^3 (for n of 0.42 and a high w_{sat} of 27%), which could be increased though compaction.

The saturated hydraulic conductivity (k_{sat}) values adopted by O’Kane are reproduced in Table 4 (Table 5.1 in the O’Kane Report). **Presumably the Sulfidic Tailings are presumed to have the same k_{sat} as the Oxide Tailings.**

Table 4 Saturated hydraulic conductivity values adopted by O’Kane

MATERIAL	SATURATED HYDRAULIC CONDUCTIVITY (m/s)
Topsoil	5×10^{-6}
Growth Medium	1×10^{-4}
Coarse Rock	5×10^{-3}
Low Permeability (Barrier) Layer	1×10^{-9}
Oxide Tailings	1×10^{-7}

The k_{sat} of the low permeability (barrier) layer is apparently presumed by O’Kane to be $1 \times 10^{-9} \text{ m/s}$ (up to 32 mm/year for a constant supply of water at unit hydraulic gradient). This is higher than that obtained in the laboratory, but lower than that obtained in the field. Under the climatic conditions of Central Queensland, rainfall may fall on perhaps 10% of the days of the year, and the low permeability layer would be unsaturated for most of the year, for which an unsaturated hydraulic conductivity of perhaps two orders of magnitude lower than the saturated value may apply, giving an average hydraulic conductivity of the order of $1 \times 10^{-10} \text{ m/s}$ (up to 3 mm/year). The k_{sat} of the Oxide Tailings is apparently presumed to be $1 \times 10^{-7} \text{ m/s}$, and may average $1 \times 10^{-8} \text{ m/s}$ (up to 315 mm/year). The estimated saturated hydraulic conductivities of the other materials appear reasonable, and it is noted that the Coarse Rock is presumed to be free-draining.

Figure 5.3 in the O’Kane Report indicates that all materials have the same saturated diffusion coefficient of $1.78 \times 10^{-9} \text{ m}^2/\text{s}$, giving a conservative (high) uptake of salts from the tailings. It would expected that the coarser-grained the material, the greater the saturated diffusion coefficient.

O'Kane adopted a conservative vegetation coverage of 28%, ***which is low compared with measured dry season coverage***. Further, O'Kane adopted a root penetration depth of 3.0 m, with the majority of the roots within the top 1.0 m depth, ***irrespective of the variable depth of the combined Topsoil and Growth Medium in the different cover system designs. This is not rational. Grass roots are relatively shallow, and would also not be expected to penetrate the Oxide Tailings, given that it is acidic (measured at 3.6, much lower than that of the Sulfidic Tailings measured at 5.9).***

2.5.4 Numerical Modelling by O'Kane

The one-dimensional (***vertical***) numerical modelling carried out by O'Kane assessed net percolation (NP) of rainfall, water storage in the cover available for revegetation, and salt uptake into the cover. O'Kane adopted a unit hydraulic gradient at the lower boundary of the model (***presumably at 3 m depth, but this is not made clear***), presuming that the water table within the tailings does not influence the water balance of the cover systems. ***However, the intention of the low permeability (Barrier) layer is to hold-up or perch water, so that the hydraulic gradient at the lower boundary will vary and could be much higher than unity following rainfall infiltration events.***

From the results of the numerical modelling, O'Kane concluded:

- The Base Case design predicted NP of approximately 54% of average annual rainfall, without revegetation.
- The double and single capillary breaks to the DES default thickness predicted a moderate reduction in NP, without revegetation.
- The alternative single capillary break thickness predicted the greatest reduction in NP (of 4% of average annual rainfall), without revegetation.
- Incorporating capillary breaks served to increase the storage of water in the cover system.
- With revegetation, low NP was predicted for all alternatives, including the Base Case.
- Incorporating a single capillary break to the DES default thickness was predicted to best limit salt uptake into the cover, although all capillary break alternatives were predicted to limit salt uptake, and the Base Case to a lesser degree.
- Rainfall runoff was predicted to increase from the Base Case (2% of average annual rainfall) to Cases 3 to 4 (16 to 20% of average annual rainfall).

The slope of the cover surface is not given by O'Kane, and no explanation is offered for the variation in rainfall runoff between the different cover system designs, which should be similar for the same slope. It could be that the slope is that of the tailings beach (presumably about 1%). A store and release cover is normally meant to contain runoff.

2.5.5 Comments on Effectiveness of O'Kane Cover System Designs

Dr Williams offers the following comments on the four O'Kane cover system designs and their likely effectiveness in sustaining grasses and limiting net percolation into the tailings:

- **Base Case 1:**
 - *The k_{sat} of the Topsoil is 50% higher than that of the bare Oxide Tailings, and hence will allow 50% greater rainfall infiltration, and reduce evaporation.*
 - *The free-draining capillary break (Coarse Rock) underlying the Topsoil will accept all of the infiltrated rainfall until it is saturated, filling a porosity of about 0.3; that is, 90 mm of rainfall.*
 - *The Oxide Tailings is sufficiently permeable to percolate all of the rainfall infiltration into the cover.*
 - *Hence, the Base Case cover system is far less effective in limiting net percolation of rainfall into the tailings than no cover.*
- **Case 2:**
 - *The 0.1 m of Topsoil and 1 m of Growth Medium will essentially allow all rainfall to infiltrate the cover and wet up the underlying capillary break (Coarse Rock).*
 - *This will make water largely unavailable to shallow-rooted grasses.*
 - *Wetting-up of the upper capillary break (Coarse Rock) will maintain a head of water above the low permeability (Barrier) layer, encouraging net percolation into the lower capillary break (Coarse Rock) and tailings below.*
- **Case 3:**
 - *The 0.1 m of Topsoil and 1.5 m of Growth Medium will essentially allow all rainfall to infiltrate the cover to the low permeability (Barrier) layer.*
 - *This will make water largely unavailable to shallow-rooted grasses.*
 - *It will also maintain a head of water above the low permeability layer, encouraging net percolation into the capillary break (Coarse Rock) and tailings below.*
- **Case 4:**
 - *The 0.1 m of Topsoil and 1 m of Growth Medium will essentially allow all rainfall to infiltrate the cover and wet up the underlying low permeability (Barrier) layer.*
 - *This will make water largely unavailable to shallow-rooted grasses.*
 - *It will also maintain a head of water above the low permeability (Barrier) layer, encouraging net percolation into the capillary break (Coarse Rock) and tailings below.*

No specification for the capillary break material is given in the O’Kane Report apart from the descriptor “Coarse Rock”. The function of a capillary break is to limit capillary rise from below, which requires the exclusion of fines that would lead to capillary rise. Coarse Rock would need to be washed to exclude fines. Placing fine-grained growth materials above a capillary break leads to the inevitable transport of fines with rainfall infiltration into the capillary break, rendering it ineffective. Further, placing a free-draining layer at the base of the growth materials serves no useful purpose and is likely to be detrimental, as described above. A capillary break would best be placed directly above the saline tailings, and beneath a low permeability layer. However, there remains a potential for fines from the low permeability layer to migrate into the capillary break. An effective low permeability layer will limit both downward and upward flow, removing the need for a capillary break, which is difficult to get right and to sustain.

No comment is made in the O’Kane Report about whether the cover system designs will limit oxygen ingress into the tailings, and hence limit the oxidation of the Sulfidic Tailings. However, due to the dry seasonal climate of Central Queensland, the covers will be relatively dry for much of the year and oxygen ingress is unlikely to be limited.

2.5.6 Construction Costs Estimated by O’Kane

The estimated construction costs for all three designs incorporating capillary breaks were considerably higher than those estimated for the Base Case, with the alternative single capillary break thickness the least costly of these. The O’Kane Report recommended a cover design incorporating the alternative single capillary break thickness as the most cost-effective. ***A store and release cover with an underlying low permeability (Barrier) layer should also be assessed for cost-effectiveness, along with direct revegetation as a base case, and a revegetated gravelly topsoil cover.***

3 CONCLUSIONS AND RECOMMENDATIONS

Based on the available information, TSF Cell B satisfies Table 6-1 in the ERC User Guide (2009) for a Low Risk Category, and grasses on a 400 to 600 mm gravelly topsoil cover is recommended. This is supported by the sulfide minerals in the Cell B tailings having completely oxidised to at least 600 mm depth, and revegetation of the trial 400 to 600 mm of gravelly topsoil placed on the Cell B tailings achieving similar success to reference sites, with similar minor erosion, over a 7-year period. The available information does not support a High Risk Category as considered by DES.

Consideration could be given to compacting the surface tailings to form a low permeability layer to enhance the store and release function of a revegetated gravelly topsoil cover on TSF Cell B. This would better hold-up moisture to be available to support revegetation, limit net percolation and seepage, and limit potential salt uptake into the cover. Surface salinity is most likely related to evaporative concentration in ponded surface water rather than to uptake from the tailings.

O'Kane did not consider a revegetated gravelly topsoil cover, as has been demonstrated to be successful on TSF Cell B tailings. O'Kane considered a deficient and limited thickness store and release cover design, with a capillary break (or drain), and with no low permeability layer to hold-up rainfall infiltration, limit net percolation and limit salt uptake. O'Kane focussed on much thicker cover system designs incorporating capillary break(s) of unspecified coarse rock and a low permeability layer of compacted clay.

O'Kane's inclusion of a capillary break in their Base Case and an upper capillary break in their Case 2 is counter-productive, since they would act as a drain to increase net percolation into the underlying tailings. Capillary breaks need to exclude fines to be effective and are considered prone to failure in the longer-term due to settlement and fines migration. Further, given the absence of residual sulfide minerals in the upper Cell B tailings and their low permeability, a capillary break is not needed. Excessive thickness of the combined topsoil and growth medium in some of the O'Kane cover system designs would lead to deep drainage beyond the rooting zone of the proposed grass cover.

APPENDIX A – Curriculum Vitae

Professor David J Williams

BE (Hons I), PhD, FIEAust, MAusIMM, CPEng, RPEQ

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Professor David Williams is a Chartered and Registered Professional Engineer with over 40 years of experience. His discipline area is Geotechnical Engineering, and he is internationally recognised for his expertise and experience in mine waste management and mine closure. He is particularly recognised for his expertise in tailings dams, and the closure and rehabilitation of tailings dams and waste rock dumps, including the design of covers. He carries out high-level reviews of and provides expert advice and opinion on tailings dam designs, tailings and waste rock facility closure, and the closure and rehabilitation of open pits.

He authored in 2016 the Tailings Management Handbook, as part of the Commonwealth Leading practice sustainable development program for the mining industry. He is on the Working Party for the Australian National Committee for Large Dams Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure published in 2012, with an Addendum on Static Liquefaction published in 2019, and commissioned to write updates.

QUALIFICATIONS

1979	PhD, Soil Mechanics	University of Cambridge, England
1975	BE (Hons I), Civil Engineering	Monash University, Australia

AWARDS/DISTINCTIONS/FELLOWSHIPS

1996	Japan Society for the Promotion of Science Fellow
1995	The University of Queensland Collaborative Research Travel Grant
1995	Australian Minerals and Energy Environment Foundation (AMEEF) Travelling Scholarship
1993	Australian Research Fellow (Industry)
1992	AMEEF Environmental Excellence Award (Individual)
1990	Masuda Fellow for Collaborative Research in Japan, Jan-Feb
1989	The University of Queensland Collaborative Research Travel Grant

MEMBERSHIPS

From 2015	Member, Australasian Institute of Mining and Metallurgy
From 2015	Registered Professional Engineer of Queensland (RPEQ)
1986-1987	Member, National Committee, Australian Geomechanics Society
2007-2008	
From 1984	Member, Queensland Committee, Australian Geomechanics Society, Chair in 1986
From 1980	Member, Australian Geomechanics Society
From 1980	Member then Fellow, Institution of Engineers, Australia

EMPLOYMENT HISTORY

2007 – Present	Professor of Geotechnical Engineering Founder and Director of Geotechnical Engineering Centre Manager of the Large Open Pit Project School of Civil Engineering The University of Queensland
1994 – 2007	Associate Professor of Geomechanics Department of Civil Engineering The University of Queensland
1990 – 1994	Senior Lecturer in Geomechanics Department of Civil Engineering The University of Queensland
1983 – 1989	Lecturer in Geomechanics Department of Civil Engineering The University of Queensland
1980 – 1983	Geotechnical Engineer Melbourne and Brisbane Golder Associates Pty Ltd
1979 – 1980	Engineer Country Roads Board (CRB) of Victoria
1976 – 1979	Research Student University of Cambridge, England
1972 – 1976	Engineer, Cadet Engineer, CRB, Victoria

SUMMARY OF CONSULTING COMMISSIONS

Board and Expert Panel Memberships

- Member of the Independent Technical Review Board for the Ranger Mine Pit 3 Capping of Tailings from 2020
- Independent Member of the Alcoa Impoundments Lead Team from 2020
- Chair of Independent Technical Review Board for Minera Escondida-BHP, Chile from 2019
- Geotechnical Advisor to Aguamarina, Chile from 2019
- Member of Expert Panel commissioned to investigate the technical causes of the failure of Tailings Dam I at the Córrego de Feijão Mine in the State of Minas Gerais, Brazil on 25 January 2019
- Member of Independent Technical Review Board for Rio Tinto Alcan Yarwun Residue Management Area Embankment Raise Designs from 2016
- Member of Independent Technical Review Panel of Life-of-Mine Tailings Storage Facility at Glencore's McArthur River Mine, Northern Territory, Australia from 2015
- Member of Northern Territory EPA Board, from 2012 to 2014

Peer Reviews of Major Projects

- Sole Independent Expert Geotechnical Reviewer for Unity Mining Limited from 2016
- Sole Independent Expert Geotechnical Reviewer for Bluestone Mines Tasmania JV Pty Ltd from 2015
- Sole Reviewer of Proposed Integrated Waste Landform Design for Central Eyre Iron Project in 2015
- Sole Independent Expert Geotechnical Reviewer for Rio Tinto Alcan Gove Residue Disposal Area from 2015
- Sole Independent Expert Geotechnical Reviewer and Annual Dam Inspections for QAL Residue Disposal Area and Ash Dams from 2013
- Sole Independent Expert Geotechnical Reviewer for Rio Tinto Alcan Yarwun Residue Management Area from 2013
- Led International Peer Review for the South Deposit TSF at Savage River Mine in Tasmania in 2012/13
- Sole Independent Expert Geotechnical Reviewer for Rio Tinto Alcan Weipa Tailings Storage Facilities in 2012 and 2014
- Peer Review of Harvey Creek Non-Erodable Waste Rock Dump Design for Ok Tedi Mining Limited in 2010/11
- Member of Expert Peer Review Team for Rio Tinto Alcan Weipa Tailings Storage Facilities from 2009
- Member of the International Technical Advisory Group reporting to the South Australian Government on Rehabilitation of Brukunga Pyrite Mine from 2007

- Led International Peer Reviews for the Savage River Rehabilitation Project in Tasmania in 2002, 2005, 2009 and 2013
- Led International Peer Review on handling acid generating waste rock dumping and dump closure strategies at Cadia Hill Gold Mine in New South Wales in 2002/3
- Member of the Peer Review Team for Stage 2 of the Stuart Oil Shale Project at Gladstone in Queensland in 2004
- Peer Reviewer of the rehabilitation of the San Manuel Copper Mine tailings facility in Arizona, USA in 2004
- Member of the 2005 Peer Review Team that reviewed future red mud disposal, containment and rehabilitation at QAL at Gladstone in Queensland in 2005
- Geotechnical Reviewer of the breach of the co-disposal dam at Burton Coal in Queensland in 2005
- Peer Reviewer of the conceptual closure plan for Worsley Alumina red mud storage in Western Australia in 2005
- Peer Reviewer for waste rock dump covers for Century Mine in North Queensland from 2007
- During 2006, David was an Expert Advisor to the EIS team for the Olympic Dam Expansion Project in South Australia, providing expert input on disposal, hydrology and closure issues for both waste rock and tailings

Expert Witness

- Expert witness through Corrs Chambers Westgarth Lawyers, in relation to coal washery rejects used as filling for residential sub-division purposes
- Expert witness through McCullough Robertson Lawyers, in relation to the failure of a concrete arch reclaim tunnel beneath a coal stockpile
- Expert witness in relation to professional misconduct cases brought by the Queensland Professional Engineers Registration Board
- Numerous expert witness commissions related to residential and commercial building footing failures and slope instability

Consultancies

Professor David John Williams is widely sought for his expert input, in particular to mine waste disposal and mine site rehabilitation and remediation at operating mines throughout Australia and overseas. In Australia, he has consulted on numerous coal mines throughout Queensland and New South Wales; on Red Dome Gold Mine closure, Kidston closure, Osborne waste disposal, Ivanhoe Cloncurry mine closure, Phosphate Hill gypsum disposal, QERL processed waste storage facility closure, and Century Zinc Mine waste rock dumping in Queensland; Cadia Hill Gold Mine waste rock dumping and dump closure in New South Wales; Mt Morgans Gold Mine co-disposal, WMC Resources' nickel operations tailings closure and Minara heap leaching in Western Australia; waste disposal issues at the Ballarat East and Heathcote gold mines in Victoria; and a review of ARD treatments at Savage River Mine in Tasmania. Overseas he has consulted on tailings depositional design and

water balance for the Kori Kollo Mine in Bolivia, a review of co-disposal of tailings and waste rock at Porgera Gold Mine and the closure of Misima Gold Mine in PNG, waste disposal design for the Goro Nickel project in New Caledonia, and advice on co-disposal for the Martabe Project in Indonesia.

David has been involved in material characterisation testing and the design of numerous mine waste covers throughout Australia, and the design, installation and monitoring of lysimeters and mine waste covers at Kidston Gold Mines, WMC Resources' Mt Keith Nickel Operations, QERL's Stuart Oil Shale Project, a large-scale trial waste rock dump at Cadia Hill Gold Mine, and a large-scale trial tailings cell at Jubilee Nickel Mine.

David has been invited to visit numerous mining regions and individual mines throughout Australia, and in Canada, the USA, Brazil, South Africa, UK, China, Chile, PNG, New Caledonia, Spain and Mozambique.

MAJOR RESEARCH ACHIEVEMENTS

From 1989, Professor Williams carried out research under NERDDC and ACARP Projects on the characterisation of the deposit formed on the pumped co-disposal of combined washery wastes, which has since been adopted at numerous coal mines in Australia and Indonesia.

From 1996, David developed the store/release cover system suited to seasonally dry climates, for application to covering acid generating rock dumps at Kidston Gold Mine in north Queensland, and has had a long-term involvement in researching and monitoring this cover system, as evidenced by his numerous papers on his research on this topic. The store/release cover system on the tops of the Kidston rock dumps has been shown to limit percolation to less than 1% of rainfall, and to support a sustainable vegetation cover comparable to that occurring along water courses in the area. He was also involved in the development of a rehabilitation strategy for the side slopes of the rock dumps at Kidston designed to maximise geotechnical and erosional stability while promoting vegetation, and analysed the wetting up by rainfall infiltration and subsequent drain-down of and seepage from the rock dumps. Store/release covers have now been adopted at numerous mine sites in dry climates worldwide.

From 1999 to 2001, David led ACARP Project C8039 to develop a risk assessment and cost-effectiveness analysis for the rehabilitation of Bowen Basin coal mine spoil. The results of the project were reported in a Literature Review and Commentary and Project Final Report, plus a spreadsheet-based risk assessment and cost-effectiveness analysis, available at: www.uq.edu.au/civil/. In 2006, David undertook a closure study for Xstrata's new Rolleston Coal Project in the Bowen Basin Coalfields.

David has since 2000 been involved in the closure design for the waste rock dump at Cadia Hill Gold Mine in New South Wales, including studies on the use of mixtures of benign trafficked rock and tailings as an alternative cover material, to overcome the shortage of suitable natural materials. In 2002/3, he led an international peer review of the rock dumping operation and closure plan. In 2004, David was successful in an ARC Linkage grant application with Cadia totalling over \$ 700,000 over 3 years, which has led to the construction of a 15 m high, world-class, demonstration, instrumented rock dump covering 7,000 m². The instrumentation includes a full weather station, 24 lysimeters at the base of the dump to monitor seepage, lysimeters on the top surface to monitor rainfall infiltration and three store/release trial covers constructed using natural and mine waste materials. To date it has shown that about 70% of the rainfall

incident on the traffic-compacted top of the dump infiltrates, with the majority going into storage within the dump during the first year, and only small amounts percolating to the base of the dump. The behaviour of the cover trials has to date been dominated by the moisture state at which they were constructed. Monitoring of the instrumented rock dump is expected to continue for at least 10 years.

From 2000 to 2003, David was a principal researcher into the physical and geochemical nature of acid generating waste rock dumps in Southern Carolina, USA (Rio Tinto's Ridgeway Mine) and Sudbury, Canada (Inco's Whistle Dump), sampled as they were being excavated and moved to a pit.

From 2001 to 2005, David led an ARC Spirt research project with industry partner WMC Resources focussed on an assessment of the long-term seepage and runoff from mine tailings storage facilities, to facilitate lease surrender. This included the monitoring of trial covers on tailings over the duration of the project and large-scale laboratory column testing and numerical analyses. Natural salt pan and rocky slope analogues under the same climatic and similar geochemical conditions were also studied to point to sustainable approaches for rehabilitating the tailings storage facilities.

From 2010, David has led three ACARP Projects, C19022, C20047 and C25040, investigating the settlement and stability of high coal mine spoil, the behaviour of problematic clay-rich coal mine tailings, and the behaviour of "mud" derived from spoil on wetting-up.

David has been sponsored by mining companies and consultants to visit numerous mining regions and mine sites worldwide, both to impart and extend his knowledge. Since 2000, he has developed a relationship with the International Network for Acid Prevention (INAP), and has contributed to INAP-sponsored research and development projects and workshops involving mine sites in the USA, Canada, Australia and PNG.

Research funding has totalled over \$10 million, including funding from ARC, ARC-SPIRT, ARC Linkage, NERDDC, ACARP-AMIRA, ACARP, MIM CRA-ATD, Kidston Gold Mines, BHP Coal and WMC Resources, Cadia Holdings, Jubilee Mines NL.

PUBLICATIONS

Professor Williams has over 300 refereed publications, including five book chapters, over 100 refereed journal articles and over 200 refereed conference publications, plus numerous research and consulting reports. About two-thirds of these publications are in the mine waste field.