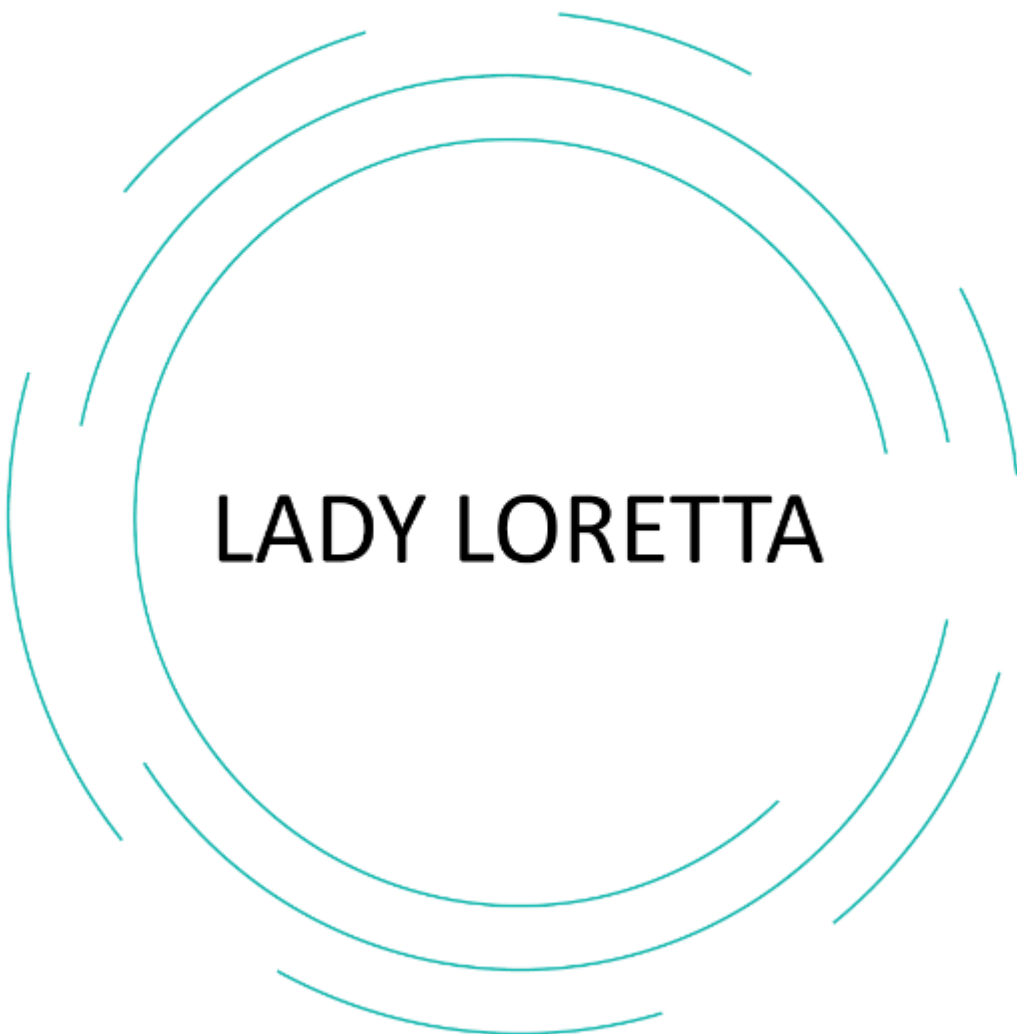


LADY LORETTA

A GLENORE Company



LADY LORETTA

Z-LLM-HSEC-PLN-Progressive Rehabilitation and Closure Plan

Cover Page

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1. INTRODUCTION

1.1. SCOPE AND OBJECTIVES

This Progressive Rehabilitation and Closure Plan (PRCP) has been developed for the Lady Loretta Mine (LLM). LLM is owned and operated by Noranda Pacific Pty Ltd, a subsidiary of Glencore plc (Glencore). The PRCP has been developed to meet the specific requirements of the *Progressive Rehabilitation and Closure Plan Transition Notice* (the PRCP Transition Notice) issued by the Queensland Department of Environment and Science (DES) on 18 September 2020, as well as requirements outlined in the LLM Environmental Authority EPML00982013 (the EA) and the *Progressive Rehabilitation and Closure Plans Guideline* (DES, 2021).

This PRCP comprises two main components:

- **Rehabilitation Planning** – Description of site characteristics and surroundings, regulatory requirements, stakeholders, post-mining land use, rehabilitation goals, rehabilitation methodology, site closure design risk assessment and monitoring program, and
- **PRCP Schedule** – Schedule of progressive rehabilitation activities and milestones.

The purpose of this PRCP is to provide details of the activities and resources required for the progressive rehabilitation, decommissioning and closure of all components of LLM during operations, closure and post-closure of the site.

1.2. LEGAL AND OTHER REQUIREMENTS

1.2.1 Mineral Resources Act 1989

Resource activities are regulated through a “resource authority” under the *Mineral Resources Act 1989* (MR Act). This provides resource companies with the right to enter land and undertake the approved activity. The MR Act applies to mining leases and informs the requirement for surrender.

1.2.2 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) is the principal legislation for protecting environmental values potentially affected by the resource industry in Queensland. The EP Act grants the Queensland Government the power and means to assess, approve and prescribe conditions on proposed mining projects.

The EP Act requires that all areas of disturbed land within the relevant mining tenure be rehabilitated to support a suitable Post-Mining Land Use (PMLU) or managed as a Non-Use Management Area (NUMA). Any disturbed land must also be identified as a PMLU. Sections 126C and 126D stipulate the requirements for PRCPs and schedules, respectively.

Under the EP Act, the Queensland Government is responsible for the issuing of an environmental authority (EA) to carry out a mining activity and approval of a PRCP schedule for a proposed PRCP. The EP Act also prescribes the requirements for surrendering an EA, including the preparation of final rehabilitation reports and post-mining management reports.

1.2.3 Land Outcome Document

Correspondence was received by DES on 11 January 2019, stipulating that the Post Mine Land Use Plan (PMLUP) for EA EPML00982013, submitted to DES on 24 August 2018 has been accepted as a land outcome document (LOD). Various components of the LOD are proposed to be transitioned into this PRCP. This includes the domains and corresponding preliminary potential end land uses and various completion criteria considered relevant at the time of developing this PRCP. The rehabilitation management methodologies primarily remain unchanged for various mine domains, including: water dams, infrastructure, ROM, paste plant and batch plant area, roads, underground openings and exploration areas. Progressive rehabilitation efforts have meant various stockpiles no longer exist, i.e. LMD Stockpile and the cover material stockpile near the waste disposal trench. The proposed rehabilitation management methodologies for the WRE have subsequently been advanced and improvements made since the PMLUP development, with an alternative WRE landform and cover system design. LLM rehabilitation monitoring program as stipulated in the PMLUP has fundamentally remained unchanged, noting recent improvements made subject to key learnings as a result of ongoing rehabilitation monitoring efforts. The knowledge gaps as stipulated in the PMLUP aimed to strengthen closure planning at LLM have been addressed through ongoing investigations and closure planning studies, resulting in various advancements to closure planning design.

1.2.4 Mineral and Energy Resources (Financial Provisioning) Act 2018

In Queensland, the *Mineral and Energy Resources (Financial Provisioning) Act 2018* regulates a financial provisioning scheme for reducing potential risks to the Government in the event an EA holder fails to meet their environmental and rehabilitation obligations. This act also amended the EP Act to require mining companies to develop PRCPs.

1.2.5 Guideline: Progressive Rehabilitation and Closure Plans

This guideline, prepared by the DES, contains information to assist applicants in developing a PRCP as part of a site-specific EA application for a new mining activity. The guideline also provides information to assist existing EA holders transition their mining activity to the PRCP framework. The administering authority must consider this guideline when making a decision about a PRCP schedule under section 176A of the EP Act.

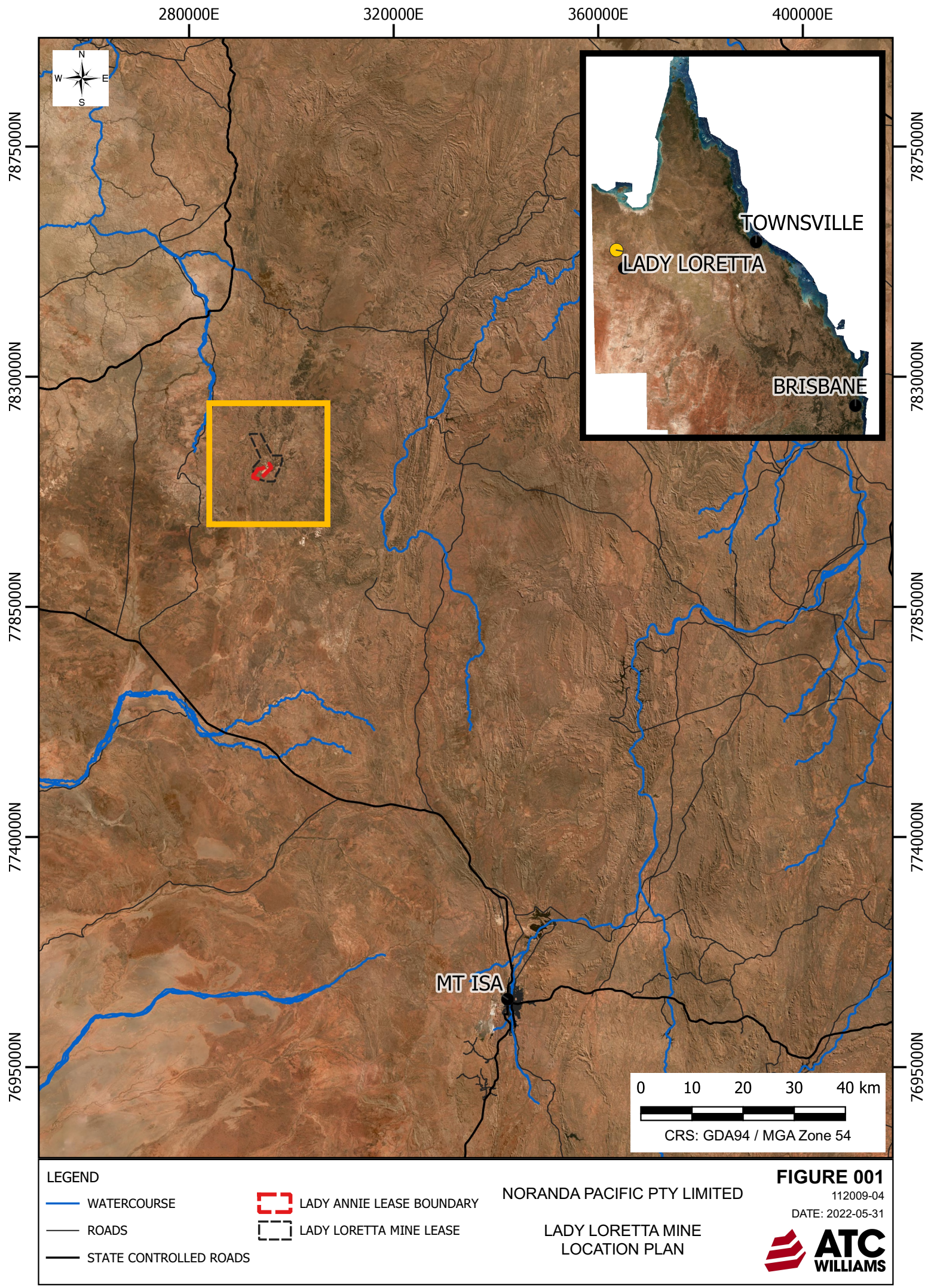
2. BACKGROUND INFORMATION

2.1. PROJECT DESCRIPTION

LLM (the Site) is located approximately 140 kilometres (km) north north-west of Mount Isa in north-west Queensland within the Mount Isa City Council (MICC) local government area. Mining Lease (ML) 5568 occupies approximately 2,783 Hectares (Ha) and was granted in 1984. Of this, approximately 140 Ha has been disturbed by mining activity. Immediately to the west of the Site is the Lady Annie Copper Mine (Mining Lease 90179), which is operated by a subsidiary of Austral Resources Limited.

Access to the Site is via a 53 km, unsealed road that connects LLM with the Barkly Highway.

A locality plan is presented in Figure 1.



LEGEND

- WATERCOURSE
- ROADS
- STATE CONTROLLED ROADS
-  LADY ANNIE LEASE BOUNDARY
-  LADY LORETTA MINE LEASE

NORANDA PACIFIC PTY LIMITED

LADY LORETTA MINE
LOCATION PLAN

FIGURE 001
112009-04

DATE: 2022-05-31



2.1.1 Tenure

LLM operates an underground zinc, lead and silver mine on ML5568.

Land tenure details are shown in Table 1 and Figure 2.

Table 1: Current Tenement Details

Lease	Lease Area (Ha)	Expiry Date	Background Landholder	Lot/Plan
ML5568	2,783	21 January 2026	Noranda Pacific	Lot 1 (Crown Plan UN6) County Undilla Parrish Burburgate

2.1.2 Surrounding Landholdings

The entirety of ML5568 is surrounded by the Thornton Station pastoral lease. The nearest inhabited dwellings are:

- Thornton Station, 33 km to the north north-west,
- Carlton Hills Station, 54 km to the south-east,
- Capricorn Copper Mine accommodation camp (located in previous township of Mount Gordon), 35km to the east,
- Lady Annie Camp, 17 km to the south-east, and
- Koolamara Station, 19 km to the south-east.

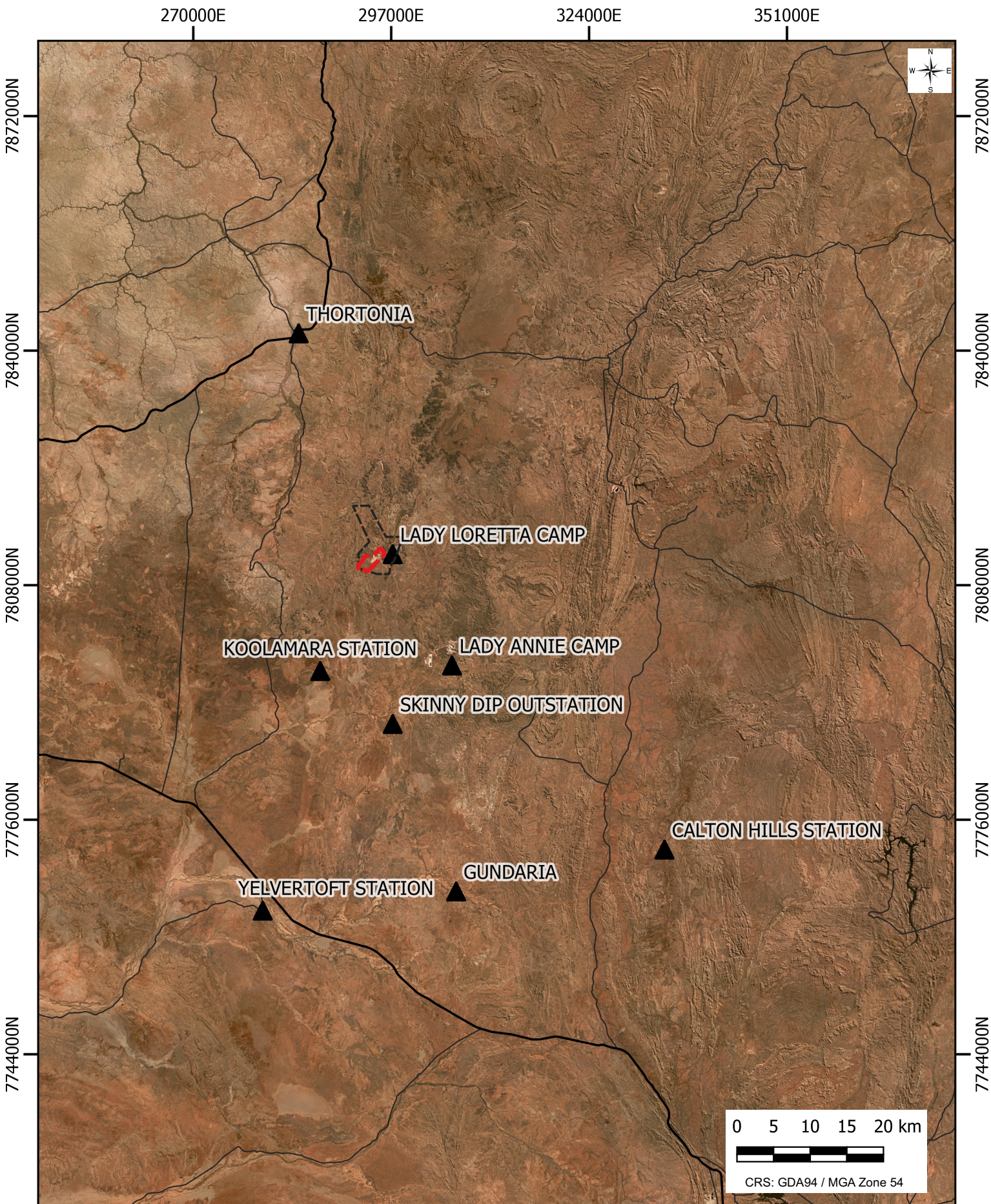
Additional neighbouring landholdings are: Skinny Dip Outstation, Gundaria, and Yelvertoft. Station locations are shown in Figure 2.

2.1.2.1. Traditional Owners and Cultural Heritage

LLM currently engages with both the Kalkadoon Community Pty Ltd (Kalkadoon) and Indjilandji/Myuma Pty Ltd.

An archaeological survey of the LLM and immediate surrounds was undertaken in 1981 by Hill, with more recent assessments undertaken in 1998 and 1999 by Dr Luke Goodwin and Ian McNiven. The LLM operates in accordance with the existing Commercial in Confidence Cultural Heritage Management Plan (CHMP). The CHMP is made between the Kalkadoon claimants and Noranda Pacific. Cultural heritage matters are dealt with in accordance with the arrangement of the CHMP.

A European Heritage Investigation undertaken in 2000 (Heritage Management Consultants Pty Ltd; cited in Xstrata Zinc, 2012) reported exploration activities at the LLM deposit over the past 30 years involving construction of a variety of features (e.g. access tracks and drill pads). These sites were not considered significant to the European heritage of the region due to the relatively recent age and undeveloped nature of the LLM deposit.



LEGEND

-  RESIDENCES
-  LADY LORETTA MINE LEASE
-  LADY ANNIE LEASE BOUNDARY
-  ROADS
-  STATE CONTROLLED ROADS

NORANDA PACIFIC PTY LIMITED

LADY LORETTA MINE
MINING TENURE

FIGURE 002

112009-04

DATE: 2022-05-31



2.1.3 Site History

A summary of the operations and key timeline events of LLM are outlined below:

1968: Placer Prospecting Pty Ltd and Triako Mines NL discover lead, zinc and silver mineralisation.

1987: Exploration activities begin with a 468 m deep concrete lined exploration shaft and exploratory drive constructed. Waste rock from the exploration was stockpiled in what is now known as the LMD stockpile.

1988: 6,500 t of ore was extracted for metallurgical testing, which was conducted off site. The ROM pad was built, along with basic infrastructure.

1996: Bulka Minerals Pty Ltd acquires LLM and its lease area.

1998: Bulka Mineral Pty Ltd enter a joint venture with Noranda Pacific Pty Ltd, owned by Mount Isa Mines Pty Ltd (MIM).

1996 – 2010: No mining activities were conducted over this time, however a Feasibility Study was completed. MIM was acquired by Xstrata plc in 2003.

2011: EA MIN101458310 was granted and mining activities commenced in October 2011.

2012: Amendments to the EA to include additional dams and biodiversity offset conditions to address State environmental offsets under the EP Act.

2013: Glencore plc acquires Xstrata plc. EA amendments lead to another EA issued by the DES, EPML00982013.

2015 – 2017: Works are temporarily suspended, with LLM entering care and maintenance.

2018: Mining activities resume in the first quarter under contractor Redpath Australia, who were awarded the LLM mining contract from Glencore in December 2017.

2.1.4 Mine Development

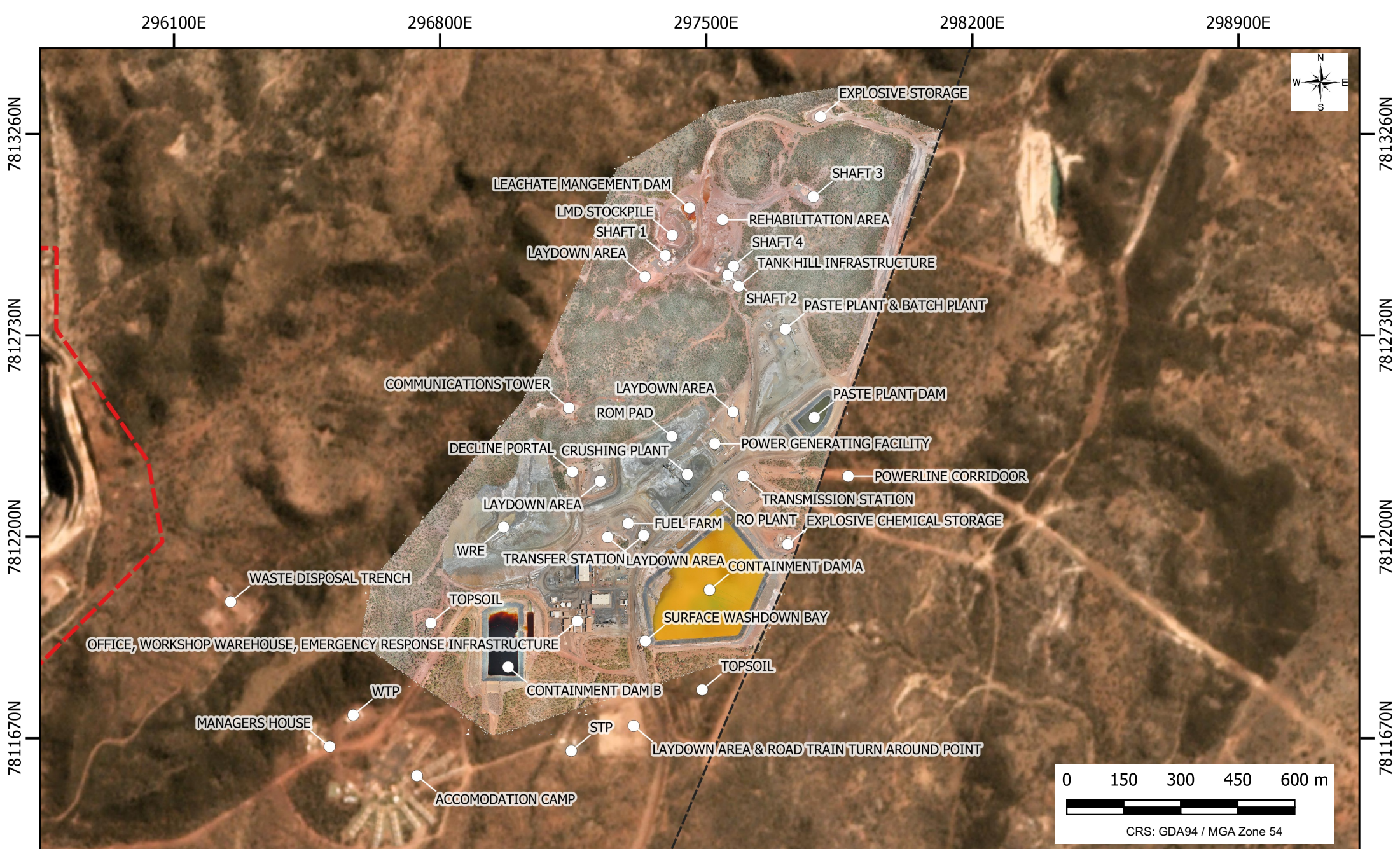
Development at the Site has centred on an underground mine from which zinc-lead ore is extracted. The underground workings have been developed to 500 m below surface and include more than 30 km of development drives. These provide access to the various stopes for drill and blast and haulage teams. Sub-level open stoping is used as the primary mining method. Cemented paste-fill is used to backfill extracted stopes to improve safety and overall recovery of ore. Run-of-mine (ROM) ore is brought to the surface with trucks for crushing. Crushed ore is exported from the Site and transported to Mount Isa for further processing. Tailings from the Mount Isa process are back-loaded to the Site for reuse in paste preparation.

Associated development at the Site includes the following surface infrastructure:

- Access tracks and haul roads,
- Accommodation camp and Manager's houses,
- Ore stockpiles and primary crushing facilities,
- Paste-fill plant and batch plant,
- ROM Pad,
- Underground openings including access portal, decline and four ventilation shafts,
- Waste Rock Emplacement (WRE) and topsoil stockpiles,
- Water management infrastructure including four regulated dams,
- Workshop, warehouse, bathhouse, administration and vehicle wash bays,

- Explosive chemical storage yard and explosive storage,
- Ventilation equipment,
- Utilities including: fuel farms, power station, transmission station, sewage treatment plant (STP), water treatment plants (WTPs),
- Waste transfer station,
- Laydown areas,
- Communications tower,
- Waste disposal trench,
- Emergency response training ground, and
- Airstrip.

A layout of the Site including the location of major infrastructure is provided in Figure 3.



2.1.5 Environmentally Relevant Activities

The DES, under EA EPML00982013, granted approval for underground mining activities for zinc, lead and silver on ML5568. The current EA took effect from 4 December 2018.

Activities that will, or have the potential to, release contaminants into the environment which may cause environmental harm are defined as environmentally relevant activities (ERAs) in the EP Act and are regulated by conditions documented in the EA.

Table 2 summarises the ERAs authorised by the EA.

Table 2: Environmentally Relevant Activities

ERA Number	Description
Schedule 2A, 09	Mining activity involving drilling, costeaning, pitting or carrying out geological surveys causing significant disturbance
Schedule 2A, 10	Investigating the potential development of a mineral resource by large bulk sampling or constructing an exploratory shaft, adit or open pit
Schedule 2A, 17	Mining copper ore
Schedule 2A, 18	Mining lead, silver or zinc separately or in any combination
Ancillary 07 – Chemical manufacturing, 3	Manufacturing, in a year, a total of 200t or more of any of the following, (d) explosives
Ancillary 08 - Chemical storage, 2	Storing 50t or more of chemicals of dangerous goods class 6, division 6.1 under subsection (1)(b)
Ancillary 15 - Fuel burning	Using fuel burning equipment that is capable of burning at least 500kg of fuel in an hour
Ancillary 16 - Extraction and screening, 3	Screening, in a year, the following quantity of material, (c) more than 1,000,000t
Ancillary 60 - Waste disposal, 2	Operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(b), (a) 50t to 2000t
Ancillary 61 - Waste incineration and thermal treatment, 2	Incinerating or thermally treating, in a year, the following quantity of general waste, (a) less than 5000t
Ancillary 63 - Sewage treatment, 1	Operating sewage treatment works, other than no release works, with a total daily peak design capacity of, (b-i) more than 100 but not more than 1500EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme

An EA Amendment application was submitted to DES on 11 May 2022 to seek authorisation to allow disposal of waste (general and demolition) underground and to update the allowable limit for waste disposal from (a) 50 t but not more than 2000 t to (e) 20,000 t but not more than 50,000 t. The increase in waste disposal threshold is required to allow demolition waste disposal on site for the purpose of implementing site rehabilitation and closure works.

2.2. PROJECT ACTIVITIES

2.2.1 Life of Asset Strategy

LLM is operated pursuant to a Life of Asset (LoA) Plan made up of five programs. The programs operate in parallel with an overall objective of maximising the economic and social value of the mineral resources located at the Site. The programs that comprise the LLM LoA are:

- Resource Development,
- Capital Development,
- Asset Management,
- Mining Operations, and
- Decommissioning and Rehabilitation.

The specific duration of each of the programs that comprise the LoA are characterised by key milestones that are described in Table 3.

Table 3: Life of Asset Key Dates

LoM Milestone	LoM Plan	Context
Grant of Exploration Permit	1967 Actual	LLM Exploration Permit was granted under the MR Act in 1967. Lead-zinc-silver mineralised was first discovered at LLM in 1968.
Grant of Mining Leases	1984 Actual	The lease was originally granted as ML 8052 in 1984. It was renumbered following the passing of the MR Act.
Grant of Environmental Authority	2011 Actual	The EA MIN101458310 authorises the operator of LLM to undertake various ERAs including mining activities pursuant to the EP Act.
Commencement of Mining Operations	2011 Actual	The first campaign of mining commenced in October 2011. Low commodity prices caused the site to be placed in care and maintenance in October 2015. The current campaign commenced in March 2018.
Completion of Mining Operations	2025 Plan	The current LoA is for the current campaign of mining to be completed in 2025. Approximately 100,000 tonnes of ore reserves (proven) will remain unmined.
End of Commercial Proposition	2032 Plan	End of Commercial Proposition represents the point where the LLM Owner determines that additional investment into the Resource Development and Capital Development programs at LLM is no longer commercially viable.
End of Decommissioning Works	2035 Plan	End of Decommissioning Works represents the point where the Decommissioning and Rehabilitation program has reached practical completion. For the purposes of this PRCP, End of Decommissioning Works is scheduled to occur three years after End of Commercial Proposition.

LoM Milestone	LoM Plan	Context
Conversion of Regulated Dams to Erosion and Sediment Control (ESC) Facilities	2044 Plan	Decommissioning of the regulated dams will commence once underground dewatering ceases, all inventories of mine-affected waters have been removed and rehabilitation of disturbed areas has been completed. A series of ESC facilities will be constructed in the footprint of the regulated dams to capture adjacent sediment.
Surrender of the Environmental Authority	2060 Plan	Surrender of the EA can only occur after all decommissioning and rehabilitation works have been undertaken and suitable vegetation has been established on the disturbance area. LLM will be required to demonstrate that the rehabilitation success criteria have been achieved. For the purposes of this PRCP, a demonstration period of 25 years has been adopted.

2.2.2 Resource Development Program

The objective of the Resource Development program is to identify zones of mineralisation at the LLM that may be suitable for classification as an Ore Reserve.

Development of the Mineral Resources at the Site commenced in 1968 when prospectors first identified mineralisation. Since that time, LLM and its antecedents have undertaken multiple campaigns of work to improve the level of understanding of the Mineral Resources present. These have included field investigation, geo-physical survey, materials sampling and analytical testing, data processing and numerical modelling. The Mineral Resources are classified as either inferred, indicated or measured where the classification represents the level of confidence or understanding of the geological characteristics. Increasing this level of understanding is a complex activity that requires significant investment and commercial risk.

The component of a Mineral Resource that can be economically mined is referred to as an Ore Reserve. Determination of an Ore Reserve is a similarly complex undertaking that considers the risks, costs and benefits associated with extracting the ore-body and converting it into saleable products. These risks, costs and benefits are all subject to change and reflect external factors including global commodity markets. As a consequence, Ore Reserves are dynamic and are subjected to periodic review.

The Resource Development program has been in continuous effect since mineralisation was first identified in 1968. Site-based work is generally completed on a campaign basis and includes drilling, down-hole and geophysical survey. These campaigns generate significant data sets that are then analysed and interpreted remotely.

Both Mineral Resources and Ore Reserves have been declared for the Site. These are reviewed annually based on the latest available data.

The Resource Development program will continue following the completion of the current mining campaign. Mineralisation associated with the Lady Loretta orebody is extensive and highly prospective. The Resource Development program will be concluded when End of Commercial Proposition is called.

2.2.3 Capital Development Program

The Capital Development program is concerned with the construction and commissioning of the fixed plant and infrastructure required to support economic extraction of zinc and lead bearing ores at the Site.

The Capital Development program commenced in 1987 with the installation of the exploration shaft and associated facilities located at what is now known as the legacy mine area.

A major campaign of Capital Development occurred in 2011 and 2012 following Grant of the Environmental Authority. These works included:

- Mine access road,

- Initial mine development including box-cut, access decline, development drives and ore handling,
- Initial mine infrastructure package including ventilation system, high-voltage distribution, mine dewatering network,
- Initial surface fixed plant package including crushing circuit, paste plant and weighbridge,
- Initial surface facilities including administration complex, warehouse, workshops, accommodation camp, and
- Initial surface infrastructure package including power generation and distribution, fuel storage, raw water supply, potable water and sewage systems.

Since that time the Capital Development program has added to the portfolio of assets at the Site. Ongoing investment via the Capital Development program is essential to maintain the commercial viability of LLM. For example, to convert existing mineral resources to an ore reserve, suitable access and ventilation and other services would have to be installed to support a mining campaign.

The current LoA Plan requires that the Capital Development program will be concluded at the End of Commercial Proposition.

2.2.4 Asset Management Program

The Asset Management Program is concerned with maintaining the various assets that comprise the LLM in good order and good standing. The program is concerned with:

- Physical assets including mobile and fixed plant, buildings, roads and ancillary infrastructure, and
- Non-physical assets including the mining leases, the environmental authority, and stakeholder obligations.

The Asset Management program was first activated in 1987 when the first fixed plant was installed at the Site. Since that time, the scope and scale of the program has been extended to match the growth of the LLM asset package.

The current LoA Plan requires that the Asset Management program remains in effect until the EA is surrendered.

Key activity types to be undertaken pursuant to the Asset Management program are discussed in the following sections.

2.2.4.1. Asset Protection

Asset protection is concerned with ensuring that the assets are not degraded by unauthorised activities such as theft, vandalism, or improper use. Asset protection is also concerned with ensuring that unauthorised persons are excluded from the Site and therefore not exposed to critical hazards.

2.2.4.2. Plant Maintenance

A key requirement of the Asset Management program is that mobile and fixed plant as well as infrastructure is maintained in a condition suitable to support the objectives of the LoA Plan.

Plant maintenance activities include:

- Routine inspection of fixed plant and infrastructure to confirm condition, operational and regulatory requirements,
- Routine activation of systems and sub-systems to maintain operability, and
- Scheduled and breakdown maintenance of systems and sub-systems.

The level of plant maintenance undertaken at the Site is a reflection of the scale, extent and utilisation of the asset portfolio. Although at a peak during active mining operations, this aspect of the Asset Management program will remain active through until Surrender of the EA.

2.2.4.3. Water Management

Water management activities at the Site are undertaken as a component of the Asset Management program. As described in Section 3.2.1.2, the Water Management System (WMS) has been implemented to:

- Provide a supply of water to the Site,
- Contain and manage mine affected waters that are unsuitable for release to the receiving environment, and
- Discharge excess waters including non-mine affected runoff from the Site.

Effective implementation and operation of the WMS is a key control in managing compliance risk and ensuring protection of the receiving environment at the Site. Execution of the Decommissioning and Rehabilitation program will act to mitigate and eventually diminish these risks. As a result, the manner in which the WMS is operated will evolve to reflect the prevailing risk profile of the Site. For the purposes of this PRCP, the WMS will transition through the following modes of operation:

- Operational water management,
- Transitional water management, and
- Passive water management.

2.2.4.3.1. Operational water management

The WMS is currently operated under the operational settings with a focus on supporting dewatering of the active mining area and ensuring that mine-affected waters are not released to the receiving environment. The WMS will continue to be managed pursuant to the operational settings until the following conditions have been met:

- Dewatering of the underground workings has been discontinued,
- Water quality monitoring demonstrates that surface runoff and seepage from the disturbance area is no longer mine-affected, and
- All inventories of mine-affected waters have been removed from the surface storages.

2.2.4.3.2. Transitional water management

Water management under the transitional settings will be concerned primarily with erosion and sediment control (ESC). Under the transitional settings, potential sources of contamination will have been eliminated or mitigated via engineered cover systems. The most significant driver of surface runoff quality will be sediment and turbidity as the water drains off disturbance areas.

To manage this risk, surface runoff from the Site will be directed to ESC facilities prior to release to the receiving environment. The ESC facilities will be monitored and maintained to ensure their effective operation during this period.

2.2.4.3.3. Passive water management

As the revegetation on the disturbance area matures, the requirement for the ESC facilities will diminish and the quality of the surface runoff will be suitable for direct release to the environment. At that time, the ESC facilities will be reprofiled so that they are free-draining, and water management will become entirely passive.

2.2.4.4. Land Management

Another key objective of the Asset Management program is to ensure that the land on which the LLM is located is appropriately managed. This includes control of invasive weeds and feral animals as well as appropriate use of fire in the local landscape. Land management activities are undertaken each year generally on a campaign basis.

2.2.4.5. Stakeholder Engagement

Stakeholder engagement is also a component of the Asset Management program. LLM will continue to engage with key stakeholders regarding the development, operation and rehabilitation of the Site right up until Surrender of the EA.

2.2.4.6. Compliance Monitoring

A primary obligation of the EA is that as the operator of the Site, LLM must undertake compliance monitoring to demonstrate compliance with the specific requirements of the EA. In addition, LLM must also collect suitable monitoring data to demonstrate that the works undertaken pursuant to the Decommissioning and Rehabilitation program have been effective and that the success criteria can be reasonably met.

The obligations to undertake compliance monitoring will remain in effect until the EA is surrendered. Specific requirements to undertake monitoring and maintenance of the Site following implementation of the Decommissioning and Rehabilitation program is provided in Section 3.8.

2.2.5 Mining Operations Program

The Mining Operations program is concerned with the economic extraction of zinc and lead bearing ores at the Site. The first campaign of mining occurred between 2011 and 2015. Low commodity prices caused the site to be placed in care and maintenance in October 2015. The current campaign commenced in 2018 and is scheduled for completion in 2025.

Mining operations undertaken at the Site have utilised underground mining methods to extract zinc and lead ores. Extracted stopes are typically back-filled with cemented paste fill to improve stability and increase resource utilisation. This mining strategy requires that suitable accesses to the ore-body are available via haulage drives, draw-points and ventilation passages. Establishment of these accesses occurs as a component of the Capital Development program.

The Mining Operations program is facilitated by the Resource Development, Capital Development and Asset Management programs. For Mining Operations to be undertaken, suitable quantities of Ore Reserve must have been defined, and the requisite access, plant, systems and services available to allow mining to proceed at an acceptable cost.

As a result, the Mining Operations program is under constant review to ensure the commercial viability of LLM. Extensions of the Mining Operations program beyond the current campaign are likely but for the purposes of this PRCP, extraction is due to be completed in 2025.

At the conclusion of the current mining campaign, at least three stopes will remain unmined. Stopes 950-280L and 950-980J have been declared probable while stope 1150-835L has been declared a proven ore reserve by a component person pursuant to the JORC Code (<https://www.jorc.org/>). These are estimated to contain approximately 37,000 tonnes (t) of zinc and lead bearing ore.

The months leading up to the end of the current mining campaign will include preparations for the non-operations period. These preparations will include:

- Draw-down and complete removal of the coarse ore and crushed ore stockpiles including deep-cleaning of the crushing and radial stacking circuits,

- Draw-down and complete removal of the pastefill input stockpile, binder inventories and deep-cleaning of the paste plant,
- Draw-down of the diesel fuel inventory.

2.2.6 End of Commercial Proposition

As described in the preceding section, the current campaign of mining operations is scheduled for completion in 2025. Conclusion of the current campaign will not result in draw-down of the entire ore reserve. The predicted mineral resource and ore reserve inventory for the LLM at the completion of the current campaign of mining is presented in Table 4.

Table 4: Predicted Resources and Reserves at Completion of Current Campaign

Lady Loretta		Tonnes (KT)	Zinc Grade (%)	Lead Grade (%)
Mineral Resources	Measured	2,280	11.65	3.3
	Indicated	1,342	10.81	2.03
	Inferred	846	8.18	2.72
	Total	4,468	10.74	2.81
Ore Reserves	Proven	3.2	7.93	1.21
	Probable	33.4	10.38	1.75
	Total	36.6	10.16	1.71

Completion of the current mining campaign will not constitute the End of Commercial Proposition. Similarly, it would not trigger the curtailment of the other LoA programs. Further investment via the Resource Development program would seek to extend the Ore Reserve. At the same time, continued investment in the Asset Management program will maintain the plant, infrastructure and systems in an operable condition to support future mining campaigns.

Continuation of the LoA programs is not without cost cannot be justified without a reasonable expectation of return on investment. End of Commercial Proposition represents the point where the asset owner can no longer support additional investment in the LoA.

For the purposes of this PRCP, it is proposed that End of Commercial Proposition is scheduled for 2032.

2.2.7 Decommissioning and Rehabilitation Program

The Decommissioning and Rehabilitation program is concerned with mitigating the long-term risks presented by the implementation of the Resource Development, Capital Development and Mining Operations programs.

The objective of the Decommissioning and Rehabilitation program is to support transition to the Post Mining Land Uses and eventual surrender of EPML00982013 and relinquishment of ML 5568.

Planning and technical elements of this program commenced prior to grant of the EA in 2011 and have been reviewed and refined to reflect the Mining Operations and Capital Development programs. Site works packages have been completed on a campaign basis since 2018 and have included termination and rehabilitation of resource definition drill collars, rehabilitation of the waste disposal trench, removal of the legacy mine waste rock landform, and recontouring and revegetation of some of the disturbance area in the vicinity of the legacy mine area.

Pursuant to section 126D of the EP Act, land disturbed by mining is considered available for rehabilitation unless:

- The land is being used for operating infrastructure or machinery for mining, including, for example, a dam or water storage facility, or

- (b) The land is identified in the proposed PRCP schedule or the application of an EA for relevant activities to which the schedule relates as containing a probable or proved ore reserve that is to be mined within 10 years after the land would otherwise have become available for rehabilitation, or
- (ba) The land is required for the mining of a probable or proven ore reserve mentioned in (b), or
- (c) The land contains permanent infrastructure identified in the proposed PRCP schedule as remaining on the land for a PMLU.

Progressive rehabilitation will continue to occur when areas become available, alongside the Resource Development, Capital Development, Mining Operations and Asset Management Programs. This PRCP details the activities and schedule attributable to the Decommissioning and Rehabilitation program.

2.2.7.1. Progressive Decommissioning

Ongoing development of the Site causes some of the previously installed infrastructure to become surplus to requirements or redundant. Under these circumstances, specific infrastructure becomes available for decommissioning and progressive rehabilitation. Opportunities for progressive rehabilitation are identified and resourced as an outcome of the business planning process. Being an underground operation, opportunities for progressive rehabilitation at the Site are limited. Some recent examples of progressive rehabilitation are discussed in the following sections.

2.2.7.1.1. Legacy Mine Disturbance

Much of the initial development at the Site occurred in and in the vicinity of the sinking of Shaft 1. Associated infrastructure including a workshop, offices, laydown areas and gravel borrows have been developed in the nearby vicinity. Additional staging areas were established to support the sinking of Shafts 2, 3 and 4 as well as the tank farm and ventilation stations.

Development of this infrastructure is complete and the associated laydown areas are no longer required. LLM commenced decommissioning and rehabilitating these areas in 2019 with excavation and removal of mineralised material, placement of inert fill in excavations, recontouring, construction of clean water diversion drains, diversion berms and associated rock erosion protections, growth media application and ripping and seeding works (Engeny, 2020). To date, approximately 1 Ha of this legacy mine disturbance area has been rehabilitated including revegetation.

The sinking of Shaft 1 also yielded mineralised waste rock that was stored in an emplacement area known as the LMD Stockpile. Surface runoff and seepage from the emplacement was mine-affected and was collected in a regulated dam (Leachate Management Dam; LMD) for interim storage and management. The LMD Stockpile was reclaimed and removed to the main WRE in 2021 as a risk reduction measure.

2.2.7.1.2. Exploration Disturbance and Access Tracks

Development of the Site has included in excess of 240 mineral drill-holes developed as a component of the Resource Development program. These disturbances present various long-term risks including drill holes acting as pit-fall traps for livestock and wildlife and disturbance areas presenting opportunities for invasive weeds to establish. Drill-holes are installed to gather geological data. They are typically maintained in an open state to allow for follow up investigations which may include hole extension or down-hole survey. In most circumstances, all useful data is extracted from a drill-hole within two to three years of installation and then they may be available for rehabilitation.

Drill holes are decommissioned and rehabilitated by cutting the collars below ground level and inserting plugs. The drill pads, sumps and access tracks are then reprofiled to conform with local terrain before being revegetated. To date, more than 200 drill-holes have been decommissioned and rehabilitated. LLM maintains a register that details the status of all drill-holes that have been installed at the Site.

2.2.7.1.3. Waste Trench

LLM operated a relatively small landfill at a site known as the waste disposal trench. The waste disposal trench received non-regulated waste streams generated at the Site. No chemicals, putrescible or other type of regulated waste has reportedly been placed in the waste disposal trench. Solid waste material was reportedly removed from the waste disposal trench in August 2020 to prepare the site for backfill with the adjacent bund and stockpiled cover material. A review of the landfill inventory undertaken prior to rehabilitation works describe the waste materials as poly pipe, plastics (chairs, reels, pallets), concrete fragments, scrap car parts, metal framework, empty fire extinguisher cases contained in IBCs and metal crates, cardboard, wooden pallets and tree cuttings. The waste disposal trench was decommissioned and rehabilitated in 2020. Works included backfilling, recontouring and installation of ESC facilities. Revegetation works were completed on the disturbance area in late 2021.

3. PRCP – REHABILITATION PLANNING

3.1. PROJECT PLANNING

3.1.1 Baseline Information

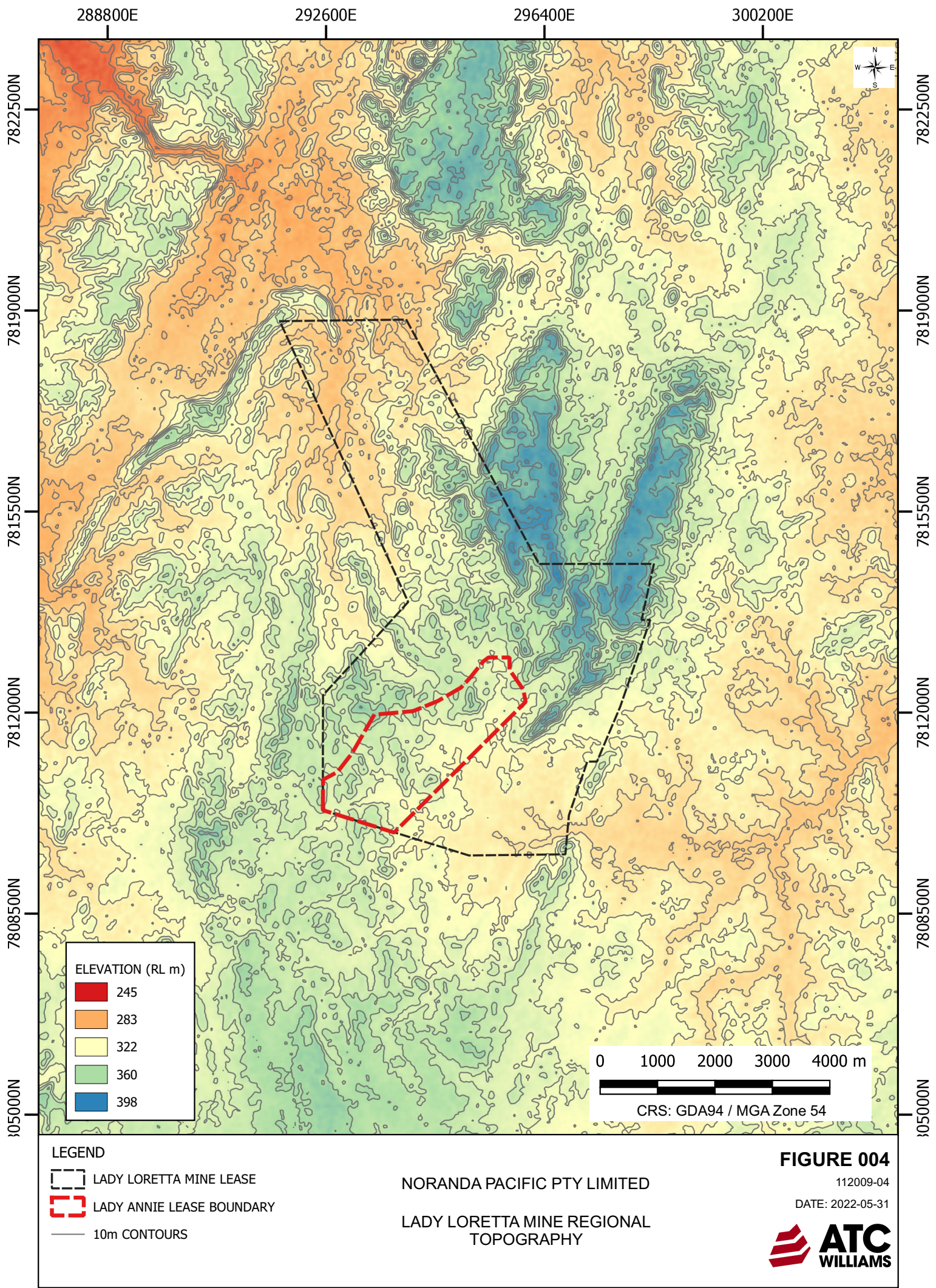
3.1.1.1. Topography

Topography of the mine is dominated by the “Big Syncline”. The eastern limb of this syncline forms the main ridgeline at LLM. The ridgeline is orientated in a north-east to south-west direction. Elevations across the mine vary from approximately 380 m Australian Height Datum (AHD) to 320 m AHD.

Most of the mine infrastructure is located on the edge of a ridgeline, occupying levels between 325 m and 335 m AHD at typically low gradients, less than 3% slope. The steepest gradients found at LLM are approximately 40% to 50% on the hill slopes of the Big Syncline.

To the east, south-east and north-east of LLM the topography flattens and is dominated by undulating plains with occasional lower hills and ridgelines (Noranda Pacific, 2000).

Regional topography is shown in Figure 4.



3.1.1.2. Climate

The area experiences a semi-arid climate with distinct wet and dry seasons. The wet season is generally from December to March and is characterised by heavy rainfall in short bursts. The dry season spans April to October with little to no rainfall during this season.

Climate data from 1960 to 2018 derived from rainfall records from the Lady Annie Mine Gauge (029172), Carlton Hills Station Gauge (029118) and Flora Downs Station Gauge (037055) was obtained from the Bureau of Meteorology (BoM) SILO data drill (SLR, 2021).

The average rainfall and evaporation data are presented in Figure 5.

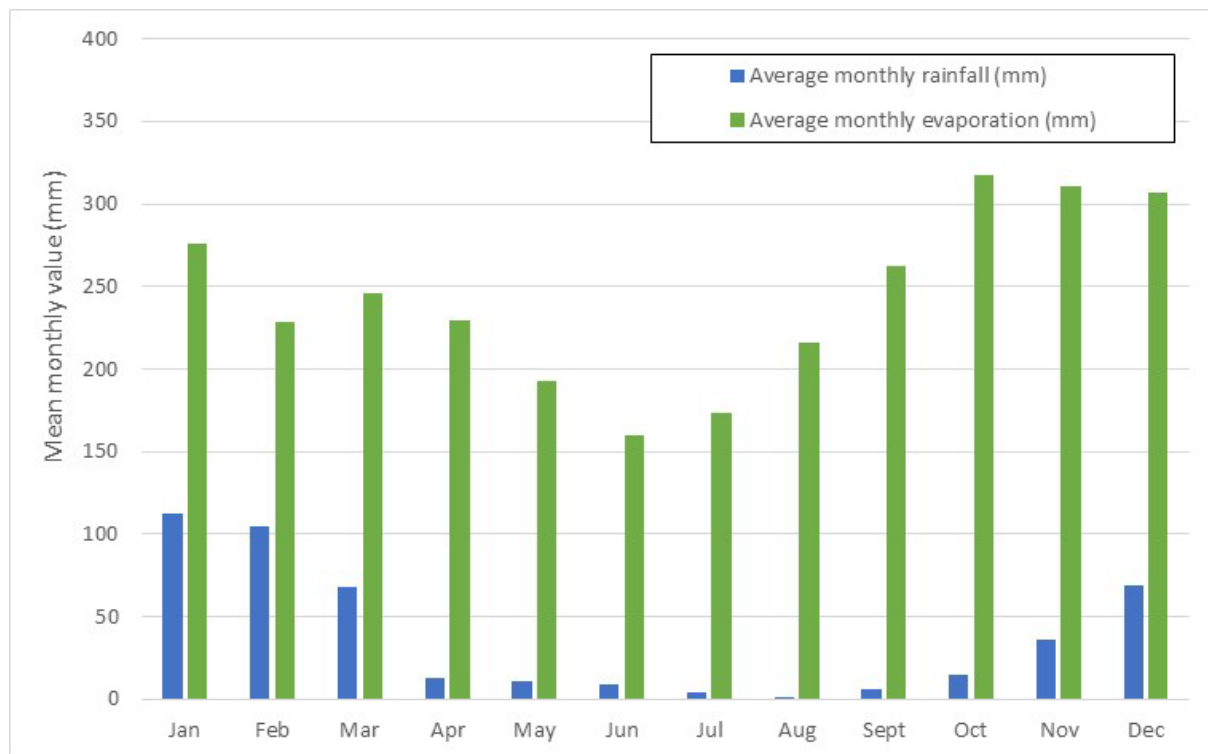


Figure 5: Climatic Conditions

3.1.1.3. Geology and Soils

LLM is situated in the Western Fold Belt of the Mt Isa Inlier. The deposit targeted by the LLM is a Pb-Zn-Ag deposit within the Mount Isa Inlier, with the ML within the Lady Loretta Formation. The deposit is considered a classic sediment-hosted base metal deposit. Sediments hosting the deposit comprise interbedded bedded siltstone, sandstone, interclastic dolomite, carbonaceous and pyritic shale. The ore horizon is a distinctive finely banded massive sulphide lens up to 50 m thick and contains pyrite, sphalerite, galena and in places barite (Noranda Pacific, 2000).

The deposit is hosted within the Palaeoproterozoic Lady Loretta Formation, which is the uppermost outcropping unit of the McNamara Group (Valenta, 2018) within the keel of the Small Syncline, a tight north-east trending fold. The Small Syncline as well as the Big Syncline are heavily faulted with a series of north-east and south trending faults.

Local geology is summarised in Figure 6.

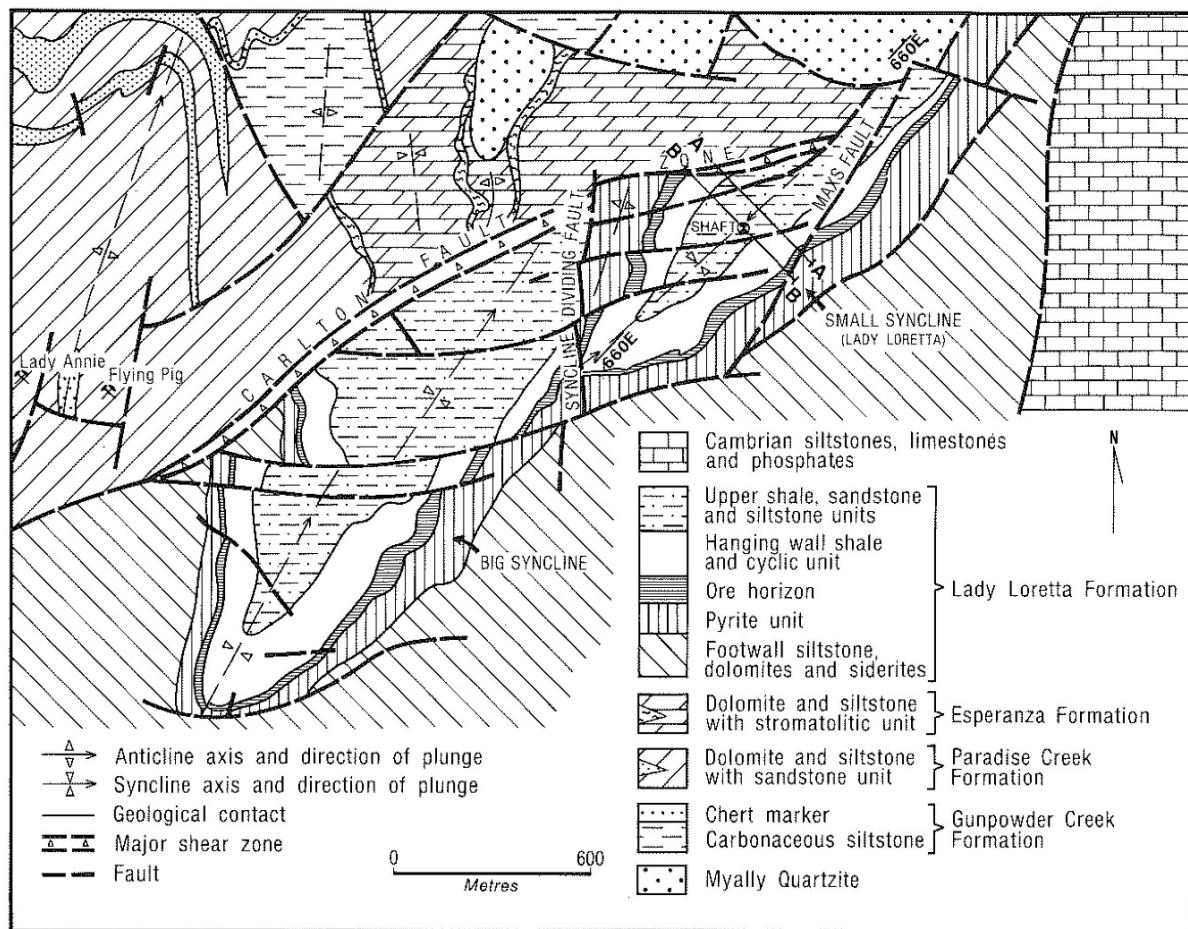


Figure 6: Plan View Geological Map of the Lady Loretta Deposit and Stratigraphic Column for the Lady Loretta Region (Hancock and Purvis, 1990)

The Mount Isa Soil Landscape Province is a dissected plateau of Precambrian igneous, metamorphic and sedimentary rocks. Lithosols (stony or gravelly soils lacking horizon development, other than an A1 horizon) are the dominant soils and have formed either in situ on the near vertically bedded shales, or from eroded material deposited on the lower slopes and along waterways. Lithosols typically consist of a shallow gravelly layer, containing minor silt and sand content, up to 1 m thick which grades into a fine to medium grained sandy loam (0.5 to 1 m thick). In some areas the gravelly layer grades into a silty clay loam or a silty clay (0.5 to 2 m depth) (Noranda Pacific, 2000). The soil horizons within the LLM generally contain a large proportion of coarse textured material, as well as iron and manganese nodules. Some sections (particularly the north-eastern part) have a thick 30cm layer of very fine-grained chert (Noranda Pacific, 2000). Soils along the laterite ridge above LLM site have naturally elevated concentrations of lead, zinc and silver associated with surface outcrops of the underlying ore horizon and associated pyrite bed (TropWATER, 2021).

The Mount Isa Land System, where LLM lies, has a relatively low stock carrying capacity, low pastoral potential and minimal agricultural potential. Broadly, the system consists of undulating country with spinifex pastures covering large areas, and smaller regions of woodland. The land use is restricted to exploration/mining and very low intensity stock grazing.

The Environmental Management Overview Strategy (EMOS) (Noranda Pacific, 2000) reports the Lady Loretta area to be predominantly land capability class VI on the flatter plains to the east of the deposit and the valley floors between ridgelines. On the slopes and ridges the land capability class is reported VII due to steepness of the slopes and generally shallow, rocky soils.

Emery (1985) describes capability class VI as:

- Land not suited to any type of cultivation but best used for grazing, and
- Generally comprising land with a range of physical or climatic limitations which may include shallow soils, high rock content, excess salt concentration, steep or awkward slope gradients.

Capability class VII is described as:

- Land best to remain under green timber owing to its high soil erosion hazard and severe site restrictions, and
- Generation areas of steep slopes, shallow soils and/or rock outcrop.

The strategy identifies the objective to return land disturbed by the mining activities to pre-mining land use of low intensity grazing and pre-mining capability class.

3.1.1.4. Hydrology

In the EA, the receiving environment for LLM is defined as the waters of Magazine Creek, Desert Creek and connected waterways within 10 km downstream of the release, or further if an impact is detected beyond 10 km. Stream flow, surface water quality, stream sediment quality, aquatic habitat and macroinvertebrates are all required to be monitored to assess the health of the receiving environment.

3.1.1.4.1. LLM catchments and drainage

ML5568 is located in the upper catchments of the Nicholson and Leichhardt Rivers, both of which drain to the Gulf of Carpentaria. The northern section of the lease drains in a northerly direction into the Gregory and Nicholson system. The south-eastern section of the lease drains to the east via a network of minor ephemeral streams. Desert and Magazine Creeks drain into Battle Creek before entering Gunpowder Creek and ultimately the Leichhardt River.

It should be noted that Desert Creek and its tributaries also receive runoff from the Lady Annie Mining Lease (ML90179). Gunpowder Creek has a catchment area of approximately 3,600 km² and Battle Creek has a catchment of approximately 475 km². ML5568 occupies less than 1% of either of these catchment areas. There are no permanent natural surface water bodies in the LLM operational area.

There is also no permanent surface water flow within ML5568. Flows are typically short, discrete events that coincide with rainfall events (Glencore, 2019). Flow gauging stations installed in Magazine and Desert Creeks demonstrates that they generally experience flows lasting one to three hours. Further downstream, in Desert Creek, flow events last, on average, 33 hours (Noranda Pacific, 2018).

3.1.1.4.2. Surface water quality

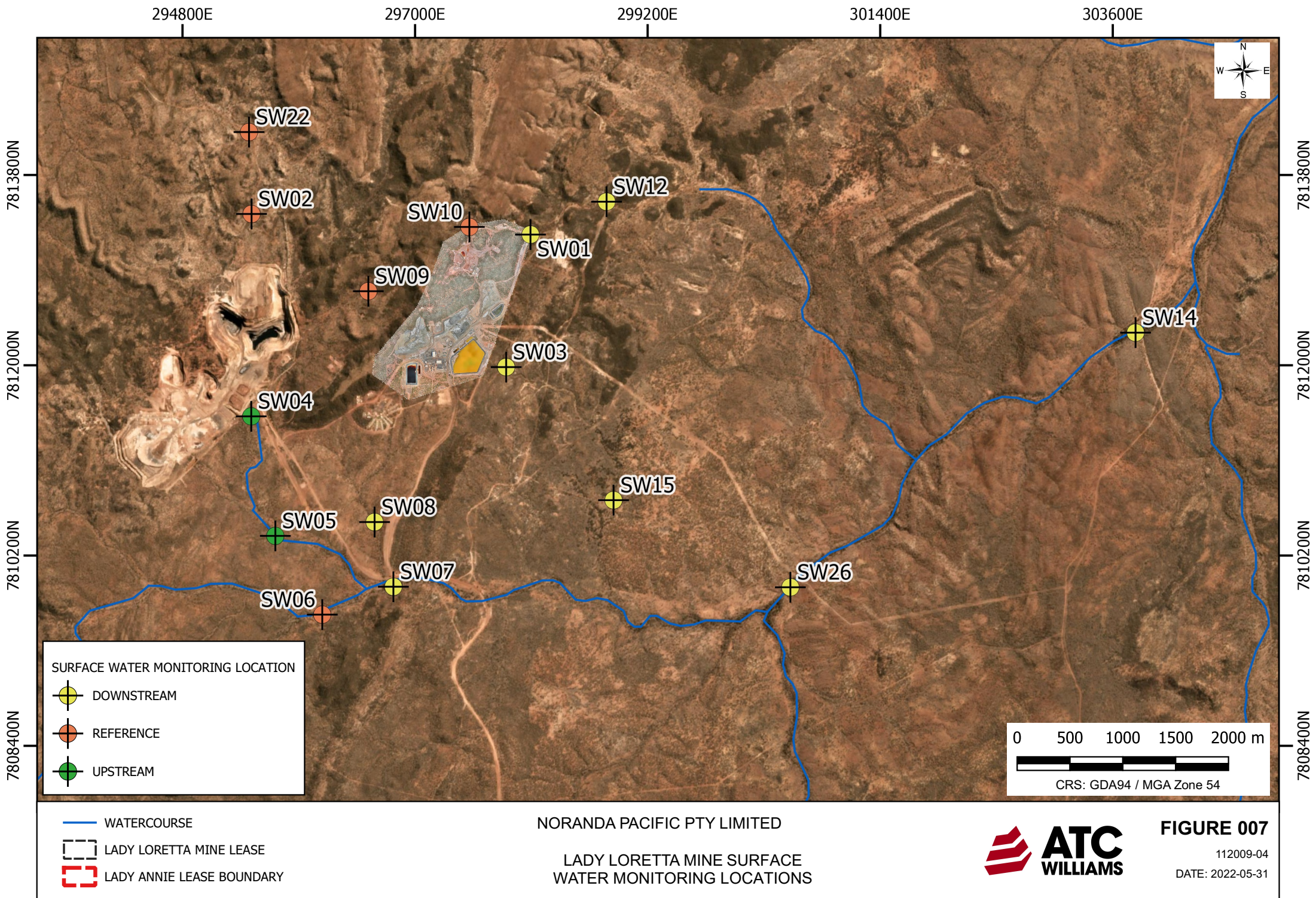
The Receiving Environment Monitoring Program (REMP) Design Report (NRA, 2013) developed for LLM nominated the key Environmental Values (EVs) as:

- Aquatic ecosystems (slightly to moderately disturbed),
- Livestock drinking water (primary industries- cattle),
- Industrial use (mining), and
- Cultural and spiritual values.

These nominated EVs are protected through the active management of Water Quality Objectives (WQOs), which have been derived based on the *Australia and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG) (2018). The adopted trigger level for toxicants is generally the higher of the default ANZG at the 95% level of protection and the 80th percentile of reference site data (see Schedule C, Table 5 of the EA). Note that an exceedance of trigger values is an early warning mechanism to alert of a potential problem, not an instrument to assess compliance (ANZG, 2018).

The surface water sampling locations are shown in Figure 7.

Data from five reference sites within and downstream of the LLM identified water to be naturally highly mineralised. The reference sites are reported (Noranda Pacific, 2018) to exceed guideline values for the protection of slightly-to-moderately disturbed aquatic ecosystems, with median values for aluminium, copper, selenium and zinc exceeding guideline values. The reference sites also have pH values more acidic than the guideline values.



3.1.1.4.3. Stream sediment quality

The quality of stream sediments is monitored twice a year (once at the end of the wet season and once at the end of the dry season) as per the requirements of the EA. Samples are collected from five reference sites, two interim upstream sites (which provide an indication of the quality of water entering the Desert Creek catchment) and eight downstream receiving environment sites (defined in Schedule C, Table 4 of the EA). The sediment sampling locations are the same as the water quality monitoring locations (refer to Figure 7). Sediment quality guideline values (SQGVs) were derived from the Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson *et al.*, 2013) and where there are no SQGVs, interim site-specific trigger values were calculated using the SQG guidelines (Simpson *et al.*, 2013). Currently stream sediment is monitored by the site under the routine Sediment Quality Monitoring Program (SQMP).

Glencore has recently engaged TropWATER to undertake an assessment of the current compliance framework of the EA for both water and sediment. The current compliance framework relies on comparison to up-gradient reference conditions which do not accommodate these underlying natural influences (TropWATER, 2021).

3.1.1.5. Hydrogeology

A number of groundwater resources occur within and proximal to ML5568. The Lady Loretta Formation is unconformably overlain by the Beetle Creek Formation and the Thornton Limestone, which are both significant water-bearing units. The Lady Loretta Formation itself also hosts groundwater resources that are less well characterised. The extensive fracturing in the Middle Proterozoic Carpentarian bedrock is thought to be the sole mechanism for flow, extraction and recharge of groundwater in the area.

The Hydrogeological Conceptual Model (AGE, 2018, 2020; CDM Smith, 2022) identified three distinct hydrogeological provinces or blocks, known as the Cambrian, Lady Loretta and Palaeoproterozoic blocks, which are separated by two major fault networks. The Carlton Fault is located north of LLM Operations and the Western Border Fault is located south-east of the LLM Operations (refer to Figure 6). LLM operations are wholly contained within the Lady Loretta Block.

Detailed hydrogeological modelling indicates that there is negligible hydraulic connectivity (i.e. groundwater flow) across these faults (AGE, 2018, 2020; CDM Smith, 2022). Dewatering is conducted by LLM operations in order to conduct underground mining activities, and evidence suggests it directly controls groundwater flow direction. Groundwater flows north beneath the mine infrastructure, towards the underground workings (CDM Smith, 2022).

The EVs identified by CDM Smith (2022) include: aquatic ecosystem protection, waters that may be used for agricultural purposes and drinking water, industrial use, and cultural and spiritual values. CDM Smith (2022) indicate that the nearest potential groundwater dependent ecosystems (GDEs) are located more than 4 km southeast of LLM, based on the Bureau of Meteorology GDE Atlas. Groundwater use for agricultural purposes and drinking water are both associated with the Cambrian block, where it has been demonstrated that there is negligible hydraulic connection from the Lady Loretta block (i.e. LLM Operations) to the Cambrian block. As groundwater flow in the Lady Loretta block is northwards towards the underground dewatering operations, and there is minimal hydraulic connection between the Proterozoic block and the Cambrian block, it can be reasonably inferred that there are no EVs associated with groundwater in the LLM (dewatering) footprint.

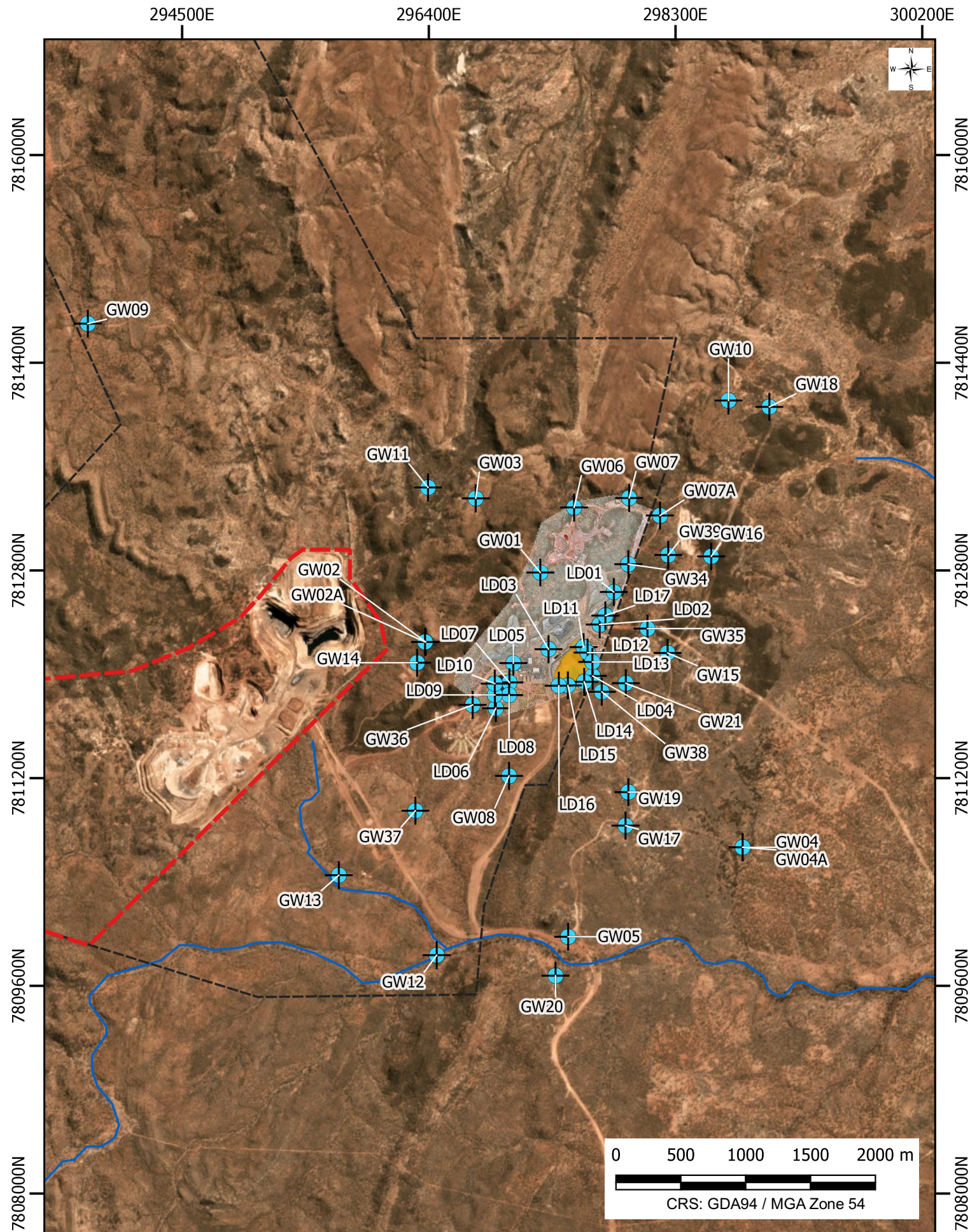
Groundwater is monitored in compliance with the EA. The groundwater monitoring locations, including reference bores, compliance bores and seepage detection bores were updated as part of the *Groundwater Monitoring Network Design Plan* (Glencore, 2019b).

The current monitoring locations are shown in Figure 8.

The construction of older bores is unknown and as such it is unclear which aquifer units they are screened across. However, static water levels (SWL) are generally between 40 and 70 metres below ground surface (m bgs).

Based on groundwater monitoring undertaken on site, electrical conductivity, sulphate and concentrations of metals and metalloids are elevated at some bores within the immediate vicinity of the mine. This is likely due to the naturally elevated levels resulting from the mineralised lithology.

Further information on groundwater is presented in the Post Mine Land Use Plan (Noranda Pacific, 2018).



LEGEND

-  GROUNDWATER MONITORING BORE LOCATION
-  LADY LORETTA MINE LEASE
-  LADY ANNIE LEASE BOUNDARY

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LADY LORETTA MINE
GROUNDWATER MONITORING NETWORK

FIGURE 008

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3.1.2 Regional Ecosystems

3.1.2.1. Terrestrial Flora

LLM is located within the Mount Isa Inlier province of the Northwest Highlands Bioregion. The bioregion is characterised by stony hills and ranges. The land within and external to the mine is dominated by spinifex pastures, with smaller areas of woodland and Mitchell grass. The pre-mining (contemporary) land use within the lease was low intensity grazing and mining.

James Warren and Associates Pty Ltd surveyed the flora of the project area in July 2000 and NRA Environmental Consultants reported post-wet season monitoring results in April 2012. The objectives of these studies were to describe plant communities (including rare and threatened species) occurring within the ML. James Warren and Associates (2000) reported four broad vegetation communities including:

- Mid-high Closed-Open Forest (lancewood) (analogous with regional ecosystem (RE) 1.7.1) - This community is found on the scree slopes in the northern section of the ML. Lancewood dominates the community and little ground and mid cover is evident.
- Mid-high Woodland (snappy gum) (analogous with RE 1.11.2) - This community dominates the valley floors in the north and undulating plains in the south of the ML. Snappy gum and other Eucalypt and Corymbian species are common. The mid-storey is dominated by climbing shrubs while Spinifex dominates the groundcover.
- Mid-high Woodland (silver-leaved box) (analogous with RE 1.11.4) - Floodways in the south and south-east of the ML are dominated by this community. Silver-leaved box and bean trees (to a lesser extent) are common in this community. River red gums occur along the edge of the main flood channel and become more prominent in the south.
- Mid-high Open Woodland (small-fruited bloodwood) (analogous with RE 1.11.2) - This community is restricted to the mesa plateaus in the northern section of the ML. The community is dominated by small-fruited bloodwood with scattered snappy gum.

Studies reported by NRA (2012) documented an updated list of RE types encountered during surveys. The RE types based on the 2012 NRA study are shown in Table 5.

Table 5: Regional Ecosystem Types Encountered within the ML (NRA, 2012)

Regional Ecosystem ¹	Short Description ¹
1.3.6	Ghost gum (<i>Corymbia aparrrerinja</i>), bloodwood (<i>Corymbia terminalis</i>) open woodland on sandy terraces.
1.3.6a	Floodplain (other than floodplain wetlands). Woodland of <i>Corymbia aparrrerinja</i> often with <i>C. terminalis</i> , <i>Eucalyptus leucophylla</i> , <i>E. camaldulensis</i> , <i>Lysiphyllum cunninghamii</i> and/or <i>Acacia cambagei</i> with a sparse ground layer of tussock grasses with <i>Triodia longiceps</i> in some places.
1.3.6x1	Riverine wetland or fringing riverine wetland. Woodland of <i>Eucalyptus leucophylla</i> and/or <i>E. pruinosa</i> , often with <i>Corymbia terminalis</i> , <i>Acacia cambagei</i> , <i>Atalaya hemiglauc</i> and <i>C. aparrrerinja</i> with a mixed ground layer of tussock grasses and <i>Triodia spp.</i>
1.3.7b	Riverine wetland or fringing riverine wetland. Fringing woodland of <i>Eucalyptus camaldulensis</i> , usually with <i>Lophostemon grandiflorus</i> and <i>Melaleuca bracteata</i> and/or <i>M. dissitiflora</i> .
1.5.3	Snappy gum (<i>Eucalyptus leucophloia</i>) low open woodland on red earths on plateaus
1.71	Snappy gum (<i>Eucalyptus leucophloia</i>) low open woodland on skeletal soils on lateritic scarps and plateaus.
1.7.1x1	Low open-woodland of <i>Acacia shirleyi</i> . Occurs on laterite.
1.7.1x3	Low open-woodland of <i>Corymbia capricornia</i> +/- <i>Eucalyptus leucophloia</i> with mixed shrub layer and ground layer of <i>Triodia pungens</i> and <i>Schizachyrium fragile</i> . Occurs on silcrete.

Regional Ecosystem ¹	Short Description ¹
1.9.6	Snappy gum (<i>Eucalyptus leucophloia</i>) and bloodwood (<i>Corymbia terminalis</i>) low open woodland on limestone hills.
1.11.2	Snappy gum (<i>Eucalyptus leucophloia</i>) low open woodland on siliceous rocky hills on folded sediments.
1.11.2a	Low open-woodland of <i>Eucalyptus leucophloia</i> often with <i>Corymbia</i> spp., <i>Terminalia aridicola</i> and <i>E. leucophylla</i> with shrub layer of <i>Acacia</i> spp. and ground layer of <i>Triodia</i> spp.
1.11.2x2a	Low woodland to open-forest of <i>Acacia shirleyi</i> . Occurs on metamorphic hills.
1.11.2x3	Low open-woodland of <i>Corymbia aspera</i> , often with <i>Terminalia aridicola</i> subsp. <i>aridicola</i> , <i>Eucalyptus leucophloia</i> and <i>C. capricornia</i> with a <i>Triodia</i> spp. understorey. Occurs on rocky metamorphic outcrops.
1.11.3	Cloncurry box (<i>Eucalyptus leucophylla</i>) low open woodland on basic rocky hills on folded sediments.

NOTE 1: Descriptions reported by NRA 2012. RE types and descriptions have since been updated

Source: NRA, 2012

RE types and descriptions have since been updated and recent mapping can be found on the DES website (i.e. RE 1.7.1x1 has recently been described as 1.7.5a, 1.11.2x2a as 1.7.5b and 1.7.1x3 as 1.7.7a). The river red gum riparian community associated with larger drainage lines in the ML and the silver-leaf box communities associated with the flat areas adjacent to the waterways are identified as conservation significant flora communities.

No flora species listed under the *Environment Protection and Biodiversity Conservation Act 1999* or *Nature Conservation (Wildlife) Regulation 2006* (previously the *Nature Conservation [Wildlife] Regulation 1994*) at the time of survey were recorded at the Project area. When surveyed by NRA, a relatively low proportion of species recorded were non-native. Buffel grass (*Cenchrus ciliaris*), calotrope (*Calotropis procera*) and sida (*Sida acuta*) were the most significant species recorded.

The land has an inherently low pastoral and agricultural potential and a low capacity to carry livestock. Twenty species of weeds are known to occur at LLM on ML5658, none are Prohibited or Restricted Matters in the Queensland Biosecurity Act (DAF, 2014). Three weeds are listed as pest plants under the Mount Isa City Council, *Local Government Area Pest Management Plan* (Mount Isa City Council, 2014):

- Noogoora Burr (*Xanthium occidentale*) – low priority weed,
- Calotrope (*Calotropis procera*) – medium priority weed, and
- Prickly Mimosa Bush (*Vachellia farnesiana*) – environmental weed.

3.1.3 Pre-mining Vegetation and Land Uses

The geology, terrain and vegetation of the Site has been described variously including Section 3 of this PRCP and the EMOS developed by Noranda Pacific in November 2000 to support authorisation of the EA. The EMOS defined four vegetation communities that occur at the Site. The spatial distribution of these communities aligns with the local topography and geology. A plan showing the pre-disturbance vegetation types is presented in Figure 9.

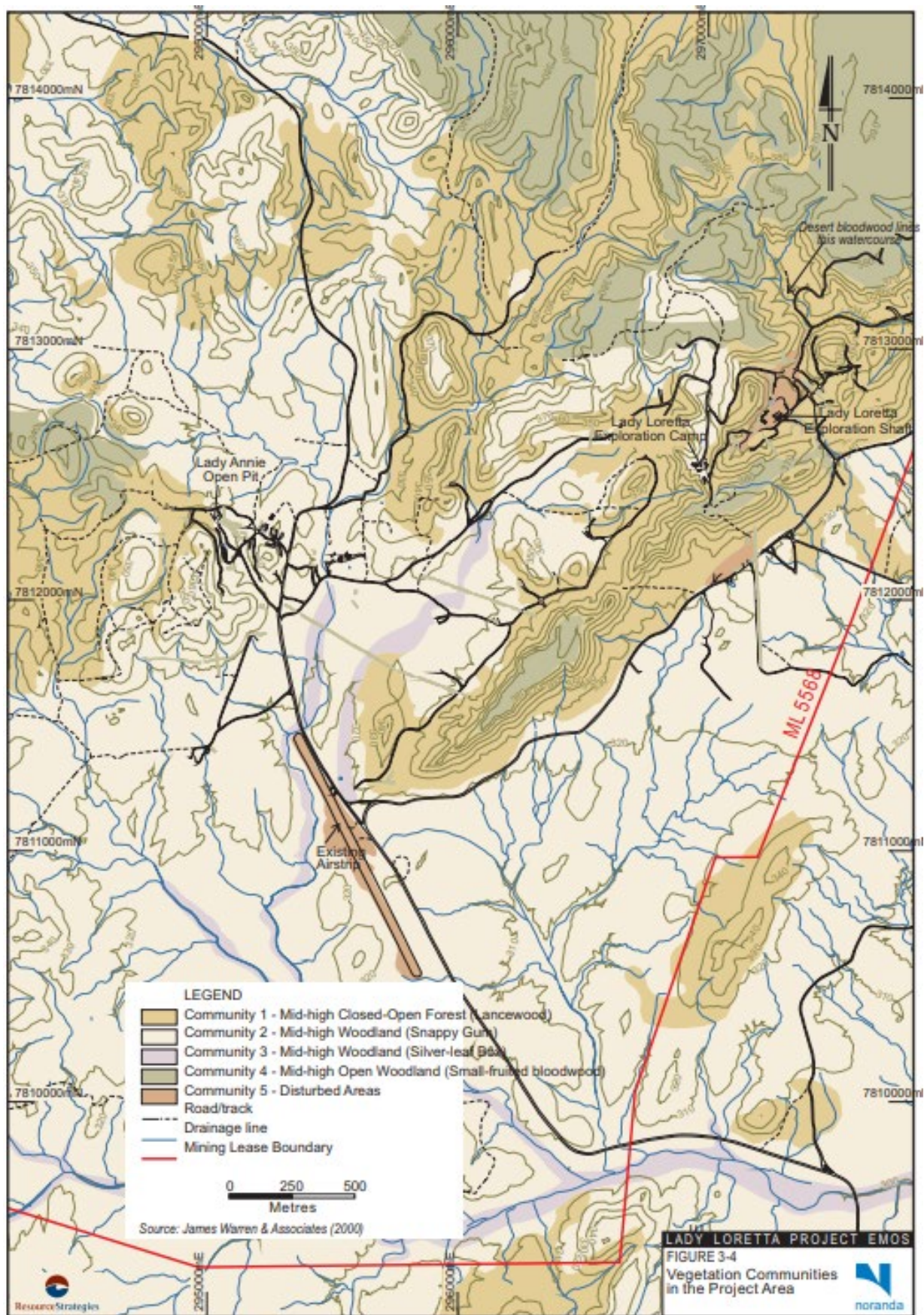


Figure 9: Pre-disturbance Vegetation Map (from EMOS Noranda Pacific 2000)

3.1.3.1. Lowland plain

Much of the fixed plant and surface infrastructure at the Site has been developed on a lowland plain bordered by the eastern boundary of the ML and the ridge that hosts the Lady Loretta orebody. The alluvial plain is relatively flat with slopes typically less than 8%. Although nutrient poor, soils and sub-soils have developed by a combination of in-situ weathering of the underlying strata and/or accumulations of sediments transported from the nearby ridges. Vegetation on this terrain type comprises Regional Ecosystems 1.11.2a and 1.3.6a. The EMOS described them as:

- Community 2 - Mid-High Woodland (Snappy gum).

Prior to mining, the lowland plain was utilised by livestock as a component of a low intensity cattle grazing land use.

3.1.3.2. Steep ridges

The Lady Loretta orebody is hosted in a ridge that runs north-east to south-west. The ridge comprises siliceous sediments that have been folded to form a dipping syncline. The folding has resulted in typical slopes of 15% but scree slopes of 40% are common. The shales and mudstones are relatively tight and resist percolation of meteoric water into the groundwater system except in areas of heavy fracturing. The sloped terrain and low rates of infiltration results in high rates of surface runoff and naturally high rates of erosion. Soils are typically sparse and nutrient poor.

The pre-mining vegetation on this terrain type reflects Regional Ecosystem; 1.11.2 (found on rocky hills), 1.7.5a and 1.7.5b (formally known as 1.7.1x1 and 1.11.2x2a respectively) and was described in the EMOS as:

- Community 1 - Mid-High Closed-Open Forest (Lancewood), and
- Community 4 - Mid-High Open Woodland (Small fruited bloodwood).

Prior to mining, the steep ridges were available for grazing of livestock but is unlikely that cattle utilised the grasses available due to their relative sparseness and lack of available drinking water. The pre-mining land use was Native Ecosystem for native fauna.

3.1.3.3. Terrestrial flora

The four dominant terrestrial fauna habitats on LLM were identified as:

- Snappy gum woodland over spinifex,
- Riparian habitat,
- Stony hills, lateritic scarps and boulder piles, and
- Lancewood woodlands.

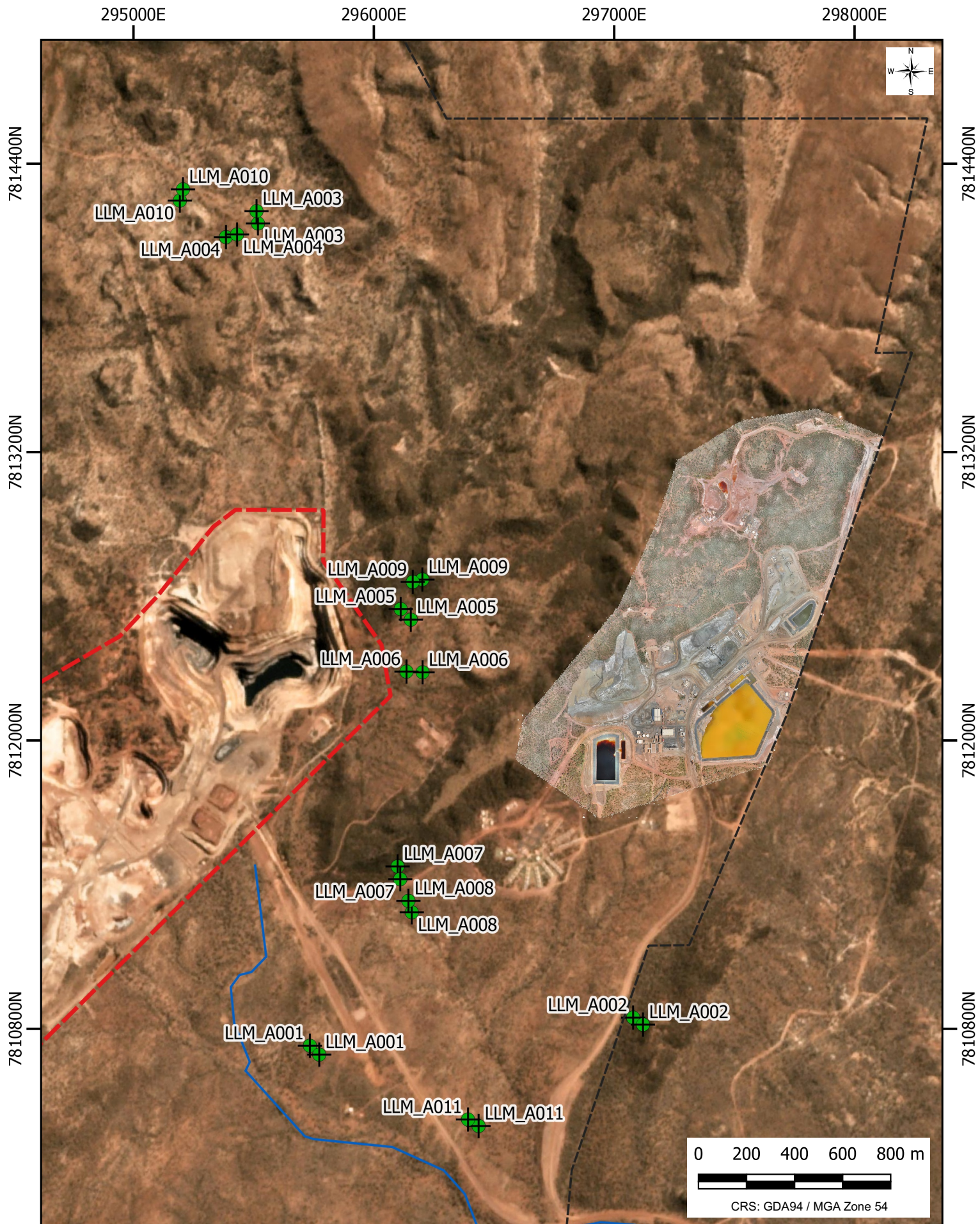
Other notable habitat features present include:

- Waterways and springs,
- Disturbed or modified environments (e.g. formed roads, mine camp), and
- Artificial water courses (e.g. mine dams, stock dams, leaking pipelines).

A Rehabilitation Monitoring Program is in place. The Rehabilitation Monitoring Program (Eco Logical, 2019) and commencement of the monitoring program established eleven analogue monitoring sites in 2018, all of which have been comprehensively monitored as of 2018 to allow comparison of rehabilitation to similar vegetation. A map of the analogue monitoring sites is provided in Figure 10.

Monitoring included Ecosystem Function Analysis (EFA), which considers Landscape Function Analysis (LFA), vegetation dynamics and habitat complexity. Recent monitoring for habitat complexity (a key attribute to facilitate fauna inhabitation) was recorded as follows:

- Low canopy cover in tree and shrub layers, minimal woody debris and groundcover available as microhabitat,
- Low canopy cover in tree and shrub layers, presence of termite mounds, minimal woody debris and groundcover available as microhabitat,
- High canopy cover in tree layer, presence of woody debris and loose bark available as microhabitat,
- Moderate canopy cover in the tree and shrub layers, presence of woody debris and ground cover creating fauna habitat, and
- Moderate canopy cover in the tree layer, presence of rocks and woody debris available as microhabitat.



LEGEND

- ANALOGUE VEGETATION MONITORING LOCATION
- LADY LORETTA MINE LEASE
- LADY ANNIE LEASE BOUNDARY
- WATERCOURSE

NORANDA PACIFIC PTY LIMITED

LADY LORETTA MINE
ANALOGUE VEGETATION MONITORING SITES

FIGURE 010

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A fauna survey of the lease in 2000 detected a fauna community that included native amphibians, reptiles, birds and mammals. Exotic species were also recorded. Results included species listed as threatened under the *Nature Conservation (Wildlife) Regulation 1994* (now the *Nature Conservation (Animals) Regulation 2020*), as follows:

- **Amphibians:** most species expected to occur around larger creeks in the south of the mining lease, for example green tree frog, desert tree frog and ornate burrowing frog. The cane toad is known to occur in the area. Most of the mining lease provides low value habitat for amphibians, with most important habitat being larger floodways in the south and southwest.
- **Reptiles:** a number of *Carlia* (four-fingered skinks) and *Ctenotus* (comb-eared skinks) species expected to occur at the mining lease as well as olive whipsnake (*Demansia olivacea*) and northern spotted rock dtella (*Gehyra nana*). Scree slopes are noted an important refugial habitat in the region.
- **Birds:** a variety of species are known to occur on the mining lease.
- **Mammals:** mammal species include small mammals, macropods, microbats and megabats.

3.1.3.4. Threatened species

Previous ecological assessments undertaken at LLM have identified eight fauna species of conservation significance which are prescribed matters of state significance under the *Environmental Offsets Act 2014*. A summary of these species and their relevant *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Nature Conservation Act 1992* (NC Act) listing status is provided in Table 6. A Biodiversity Offset Strategy has been developed for LLM to manage impacts on relevant significant biodiversity values.

Table 6: LLM Threatened Species

Species	Common Name	Status – NC Act	Status – EPBC Act
<i>Amytornis dorotheae</i>	Carpentarian grass-wren	Endangered	Endangered
<i>Erythrotriorchis radiatus</i>	Red goshawk	Endangered	Vulnerable
<i>Erythrura gouldiae</i>	Gouldian finch	Endangered	Endangered
<i>Falco hypoleucos</i>	Grey falcon	Vulnerable	-
<i>Grantiella picta</i>	Painted honeyeater	Vulnerable	Vulnerable
<i>Hipposideros stenotis</i>	Northern leaf-nosed bat	Vulnerable	-
<i>Petrogale purpureicollis</i>	Purple-necked rock-wallaby	Vulnerable	-
<i>Tachyglossus aculeatus</i>	Short-beaked echidna	Special Least Concern	-

3.1.3.5. Aquatic fauna

The Site is located within the far western portion of the Gunpowder Creek Catchment (which is also part of the greater Leichhardt River Catchment). Both watercourses are non-permanent but retain large permanent holes through the dry season. Pools may remain in some larger creeks during the dry season.

Under natural flow conditions, waterways immediately downstream of the mine generally flow for only short periods of a few hours during and following rainfall. The ephemeral creeks of the receiving environment are unlikely to support biota sensitive to poor water quality.

Results of sampling undertaken in 2018 (FRC Environmental Pty Ltd) reported waterways downstream of LLM to be ephemeral, with sand or cobble substrates and varying cover of riparian vegetation. Channel widths tended to increase with distance downstream from approximately 1 m to 10 m width. Channels are often dry within the ML with isolated pools generally persisting only in the wet season after significant rain. It was reported that during periods of flow there is little potential for aquatic organisms to move upstream (FRC Environmental Pty Ltd, 2018). Short duration of flow events (generally only hours) is considered insufficient time for the movement of organisms from refugial habitat. The upper reaches of ephemeral creeks near the LLM were reported to typically be used by short-lived aquatic species tolerant of harsh environmental conditions (such as those of ephemeral streams in the region). There is little refuge habitat for aquatic organisms within the receiving environment.

3.1.4 Air Quality

The LLM is located in a remote area. The nearest potentially sensitive receptors include (Noise Mapping Australia, 2013) are:

- Thornton Station, 33 km to the north/north-west,
- Carlton Hills Station, 54 km to the south-east,
- Capricorn Copper Mine accommodation camp, 35 km to the east,
- Lady Annie Camp, 17 km to the south-east, and
- Koolamara Station, 19 km to the south-east.

These stations (with the exception of Koolamara) were identified as potentially sensitive receptors by an air quality assessment of the LLM area and surrounds (Noranda Pacific, 2000). While no monitoring was undertaken at that time, key sources of dust/particle emissions in the area were considered to be typical of the wider North-west Region, relating to mining/exploration activities, unsealed roads and grazing activities. The typical sources of atmospheric emissions primarily relate to dust or particulates, dominated by coarse particulate fractions (i.e. greater than 10 micrometres [μm]). While presenting management concerns from a nuisance perspective, coarse particles were generally not considered to pose a health threat due to the inability of the larger particles to enter the human respiratory tract.

3.2. POST MINING LAND USE

3.2.1 Integrated Business Processes

3.2.1.1. Business Planning

3.2.1.1.1. Rehabilitation and Closure Planning

As a Glencore-owned asset, LLM is required to maintain and implement rehabilitation and closure plans that are consistent with the requirements defined by Glencore's Closure Planning Standard. The objective of this Standard is to set clear requirements for dealing with the risks and costs presented by asset closure. Aspects of the Standard include:

- Appropriate knowledge is recorded and made available,
- Program objectives and success criteria are defined,
- Rehabilitation and closure requirements are integrated into Life of Asset planning,
- Planning specificity is reflective of the Life of Asset, and
- Rehabilitation cost models and financial provisions are complete and transparent.

Business plans established for LLM are prepared pursuant to the requirements defined by Glencore and address all aspects of the LoA including decommissioning and rehabilitation. Closure planning is a process that is adopted for LLM throughout the business life-cycle. The overall target is to deliver a clear, consistently planned and executable process that provides for a sustainable post-mining land use.

3.2.1.1.2. Operational Business Planning

The management of LLM maintains a suite of business plans that are revised on an annual basis. The Plans set the performance objectives for the Site and allocate suitable resources to meet those objectives. Plans are defined for periods of 12 months and five years.

3.2.1.2. Water Management

Effective water management is a key driver of the overall success of LLM. To that end, the Site has established and maintains a WMS that comprises the following elements:

- Water management plan,
- Water management network, and
- Probabilistic water balance model.

3.2.1.2.1. Water Management Plan

LLM maintains a Water Management Plan (WMP) that describes the context, systems, and equipment used to manage water at the Site. The WMP is required under the EA.

3.2.1.2.2. Water Management Infrastructure

The Water management infrastructure is the physical or equipment features used to collect, store, distribute and dispose of water at the Site. Key features are described below.

3.2.1.2.2.1. Water supply

Water supply to the site is provided by operating a production wellfield located to the east of ML pursuant to a contractual right. The water supply system includes:

- Four production wells fitted with casing, electric pumps, instrumentation and power supplies,
- Transfer and delivery systems comprising pipes, transfer tanks and transfer pumps,
- Raw water storage tanks,
- Reverse osmosis potable water treatment plant, and
- Reticulation network.

Raw water from the wellfield is transferred to tankage located on elevated land north of the paste plant. Raw (or untreated) water is used variously across the Site including underground for machine cooling and in paste production. Raw water is also treated to produce potable water in a package plant.

3.2.1.2.2.2. Mine affected waters

Surface and groundwaters that interact with mineralised materials such as the orebody, the underground mine workings, ore stockpiles, tailings stockpiles, or waste rock stockpiles can become contaminated with acid and/or dissolved heavy metals and salts. The potentially mine-affected waters are generally unsuitable for direct release to the environment and must be managed on site. Mine-affected waters are generated by dewatering of the underground mine workings as well as by capturing surface runoff from mine-affected catchments. Key features of the mine affected water system include (Glencore, 2017):

- Water storages – including four regulated dams, Containment Dam A (CDA), Containment Dam B (CDB), Paste Plant Dam (PPD) and Leachate Management Dam (LMD). Receiving waterways for each structure is Desert Creek, with the exception of LMD where the receiving waterway is Magazine Creek,
- Transfer systems – includes transfer systems internal to the integrated catchment system, and discharge lines transferring water out of the catchment system,
- Water diversions to maintain a separation of clean water and dirty areas – including WRE Diversion Drain, CDB Diversion Drain, Village Link Drain, ROM Diversion Drain, Batch Plant Diversion Drain, Paste Plant Diversion Drain, Paste Plant Link Drain and LMD Diversion Drain, and
- Process demands – including underground dewatering, bore fields, workshop and vehicle wash dirty water, Clean In Clean Out (CICO) wastewater and water treatment plant rejects.

Management of the mine-affected water inventory is achieved by various means including reuse underground for dust suppression, direct evaporation and treatment. Treatment of mine-affected waters occurs on-site in a dedicated package plant that utilises filtration and reverse osmosis. The permeate stream is release off-site (under license) for beneficial reuse and the reject is transferred back to the mine-affected water inventory.

3.2.1.2.2.3. Wastewater disposal

Wastewaters generated at the site are collected and treated prior to disposal into the mine-affected water system. The wastewater disposal system includes:

- Sewage collection network,
- Transfer systems comprising pumps and rising mains, and
- Package treatment plant and evaporation beds.

3.2.1.3. Spill Risk and Probabilistic Water Balance

A key requirement for LLM is to ensure that mine-affected waters are effectively managed at the Site. In most regards, these waters are not suitable for direct release to the receiving environment as they are contaminated with dissolved heavy metals and soluble salts. Inventory management is a key consideration and suitable areas must be maintained to store both the mine-affected water inventory as well as any additional waters generated by rainfall. As a result, the risk of spill is routinely monitored and assessed by site management.

Many of the factors affecting spill risk are relatively well known or controllable. For example, although variable on a day-to-day basis, the rate of direct evaporation over the course of a year is relatively consistent. Similarly, management actions are also relatively predictable. Such actions include controlling the rate of transfer from underground to the surface storages as well as activating water treatment processes.

Inventories of mine-affected waters resultant from the capture of surface runoff however are less predictable. The majority of surface runoff is generated during the short and (generally) intense wet season that occurs between November and March of each year. Median annual rainfall for the site is around 500 mm but accumulations can vary significantly from year to year. The amount of surface water generated and the time at which it is generated is uncertain.

In order to manage the risk of spill, LLM maintains a probabilistic spill risk model that supports management of the mine-affected water inventory to ensure that the risk of spill is maintained below an acceptable criterion. The current LLM water balance model (WBM) is developed using the GoldSim model software and has recently been updated and calibrated. In early 2022, LLM engaged Engeny Pty Limited (Engeny) to undertake an assessment of the WMS under various post mining operations and closure scenarios. A report documenting this review is provided Appendix A.

3.2.1.3.1.1. Mining operations

The mine-affected water balance whilst mining operations is expected to be in minor surplus. Raw water used to cool mining equipment underground as well as bleed water from the paste backfill operation is a significant contributor to the overall balance. Passive evaporation from the surface storages (CDA, CDB and PPD) is the most significant water export along with dust suppression underground. Excess water inventories associated with high rainfall years can be effectively managed by enhanced evaporation (irrigation of the batters of the HPDP lined dams) or by operation of the reverse osmosis plant.

3.2.1.3.1.2. Post mining operations

Engeny concluded that following the cessation of mining operations, the mine-affected water balance will move into long-term deficit and the storage provided by CDA, CDB and the PPD will provide suitable containment for the 1 % AEP rainfall. Long-term water balance modelling also considered how much water will need to be disposed of at the time when the mine affected water dams are converted to ESC facilities. Engeny concluded that 99% of all rainfall scenarios will require that less than 50 ML of mine affected waters will need to be transferred underground. The 50 %ile inventory was estimated to be 2 ML.

3.2.1.4. Demolition Strategy

Decommissioning and rehabilitation of the LLM will require all plant, infrastructure and equipment to be de-energised, demolished and disposed of or dismantled and removed from the Site. Technical analysis of the activities required to do this is concerned with maximising the commercial value of the installed equipment at the point when it is no longer required. This will be achieved by a combination of salvaging assets for sale or redeployment and by minimising the costs associated with demolition and waste disposal. The analysis requires an appreciation of the specific economic conditions prevailing at the time of assessment.

To assist management of this aspect, LLM routinely engages subject matter specialists to define scope and assess costs associated with the full demolition of all fixed plant and infrastructure located at the Site. This work includes maintenance of a database that details discrete scopes of work and the tonnage of waste streams likely to be generated including scrap steel, concrete and other demolition wastes. The database is routinely reviewed every three years with the most recent review completed in 2020 (CMA, 2020).

The Demolition Strategy currently assumes that no plant and equipment will be salvaged for beneficial reuse.

3.2.1.5. Non-Mineral Waste Strategy

Decommissioning and rehabilitation of the Site will result in the generation of various non-mineral waste streams. These will include:

- Soils and sediments contaminated with heavy metals and salts,
- High density poly-ethylene (HDPE) sheeting and piping, and
- Demolition waste, including concrete and light and heavy gauge scrap steel.

Generation of non-mineral waste streams will be avoided as much as reasonably practicable in the lead up and during the post operations phase of the project. This will include run-down of inventories towards the end of operational activities, salvaging plant for beneficial reuse and recovery of saleable scrap.

Non-mineral waste streams such as HDPE and demolition waste generated during the decommissioning and rehabilitation program will be disposed of at the Site pursuant to the requirements of the EA. Permanent disposal strategies for some of the major non-mineral waste streams include:

- Off-site beneficial reuse and recycling: salvage items, scrap steel,
- Encapsulation within upper benches of the WRE: soils and subsoils contaminated with heavy metals and salts,
- Backfill of the upper 460 m of the mine decline: non-regulated wastes,
- Backfill of the upper sections of the mine ventilation shafts: non-regulated wastes,

- Off-site disposal: others.

Backfill of the upper section of the mine decline and ventilation shafts is a requirement to mitigate the long-term effects of subsidence and may present an opportunity for permanent disposal of demolition wastes.

3.2.2 Rehabilitation Objectives and Transition to Post Mining Land Uses

3.2.2.1. Rehabilitation Planning Domains and Objectives

Section 176 of the EP Act requires that mined land must be rehabilitated to a stable condition. Section 111A of the Act defines that land is in a stable condition when:

- The land is safe and structurally stable,
- There is no environmental harm being caused by anything on or in the land, and
- The land can sustain the post mining land use.

These three conditions are the general rehabilitation goals for all lands disturbed by mining in Queensland. These high-level goals have informed the location-specific set of Rehabilitation Objectives presented in Table 7.

Table 7: Rehabilitation Objectives

Rehabilitation Objective	Element	Design Intention	Measure
Physically Stable	Slope Stability	ANCOLD Guideline	Numerical analysis (Stability analysis)
	Consolidation Settlement and Subsidence	- ANCOLD - No ponding of water - Surface subsidence does not exceed 500 mm	Direct measurement (Survey)
	Erosion	Long term containment of waste	- Numerical Analysis (Landform evolution modelling) - Direct observation (Photography, survey)
Chemically Stable	Water Flux Through Waste	Oxidation products (salt, acid) remain contained within the waste mass	- Numerical Analysis (Soil moisture modelling) - Direct measurement (Arrayed soil moisture and matric suction sensors)
	Capillary Rise	- Oxidation products (salt, acid) remain contained - Waste not subject to cyclic wetting and drying	- Numerical Analysis (Soil moisture modelling) - Direct observation (Photography)
	Receiving Environment Surface Waters and Stream Sediment	Compliance with Conditions of EA (Schedule C)	- Direct measurement (surface water quality and sediment quality) - Receiving Environment Monitoring Program
	Local Groundwater	- No deleterious impacts to groundwater - Compliance with Conditions of EA (Schedule C)	Direct measurement (Groundwater quality)
Supports a Viable Vegetation Community	Viable Vegetation	- Suitable diversity - Capable of reproduction - Soil development	Direct and Indirect measurement (Ecosystem Function Analysis)
	Absence of Declared Weeds	Legal obligation	Direct observation (Photography)
	Resilience to Stressors	Resilience through drought / fire / flood / overgrazing	Direct and Indirect measurement (Ecosystem Function Analysis)

3.2.3 Assessment of Post Mining Land Use Options

Mining disturbance at the Site has been restricted to a relatively minor 140 Ha located in the south-eastern sector of ML 5568. These disturbances have either occurred on the siliceous rocky hills that comprise the steep ridge hosting the Lady Loretta orebody, or the lowland plain found immediately to the east.

As discussed in Section 3.1.3, the pre-mining land uses at the Site were effectively pre-determined by terrain type and vegetation. The lowland plains which include the open woodland vegetation communities (Community 2) are suitable for grazing livestock at low intensity. The siliceous ridges that support the closed woodland communities (Communities 1 and 4) are not suited to grazing livestock and provide other services related to Native Vegetation and Native Habitat. PMLUs for the Site were first nominated in the EMOS (Noranda Pacific, 2000) and later in the PMLUP (Noranda Pacific, 2018). The PMLUs proposed were Native Habitat, Low Intensity Cattle Grazing, and a combination of the two where domains (rehabilitation areas) intersect both terrain types.

Rehabilitation planning including stakeholder consultation completed after the preparation the PMLUP identified some minor inconsistencies that have been amended. A PMLU of Native Habitat was previously proposed for the ROM, Paste Plant and Batch Plant area. Rehabilitation of this area however will result in a final landform and terrain type that has been specifically designed to encourage livestock. As a result, the PMLU proposed for the ROM, Paste Plant and Batch Plant has been revised to Low Intensity Cattle Grazing. Rehabilitation of the regulated dams will include reprofiling of the land and establishment of vegetation. Regulated dams CDA, CDB and PPD and associated sediment dams are all located on the lowland plain. As a result, the PMLU proposed for these facilities has been revised to Low Intensity Cattle Grazing.

It should be noted, the proposed PMLUs are consistent with the potential end land uses as described under an approved LOD being the PMLUP, with the exception of the ROM, Paste Plant and Batch Plant and various Regulated Dams.

The Decommissioning and Rehabilitation program has been designed to deliver a final landform that supports PMLUs that are consistent with the pre-mining land uses. Disturbances located on the low slope alluvial plains will be rehabilitated to support a PMLU of Low Intensity Cattle Grazing. Disturbances on the steep ridge terrain will be rehabilitated to support a PMLU of Native Habitat.

The rehabilitation areas (RAs) adopted for the LLM and their proposed PMLU are presented in Table 8 and Figure 11.

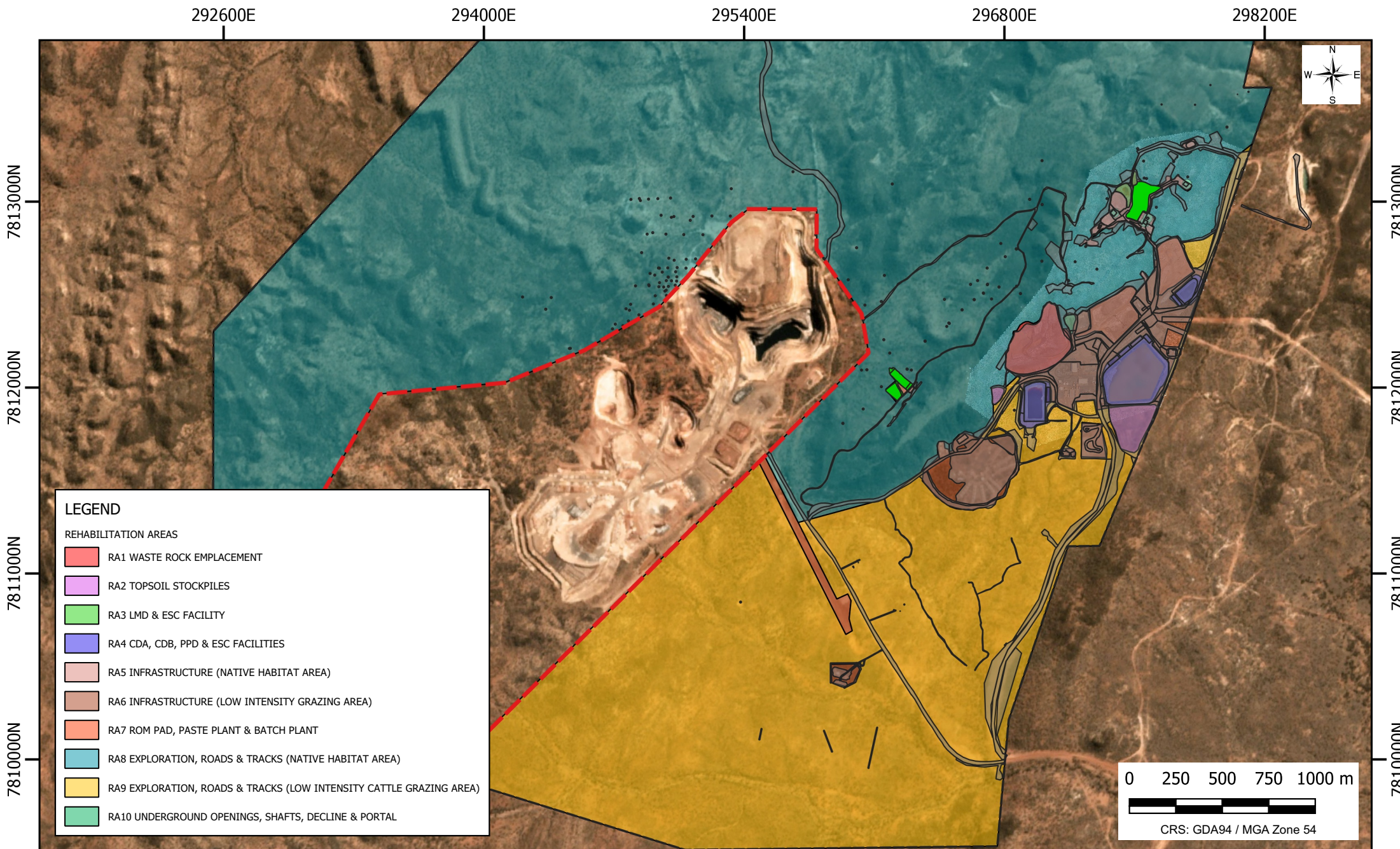
Table 8: Rehabilitation Areas and Proposed PMLU

Rehabilitation Planning Areas	Area (Ha)		Pre-Mining Land Use	Post-Mining Land Use
	Disturbance *	To be Rehabilitated		
RA1 Waste Rock Emplacement	11	11	Native Habitat	Native Habitat
RA2 Topsoil Stockpiles	6	6	Low Intensity Cattle Grazing	Low Intensity Cattle Grazing
RA3 LMD and ESC Facility	1	1	Native Habitat	Native Habitat
RA4 CDA, CDB, PPD and ESC Facilities	14	14	Low Intensity Cattle Grazing	Low Intensity Cattle Grazing
RA5 Infrastructure (Native Habitat Area)	12	9**	Native Habitat	Native Habitat
RA6 Infrastructure (Low Intensity Grazing Area)	44	44	Low Intensity Cattle Grazing	Low Intensity Cattle Grazing
RA7 ROM Pad, Paste Plant & Batch Plant	12	12	Low Intensity Cattle Grazing	Low Intensity Cattle Grazing
RA8 Exploration, Roads and Tracks (Native Habitat Area)	21	20***	Native Habitat	Native Habitat
RA9 Exploration, Roads and Tracks (Low Intensity Cattle Grazing Area)	39	39	Low Intensity Cattle Grazing	Low Intensity Cattle Grazing
RA10 Underground Openings, Shafts, Decline and Portal	1	1	Native Habitat	Native Habitat

*Disturbance – This includes actual disturbance and additional disturbance required to support the rehabilitation activities and final landform design works.

** – 3ha has been rehabilitated.

*** – 1ha has been rehabilitated



3.2.3.1. Availability of Areas for Progressive Rehabilitation

Most of the RAs include infrastructure that is critical to the underground mining operation and will be required to remain in an operational condition until End of Commercial Proposition is called. As a result, the land currently available for progressive rehabilitation at the Site is limited noting opportunities to undertake progressive rehabilitation on the site have already been implemented as detailed in section 2.2.7. Key drivers and constraints for each of the RAs is presented in Table 9.

Table 9: Availability for Progressive Rehabilitation

Relevant Activity	LoA Requirements *	Progressive Rehabilitation Availability
RA1 Waste Rock Emplacement		
WRE	Present - 2033	Available for rehabilitation once borrow material sources are available in the mine infrastructure footprint. Borrow sources in undisturbed locations are not currently available, therefore capping of the WRE is not available until site demolition works and contaminated land stripping works have ceased in 2033 - 2034 in the mine development area. Careful planning will be required to ensure demolition scheduling works takes place to ensure the availability of suitable borrow material by 2033. Ongoing reshaping works for the final WRE closure design will continue during operations.
RA2 Topsoil Stockpiles		
Topsoil Stockpile (near WRD)	Present - 2035	Available for rehabilitation following removal of the topsoil stockpile for rehabilitation. It is estimated to take three years to complete the majority of rehabilitation works on site.
Topsoil Stockpile (near CDA)	Present - 2035	Available for rehabilitation following removal of the topsoil stockpile for rehabilitation. It is estimated to take three years to complete the majority of rehabilitation works on site.
RA3 Leachate Management Dam and Erosion and Sediment Control Facility (Low Intensity Cattle Grazing)		
Leachate Management Dam	Present - 2025	Due to progressive rehabilitation works in the LMD catchment, including removal of the LMD Stockpile and other mineralised material, the LMD can be decommissioned prior to the other regulated dams. A timeframe of three years has been proposed to allow completion of a decommissioning plan, including on-going sampling.
Erosion and Sediment Control Facility	2025 - 2045	The ESC facility will be required for water management purposes to manage sediment runoff. The ESC facility will be available for decommissioning following the completion of rehabilitation works in the upper catchment (proposed for completion in 2035) and when the vegetation established on the disturbance areas in the upper catchment is suitably mature. A conservative timeframe has been adopted to account for uncertainty.
RA4 CDA, CDB, PPD, Sediment Dams and Erosion and Sediment Control Facility		
CDA, CDB and PPD and associated Sediment Dams	Present - 2044	Required for ongoing water management of mine-affected water inventory. Decommissioning of the regulated dams cannot commence until underground dewatering ceases, all inventories of mine-affected waters have been removed and rehabilitation of disturbed areas has been completed.
Erosion and Sediment Control Facility	2044 - 2052	The ESC facilities will be required for water management purposes to manage sediment runoff. The ESC facility will be available for decommissioning following the completion of rehabilitation works in the upper catchment (proposed for completion in 2035) and vegetation establishment is considered suitably mature.

Relevant Activity	LoA Requirements *	Progressive Rehabilitation Availability
RA5 Infrastructure (Native Habitat)		
Former LMD Stockpile	Present - 2025	The area under the former LMD Stockpile will be available for surface preparation and revegetation works.
Infrastructure and Laydown areas	Present - 2032	Available for rehabilitation once the end of commercial proposition is called in 2032. Infrastructure is essential for the ongoing operation of the mine site.
RA6 Infrastructure (Low Intensity Cattle Grazing)		
Infrastructure (Camp, Managers Houses, STP, WTPs, Power Station and Transmission Station)	Present - 2039	Available for rehabilitation following completion of the three-year active rehabilitation phase and additional allowance of services to remain for ongoing monitoring and maintenance activities, including mine dewatering and continued water treatment and services.
All other Infrastructure and Laydown areas	Present - 2032	Available for rehabilitation once the end of commercial proposition is called in 2032. Infrastructure is essential for the ongoing operation of the mine site.
Areas adjacent to the dams	Present - 2044	The area adjacent to the regulated dams is not available for rehabilitation until the dams are decommissioned (in 2044).
RA7 ROM Pad, Paste Plant and Batch Plant		
ROM Pad, Paste Plant and Batch Plant	Present - 2032	Available for rehabilitation once the end of commercial proposition is called in 2032. Infrastructure is essential for the ongoing operation of the mine site.
RA8 Exploration, Roads and Tracks (Native Habitat)		
Exploration, Roads, Tracks and Haul Road	Present – 2032 Present - 2060	The majority of roads and tracks are required to ensure access for ongoing monitoring and maintenance works and future exploration activities to continue. Opportunities to rehabilitate certain roads and tracks have been identified.
RA9 Exploration, Roads, Tracks and Haul Road (Low Intensity Cattle Grazing)		
Exploration, Roads, Tracks and Haul Road	Present – 2032-2044 Present - 2060	The majority of roads and tracks are required to ensure access for ongoing monitoring and maintenance works and future exploration activities to continue. Opportunities to rehabilitate certain roads and tracks have been identified.
RA10 Underground Openings – Shafts, decline, portal		
Four Shafts, Decline and Portal	Present - 2035	The four shafts and decline will be available for backfilling in 2032 when the end of commercial proposition is called and contaminated soils are removed from the ROM Pad and site demolition works are complete. The sealed concrete bulkhead for the decline and backfill of boxcut will be available for installation once the regulated dams have been decommissioned in 2044 to allow further demolition waste disposal underground.

3.3. NON-USE MANAGEMENT AREAS

For the purposes of this PRCP, no Non Use Management Areas (NUMAs) are proposed for the Site.

3.4. VOIDS IN FLOODPLAINS

In 2020, LLM commissioned a suitably qualified and experienced water engineer to review the risks presented by a failure of any of the regulated dams at the Site. WRM Water and Environment Pty Limited prepared a failure impact assessment which included consideration of the credible modes of failure under both sunny day and flooded conditions.

The failure impact assessment considered the incremental risk afforded by a dam breach under the flooded condition. This included determination of the most critical flood under the 0.5 % Annual Exceedance Probability (AEP) for the Desert Creek catchment. The results of flood inundation mapping under the 0.5 % AEP flood in addition to a dam breach at CDA are provided in Appendix B.

WRM was also commissioned to remodel the inundation zones for Desert Creek under the probable maximum precipitation scenario or 0.1 % AEP for the proposed final landform closure design. Their report was finalised in 2022 and is presented as Appendix B.

Inundation mapping for the 0.1 % AEP rainfall event is provided in Figure 12. Results of the modelling clearly indicate that:

- The Site will be free draining, and
- Under the 0.1 % AEP flood, the major facilities that comprise LLM are above the inundation zone.

Consequently, the risk of floodwaters affecting future rehabilitation areas or inundating final voids is not material.

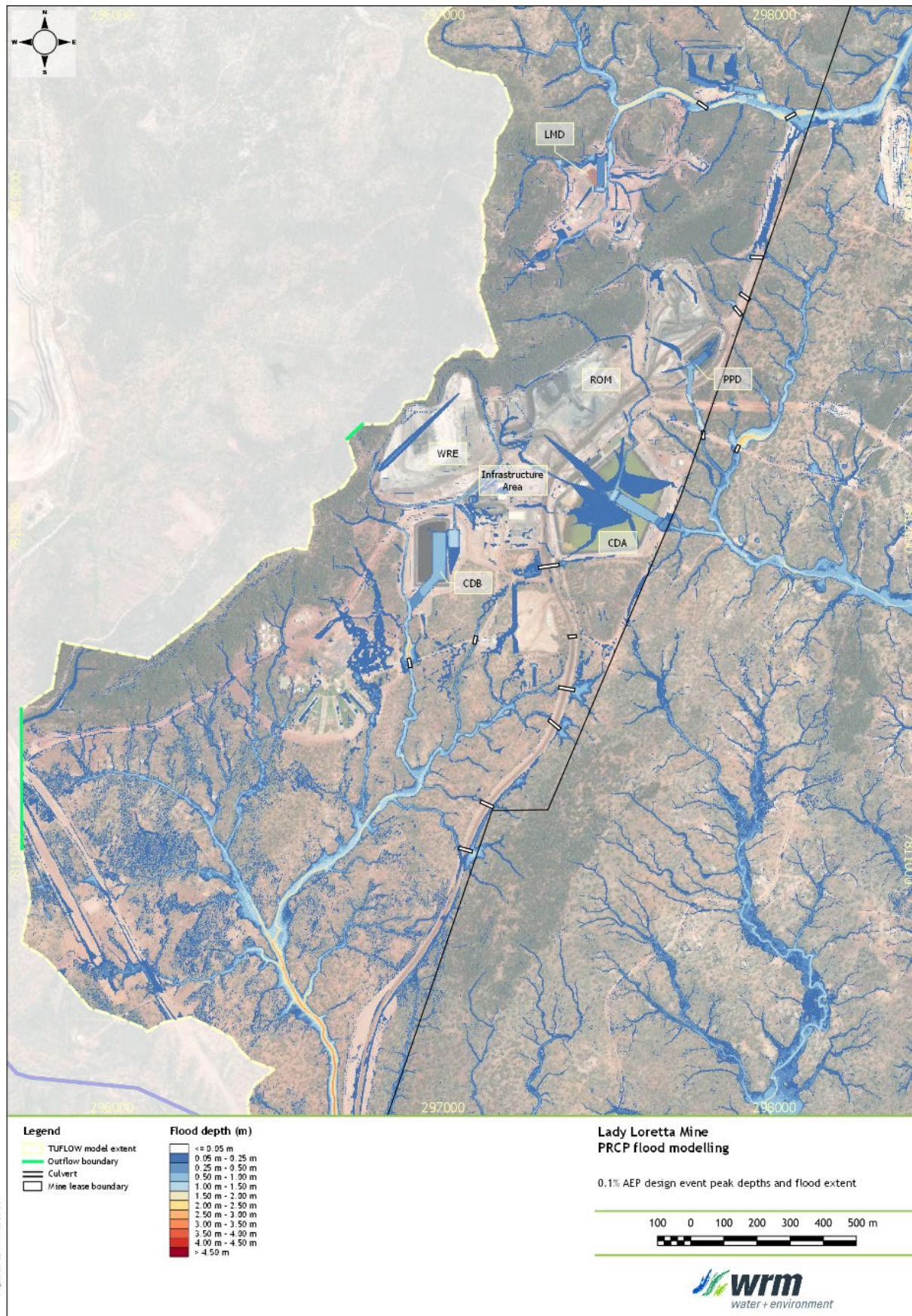


Figure 12: Flood Inundation Map - 0.1 % AEP Rainfall

3.5. STAKEHOLDER CONSULTATION

3.5.1 Overview

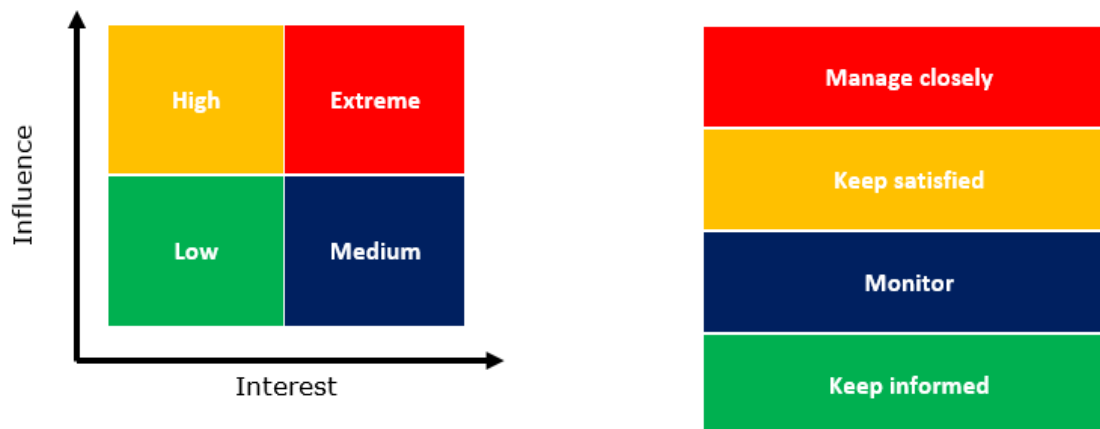
These relevant stakeholder groups to the development, operation and rehabilitation of the LLM are presented in Table 10.

Table 10: LLM Stakeholders

LLM Workforce - Glencore employees - Redpath employees - Other contractors - Unions	Pastoral Landholders - Koolamara - Skinny Dip Outstation - Thorntonia - Gundaria - Yelvertoft - Calton Hills	Traditional Owners - Kalkadoon - Indjilandji - Myuma
Local and State Governments - Mount Isa City Council - Department of Environment and Science - Department of Resources - Department of State Development, Infrastructure, Local Government and Planning - Department of Transport and Main Roads - Department of Agriculture and Fisheries	Federal Government - Department of Industry, Science, Energy and Resources - Department of Agriculture, Water and the Environment	Non-Government Organisations - Queensland Resources Council - Minerals Council of Australia - Industry Queensland - Commerce North Queensland - North Queensland Conservation Council - Southern Gulf Catchments - Georgina Diamantina Catchment Committee - News media
Neighbouring Mines - Lady Annie Copper - Paradise South Phosphate - Capricorn Copper	Communities - Mount Isa - Cloncurry - Townsville - Member for Kennedy (Commonwealth) - Member for Traeger (Queensland)	Utilities, Services and Corporations - Ergon Energy - Telstra - Logistics suppliers - Fuel suppliers - Airlines

LLM recognises and respects the rights, concerns and aspirations of all stakeholders and seeks to engage with them in a fair and transparent manner in planning and executing closure of the LLM. Glencore recognises that decommissioning and rehabilitation of the LLM will have a different impact on different groups. To that end, Glencore operates pursuant to a LLM Stakeholder Engagement and Communication Strategy that includes a framework to assess the relative importance of each stakeholder group.

The assessment framework is presented in Plate 1.

Plate 1: LLM Stakeholder Assessment Framework

The strategy is aligned with the International Association for Public Participation (IAP2) public participation spectrum which is a recognised framework. The IAP2 Public Participation Spectrum (Inform, Consult, Involve, Collaborate and Empower) was applied to determine the appropriate engagement activity, based on the priority rating of each stakeholder group, as shown in Plate 2.

Plate 2: IAP2 Public Participation Spectrum

IAP2 Public Participation Spectrum

	Inform	Consult	Involve	Collaborate	Empower
Goal	To provide stakeholders with information to assist them in understanding the problems, alternatives, opportunities and solutions	To obtain feedback on analysis, alternative and or decisions	To work directly with stakeholders throughout the process to ensure public concerns are consistently understood and considered	To partner with stakeholder in each aspect of the decision including the development of alternatives and the identification of the preferred solution	To place final decision-making in the hands of stakeholders
Promise	"We will keep you informed."	"We will keep you informed, listen to and acknowledge your concerns aspirations and provide feedback on how your input influenced the decision."	"We will work with you to ensure your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision."	"We will look to you for direct advice and innovation in formulating solutions, and incorporate your advice and recommendations into the decision to the maximum extent possible."	"We will implement what you decide."
Risk Rating	Low	Medium	High	Extreme	Not applicable to our activities at this time

The stakeholder groups identified as “Collaborate” or those that will be directly engaged in the development and implementation of this PRCP are:

- LLM workforce,
- Traditional owners – Kalkadoon, Indjilandji and Myuma peoples,
- Neighbouring landholders,
- Local government – MICC, and
- State government – Queensland.

Affected stakeholders are engaged in rehabilitation planning and performance, LoA, regulatory compliance and other relevant topics as a matter of course. Consultation and discussion regarding decommissioning and rehabilitation plans and works occur within a broader context.

A key stakeholder engagement event that occurs annually is the Neighbours’ Day which is held on-site at LLM. All key stakeholders (including landholders) and other community stakeholders are invited. Topics of discussion include LoA planning, closure planning and the PRCP, the proposed PMLUs, progressive rehabilitation and beneficial reuse opportunities. In addition to the Neighbours Day, broader Community Information Sessions are convened in Mount Isa by Glencore’s Queensland Metals on a six-monthly basis. These take a town-hall style but include opportunity for question and answers. LoA, regulatory compliance and mine closure are regular topics. The stakeholders who attend often include: the Mount Isa City Council, Mount Isa Community, local industry leaders, workforce and contractors/suppliers. Ongoing stakeholder engagement will occur, including further collaboration (face-to-face meetings) with neighbouring landowners to discuss potential transfer of facilities.

A key element of the Stakeholder Strategy is that engagements with stakeholders affected by the development, operation and rehabilitation of the LLM are registered. Glencore maintains a Stakeholder Engagement Register which includes past and future consultations. The following data is recorded in the Stakeholder Engagement Register:

- Date of engagement,
- Topic/event – includes type of interaction,
- Stakeholder details,
- Glencore representatives involved,
- Details of the engagement – list of stakeholders, information provided, record of issues / questions raised by stakeholders, discussions and outcomes, and
- Follow up action – to address how issues have been considered, who’s responsible and commitment dates, where applicable.

3.5.2 Development of this PRCP

Development of the LLM has included extensive engagement and consultation with key stakeholders. This engagement commenced prior to the grant of the EA and will continue until at least when the EA is surrendered. Key episodes in the development of the closure strategy and in the development of this PRCP are described in Table 11.

Table 11: Stakeholder Consultation Register

Date	Consultation Type	Stakeholders Engaged	Information Provided or Sought	Decisions/Outcomes	Commitments Made
May 2022	Community Information Session	Mount Isa Community Mount Isa City Council Contractors/Suppliers MIM Workforce Media Local industry leaders	Operational update on mine production and Life of Asset. Progressive rehabilitation and closure planning works discussed including progressive rehabilitation of the LLM waste disposal trench. Expected closure and post-closure periods, including discussion on key activities and milestones within each period. ABC Interview with Queensland Metals and Zinc Assets Australia Chief Operating Officer (COO) occurred following the Community Information Session.	No follow up actions	Continuation of community information session on LLM
April 2022	Kalkadoon Native Title Corporation face to face meeting	Board Members of Kalkadoon Native Title Corporation	Indigenous land use agreements (ILUA). Queensland Metals business updates, with LLM business continuing as normal at LLM and Life of Asset on track.	No action	Ongoing engagements on ILUA and other relevant topics
October 2021	Site Visit to LLM	Qld Fire and Emergency Services (QFES) officers President of Commerce North West Treasurer of Commerce North West Regional Development Officer of Mount Isa to Townsville Economic Development Zone (MITEZ) Executive Officer of MITEZ Electorate Officer to Hon Bob Katter MP, Federal Member for Kennedy	Presentation on site history, operations and production, site domains and disturbance footprints, rehabilitation and key closure studies, including completed and proposed progressive rehabilitation works. Post Mine Land Uses, PRCP obligations and legislative process, Life of Asset and community support programs discussed. Key closure planning programs mentioned including: final landform designs, WRE cover system, borrow material investigations, infrastructure demolition plans, rehabilitation methodology, long term water management and closure criteria. Questions were raised regarding changes to the legislative process around rehabilitation. Clarification was provided; LLM rehabilitation and closure commitments will change should legislation change. Questions were raised regarding workforce transition once mine comes to end of its life. Many Departments, in particular environment staff, will be needed until rehabilitation process is complete. Workforce transition opportunities will be available once mine comes to an end, through rotation across other Glencore operations. Surface and underground tour provided.	No follow up actions identified	Compliance with regulatory mechanisms for closure. Progressive rehabilitation efforts continue. PMLUs of grazing and native habitat remain unchanged.

Date	Consultation Type	Stakeholders Engaged	Information Provided or Sought	Decisions/Outcomes	Commitments Made
October 2021	Community Information Session	33 attendees made up of key stakeholders and community members	Overview of current LLM Life of Asset and progressive rehabilitation and closure planning process. Discussion topics included demand for metals, major projects, mining rosters, HSEC programs and school pathway programs. ABC Interview with Queensland Metals and Zinc Assets Australia Chief Operating Officer (COO) occurred following the Community Information Session.	No follow up actions	Continuation of community information session on LLM
December 2020	Newsletter	All Stakeholders	Fact Sheet supplied detailing PRPC obligations for mining companies and the process for LLM.	Nil	Compliance with PRCP obligations.
October 2020	Site Visit to LLM	20 Stakeholders in attendance: QFES Police-Citizens Youth Club Mount Isa Commerce North West Mount Isa to Townsville Economic Development Zone (MITEZ) Department of State Development Tourism and Innovation Federal Member for Kennedy office Koolamara Station May Downs Station Austral Resources (Lady Annie Mine).	Presentation including site history, Life of Asset, life of asset production, closure planning activities, and key milestone dates, progressive rehabilitation undertaken on site (LMD remediation works, exploration borehole program, trench works and rehabilitation material program update), proposed post mining land uses (of grazing and native habitat), Queensland Government reforms and PRCP requirements discussed including closure goals for LLM. Surface and underground tour provided.	Positive feedback received on the day of the event. No issues or enquiries requiring action/feedback.	Compliance with regulatory mechanisms for closure. Progressive rehabilitation efforts. PMLUs of grazing and native habitat.

3.5.3 Stakeholder Engagement Plan

Implementation of this PRCP and execution of the Decommissioning and Rehabilitation program will occur over several years. Evolution of the plan is inevitable, so it is essential that stakeholders remain engaged and are relevantly included in any future modifications or amendments. Specific changes are difficult to predict but are likely to include LoA extension, technical understanding of the risks and opportunities presented at the Site, as well as technological improvement in their control. LLM will continue to engage with key stakeholders with a view to maximising opportunities and minimising losses associated with the decommissioning and rehabilitation of the LLM. The current plan detailing the specific objectives and approaches of this consultation is provided in Table 12. The future plan for stakeholder consultation allows stakeholders the opportunity to comment and provide feedback, a fundamental part to the success of the stakeholder consultation process. This plan will adapt as new opportunities and/or challenges present themselves, as appropriate.

Table 12: Stakeholder Engagement Plan

IAP2 Public Participation Spectrum Category	Engagement Type	Engagement Frequency	Stakeholders	Information Topic	Objective and Information Released
Inform (Keep informed)	Resourceful e-newsletter (Queensland Metals)	Monthly (monthly publication with LLM content included as appropriate)	All	Life of Asset	- Education piece on lifecycle of a mine, detailing activities required under Life of Asset plan and framing next steps as a natural progression in responsible mining. - Opportunistic Life of Asset messaging included in operational stories, where appropriate. - Increase reach by incorporating information in social media posts and direct linking relevant stories from e-newsletter in Queensland Metals Facebook posts.
				Operational performance / regulatory compliance	Promote major operational milestones, including production and safety achievements and any improvement initiatives and include Life of Asset messaging.
				Rehabilitation and Closure Activities	- Include updates on progressive rehabilitation underway across LLM operation. - Profile best-practice rehabilitation success outcomes to build community trust.
	Intranet	As required	Workforce	All Topics	Continue to use intranet to support LLM internal engagement campaigns and reinforce messaging in line with key milestones and activities.
	COO/General Manager/Manager briefings	Quarterly	Workforce	Life of Asset / Rehabilitation and Closure / Operational Performance / Regulatory compliance	- Written reporting and/or face-to-face engagement where practicable to reflect on performance, and clarify goals, align expectations and identify upcoming actions for leaders. - Incorporate video upload to intranet for key talks, as appropriate.
	Social Media	Ongoing	All	Life of Asset / Rehabilitation and Closure Activities / Operational Performance / Regulatory Compliance / Others, as required	- Contribute to fortnightly social media plan developed by Communications and Engagement and Corporate Affairs - Incorporate social media into regular external communication planning where appropriate. - Leverage relationships with stakeholders to promote news on their social media platforms (e.g. QRC, city councils, partner organisations, etc).
	Glencore website	Ongoing	All	Life of Asset / Rehabilitation and Closure Activities / Operational Performance / Regulatory Compliance / Others, as required	Provide information on Life of Mine discussions, decisions, milestones and closure timeframes as well as an update on rehabilitation plans and activities including those relevant to the PRCP.

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IAP2 Public Participation Spectrum Category	Engagement Type	Engagement Frequency	Stakeholders	Information Topic	Objective and Information Released
Monitor	Contractors/Suppliers Forum	One-year before closure	Contractors/suppliers	Life of Asset	- Host forum in Mount Isa to outline Lady Loretta Mine Closure timeframes. - Ensure key suppliers informed and engaged through transition.
	Pre-deployment meetings/Toolbox talks	Ongoing	Mount Isa Mines workforce	Life of Asset / Rehabilitation and Closure / Operational Performance / Regulatory Compliance / Others, as required	Provide information on Life of Mine discussions, decisions, milestones and closure timeframes as well as an update on rehabilitation plans and activities.
Involve (Keep satisfied)	Site visit	Annually	Mount Isa Community Leaders Neighbouring Landowners Neighbouring Mines The occasional state or federal representative as requested or required	Life of Asset / Rehabilitation and Closure Activities / Operational Performance / Regulatory Compliance / Others, as required Potential transfer of LLM facilities / infrastructure to Neighbouring Landowners	- Host a Neighbours Day at Lady Loretta Mine to discuss closure timeframes and plans, Post Mine Land Uses, progressive rehabilitation activities, final landform designs and PRCP requirements. - Stakeholder awareness of site activities and how mining impacts are minimised during operations and closure. - Allowance for discussion on topics relevant to stakeholders (risk to livestock, dust impacts, availability of site infrastructure - i.e. roads, etc.). - Requests made or invitations made to State or Federal representatives to visit the operations to achieve a greater understanding of the closure timeframes and plans.
	Water Licence Extraction Permit	One-year before closure	Neighbouring Landowner – Thornton Limestone Borefield	Regulatory Compliance	Adherence to Water Licence permits extraction from Thornton Limestone Borefield. Licence specifies that Noranda must enter into arrangements with the bore owner one-year prior to closure.
	Community Information Sessions	Bi-Annually	Mount Isa Community Mount Isa Council Contractors/Suppliers MIM Workforce Media Local industry leaders	Life of Asset / Rehabilitation and Closure / Operational Performance / Regulatory Compliance / Others, as required	Content of the information sessions to be simple and provide an operational update and information relating to operational performance and other topics, as required.
	Stakeholder feedback and complaints	Ongoing	ALL	Life of Asset / Rehabilitation and Closure / Operational Performance / Regulatory Compliance / Others, as required	- Maintain grievance mechanisms in line with Glencore Corporate Practice, including 24-hour Community Feedback Hotlines across all operational communities. - Engage with internal stakeholders on process for addressing concerns raised by community members and stakeholders.

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IAP2 Public Participation Spectrum Category	Engagement Type	Engagement Frequency	Stakeholders	Information Topic	Objective and Information Released
	Media Engagement	As required	Media/All	Life of Asset / Rehabilitation and Closure / Operational Performance / Regulatory Compliance / Others, as required	- Adopt a more proactive approach, with early background briefings for key challenges/changes. - Proactive media releases detailing progress of closure and rehabilitation plans.
Collaborate (Manage closely)	Queensland Department Briefings	Ongoing	Queensland Government departments	Life of Asset / Rehabilitation and Closure Activities / Operational Performance / Regulatory Compliance / Others, as required	Face-to-face engagement where possible to reflect on performance, and clarify goals, align expectations and identify actions for the month ahead.
	Face-to-face meetings	Ongoing	Representatives of: Mount Isa Local Council State Government Federal Government Neighbouring Landowners Government Owned Corporations Glencore Corporate Office	Life of Asset / Rehabilitation and Closure Activities / Operational Performance / Regulatory Compliance / Others, as required	- Business leaders and Corporate Affairs Team is accountable for Glencore's State and Federal Government Engagement activities relating to its regional operations. - Communication and Engagement Team accountable for all engagement with our North Queensland operations' local governments and members and keeping Corporate Affairs up to date in relation to engagement activities with local governments and local members. - Environment Team accountable for engagement with State and Federal Government environmental agencies, on operational and regulatory performance, EA Amendments and rehabilitation and closure activities, as required. - Communication and Engagement Team, Lady Loretta Mine Manager and Environment Team work closely to ensure meetings with landowners take place. - Communication and Engagement Team to be kept informed and involved wherever possible in State and Federal government meetings relating to regional operations, particularly in relation to issues of local impact/importance.
	Face to face meetings with Indigenous groups	Ongoing	Indigenous groups	Life of Asset / Rehabilitation and Closure / Operational Performance / Regulatory Compliance / Others, as required	- Face-to-face engagement with the Kalkadoon People where practicable to reflect on quarterly performance, and clarify goals, align expectations and identify actions for the month ahead. - Face to face engagement to discuss LLM rehabilitation and closure activities and promote opportunities for involvement. - Allowance for discussion on topics of relevance to indigenous groups.

IAP2 Public Participation Spectrum Category	Engagement Type	Engagement Frequency	Stakeholders	Information Topic	Objective and Information Released
	Stakeholder closure planning workshops / face-to-face meetings	As required	Neighbouring Landowners Mount Isa City Council Southern Gulf NRM Ltd	Life of Asset / Rehabilitation and Closure Activities / Operational Performance / Regulatory Compliance / Others, as required	- Stakeholder awareness of site activities and mining impacts are minimised during operations and closure. - Opportunities for beneficial reuse identified and assessed with stakeholders. - Face-to-face meetings with landholders to discuss closure timeframes and plans, PMLUs, progressive rehabilitation activities, final landform designs and PRCP requirements. - Allowance for discussion on topics relevant to stakeholders (risk to livestock, dust impacts, availability of site infrastructure - i.e. roads, etc.).

3.6. REHABILITATION AND MANAGEMENT METHODOLOGY

3.6.1 General Practices

Full implementation of the Decommissioning and Rehabilitation program will result in a post mining final landform that broadly reflects the pre-mining condition. Mining development at the Site has not included a Tailings Storage Facility (TSF). The most significant change is the development of the Waste Rock Emplacement (WRE). Minor changes will also include the vicinity of the ROM Pad and the regulated dams (CDA, CDB and PPD). These are discussed in the following sections.

The post mining final landform for the majority of the disturbance area will see a return to the pre-disturbance condition. Following the removal of the site fixed plant and infrastructure, any voids will be sealed and backfilled before being reprofiled to coincide with the undisturbed areas at slopes approximating the pre-mining condition. These slopes will generally not exceed 4 H:1 V (14°) and are generally flatter than 10 H:1 V (5.5°). Following reprofiling, disturbed areas will be deep ripped along contour and revegetated with species consistent with the proposed PMLU.

A snapshot of the landform and surface water drainage features of the Site in 2021 is presented in Figure 13. Catchment A drains from the northern portion of the Site to Magazine Creek via the SW01 monitoring station. Catchments B and C drain to Desert Creek via SW03 and SW07 respectively. A snapshot of the landform following conversion of the mine affected water dams to ESC facilities is presented in Figure 14 and the proposed post mining final landform is presented in Figure 15.

A three-dimensional representation of the Site following implementation of the Decommissioning and Rehabilitation program is attached in Appendix C.

295800E

296400E

297000E

297600E

298200E

7813800N

7813200N

7812600N

7812000N

7811400N

7810800N

7810200N

7813800N

7813200N

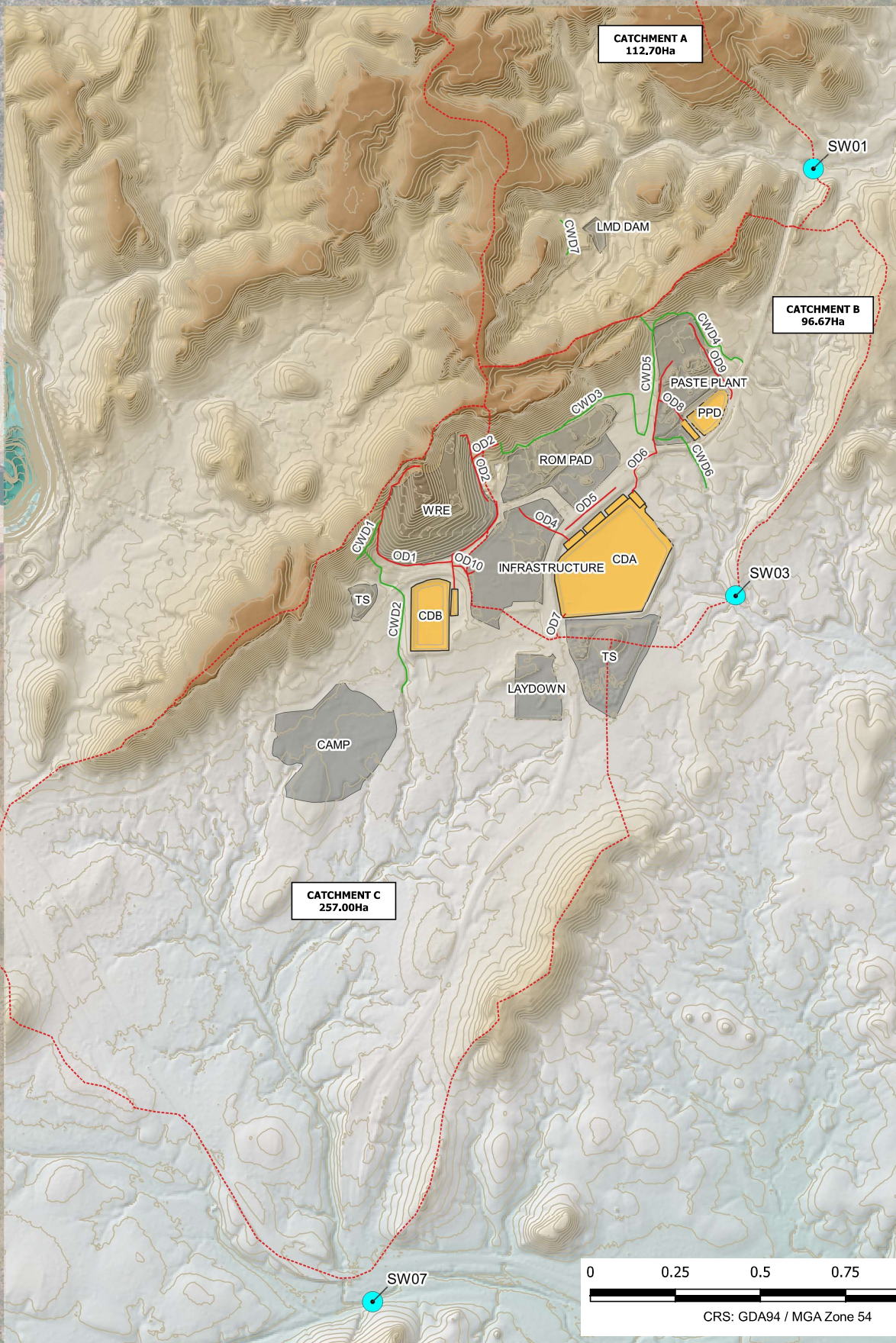
7812600N

7812000N

7811400N

7810800N

7810200N



LEGEND

WM POINTS

CURRENT MINING CATCHMENT

PHASE 1 INFRASTRUCTURE

PHASE 1 DAMS

PHASE 1 CLEAN WATER DRAINS

PHASE 1 DIRTY WATER DRAINS

PHASE 1 CONTOURS (2.5m)

LADY LORETTA MINE PROJECT

CURRENT LANDFORM

FIGURE 012

112009-04

DATE: 2022-05-27



295800E

296400E

297000E

297600E

298200E

7813800N

7813200N

7812600N

7812000N

7811400N

7810800N

7810200N

7813800N

7813200N

7812600N

7812000N

7811400N

7810800N

7810200N



CATCHMENT A
112.70Ha

CATCHMENT B
96.67Ha

CATCHMENT C
257.00Ha

WRE

ROM PAD

ESC2

ESC3

ESC4

ESC5

SW03

SW01

SW07



LEGEND

- | | |
|-----------------------|-------------------------------|
| WM POINTS | WRE |
| POST MINING CATCHMENT | PHASE 2 CLEAN WATER DRAINS |
| ESC Basin | PHASE 2 SEDIMENT LADEN DRAINS |
| ROM PAD | PHASE 2 CONTOURS (2.5m) |

LADY LORETTA MINE PROJECT

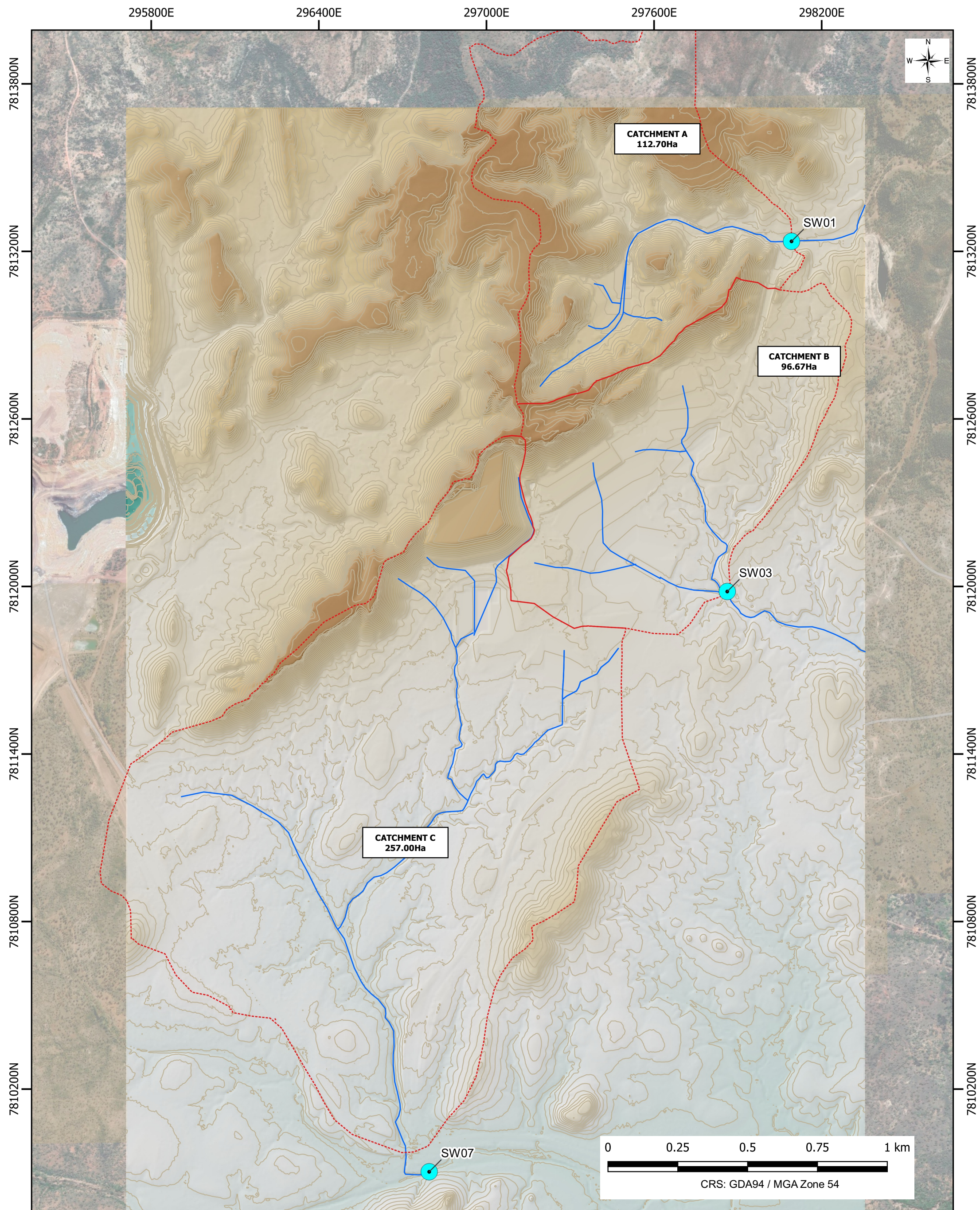
TRANSITIONAL LANDFORM
- END OF MINE AFFECTED
WATER MANAGEMENT

FIGURE 013

112009-04

DATE: 2022-05-27





LEGEND

- WM POINTS
- CURRENT MINING CATCHMENT
- PHASE 3 CONTOUR (2.5m)
- PHASE 3 DRAINS

LADY LORETTA MINE PROJECT

POST MINING
FINAL LANDFORM

FIGURE 014

112009-04

DATE: 2022-05-27



3.6.1.1. Soil and Capping Material Assessment

Decommissioning and rehabilitation of the Site will require a suitable inventory of borrow materials to be available for various works including capping, revegetation, backfill and water management. LLM engaged RGS Environmental Consultants Pty Ltd to analyse the borrow material requirements for the Decommissioning and Rehabilitation program

Borrow material requirements will include:

- Topsoil and sub-soil,
- General backfill,
- Rock mulch, and
- Rock armour.

RGS Environmental Consultants Pty Ltd was engaged to identify, characterise and quantify suitable inventories of borrow materials to support the Decommissioning and Rehabilitation program. Site based investigations were completed in 2020 and 2021. The material balance calculations verify sufficient volume of rehabilitation materials can be sourced at the Site¹. The borrow material requirements (conservative upper target volumes) are presented in Table 13.

Table 13: Borrow Material Requirements

Borrow Type	Conservative Upper Target Volume (loose m ³)	Basis
Topsoil and Sub-soil	42,000	Sufficient to apply 100 mm over 40 Ha
General Backfill	45,000	Sufficient to backfill: • Decline and box-cut (20,500 m³) • Ventilation shafts (12,000 m³) Surplus to remain in ROM Pad
Rock Mulch	500,000	Sufficient to apply: • 1.5m to 5 Ha crest of WRE as ISL (75,000 m³) • NAF protection layer to 6.5 Ha WRE batter (conservative approximate volume of 195,000 m³) as batter treatment Surplus to growth media and general fill
Rock Armour	200,000	Sufficient to apply a protection layer to 6 Ha of WRE batter (conservative approximate volume of 120,000 m ³) Surplus for erosion protection

3.6.1.1.1. Stockpiled Soils

Development of the infrastructure and fixed plant at the Site required that topsoil and subsoils were stripped to expose suitable foundations. Most of the stripping occurred during major construction and these Soil inventories were stockpiled for reuse in rehabilitation works at two locations. Both stockpiles were developed to a maximum height of 2 m and the viable seed bank enabled vegetation to establish quickly.

¹ Proposed rehabilitation borrow pit areas are currently being assessed and will be confirmed through further investigation (in accordance with the footnote to Schedule A – Table 1 of the EA) and will be authorised under the EA via a future EA Amendment.

Topsoil Dump North is located immediately south of the CDA and holds approximately 35,500 m³ of soil media. The WRE Topsoil Dump is located to the west of the WRE and contains approximately 7,000 m³ of material. It is anticipated that the soils stored will be a useful resource for the Decommissioning and Rehabilitation program as they will have retained soil carbon and microbial activity. The stockpiled topsoil will be used as a soil ameliorant and as growth media on disturbed areas at the Site characterised by low fines or poor moisture holding capacity. Balancing growth media requirements for disturbed areas is an important component to mine rehabilitation planning, in particular at LLM where topsoil is limited.

3.6.1.1.2. ROM Pad Borrow

The ROM Pad was developed to store extracted ore prior to crushing. The Pad was constructed with approximately 200,000 m³ of non-mineralised waste extracted during development of the decline. Waste rock used to develop the ROM Pad is characterised as Non-Acid Forming (NAF).

This material will be available for reuse as borrow material for various work elements defined in the Decommissioning and Rehabilitation program.

Decommissioning and rehabilitation of the ROM Pad will include re-mining of a portion of the inventory for the purposes of backfilling the decline and ventilation shafts. The ROM pad will be managed to ensure that any potential contamination arising from storage and handling of extracted ore is removed. Decommissioning and rehabilitation of any unused material will include recontouring to match the local topography and drainage lines.

3.6.1.1.3. Rock Mulch

The Decommissioning and Rehabilitation program requires that rock mulch is available for reuse as growth media as well as forming low permeability zones. Rock mulch is typically sourced by borrowing moderately to highly weathered sedimentary rocks that yield a well graded, non-plastic to low plasticity matrix. A combination of both fine and coarse particles provides both acceptable moisture holding capacity whilst retaining some resistance to erosion making them generally suitable for use as growth media. Similarly, these well graded materials can be compacted to form low permeability zones in embankments and cover systems.

The Decommissioning and Rehabilitation program requires that the rock mulch be comprised of materials that are:

Chemically stable that does not generate acid or saline drainage on weathering,

Comprised of well-graded, non-plastic to low plasticity matrix with:

- a) Moderate fines (30 % < 2 mm), and
- b) Moderate coarse (30 % > 4.75 mm)

Investigations undertaken by RGS have identified that suitable inventories of rock mulch are available on the lowland plain located to the south-west of the Lady Loretta ridge (subject to further investigation and authorisation). The shallow soils and subsoils are underlain by weathered mudstones and siltstones that are not affected by mineralisation. Simple borrow pits of relatively shallow depth could be developed to yield the required inventories of rock mulch.

3.6.1.1.4. Rock Armour

High intensity rainfall events occur commonly at the Site and soils and meta-soils disturbed by mining are at high risk of erosion particularly during the period whilst vegetation is establishing. Suitable inventories of rock armour are required to provide a very high level of resistance to erosion along high slope and/or high rate drainage as well as slopes greater than 4 H:1 V.

Characteristics of suitable Rock Armour include:

- Chemically stable that does not generate acid or saline drainage on weathering,
- Comprised of predominantly coarse rock (70 % > 4.75 mm) with minor fines.

Site-based investigations have identified that the ridge immediately to the north of the magazine is comprised of quartzite rock that would make a suitable rock armour (subject to further investigation and authorisation). A small quarry would need to be developed where material would be won using conventional drill and blast techniques. This rock would then be crushed to achieve the required particle size.

3.6.1.2. Waste Rock Characterisation

Extraction of zinc and lead ores requires development of suitable access to the economic orebodies. This development involves excavation of sub-economic material which is referred to as waste rock. Some of the waste rock inventory is reused in the mining effort as back-fill but a large component is brought to the surface for permanent disposal. Permanent storage of the waste rock inventory at surface presents various risks which are managed pursuant to the Waste Rock and Spoil Management Plan (WRSMP).

All waste rock generated at the Site is characterised in terms of its geochemical risk. The classification criteria are represented in Table 14.

Table 14: Waste Rock Classification

Geochemical Management Unit	Criteria	Rock Units	Management
NAF Non Acid Forming	Total Sulphur < 0.1 % Maximum Potential Acidity ≥ 3 times Acid Neutralising Capacity NAG pH ≥ 4.5	Upper Siltstone Unit – Interbedded to interlaminated siltstone Cyclic Unit - Interbedded dolomitic sandstone/siltstone Lower Dolomite Unit – Interbedded dolomitic siltstone and sandstone	Reused in development of the ROM Pad
PAF Potentially Acid Forming	Total Sulphur > 0.1 % Maximum Potential Acidity ≤ 3 times Acid Neutralising Capacity NAG pH ≤ 4.5	Cyclic Unit - Interbedded dolomitic sandstone/ siltstone Upper Pyrite Marker – Upper Mineralised Marker – Interbedded siltstones and sulphides Massive Unit – Massive siltstone, locally pyritic Ore Horizon – Banded to massive sulphides Pyrite Unit – Interbedded pyrite	Permanent storage at WRE

Early development of the underground mine was focussed on establishing access to the Lady Loretta orebody and excavation of the access decline. Much of this development occurred in the Upper siltstone and Cyclic units which yielded NAF waste rock. This material was available for reuse in development of the ROM Pad and embankments of the regulated dams.

Following initial development, the vast majority of the waste rock generated was from the Massive Unit, Ore horizon and Pyrite unit which are predominantly PAF. Any waste rock brought to surface that was not used in construction was placed into the WRE for permanent storage.

In 2016, LLM undertook a validation program to confirm the geochemical character of the waste rock stored in the WRE. A total of 32 samples representing the lateral and elevation extent of the facility were collected and tested for acid-base-accounting (ABA) parameters and well as total metals and chromium reducible sulphur. The survey returned an average total sulphur concentration of 7.6% giving an average Maximum Potential Acidity (MPA) of 240 KgH₂SO₄/T. The average Acid Neutralising Capacity (ANC) was determined to be 43 KgH₂SO₄/T. Further detail on waste rock characterisation undertaken at the Site is outlined in the WRSMP.

3.6.2 Final Landform Design - WRE

3.6.2.1. Basis of Design

The WRE will constitute the most significant post mining landform and will provide for containment of the moderate-high risk waste rock inventory. Basis of Design criteria for the WRE are provided in Table 15.

Table 15: Basis of Design Waste Rock Emplacement

Aspect	Criteria
Design objectives	Long-term containment of high-capacity waste rock Not require ongoing maintenance No direct runoff from crest Maximise (low slope) crest area Minimise batter slope area and length
Bulk stability minimum factor of safety	Static/long term > 1.5 Operating basis earthquake >1.1 Maximum design earthquake > 1.0
Erosion	Negligible
Water flux	Net infiltration < 10 % of rainfall

3.6.2.1.1. Installation of Cover System

Technical evaluation of the works required to decommission and rehabilitate the WRE have been completed by a suitably qualified and experienced consulting engineer. Studies including options assessments and closure design were completed by ATCW.

Works to decommission and rehabilitate the WRE will be focused on the installation of a cover system to provide for permanent containment of the waste rock. The cover system will include:

- Recontouring of the waste rock inventory to achieve batter slopes of 2.5 H:1 V and a crest slope of less than 20 H:1 V (5%),
 - Placement of batter treatments comprising a buttress comprised of compacted PAF waste, compacted NAF protection layer using Rock Mulch, and a Rock Armour protection layer.
- Placement of crest treatments based on the 'Store and Release' (SAR) concept comprising:
 - An Infiltration Storage Layer (ISL) comprised of 1.5 m of loosely placed Rock Mulch and vegetation, and
 - A Reduced Permeability Layer (RPL) comprised of a Bituminous Geo-Membrane (BGM) and protection material,
- Installation of four monitoring stations comprising arrayed volumetric soil moisture and matric suction sensors,
- Modification of existing clean water diversion drains at the perimeter of the WRE including the application of rock armour to resist erosion,
- Documentation of the construction via an As-constructed Report including certification that the design intention was achieved by a suitably qualified and experienced engineer.

Specific features of the design as well as key risk areas are discussed in the following sections.

3.6.2.2. WRE Crest

The low slope (10 H:1 V) crest area of the WRE will be treated with a Store and Release (SAR) cover. The design includes an Infiltration Storage Layer (ISL) that features a highly textured, loosely placed layer of rock mulch that acts as the growth media for a vegetation community dominated by trees. The ISL thickness (1500 mm), and method of placement (paddock dumped with no compaction) provides for complete storage of rainfall within the ISL which results in a no runoff surface. Meteoric water stored in the ISL is then lost to direct evaporation or evapotranspiration.

The design of the ISL was informed by water balance modelling undertaken in VADOSE. This analysis considered climatic conditions as well as the soil moisture characteristics of the rock mulch to determine the optimum thickness of the ISL and to ensure full storage of rainfall over the course of a wet season. The additional storage provided by the hummocked landscape was not considered in the analysis making the design conservative. SAR covers have been successfully applied on lands disturbed by mining activities at numerous sites in northern Australia including Mt Whaleback (WA), Frances Creek (NT), Kidston (Qld) and Century (Qld).

Placement of the proposed crest treatments can only occur after all of the mineralised waste generated by the mining operation and any contaminated soils generated by rehabilitation of other RAs have been placed into final position on the WRE. These streams will include:

- Waste rock generated by the Mining Operations program, and
- Contaminated soils generated by stripping potentially contaminated materials in RA 6 (Infrastructure (Low Intensity Cattle Grazing Area) and RA7 (ROM Pad, Paste Plant and Batch Plant).

As a result, the proposed schedule includes a three-year window to place all mineralised waste into the WRE and a further two years to undertake final reprofiling and installation of the crest treatments.

3.6.2.3. WRE Batter Slopes

The outer batters (2.5 H:1 V) of the WRE will be covered with a buttress comprised of compacted rock mulch overlain by a layer of rock armour. Vegetation is not proposed on the batter slopes.

The design of the final landform adopted this approach because it provides for robust containment that is consistent with the PMLU and the alternate approach of a vegetated batter slope is not feasible. A vegetated batter slope would require suitable growth media (containing fine particles) to be applied to the batters. These sloped surfaces would generate high rates of surface runoff which would result in:

- High rates of erosion even on slopes flatter than 5 H:1 V, and
- Low retention of plant available moisture resulting in stunted vegetation growth.

Placement of the proposed crest treatments can only occur after all of the mineralised waste generated by the mining operation and any contaminated soils generated in rehabilitation of other areas has been placed into final position on the WRE. These streams will include:

- Waste rock generated by the Mining Operations program, and
- Contaminated soils generated by stripping potentially contaminated materials.

As a result, the proposed schedule includes a three-year window to place all mineralised waste into the WRE and a further two years to undertake final reprofiling and installation of the cover system.

Placement of the proposed treatments on the outer batters of the WRE commenced in 2022 with foundations and drainage works applied at the southern margin. Construction of the batter treatments can and will progress concurrently with the placement of waste rock but they cannot advance in front of mining operations. As a result, installation of the batter treatments will occur on a campaign basis where construction teams are periodically mobilised to raise the batter treatments up to a level that corresponds with placement of the waste rock.

Operational practicalities are such that the campaign to place the uppermost section of the batter treatments will coincide with placement of the crest treatments.

3.6.2.4. Oxidation During Construction

The waste rock generated at the site contains appreciable concentrations of acid forming minerals that are available to oxidise when exposed to atmospheric moisture and air. The inventory also includes alkaline minerals that act to neutralise the acid generated but this does little to reduce the risk of neutral mine drainage.

Controlled placement of waste rock into the WRE has included placement of thin (approximately 1 m) lifts and routine compaction using a vibrating pad-foot roller pursuant to the WRSMP. This approach has resulted in a well-consolidated landform that has resisted the infiltration of water and air. This in turn has limited the rate of oxidation of the accumulated waste rock. Tell-tale signs such as fumaroles and heaving have not been observed.

A significant consequence of this approach is that only minor volumes of seepage are generated. These are acidic and contain dissolved heavy metals and salts, but the volume is minor. Surface runoff however is significant, and it too is of poor quality.

3.6.2.5. Flux of Water through the Contained Waste

Infiltration of rainfall into the stored waste will bring water and oxygen into contact with the acid forming minerals which over the long term will result in oxidation. Most importantly however, infiltration of rainfall may result in a flux of water through the contained waste. This flux would act to flush (existing and new) oxidation products including acid, dissolved heavy metals and salt, from the final landform and potentially into the receiving environment. By limiting infiltration of rainfall, water flux through the waste and therefore contaminant transport, can be suitably reduced to ensure chemical stability in the long-term.

The adopted design for the crest treatment includes a duplex SAR cover comprised of an ISL as well as a BGM. The ISL will provide storage that will act to hold incident rainfall within the cap and the RPL will retard infiltration into the underlying waste. The RPL will include a BGM which will provide for negligible infiltration.

Infiltration into the batter slopes of the WRE will be negligible as the adopted slope will cause rainfall to runoff rather than infiltrate. Any infiltration that does occur will only penetrate into the NAF buttress before desiccating.

Performance monitoring will be undertaken to validate performance of the batter and crest treatments. Monitoring stations comprised of arrayed volumetric moisture content and matric suction sensors will be used to confirm that net infiltration into the contained waste is less than 10 % of rainfall.

3.6.2.6. Runoff from High Intensity Rainfall

The design of the WRE includes a crest surface that will generate little to no surface runoff. Placement of the ISL will occur so that the layer remains loose and highly textured. The thickness of the ISL has been designed to provide sufficient storage for the short but intense wet seasons experienced at the Site and the hummocked surface will provide short term storage whilst infiltration into the ISL occurs. Meteoric water stored in the ISL will then be available to support plant growth.

The decommissioning and rehabilitation works will also include a layer of rock armour placed on the batters to protect against erosion. The high-intensity rainfall and dispersive nature of the soils encountered at the Site means that a batter treatment based on vegetation is unlikely to provide suitable protection against erosion in the long term. The rock armour layer adopted in the design will be highly resistant to erosion and discourage access by cattle.

3.6.2.7. Sustain the PMLU of Native Habitat

The crest of the rehabilitated WRE will include an open woodland vegetation community comprised of endemic species consistent with the adjacent ridgelines. The ISL will be placed to a thickness of 1.5 m which will provide ample root space for species endemic to the local area and the creation of a native habitat PMLU.

Vegetation is not expected to readily establish on the outer batters within the decades immediately following the rehabilitation works. Trees will establish in the rocky slopes over a prolonged period but they will provide no function to the final landform other than aesthetics.

The proposed rocky scree slopes are commonly found on the local ridges.

3.6.2.8. Demonstration of Chemical Stability

Works to decommission and rehabilitate the WRE are primarily concerned with ensuring physical and chemical stability of the final landform that contains an inventory of moderate-high-risk mineralised waste rock.

The works described in this PRCP have been designed to provide suitable containment in the long term. It is essential however that the performance of the crest and batter treatments are suitably demonstrated prior to decommissioning of the facilities used to manage mine-affected water.

Performance of the cover will be assessed following periodic review of monitoring data. Classes of monitoring data will include:

- Drawdown of the phreatic surface within the waste stockpile,
- Rate of infiltration into the contained waste,
- Volume and chemical constituency of drainage departing from the stockpile,
- Photography, and
- Visual assessment.

3.6.2.9. Final Landform - ROM Pad

The ROM Pad was constructed with non-mineralised waste rock generated by development of the mine decline. Following decommissioning works, a component of the ROM Pad will be reclaimed for reuse as borrow material but approximately 150,000 m³ will remain unused. The remaining material will form a side-hill landform at the transition between the steep ridges and lowland plains. The ROM Pad will be reprofiled to coincide with local terrain.

3.6.3 Water Management System

The WMS has two primary functions which are to manage the mine-affected and non-mine affected water streams. Surface run-off from low disturbance and non-mineralised areas are referred to as non-mine affected waters. These are diverted away from the management area and passively released to the receiving environment via ESC facilities.

Decommissioning and rehabilitation of the WMS can only occur after major works are completed in the catchments generating mine affected waters and that these works have been effective in mitigating the risks presented to the receiving environment. In addition, the Site must reasonably demonstrate that surface and drainage waters reporting from these catchments are suitable for direct release to the receiving environment in terms of dissolved heavy metals and salinity.

Works to decommission and rehabilitate the water management system cannot commence until:

- Dewatering of the underground workings has been discontinued,
- Batter and crest treatments have been applied to the WRE,
- All significant inventories of mineralised ore and pastefill inputs have been removed from the ROM Pad, Paste and Batch Plant, and
- All significant inventories of Dangerous Goods have been removed from the Site.

Decommissioning and rehabilitation of the water management system have been designed to support a PMLU of Low Intensity Cattle Grazing. To achieve this outcome, the following rehabilitation activities will be undertaken:

- Infrastructure decommissioning and removal,
- Contaminated soils removal,
- Landform development/reshaping,
- Surface preparation, and
- Revegetation of disturbed areas.

For the purposes of this PRCP, these works are scheduled to be completed within 20 years of End of Commercial Proposition. Specific aspects of the program including risk mitigation measures are discussed in the following sections.

3.6.3.1. Decommissioning of Regulated Dams

The CDA, CDB and PPD dams are formed by embankments constructed with a combination of non-mineralised waste rock generated by development of the mine access decline, and in-situ material (residual soils, weathered rock) excavated from the impoundment areas. The largest dam is CDA with a crest height approximately 6 m above the surrounding landscape. The CDA, CDB and PPD facilities are 'Regulated Dams' pursuant to the EP Act and are therefore subjected to specific requirements related to surveillance and provision of suitable freeboard. In addition, the Site must maintain these facilities until it can reasonably demonstrate that surface and drainage waters reporting from these catchments is suitable for direct release to the receiving environment in terms of dissolved heavy metals and salinity.

Works to decommission and rehabilitate the Dams cannot commence until:

- Dewatering of the underground workings has been discontinued,
- Batter and crest treatments have been applied to the WRE,
- All inventories of mineralised ore and tailings have been removed from the ore storage and paste preparation areas, and
- All inventories of Dangerous Goods have been removed from the infrastructure areas.

Decommissioning and rehabilitation of the dam embankments will include removing sections of the embankments so that they become free draining. Other sections of the embankments will be reprofiled to reduce the slopes to flatter than 4 H:1 V (14°) before deep ripping along contour. Vegetation will then be established on the slopes.

At the point when these facilities do become available for decommissioning, they will first be converted to ESC facilities. Decommissioning and rehabilitation of the mine affected water facilities will be undertaken in stages which are described in the following sections.

3.6.3.2. Removal of mine affected water inventory

As discussed in Section 3.2.1.3, cessation of dewatering of the underground workings will put the mine affected water inventory stored at surface into substantial deficit. Water will accumulate during the wet season but will be lost to evaporation each year. The 50%^{ile} inventory has been estimated at 2 ML and the 99%^{ile} estimated at 50 ML. At the appropriate time, any waters remaining in the surface storages will be transferred to the underground workings. Survey of the mine workings indicates that in excess of 600 ML of storage is available.

3.6.3.3. Convert water storages to ESC facilities

Following the removal of the mine affected water inventory from the surface storages, CDA, CDB and the PPD will no longer be required and will be available for repurposing as ESC facilities. At this point in the program schedule, revegetation on the disturbed areas in the upslope catchments will be immature and surface runoff may be affected by erosion. Repurposing the CDA, CDB and PPD to ESC facilities will include:

- Recovery of any accumulated sediments and HDPE liners and disposal underground pursuant to the requirements of the EA,
- Assessing the contaminated land risk and where necessary implementing remediation measures,
- Removal of leak detection system, piezometers, monitoring equipment (if present),
- Lowering the invert level of the emergency spillways, and
- Reprofilling of the containment embankments to achieve a final landform that is consistent with the PMLU and slopes that do not exceed 4 H:1 V.

Conversion of the CDA, CDB and PPD will extinguish their Regulated Dam status.

3.6.3.4. Decommissioning of ESC Facilities

The ESC facilities will be available for decommissioning when the vegetation established on the disturbance area is suitably mature to provide soil conservation services. This is expected to be ten years following the conversion of the regulated dams to ESC facilities. At that time, the ESC facilities will be reprofiled so that the final landform is free draining.

At the time of decommissioning, the ESC facilities will be deep ripped, and seed applied pursuant to the methods described in the Revegetation Plan.

A key requirement for decommissioning and rehabilitation of the Site is that the landscape does not pond water. Accumulations of water that persist for more than a few days tend to attract livestock and feral animals such as pigs. This in turn leads to localised overgrazing, tracking and associated erosion as well as weeds infestations.

3.6.4 Tailings Storage Facility

All lead and zinc bearing ore extracted from the underground mine is crushed at Site before being transported to Mount Isa for further beneficiating and processing. Development of the Site has not included a Tailings Storage Facility. Some process tailings are imported to the Site for production of cemented paste back-fill and will be removed from site.

3.6.5 Voids

Mineral development at the Site did not include excavation of conventional open pits. The most significant excavation was the box-cut that provides safe access to the underground mine portal and access decline which will be back-filled.

3.6.6 Underground Mining

Extraction of lead and zinc bearing ores at the Site has occurred via underground mining methods. The major surface expressions of the Underground Mine are presented in Figure 3 and include:

- Box-cut, decline and underground workings,
- Ventilation shafts,
- Mine affected groundwater.

The infrastructure provides both primary access and secondary egress to the mine workings as well as ventilation. As a result, these are essential to future operations and decommissioning and rehabilitation of this infrastructure cannot commence until End of Commercial Proposition has been called. Decommissioning and rehabilitation activities will include:

- Infrastructure decommissioning and removal,
- Landform development/reshaping,
- Surface preparation,
- Revegetation of disturbed areas.

For the purposes of this PRCP, these works are scheduled to be completed within 13 years of End of Commercial Proposition. Specific aspects of the Decommissioning and Rehabilitation program that relate to the underground mine including risk mitigation measures are discussed in the following sections.

3.6.6.1. Box-cut, Access Decline and Underground Workings

Disturbance related to the box-cut and mine decline includes a 6.5 m by 6.0 m tunnel that provides the main access to the underground workings. The system has been designed, constructed and maintained to provide safe access for personnel and mobile equipment and includes various reinforcements to resist collapse of the surrounding ground. As a result, the box-cut and mine decline are robust systems and will be capable of remaining open for several decades without any intervention.

The underground workings present significant risks to humans, livestock and native fauna. Such risks include fall from height, collapse of unstable ground, drowning, asphyxiation, and disorientation. In addition, the underground workings provide a potential habitat for fauna such as bats and invertebrates.

In the long term however, the mine workings will not remain open. Natural movement in the rock mass, weathering and the effects of groundwater movement will cause localised failures and rock will effectively break-off and into the available void space in a process known as caving. The voids will fill but large void spaces relatively close to surface can result in cave induced subsidence at surface. Subsidence at surface would represent a significant risk to livestock and would potentially influence recharge of the local ground water system.

The subsidence risk has been assessed by a suitably qualified and experienced mining engineer and their findings are documented in Appendix C.

Decommissioning and rehabilitation works proposed for the box-cut, decline and underground workings include:

- Partial backfill of the decline to chainage 460 m from portal to mitigate the subsidence risk. Backfill materials will include:
 - Construction and demolition waste from decommissioning of the Site,
 - ROM Pad borrow,
- Installation of concrete bulkheads at the top and bottom of the backfill zone to resist the ingress of water, humans, livestock and native fauna,
- Backfill of the box-cut 3 m above portal backs with ROM Pad borrow (non-mineralised waste rock) or rock mulch to resist the infiltration of surface runoff into the groundwater environment, and
- Documentation of the construction via an As-Constructed Report including certification that the design intention was achieved by a suitably qualified and experienced engineer.

Works to decommission the Access Decline and Box-cut will require ROM Pad borrow to be reclaimed for use as back-fill. Site demolition works also needs to be completed prior to the waste being used as backfill underground. As a result, this work cannot commence until all infrastructure and sources of contamination have been removed from the ROM Pad. This is not scheduled to occur until three years after End of Commercial Proposition.

3.6.6.2. Ventilation Shafts

Development at the Site has also included sinking of four large diameter shafts that are used for ventilation and emergency egress from the mine. The shafts range in depth between 120 m and 200 m.

These shafts present a significant risk of fall under the proposed PMLU. The shafts are currently protected with mechanical barriers, but these require routine inspection and maintenance. As such, they are not permanent features.

In addition to the risk of fall, the ventilation shafts also present a subsidence risk. These risks have been assessed and are reported in Appendix C.

To mitigate these risks, the Decommissioning and Rehabilitation program includes for the backfill of the upper sections of the ventilation shafts. Backfill material will comprise rock-fill borrow from the ROM Pad and suitable borrow from alternate sources as authorised by the EA. Material backfilled into the ventilation shafts will exhibit significant consolidation settlement. As a consequence, subsequent backfill episodes will be required to “top-up” the volume lost to consolidation. Surplus backfill material will be stockpiled for this purpose.

For the purposes of this PRCP, initial backfill of the ventilation shafts cannot commence until sufficient works have been completed at the ROM Pad to support reclaim of this borrow source. Following initial backfill, it is anticipated that significant consolidation will occur over a five-year period.

3.6.6.3. Hydrogeological Assessment

The underground also includes the groundwater in the vicinity of the mine workings. These groundwaters are naturally saline and reflect the extent of mineralisation of the area, but disturbance by mining has increased both the volume of groundwater and the available storage within the rock mass. Dewatering of the underground workings will continue for 6 months after the End of Commercial Proposition milestone is called at which time groundwater will flood the underground workings and the phreatic surface will recover to a long-term equilibrium level.

This new equilibrium level and the rate of rebound is an important consideration and is influenced by:

- Availability of preferential pathways to accelerate groundwater recharge such as the ventilation shafts and decline,
- Transfers of mine affected waters from the regulated dams,
- Natural groundwater inflow, and
- Rainfall.

The hydrogeological conceptual model developed for the numerical modelling was used to understand the fate and transport for potential contaminants of concern (COCs). The conceptual model identified contaminant sources, migration pathways and sensitive receptors for potential COCs and determined that contaminated groundwater migration to surface water is not a complete pathway and does not present a significant risk.

Fate and transport modelling was based on conservative assumptions regarding contaminant source areas at each of water dams remaining in place after closure as a measure to assess a “worst-case” scenario. However, the water dams will be decommissioned during mine closure and will not remain a contaminant source and represents a mitigation measure to reduce groundwater contamination presence and migration estimated in the conservative model.

Assessments of the groundwater conditions following the cessation of dewatering have been undertaken by CDM Smith (2022) and documented in Appendix D.

These assessments have concluded that:

- Potential COCs associated with decommissioned water dams do not migrate more than 200 m from the contaminant source areas and do not preclude the PMLU,
- Recovery of the phreatic surface to its post-mining equilibrium state will reach an approximate elevation of 280 m AHD. The majority of recovery will occur between 2036 and 2040, but will take more than 200 years to fully reach equilibrium, and
- There will be little to no interaction between the groundwater and Desert Creek.

Routine groundwater monitoring is required to understand post-closure groundwater recovery and to validate the predictions of the model. Given the long timeframes for groundwater recovery (on the order of decades), bi-annual monitoring will provide sufficient information to understand long-term groundwater behaviour and capture seasonal influence. Routine groundwater monitoring will continue to be conducted for a period of time to build a dataset that provides statistically valid trends. This will allow measurement of groundwater level recovery and groundwater quality for comparison against the groundwater model predictions.

3.6.7 Built Infrastructure

3.6.7.1. Overview

Development at the Site has resulted in a significant portfolio of built infrastructure including:

- Mineral processing and rotating equipment,
- Buildings,
- Utilities and services, and
- Exploration drill-holes.

The Built infrastructure provides essential services to the underground mining operation. As a result, decommissioning and rehabilitation of this infrastructure cannot commence until End of Commercial Proposition has been called. Any plant that is not salvaged for beneficial reuse will be demolished and scrapped. Scrap metal will be segregated and removed from site for recycling. The primary demolition waste generated will be concrete. Some of this stream may be suitable for reuse as rock armour. All other demolition waste will be disposed of pursuant to the EA either on or off-site. LLM has submitted an application to authorise demolition waste disposal to the underground environment via an EA amendment. Further detail including a full list of infrastructure identified for decommissioning including associated costs are outlined in the demolition studies undertaken by CMA, as stated in Section 3.2.1.4 above.

For the purposes of this PRCP, these works are scheduled to be completed within three years of End of Commercial Proposition. Specific aspects of the Decommissioning and Rehabilitation program including risk mitigation measures are discussed in the following sections.

3.6.7.2. Beneficial Reuse

For the purposes of this PRCP, the built infrastructure will not present a beneficial reuse opportunity under the proposed PMLU. As a consequence, the current assumption is that all of this fixed plant will be either salvaged for off-site reuse or demolished and scrapped. Demolition waste will be disposed of on-site pursuant to the requirements of the EA.

Transition of the Site from mining operations to the proposed PMLUs however is highly likely to present numerous opportunities for beneficial reuse. Decommissioning and removal of the infrastructure suite is likely to include controlled removal as modular components. To that end, implementation of the Asset Management program is scheduled to continue right up to End of Commercial Proposition. Acting upon these opportunities will be the result of engagement and negotiation with key stakeholders prior to entering into written agreements.

Beneficial reuse opportunities are likely to include:

- Retention of the mine access road and its appurtenant works (drainage, signage),
- Water bore-field including pumps, power supplies, pipelines,
- Workshop buildings,
- Accommodation camp, and
- Mine access road.

3.6.7.3. Contamination from Mineralised Streams

A key requirement for decommissioning and rehabilitation at RA7 will be the removal of contaminant source terms prior to reprofiling and establishment of a self-sustaining vegetation community.

Storage and handling of mineralized ore and process tailings at the Rom Pad, paste plant and batch plant presents a significant long-term risk. The extracted ore and process tailings imported to the Site for paste production are enriched with heavy metals including zinc and lead but also arsenic, cadmium and copper. Both streams are enriched with pyrite and are potentially acid forming.

All inventories of mineralised ore, process tailings and dangerous goods will be removed by run-out of the active stock levels during the final months of the current mining campaign. In addition, the crushing circuit as well as the paste preparation plant will be washed down.

Run-out and wash-down of the ore handling and paste preparation circuits is unlikely to remove all sources of contamination. Transport by spillage, dust and runoff presents a material contamination risk to the stockpile pads, roadways and drainage lines. These areas will be investigated, and contaminated areas remediated so that they do not present an unacceptable risk to the PMLU. Remediation efforts will be focused on excavating contaminated soils and sediments. These streams will be disposed of by placement on the crest of the WRE.

Disposal of contaminated soils and sediments in the underground workings present advantages in terms of cost and reduced environmental risk.

3.6.7.4. Contamination from Dangerous Goods

Elements of the Mining Operations and Asset Management Programs have been concerned with storage and handling of various Dangerous Goods at the Site. These include liquid hydrocarbons (diesel fuel and lubricants), explosives, binding agents, solvents and gases.

Storage and handling of Dangerous Goods at the Site is unlikely to have resulted in any long-term risks arising from spillage or improper use or storage. These inventories however will have no reuse opportunities pursuant to the PMLU and therefore will be removed as a component of the Decommissioning and Rehabilitation program. Management of Dangerous Goods at the Site includes management of stock levels to minimise risks. Any surplus Dangerous Goods will be removed from the Site when they are no longer required.

3.6.8 Methods to Rehabilitate Land to a Stable Condition

3.6.8.1. Revegetation Plan

Mining development at the Site has resulted in material areas of disturbance. These areas are at increased risk of erosion and associated impacts related to final landform stability and water quality in the receiving environment. Disturbance areas are also at increased risk of infestation by weeds. Development of robust vegetation communities comprised of trees, shrubs and groundcovers are essential to mitigating these risks.

A key objective of the Decommissioning and Rehabilitation program is to establish a robust vegetation cover on all areas that have been disturbed by mining development. The disturbed areas at the Site are comprised of soils and meta-soils that have low levels of soil structure and moisture holding capacity. Establishment of an effective vegetation cover comprised of shrubs and/or groundcovers is necessary to support the proposed PMLUs.

A viable vegetation cover is essential in the development of productive soils and play an important role in nutrient capture/cycling and particularly in the accumulation of soil carbon. Plants are also critical in providing food-sources and microhabitats for fauna. Effective vegetation is essential in building biodiversity and overall ecosystem resilience.

The methods used to establish vegetation of the disturbance areas at the Site are described in the following sections. Revegetation works will occur as campaigns following the completion of the decommissioning works described elsewhere in this PRCP.

Establishment of vegetation on mine affected soils is generally a challenging undertaking. Risks and issues faced includes:

- The degree of disturbance and availability of soil services including structure, nutrition and soil moisture capacity,
- The climatic conditions experienced at the site,
- The influence of stressors such as fire, drought and over-grazing, and
- Weed infestation from areas outside of the control of LLM.

LLM has defined the methods and processes used for establishing viable and self-sustaining vegetation communities on mine disturbed soils and meta-soils at the Site.

3.6.8.2. Application of Soil Ameliorants

Previous studies have determined that the soils and sub-soils at the site are naturally low in nutrients and organic carbon/matter when compared to agricultural soils, however do support native vegetation and on-site soils can be used for rehabilitation of mine areas. Notwithstanding, these studies also found no evidence to suggest that successful rehabilitation of the Site could not be expected if suitable methods and practices were adopted (RGS, 2021).

Following the removal of infrastructure and contaminated soils, reshaping works will be undertaken to achieve the final profile. At that point, a suitably qualified person will assess the growth media and whether amelioration is required to support establishment of vegetation consistent with the PMLU. The assessments will consider key aspects including soil nutrition, moisture holding capacity, and texture and provide advice as to the applicability of soil ameliorants.

Should the application of soil ameliorants be required, the following options are available:

- Application of fertiliser to improve soil nutrition,
- Application of gypsum to act as a soil binder,
- Application of sulphur (to increase soil pH) or agricultural limestone/gypsum (to lower soil pH),

- Application of dry vegetation matter to reduce erosion and increase recruitment of soil carbon,
- Application of top-soil as growth media to improve nutrition, moisture holding capacity and recruit soil microbes,
- Application of rock mulch as growth media.

Where practicable, application of soil ameliorants will be undertaken during the dry season so that deep ripping and seed application can occur at the onset of the wet season.

The stockpile of topsoil available at the Site is a significant resource but it is not unlimited. Topsoil will be applied on a greatest needs/benefits basis until the entire inventory is exhausted. The topsoil inventory includes limited coarse particles. As a result, it is not a useful ameliorant on sloped disturbance areas as it is prone to erode.

3.6.8.3. Deep Ripping

Deep ripping is an important component of revegetation and is undertaken for the following purposes:

- Reduces path length for surface run-off thereby reducing concentrations of flow and the risk of erosion,
- Softens the overall texture of the landscape and improves accumulation of soil nutrients and organic matter,
- Reduces surface runoff and increases storage of plant available moisture to support vegetation growth, and
- Provides microhabitat for seed germination and early establishment.

Deep ripping will be completed to a minimum depth of 500 mm using a track-dozer fitted with rippers. Deep ripping will be completed along contour with an overall density of one line every two metres down slope. On occasion, deep ripping will cause large boulders to be brought to surface. This is tolerable and provides micro habitat for reptiles and avian fauna.

Where practicable, deep ripping will be completed during the late dry season and early wet season and coordinate closely with application of soil ameliorants and seed. "Fresh" rip-lines provide a more favourable substrate for seed germination.

Deep ripping will not be undertaken on surfaces treated with rock armour or other erosion protection measures.

3.6.8.4. Application of Seed

Vegetation will be established on disturbed areas by broadcasting suitable seed onto suitably prepared surfaces. This method has been successfully demonstrated at numerous metalliferous mine sites in northern Australia including Century (Qld), Kidston (Qld), Frances Creek (NT) and Mt Whaleback (WA).

The following seed application measures will be implemented, and will also include specific preparations including seed scarification, coating and inoculation where appropriate:

- Specific species mixes have been designed for each of the PMLUs. These are presented in Table 16,
- Application by hand: suited to small areas such as drill pads,
- Application by vehicle mounted air spreader: suited to moderate to large areas including slopes of 4 H:1 V,
- Application by helicopter: suited to high sloped terrain and highly textured surfaces such as the ISL of the WRE.

Seed for revegetation purposes will generally be applied during the first few weeks of the wet season when:

- Initial storms have provided some plant available moisture, and
- The probability of follow up rain is maximised, thereby providing the greatest possible growing season.

The species mix applied to the Low Intensity Cattle Grazing area reflects the open woodlands dominated by *Eucalyptus leucophloia* and native grasses including spinifex. Some improved pasture species will be used to improve the palatability of the grasses present. The species mix applied to the Native Habitat area will reflect the woodlands dominated by Lancewood and the small-fruited bloodwood. The species mixes have been designed to give due regard to availability as well as to meet the success criteria defined in this PRCP. Specific mixes may be modified slightly to account for variation in environmental features of the rehabilitation area. For example, sites along watercourses would also include the seed of *Eucalyptus camaldulensis* (River Red Gum: 200 g ha⁻¹), while sites on rocky scree slopes would include a greater proportion of *Acacia shirleyi* (300 g ha⁻¹) and no *Eucalyptus pruinosa*, *Corymbia terminalis* or *Grevillea striata*.

Table 16: Revegetation Seed Mix

Species	Common Name	PMLU 1: Low Intensity Grazing		PMLU 2: Native Habitat		PMLU 2: WRE (Crest and Benches)	
		Selection	Sowing Rate (g/ha)	Selection	Sowing Rate (g/ha)	Selection	Sowing Rate (g/ha)
Groundcover (Grasses)							
<i>Aristida holathera</i>	Kerosene grass	✓	180	✓	10	✓	30
<i>Aristida latifolia</i>	Feathertop Wiregrass	✓	180	✓	10	✓	30
<i>Aristida lazardis</i>	Wiregrass	✓	150	✓	10	✓	20
<i>Bothriochloa ewartiana</i>	Desert Bluegrass	✓	100	✓	10	✓	20
<i>Cymbopogon bombycinus</i>	Silk Grass	✓	100	✓	20	✓	100
<i>Enneapogon polyphyllus</i>	Leafy Nineawn Grass	✓	70				
<i>Eriachne mucronata</i>	Mountain Wanderie Grass	✓ ¹	500	✓ ¹	100	✓ ¹	200
<i>Eulalia aurea</i>	Silky Browntop	✓	100				
<i>Paspalidium rarum</i>	Bunch Paspalidium	✓ ¹	400	✓ ¹	100	✓ ¹	200
<i>Ptilotus clementii</i>	Pussycats Tails	✓	150	✓	20	✓	100
<i>Ptilotus exaltatus</i>	Mulla Mulla	✓ ¹	300	✓ ¹	90	✓ ¹	100
<i>Ptilotus fusiformis</i>	Skeleton Bush	✓	150	✓	40	✓	50
<i>Ptilotus schwartzii</i>	Horse Mulla Mulla	✓	100	✓	40	✓	50
<i>Schizachyrium fragile</i>	Fire Grass	✓	200	✓	50	✓	60
<i>Senna notabilis</i>	Cockroach Bush	✓	150	✓	50	✓	60
<i>Setaria surgens</i>	Pigeon Grass	✓	100	✓	100	✓	100
<i>Solanum echinatum</i>	Poison Gooseberry	✓	50				
<i>Solanum ellipticum</i>	Potato Bush	✓	50				

Species	Common Name	PMLU 1: Low Intensity Grazing		PMLU 2: Native Habitat		PMLU 2: WRE (Crest and Benches)	
		Selection	Sowing Rate (g/ha)	Selection	Sowing Rate (g/ha)	Selection	Sowing Rate (g/ha)
<i>Triodia molesta</i>	Buck Spinifex	✓	640	✓	450	✓	620
<i>Triodia longiceps</i>	Giant Grey Spinifex	✓	630	✓	400	✓	610
<i>Triodia pungens</i>	Soft Spinifex	✓ ¹	700	✓ ¹	500	✓ ¹	650
Groundcover (TOTAL Sowing Rate)			5kg/ha		2kg/ha		3kg/ha
Midstorey Species (Shrubs)							
<i>Acacia chisholmii</i>	Turpentine	✓ ¹	500	✓ ¹	700	✓ ¹	1000
<i>Acacia holosericea</i>	Silver Wattle	✓	100	✓	400	✓	800
<i>Acacia megalantha</i>	None recorded	✓	100	✓	300	✓	700
<i>Acacia monticola</i>	Hill Turpentine	✓ ¹	400	✓ ¹	400	✓	800
<i>Acacia retivenaea</i>	Net-veined Wattle	✓ ¹	400	✓ ¹	300	✓ ¹	800
<i>Acacia tenuissima</i>	Broom Wattle	✓	100	✓	200	✓	500
<i>Atalaya hemiglauc</i>	Whitewood	✓ ¹	400	✓ ¹	500	✓ ¹	900
<i>Flueggea virosa</i>	White Currant	✓	200		250	✓	300
<i>Gossypium australe</i>	Native Cotton	✓	200	✓	250	✓	300
<i>Grevillea wickhamii</i>	Wickham's Grevillea	✓	200	✓	250	✓	300
<i>Acacia cambagei</i>	Gidgee	✓	200	✓ ¹	250	✓ ¹	300
<i>Acacia aneura</i>	Mulga Wattle	✓	200	✓ ¹	200	✓ ¹	300
Midstorey (TOTAL Sowing Rate)			3kg/ha		4kg/ha		7kg/ha
Canopy Species (Trees)							
<i>Acacia shirleyi</i>	Lancewood			✓ ¹	500		
<i>Corymbia terminalis</i>	Inland Bloodwood	✓ ¹	200	✓ ¹	500		
<i>Corymbia aparrerinja</i>	Inland Ghost Gum	✓ ¹	100	✓ ¹	300		
<i>Corymbia dichromophloia</i>	Small-fruited Bloodwood	✓ ¹	400	✓ ¹	500		
<i>Eucalyptus leucophloia</i>	Snappy Gum	✓ ¹	600	✓ ¹	800		
<i>Eucalyptus leucophylla</i>	Cloncurry Box	✓ ¹	300	✓ ¹	500		
<i>Eucalyptus pruinosa</i>	Silver-leaf Box	✓ ¹	300	✓ ¹	500		
<i>Grevillea striata</i>	Beefwood	✓	60	✓	200		

Species	Common Name	PMLU 1: Low Intensity Grazing		PMLU 2: Native Habitat		PMLU 2: WRE (Crest and Benches)	
		Selection	Sowing Rate (g/ha)	Selection	Sowing Rate (g/ha)	Selection	Sowing Rate (g/ha)
<i>Lysiphyllum cunninghamii</i>	Red Bauhinia	✓	40	✓	200		
Canopy (TOTAL Sowing Rate)			2kg/ha		4kg/ha		0kg/ha

¹ Priority Species

3.6.8.5. Adaptive Management

In the event that the rehabilitation monitoring identifies that revegetation results are sub-optimal and/or improvements can be made, further investigation will be undertaken to establish a cause and appropriate strategy(s) will be implemented. Aspects that may be considered as part of the investigation may include, but are not necessarily limited to:

- Nutrient availability,
- pH, salinity and metal toxicity,
- Shallow root depth,
- Other soil limitations,
- Plant diseases,
- Insect attack,
- Lack of nitrogen fixing legumes,
- Insufficient density and diversity of long-lived plants (e.g. overstorey trees),
- Lack of organisms involved in litter breakdown (e.g. fungal fruiting bodies) and nutrient cycling (e.g. puff balls),
- Predation,
- Evidence of drought effects or rainfall damage,
- Inappropriate plant species density and diversity,
- Poor soil and/or landscape preparation, and
- Weed competition and/or competition with other species in the seed / tube stock mix.

The composition and structure of revegetated areas will also be compared with the target vegetation found at the analogue sites, as per LLM Rehabilitation Monitoring Program. A representative number of analogue sites within both PMLUs have been established with ongoing improvements made, where necessary.

3.6.8.6. Maturation of Vegetation Communities

Revegetation of landscapes disturbed by mining is characterised by various risks that are very difficult to mitigate. The most significant of these is the variability of rainfall. The success of seed germination and seedling development is largely dependent on the soil moisture conditions experienced in the six months following revegetation works. Rainfall years that are characterised by low total accumulations and/or a low number of rainfall days are likely to result in poor rates of establishment and growth.

Other issues including seed viability, unplanned fire and unplanned grazing can also be significant. An unplanned fire in an immature revegetation area late in the dry season can be catastrophic and may require revegetation of the affected area recommence.

To account for these risks, the PRCP Schedule proposes a nominal 20-year period to allow for the establishment, development and maturation of vegetation to the point that it is on a suitable trajectory to support the PMLUs. In an effort to provide greater clarity and certainty to the overall program, this PRCP frames the establishment of vegetation as a series of waypoints. These are:

- An initial waypoint that demonstrates that works to initiate establishment of vegetation have been completed,
- A trajectory waypoint (nominally 10 years after seeding) at which it can be reasonably expected that revegetation works are broadly on target, and
- A final waypoint (nominally 20 years after seeding) at which the PMLU objectives have been achieved.

3.7. RISK ASSESSMENT

3.7.1.1. Hazard Identification and Risk Management

LLM takes a risk-based approach to the planning, scheduling and execution of all decommissioning and rehabilitation activities undertaken at the Site.

Glencore has defined the framework requirements for hazard identification and risk assessment via the Glencore Corporate Risk Management Framework (RMF). The RMF applies at all Glencore operations including LLM. The RMF aligns with the requirements of ISO31000 – Risk Management and requires that all credible loss events are defined and assessed. The RMF applies to all classes of risk including long-term exposures including impediments to relinquishment of the Mining Leases. The Framework requires that all identified risks are assessed using a standardised approach that gives due consideration to various impact classes including societal, financial and regulatory consequences. This qualitative approach considers both consequence and likelihood using a conventional a five-by-five matrix.

Development of the mineral resources at the Site has exposed LLM to a number of risks and hazards that must be mitigated if closure of the Site and lease relinquishment is to be achieved. LLM has defined these risks by way of a Closure Risk Assessment (CRA). The CRA defines all of the aspects and impacts (risks) that are currently at foot and nominates the current control measures. Each aspect is then assessed to determine the residual risk value on a one to twenty-five scale and the CRA ranked in terms of residual risk. An action plan is then implemented including timing and scheduling.

The CRA identified the risks of a stable condition for LLM rehabilitation not being achieved, and how those risks are intended to be managed or minimised in accordance with section 126C of the EP Act. Current control measures were identified, and the residual risks assessed using the tools defined by the RMF. Any risks with a current risk rating of high based on the current controls were designated key risks. The CRA identified a total of twelve main risks of a stable condition not being achieved which are presented in Table 17. Upon implementation of additional controls, the residual risk scores of these main risks were reduced to medium or low.

Table 17: Key Risks to LLM Rehabilitation not being achieved, and their Controls

Aspect and Impacts	Current Controls	Additional Controls and Justification of Treatment Option	Residual Risk Score
Inadequate design and construction of the waste rock emplacement (WRE), and WRE cover system, relevant to milestone RM2 and RM11	- Options analysis for the WRE final landform and capping system (performed by suitably qualified organisation) - assessing environmental performance and engineering and maintenance optimisation and cost - WRE final landform and cover system design works underway including performance modelling - Waste characterisation completed - Leachate water quality modelling for WRE - Geotechnical investigation work of WRE	- Finalise WRE final landform and detailed cover system design - Design and implement a WRE cover system trial, if required - Monitor and undertake a comparison of WRE cover system findings with trial results to support the preferred WRE cover option, if required - Ensure construction of the WRE according to design. Collate construction methods, obtain as-builts for construction verification and quality assurance.	14 M
Insufficient availability of material (spoil, subsoil, and topsoil) to achieve the final landform and rehabilitation, relevant to milestone RM6	- Current stockpiles are mapped and surveyed - Disturbance mapping is up to date with process in place to map future disturbance - Borrow source investigation works completed 2020 and ongoing - Materials balance updated in 2020	- Finalise WRE final landform and detailed cover system design and prepare a final material balance. - Finalise borrow/quarry shell designs. Once the proposed borrow areas are established: - Determine the final extent of disturbance required for closure - Undertake an environmental assessment of the proposed additional disturbance areas - Lodge an EA Amendment - Ensure ongoing monitoring of rehabilitation material availability for site rehabilitation works. This is to include: - Ongoing review and update of material availability and assumptions and develop contingency for maintenance process - Construction supervision and controls (to avoid overuse of material)	9 M
Inadequate contractor engagement and management during closure works relevant to achieve all milestones	Standard procurement process	- Develop a scope of works/tender package - Contractual Agreements in place for the execution of closure works - Develop a contractor execution strategy for closure works	13 M
Progressive rehabilitation progress does not achieve rehabilitation milestones in accordance with the PRCP or PRCP Schedule	- Annual review of rehabilitation provision internal budget - Progressive rehab opportunities identified and implemented during operations (trench, exploration pads, Leachate Management Dam area) - WRF landform design work underway	- Undertake ongoing meetings with DES - Complete the LLM PRCP submission to DES - Identify opportunities for progressive rehabilitation - Prepare the PRCP schedule with realistic and achievable milestone and outcomes (i.e. consideration of climate variability, etc, and strategic retention of infrastructure)	9 M

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Owner: HSEC - Manager Environment

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Aspect and Impacts	Current Controls	Additional Controls and Justification of Treatment Option	Residual Risk Score
	- Operational borrow areas identified - On-site rehabilitation works and key learnings identified	- Establish appropriate/achievable milestone criteria - Undertake ongoing rehabilitation monitoring to test the revegetation strategies and optimise rehabilitation methods and monitoring to ensure milestone criteria can be achieved.	
Changing government expectations over time	- Planning to look at emerging regulatory updates - Involvement in industry forums - Regular engagement with DES - DES approval of PRCP - Final land use consistent with surrounding landscape	As low as reasonably practical	8 M
Inability to surrender the EA	- Planning to look at emerging regulatory updates - Involvement in industry forums - Regular engagement with DES - DES approval of the PRCP - Final land use consistent with surrounding landscape	Implementation of all additional controls identified	13 M
Plant decommissioning schedule is delayed and does not align with requirements during closure works, relevant to milestone RM1	- Standard procurement process - Internal budget for closure and acknowledges requirements for ongoing services.	- Develop and implement an asset decommissioning strategy that considers strategic asset retention. - Workforce planning for closure works. - PRCP milestone schedule to acknowledge requirements for ongoing services. - Develop a contractor execution strategy for closure works.	5 L
Surface subsidence caused by the underground operations, relevant to milestone RM3	- Mining methods and backfilling - Geotechnical study assessment to determine risk	As low as reasonably practical	6 L
Surface slumping of the WRE, relevant to milestone RM11 and RM12	- WRE final landform and cover design works assesses landform stability, environmental performance and erosion stability modelling - Geotechnical investigation work of WRE - Development of Post Closure Monitoring and Maintenance Plan	- Preparation of Construction Documentation for WRE - Construction of WRE according to design - Implement Post Closure Monitoring and Maintenance Plan	14 M

Aspect and Impacts	Current Controls	Additional Controls and Justification of Treatment Option	Residual Risk Score
Inadequate revegetation strategies (including surface preparation), relevant to milestone RM6, RM7, RM8, RM9, RM10, RM11, RM12 and RM13	- Borrow source investigations to identify suitable quality and quantity of material - Rehabilitation monitoring program and key learnings identified - Development of revegetation strategies to address constraints (i.e. unsuitable seed mix, methods of application, insufficient growth media, naturally low levels of soil fertility, availability of seed mix, environmental constraints such as climate variability and available plant / soil moisture), timing of revegetation and pest / native / cattle control).	- Complete reporting on borrow sources investigation project - Undertake rehabilitation monitoring against milestone criteria	9 M
Proliferation of weeds and pests during closure activities and post closure monitoring and maintenance phase, relevant to milestone RM9, RM10, RM12 and RM13	- Pest management - Ongoing weed control - Fencing to exclude cattle - Development of revegetation strategies to address weeds pest	- Implement revegetation plan - Ongoing rehabilitation monitoring and maintenance	2 L
Insufficient defensible data is available to demonstrate that rehabilitation milestone criteria have been achieved to meet final milestones (achievement of PMLUs) RM12 and RM13	- EA monitoring and internal monitoring programs - Contaminated land investigations - Ongoing rehabilitation monitoring - Database to store information and data trend analysis - Development of Post Closure Monitoring and Maintenance Plan - Development of revegetation strategies	- Implement post closure monitoring and maintenance plan - Ongoing EA monitoring and investigations, including development of revised criteria - Further development of groundwater modelling and expand groundwater network design plan, as required - Contaminated land intrusive investigation work and develop remediation action plan - Rehabilitation monitoring and rework - Ongoing review of internal budgets to allow closure works to continue (rehabilitation provision schedules and resourcing) - Constructed to design specifications (as built for verification) - Implement plans throughout the closure and post closure phases	9 M

L = Low Risk

M = Medium Risk

3.8. MONITORING AND MAINTENANCE PLAN

3.8.1 Overview

Monitoring and maintenance of the Site will be undertaken to support implementation of the Decommissioning and Rehabilitation program. The program provides for demonstrating that specific Rehabilitation Milestones have been achieved. Key aspects of the monitoring and maintenance plan are:

- Inspection and surveillance,
- Performance monitoring,
- Corrective and preventative action, and
- Review and reporting.

3.8.2 Inspection and Surveillance

3.8.2.1. Routine Inspections

Following the implementation of the Decommissioning and Rehabilitation program, the Site will be subjected to routine inspection to ensure that any shortcomings or non-conformances are identified early, and appropriate interventions initiated. Routine inspections of the Site will be:

- Completed four times per year,
- Completed by a person or persons with suitable understanding of the Site and knowledge in land management practices, and
- Recorded on a Site-specific check-sheet.

The routine inspections will be supported by a suitable check-sheet prepared by LLM. Aspects will include:

- Water management: mine affected water inventory, spill risk, drainage lines,
- Erosion and sediment control: instances of erosion or scour, sediment accumulation in ESC facilities,
- Consolidation settlement: evidence or instances of ground subsidence,
- Fauna activity: evidence or sightings of native fauna in underground workings, and
- Land management: status of stockproof fencing, fire risk, presence of weeds.

3.8.2.2. Event-Based Inspections

Event-based inspections may be undertaken in response to specific events such as: earthquake, fire, heavy rainfall, or any other suitable trigger. Event-based inspections would typically be completed pursuant to the check sheets used to support the routine inspections.

3.8.3 Performance Monitoring

3.8.3.1. Meteorological Monitoring

LLM operates an automatic weather station located adjacent to the mining block carpark. The station is fitted with sensors suitable to record key climatic data including rainfall and evaporation.

3.8.3.2. Revegetation Success Monitoring

For the purposes of this PRCP, EFA will be used to monitor the establishment of the self-sustaining landform at the Site in accordance with the schedule as outlined in the Glencore NQ Rehabilitation Monitoring Program. EFA was developed by Australian researchers including the CSIRO during the 1990's and early 2000's. The methods have undergone refinements including codification and have become widely accepted as the appropriate framework to assess the value of soils and vegetation on lands disturbed by mining. A detailed methodology is provided in *Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes* (Tongway and Hindley, 2005). A summary of the methodology is provided below.

The EFA methodology includes assessment of three core components:

- Landscape Function Analysis (LFA),
- Vegetation dynamics, and
- Habitat complexity.

3.8.3.2.1. Landscape Function Analysis

LFA is a measure of how well the landscape retains and uses key resources such as water and organic matter. The way in which each type of resource is utilised within micro catchments influences the way the landscape develops and ultimately functions. A well-functioning landscape will recruit and retain resources including moisture and nutrients effectively. LFA monitoring assesses 11 attributes of the soil surface and vegetation cover to derive indices of “stability”, “infiltration” and “nutrient cycling”, on which several milestone criteria will be assessed against.

3.8.3.2.2. Vegetation dynamics

The vegetation dynamics component of EFA focuses on the functional role of vegetation in rehabilitation performance. Data is collected using either the Point Centred Quarter (PCQ) or Wandering Quarter (WQ) method, both of which measure plant density and canopy volume using the LFA transect as an analogue.

3.8.3.2.3. Habitat complexity

The habitat complexity component of EFA assesses the extent to which habitat and shelter for vertebrate fauna are developing in the rehabilitated landscape. Habitat complexity involves the assessment of five habitat characteristics within an area surrounding the centre of the LFA transect. The following five attributes are assessed include canopy cover, shrub cover, ground vegetation cover, non-vegetative ground cover (litter, fallen logs and rocks) and free water availability.

The EFA process works by undertaking specific measurements in the field at locations representative of the ecosystems under consideration. Results from the specific measurements are used to determine index scores for the specific monitoring event. Index scores derived from subsequent monitoring events are then assessed to establish the success or otherwise of the vegetation establishment.

3.8.3.2.4. Species richness and recruitment

In addition to the EFA method, species richness is assessed within a 20m x 20m plot. Species richness is assessed to collect data on the development of the vegetation community as well as to assess germination success of the seed mix. The plot is established with its centre point coinciding with the centre point of the LFA transect. Species richness is calculated as the total number of vascular plant species within the plot. All living, above-ground plant parts, including overhanging vegetation, that occur within each plot are included in the count.

Recruitment is also assessed for tree species within the 20m x 20m plot. Assessment of tree species recruitment gives an indication of the sustainability of the vegetation community. Any seedlings or suckers that have established at least two years after initial seeding took place are recorded as evidence of recruitment. The species recruiting and the number of juveniles should be recorded.

3.8.3.3. Rehabilitation Monitoring Sites

Establishment of viable vegetation communities on soils and meta-soils disturbed by and derived from mining wastes is influenced by many factors. Some of these factors including nutrition, terrain type and sun aspect are relatively static and therefore predictable. Other factors can vary significantly from period to period. Variable factors include climatic conditions, effects of bushfire, and grazing. Of all these, rainfall is the most significant factor particularly in the highly seasonal and highly variable rainfall.

To account for this variability, the monitoring program considers both reference (or analogue) sites and monitoring sites. Reference sites are established on land not affected by mining and are subjected to the same tests and measurements as the monitoring sites.

LLM has established 11 reference monitoring sites at LLM to support the revegetation. Monitoring campaigns undertaken since 2018 have been used to refine methodologies and develop a baseline dataset.

In accordance with condition E9 of the EA, vegetation monitoring will be undertaken annually or on an agreed schedule. The frequency of monitoring may be adjusted based on the results of early monitoring and declining risk of failure over time. Vegetation monitoring should be undertaken between March and June to provide the most accurate species diversity results.

Condition E10 of the EA specifies that “verification of rehabilitation success is to be carried [out] for each domain. Monitoring must be carried out for each domain at a minimum sampling intensity of 1:15,000 and must include sufficient replication to enable statistical analysis of results at an acceptable power.” A sampling intensity of 1:15,000 equates to an approximate density of one site per nine hectares.

The Glencore NQ Rehabilitation Monitoring Program will be periodically updated to ensure an appropriate schedule is adopted and the number of monitoring locations per domain will support assessment against the milestone criteria stipulated in this PRCP.

3.8.3.3.1. Soil Geochemical Analysis

Soil geochemical analysis is also undertaken to identify any potential constraints to rehabilitation success associated with the growth media at each rehabilitation area. For example, if growth media salinity is high vegetation germination and establishment success is likely to be reduced and overall rehabilitation outcomes may be negatively impacted.

Where areas of persistent bare ground exist at a rehabilitation area (and this is not consistent with analogue sites), targeted soil geochemical analysis may be required to identify the cause and any required remediation.

3.8.3.3.2. Rehabilitation Inspection

Each rehabilitation area is inspected concurrently with the EFA monitoring assessment at all sites. The rehabilitation inspection consists of a “walkover” of the rehabilitation area, with a focus on identifying:

- Any areas that appear to have generally poor vegetation condition,
- Areas that lack vegetation or have large areas that are bare,
- The presence and abundance of key weeds,
- Rubbish, vandalism or damage caused by vehicles etc.,
- Integrity of water management structures,
- Stability and function of erosion and sediment structures,
- Soil issues (e.g. contamination or staining) at a scale that is likely to affect milestone criteria and/or relinquishment, and
- Areas of erosion, instability, slumping or other surface instability.

A Rehabilitation Inspection (Walkover) Form is used to record details of any remedial actions required and an Aftercare and Maintenance Plan is completed for each rehabilitation area based on results of the site walkover. These templates can be found in the Glencore NQ Rehabilitation Monitoring Program.

3.8.3.4. Reintroduction of Grazing

The reintroduction of grazing may be conducted on proportions of relevant RAs proposed for low intensity cattle grazing. Specific locations will be determined at a later time. Reference pens may also be trialled to provide data to compare with the rehabilitated sites. Reference pens should be in locations that have not been disturbed by mining, and that have been spelled from cattle for at least two years. Reference sites will be selected in areas that display similar vegetation communities and soil characteristics to the rehabilitated sites.

It is recommended that the reintroduction of grazing on rehabilitation sites do not take place until pasture biomass remains stable for at least three years and landscape function analyses indicate that the sites are moving on a trajectory towards a stable, functional ecosystem. Reintroduction of grazing should not commence until at least ten years after rehabilitation sites are first seeded. Reintroduction of grazing may provide the final indicators of rehabilitation performance.

The details for the proposed reintroduction of grazing will be finalised at a later date, in consultation with relevant suitably qualified personnel and the local graziers.

3.8.3.5. Waste Rock Emplacement Water Balance

Decommissioning and rehabilitation of the WRE will include the application of low water flux covers to the crest and batters. These will act to resist the infiltration of meteoric water into the contained waste rock and thereby remove the mechanism that may act to transport contaminants into the receiving environment. In addition, the crest and batter treatments have been designed to provide functions such as resistance to erosion and storage of water to support plant growth.

The WRE will be a permanent feature of the post-mining landscape and it is essential that the performance of the crest and batter treatments are demonstrated before other risk control measures such as the WMS are decommissioned. For the purposes of this PRCP, a minimum performance demonstration period of five years has been adopted to account for the variable climatic conditions experienced at the Site.

Monitoring of the WRE water balance will be completed using a network of four instrumented monitoring stations located in both the crest and batter treatment areas. Each station will comprise paired sensor arrays monitoring volumetric moisture content and matric suction located at strategic levels in the capping media as well as in the contained waste. A weather station will also be maintained at the WRE. Data will be captured continuously and analysed annually to assess the water balance of the landform including:

- Rainfall,
- Storage,
- Losses to runoff,
- Losses to evapo-transpiration, and
- Net losses to infiltration.

3.8.3.6. Subsidence and Consolidation Settlement

Subsidence and consolidation assessment will be monitored by comparison of topographic survey on an annual basis. Assessment results would typically be reported by way of “heat maps” that identify areas of potential concern.

Consolidation settlement of the backfill material placed into the ventilation shafts will be assessed visually as a component of the routine inspection program.

3.8.3.7. Erosion

Three separate processes will be used to monitor erosion at the Site. These are:

- Geomatic survey,
- Visual observation of the landscape as a specific item of the routine inspections, and
- Comparison of photographs taken at strategic locations across the site over time.

3.8.3.8. Weeds

Monitoring for the presence of declared and potentially problematic weeds at the Site will be undertaken as a component of the routine inspections. Any infestations identified will be mapped and typically controlled with chemical herbicide.

3.8.3.9. Surface Water, Stream Sediment and Macroinvertebrates

Monitoring of surface waters, stream sediment and macroinvertebrate communities at the Site and in the receiving environment will continue to be undertaken pursuant to the requirements Schedule C of the EA.

3.8.3.10. Groundwater Quality and Flow

Monitoring of groundwater quality will continue to be undertaken pursuant to the requirements Schedule C of the EA.

3.8.4 Non-Conformance, Corrective and Preventative Action

Non-conformances with the requirements of this Plan may come about from a variety of sources including:

- Routine or event-based inspection,
- Review of rehabilitation performance data,
- Stakeholder inspection or concern, or
- Regulator inspection.

Minor non-conformances are expected and once identified, appropriate steps should be taken to correct the issue and if appropriate, prevent recurrence. In most cases this will entail scheduling non-routine maintenance via the Glencore enterprise reporting platform. Maintenance activities may include:

- Repairs to fencing and exclusion of livestock,
- Repairs to drainage paths,
- Application of soil ameliorants or fertilisers,
- Additional deep ripping and broadcast of seed.

Significant non-conformances represent a serious or systematic failing which may delay the rehabilitation schedule. Such instances will be formally investigated, and a suitable corrective actions plan initiated.

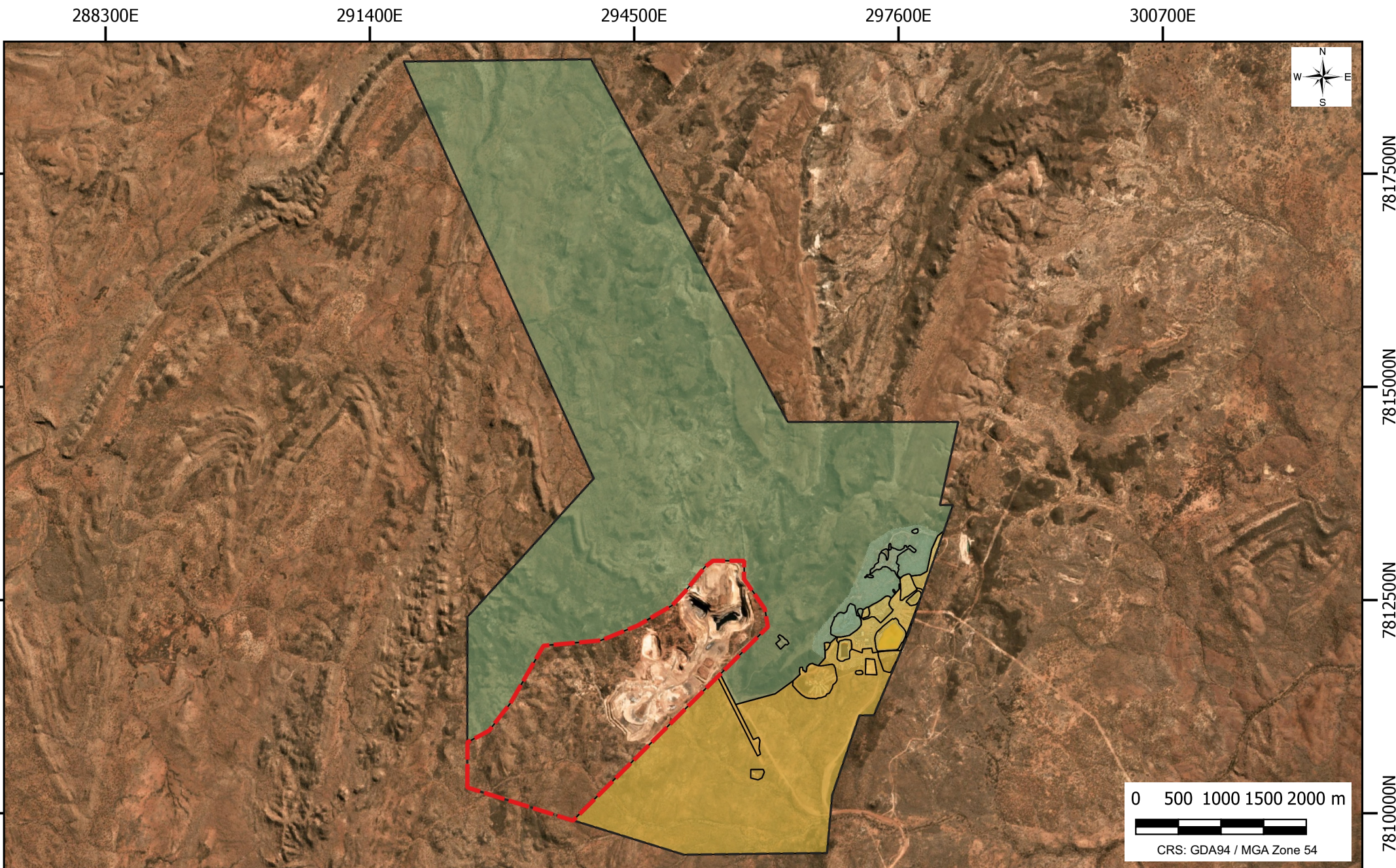
3.8.5 Assessment and Reporting

LLM will review the rehabilitation monitoring data on an ongoing basis. Data captured during the preceding year will be reviewed and assessed and integrated with the historic data.

4. PRC SCHEDULE

4.1. FINAL SITE DESIGN

The final site design proposes a PMLU for the entire area of the ML. No NUMAs are proposed for ML5568. The final site design is presented as Figure 16.



LEGEND

	LADY LORETTA MINE LEASE		LOW INTENISTY CATTLE GRAZING AREA (567 HA)
	LADY ANNIE LEASE BOUNDARY		NATIVE HABITAT AREA (2206 HA)
	REHABILITATION AREAS		

NORANDA PACIFIC PTY LIMITED

LADY LORETTA MINE
FINAL SITE DESIGN

**ATC
WILLIAMS**

FIGURE 016

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4.2. REHABILITATION AREAS

Rehabilitation and closure planning for sites affected by mining operations is a complex undertaking. Different types of disturbance result in various risk exposures which in turn require the application of diverse mitigation measures. In order to deal with this complexity, a precinct planning approach has been adopted in this PRCP.

The final site design includes ten Rehabilitation Areas (RAs). The RAs have been categorised according to the mitigation measures required to achieve the objectives of the Decommissioning and Rehabilitation program and a common PMLU.

The RAs adopted for the Site are:

- RA1 Waste Rock Emplacement,
- RA2 Topsoil Stockpiles,
- RA3 LMD and ESC Facility,
- RA4 CDA, CDB, PPD, Sediment Dams and ESC Facilities,
- RA5 Infrastructure (Native Habitat Area),
- RA6 Infrastructure (Low Intensity Grazing Area),
- RA7 ROM Pad, Paste Plant and Batch Plant,
- RA8 Exploration, Roads and Tracks (Native Habitat Area),
- RA9 Exploration, Roads, Tracks and Haul Road (Low Intensity Cattle Grazing Area), and
- RA10 Underground Openings, Shafts, Decline and Portal.

A map showing the location and extent of the RAs is presented in Figure 17.

292600E

294000E

295400E

296800E

298200E



7813000N

7812000N

7811000N

7810000N

RA8-EXPLORATION ROADS AND TRACKS (NATIVE HABITAT AREA)

RA5-MAGAZINE

RA3-LMD

RA3-ESC FACILITY

RA10-SHAFT 3

RA10-SHAFT 1

RA10-SHAFT 4

RA10-SHAFT 2

RA7-PASTE & BATCH PLANT

RA5-INFRASTRUCTURE (NATIVE HABITAT AREA)

RA10-BOX-CUT & PORTAL

RA1-WASTE ROCK EMPLACEMENT

RA4-PPD

RA7-ROM PAD

RA4-CDA

RA6-INFRASTRUCTURE

RA2-TOPSOIL

RA6-ROAD TRAIN PARK UP

RA5-WASTE TRENCH

RA2-TOPSOIL

RA6-CAMP

RA6-STP

RA4-CDB

RA6-AIRSTRIP

RA6-EMERGENCY TRAINING GROUND

RA9-EXPLORATION ROADS AND TRACKS (LOW INTENSITY CATTLE GRAZING AREA)

LEGEND

REHABILITATION AREAS

- RA1 WASTE ROCK EMPLACEMENT
- RA2 TOPSOIL STOCKPILES
- RA3 LMD & ESC FACILITY
- RA4 CDA, CDB, PPD & ESC FACILITIES
- RA5 INFRASTRUCTURE (NATIVE HABITAT AREA)
- RA6 INFRASTRUCTURE (LOW INTENSITY GRAZING AREA)
- RA7 ROM PAD, PASTE PLANT & BATCH PLANT
- RA8 EXPLORATION, ROADS & TRACKS (NATIVE HABITAT AREA)
- RA9 EXPLORATION, ROADS & TRACKS (LOW INTENSITY CATTLE GRAZING AREA)
- RA10 UNDERGROUND OPENINGS, SHAFTS, DECLINE & PORTAL
- R10 - SHAFTS

0 250 500 750 1000 m

CRS: GDA94 / MGA Zone 54

LEGEND

- LADY LORETTA MINE LEASE
- LADY ANNIE LEASE BOUNDARY

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LADY LORETTA MINE
REHABILITATION AREA REFERENCE



FIGURE 017

112009-04

DATE: 2022-05-31

4.3. PRC SCHEDULE

A proposed PRC Schedule for the LLM is presented as the standard template which was downloaded from <https://www.business.qld.gov.au/running-business/environment/licences-permits/rehabilitation/progressive-rehabilitation-closure-plans>.

The proposed PRC Schedule is provided in Appendix E.

4.4. REHABILITATION MILESTONES AND SUCCESS CRITERIA

Effective demonstration that the rehabilitation objectives have been achieved and that the PMLUs can be implemented requires definition of objective criteria.

Rehabilitation milestones and success criteria for the Native Habitat and Low Intensity Cattle Grazing PMLUs areas are presented in Table 18. These criteria were adopted from knowledge and experience in rehabilitating lands disturbed by mining activities in Queensland, Australia and internationally.

Table 18: Rehabilitation Milestones and Success Criteria

Milestone Reference	Rehabilitation Milestone	Milestone Criteria	Applicable Rehabilitation Areas
RM1	Infrastructure Decommissioning and Removal (Fixed Plant)	a) Services disconnected (excluding services agreed with stakeholders for retention) b) Surface fixed plant and infrastructure including foundations (excluding that required for drainage or otherwise agreed with stakeholders for retention) has been removed ## c) Drillholes are capped/plugged and decommissioned in accordance with ESR/2016/1985	RA5, RA6, RA7
RM2	Installation of cover system (WRE)	a) Batter and crest treatments have been applied, and monitoring stations installed consistent with the WRE engineering design b) A suitably qualified and experienced person has prepared an As-Constructed Report that details the works undertaken, and certified that construction and encapsulation works met the design intent	RA2
RM3	Landform development and reshaping/re-profiling (Underground Openings)	a) Upper sections of ventilation shafts have been backfilled with ROM borrow material to preclude access to underground workings b) Surface subsidence generated depression as determined by subsidence monitoring is no greater than > 500 mm c) Upper section of mine decline has been backfilled with ROM borrow material to preclude access to underground workings d) Portal sealed and box-cut backfilled with inert material to form a free draining final surface e) A suitably qualified and experienced person has prepared an As-Constructed Report that details the works undertaken, and certified that construction and backfilling of underground openings met the design intent	RA10
RM4	Landform development and reshaping / re-profiling (ROM Pad, Paste Plant and Batch Plant and Infrastructure Area, Topsoil Stockpiles)	a) Terrain has been reprofiled with disturbed slopes not steeper than 4 H:1 V and verified by an appropriately qualified person	RA2, RA5, RA6, RA7

Milestone Reference	Rehabilitation Milestone	Milestone Criteria	Applicable Rehabilitation Areas
RM5	Landform development and reshaping / re-profiling (Regulated Dams and Erosion and Sediment Control Facilities)	a) Recommendation by suitably qualified and experienced engineer that Regulated Dam status can be rescinded. b) Terrain has been reprofiled with disturbed slopes not steeper than 4 H:1 V and verified by an appropriately qualified person c) Erosion and sediment control facilities (excluding facilities agreed with stakeholders for retention) decommissioned and left free draining	RA3, RA4
RM6	Surface Preparation	a) A suitably qualified person has assessed the characteristics of the soil and growth media and defined requirements for ameliorants and other treatments necessary to achieve the PMLU b) Ameliorants and other treatments (including application of stockpiled growth media) have been applied, as recommended by suitably qualified person. c) Final surface has been deep ripped on surfaces, with the exception of WRE (RA1) d) Placement of maximum thickness of 100 mm of growth media at ROM, Paste Plant and Batch Plant Area (RA7), subject to recommendations by suitably qualified person.	RA1, RA3, RA4, RA5, RA6, RA7, RA8, RA9
RM7	Revegetation (all disturbed areas excluding WRE)	a) Complete seeding to the WRE crest area using seed mix and sowing rates described in Table 16 of this PRCP, or based on more recent seed mix and sowing rates as recommendations by suitably qualified person	RA2, RA3, RA4, RA5, RA6, RA7, RA8, RA9
RM8	Revegetation (WRE)	a) Complete seeding to the WRE crest area using seed mix and sowing rates described Table 16 of the PRCP, or based on more recent seed mix and sowing rates as recommendations by suitably qualified person	RA1
RM9	Achievement of surface requirements - Vegetation on Developmental Trajectory (Native Habitat areas)	a) Corrective actions that are recommended by a suitably qualified person identified through the rehabilitation monitoring methodology has been implemented. b) Corrective action arising from the routine inspections program have been undertaken to include weed control, erosion repair, livestock exclusion. c) Ecosystem Function Analysis index scores compared to equivalent reference sites are: - Stability > 50% of reference - Infiltration > 40% of reference	RA1, RA3, RA5

Milestone Reference	Rehabilitation Milestone	Milestone Criteria	Applicable Rehabilitation Areas
		- Nutrient Cycling > 20% of reference - Species Richness > 40% of reference - Vegetation Dynamics > 20 % of reference - Habitat Complexity > 20% of reference	
RM10	Achievement of surface requirements - Vegetation on Developmental Trajectory (Low Intensity Cattle Grazing areas)	a) Corrective actions that are recommended by a suitably qualified persons identified through the rehabilitation monitoring methodology has been implemented. b) Corrective action arising from the routine inspections program have been undertaken to include weed control, erosion repair, livestock management. c) Ecosystem Function Analysis index scores compared to equivalent reference sites are: - Stability > 50% of reference - Infiltration > 40% of reference - Nutrient Cycling > 20% of reference - Vegetation Dynamics > 20% of reference d) The basal area of grasses is > 30% of reference	RA2, RA6, RA7
RM11	Achievement of surface requirements - WRE	a) A suitably qualified person has assessed the performance monitoring data for the WRE and verified that: - No rill/gully erosion > 500 mm - Water flux into contained waste is < 10% of rainfall	RA1
RM12	Achievement of post-mining land use to stable condition (Native Habitat areas)	a) Ecosystem Function Analysis index scores compared to Native Habitat reference sites are: - Stability Index > 80% of reference - Infiltration > 60% of reference - Nutrient Cycling > 60% of reference - Species Richness > 60% of reference	RA1, RA3, RA5, RA8, RA10

Milestone Reference	Rehabilitation Milestone	Milestone Criteria	Applicable Rehabilitation Areas
		- Vegetation Dynamics > 40% of reference - Habitat Complexity > 40% of reference b) Proportion of Category 3 restricted invasive plant species is not >10% of total vegetation groundcover** c) Weed densities will be similar to surrounding reference sites## d) No unrepaired active gullies (i.e. showing active sediment deposition and sides/floor devoid of cover) > 1 m deep## e) Surface water quality at downstream compliance points to meet contaminant limits defined in the current EA## f) Assessment and validation by suitably qualified person that the long-term risks presented by groundwater contamination do not preclude the PMLU g) Evidence in rehabilitation report that appropriate risk assessment for geotechnical stability at the WRE and Underground Openings has been undertaken and control measures are in place## h) Contaminated land investigation completed by suitably qualified person. i) Contaminated Land Site Investigation verifies residual contamination presents no unacceptable risk to achieving the PMLU j) Backfill of ventilation shaft complete to pose no unacceptable safety risks to humans or wildlife k) Underground opening certified as safe by a suitably qualified geotechnical engineer (this only applies to RA10)	
RM13	Achievement of post-mining land use to stable condition (Low Intensity Cattle Grazing areas)	a) Assessment by suitably qualified and experienced person that pasture is sufficiently productive to support low intensity cattle grazing b) Ecosystem Function Analysis index scores compared to equivalent reference sites are: - Stability > 80% of reference - Infiltration > 60% of reference	RA2, RA4, RA6, RA7, RA9

Milestone Reference	Rehabilitation Milestone	Milestone Criteria	Applicable Rehabilitation Areas
		- Nutrient Cycling > 60% of reference - Vegetation Dynamics > 40% of reference c) The basal area grasses is > 60% of reference d) Proportion of Category 3 restricted invasive plant species is not >10% of total vegetation groundcover** e) Weed densities will be similar to surrounding reference sites^{##} f) No unrepaired active gullies (i.e. showing active sediment deposition and sides/floor devoid of cover) > 1 m deep^{##} g) Evidence in rehabilitation report that appropriate risk assessment for geotechnical stability at the ROM, Paste Plant and Batch Plant, Infrastructure and Water Dam areas has been undertaken and control measures are in place^{##} h) Surface water quality at downstream compliance points to meet contaminant limits defined in the current EA^{##} i) Groundwater quality to meet contaminant limits defined in the current EA^{##} j) Assessment and validation by suitably qualified person that the long-term risks presented by groundwater contamination do not preclude the PMLU being sustained k) Contaminated land investigation completed by suitably qualified person l) Contaminated Land Site Investigation verifies residual contamination presents no unacceptable risk to achieving the PMLU	

NOTE. Success Criteria previously approved under a Land Outcome Document (LOD) are indicated as notes to the Tables.

^{##} Milestone Criteria adopted from LLM Post Mining Land Use Plan (Noranda Pacific, 2018)

^{**} Biosecurity Act 2014

5. SURRENDER OF ENVIRONMENTAL AUTHORITY

5.1. OVERVIEW

The ultimate objective of this PRCP is to transition the Site to the proposed PMLUs and support surrender of the EA. Implementation of the Decommissioning and Rehabilitation program defined in this PRCP will result in a landscape capable of supporting the proposed PMLUs. Surrender of the EA will require:

- Demonstrated compliance with all requirements of EPML00982013,
- Compilation of a Contaminated Lands Assessment for the Site, and
- Preparation of a Post-Surrender Management Report.

These specific requirements are described in the following sections.

5.2. COMPLIANCE WITH ENVIRONMENTAL AUTHORITY

Any application to surrender the EA must demonstrate full compliance with the requirements of the EA and present an expectation that ongoing compliance can be expected under the proposed PMLU. Particularly, this would entail demonstrated compliance with:

- Schedule C - Water Management
- Schedule E - Land and Rehabilitation

5.3. CONTAMINATED LANDS ASSESSMENT

Prior to surrender of the EA, soil and groundwater contamination must be remediated in compliance with the requirements of the EA and applicable Queensland regulations, including removal from the Environmental Management Register.

Removal from the Registers requires submittal of a Contaminated Land Investigation Document (CLID) that demonstrates:

- No ongoing notifiable activity being carried out on the land; and
- The land is not contaminated and suitable for any use.

The CLID must be completed by a Suitably Qualified Person and certified by an Auditor. The CLID presents site investigation outcomes, remedial objectives and actions, validation of clean-up efforts and a site management plan, if necessary for any further work required to address contamination.

The Contaminated Land Validation Report documents remedial activities and validation data to confirm the success of clean-up efforts.

The Site Suitability Statement will be completed to certify that all contaminated land has been remediated and confirms that the land is suitable for the designated PMLU.

5.4. POST MINING MANAGEMENT REPORT

Any application to surrender the EA must include submission of a Post Mining Management Report. The Post Mining Management Report must be prepared by a suitably qualified and experienced person and certify that satisfies the requirements of section 111A of the EP Act, and specifically that:

- The land is safe and structurally stable,
- There is no environmental harm being caused by anything on or in the land, and
- The land can sustain the post mining land use.

6. REFERENCES

- [1] ANE, 2000. Air Noise Environment Pty Ltd, Noise and Air Quality Review – Lady Loretta Project.
- [2] AGE, 2018. Report on Lady Loretta Mine, Hydrogeological Conceptual Model, Australian Groundwater and Environmental Consultant Pty Ltd.
- [3] AGE, 2020. Lady Loretta Mine Hydrogeological Conceptual Model 2020 Update. G1834H.Lady_Loretta_Groundwater_Conceptual_Model_Update_2020.v01.02. 1 September 2020.
- [4] ANZG, 2018. d, 2018.
- [5] ATC Williams, 2022. Report Noranda Pacific Pty Ltd, Lady Loretta Mine WRSF Closure Concept Report, May 2022.
- [6] CDM Smith, 2022. Glencore Australian, Lady Loretta Mine Groundwater Closure Report, May 2022.
- [7] CMA Contracting, 2020. LLM Financial Assurance Estimated Rehabilitation Cost Update Demolition. 7 October 2020.
- [8] DES, 2021. Guideline Progressive Rehabilitation and Closure Plans (PRCPs). ESR/2019/4964 Version 2.00. 17 March 2021. Queensland Department of Environment and Science.
- [9] Eco Logical Australia, 2019. North Queensland Rehabilitation Monitoring Program: MIM, LLM and Limestone Leases, April 2019.
- [10] Emery, K.A., 1985. Rural Land Capability Mapping. Soil Conservation Service of New South Wales.
- [11] Engeny Water Management, 2020. Lady Loretta Mine – Leachate Management Dam Construction Report. Prepared for Noranda Pacific Pty Ltd, 2020.
- [12] Engeny Water Management, 2022. Lady Loretta Mine – Mine Closure Water Balance Assessment, Water Balance Assessment Report, May 2022.
- [13] FRC Environmental Pty Ltd, 2018. Lady Loretta Mine Stream Surface Water Quality Investigation Report, December 2018.
- [14] FRC Environmental Pty Ltd, 2018a. Lady Loretta Mine Receiving Environment Monitoring Program 2017/2018 Annual Report, 2018a.
- [15] FRC Environmental Pty Ltd, 2018b. Report, Receiving Environment Monitoring Program Design: Lady Loretta Mine (ML5568), 2018b.
- [16] Glencore, 2017. Lady Loretta Mine Surface Water Operational Plan, 2017.
- [17] Glencore, 2019. Lady Loretta Receiving Environmental Monitoring Program Design, 2019.
- [18] Glencore, 2019b. Lady Loretta Groundwater Monitoring Network Design Plan, 2019b.
- [19] Glencore, 2021. Lady Loretta Mine Biodiversity Offset Strategy, 2021.
- [20] Glencore, 2022. Lady Loretta Z-LLM-OPS-PLN-Water Management Plan, 2022.
- [21] Hancock, M.C., Purvis, A.H., 1990. Lady Loretta Silver-Lead-Zinc deposit: in Hughes F E (Ed.), Geology of the Mineral Deposits of Australia and Papua New Guinea The AusIMM, Melbourne Mono 14, v1, 943-948.
- [22] MEC Mining, 2022. Glencore Lady Loretta Mine, Mine Closure Geotechnical Study, April 2022.
- [23] Noise Mapping Australia, 2013. Lady Loretta Zinc-Lead-Silver Project, Noise and Vibration Assessment, June 2013.
- [24] Noranda Pacific Pty Ltd, 2018. Post Mine Land Use Plan: Lady Loretta (PMLUP), 2018.
- [25] Noranda Pacific Pty Ltd, 2000. Lady Loretta Project Environmental Management Overview Strategy (EMOS), November 2000.

- [26]** NRA, 2012. Lady Loretta Flora and Fauna Interim West Season Report. Technical Note prepared by NRA Environmental Consultants for Xstrata Zinc Australia, July 2012.
- [27]** NRA, 2013. Lady Loretta Receiving Environment Monitoring Program. Report prepared by NRA Environmental Consultants for Noranda Pacific Pty Ltd – Lady Loretta (Glencore), November 2013.
- [28]** RGS, 2021. Mine Waste and Water Management, Factual Report Phase 1 – Rehabilitation material sampling and analysis program (RMSaAP) and material management, Lady Loretta Mine, July 2021.
- [29]** Simpson SL, Batley GB and Chariton AA, 2013. Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines. CSIRO Land and Water Science Report 08/07. CSIRO Land and Water, May 2013.
- [30]** SLR, 2021. Lady Loretta Water Balance Model Development Report. SLR Ref. No. 62012436-LLM-WBZM-Development-Report-R01-v01_DRAFT. 22 February 2021.
- [31]** TropWATER, 2021. Glencore Lady Loretta Mine Compliance Framework Review. Report No. 21/52, prepared by Tropwater. November 2021.
- [32]** WRM, 2022. Dam Failure Consequence Assessment for Lady Loretta Mine. Report No: 1636-01-D1. 24 February 2022.
- [33]** WRM, 2022. Flood Study, May 2022.
- [34]** Xstrata Zinc, 2012. Lady Loretta Project Environmental Management Plan (EMP), June 2012.

7. APPENDICES AND ATTACHMENTS

APPENDIX A:	MINE CLOSURE WATER BALANCE ASSESSMENT
APPENDIX B:	FLOOD ASSESSMENT
APPENDIX C:	CLOSURE GEOTECHNICAL STUDY
APPENDIX D:	CLOSURE GROUNDWATER MODELLING REPORT
APPENDIX E:	PRCP SCHEDULE
APPENDIX F:	FINAL LANDFORM 3D MODEL

APPENDIX A MINE CLOSURE WATER BALANCE ASSESSMENT



Lady Loretta Mine

Mine Closure Water Balance Assessment

Water Balance Assessment Report

31 May 2022

M66000_099-REP-001-4

Job no. and Project Name: M66000_099 Lady Loretta Mine Water Balance Model
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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
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2	19/05/2022	Final Issue	Laura Vincent	Aaron Baldwin	Laura Vincent	Aaron Baldwin
3	20/05/2022	Final Issue	Laura Vincent	Aaron Baldwin	Laura Vincent	Aaron Baldwin
4	31/05/2022	Final Issue	Laura Vincent	Aaron Baldwin	Laura Vincent	Aaron Baldwin

Signatures



DISCLAIMER

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1 INTRODUCTION

Engeny Water Management (Engeny) has been engaged to assist Lady Loretta Mine (LLM) to assess the water management system under a closure scenario to support the Progressive Rehabilitation and Closure Plan (PRCP). The assessment has been undertaken using the existing calibrated and routinely maintained operational water balance model. This report details the development and calibration of the water balance model as well as the proposed water management strategy for closure and the assessed system performance.

2 WATER BALANCE MODEL DEVELOPMENT AND CALIBRATION

2.1 WATER BALANCE MODEL

The LLM water balance model (WBM) is developed using the Goldsim model software and is used by site to assist with water management decision making. The WBM receives annual updates and recalibrations as part of the continuous improvement of effective site water management at LLM. The two previous updates were completed by SLR in 2020 and Engeny in 2021.

Goldsim is a software program developed by the GoldSim Technology Group and is capable of analysing complex time dependant systems. The model operates on a daily time step. For each scenario modelled, the model simulates 500 “realisations” derived using stochastic rainfall data developed for LLM from historical climate records on the Queensland Governments Scientific Information for Land Owners (SILO) Patch Point Data set. The stochastic data was produced from records from Jan 1960 to Dec 2018 and 500 replicates of 10 year rainfall data was developed. The first realisation uses climatic data commencing in 1960, the second commences with data from 1961 and the third with data from 1962 and so on. The results from all realisations are used to generate water forecasts including storage volume estimates, supply reliability and other relevant water balance statistics. This method effectively includes all recorded historical climatic events in the water balance model, including high, low, and median rainfall periods.

2.1.1 Water Management System

The LLM site WBM schematic is shown in Figure 2.1 and represents the site storages, movement of water, demands and inflows. The model consists of the four mine water storages on site representing the site’s water management system, which are shown on Figure 2.2 and listed below.

- Containment Dam A (CDA).
- Containment Dam B (CDB).
- Paste Plant Dam (PPD).
- Leachate Management Dam (LMD).

The WBM has been updated frequently since the initial development as part of the continuous improvement of effective site water management, based on the management strategies to control water risks at LLM. These are in line with the Lady Loretta Water Management Plan (LLM, 2021) and include:

- Operating and maintaining a water management network that:
 - diverts clean water away from operational areas;
 - directs mine affected water to containment structures; and
 - minimises risk to the receiving environment during the transfer and use of process water.
- Maximising available containment storage at all times;
- Conducting predictive modelling of water infrastructure performance in response to rainfall events;
- Implementing the LLM regulated dam Trigger Action Response Plan (TARP); and
- Managing and minimising land disturbance activities and soil erosion.

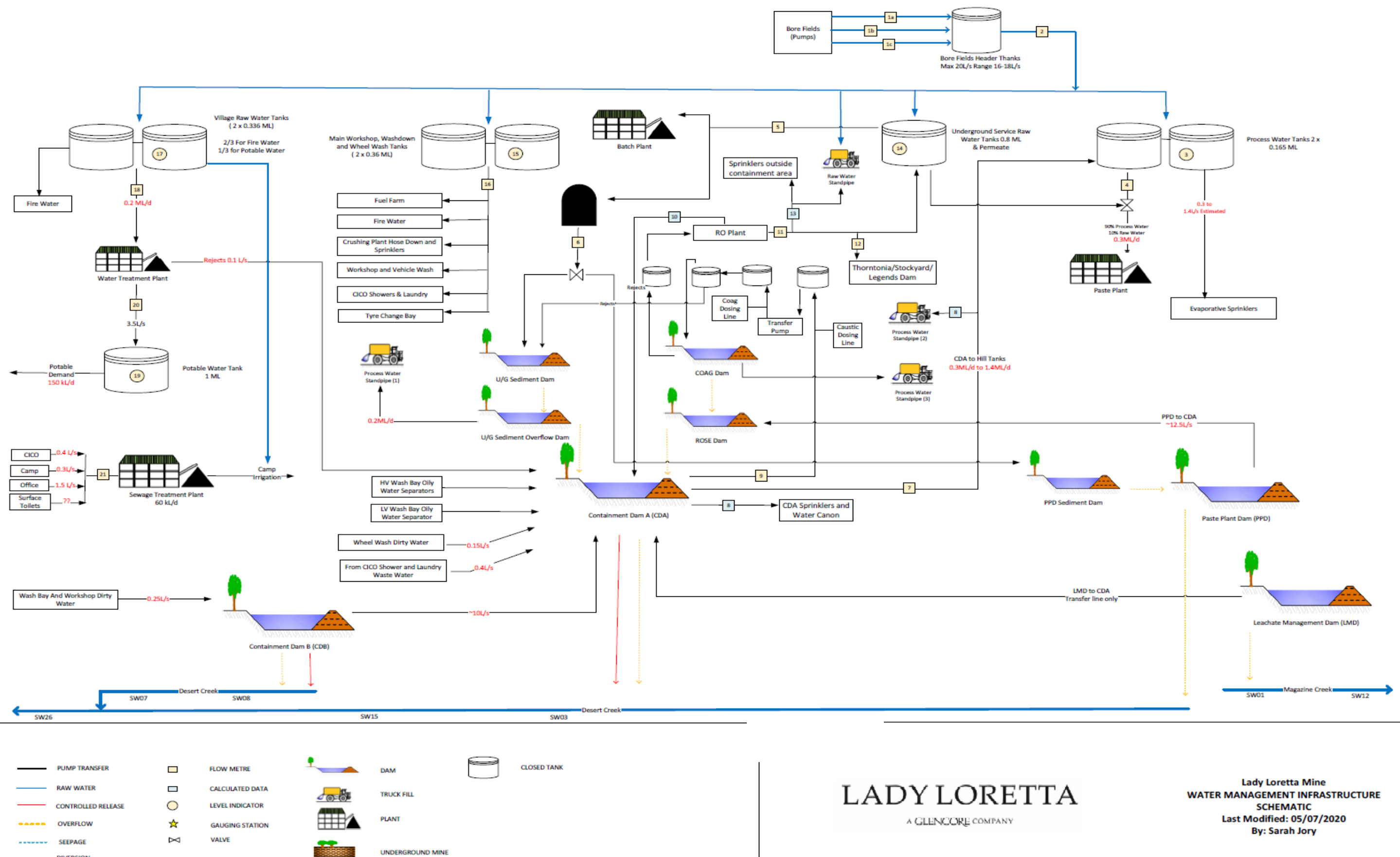


Figure 2.1: LLM Water Balance Model Schematic

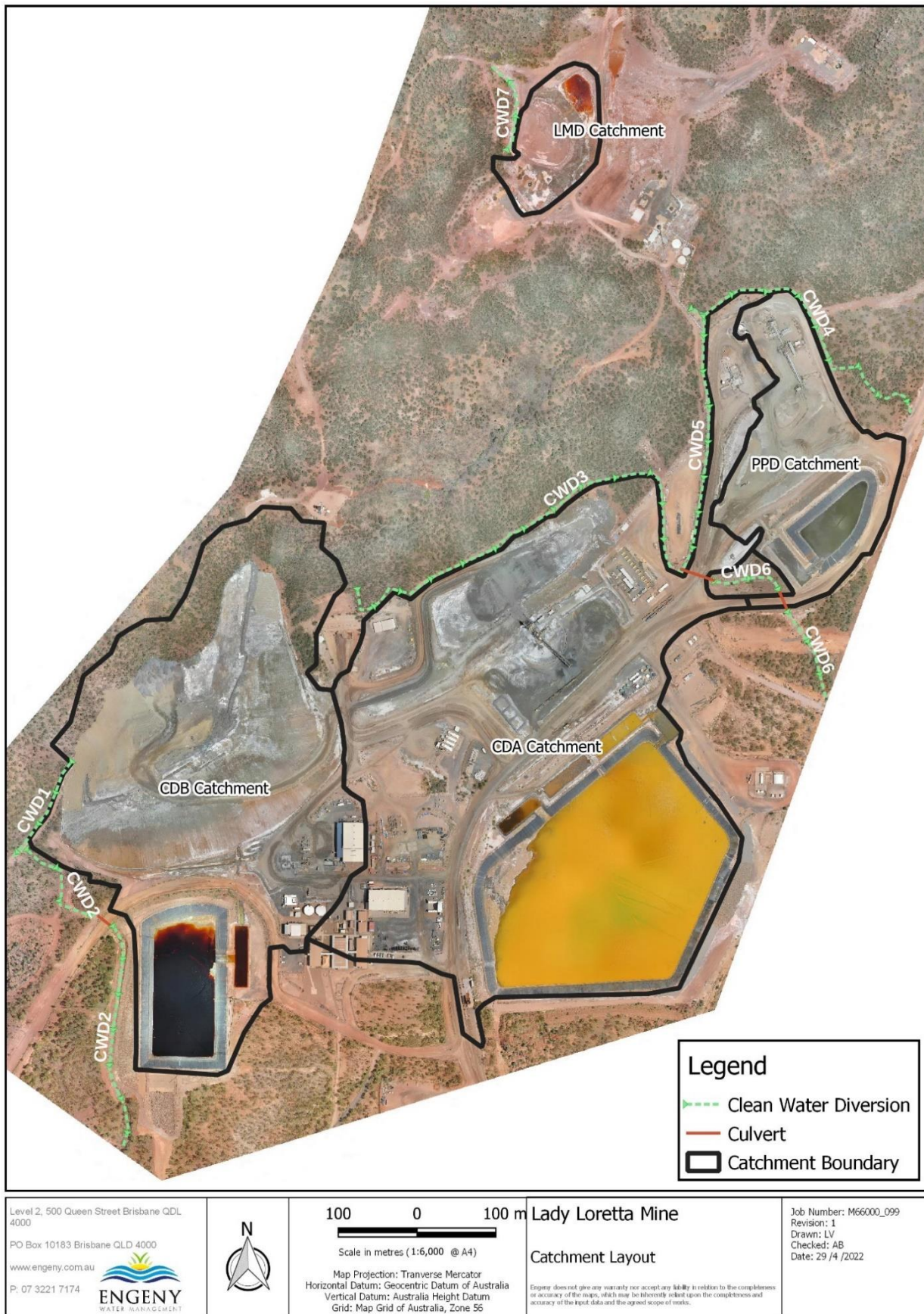


Figure 2.2: Catchment Layout

2.2 INPUT DATA

The following sections discuss the input to the water balance model.

2.2.1 Rainfall

The LLM model include two types of rainfall data:

- Stochastic daily rainfall data used to undertake forecast simulations; and
- Historical daily recorded rainfall data used for model calibration.

Stochastic rainfall data has been generated for the LLM WBM using the eWater CRC stochastic climate library. The rainfall data was sourced from the Queensland Governments Scientific Information for Land Owners (SILO) Patched Point Data set. The Patched Point Data set provides infilling of any missing data from nearby gauges based on relationships developed between the overlapping records of each gauge. The Patched Point Data used rainfall records from the Lady Annie Mine Gauge (029172), Calton Hills Station Gauge (029118) and Flora Downs Station Gauge (037055). The stochastic data was produced from records from Jan 1960 to Dec 2018. The stochastic rainfall data produced was for 500 replicates of 10-year rainfall data.

Historical daily rainfall data has been sourced from the LLM site rainfall gauge. Rainfall data was available from 1st of January 2017 until the 28th of May 2021. Figure 2.3 shows the rainfall recorded for this period. It shows distinct wet season periods between November and April each water year (1st of July to 30th of June each year).

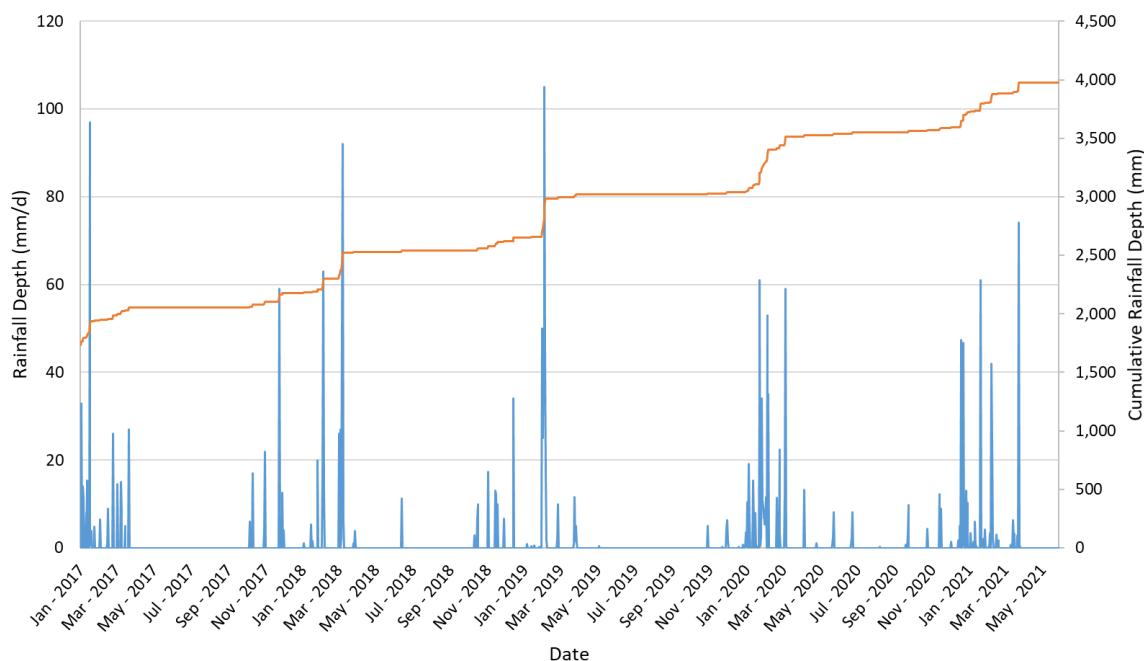


Figure 2.3: LLM Daily Recorded Rainfall

2.2.2 Runoff Modelling

The LLM WBM utilises the Australian Water Balance Model (AWBM) rainfall runoff module to simulate the rainfall and runoff inflows in each catchment. AWBM estimates catchment yield (flow) from rainfall and evaporation and is one of the most widely used rainfall-runoff models in Australia. The WBM simulates seven (7) different catchment types through separate AWBM modules, representing the runoff response for each of the following land use types:

- Natural.
- Dam.
- Hardstand.
- Paste Plant.

- Portal.
- Stockpile Crushing.
- Waste Dump.

The runoff simulated from the AWBM can be split into two forms:

- Surface runoff which travels overland to the destination; or
- Sub-surface which travels through the ground to reach the destination.

The focus of the 2021 model calibration is on verifying the calibrated AWBM and evaporation parameters used in the model to represent the rainfall and runoff response of the WBM.

2.2.3 Evaporation

The pan evaporation rates in the model were obtained from the SILO data base (Lat: -190.80°S Long: 139.05°E) and were generated based on interpolative methods using available Bureau of Meteorology (BoM) stations in the region. Due to limited number of stations in the region, long term average values were used in the WBM. Figure 2.4 shows the adopted daily evaporation rates per month. A pan factor of 0.85 was determined appropriate through model calibration (SLR, 2020) and applied to convert pan evaporation to lake evaporation.

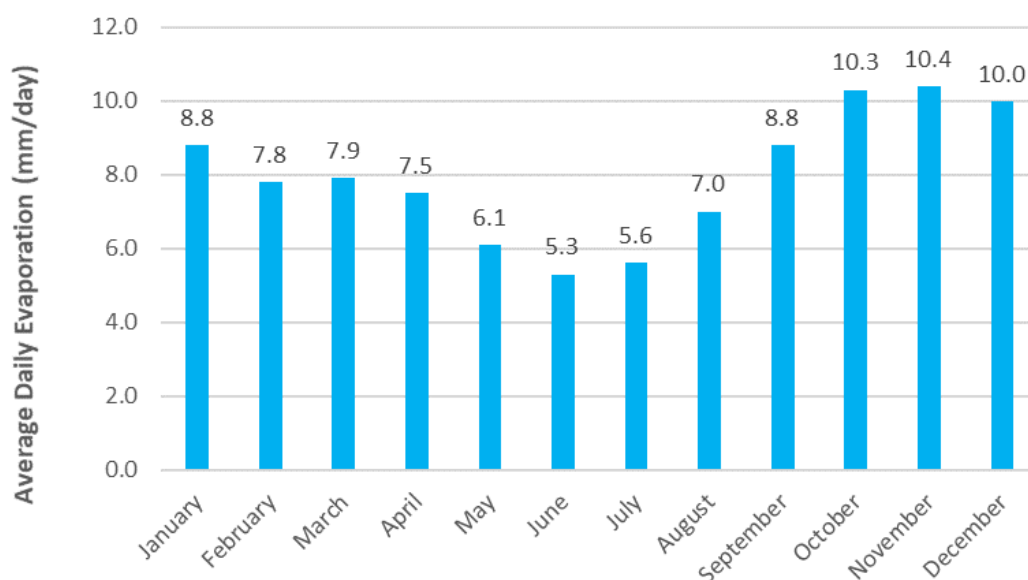


Figure 2.4: Adopted Evaporation Rates

2.2.4 Catchments

The four (4) catchments and landuse areas have been delineated based on recent aerial survey and imagery. Catchment areas are broken down into seven (7) separate landuse classifications which each have distinct runoff parameters effecting rainfall runoff yield. The current catchment boundaries are shown on Figure 2.1. Table 2.1 summarises the catchment and land use breakdown adopted in the existing WBM.

Table 2.1: Catchment Land Use Breakdown

Land Use	Area (ha)			
	CDA	CDB	PPD	LMD
Waste Dump	5.14	8.27	0.05	0.00
Stockpile Crushing	0.00	0.00	0.00	0.00

Land Use	Area (ha)			
	CDA	CDB	PPD	LMD
Dam	8.69	2.63	1.13	1.13
Paste Plant	0.00	0.00	0.69	0.00
Portal	0.00	0.00	0.00	0.00
Cleared or Hardstand	12.58	3.63	3.35	0.53
Natural / Rehabilitation	0.21	3.23	0.00	0.00
TOTAL	26.61	17.76	5.22	1.66

2.2.5 Process Inflows and Demands

LLM records the following process demands and inflows weekly (during the wet season) and monthly (outside of the wet season). Data provided for the period of 22nd June 2018 to 1st June 2021 was adopted in the model calibration (Engeny, 2021) and used as the basis of the adopted values in the assessment (refer to Sections 3.1, 4.1.1 and 4.2.1).

- Underground mine dewatering into CDA (Inflow).
- CDA to RO Plant (Demand).
- CDA to Sprinklers or Water Carts (Demand).
- CDA to Paste Plant (Demand).

It is noted that there are five minor wastewater inflows represented in the model that are estimates only. The following average site operation wastewater inflows have been adopted in the model, based on historical usage, as provided by LLM:

- Water Treatment Plant reject – 0.1 L/s.
- Wheel Wash Dirty Water – 0.15 L/s.
- CICO Shower and Laundry wastewater – 0.4 L/s.
- Light Vehicle and Heavy Vehicle Wash Bay wastewater – 0.25 L/s.
- Washbay Workshop wastewater – 0.25 L/s.

2.2.6 Operating Rules

The adopted storage capacities for the storages are based on storage curves provided by LLM and known spillway levels. The full supply volume (capacity) for each storage is summarised in Table 2.2.

Table 2.2: Storage Capacities

Storage	Storage Capacity (ML)
CDA	173.9
CDB	60.5
PPD	24.9
LMD (until ~2024)	5.3

The key operating rules and assumptions in the WBM include:

- Water management actively consolidates water to CDA.
- CDB transfers to CDA when the volume at CDB is greater than 10 ML and stops when CDA volume is greater than 100 ML.
- PPD transfers to CDA when volume at PPD is greater than 0.78 ML and stops when CDA volume is greater than 120 ML.
- LMD transfers to CDA when volume at LMD is greater than 1.92 ML and stops when CDA volume is greater than 145 ML.

2.3 AWBM PARAMETERS

Table 2.3 shows the AWBM parameters adopted in the 2021 WBM. These parameters were derived in the 2020 calibration update (SLR, 2020b) and confirmed in the 2021 review (Engeny, 2021). The performance of the WBM using the parameters in Table 2.3 are discussed in Section 2.4.

Table 2.3: AWBM Parameters

Parameter		Hardstand	Natural	Dam	Paste Plant	Stockpile	Waste Dump
Small storage capacity (mm)	C1	5	11	5	5	10	10
Medium Storage Capacity (mm)	C2	10	116	10	8	75	90
Large storage capacity (mm)	C3	25	232	15	18	110	130
Small partial area portion	A1	0.134	0.134	0.134	0.134	0.134	0.134
Medium partial area portion	A2	0.433	0.433	0.433	0.433	0.433	0.433
Large partial area portion	A3	0.433	0.433	0.433	0.433	0.433	0.433
Baseflow index constant	BFI	0.1	0.2	0.2	0.2	0.2	0.2
Baseflow recession constant	K	0.1	0.1	0.1	0.1	0.1	0.1
Daily streamflow recession constant	Ks	0.1	0.1	0.1	0.1	0.1	0.1

2.4 MODEL CALIBRATION

The WBM receives annual updates including recalibration as part of the continuous improvement of effective site water management. The model has most recently been calibrated for the period June 2018 to May 2021 and is discussed in detail in the *Lady Loretta Mine Water Balance Model Update and DSA Assessment* (Engeny, 2021).

The total recorded combined volume for the four storages against the calibration model results from the WBM are shown in Figure 2.5 (Engeny, 2021). The calibration results for this period show the model reproduces the site inventory trend well however there are some inconsistencies in peak volumes as well as rates of reduction. Inconsistencies in the model calibration are a function of the following:

- Runoff parameters.
- Demands applied as a constant historical average rate
- Spatial distribution of rainfall over the sites catchment not captured by the site's rainfall gauge.

Sensitivity analyses of the runoff parameters indicated that adopting parameters producing unrealistically high runoff did not significantly improve the match during the larger rainfall events (January 2019 and December 2020 events) and worsened the match for other parts of the calibration period. Recalibration of AWBM parameters was not undertaken during this calibration effort.

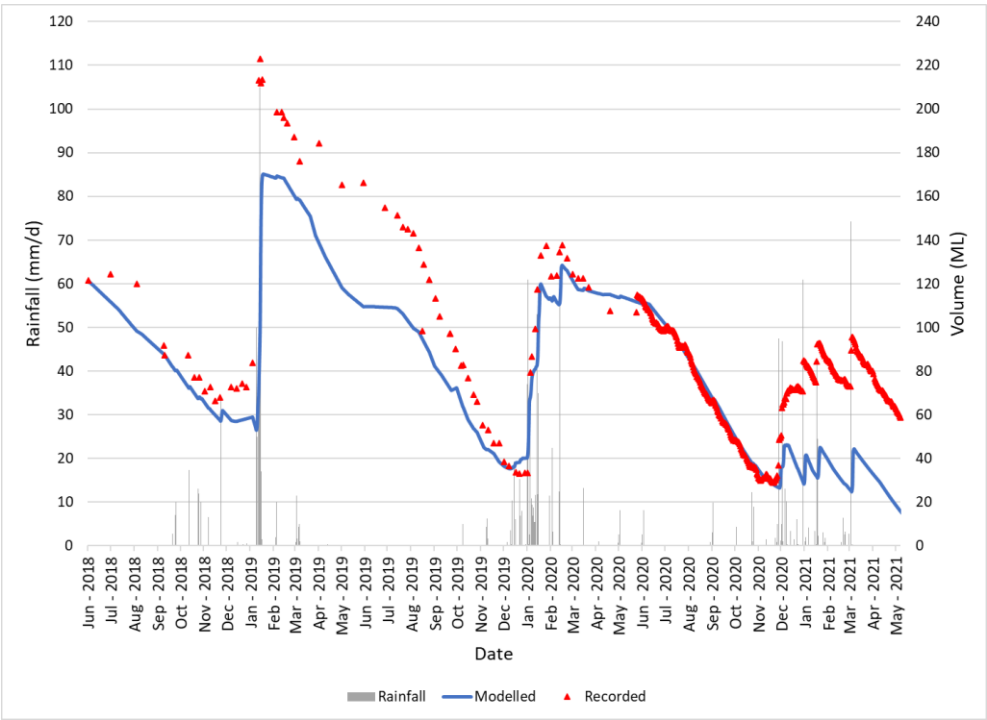


Figure 2.5: Total Site Inventory Calibration Results

3 EXISTING SYSTEM PERFORMANCE

An assessment of the existing water management system performance has been undertaken using the calibrated water balance model. The system performance is assessed based on containment performance of the water storages.

3.1 PROCESS INFLOWS AND DEMANDS

The following water sources and demands were used to assess the performance of the existing system and are based on data supplied by LLM on the long-term average source and demands whilst the site is in operation.

- Underground Mine Dewatering into CDA – 0.7 ML/d (Source).
- CDA to RO Plant – 0.3 ML/d (Demand).
- CDA to Sprinkler/Watercarts – 0.4 ML/d (Demand).
- CDA to Paste Plant – 0.3 ML/d (Demand).

3.2 ASSESSMENT METHODOLOGY

The operational water balance model was simulated over a 1 year forecast period for 500 realisations using stochastic climate data to determine the containment performance of each of the storages. The containment performance of the storages is assessed as the frequency of years overflow occurs from each storage. The operational performance target for all storages is achieving 1% Annual Exceedance Probability (AEP) of overflow or rarer.

3.3 ASSESSMENT RESULTS

The containment performance of the water containment storages at LLM are summarised in Table 3.1 and the total site inventory forecast for the assessment is shown in Figure 3.1. The total system initial volume (~50 ML) was adopted as it is representative of the typical volume prior to the start of the wet season, as predicted by model runs and based on historical dam inventories. The results show the dams have a very high containment standard with all dams overflowing 1% of years or less.

Table 3.1: Containment Assessment – Existing System

Storage	Capacity (ML)	Initial Volume (ML)	Annual Overflow Frequency (%)
CDA	173.9	30	0.2
CDB	60.5	15	1.0
PPD	24.9	5	0.4
LMD	5.3	0.25	0.4

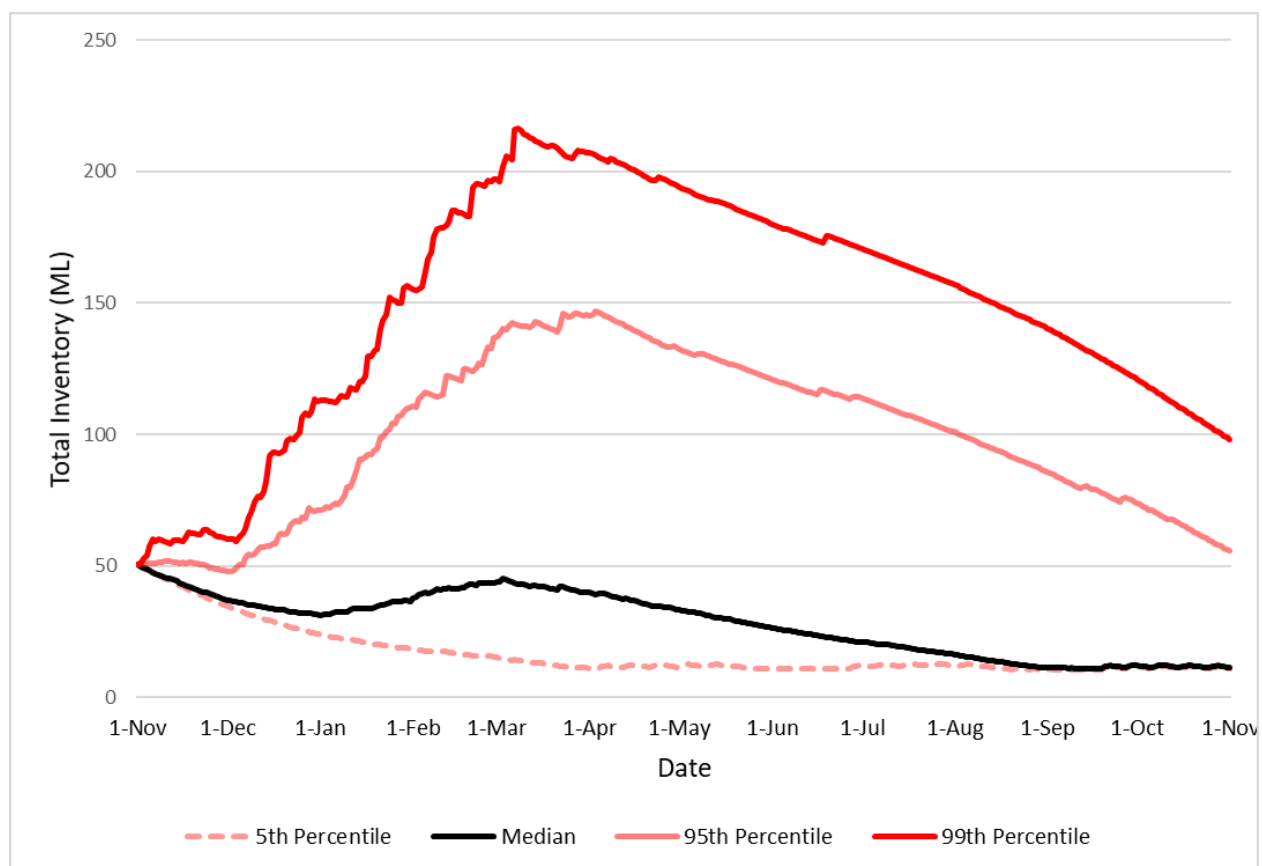


Figure 3.1: Total Site Inventory – Existing System

4 CLOSURE WATER MANAGEMENT ASSESSMENT

Lady Loretta Mine closure is planned to occur over two stages which have distinct water management strategies. These stages include:

Stage 1 – End of mining operations – the current campaign of mining is completed (2025) and minimal activities on site (years 2025 to 2032).

Stage 2 - End of commercial proposition – The LLM site undergoes rehabilitation, decommissioning and ongoing monitoring (From 2032).

This section outlines the water management system under the above two stages and the performance of the water management system.

Up until the end of Stage 1, it is expected there will be minimal changes to the LLM site catchments. The existing regulated dams will continue operating. There will be minimal landform design works and clean water catchments will remain in place, with the exception of LMD with planned decommissioning works prior to this stage (~2024). Following completion of the current mining campaign, LLM shall maintain the various fixed plant and infrastructure facilities in an operable condition to support future mining campaigns.

At the end of commercial proposition, full implementation of the decommissioning and rehabilitation program will occur and a post mining final landform that broadly reflects the pre-mining condition will be created. Demolition and rehabilitation works will commence and changes to the characteristics of the site catchment and runoff will occur as part of the post mining final landform design.

The three remaining regulated dams, once no longer required for management of the mine affected water inventory, will be converted to Erosion and Sediment Control (ESC) facilities to support the establishment of vegetation. Once this has been achieved, the ESC facilities will be available for decommissioning and the area reprofiled to complement the local terrain and made to be free draining.

It is anticipated, the three regulated dams will remain in place for 12 years after the end of commercial proposition. The most significant change of the post mining final landform will be the Waste Rock Emplacement which will comprise a steeply sloped batter and relatively flat crest plateau. Non-mineralised waste rock at the ROM pad will be partially relocated for underground backfill and the area recontouring to match the local topography and drainage lines. Revegetation works will occur across site whereby the land will be ripped and seeded which will alter runoff response across the catchments.

4.1 STAGE 1 – END OF MINING OPERATIONS

4.1.1 Process Inflows and Demands

The following water sources and demands were used to assess the performance of the Stage 1 – End of mining operations scenario and are based on data supplied by LLM.

Inflows

- Mine dewatering continues to CDA – 0.7ML/day (groundwater inflow rate).
- Workshop / vehicle wash down water to CDB – 0.0025 ML/day (1% of current activity).
- Wheel wash to CDA – 0.0015 ML/day (1% of current activity).
- CICO Laundry to CDA – 0.004 ML/day (1% of current activity).

Demands

- CDA RO plant runs as required when CDA level is above DSA – 0.8 ML/day (permeate transferred to third party).
- CDA to underground occurs as required when CDA level is above the mandatory reporting level (MRL) – 1 ML/day.
- CDA to dust suppression occurs as required when CDA level is above MRL – 0.3 ML/day.
- Paste plant not operational.

Based on data supplied by LLM, the underground void volume of ~600ML will remain at completion of the current Life of Asset (LOA); 2025.

4.1.2 Catchment Changes

LMD is proposed to be decommissioned in ~2024, before the beginning of the Stage 1 period, and its catchment is therefore not considered in the modelling for Stage 1 – End of mining operations. The catchment breakdown for CDA, CDB and PPD will remain as per Table 2.1 as minimal landform design works are proposed for the Stage 1 period.

4.1.3 Dam Transfer Rules

- Water is actively consolidated in CDA.
- CDB transfers to CDA when CDB volume > 20 ML, stops when CDA volume > 130 ML (~15 ML above CDA MRL).
- PPD transfers to CDA when PPD volume > 10 ML, stops when CDA volume > 120 ML (per current operations).
- LMD decommissioned (~2024).

4.1.4 Assessment Methodology

The Stage 1 – End of mining operations water balance model was simulated over a 7-year forecast period (2025 – 2032) for 500 realisations using stochastic climate data to determine the containment performance of each of the storages. The containment performance of the storages is assessed as the frequency of years overflow occurs from each storage. The operational performance target for all storages is less than 1% Annual Exceedance Probability (AEP) of overflow.

4.1.5 Assessment Results

The containment performance of the water containment storages at LLM are summarised in Table 4.1 and the total site inventory is shown in Figure 4.1. The results show after the end of mining operations all dams are expected to continue to achieve a containment standard better than 1% AEP (overflows is less than 1% of years) besides CDB which has a slightly increased overflow rate due to proposed changes to demands and dam transfer rules compared to the existing operational system. Contingencies are available to slow down underground mine dewatering rates and other approaches such as dam transfers and sending water back underground to reduce the annual overflow frequency below 1% at CDB.

The Stage 1 – End of mining operations containment modelling results indicate the following key conclusions:

- Under all climate scenarios (up to the 99th percentile), the total site inventory does not exceed the maximum available storage capacity (259 ML).
- The overall trend in storage inventory, including maximum volume, is relatively consistent across each year of the simulation. This indicates that LLM is not expected to accumulate water across the Stage 1 period.

Table 4.1: Containment Assessment – End of Mining Operations

Storage	Capacity (ML)	Initial Volume (ML)	Average Annual Overflow Frequency (%)
CDA	173.9	30	0.4
CDB	60.5	15	1.2
PPD	24.9	5	0.7
Total Volume	259	50	

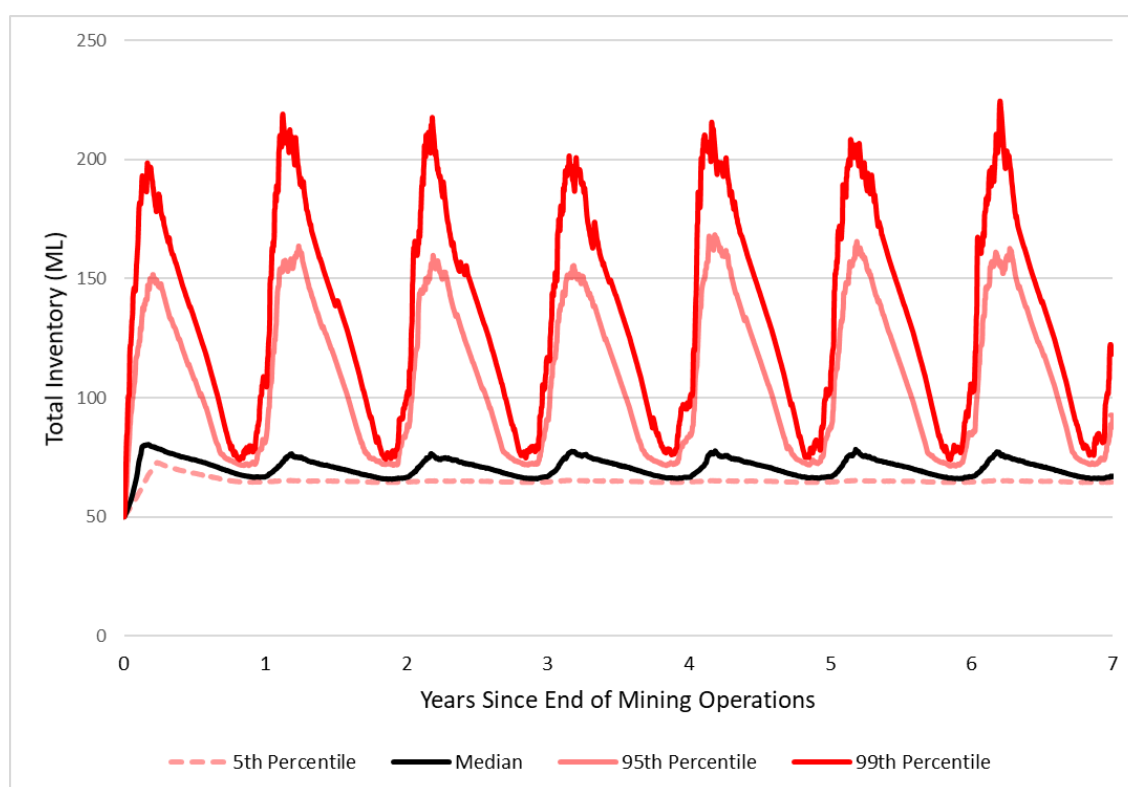


Figure 4.1: Total Site Inventory – End of Mining Operations

4.2 STAGE 2 – END OF COMMERCIAL PROPOSITION

4.2.1 Process Inflows and Demands

Following the end of commercial proposition stage, a 3-year decommissioning and rehabilitation phase will occur, followed by a nominal 25-year post-closure monitoring and maintenance phase. The first three years include water demands, transfers and catchment changes while the decommissioning and rehabilitation works are being undertaken. The following 5 years includes no water demands and transfers and the dam inventories are managed by evaporation only while the rehabilitation establishes (following this, the remaining regulated dams are proposed to be decommissioned). The following water sources and demands were used to assess the performance of the Stage 2 – End of commercial proposition scenario and are based on data supplied by LLM.

Inflows

- Mine dewatering continues to CDA – 0.7 ML/day for 6 months to allow removal of infrastructure.
- Workshop / vehicle wash down water to CDB – 0.25 ML/day for 12 months.

- Wheel wash to CDA – 0.15 ML/day for 12 months.
- CICO Laundry to CDA – 0.4 ML/day for 6 months.

Demands

- CDA RO plant runs as required when CDA inventory is above 10 ML – 0.8 ML/day for a 3-year decommissioning period.
- CDA to underground occurs as required when CDA level is above MRL – 1 ML/day.
- All other demands are no longer operational.

4.2.2 Catchment Changes

The three remaining regulated dams, once no longer required for management of the mine affected water inventory, will be converted to Erosion and Sediment Control (ESC) facilities to support the establishment of vegetation (i.e. 3-year decommissioning and rehabilitation phase). Following this phase, the modelling assumes full rehabilitation of all catchment areas reporting to the remaining regulated dams. This is highlighted in Table 4.2, based on the following timeline:

- 2032 = Beginning of decommissioning and rehabilitation phase.
- 2035 = Beginning of post closure maintenance and monitoring phase.

Table 4.2: Catchment Land Use Breakdown (Stage 2)

Stage	Area (ha)							
	Waste Dump	Stockpile Crushing	Dam	Paste Plant	Portal	Cleared or Hardstand	Natural / Rehabilitation	Total
CDA								
2032	5.15	0	8.69	0	0	12.58	0.21	26.61
2035	0	0	8.69	0	0	0	17.92	
CDB								
2032	8.27	0	2.63	0	0	3.63	3.23	17.76
2035	0	0	2.63	0	0	0	15.49	
PPD								
2032	0.05	0	1.13	0.69	0	3.35	0	5.22
2035	0	0	1.13	0	0	0	4.09	

It is anticipated that the dam areas will also be decommissioned and rehabilitated over the full post closure phase. As the focus of this assessment is on the containment performance of the regulated dams, the catchment changes post dam decommissioning have not been captured.

4.2.3 Dam Transfer Rules

- Dam rules as per Section 4.1.2 throughout a 3-year decommissioning period and then no transfers for the remaining 5 years (establishment period).
- Increased transfer rate from CDB to CDA – 10 L/s for the first three years.

4.2.4 Assessment Methodology

The Stage 2 – End of commercial proposition water balance model was simulated over a 8-year forecast period for 500 realisations using stochastic climate data to determine the containment performance of each of the storages. This includes the 3-year decommissioning and rehabilitation phase, followed by 5 years with no water demands or transfers and the dam inventories are managed by evaporation only. Following this 8-year period, rehabilitation is expected to be fully established, and

the performance of the water management system is not expected to change. The containment performance of the storages is assessed as the frequency of years overflow occurs from each storage. The operational performance target for all storages is less than 1% Annual Exceedance Probability (AEP) of overflow.

4.2.5 Assessment Results

The containment performance of the water containment storages at LLM are summarised in Table 4.3 and the total site inventory is shown in Figure 4.2. The results show after the end of commercial proposition all remaining dams are expected to continue to achieve a containment standard better than 1% AEP (overflows in less than 1% of years).

The Stage 2 – End of commercial proposition containment modelling results indicate the following key conclusions:

- Under all climate scenarios (up to the 99th percentile), the total site inventory does not exceed the maximum available storage capacity (259 ML). Figure 4.3 to Figure 4.5 show the modelled inventories against available capacity for individual dams.
- Following the first year, and full dewatering is achieved, the overall trend in storage inventory, including maximum volume, is relatively consistent across each year of the simulation. This indicates that LLM is not expected to accumulate water across the Stage 2 period.
- Once the regulated dams are decommissioned and repurposed as erosion and sediment control facilities, there will likely be between 2 ML (50th percentile climate scenario) and 50 ML (99th percentile climate scenario) of surface water runoff remaining in the storages.

Table 4.3: Containment Assessment – End of Commercial Proposition

Storage	Capacity (ML)	Initial Volume (ML)	Average Annual Overflow Frequency (%)
CDA	173.9	30	0.1
CDB	60.5	15	0.9
PPD	24.9	5	0.4
Total	259	50	

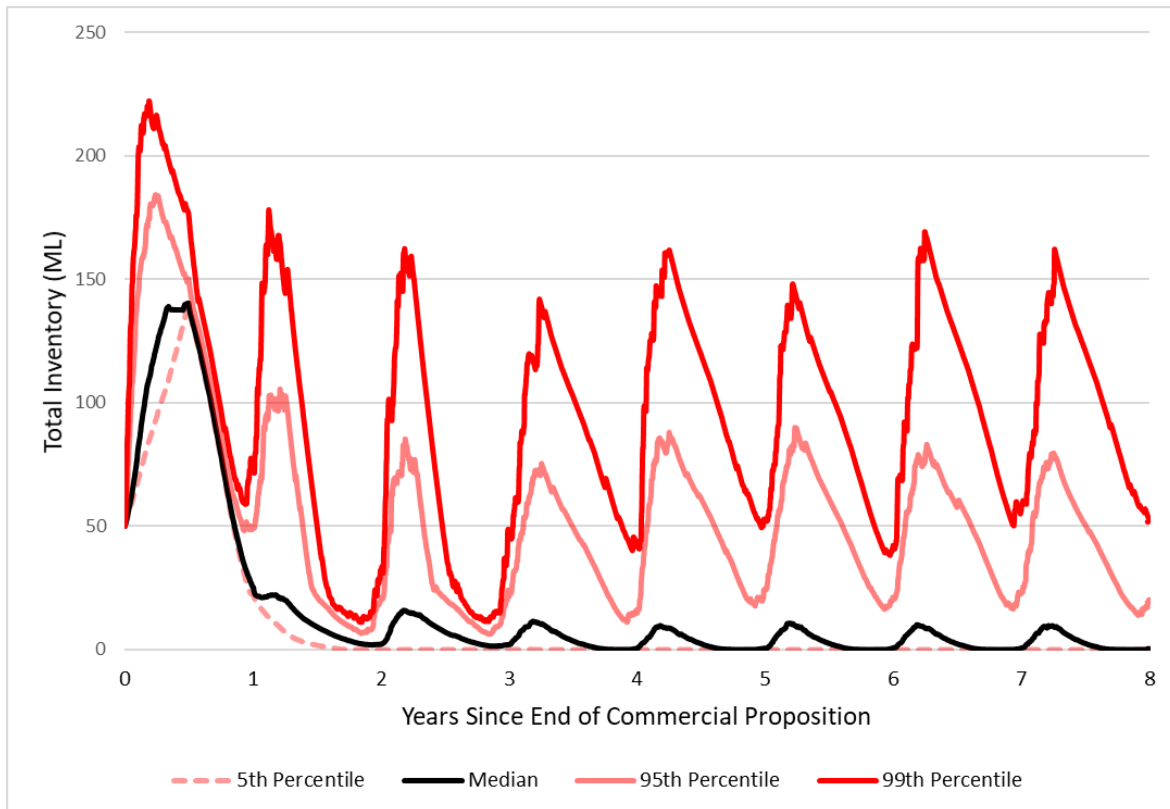


Figure 4.2: Total Site Inventory – End of Commercial Proposition

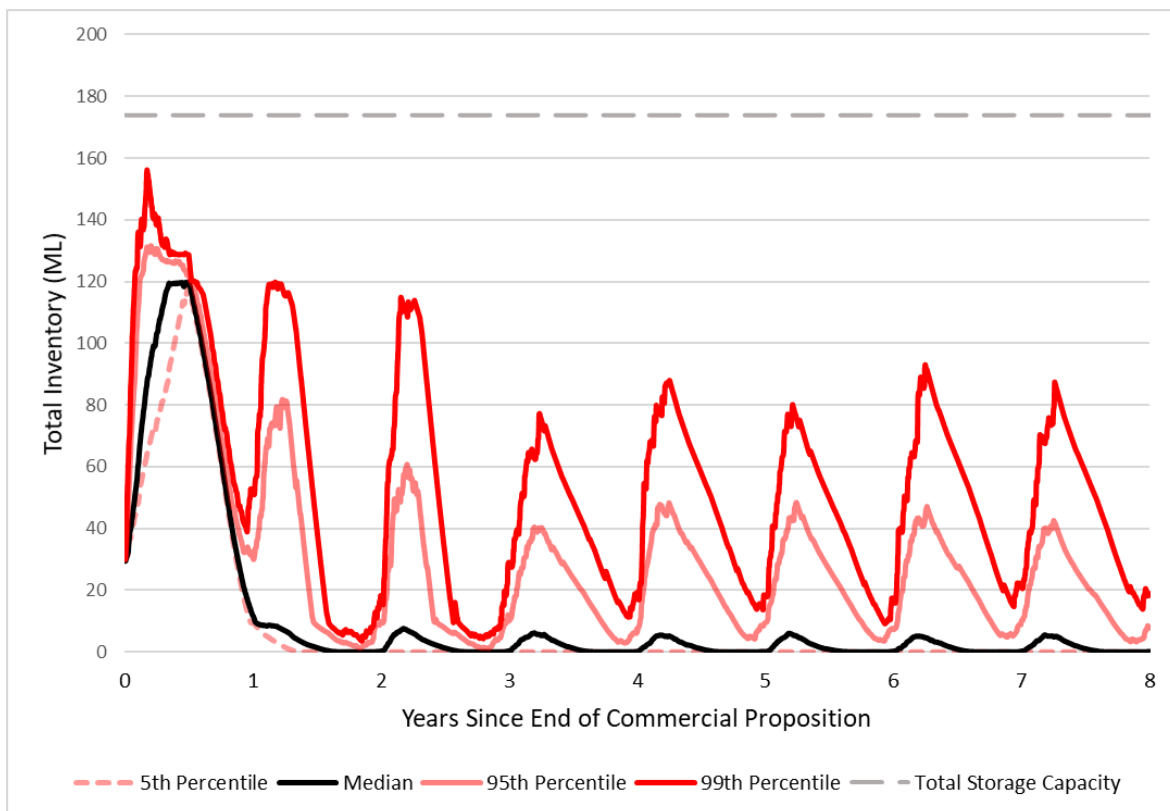


Figure 4.3: CDA Inventory – End of Commercial Proposition

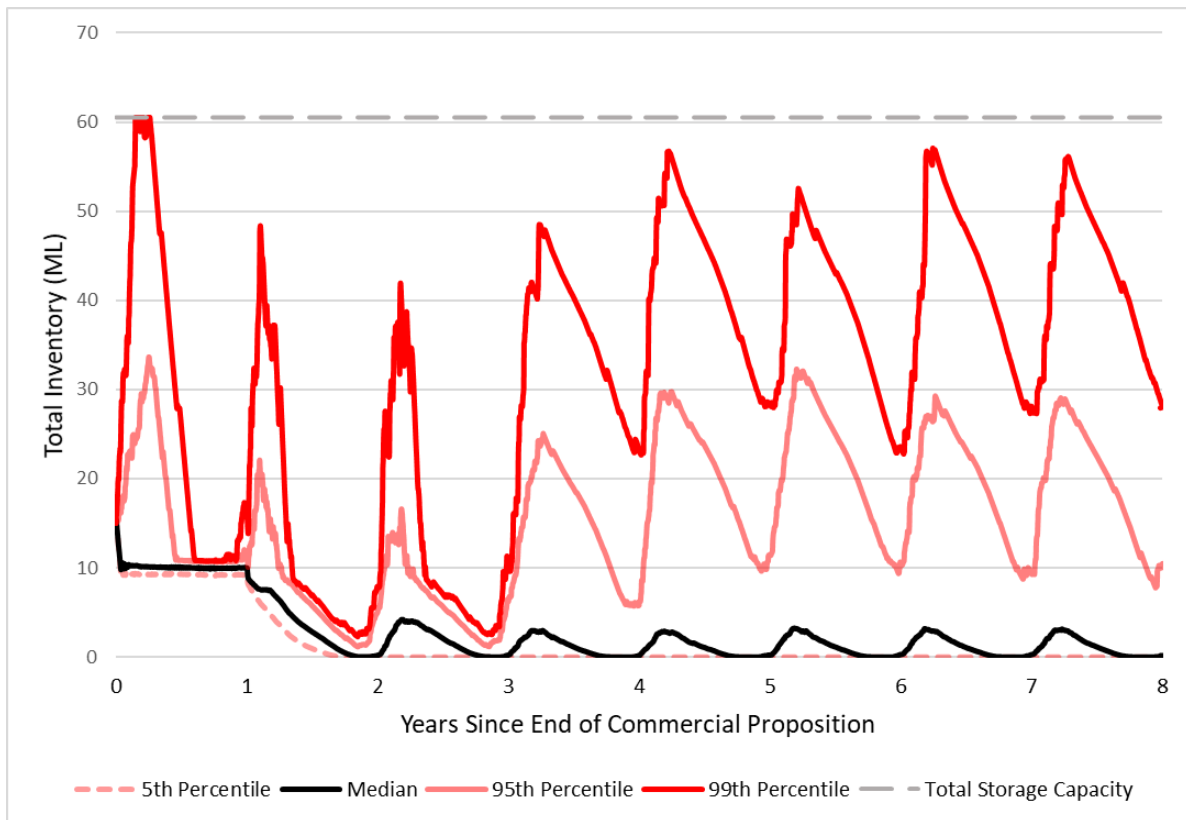


Figure 4.4: CDB Inventory – End of Commercial Proposition

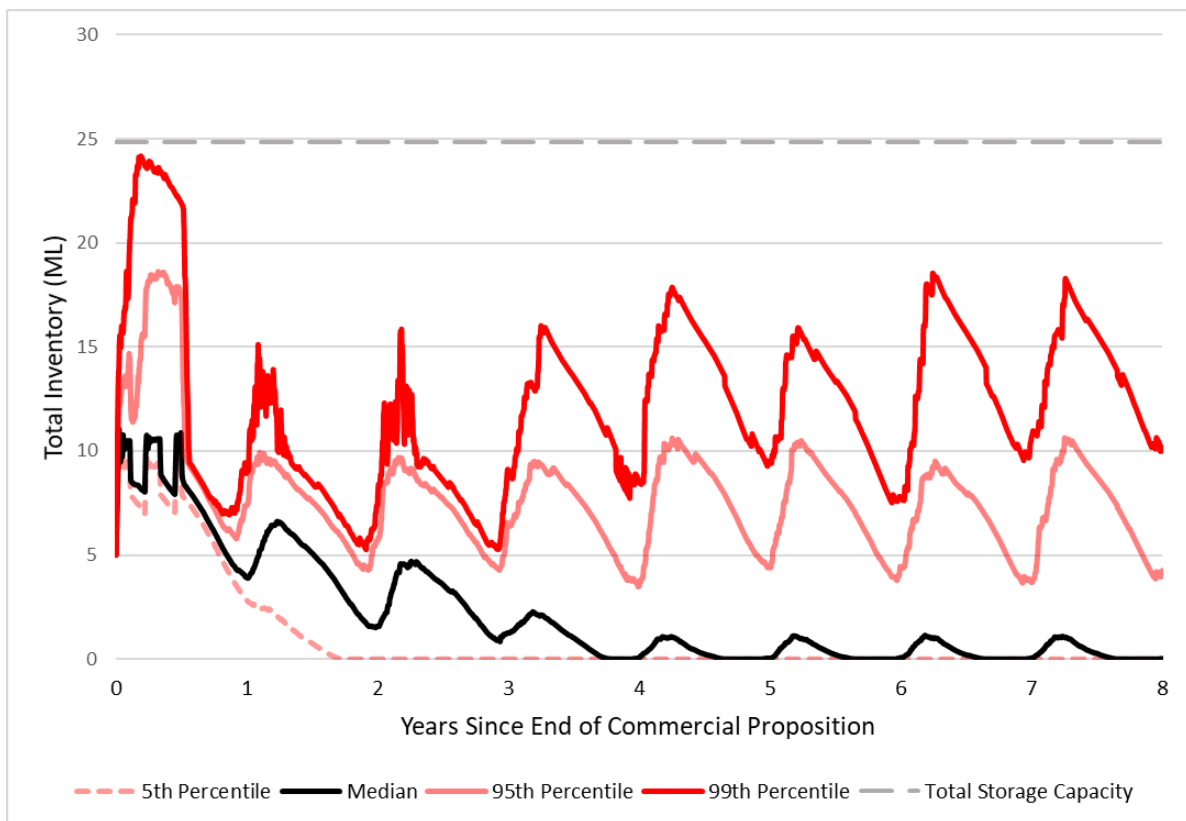


Figure 4.5: PPD Inventory – End of Commercial Proposition

5 CONCLUSIONS AND RECOMMENDATIONS

A containment assessment was undertaken on LLM's regulated dam structures to assess the performance of the site water management system under a closure scenario in support of the Progressive Rehabilitation and Closure Plan (PRCP). The assessment was undertaken using the existing calibrated and routinely maintained operational water balance model.

Two closure scenarios, representing the proposed progressive rehabilitation stages were assessed, including:

- Stage 1 – End of mining operations – the current campaign of mining is completed (2025), and minimal activities on site (years 2025 to 2032).
- Stage 2 - End of commercial proposition – The LLM site undergoes rehabilitation, decommissioning, and ongoing monitoring (From 2032).

The assessment indicated that during Stage 1 – End of mining operations, all dams are expected to continue to achieve a containment standard better than 1% AEP (overflows is less than 1% of years) besides CDB which has a slightly increased overflow rate (1.2%) due to proposed changes to the demands and dam transfer rules compared to the existing operational system. During Stage 2 – End of commercial proposition, all dams are expected to achieve a containment standard of 1% AEP or better.

The performance assessment for both stages indicate:

- Under all climate scenarios (up to the 99th percentile), the total site inventory does not exceed the maximum available storage capacity (259 ML).
- The overall trend in storage inventory, including maximum volume, is typically consistent across each year of the simulation. This indicates that LLM is not expected to accumulate water during the closure period.
- Once the remaining regulated dams (CDA, CDB and PPD) are decommissioned and repurposed as erosion and sediment control facilities, there will likely be between 2 ML (50th percentile climate scenario) and 50 ML (99th percentile climate scenario) of surface water runoff remaining in the storages.

The only impact identified by the performance assessment is the 1.2% overflow frequency (greater than the target 1%) from CDB during Stage 1 – End of mining operations. In order to reduce the annual overflow frequency below 1%, increased pumping capacity is required between CDB and CDA (approximately 10 L/s pump rate). Sufficient underground void volume (of ~600ML) will remain at completion of the current LOA and contingencies such as slowing down underground mine dewatering rates and transferring water back underground will be available.

6 QUALIFICATIONS

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7 REFERENCES

DES. (2016). *Manual for assessing consequence categories and hydraulic performance of structures – Version 5.02*.

Engeny (2021). *Lady Loretta Mine Water Balance Model Review and DSA Assessment* (Doc ref: M66000_066-REP-001).

Lady Loretta, LLM (2021). *Lady Loretta Water Management Plan* (Z-LLM-OPS-PLN-Water Management Plan).

SLR. (2020a). *Lady Loretta Mine Water Balance Update and DSA Calculation* (Doc ref: 620.12436.00017).

SLR. (2020b). *Lady Loretta Mine Water Balance Model Calibration* (Doc ref: 620.12436-MO1).



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APPENDIX B FLOOD ASSESSMENT

Flood Assessment for the Progressive Rehabilitation and Closure Plan

Lady Loretta Mine

Gencore Limited
1636-03-B2, 25 May 2022

Report Title	Flood Assessment for the Progressive Rehabilitation and Closure Plan, Lady Loretta Mine
Client	Gencore Limited
Report Number	1636-03-B2

Revision Number	Report Date	Report Author	Reviewer
0	14 May 2022	JF	JO
1	23 May 2022	JF	JO
2	25 May 2022	JF	JO

For and on behalf of WRM Water & Environment Pty Ltd
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Julian Orth
Principal Engineer

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1 Introduction

1.1 BACKGROUND

Glencore Limited (Glencore) is currently preparing the Progressive Rehabilitation and Closure Plan (PRCP) for final landforms associated with the Lady Lorretta Mine (LLM). Figure 1.1 shows the site location and drainage characteristics. Figure 1.2 shows the locations of the PRCP related infrastructure, which includes the rehabilitated waste rock emplacement, rehabilitated dams, and rehabilitated infrastructure areas and associated drainage. The site is proposed to be fully rehabilitated, and no Non-Use Management Areas (NUMAs) such as final voids are proposed.

Glencore engaged WRM Water & Environment Pty Ltd (WRM) to undertake hydrologic and hydraulic modelling for these LLM final landforms in support of the PRCP preparation.

The Department of Environment and Science's (DES) *Guideline - Progressive rehabilitation and closure plans* (PRC plans) (DES, 2019) require a flood plain model report to be included in the rehabilitation planning part of the PRCP, the intent of which is to:

- represent the flood plain under removal of all temporary structures or features;
- assess the flooding susceptibility and influence across the site; and
- confirm the final landform to be stable.

The PRCP guidelines require flood plain modelling to be undertaken in accordance with the Australian Rainfall and Runoff (ARR) guidelines and excluding artificial features on the site. Artificial features under the PRCP schedule are defined as structures or features that are temporary, that will require a level of maintenance greater than the level of maintenance that would be required had the schedule not been carried out, or that interfere with or affect relevant watercourses of the natural flow of water. Such features will be identified and excluded from the flood modelling.

DES (2019) defines a “relevant watercourse” as a watercourse that, under the Strahler method, is a stream ordered as a fourth order stream or higher. It is noted that lower ordered streams also require assessment against the decision criteria in the EP Act.

Hydrologic and hydraulic modelling for the 50% Annual Exceedance Probability (AEP), 1% AEP, 0.1% AEP event and Probable Maximum Flood (PMF) was undertaken to assess flooding characteristics at the LLM under final landform conditions as per the DES (2019 & 2020) requirements.

1.2 PURPOSE OF REPORT

This flood modelling report provides a description of the adopted assessment methodology and the key modelling results for the assessment of flooding at the LLM. The contents of this report may be used as input to the PRCP.

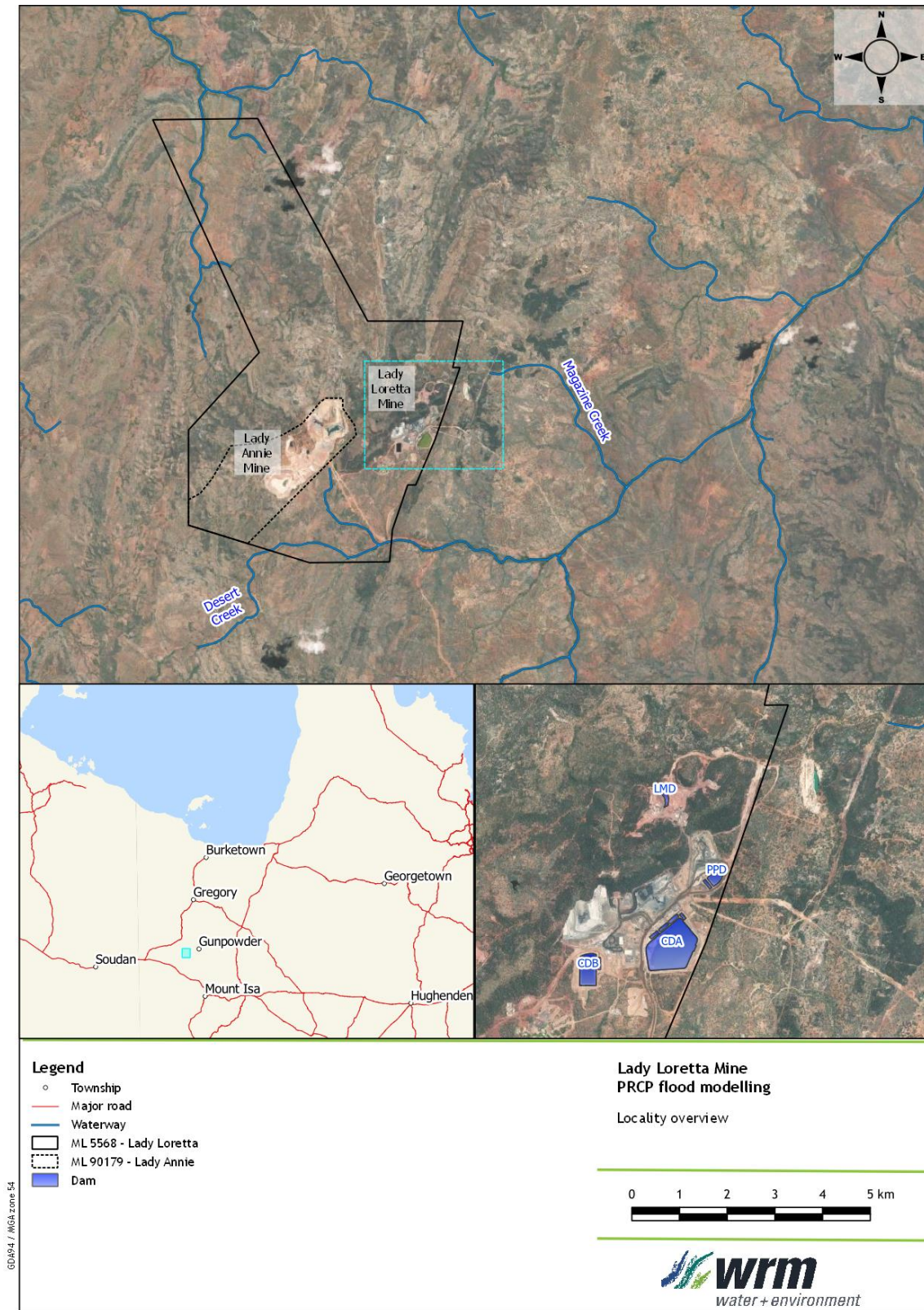


Figure 1.1 - Locality and key drainage features

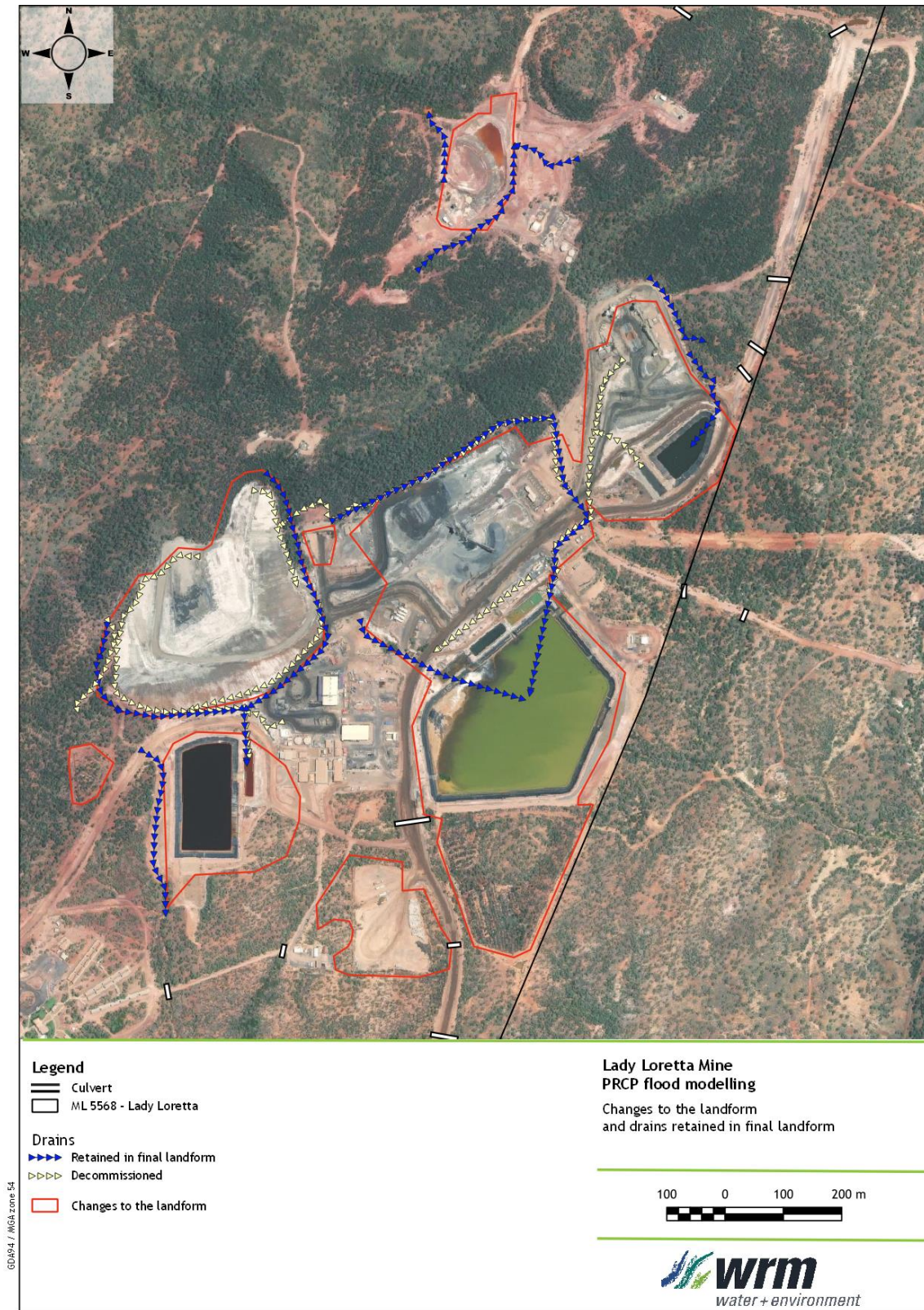


Figure 1.2 - Site overview, proposed changes to the landform and drains

2 Regional and local catchments

Figure 2.1 shows the catchments and key drainage features in the vicinity of LLM. The following sections describe the existing catchments and drainage features in the vicinity of the site.

2.1 REGIONAL TOPOGRAPHY AND CATCHMENTS

The LLM operation is located within the Leichhardt River catchment at the headwaters of Magazine and Desert creeks. The southern part of the LLM site is located within the Desert Creek catchment. The northern part of the LLM site is located within the Magazine Creek catchment. The nearby Lady Annie operation is in the Desert Creek catchment upstream of LLM.

Based on the GeoScience Australia dataset, the upper headwaters of Magazine and Desert Creeks are characterised by steep first and second order watercourses (see Figure 2.1). These upstream catchments have been modified within the Mine site to allow for mining operations.

Magazine Creek remains a first stream order classification from its northern headwaters and past the northeastern mine lease boundary and is a second order stream at its confluence with Desert Creek. The Desert Creek stream order classification ranges between first order streams in the upper southwestern headwater to a fourth order watercourse at the downstream southeastern boundary of the mine lease. Desert Creek is of fifth stream order classification at its confluence with Magazine Creek approximately 6.2 km downstream of the LLM mine lease boundary. The following catchment areas are of note:

- Desert Creek has a catchment area of approximately 29.7 km² to the downstream mine lease boundary and an additional 107.7 km² upstream of the Magazine Creek confluence; and
- Magazine Creek has a catchment area of approximately 1.5 km² to the downstream mine lease boundary and 10.5 km² upstream of the Desert Creek confluence.

2.2 SITE DRAINAGE

The Mine site is located at the headwaters of Magazine and Desert creeks. Little external catchment drains to the Mine, with only first order watercourses intersecting the site (see Figure 2.1).

Several drains direct runoff around the mine site, a number of which are proposed to be retained in the final landform (see Figure 1.2).

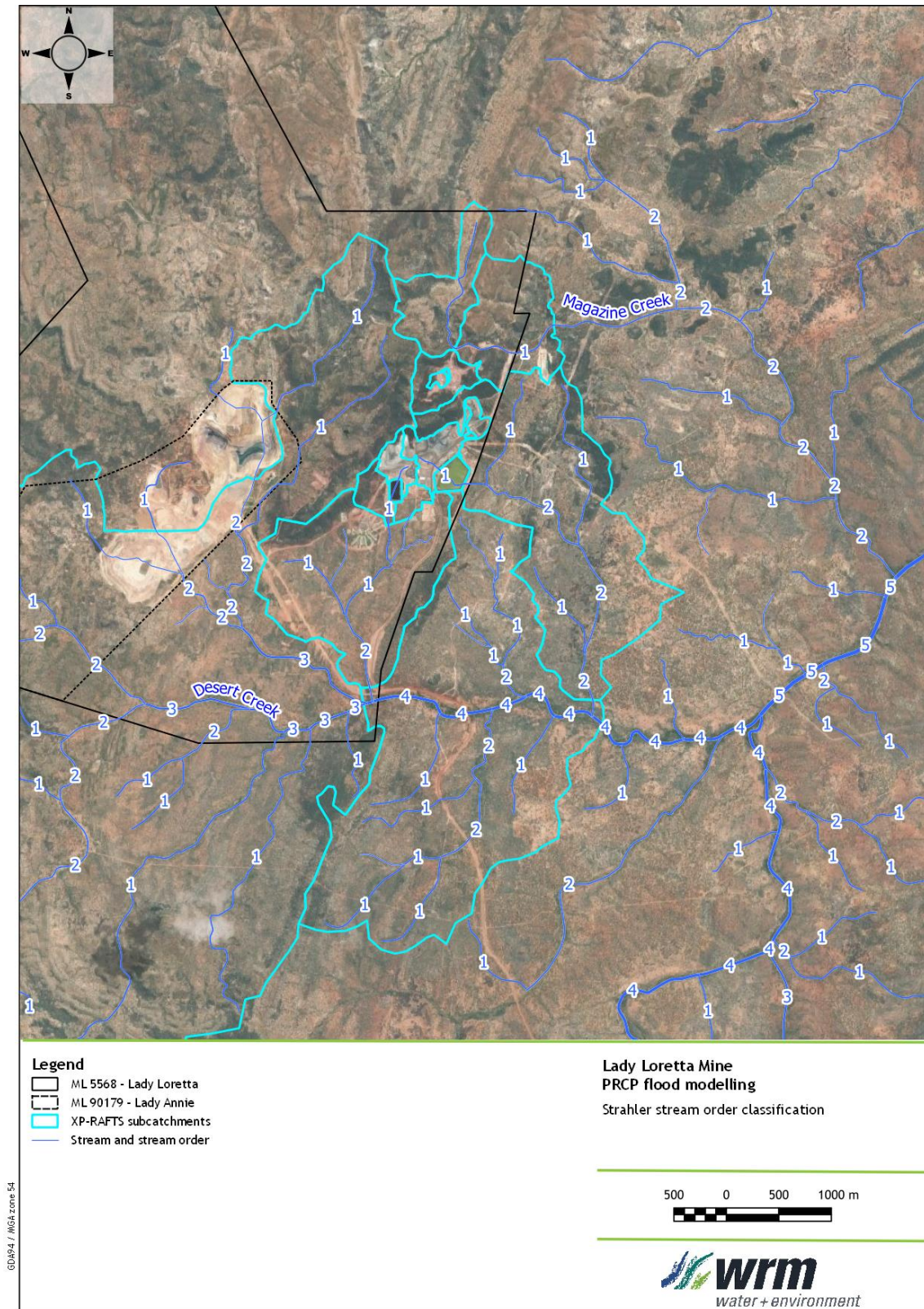


Figure 2.1 - Regional and local catchments and Strahler stream order classification

3 Available data

3.1 FLOODPLAIN TOPOGRAPHIC DATA

Figure 3.1 shows the extents of available topographic data for the study. The topographic data was used to develop a XP-RAFTS hydrologic model (refer to Section 5) and Two-Dimensional Unsteady Flow (TUFLOW) hydraulic model (refer to Section 6) developed for this study. The following topographic data was available for use in this study:

- Light Detection and Ranging (LiDAR) data provided as 199 American Standard Code for Information Interchange (ASCII) tiles merged to a grid with 1 m resolution covering the hydraulic model extent including the existing waste rock emplacement, mine infrastructure area, mine water dams and around the camp and Sewage Treatment Plant (STP) within the LLM mine lease;
- the final landform surface “Post Mining Final Landform.tif”, which had a grid resolution of 5 m, was provided as by ATC Williams on 28 March 2022. It was assumed for the purpose of this assessment the landform surface provided only included permanent features and temporary features were removed; and
- SRTM data for the remaining areas, used to define the hydrologic model where higher resolution data was unavailable.

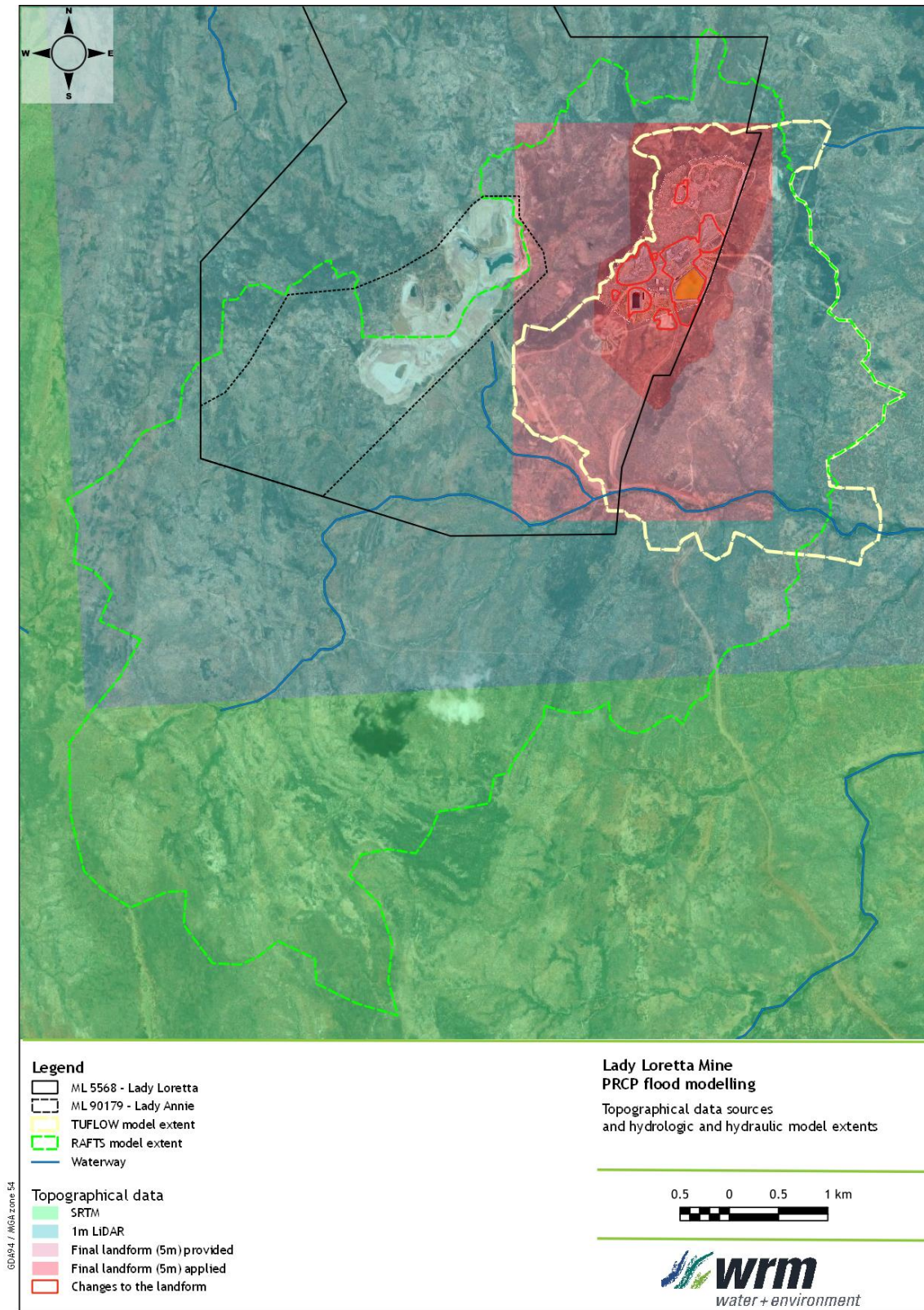


Figure 3.1 - Topographical data availability

4 Final landform configuration

The available topographic data described in Section 3 was combined with the post-mining landform data provided by ATC Williams to develop the final landform topography at the LLM site. The final landform topography was used as the basis for hydrologic and hydraulic modelling. Figure 4.1, Figure 4.2 and Figure 4.3 show the modelled final landform configuration for CDA, CDB, PPD, LMD, mine infrastructure area and waste rock emplacement.

The portal box cut, infrastructure areas including the Run of Mine (ROM), Paste Plant area and dams will be regraded where required to be free draining and rehabilitated. It is proposed to retain the rehabilitated waste rock emplacement, haul roads and associated drainage in the final landform, subject to landholder engagement. There are no residual voids associated with the final landform of the LLM site.

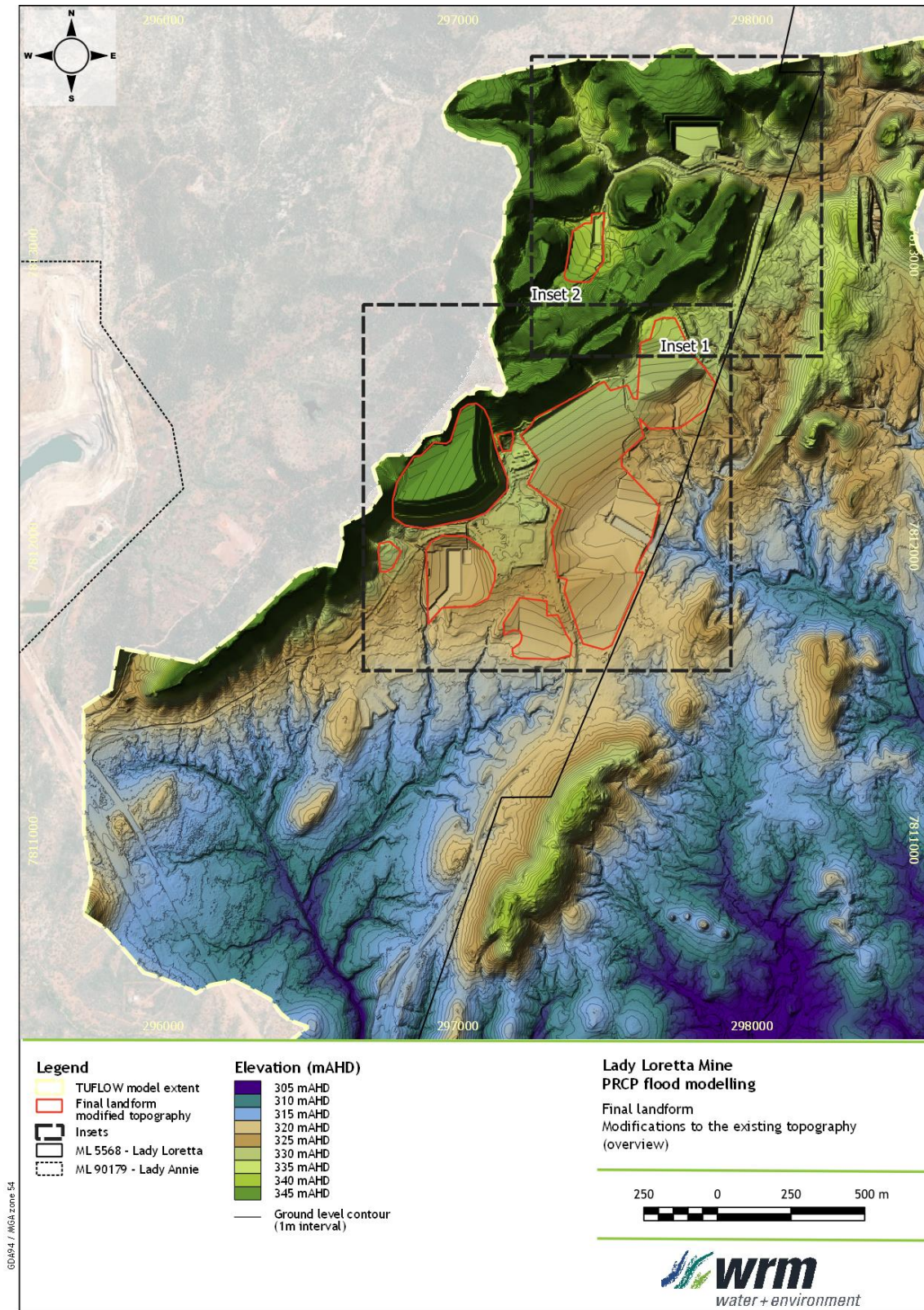


Figure 4.1 - Final landform configuration, overview

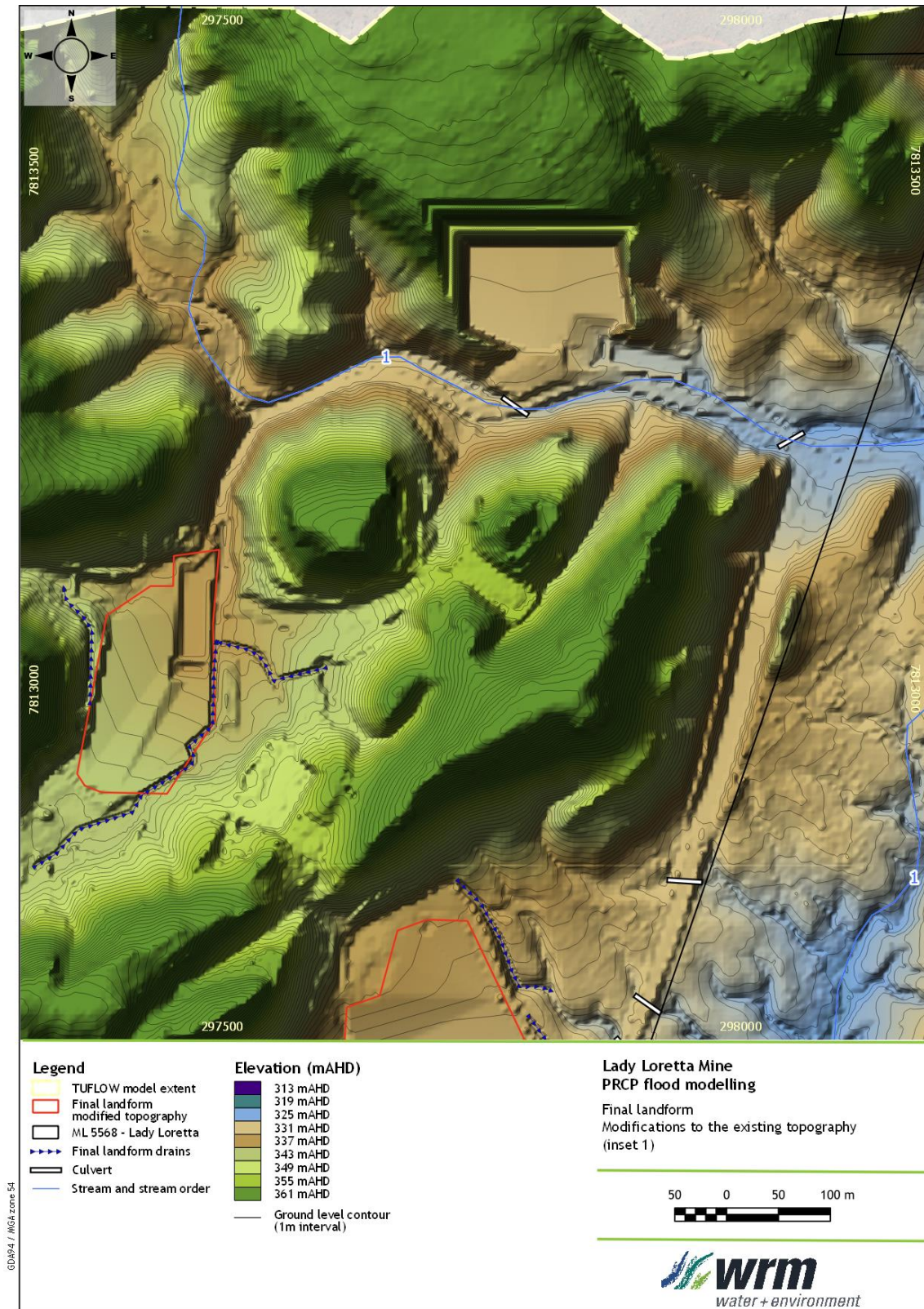


Figure 4.2 - Final landform configuration, LMD (inset 1)

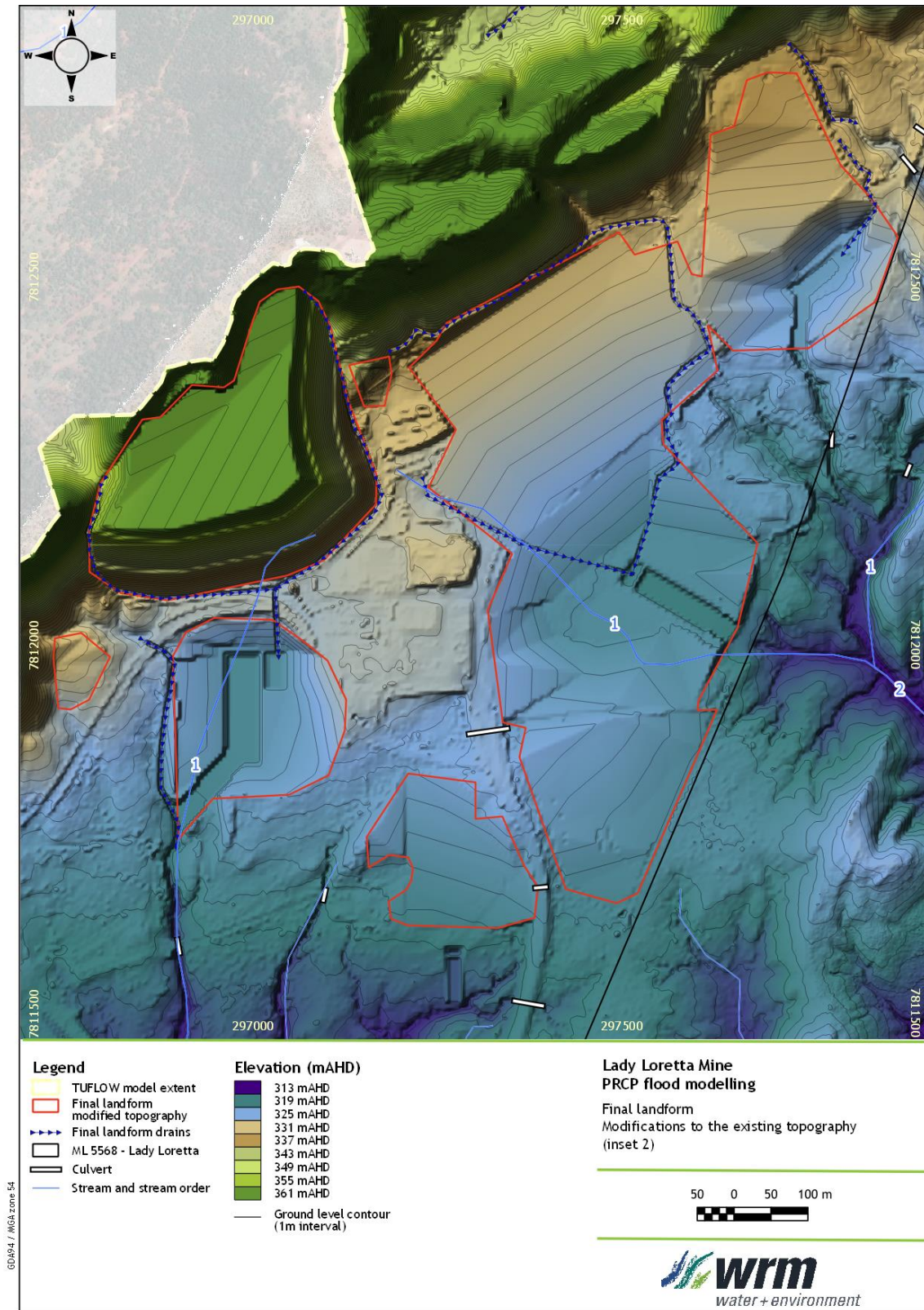


Figure 4.3 - Final landform configuration, CDA, CDB, PPD, WRE, Infrastructure Areas and ROM / Paste Plant (inset 2)

5 Estimation of discharges

5.1 OVERVIEW

An XP-RAFTS runoff-routing model (Innovyze, 2018) was developed to estimate design discharges for Desert Creek and Magazine Creek and the local catchments draining the LLM site for the 50% (1 in 2) AEP, 1% (1 in 100) AEP and 0.1% (1 in 1,000) AEP design flood events. The model was also used to produce design discharge hydrographs for the PMF event.

The XP-RAFTS model was validated for the 50% AEP, 2% AEP and 1% AEP design events against the Rational Method and the Regional Flood Frequency Estimation (RFFE) (see Section 5.2). The validated XP-RAFTS model was then used to estimate design discharges in the creeks and the local catchments using the Australian Rainfall and Runoff (ARR) 2019 guidelines (Ball et al., 2019) for the 0.1% AEP design event as well as the Probable Maximum Flood (PMF) event for a range of storm durations up to 6 hours to determine the critical storm durations at key locations. The derived hydrographs were used as inputs to the TUFLOW hydraulic model.

Figure 5.1 shows the Desert Creek hydrologic model configuration. The model covers the entire Desert Creek and Magazine Creek catchments to their common confluence and consists of 15 sub-catchments. Table 5.1 provides a description of each catchment as well as the adopted catchment parameters.

A uniform rainfall depth and temporal pattern were assumed over the entire catchment. Rainfall losses (initial loss /continuing loss) across the catchment were assumed to be uniform.

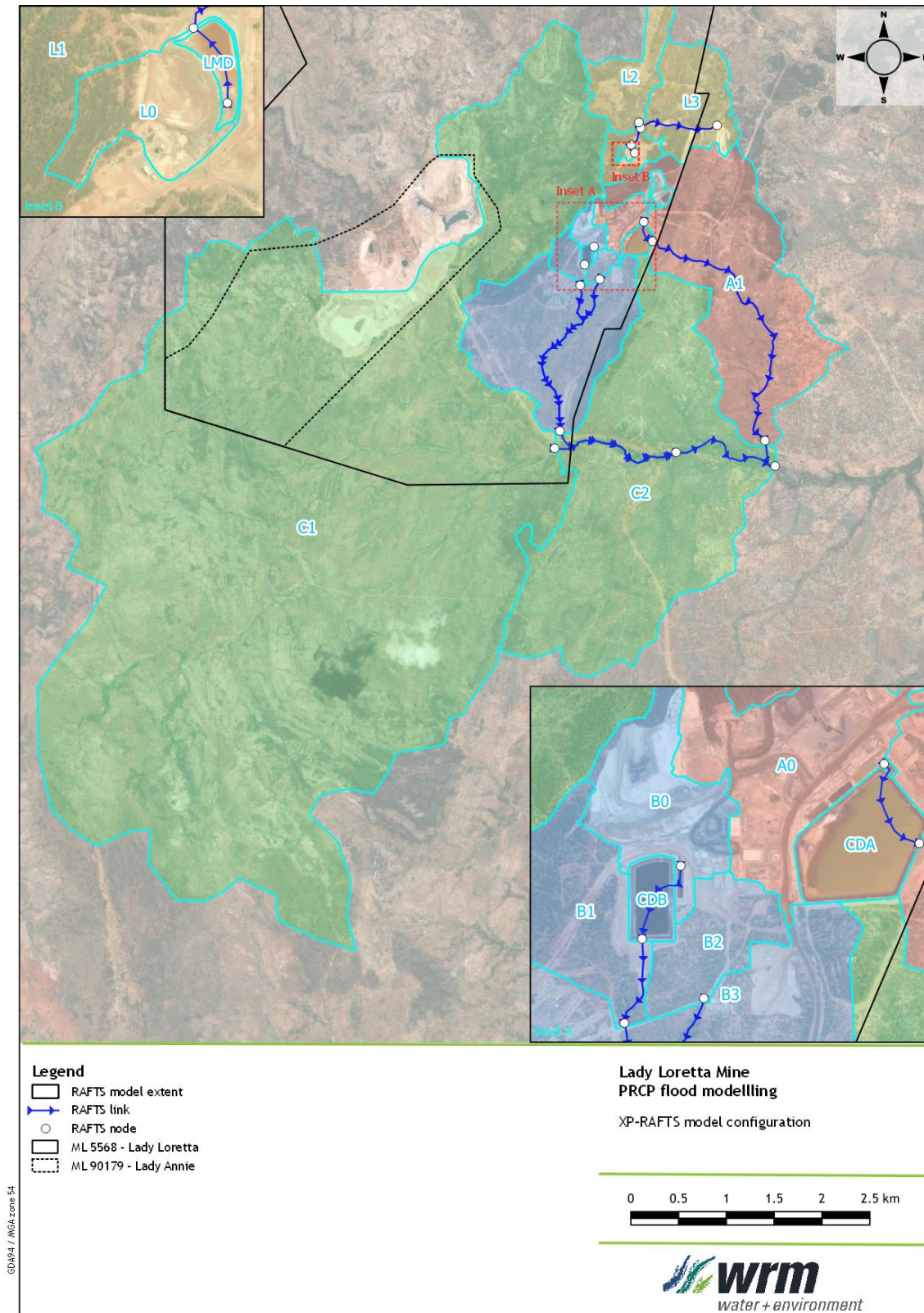


Figure 5.1 - XP-RAFTS hydrologic model configuration

5.1.1 XP-RAFTS subcatchment parameters

Table 5.1 shows the adopted XP-RAFTS model sub-catchment parameters. A PERN 'n' of 0.05 was adopted throughout the model. The percentage impervious for the dam catchments and former dams was assumed to be 10% for the post mining landform. The remaining catchments were assumed to be natural with 0% imperviousness.

The sub-catchment slopes were determined as area-weighted slopes based on SRTM and confirmed against the higher resolution LiDAR where available. Slopes in the dam catchments were determined based on the final landform surface.

Table 5.1 - Adopted XP-RAFTS model subcatchment parameters

Node ID	Description	Area (ha)	PERN 'n'	% Impervious	Slope (%)
A0	CDA catchment	22.3	0.05	10	7.74
CDA	CDA surface	8.0	0.05	10	2.64
B0	CDB catchment	12.1	0.05	10	9.51
CDB	CDB surface	2.5	0.05	10	3.72
L0	LMD catchment	2.0	0.05	10	12.51
LMD	LMD surface	0.4	0.05	10	4.28
A1	PPD catchment and natural catchment between sewerage treatment plant and creek	336.5	0.05	0	3.14
B1	Natural catchment upstream camp	13.9	0.05	0	12.02
B2	Natural catchment upstream sewerage treatment plant	7.6	0.05	0	2.14
B3	Natural catchment between camp and creek	219.8	0.05	0	3.49
C1	Catchment of Desert Creek	2962.2	0.05	0	3.63
C2	Residual natural catchment to creek	632.0	0.05	0	2.91
L1	Natural catchment around LMD	23.9	0.05	0	9.91
L2	Natural catchment downstream LMD	61.8	0.05	0	6.90
L3	Natural catchment downstream LMD	90.1	0.05	0	9.04

5.1.2 Dam configuration

The dams will be decommissioned. Hence, they were not represented in the XP-RAFTS model as storages.

5.1.3 Design rainfalls

Design rainfall depths were obtained from the Bureau of Meteorology (BoM) intensity frequency duration data system (2016 IFD) on 3 May 2022. For the estimation of design discharges, design rainfalls were obtained for the centroid of the Mine (at -19.774 latitude and 139.065 longitude).

Probable Maximum Precipitation (PMP) rainfall depths for durations up to 6 hours were estimated using the methodology given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method - GSDM* (BoM, 2003).

Table 5.2 shows the adopted depths for the modelled design events.

Table 5.2 - Adopted PMP design rainfall depths

Storm Duration (minutes)	PMP (mm)	0.1% AEP (mm)	1% AEP (mm)	50% AEP (mm)
20	-	-	57.1	23.4
25	-	-	63.7	26.1
30	-	-	69.1	28.5
45	-	-	80.9	33.6
60	500	137	89.2	37.1
90	-	-	101	41.9
120	640	169	110	45.2
180	730	190	123	49.7
270	-	-	138	54.2
360	890	235	151	57.6

5.1.4 Design losses

The following is of note for the adopted design rainfall losses:

- For the 50%, and 1% AEP events, an initial loss of 20 mm and a continuing loss of 3.2 mm/hr were adopted based on the validation against the Rational Method and RFFE (see Section 5.2);
- for the 0.1% AEP event, an initial loss of 6.9 mm and a continuing loss of 1.6 mm/hr were adopted based on the linear interpolation on a log-log frequency plot between the losses adopted for the 1% AEP event and the losses adopted for the PMP event as recommended in the ARR guidelines; and
- for the PMP event, a 0 mm initial loss and 0 mm/hr continuing loss were adopted.

5.1.5 Areal reduction factor

No areal reduction factors were applied to the design rainfalls.

5.1.6 Temporal patterns

Temporal patterns for the 0.1% AEP and PMP events and for durations up to and including 6 hours were obtained from the *Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (GSDM)* (BoM, 2003) as per the recommendation in ARR 2019.

Design rainfall temporal patterns for the more frequent events were derived using the ensemble approach outlined in the ARR 2019 guidelines (Ball et al., 2019). Using this approach, an 'ensemble' of 10 temporal patterns was run for each storm duration for each event. The critical storm duration was selected based on the duration which produces the highest average peak discharge at the location of interest. As recommended in the guidelines, the temporal pattern of the duration producing the next higher discharge was selected for the analysis.

To illustrate the variation in peak discharges from the ensemble of 10 temporal patterns for each storm duration, Figure 5.2 provides box and whisker plots (box plots) showing the distribution of peak discharges in Desert Creek for the 1% AEP event. For each duration, the rectangle box represents the 25%ile and 75%ile (1st and 3rd quartile, the interquartile range or IQR) bound of the estimate. The horizontal lines at the top and bottom (whiskers) represent the upper and lower estimates for 1.5 times the IQR. The horizontal line within the box is the median value and the “X” represents the mean value, the value of which is shown above the box plots (critical in green).

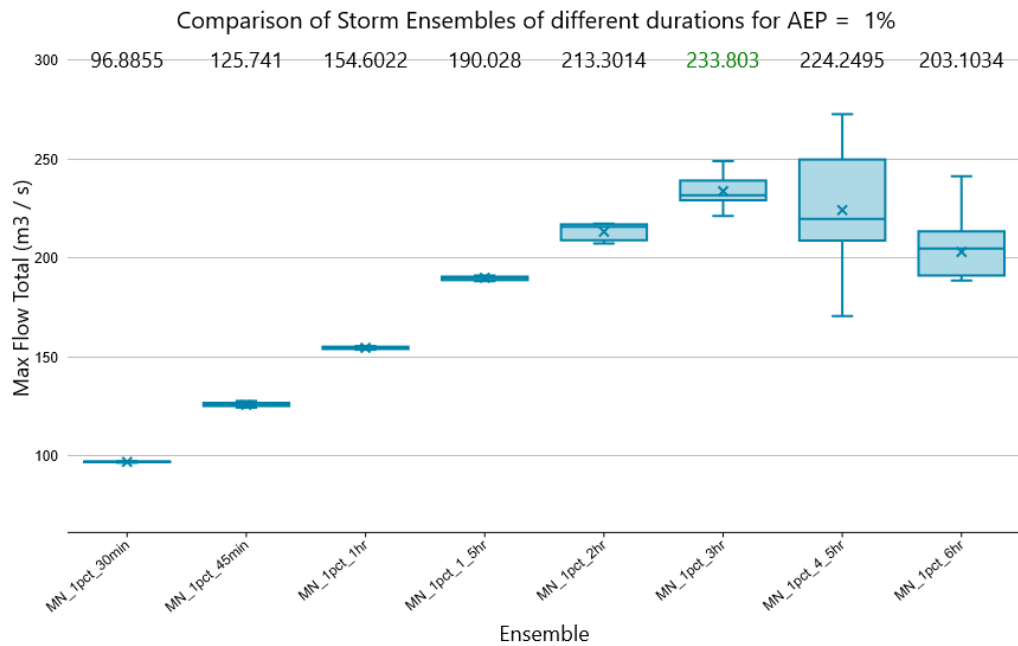


Figure 5.2 - Distribution of 1% AEP design peak discharges at Desert Creek

By comparing the critical temporal pattern derived following the above approach at three key locations, i.e., downstream of CDA, downstream of CDB, and downstream of LMD, a representative temporal pattern was selected for each duration ranging from the 10 minutes to the 6 hours storm for the 50% AEP and 1% AEP design event, respectively. The critical duration for these events was determined using the hydraulic model by superimposition of the result grids. Table 5.3 outlines the representative temporal pattern chosen for the modelled design events.

Table 5.3 - Representative temporal pattern selected per duration

Duration	2% AEP	1% AEP	0.1% AEP	PMF
10min	-	1	GSDM	GSDM
15min	-	4	GSDM	GSDM
20min	1	10	GSDM	GSDM
25min	5	9	GSDM	GSDM
30min	9	8	GSDM	GSDM
45min	6	7	GSDM	GSDM
1hr	4	8	GSDM	GSDM
1.5hr	5	6	GSDM	GSDM
2hr	6	5	GSDM	GSDM
3hr	10	10	GSDM	GSDM
4.5hr	10	10	GSDM	GSDM
6hr	10	2	GSDM	GSDM

5.1.7 Local catchment design discharges

The XP-RAFTS model was run for the 50% AEP, 1% AEP, 0.1% AEP and PMF flood events for the 10-minute hour to 6 hour storm durations to determine the catchment design hydrographs. Table 5.4 summarises the XP-RAFTS model predicted peak discharges at key locations for each event (refer to Figure 5.1).

The XP-RAFTS model results show that the critical storm duration is:

- Between 20 and 30 minutes for local headwater tributaries within the LLM site;
- approximately 3 hours for Desert Creek; and
- approximately 1 hour for Magazine Creek.

Table 5.4 - XP-RAFTS model predicted PMF flood peak discharges

Reporting Location	50% AEP		1% AEP		0.1% AEP		PMF	
	Peak discharge (m ³ /s)	Critical duration in hours (TP)	Peak discharge (m ³ /s)	Critical duration in hours (TP)	Peak discharge (m ³ /s)	Critical duration in hours	Peak discharge (m ³ /s)	Critical duration in hours
CDA	2.17	1 (4)	10.1	0.5 (10)	14.978	1	58.61	1
CDB	1.34	1 (4)	5.7	0.5 (7)	7.571	1	28.65	1
LMD	0.3	1 (4)	1.14	0.33 (10)	1.281	1	4.94	1
C1	39.5	6 (2)	236.3	3 (2)	477.813	2	2616.5	2
A1	8.83	3 (3)	43.92	2 (9)	85.564	1	451.89	1

TP - temporal pattern

5.2 XP-RAFTS DESIGN DISCHARGE VALIDATION

The XP-RAFTS design discharges estimated in Section 5.1.7 for Desert Creek (node C1 in Figure 5.1) were validated to design discharges estimated using two methodologies:

- The regional flood frequency estimation (RFFE) methodology recommended for ungauged catchments in the ARR 2019 guidelines (Ball et al., 2019); and
- the Rational Method as described in QUDM (2017).

As per the ARR (2019) guidelines, the Rational Method is valid only up to and including the 1% AEP event. Validation was carried out for the 50% AEP, 2% AEP and 1% AEP event and additionally confirmed against a RFFE assessment. A summary of the validation assessments undertaken is shown in Table 5.5 and Figure 5.3. A good agreement with the peak discharges predicted by the Rational Method was achieved. Therefore, the adopted model parameters are considered suitable for this assessment.

Table 5.5 - Rational Method and RFFE discharge validation for Desert Creek

Annual exceedance probability	XP-RAFTS peak discharge	RFFE discharge	Dif	RM Bransby Williams Eq. peak discharge	Dif	RM Modified Friends Eq. peak discharge	Dif
(% AEP)	(m ³ /s)	(m ³ /s)	(%)	(m ³ /s)	(%)	(m ³ /s)	(%)
50	39	25.5	55%	63	-37%	65	-39%
2	200	167	20%	193	3%	210	-5%
1	236	220	7%	223	6%	244	-3%

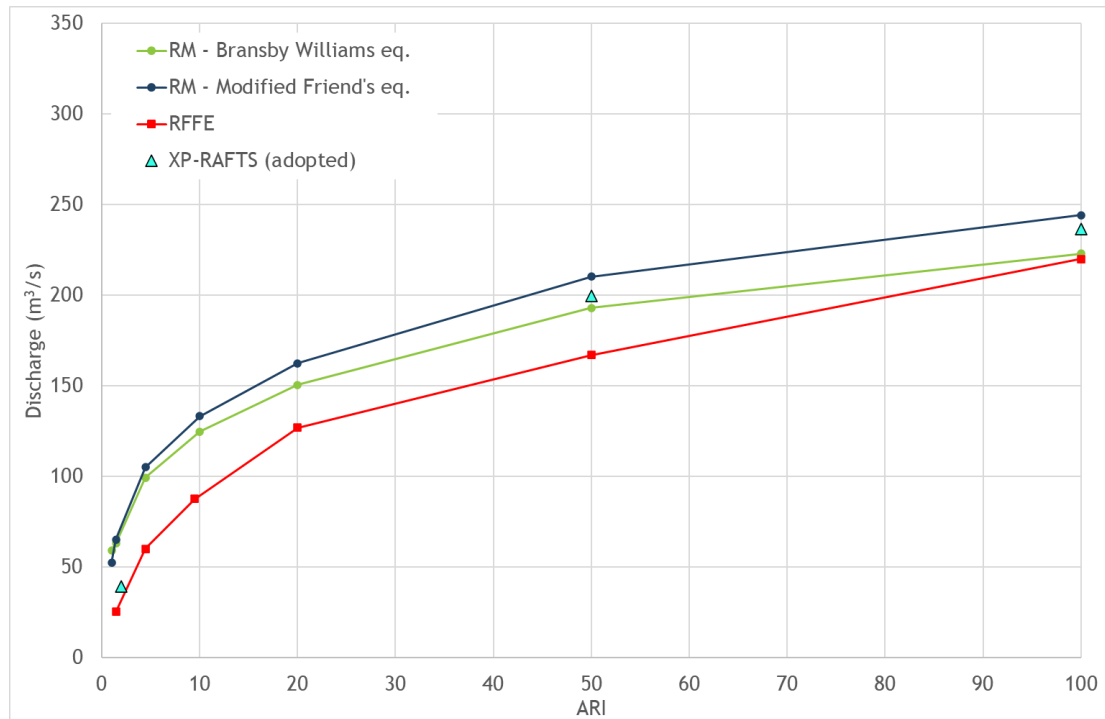


Figure 5.3 - Rational Method and RFFE discharge validation for Desert Creek

6 Hydraulic model development

6.1 OVERVIEW

A TUFLOW two-dimensional hydraulic model (BMT, 2019) was developed to simulate the runoff behaviour in the Mine catchments using the discharge hydrographs estimated in XP-RAFTS as inflows (refer to Section 5). The TUFLOW hydraulic model was used to estimate peak flood extents, depths and velocities in the vicinity of the Mine for the 50% AEP, 1% AEP and 0.1% AEP design events and the PMF.

6.2 MODEL EXTENT AND CONFIGURATION

Figure 6.1 shows the spatial extent and configuration of the TUFLOW hydraulic model developed for this study. The model covers an area of 10.93 km² and extends:

- Approximately 1.5 km upstream and 3.2 km downstream of the mine lease boundary along Desert Creek; and
- Approximately 750 m upstream and 900 m downstream of the mine lease boundary along Magazine Creek.

The model was configured as HPC-GPU (high-performance computing graphics processing unit) model with a 2 m fixed grid resolution and solved using the TUFLOW model version 2020-10-AB.

6.3 TOPOGRAPHY

The following topographic data was incorporated in the hydraulic model:

- LiDAR data provided as 199 ASCII tiles merged to a grid with 1 m resolution covering the entire hydraulic model extent; and
- the final landform surface “Post Mining Final Landform.tif”, which had a grid resolution of 5 m, was provided as by ATC Williams on 28 March 2022, clipped to the mine area as shown in Figure 3.1 (refer also Figure 4.2 and Figure 4.3) overlying the LiDAR data.. It was assumed for the purpose of this assessment the landform surface provided only included permanent features and temporary features were removed.

6.4 INFLOW AND OUTFLOW BOUNDARY CONDITIONS

The discharge hydrographs estimated using XP-RAFTS were applied at 16 inflow locations throughout the model. Figure 6.1 shows the locations of the inflow polygons. The regional inflow boundary for Desert Creek was configured as a 2D boundary condition (BC) at the code boundary to the west. The local model inflow boundaries were configured using 2D surface area (SA) polygons. Inflow hydrographs at these locations were applied equally distributed across all active cells within a given subarea, effectively applying runoff to all areas within the model extent. The model inflow approach was validated by comparing design discharges against those estimated by the hydrologic model. Peak flows were found to be generally similar (less than 5% to 10% difference). These small differences were expected to occur and were considered acceptable when accounting for storage and breakout flows represented in the hydraulic model that were not represented in the hydrologic model.

Four outflow boundaries were included in the model:

- The Desert Creek outflow boundary was located approximately 3.2 km downstream of the mine lease boundary at a normal depth slope of 0.2%.
- The Magazine Creek outflow boundary was located approximately 900 m downstream of the mine lease boundary at a normal depth slope of 1.0%.
- A western outflow boundary at a normal depth slope of 2%.

- A northern outflow boundary at a normal depth slope of 1.0%.

6.5 ADOPTED MANNING'S 'N' VALUES

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance of different material types. For the final landform modelling, a uniform Manning's 'n' value of 0.060 was adopted to represent natural and rehabilitated areas. A Manning's 'n' value of 0.050 was assumed for waterways and for the drains retained in the final landform.

6.6 HYDRAULIC STRUCTURES

Figure 6.1 shows the locations of key hydraulic structures included in the TUFLOW model. Details of the hydraulic structures are based on information and photographs provided by LLM personnel and the available topographic information as well as aerial imagery.

The modelled culverts were represented as 1D structures in the model. Table 6.1 shows the details adopted for the culverts in the TUFLOW model.

Table 6.1 - Adopted culvert details

ID	Location	Type	Barrels	Width or Dia (m)	Height (m)	Manning's 'n'	Block (%)	U/S invert* (mAHD)	D/S invert* (mAHD)
1	Camp	CMP	2	0.75		0.02	0	316.0	315.5
2	STP	CMP	2	0.6		0.02	30	319.0	318.5
3*	DS LMD	CMP	1	1.05		0.02	0	329.7	329.2
4*	DS LMD	CMP	2	0.75		0.02	0	325.7	325.5
10*	North PPD	CMP	1	0.6		0.02	0	328.5	326.8
11*	North PPD	CMP	1	0.6		0.02	0	330.3	329.0
12*	North PPD	CMP	1	0.6		0.02	0	330.3	328.7
13*	DS PPD	CMP	1	1.05		0.02	0	320.2	319.1
14*	DS PPD	CMP	1	1.05		0.02	0	317.4	317.1
15	Haul road	CMP	1	0.6		0.02	90	324.6	323.8
16	Haul road	Cattle grid	1	1.8	0.3*	0.02	80	321.6	321.6
17	Haul road	CMP	1	0.9		0.02	5	318.0	317.0
18	Haul road	CMP	1	1.05		0.02	5	318.8	318.0
19	Haul road	CMP	1	1.05		0.02	0	319.1	318.0
20	Haul road	CMP	1	1.05		0.02	0	318.0	317.2
22*	Desert Creek	RCBC	2	1.2	1.2	0.013	0	302.8	302.3
23*	Desert Creek	RCBC	2	2.4	1.2	0.013	0	302.1	302.0

*estimated

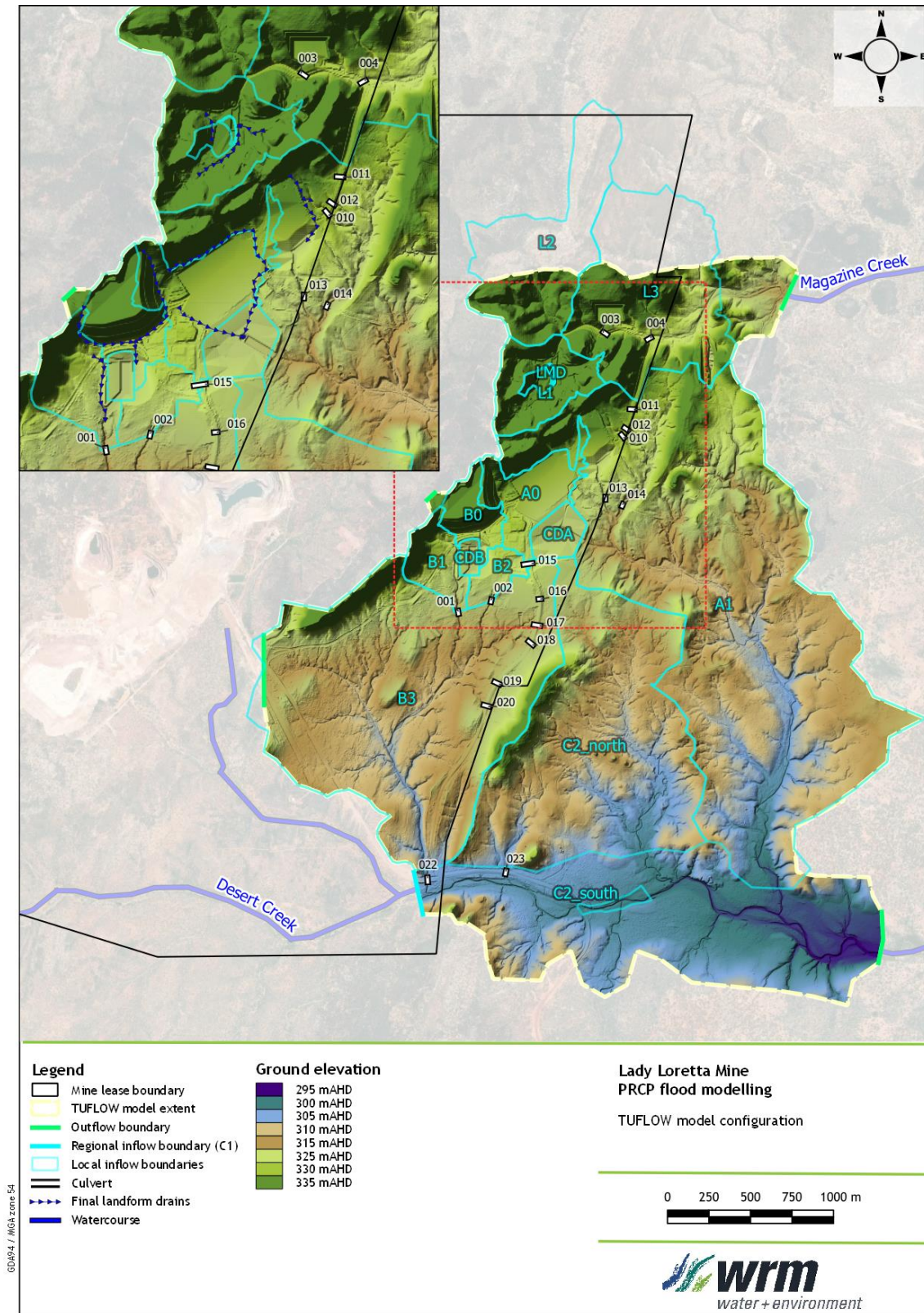


Figure 6.1 - TUFLOW hydraulic model configuration (final landform)

7 Hydraulic model results

Figure 7.1 shows the TUFLOW model predicted 50% AEP peak flood depths and extents in the vicinity of the Mine under post-mining conditions. Figure 7.2 shows the corresponding peak velocities.

Figure 7.3 shows the TUFLOW model predicted 1% AEP peak flood depths and extents in the vicinity of the Mine under post-mining conditions. Figure 7.4 shows the corresponding peak velocities.

Figure 7.5 shows the TUFLOW model predicted 0.1% AEP peak flood depths and extents in the vicinity of the Mine under post-mining conditions. Figure 7.6 shows the corresponding peak velocities.

Figure 7.7 shows the TUFLOW model predicted PMF peak depths and extents in the vicinity of the Mine under post-mining conditions. Figure 7.8 shows the corresponding peak velocities.

In general, the following is of note:

- Final landforms at the Mine are not affected by a “relevant watercourse” as per the DES (2019) definition. That is, final landforms at the Mine are not affected by Desert Creek flooding.
- The proposed final landform is not inundated by flood waters from streams draining through the site.
- Runoff through the former CDA, CDB, PPD, and LMD as well as the Paste Plant Area, ROM, Infrastructure Area and the WRE is conveyed from the proposed final landform to the receiving waters in a similar manner to pre-mining conditions. The final landform is free draining.
- Flooding in the vicinity of the Mine is characterised by shallow sheet flow across the majority of the Mine. Increased depths are predicted in the narrow and steep channelised landforms, resulting in elevated velocities in some drainage paths. The design of these drains should include adequate erosion protection in drainage paths to consider elevated velocities, if not already in place.
- Flood velocities are naturally high in streams within and downstream of the mine due to the steep topography.
- The proposed final landforms will not significantly modify stream catchments downstream of the mine. Hence, the risk of the final landform contributing to flooding or erosion in the downstream environment is low.
- For the 50% AEP and 1% AEP events:
 - Peak velocities within the proposed dam landforms generally do not exceed 1 m/s.
 - Peak velocities of up to 1.3 m/s (50% AEP) and 2.65 m/s (1% AEP) are predicted along the proposed final landform drain west of the Waste Rock Emplacement, and the steep drain into the former sediment dam at CDB.
 - Peak velocities exceeding 1.5 m/s (1% AEP) are predicted along the proposed final landform drain east of the Waste Rock Emplacement. Peak velocities in the 50% AEP design event remain below 1 m/s along the proposed drain east of the Waste Rock Emplacement.
 - Peak velocities of up to 2 m/s (1% AEP) are predicted downstream of the former LMD in the flowpath towards Magazine Creek. Except for localised exceedances, peak velocities in the 50% AEP design event remain below 1 m/s.
 - Peak velocities in the proposed final landform drains upstream of LMD exceed 1 m/s in the 1% AEP design event.

- For the 0.1% AEP event:
 - Peak flood depths within the Mine are generally low (less than 0.05 m) with shallow sheet flow across the landforms. Increased depths occur within the drains but are generally contained. Localised ponding occurs along haul roads but will be conveyed by the local cross drainage structures. The post-mining landform remains free draining.
 - Predicted peak velocities within the proposed dam landforms do not exceed 1 m/s, except for the transition between the former sediment dam at CDB and parts of the dam landform itself.
 - Peak velocities in the natural drainage line downstream of CDB towards the former Camp exceed 1.5 m/s.
 - Peak velocities are predicted along the proposed final landform drain west of the Waste Rock Emplacement of up to 2.7 m/s, and the steep drain into the former sediment dam at CDB with localised peaks of up to 3 m/s.
 - Peak velocities along the proposed final landform drain east of the Waste Rock Emplacement are up to 1.5 m/s.
 - Peak velocities in the natural drainage line downstream of the LMD landform are up to 2.0 m/s.
- For the PMF event:
 - Peak flood depths within the Mine are generally low (less than 0.05 m) with shallow sheet flow across the steep landforms. Increased depths occur within the drains but are generally adequately contained. While peak depths within the dam landforms may exceed 1 m, the landform remains free draining.
 - Peak velocities within the proposed dam landforms generally remain below 1.2 m/s, except for the transition between the former sediment dam at CDB and the parts of the dam landform itself, with predicted peak velocities of up to 2.4 m/s.
 - Peak velocities in the natural drainage line downstream of CDB towards the former Camp exceed 2.5 m/s.
 - Peak velocities exceed 2 m/s at the western batter of the Waste Rock Emplacement plateau before entering the final landform drainage.
 - Peak velocities are predicted along the proposed final landform drain west of the Waste Rock Emplacement of up to 4.5 m/s, and the steep drain into the former sediment dam at CDB with localised peaks of up to 4.0 m/s.
 - Peak velocities along the proposed final landform drain east of the Waste Rock Emplacement are up to 2.5 m/s.
 - Peak velocities in the natural drainage line downstream of the LMD landform are up to 2.5 m/s.

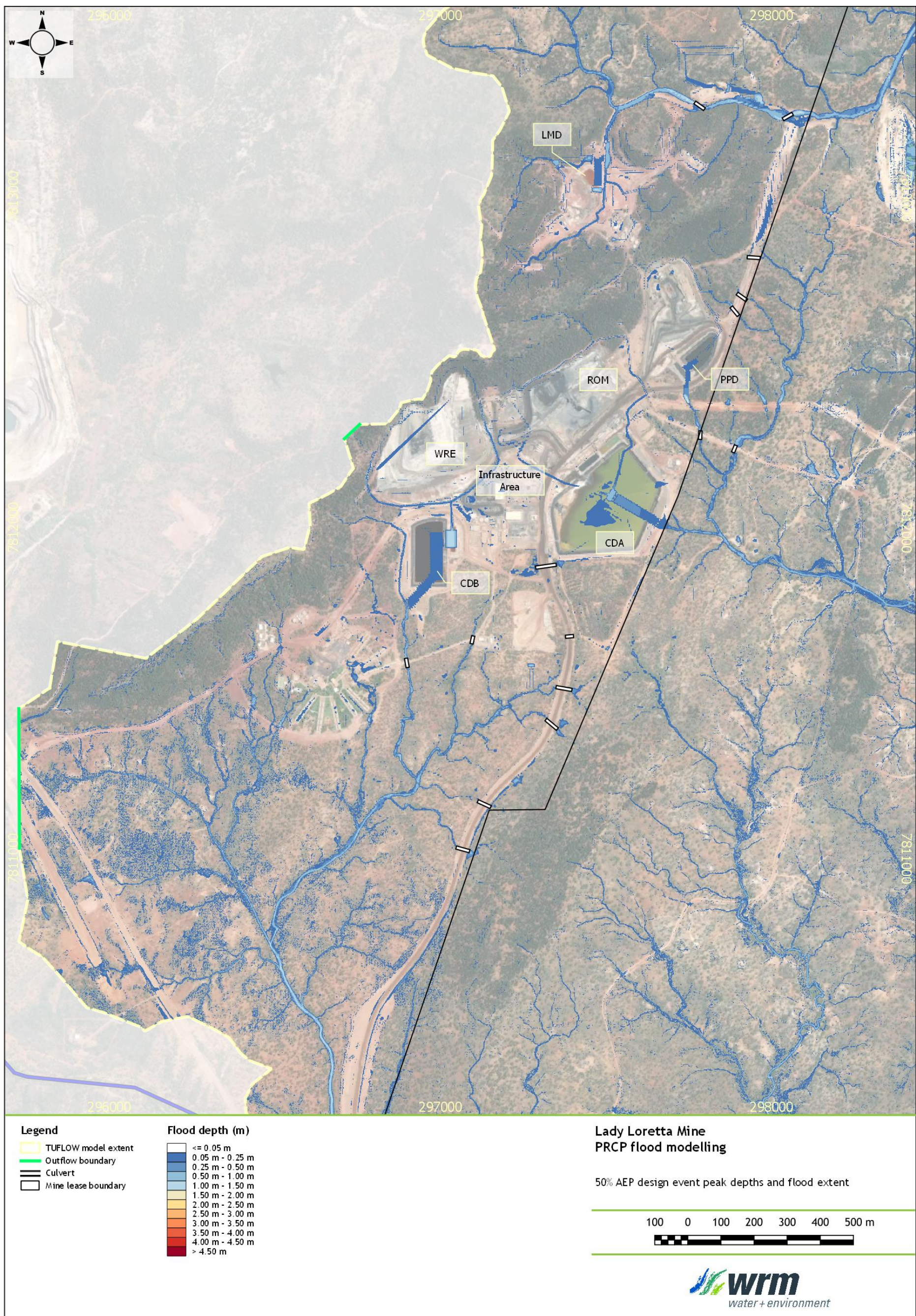


Figure 7.1 - Predicted 50% AEP peak flood depths in the vicinity of the Mine for post-mining conditions



Figure 7.2 - Predicted 50% AEP peak flood velocities in the vicinity of the Mine for post-mining conditions

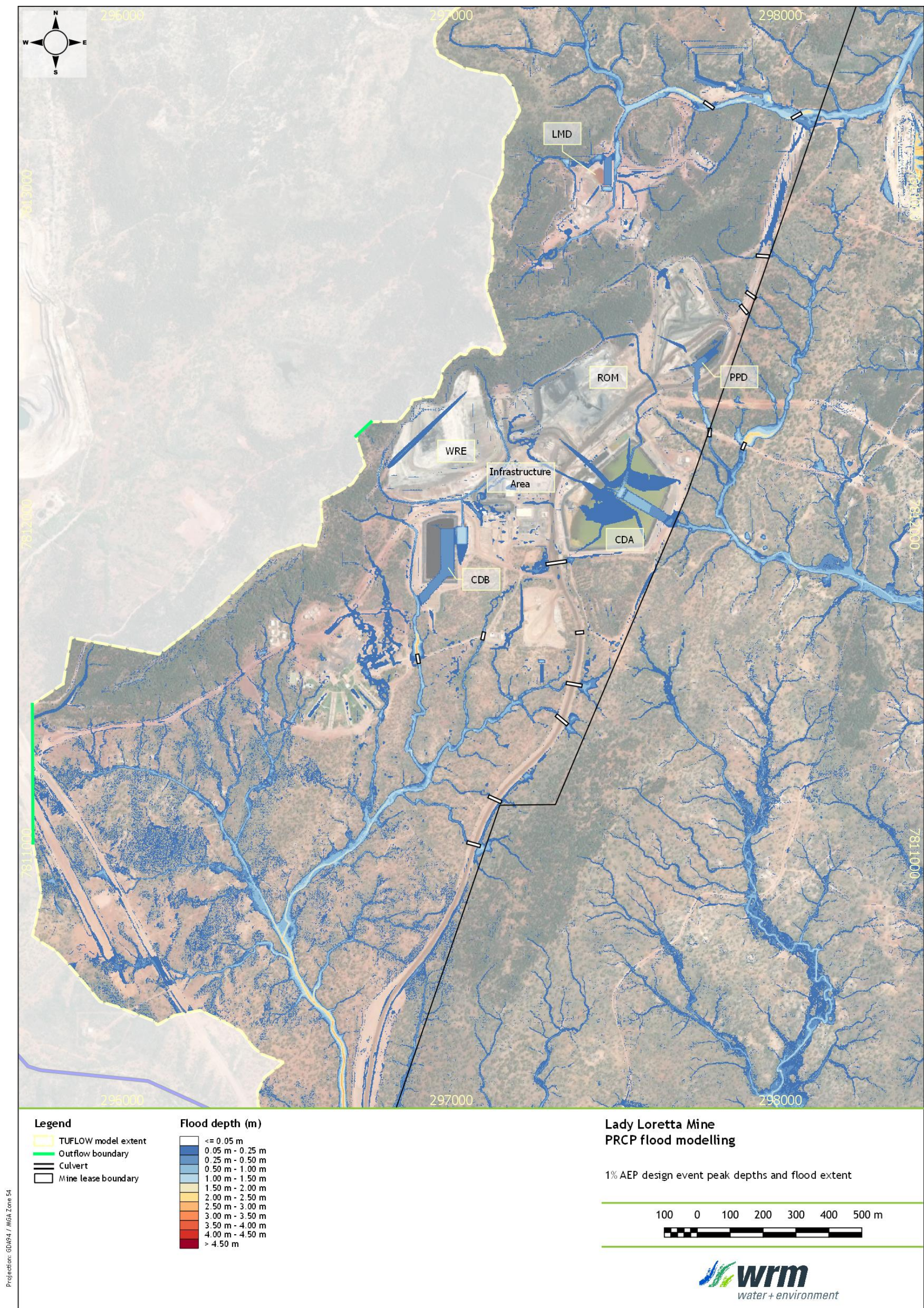


Figure 7.3 - Predicted 1% AEP peak flood depths in the vicinity of the Mine for post-mining conditions

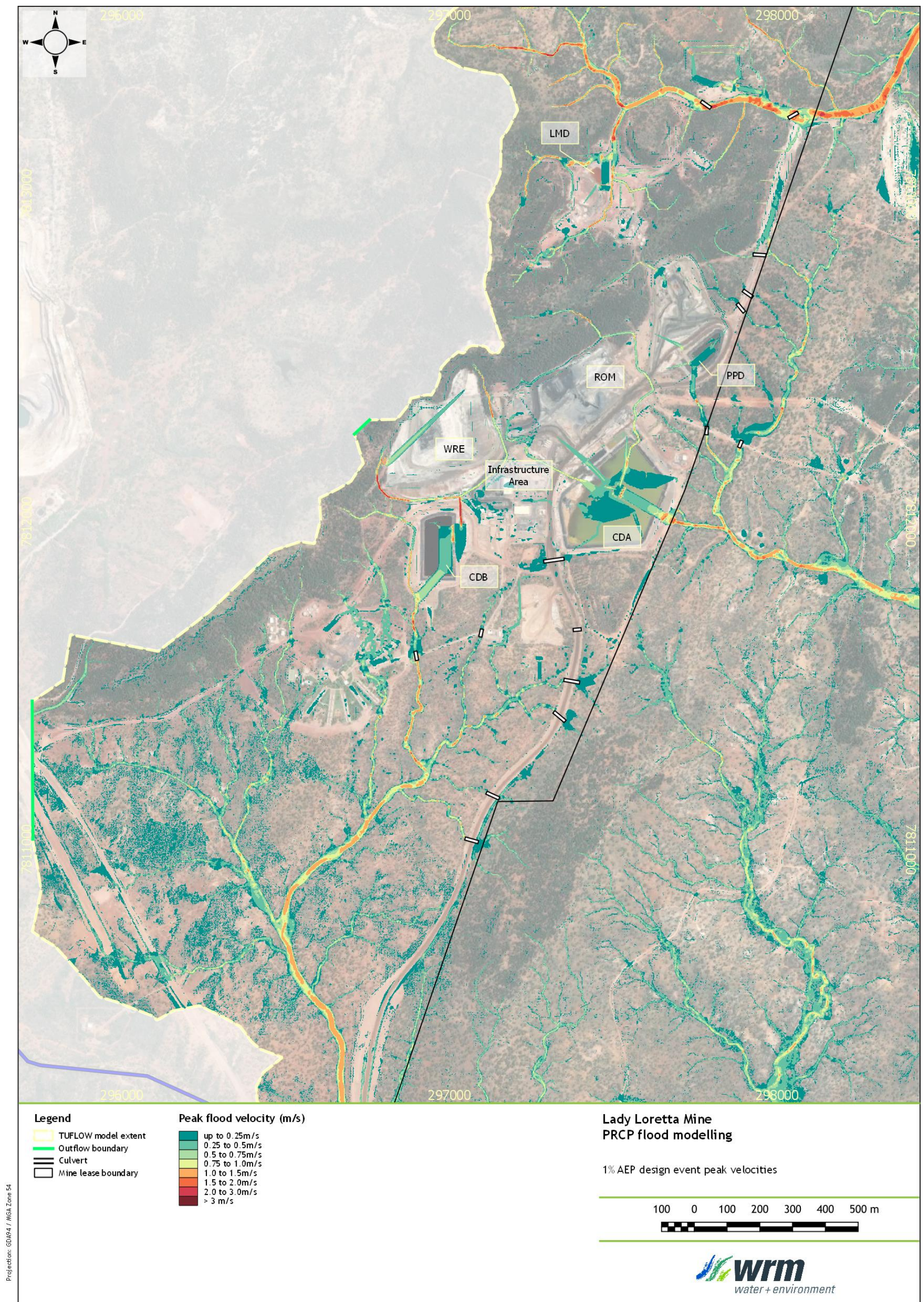


Figure 7.4 - Predicted 1% AEP peak flood velocities in the vicinity of the Mine for post-mining conditions

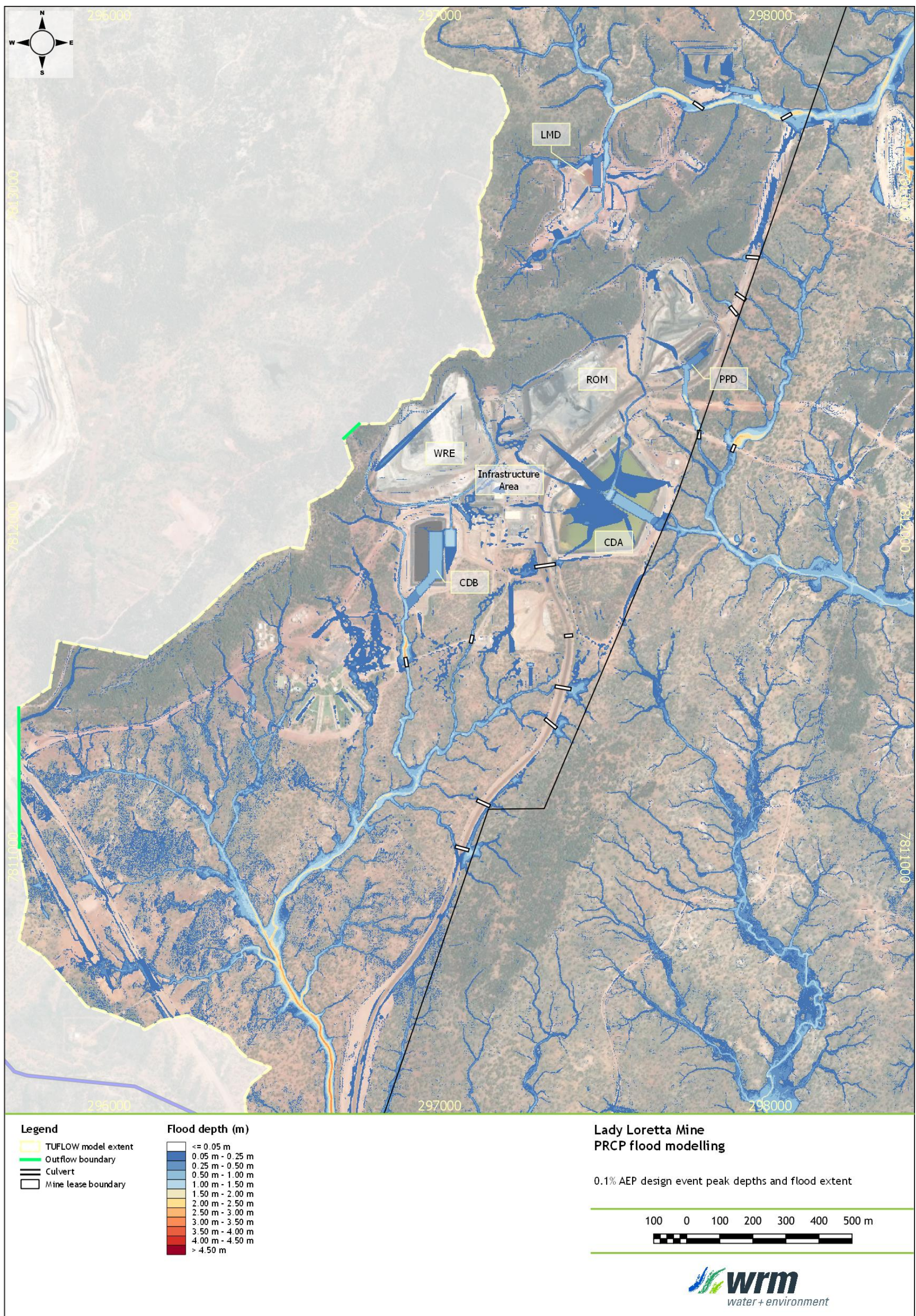


Figure 7.5 - Predicted 0.1% AEP peak flood depths in the vicinity of the Mine for post-mining conditions



Figure 7.6 - Predicted 0.1% AEP peak flood velocities in the vicinity of the Mine for post-mining conditions

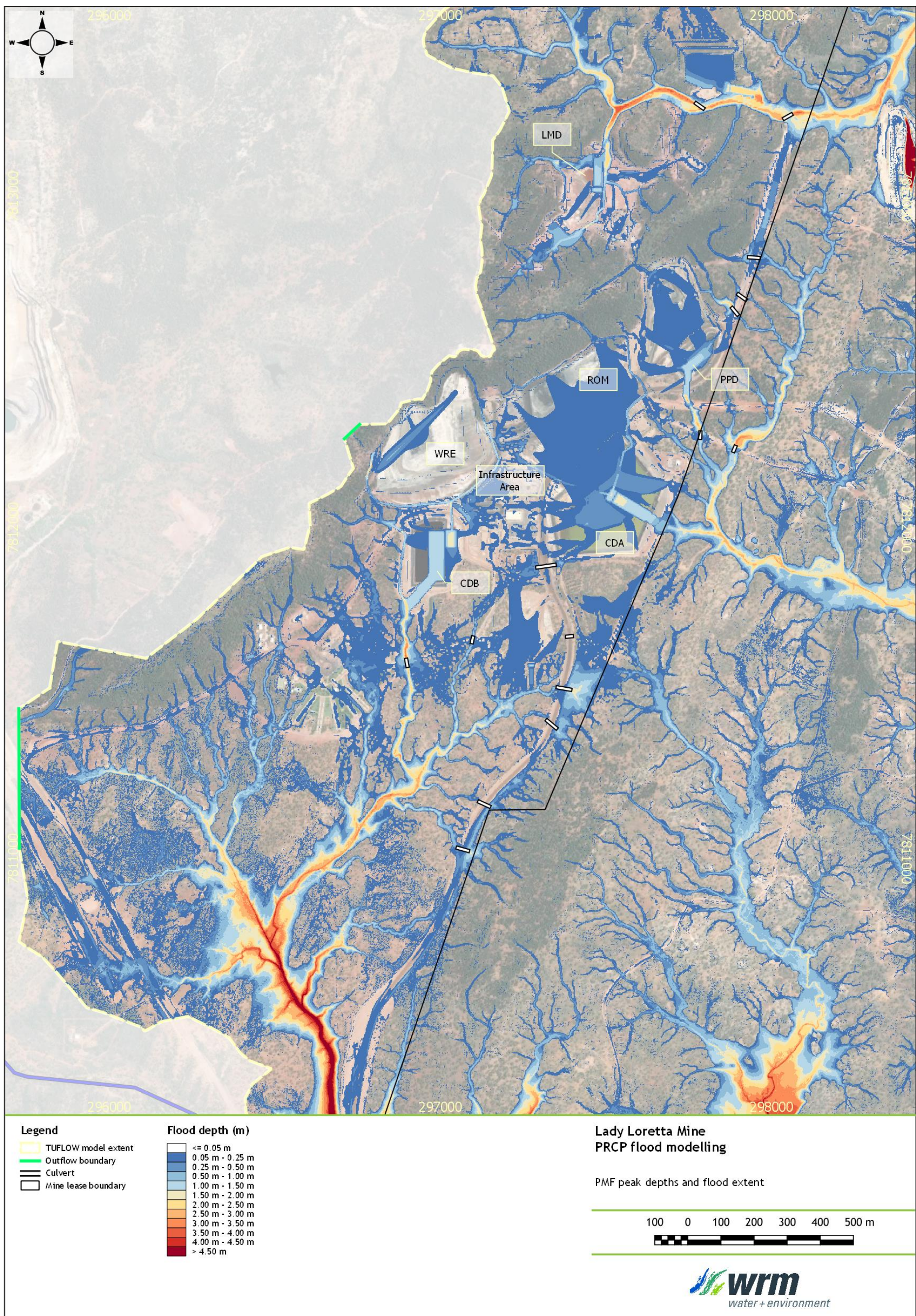


Figure 7.7 - Predicted PMF peak flood depths in the vicinity of the Mine for post-mining conditions

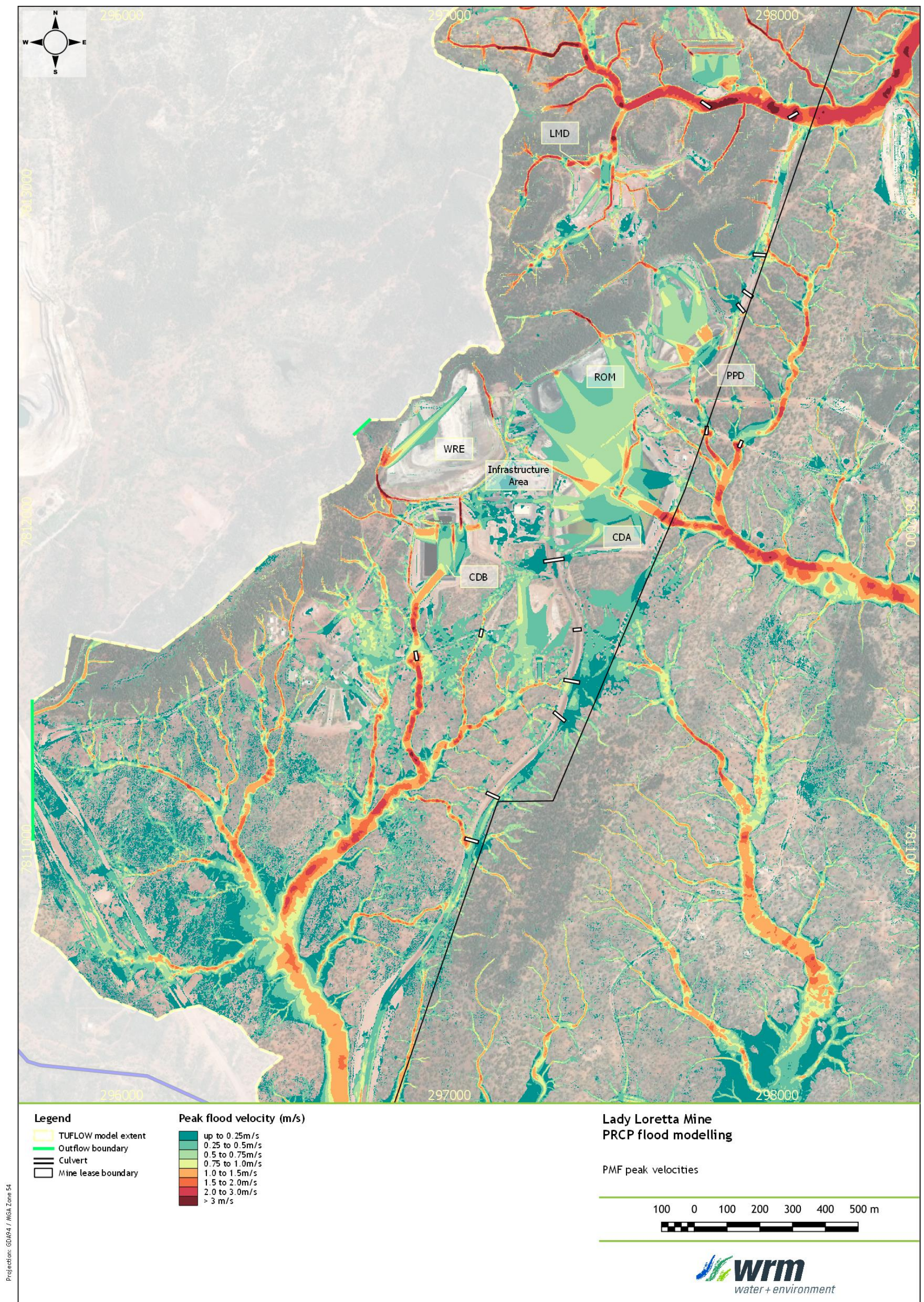


Figure 7.8 - Predicted PMF peak flood velocities in the vicinity of the Mine for post-mining conditions

8 Summary of findings

Hydrologic and hydraulic modelling was undertaken for Lady Loretta Mine to assess the flooding characteristics for the 50% AEP, 1% AEP and 0.1% AEP design flood event as well as the PMF as per the DES (2019 & 2020) requirements.

The portal box cut, infrastructure areas, including the ROM, Paste Plant area and dams will be regraded where required to be free draining and rehabilitated. It is proposed to retain the rehabilitated waste rock emplacement, haul roads and associated drainage in the final landform. There are no residual voids associated with the final landform of the LLM site.

In summary, the proposed final landforms will not significantly modify stream catchments downstream of the mine and the risk of flooding is very low. Hence, the risk of the final landform contributing to flooding or erosion in the downstream environment is low and final landform stability will not be impacted from a flooding perspective. The following is of note:

- Only minor first order streams intersect the Mine. On this basis, the Mine would not be located within the flood extent of a “relevant watercourse” as defined by DES (2019). Only a minor part of Desert Creek where it intersects the south-eastern corner of the mine lease is classified as a fourth order stream. This section of Desert Creek does not impact on any post-mining landform.
- No part of the Mine’s post-mining landform is located within the 0.1% AEP flood extent of Magazine or Desert Creek, with only the latter considered to be a “relevant watercourse” according to DES (2019). There are no voids located within the 0.1% AEP flood extent.
- Drains retained within the final landform are generally steep, with elevated velocities predicted in the drains. Careful consideration should be given to ensure adequate erosion protection during the design and construction phases to ensure the drains and receiving streams remain stable.
- Flooding in the vicinity of the Mine is characterised by shallow sheet flows across the majority of the Mine. Increased depths are predicted for the narrow and channelised flows due to the steep topography in the upstream catchments. With steep upstream catchments and no higher order watercourses, peak flood levels at the Mine are generally low and contained within drainage paths. Hence, the proposed LLM final landform is not at risk of flooding.
- Peak 0.1% AEP flood depths within the mine are generally less than 0.05 m, with shallow sheet flow occurring across the majority of the Mine and greater depths confined to narrow but steep channels.

9 References

- Ball et al., 2019 Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia), 2019.
- BOM, 2003 *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*, Commonwealth Bureau of Meteorology, Hydrometeorological Advisory Service, June 2003.
- BoM, 2016 *2016 Rainfall IFD Data System*, Bureau of Meteorology
< <http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016> >.
- BMT, 2019 BMT Pty Ltd 2019, *TUFLOW User Manual - GIS Based 1D/2D Hydrodynamic Modelling*, Brisbane QLD.
- DES, 2019 Queensland Government Department of Environment and Science, November 2019, *Guideline - Progressive rehabilitation and closure plans (PRC plans)*.
- DES, 2020 Queensland Government Department of Environment and Science, March 2020, *Information sheet - Voids in floodplains*.
- ELVIS, 2020 *ELVIS - Elevation and Depth - Foundation Spatial Data*, Version: 0.6.5, ICSM Anzlic Committee on Surveying & Mapping, obtained on 26 August 2020,
< <https://elevation.fsd.org.au/> >.
- Innovyze, 2018 *XP-Software, 2018*, Innovyze Pty Ltd.
- QUDM, 2017 *Queensland Urban Drainage Manual*, fourth edition, IPWEA Institute of Public Works Engineering Australasia, 2017.

APPENDIX C CLOSURE GEOTECHNICAL STUDY



Glencore - Lady Loretta Mine

Mine Closure Geotechnical Study

7th April 2022

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EXECUTIVE SUMMARY

Glencore's Lady Loretta Mine (LLM), located in Northwest Queensland, 140 km NNW from Mount Isa is preparing for closure. The Progressive Rehabilitation and Closure Plan (PRCP) for Lady Loretta Mine requires a geotechnical assessment of the long-term risk of underground mine subsidence and its control.

This report presents a geotechnical data discovery review, geotechnical modelling and assessment, and geotechnical recommendations for closure considerations. The geotechnical investigation and assessment focusses on failure and subsidence risk of the upper Decline, underground stopes, and shafts. Methods of assessment used includes empirical and numerical modelling. The report also considers long term deterioration of concrete and ground supporting elements, backfilling requirements, and monitoring recommendations.

All ground voids constitute elements of weakness within a rock mass, and any stope crowns that are not tight filled, upper Declines, and shaft failures, can create a significant geohazard. The natural consequence of ground failure is upward void migration, which may reach the surface and cause varying levels of subsidence. Subsidence could be dangerously instantaneous or could occur slowly over many years. Two controls that will mitigate subsidence risk after mine closure are backfilling and mine flooding.

A stability assessment of crown pillars in the Eastern Limb, Western Limb, and North Ore Body (NOB) left by mining found that caving failure will occur in some scenarios, with the collapsed rock mass occupying voids left by mining. An empirical analysis using the Scaled Span Method for the crown pillars, revealed an acceptable factor of safety (FoS) for the most likely scenario of ground and water condition. Most scenarios using the poorer ground conditions (1st quartile Q), which have a low likelihood of occurrence and cannot be completely discounted, had unacceptable FoS, and service life. In consideration of the critical cases FoS can be as low as 0.9, but generally around 1.3. This corresponds to a service life of generally 2-5 years. In real terms, this assessment considers the void backs in the 1200 level are unsupported, so at such time when ground support has deteriorated beyond its usefulness, the backs will begin to unravel in (critical case) 2-5 years.

Exploring the Scaled Span Method critical cases, all crown pillars were assumed to fail, and a bulking of failure analysis was undertaken. This assessment indicated that any and all upward ground collapse will be arrested prior to reaching the surface for all crown pillar areas. Failure propagation would reach 38 m below ground level (bgl) for the Eastern Limb and 92 m bgl for the Western Limb. Since NOB has been tight filled, there is no void to allow propagation of failure. The empirical assessment concluded that although crown pillar failure could occur, it would not cause settlement on the surface.

2D modelling of the crown pillar was conducted using Rocscience RS2® for representative sections in the Eastern Limb, Western Limb, and NOB. The results are summarised in Table E1. At final stages of mining, modelling suggests minor subsidence in the Eastern Limb and the North Ore Body and small uplift in the crown pillar above

the Western Limb due to the buoyancy effect. These vertical movements would likely go unnoticed by visual observations. The 2D modelling is supported by the empirical assessment.

Table E1- Surface displacement at various stages from 2D Analysis

	At Final Stage of Mining (Dry Mine)	Buoyancy Effect (Mine Recharged)	Net subsidence from pre-mining
Eastern Limb	20 cm ↓	18 cm ↑	2 cm ↓
Western Limb	20 cm ↓	32 cm ↑	12 cm ↑
NOB	19 cm ↓	9 cm ↑	10 cm ↓

The stability assessment for the upper Decline, where composed of weathered rock mass, was undertaken using an empirical bulking failure analysis. Results indicate that ground failure would arrest by choking at depths lower than 60 m below surface. Above this depth from surface, subsidence will occur, and the Decline requires backfilling to chainage 460 m from portal. It is estimated that a total volume of around 20,500 m³ of waste will be required to backfill the upper Decline and the boxcut.

There are four shafts linked to surface which were deemed unstable during construction and thus supported over their entire length. There is one additional historical shaft which was unsuccessful in excavation and has been backfilled. The existing concrete lining support is anticipated to deteriorate over time, and ground collapse will occur if shafts are not backfilled for post closure stability. It is estimated that a total of 12,000 m³ of waste will be required to backfill the four shafts.

Backfill material should be sourced primarily from the ROM pad due to its larger coarser fraction and limited fines. Only ROM pad material should be used to backfill the shafts. Material from the waste rock dump can be used in the Decline after ROM material has been exhausted.

Areas above the portal, upper level of the Decline and around the shafts must be barricaded and sign posted as future subsidence can occur atop these areas. Surface monitoring is recommended of these areas and proactively above the crown pillar.

1 INTRODUCTION

Glencore Lady Loretta Mine (LLM) engaged MEC Mining (MEC) to conduct a geotechnical study of the Lady Loretta Mine Closure. This report presents:

- Overview of geotechnical nature of the LLM,
- Review of mine operations and management of subsidence risk, and
- Assessment (including modelling) of long-term geotechnical risk and recommendations for controls following cessation of operations.

2 LADY LORETTA MINE (LLM) OVERVIEW

This section provides a summary of the geotechnical setting associated with Lady Loretta Mine upon reviewing of supplied documents. Also presented are geotechnical, geological, and hydrogeological settings, and known geotechnical performance history.

2.1 Documents Supplied and Reviewed

In conjunction with the Lady Loretta Mine Ground Control Management Plan (GCMP), key reports and other documentations that were reviewed include:

- AMC Consultants, 2000. Lady Loretta Feasibility Study Geotechnical Review. AMC Project 300026, October 2000.
- AMC Consultants, 2020. Lady Loretta Numerical Modelling. AMC Project 220083, 30 October 2020.
- ATC Williams, 2020. Lady Loretta Operations Geotechnical Investigation of the Waste Rock Dump and Potential Capping Materials, November 2020.
- Australasian Groundwater and Environmental Consultants (AGE, 2020). Lady Loretta Mine Hydrogeological Conceptual Model 2020 Update. Project G1834H, 01 September 2020.
- Beck Engineering 2012. LADY LORETTA Global Back fill deformation, 25 May 2012.
- Brummer, R 2006. Geotechnical review of the Lady Loretta Mine project. Unpublished report Itasca, 19 September 2006.
- Bieniawski, Z. T., 1989. Engineering rock mass classifications. New York: Wiley.
- Carter TG 2014. Guidelines for use of the Scaled Span Method for Surface Crown Pillar Stability Assessment; Golder and Associates.
- C.M Jewel & Associates 2006. Hydrogeological Study Lady Loretta, QLD for Noranda Pacific, September 2006.
- Douglas Partners 2012. Development of a Dewatering Strategy & Groundwater Management Plan for Lady Loretta Mine, July 2012.
- Entwisle, D, Lee, K A, and Lawley, R S. 2015. User guide for 'BGS Civils' - a suite of engineering properties datasets. British Geological Survey Internal Report, OR/15/065.
- EUROPEAN COMMISSION DIRECTORATE-GENERAL RESEARCH, 2013. Mine Shafts: improving security and new tools for the evaluation of risks.
- Koski, John A., 1994. Sealing Abandoned Mine Shafts with Concrete. PUBLICATION #J941015, Copyright © 1994, The Aberdeen Group.
- Lady Loretta Mine Backfill Management Plan 2021. Including Bulkhead Design, Paste Design and Paste Reticulation.

-
- McCracken, A. & Stacey, T.R., 1989, Geotechnical risk assessment of large-diameter raise-bored Shafts, IMM, *Proceedings Shaft Engineering Conference*, pp 309-316.
 - MineGeoTech 2018. Lady Loretta Mine Domaining Project, 31 October 2018.
 - Mining One 2011. Lady Loretta Box Cut Geotechnical Mapping, September 2011.
 - Mining One 2012. Lady Loretta Geotechnical Factual Report Proposed Decline and Shaft, February 2012.
 - Progressive rehabilitation and closure plans (PRC plans) 2021. Guideline—Progressive rehabilitation and closure plans (PRC plans), Department of Environment and Science (Queensland Government), Last reviewed on 17 March 2021.
 - Sandy, M. P., 2000. Lady Loretta feasibility study geotechnical review. Unpublished report AMC300026, October 2000.
 - Wolkersdorfer C 2008. Water Management at Abandoned Flooded Underground Mines. Springer 2008 465 pages. ISBN 978-3-540-77330-6.
 - Work Health and Safety Regulation 2011 (Qld) – Part 4.4 Falls <https://www.legislation.qld.gov.au/view/html/inforce/current/sl-2011-0240>
 - W. Yang, A. M. Marshall, D. Wanatowski, L. R. Stace, "An Experimental Evaluation of the Weathering Effects on Mine Shaft Lining Materials", *Advances in Materials Science and Engineering*, vol. 2017, Article ID 4219025, 12 pages, 2017. <https://doi.org/10.1155/2017/4219025>

2.2 Lady Loretta Mine

Lady Loretta Mine is an underground zinc, lead, silver mine with legacy workings. The deposit was discovered in 1969, and in 1987–1988 the first shaft was developed by Pancontinental Mining Ltd in the area near the current underground mine. Glencore Zinc Australia has owned the mine since 2012, when it merged with Xstrata Plc (previous owner). Underground operations at Lady Loretta commenced in 2013 and paused in 2015 in response to global zinc prices. Mining re-commenced in 2018 and is scheduled to reach end of LOM (life of Mine) in 2025. The modern Decline (initiated in 2013) is 500 m deep and is hosted within a Dolomite Unit of the Lady Loretta Formation. The main mineral resource is hosted in the ore sequence of the Lady Loretta Formation, which stratigraphically overlies this dolomite. Stopping is conducted into the ore bearing unit from the main Decline. On-site infrastructure includes several water storages (Catchment Dam A–CDA; Catchment Dam B–CDB; Paste Plant Dam (PPD); Leachate Management Dam–(LMD), legacy (potentially acid forming [PAF]) and modern waste rock dumps (WRD), a paste production plant, and a run of mine (ROM) area (Figure 1, AGE, 2020).

During active mining, the underground mine workings are backfilled in stages using paste produced from tailings in the paste production plant, and/or rockfill. Water for the paste production is held in the PPD (Figure 1, AGE, 2020). To ensure stability of the underground mine, the maximum allowable void volume (represented as a mass) at any one time is 150,000 tons. So that the void volume does not exceed the allowable limit, stoping and paste-filling occur concurrently, and they can overlap in different areas.

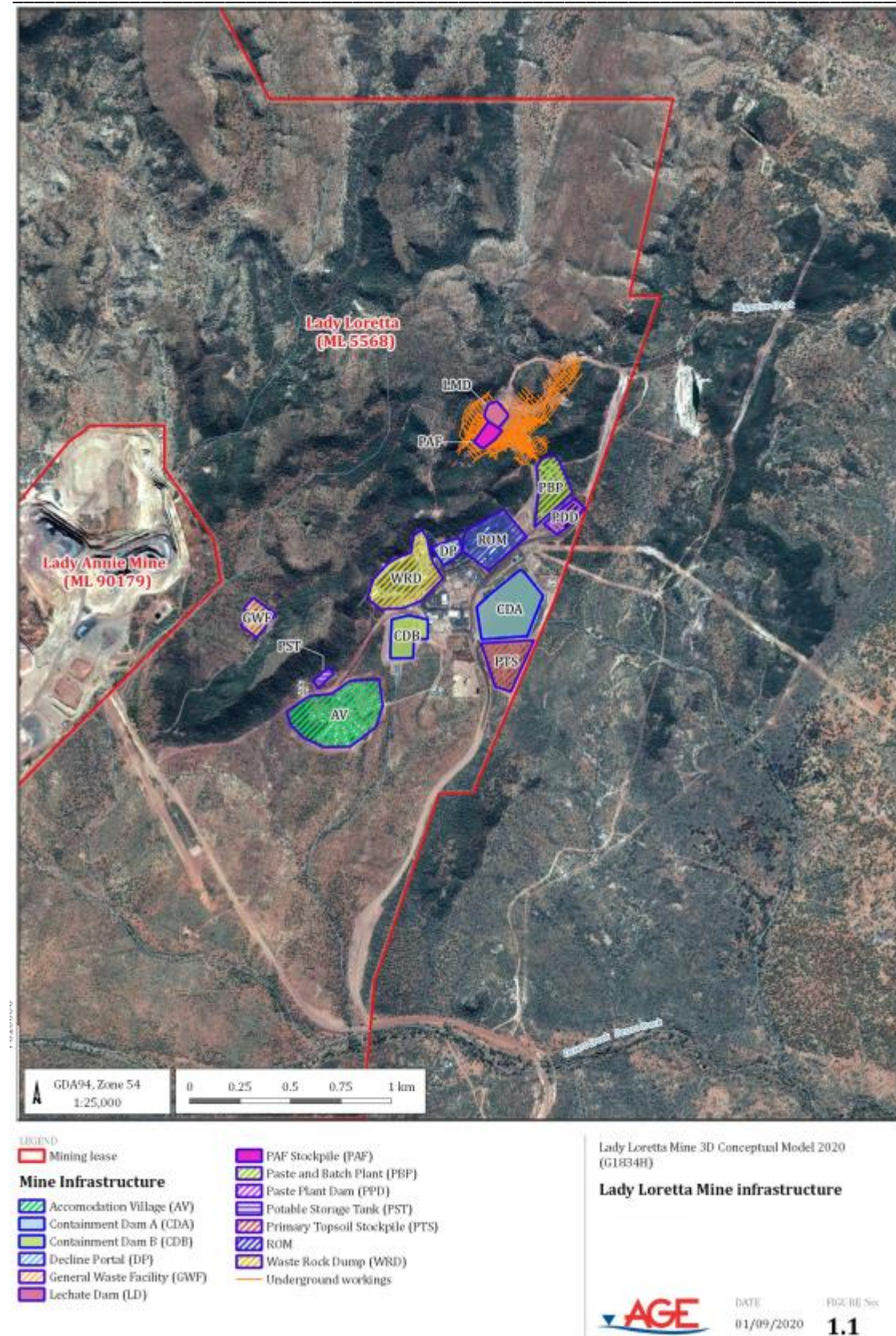


Figure 1 - Mine Surface Infrastructure.

2.3 Geological Setting

The geological settings summarised below were extracted from Noranda Pacific PTY LTD - Lady Loretta Feasibility Study in Brummer (2006) and Lady Loretta Feasibility Study Geotechnical Review (AMC, 2000).

The Lady Loretta deposit is in Northwest Queensland, 114 km NNW from Mount Isa. The deposit is considered a classic example of a sediment hosted Lead Zinc SEDEX deposit. It shares many features found in similar deposits within the Mount Isa inlier (i.e., Mount Isa, Hilton, and George Fisher). The deposit is unique for the inlier, having a single ore lens position, high base metal grades, and strong association with barite mineralisation. Age dating of tuff units within the host rocks indicates an age of 1,647 Ma. The deepest portion of the ore body reaches elevation 830 mRL in relation to AHD (510 m below the surface). Note, all levels in this report are provided in RL in relation to The Australian Height Datum 1971 (AHD71).

The deposit is hosted within the upper portion of the Lady Loretta Formation and is localised within a synformal structure locally referred to as the Small Syncline. The structure is characterised as a dominantly northeast plunging, tight syncline with an axial length of approximately 1.3km. To the southwest, a larger Big Syncline occurs which is separated from the Small Syncline by a tight anticlinal fold. Both synclines are complicated by several significant, cross cutting faults that display local offsets.

Sulphide mineralisation within the Small Syncline occurs on both steeply dipping limbs, which at depth join to form a keel structure. Northern and southern extents of the deposit are fault truncated by the Carlton and Max's Fault's, respectively.

The ore hosting sediments are dark grey massive siltstone and marks the base of an interbedded sequence and sandstones known as the Cyclic Unit. This unit overlies an interbedded pyritic siltstone unit (the Pyrite Unit). The ore sits in a stratigraphical position indicative of a major sedimentological change. This change is expressed by stratigraphy grading upwards indicating a period of quiescent deposition (the Pyrite Unit), then reverting to a higher energy environment reflected by the interbedded Cyclic Unit. The ore horizon is directly overlaid by the Cyclic Unit.

Fine grained pyrite with intergrown sphalerite and galena dominate the ore deposit. Mineralisation displays a well-defined zonation from finely banded massive sulphides in the keel (with lesser pyrite), to a coarser, baritic type mineralisation found higher on the deposit limbs. Overall, the deposit exhibits a pronounced metal zonation from high lead, zinc-rich mineralisation found in the Western Limb and keel, to a low lead, zinc-rich mineralisation found in the Eastern Limb.

Figure 2 from Brummer (2006) is a lithological cross section through 2300N (mine grid). This figure shows the major identified fault structures, which are locally known as the Carlton, Max's, and Koff's Faults.

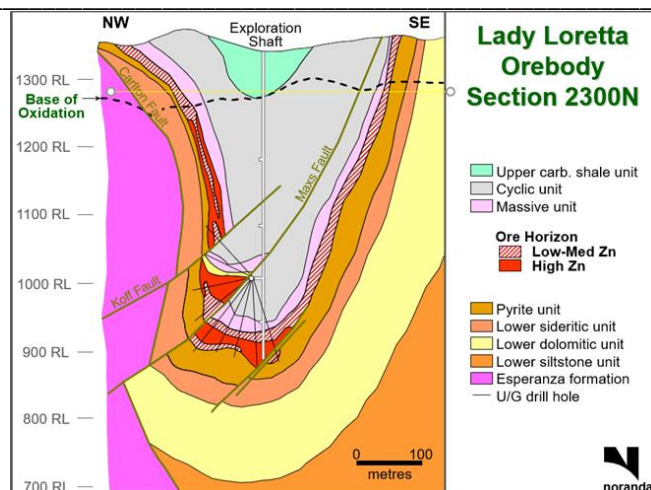


Figure 2- Lithological Section through 2300 N (Brummer, 2006)

2.4 Rock Mass Properties

Rock mass is a matrix consisting of rock material and rock discontinuities. Rock mass characterisation and classification is determined by assigning values to a set of characteristics parameters. Reliable estimates of the strength and deformation characteristics of rock masses are required for almost any form of geotechnical engineering investigation and are important for analysis and modelling of potential subsidence of an underground mine.

The intact mechanical properties for the diverse types of lithologies found at Lady Loretta have been assessed during previous feasibility studies. Shorthand abbreviations for their lithologies are summarised in Table 1 and results are respectively located in Table 2 and Table 3.

Table 1- Shorthand Abbreviations for the Different Lithologies

Lithological Unit	Abbreviation
Cyclic Unit	CU
Massive Unit	MU
Ore Horizon Banded	OH Banded
Ore Horizon Massive	OH Massive
Ore Horizon (Banded and Massive)	OH Combined
Pyritic Unit	PU
Lower Siderite/Dolomite Unit	LS/LD

Table 2- Intact Rock Properties from BFP 1997 Study

BFP, 1997	Mean UCS ₅₀ (MPa)	Std. Dev.	Samples	Mean Young's Modulus, E (GPa)
CU	158	58	4	55
MU	134	-	1	-
OH	80	34	7	64
PU	-	-	-	149
- Tested by James Cook University of North Queensland and Queensland Institute of Technology. - Individual modulus results not provided, 'secant' or 'tangent' not specified. - UCS results normalised for 50 mm diameter core.				

Table 3- Intact Rock Properties from Noranda 2000 Study

Noranda, 2000	UCS ₅₀ (MPa)	Std. Dev. (MPa)	No. of Samples	E (GPa)	Std. Dev (GPa)	ν	Std. Dev	Samples
CU	122	70	4	-	-	-	-	-
MU	83	53	3	-	-	-	-	-
OH								
Banded	143	103	9	75	20	0.24	0.04	8
Massive	87	28	4	58	11	0.26	0.04	7
Combined	126	89	13	67	18	0.24	0.04	15
PU	101	33	3	36	25	0.27	0.11	11
LS/LD	95	29	2	-	-	-	-	-
- UCS results normalised for 50 mm diameter core, results from 'intact' failure only. - E: Secant Young's Modulus at 50% UCS. - ν: Poisson's Ratio.								

2.5 Rock Mass Domaining

To assist in the geotechnical analysis, the rock mass is divided into a series of domains. Historically, the rock mass at Lady Loretta has been divided in the three ground types based on the Barton's Q system: hereafter labelled 'Type 1 Ground', 'Type 2 Ground' and 'Type 3 Ground'. MineGeoTech (2018) highlighted an insufficient database of Q parameters to provide the necessary resolution for determination of ground classification and therefore support selection on a local scale. The three ground type classification system was thereafter updated to use Rock Quality Designation (RQD) as the driving factor since significantly more data was available, and the results compared well with underground observations. As set out in the MineGeoTech (2018) report, the division between Type 2 Ground and Type 3 Ground was set at RQD of 15. Further mapping/logging conducted by MineGeoTech (2018) improved the resolution of the ground type model. The three ground types are shown in Table 4.

Table 4- Rock mass Domains

Group Type	RQD values	Group Description	Presence	Characteristics
Type 1	> 75	Fair to Good Ground	~40% of diamond drilling with RQD data	Can be jumbo scaled to solid with moderate effort, and hole blockage problems rarely occur.
Type 2	15 – 75	Very Poor to Fair	~52% of diamond drilling with RQD data	Not easily scaled to solid; Drive profile may over break up to 1.0m. Hole blockage may occur.
Type 3	< 15	Extremely Poor Ground	~8.7% of diamond drilling with RQD data	Over-scaling may destabilise ground and is hazardous; Common where major structures intersect. Partial blockage common in horizontal holes. High specification ground support required. Development support required as soon as possible to prevent deterioration.

2.6 Structural Domaining

The structural domaining at LLM reflects a global view of the discontinuity regime in the underground mine. MineGeoTech (2018) conducted a structural review using historical and newly collected data and compiled five structural domains. This data includes geotechnical logging from drilled cores, geology sirovision database and underground face and wall mapping to produce these structural domains (Figure 3). These five geotechnical domains identified at Lady Loretta are:

- Domain 1: Western Limb
- Domain 2: Western Limb between Max and Koff's faults
- Domain 3: Western Limb below Max's Faults
- Domain 4: Western Side of the Keel, and
- Domain 5: The Eastern Keel and Eastern Limb

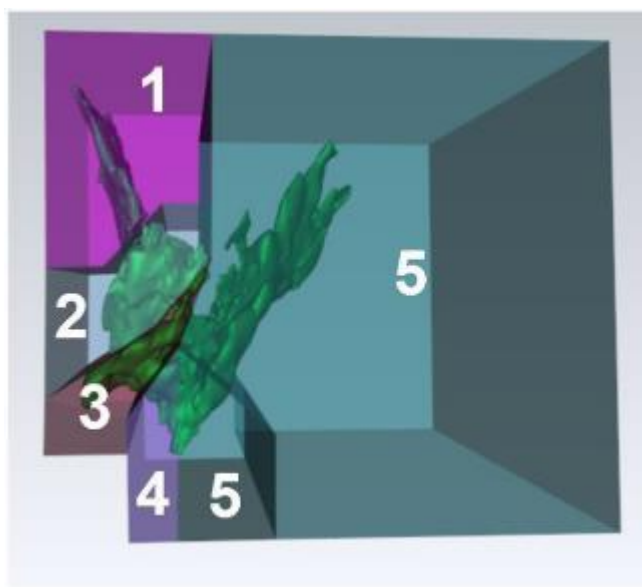

Figure 3- Lady Loretta Structural Domains

Table 5 contains a summary of the main discontinuity set data associated with each domain.

Table 5- Main Discontinuities Sets by Domain

Domain	Set Number	Dip/Dip Direction	Direction	Type
1: Western Limb	1	75/68	East Dipping	Bedding
	2	52/285	West Dipping	Joint
	3	63/202	South Dipping	Joint
2: Western Limb between Max and Koff's faults	1	73/152	South Dipping	Joint
	2	80/64	East Dipping	Bedding
	3	41/241	North Dipping	Fault
3: Western Limb below Max's Faults	1	60/66	East Dipping	Bedding
	2	44/178	South Dipping	Joint
	3	87/139	South Dipping	Joint
	4	70/257	West Dipping	Bedding
4: Western Side of the Keel	1	52/52	East Dipping	Bedding
	2	66/115	East Dipping	Bedding
	3	65/173	South Dipping	Joint
	4	60/247	West Dipping	Joint
5: The Eastern Keel and Eastern Limb	1	64/264	West Dipping	Bedding
	2	59/161	South Dipping	Joint

2.7 Faults

There are several major (regional) fault structures that have been identified within the Lady Loretta deposit, with some defining the structural domains. At LLM, rock mass within the fault zones is generally poor. Table 6 lists faults with descriptions by Sandy (2000). Regional faults and localised structures are used when undertaking slope stability assessments.

Table 6- Summary of Major Structures (Sandy, 2000)

Fault Name	Location	Strike Length	Dip Length	Dip/Direction	Comments
Max's	East Limb	+500m	+600m	50/280*	5 -10m thick, low RQD, contains gouge and open in all extents
Koff's	East Limb	+250m	+400m	40/280*	1-2m thick, gouge and interspersed broken rock, open in all extents
Carlton	West Limb	+500m	+600m	72/095*	2-20m thick, low RQD bands open in all extents
Thorpedo	East Limb	+500m	+600m	67/246	2-10m thick, gouge, highly weathered rock
Craig's	West Limb	+500m	+600m	88/297	1-2m thick, gouge and interspersed broken rock, open in all extents

2.8 Stress Magnitude and Orientation

The stress magnitude and orientation are important measurements to evaluate the level of rock mass stability. The Acoustic Emission (AE) method was used to estimate the in-situ stresses from two locations at LLM and to calculate the magnitude versus depth linear relationships (WASMAE-Lady Loretta – August 2015 – extracted from GCMP). Table 7 summarises the results.

Table 7- Magnitude and Orientation of Stress Component versus Depth

Vertical depth (m)	Sample location Borehole ID	Stress component	Magnitude (MPa)	Bearing (°)	Plunge (°)
363	Hole GT_1100_01	σ_1	23	314	02
		σ_2	16	044	02
		σ_3	10	176	87
393	Hole GT_1100_01	σ_1	26	314	06
		σ_2	17	044	04
		σ_3	11	171	83

2.9 Hydrogeological Model

LLM is being dewatered for mining activities and will naturally become flooded after cessation of the operations and dewatering. As such, hydrogeological aspects of LLM are important for the analysis and modelling. Typical of northwest Queensland, the Lady Loretta Mine experiences a tropical climate, with pronounced “dry” winter and ‘wet’ summer seasons.

Annual rainfall in the area is highly variable. The average total annual rainfall, evaporation, and potential evapotranspiration derived from Silo Data Drill records (1889–2017) are shown in Figure 4 (AGE, 2020).

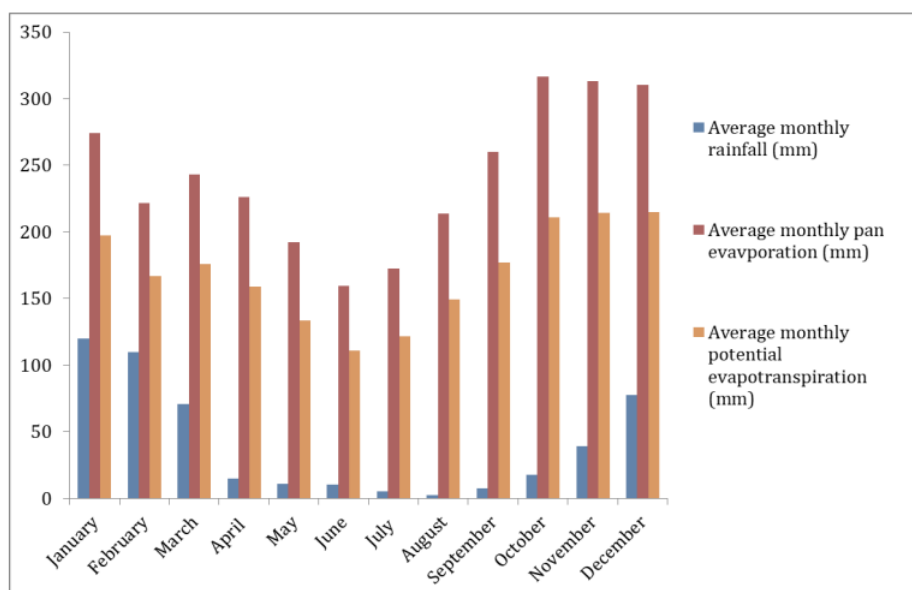


Figure 4 - Long term average climate data

The pre-mining groundwater level at Lady Loretta Mine was measured between 40 and 70 metres below ground level (m bgl) which is roughly at 1340 mRL, with deeper levels occurring in topographically elevated areas (C.M Jewel & Associates, 2006). The groundwater table in the vicinity of the exploration shaft at pre-construction was 58 m bgl. During shaft construction a low groundwater inflow rate was observed, typically around 2 litres per second (Douglas Partners, 2012).

Based on the groundwater monitoring station data, C.M Jewel & Associates (2006) concluded that the potentiometric surface would be a subdued reflection of topography, and regional groundwater flow directions would reflect surface water drainage channels with very low hydraulic gradients.

Lady Loretta Mine is a relatively “dry” mine. Underground observations indicate an increase of groundwater inflow after intense rain events, particularly from the water bearing Thorpedo Fault at upper levels of the mine. Groundwater recharge occurs mainly through direct rainfall infiltration, infiltration of slope run-off, and through stream channel seepage and overflow flooding events (C.M Jewel & Associates 2006). The typical groundwater ingress recorded to the underground workings during Care and Maintenance was approximately 21 ML per month, equivalent to 0.7 ML/day or 8.1 L/s (AGE, 2020).

The estimated hydraulic properties for the Lady Loretta Formation are presented in Table 8. These properties are derived from various methods including field testing, modelling, and analytical methods and assumes that the Lady Loretta Formation is behaving as a confined aquifer (AGE, 2020). The existing values are related to the bulk rock properties. However, observations on site indicate the aquifer is heterogeneous, due to the stratigraphic variability.

Table 8- Hydraulic Properties of the Lady Loretta Formation

Transmissivity	Storativity	Specific storage	Hydraulic conductivity	Source	Details
0.2 to 0.5 m ² /day	1 x 10 ⁻³ to 2 x 10 ⁻³		5.0 x 10 ⁻⁴ to 1.3 x 10 ⁻³ m/day	Woodward-Clyde, 1994	Theim analysis on drawdown during shaft development
3 m ² /day	4.5 x 10 ⁻⁴		2.0 x 10 ⁻² m/day	Golder, 1986b	Packer tests on shafts and holes about 150 m to 250 m deep
	5 x 10 ⁻⁴ m ⁻¹ *	5 x 10 ⁻⁵ m ⁻¹		AGE, 2015	Model calibration
	2 x 10 ⁻³ m ⁻¹ *	2 x 10 ⁻⁴ m ⁻¹		AGE, 2018b	Groundwater storage calculation from water balance

Mine water is moderately acidic and brackish (Douglas Partners, 2012). From underground observations in LLM and other mines, localised corrosion in rock bolts and mesh are observed not only due to the presence of acidic groundwater, but also due to trapped SO₂ commonly present in open stopes that have a delay in backfilling, and in areas of poor ventilation.

As the mine approaches life of mine (LoM) in 2025, and the end of commercial proposition is called in 2032, plans to cease operations will include the withdrawal of groundwater pumps from the underground. Consequently natural flooding of the mine will commence. Seepage and groundwater modelling was not part of this study however it can be thought that over time, the groundwater flow directions may change, as the water levels recover and adjust to a new equilibrium. Therefore, the receptors that are currently protected from potential contamination by the flow directions under the cone of depression could become at risk under a future post-recovery groundwater regime.

The last numerical model (AGE, 2020) simulated water recovery after mine closure, and predicted a rapid, but not complete, recovery (i.e. a remnant cone of depression could persist after mine closure). Glencore is currently planning to update the groundwater modelling to predict the likely temporal and spatial patterns of the recovery, using the most up to date plans for the mine. This will inform strategies for mine rehabilitation (AGE,2020).

2.10 Mining Method and Backfilling

LLM uses an underground conventional long hole stoping and paste fill method of mining. Stopes currently follow a bottom-up longitudinal and transverse sequence with paste filling of voids. Loose Waste Rock Fill (RF) and PAF (Potential Acid Forming material) is also used where there are no exposures to subsequent stoping, and the fill material is not required to be self-supporting. The upper levels of the mine employed a top-down longitudinal and transverse sub-level open stoping method, with paste filling of the voids. The top-down sequence was minimised due to instances of caving from stope crowns exposing the paste filled stopes above. There are some remaining stopes in this sequence still to be mined, particularly at the sill pillar between 1025 and 1050 levels, with paste exposures in the crown.

2.10.1 Paste Filling

Backfilling is used as part of the mining process at Lady Loretta to maintain stable ground conditions and maximise ore extraction in a timely manner. The bottom up, primary/secondary/tertiary stoping mining method employed at Lady Loretta now leads to paste fill being the most appropriate backfill material for most of the stopes underground. When placed, this paste fill must:

- Provide a suitable bulking material that restrains rock mass unravelling.
- Remain self-supporting during nearby blasting activities.
- Maintain stability when exposed vertically or horizontally during adjacent mining activities.
- Has sufficient bond strength to avoid liquefaction during dynamic events.

Where there are no future exposures (vertical or horizontal) to the stope, loose waste Rock Fill (RF) can be used as the fill is not required to be self-supporting. This method is generally reserved for the final stopes in the stoping panel.

2.10.1.1 Paste Binder Content and Strength

Lady Loretta uses GP cement as the binder to their paste. The paste strength is sensitive to GP cement content and Figure 5 illustrates the relationship at 14 days hydration. The strength to GP cement content relationship is consistent also with 7 and 28 days hydration. The graph in Figure 5 indicates:

- The paste strength has a lineal relationship to binder content such that a 1% change in GP% corresponds to a strength increase of approximately 200-300 kPa.
- Paste batched with 2% binder generates no tangible strength.
- Due to variability in the imported tailings (and resulting solids%), 4% GP cement content generally produces paste with lower than the required design strength for vertical exposures. 4% GP cement content has historically caused large overbreak.

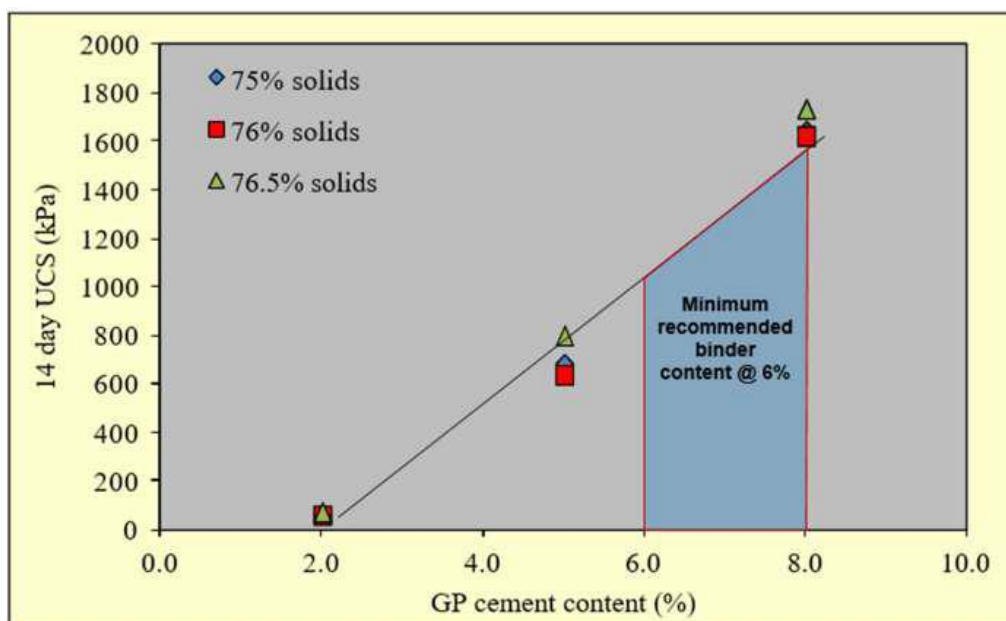


Figure 5- Curing time and GP cement content relation

Prior to the LLM temporary closure (from Q4 2015 to Q1 2018), most of the paste used low heat cement. Low heat cement produces higher strengths for the medium and longer curing times compared to GP cement. Historically, paste with 4% low heat cement content reached strengths of 1,000 – 1,200 kPa. This is compared to 400 – 500 kPa for paste with 4% GP cement. The top-down sequence stopes from 1175 level were backfilled with paste composed of low heat cement.

No time dependent deterioration study has been conducted of paste made at LLM. Deterioration is relevant for tailings containing sulphates which over time causes strength loss, and disintegration of the cement bonds within the paste. From the writer's professional experience at other copper mining operations, there can be a 3-5% decrease in strength per year from peak strength. The peak strength is generally in the vicinity of 28-112 days of curing.

2.11 Ground Support

All accessible areas by personnel at LLM are deemed supported ground, whereby an approved design of ground supporting elements have been installed. Various methods are used for designing ground support in LLM. The designs are based on a static loading environment. The mine is mostly within a medium stress state and does not experience seismicity. The methods used for ground support design include:

- Barton (1974) empirical Ground Support Design Chart.
- First principle calculations.
- Numerical Modelling (Map3D, Unwedge).
- Site experience and observation-based approach.

Figure 6 (extracted from the LLM GCMP) illustrates the use of Barton (1974) empirical Ground Support Design Chart. The graph plots each geotechnical domain boundary against the range of excavation profiles typically used at Lady Loretta.

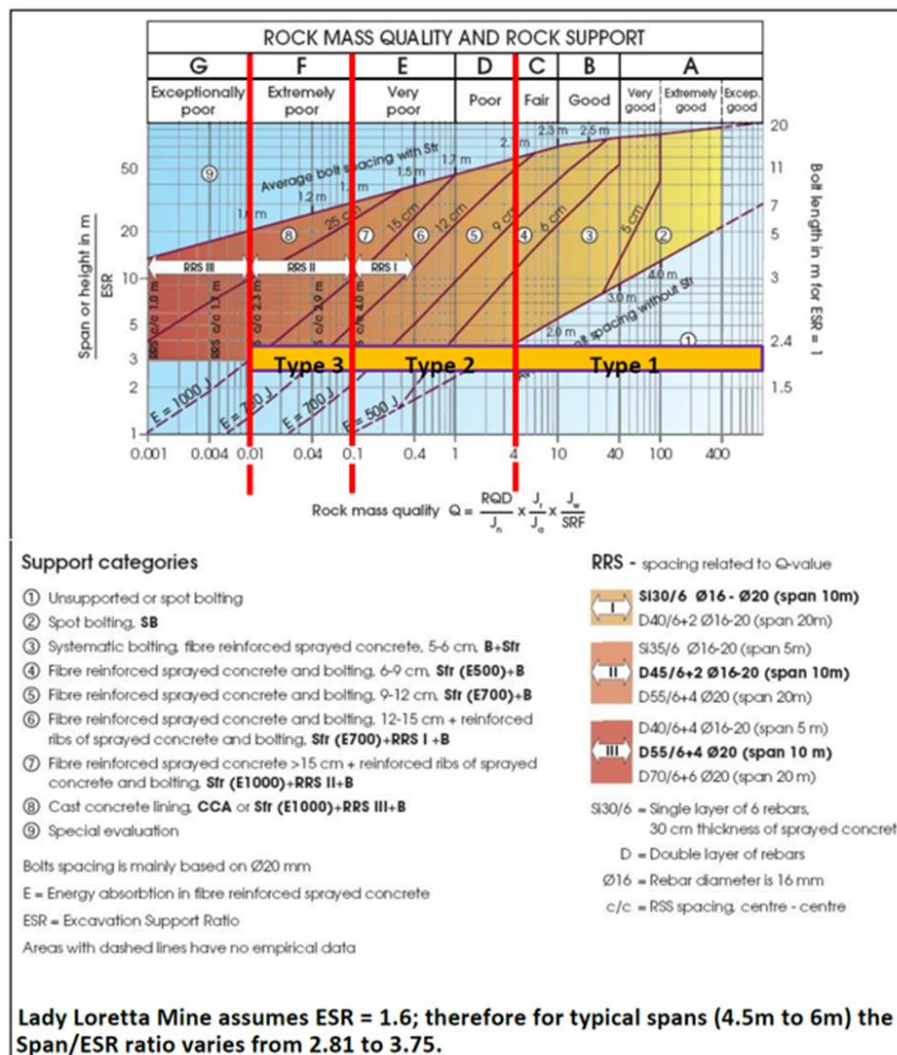


Figure 6- Lady Loretta Modified Barton Q-Method Handbook (2013) Ground Support Design Chart

2.12 Geotechnical Performance History

The ground condition excavated through LLM development drives is generally classified as 'Fair' to 'Good' (Bieniawski, 1989). However, there are four geological/geotechnical performance aspects to consider.

- Faults with exception of Thorpedo fault, exhibit poor ground. Fault exposures have additional ground support installed; 2 rings of 6 m long cable bolts spaced 2m x 2m, from 5m either side of the footwall and hanging wall fault contact. The Thorpedo Fault comprises fair ground, and it is water bearing which contributes to corrosion of support elements. Site observations indicate that faulting, on various occasions, prompted some falls of ground prior to installing the first pass of support (fibrecrete and bolting) and on one occasion, prior to second pass of support (cable bolting).
- The Massive Pyrite Layer localised stratigraphically at the top of the Pyrite Unit, prior reaching the Ore Horizon, is a highly fractured, very soft material. Its formation is likely due to shearing of this less competent layer in contact with the more competent Ore Horizon created during the formation of the syncline. This layer can be some 5m to 7m in thickness, and when intersected during ore drive development, falls of ground generally follow. To stabilize the poor ground, the support applied in most cases comprises an initial 50 mm of fibrecrete, mesh with stiff sets, and another layer of 50 mm of fibrecrete with 6 m long cable bolts spaced 2m x 2m in the backs. A fan of 4.5 m long cable bolts is occasionally installed if the overbreak is excessive. There have been no major stability issues since this heavy support has been applied.
- Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) formation within the rock mass, mostly observed in the Pyrite Unit, is the critical driver for ground support rehab at LLM. Gypsum formation is derived by the reaction with the acidic water percolating into the calcium rich mineralogy of the rock mass. The gypsum has a distinguishing crystal growing effect which can puncture and crack the fibrecrete, and snap resin bolts. Its prevalence is observed closer to the floor level where water ponds or at localised bearing water structures. Some fall of ground events occurred with the delamination of fibrecrete and slabbing in walls against bedding planes.
- The presence of SO_2 originating from high grade stopes left open for extended periods has increased corrosion rates in split sets, notably within the first 300 mm from the plate. SO_2 is lighter than air, so the gas concentrates at higher levels of drives and open stopes. Therefore, corroding ground support is prevalent in the backs and upper shoulders of the drives. Schedule constraints and paste availability are responsible for stopes being left open for extended periods. The level of corrosion varies according to the exposure time and concentration of the gas. Bolts have been replaced in cases of extreme corrosion.

Stope performance can be described generally as Good. Stopes typically experience overbreak in tension zones between the crown of the stope and the drives atop. There have been sporadic falls of ground associated with faults and structures that have been identified through back analysis and modelled. Insufficient paste strength has sometimes caused large overbreak on walls, particularly in stopes where cement content was 4%. Since the introduction of >6% cement in June 2020, overbreak in paste has generally not occurred. The Massive Pyrite Layer in the hanging wall of the western stopes and in the footwall of the eastern stopes has commonly caused large overbreak with slumping of material soon after firing and even during bogging.

3 SUBSIDENCE RISK MITIGATION CONTROLS

The service life of ground support is not indefinite and therefore will deteriorate and cease to function at some point in the future. Two main controls are in place to mitigate subsidence risk after mine closure, they being backfilling and flooding. Subsidence risk analysis should consider the time dependent factors involved in a mine closure with its underground openings, especially the continuous rock mass deterioration around voids not backfilled including the upper Decline.

3.1 Backfilling

Backfilling is the most important method of controlling subsidence at LLM during mining, and post closure since the creation of voids during mining are eliminated. All stopes will be backfilled at LLM. Most stopes will be tight filled (filled with no void remaining) except the top-down sequenced stopes at 1175 Level to 1050 Level. The uppermost operating levels of the mine are the 1175 Level and 1200 Level, with the surface at least 140 m above, at 1340 mRL. The subvertical orientation of the ore body, coupled with the relatively small span from footwall to hanging wall of the upper levels have been analysed for subsidence risk at the surface. These stopes have been paste filled to levels generally 5 m below floor of the supported drive. This void will be considered in the empirical and 2D model.

3.2 Flooding

After mine closure, the main dewatering pumps located at the bottom at 875 level will be decommissioned. Water inflow will fill the mine until the pre-mining water table level is reached at approximately 1290 mRL. The average surface level is around 1340 mRL. The highest level of the mine (the 1200 Level) and base of the crown pillar is located at 1215 mRL. Given the pre-mining water table, all mined stopes and developed levels are expected to eventually be under water. The water table at 1290 mRL after recharging will be located approximately in between stockpiles SP2 and SP3 in the Decline (Figure 7).

As the rising water level floods the mine, pore pressures will increase, and buoyancy forces will be generated. As a result, the overburden pressure and the potential for subsidence should be minimised. Although a buoyancy effect in mines is not commonly considered or acknowledged, Goetz et al, 1994 (in Wolkersdorfer C., 2008) observed positive buoyancy effects with lifting of the surface over an abandoned and flooded mine.

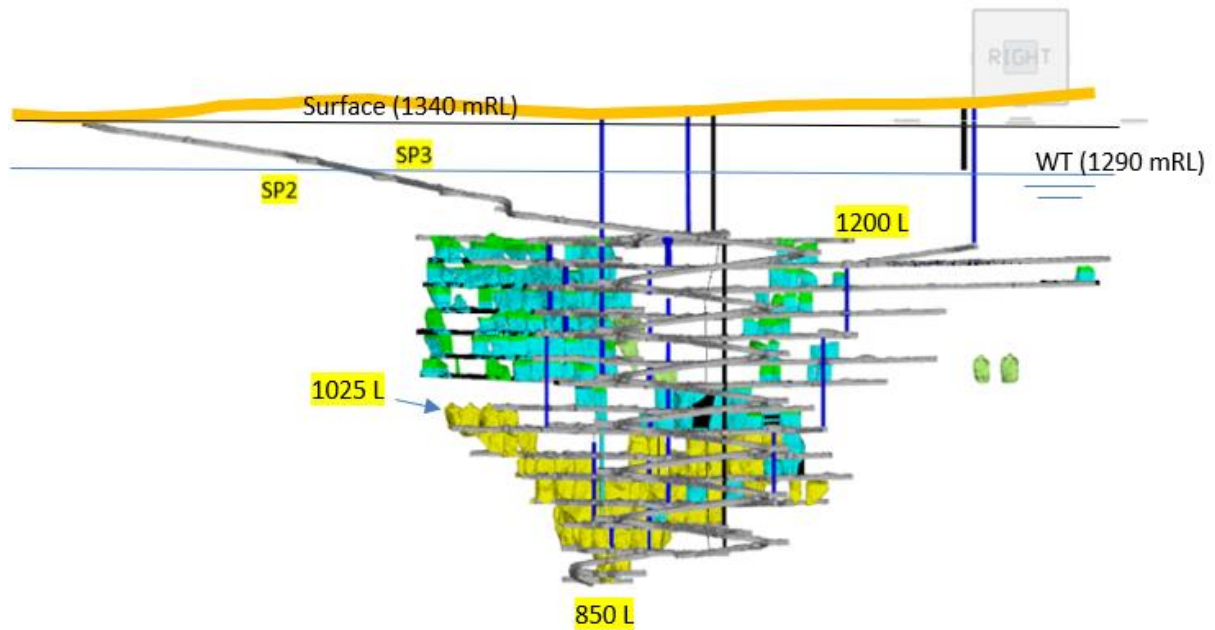


Figure 7- View from East showing location of SP2 and SP3 along the Decline. Pre-mining water table (WT), topographic surface and some levels shown for reference.

The recharged water will likely reach a pH and chemical composition close to pre-mining quality. Flooded areas of the mine will have no free oxygen radicals, which will delay further ground support deterioration. A benefit of flooding of the mine is also the prevention of disulphide oxidation.

4 GEOTECHNICAL MODELLING AND ASSESSMENT

Geotechnical modelling for the LLM closure subsidence risk was conducted using two methods. An empirical method analysed the failure probability of the three crown pillars (defined as the rock mass situated above an uppermost stope of the mine) – Eastern Limb, Western Limb, and North Ore Body, presenting the largest voids in the mine. Additionally, 2D modelling of these scenarios was conducted using Rocscience RS2®.

4.1 Representative Sections

The sections for the empirical and 2D analysis are illustrated as red lines in Figure 8. They are the three crown pillars for the underground mine. At the time of writing this report, the North Ore Body (NOB) crown pillar stopes had not been extracted.

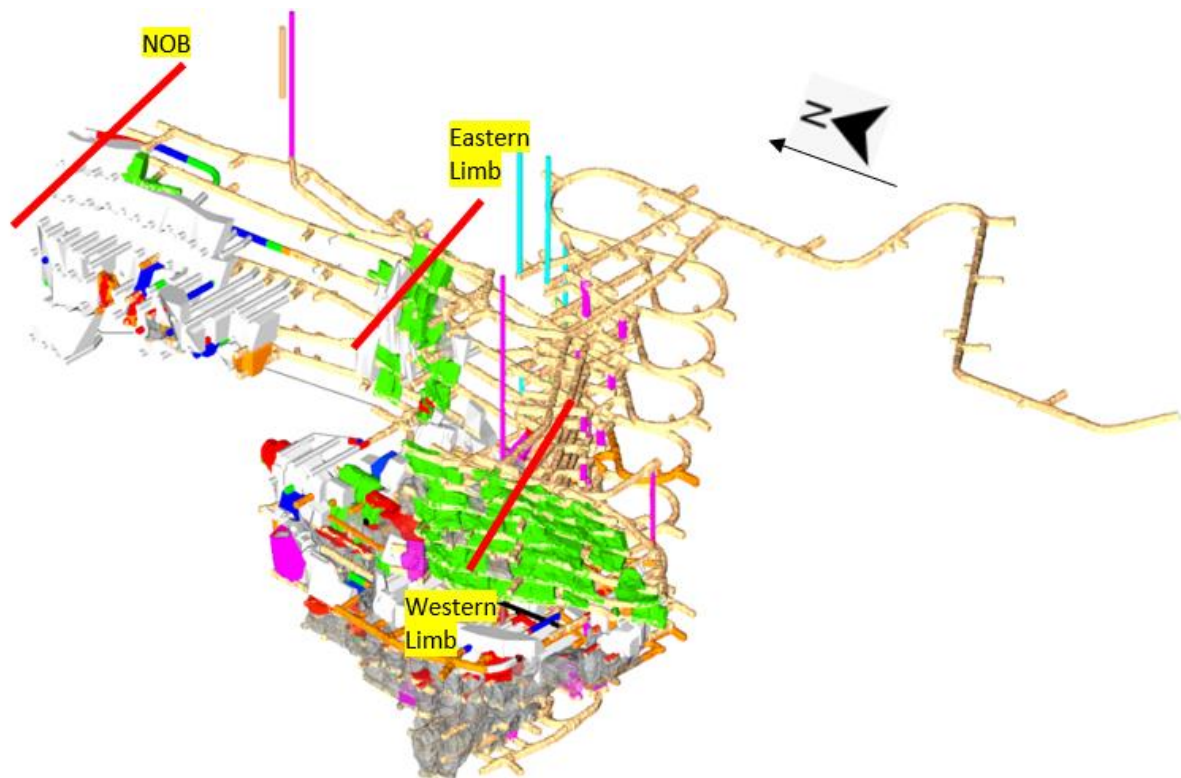


Figure 8- Underground location of the three crown pillars analysed. Red lines are representative sections.

4.2 Empirical Analysis - The Scaled Span Method

Carter (1992 and 2014) developed a method of designing stable crown pillars from a series of case studies measuring crown pillar stability. The 'Scaled Crown Span' concept characterises the geometry of a crown pillar in three dimensions and has been used widely in Australia and internationally. A summary of the method follows, and Appendix A provides further details.

4.2.1 Assessment methodology

Carter (2014) describes an empirical methodology for assessing crown stability using an empirical graph. To make the assessment from the graph two parameters are required:

- The rock mass quality, such as Q (including the groundwater factor, Jw) or RMR.
- The Scaled Span factor (CS) which is defined by:

$$C_s = S \left(\frac{\gamma}{T(1 + S_r)(1 - 0.4 \cos \theta)} \right)^{0.5}$$

where: S = crown pillar span (m);
 γ = specific gravity (which is dimensionless but has the same numerical value as rock mass unit weight, tonnes/m³);
T = thickness of crown pillar (m);
 θ = orebody/foliation dip, and;
S_r = span ratio = S/L.
(crown pillar span/crown pillar strike length)

4.2.2 General Assumptions

Variations in span and length of the crown have been accounted for in using the following dimensions:

- 13 m x 50 m for the Eastern Limb,
- 14 m x 125 m for the Western Limb, and
- 12 m x 70 m for the NOB.

Two cases are considered for the crown to account for the variability in the rock mass across the stope crown:

- Case 1. Fresh or slightly weathered rock carries all overlying domains (i.e. a worst-case scenario where the weathered rock is assumed to have no self-supporting capability).
- Case 2. Fresh, slightly weathered rock and the weathered domain supports the overlying cover (the weathered domain is self-supporting).

4.2.3 Rock Mass Characterisation

The Q values used in this assessment have been taken from the geotechnical report 'LLM Geotechnical Factual Report' (Mining One, 2011 and 2012). These values are summarised in Table 9. Underground observations taken by the geotechnical team at LLM post completion of this geotechnical report confirm 2nd quartile Q values are most appropriate. To consider post closure sensitivity the 1st quartile Q parameters will also be investigated.

Table 9- Q Values for different weathering grades

Weathering Grade	Q 1 st Quartile	Q 2 nd Quartile
Extremely Weathered	0.06	0.18
Highly Weathered	0.11	0.54
Moderately Weathered	0.16	1.11
Slightly Weathered	0.43	2.73
Fresh	1.1	4.21

The joint water value (Jw) in the Q classification can vary over time; both $Jw = 1$ and $Jw = 0.66$ have been included in the assessment. At “wet” conditions ($Jw = 0.66$) larger water inflows into voids have potential to outwash joint filling and place outward pressure on the rockmass surrounding these voids. This wet scenario has been included in the analyses to represent the critical case; it is expected to be temporary only during the recharging stage when the ground water reaches the base of these crown pillars (125-128 m bgl). Once groundwater has recharged, pressures will equalise to a state equal or better to that of “dry” conditions, where $Jw = 1$. Above the water table level (recharging and recharged) Jw can vary between that of wet and dry depending on presence of void and seasonal fluctuations.

4.2.4 Vertical distribution of domains

The vertical distribution of domains in the crown were inferred from available drillholes. The base of oxidation is highly variable at LLM. Two ranges of domain thicknesses were assessed, one is the average thickness across all drillholes, the other is based on the minimum thickness of fresh rock at the base of the crown. Table 10 presents the thickness of the materials assumed in the analysis.

Table 10- Material Domains Minimum Thickness (in metres)

Domain	Eastern Limb	Western Limb	North Ore Body
Cover (Soil)	3	3	3
Weathered (assumed)	37	37	37
Fresh or Slightly Weathered Rock	91	88	116

4.2.5 Geometry of the Stopes and Faults

Figure 9 and Figure 10 show the Eastern Limb and Western Limb, respectively. The Eastern Limb has two combined stopes as part of the crown pillar at this region. The Western Limb has five combined stopes.

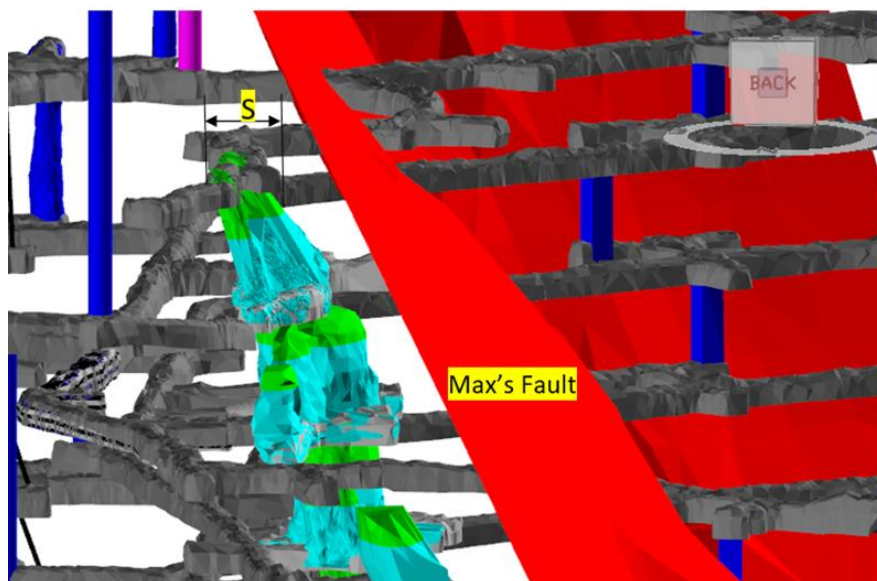


Figure 9- Eastern Limb with crown at 1200 level and Max's Fault. S = crown pillar span.

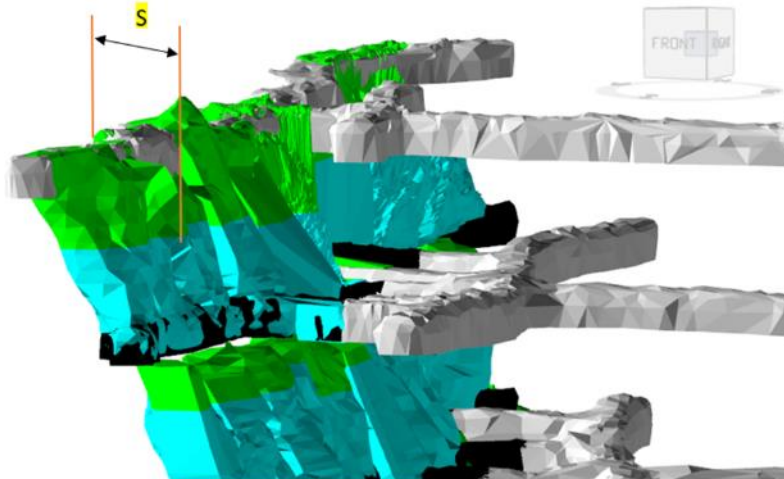


Figure 10- Western Limb and 5 longitudinal stopes mined (1175 to 1200 level). S = crown pillar span.

4.2.6 Results

Figure 11 and Figure 12 present the crown stability calculations for Case 1 and Case 2, respectively, for each region (Eastern and Western limbs and NOB). The figures are divided by the assumption of Q value for 1st and 2nd quartile data.

The results indicate the Western Limb has a lower Factor of Safety (FoS) due to its larger span (14m), longer length (125 m) and closer proximity to surface compared to the Eastern Limb and North Ore Body. The 'dry conditions' FOS (when $J_w = 1$) is applicable for the dry conditions during active mining, or upon completion. The wet FoS ($J_w = 0.66$ - medium inflow parameter) is a conservative application to wet areas or where water recharging is in progress. It can be assumed that when the mine is fully recharged to pre-mining water level that the FoS would replicate (or be better than) the dry condition FoS.

Crown Stability (Eastern Limb) - Q 2nd quartile - Weathered Rock Not Self-supporting						Crown Stability (Eastern Limb) - Q 1st quartile - Weathered Rock Not Self-supporting					
Level - 1175 - 1200 (Eastern Limb)						Level - 1175 - 1200 (Eastern Limb)					
Cs	2.60	Scaled crown span (m)				Cs	2.60	Scaled crown span (m)			
S	13.00	Slope span (m)				S	13.00	Slope span (m)			
γ	4.17	Ore Density (t/m ³)	weighted for surcharge			γ	4.17	Ore Density (t/m ³)	weighted for surcharge		
T	91.00	Thickness (m)		radians	cos	T	91.00	Thickness (m)		radians	cos
θ	77.00	Orebody Dip (degrees)		1.3439	0.225	θ	77.00	Orebody Dip (degrees)		1.3439	0.225
Sr	0.26	Span Ratio (= Span / Strike Length)				Sr	0.26	Span Ratio (= Span / Strike Length)			
S	13.00	Span of crown (m)				S	13.00	Span of crown (m)			
L	50.00	Length (m)				L	50.00	Length (m)			
Sc	6.16	Critical Span	5.1381			Sc	3.44	Critical Span	2.8744		
Q	4.21	Dry conditions	2.7786	Wet conditions		Q	1.10	Dry conditions	0.726	Wet conditions	
FOS	2.37	Factor of Safety	1.9771	FOS - wet (Jw = 0.66)		FOS	1.32	Factor of Safety	1.106	FOS - wet (Jw = 0.66)	
Pf	0.04	Probability of Failure	3.79	%		Pf	0.32	Probability of Failure	31.56	%	

Crown Stability (Western Limb) - Q 2nd quartile - Weathered Rock Not Self-supporting						Crown Stability (Western Limb) - 1st quartile - Weathered Rock Not Self-supporting					
Level - 1175 - 1200 (Western Limb)						Level - 1175 - 1200 (Western Limb)					
Cs	3.12	Scaled crown span (m)				Cs	3.12	Scaled crown span (m)			
S	14.00	Slope span (m)				S	14.00	Slope span (m)			
γ	4.20	Ore Density (t/m ³)	weighted for surcharge			γ	4.20	Ore Density (t/m ³)	weighted for surcharge		
T	88.00	Thickness (m)		radians	cos	T	88.00	Thickness (m)		radians	cos
θ	70.00	Orebody Dip (degrees)		1.2217	0.342	θ	70.00	Orebody Dip (degrees)		1.2217	0.342
Sr	0.11	Span Ratio (= Span / Strike Length)				Sr	0.11	Span Ratio (= Span / Strike Length)			
S	14.0	Span of crown (m)				S	14.0	Span of crown (m)			
L	125.0	Length (m)				L	125.0	Length (m)			
Sc	6.16	Critical Span	5.138			Sc	3.44	Critical Span	2.874		
Q	4.21	Dry conditions	2.779	Wet conditions		Q	1.10	Dry conditions	0.726	Wet conditions	
FOS	1.97	Factor of Safety	1.646	FOS - wet (Jw = 0.66)		FOS	1.10	Factor of Safety	0.921	FOS - wet (Jw = 0.66)	
Pf	0.10	Probability of Failure	9.52	%		Pf	0.44	Probability of Failure	43.77	%	

Crown Stability (NOB) - Q 2nd quartile - Weathered Rock Not Self-supporting						Crown Stability (NOB) - 1st quartile - Weathered Rock Not Self-supporting					
Level - 1150 - 1175 (NOB)						Level - 1150 - 1175 (NOB)					
Cs	2.19	Scaled crown span (m)				Cs	2.19	Scaled crown span (m)			
S	12.00	Slope span (m)				S	12.00	Slope span (m)			
γ	3.90	Ore Density (t/m ³)	weighted for surcharge			γ	3.90	Ore Density (t/m ³)	weighted for surcharge		
T	116.00	Thickness (m)		radians	cos	T	116.00	Thickness (m)		radians	cos
θ	70.00	Orebody Dip (degrees)		1.2217	0.342	θ	70.00	Orebody Dip (degrees)		1.2217	0.342
Sr	0.17	Span Ratio (= Span / Strike Length)				Sr	0.17	Span Ratio (= Span / Strike Length)			
S	12.0	Span of crown (m)				S	12.0	Span of crown (m)			
L	70.0	Length (m)				L	70.0	Length (m)			
Sc	6.16	Critical Span	5.138			Sc	3.44	Critical Span	2.874		
Q	4.21	Dry conditions	2.779	Wet conditions		Q	1.10	Dry conditions	0.726	Wet conditions	
FOS	2.81	Factor of Safety	2.348	FOS - wet (Jw = 0.66)		FOS	1.57	Factor of Safety	1.314	FOS - wet (Jw = 0.66)	
Pf	0.01	Probability of Failure	1.14	%		Pf	0.21	Probability of Failure	20.83	%	

Figure 11- Crown Stability Calculations Considering Weathered Rock Not Self-supporting (Case 1)

Crown Stability (Eastern Limb) - Q 2nd quartile - Weathered Rock Self-supporting									
Level - 1175 - 1200 (Eastern Limb)									
Cs	1.85	Scaled crown span (m)							
S	13.00	Stope span (m)							
γ	2.97	Ore Density (t/m ³)	weighted for surcharge						
T	128.00	Thickness (m)			radians	cos			
θ	77.00	Orebody Dip (degrees)			1.3439	0.225			
Sr	0.26	Span Ratio (= Span / Strike Length)							
S	13.00	Span of crown (m)							
L	50.00	Length (m)							
Sc	6.16	Critical Span	5.1381						
Q	4.21	Dry conditions	2.7786	Wet conditions					
FOS	3.33	Factor of Safety	2.7784	FOS - wet (Jw = 0.66)					
Pf	0.00	Probability of Failure	0.22	%					

Crown Stability (Eastern Limb) - Q 1st quartile - Weathered Rock Self-supporting									
Level - 1175 - 1200 (Eastern Limb)									
Cs	1.85	Scaled crown span (m)							
S	13.00	Stope span (m)							
γ	2.97	Ore Density (t/m ³)	weighted for surcharge						
T	128.00	Thickness (m)			radians	cos			
θ	77.00	Orebody Dip (degrees)			1.3439	0.225			
Sr	0.26	Span Ratio (= Span / Strike Length)							
S	13.00	Span of crown (m)							
L	50.00	Length (m)							
Sc	3.44	Critical Span	2.8744						
Q	1.10	Dry conditions	0.726	Wet conditions					
FOS	1.86	Factor of Safety	1.5543	FOS - wet (Jw = 0.66)					
Pf	0.12	Probability of Failure	12.03	%					

Crown Stability (Western Limb) - Q 2nd quartile - Weathered Rock Self-supporting									
Level - 1175 - 1200 (Western Limb)									
Cs	2.20	Scaled crown span (m)							
S	14.00	Stope span (m)							
γ	2.97	Ore Density (t/m ³)	weighted for surcharge						
T	125.00	Thickness (m)			radians	cos			
θ	70.00	Orebody Dip (degrees)			1.2217	0.342			
Sr	0.11	Span Ratio (= Span / Strike Length)							
S	14.0	Span of crown (m)							
L	125.0	Length (m)							
Sc	6.16	Critical Span	5.138						
Q	4.21	Dry conditions	2.779	Wet conditions					
FOS	2.80	Factor of Safety	2.333	FOS - wet (Jw = 0.66)					
Pf	0.01	Probability of Failure	1.20	%					

Crown Stability (Western Limb) - 1st quartile - Weathered Rock Self-supporting									
Level - 1175 - 1200 (Western Limb)									
Cs	2.20	Scaled crown span (m)							
S	14.00	Stope span (m)							
γ	2.97	Ore Density (t/m ³)	weighted for surcharge						
T	125.00	Thickness (m)			radians	cos			
θ	70.00	Orebody Dip (degrees)			1.2217	0.342			
Sr	0.11	Span Ratio (= Span / Strike Length)							
S	14.0	Span of crown (m)							
L	125.0	Length (m)							
Sc	3.44	Critical Span	2.874						
Q	1.10	Dry conditions	0.726	Wet conditions					
FOS	1.56	Factor of Safety	1.305	FOS - wet (Jw = 0.66)					
Pf	0.21	Probability of Failure	21.22	%					

Crown Stability (NOB) - Q 2nd quartile - Weathered Rock Self-supporting									
Level - 1150 - 1175 (NOB)									
Cs	1.66	Scaled crown span (m)							
S	12.00	Stope span (m)							
γ	2.96	Ore Density (t/m ³)	weighted for surcharge						
T	153.00	Thickness (m)			radians	cos			
θ	70.00	Orebody Dip (degrees)			1.2217	0.342			
Sr	0.17	Span Ratio (= Span / Strike Length)							
S	12.0	Span of crown (m)							
L	70.0	Length (m)							
Sc	6.16	Critical Span	5.138						
Q	4.21	Dry conditions	2.779	Wet conditions					
FOS	3.71	Factor of Safety	3.096	FOS - wet (Jw = 0.66)					
Pf	0.00	Probability of Failure	0.06	%					

Crown Stability (NOB) - 1st quartile - Weathered Rock Self-supporting									
Level - 1150 - 1175 (NOB)									
Cs	1.66	Scaled crown span (m)							
S	12.00	Stope span (m)							
γ	2.96	Ore Density (t/m ³)	weighted for surcharge						
T	153.00	Thickness (m)			radians	cos			
θ	70.00	Orebody Dip (degrees)			1.2217	0.342			
Sr	0.17	Span Ratio (= Span / Strike Length)							
S	12.0	Span of crown (m)							
L	70.0	Length (m)							
Sc	3.44	Critical Span	2.874						
Q	1.10	Dry conditions	0.726	Wet conditions					
FOS	2.07	Factor of Safety	1.732	FOS - wet (Jw = 0.66)					
Pf	0.08	Probability of Failure	7.65	%					

Figure 12- Crown Stability Calculations Considering Weathered Rock Self-supporting (Case 2)

Currently, the crown of the 1175 – 1200 level stopes are partially supported by the development drive ground support. In the writer's experience at LLM, this support was observed to have deteriorated since installation some 8-9 years ago. Observations of gypsum formation, dislodgement of fibrecrete, and rock bolts in advanced stage of corrosion were noted. For the closure stability assessment ground support within the mine will be disregarded.

Carter (2014) provides a classification for the suitable FoS requirements for design of crown pillars relevant to their service life (Table 11. For a closure assessment, Table 11 would indicate a FoS requirement of >>2 to safely consider the crown pillar 'Stable'.

Table 11- Acceptable Risk Exposure Guidelines - Comparative Significance of Crown Pillar Failure

Class	Probability of Failure %	Minimum Factor of Safety	Maximum Scaled Span, $C_s (= S_c)$	ESR (Barton et al. 1974)	Design Guidelines for Pillar Acceptability/Serviceable Life of Crown Pillar				
					Expectancy	Years	Public Access	Regulatory position on closure	Operating Surveillance Required
A	50 – 100	<1	$11.31Q^{0.44}$	>5	Effectively zero	< 0.5	Forbidden	Totally unacceptable	Ineffective
B	20 – 50	1.0	$3.58Q^{0.44}$	3	Very, very short-term (temporary mining purposes only ; unacceptable risk of failure for temporary civil tunnel portals	1.0	Forcibly Prevented	Not acceptable	Continuous sophisticated monitoring
C	10 – 20	1.2	$2.74Q^{0.44}$	1.6	Very short-term (quasi-temporary stope crowns ; undesirable risk of failure for temporary civil works)	2 – 5	Actively prevented	High level of concern	Continuous monitoring with instruments
D	5 – 10	1.5	$2.33Q^{0.44}$	1.4	Short-term (semi-temporary crowns, e.g. under non-sensitive mine infrastructure)	5 – 10	Prevented	Moderate level of concern	Continuous simple monitoring
E	1.5 – 5	1.8	$1.84Q^{0.44}$	1.3	Medium-term (semi-permanent crowns, possibly under structures)	15–20	Discouraged	Low to moderate level of concern	Conscious superficial monitoring
F	0.5 – 1.5	2	$1.12Q^{0.44}$	1	Long-term (quasi-permanent crowns, civil portals, near-surface sewer tunnels)	50–100	Allowed	Of limited concern	Incidental superficial monitoring
G	<0.5	>>2	$0.69Q^{0.44}$	0.8	Very long-term (permanent crowns over civil tunnels)	>100	Free	Of no concern	None required

4.2.7 Results Discussion

The results in Figure 11 and Figure 12 indicate that the crown pillar FoS against rock mass collapse varies with the different scenarios.

Table 12 below summarises the results including the probability of failure and the serviceability life (including those that are unacceptable, coloured red).

Discussed above, the most likely conditions are those of 2nd quartile Q parameters and $J_w = 1$. In all Cases (1 and 2) the FoS is acceptable above 2.0. Evidently, all scenarios utilising 1st quartile Q parameters, apart from Case 2 in NOB, are unacceptable with some very low FoS, and service life. Whilst 2nd quartile Q parameters are most likely, there will be occurrence of 1st quartile Q parameters in LLM, especially in association with fault zones. It is worth noting that “failure” does not imply total collapse, but the commencement of unravelling failures. The Western Limb achieved an unacceptable FoS when $J_w = 0.66$ for Case 1 (weathered rock is not self-supporting) and all J_w conditions. This scenario cannot be discounted as it is assumed for early closure, during ground water recharge. The Western Limb crown pillar when “wet” and covered by Case 1 ground, found to have a FoS of 1.6, equating to a probability of failure of 5-10% and service life of 5-10 years.

For a closure assessment the results for the critical case must be addressed, that being Case 1, $J_w = 0.66$ and 1st quartile Q parameters. Results in Table 12 indicate that FoS can be as low as 0.9, but generally around 1.3. This corresponds to a service life of generally 2-5 years. In real terms, this assessment considers the void backs in the

1200 level are unsupported, so at such time when ground support has deteriorated beyond its usefulness, the backs will begin to unravel in (critical case) 2-5 years.

Table 12- Summary of FoS Results for the Scaled Span Method

Location	Case	JW	Q Quartile	FOS (Probability of failure%)	Serviceability Life (years)
Eastern Limb	1	0.66	1st	1.1 (20-50%)	1-2
			2nd	2.0 (0.5-1.5%)	50-100
		1	1st	1.3 (10-20%)	2-5
			2nd	2.4 (0.5-1.5%)	50-100
	2	0.66	1st	1.6 (5-10%)	5-10
			2nd	2.8 (<0.5%)	>100
		1	1st	1.9 (1.5-5%)	15-20
			2nd	3.3 (<0.5%)	>100
Western Limb	1	0.66	1st	0.9 (50-100%)	<0.5
			2nd	1.6 (5-10%)	5-10
		1	1st	1.1 (20-50%)	1-2
			2nd	2.0 (0.5-1.5%)	50-100
	2	0.66	1st	1.3 (10-20%)	2-5
			2nd	2.3 (0.5-1.5%)	50-100
		1	1st	1.6 (5-10%)	5-10
			2nd	2.8 (<0.5%)	>100
NOB	1	0.66	1st	1.3 (10-20%)	2-5
			2nd	2.3 (0.5-1.5%)	50-100
		1	1st	1.6 (5-10%)	5-10
			2nd	2.8 (<0.5%)	>100
	2	0.66	1st	1.7 (1.5-5%)	15-20
			2nd	3.1 (<0.5%)	>100
		1	1st	2.1 (0.5-1.5%)	50-100
			2nd	3.7 (<0.5%)	>100

RED FoS and Service Life are unacceptable for Closure

4.3 Empirical Analysis - Bulking of Failure

To explore the impact of the critical condition of crown pillar failure, a bulking failure analysis has been undertaken to assess the extent of the upward failure progression and subsidence at the surface. This method has also been applied to the upper Decline and is the basis for discussion for all capital / development openings.

4.3.1 Assessment methodology

The bulking failure analysis assumes failure progression only occurs in the vertical direction. The void decreases as the failure moves upwards until a point of choking, the depth of the void H is estimated as:

$$H = H_o - xB > 0 \quad (1)$$

where H_o is the starting void height, x is the amount of failed ground (a length), and B is the bulking factor.

At void chocking, $H = 0$, the amount of failed ground equates to $x = H_o/B$. After failed ground, the depth from the surface to the top of a void is estimated as:

$$D = D_o - x > 0 \quad (2)$$

where D_o is the starting depth. Given $x = H_o/B$ at void chocking, Equation 2 becomes:

$$D = D_o - H_o/B > 0 \quad (3)$$

which estimates the depth from the surface where void chocking occurs. Given void chocking occurs at the surface or lower ($D = 0$), the critical bulking factor is then:

$$B = H_o/D_o \quad (4)$$

Conversely, the critical starting depth is:

$$D_o = H_o/B \quad (5)$$

Bulking of soils and rocks classification descriptions from the British Geological Survey (BGS - Entwisle, D. et al, 2015) indicates that weak rocks that are likely to break into a wide variety of particle sizes, sand to cobble or even boulder, have a bulking factor of 0.40 (40%) to 0.55 (55%). For sandy material, the BGS indicates a bulking factor of 0.15 (15%).

For the assessment, a bulking factor of 0.1 (10%) was chosen for the weathered rock above the base of oxidation (around 40 m bgl). Rock below the base of oxidation has a bulking factor of 0.3 (30%) applied. These values are conservative compared to BGS (2015) but are frequently adopted in mining operations and considered appropriate.

4.3.2 Crown Pillar - Eastern and Western Limbs Bulking Results

As mentioned in Section 3.1, the upper level stopes of the mine in the Eastern and Western limbs are, and will not be, tight filled. Material that fails / unravels will occupy the void between the top of the backfill and the crown of the stopes. The drives atop the stopes are within the crowns of these stopes. As such, an overall void height of $H_o = 9$ metres between the top of paste backfill and backs of the drives can be assumed to remain for the life of mine. This void height is the average height along the wider section (13 m) of crown span.

Due to Max's Fault proximity to the Eastern limb crown pillar, poor rock mass characteristics is expected. This fault, presenting a 5-10m thick zone mapped underground, will unravel, and occupy the void between the top of the back fill and the crown of the stopes. As shown in Figure 13, using Equation 3 and a bulking factor representative of poor ground of 10% ($B = 0.1$), the void chocking occurs $D = 38$ m below the 1340 mRL surface level.

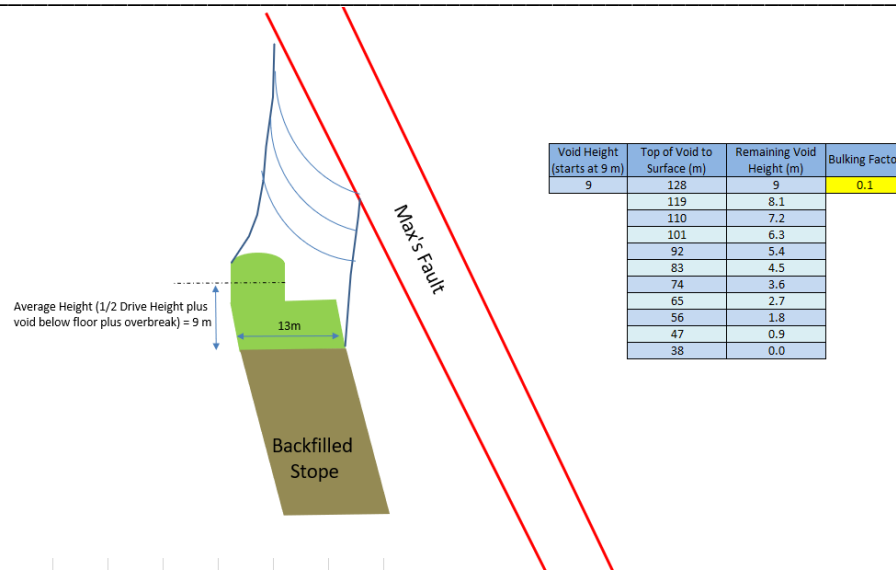


Figure 13- Schematic concept of void with filling by material from unravelling Max's Fault and chocking stage at 38 m below surface at the Eastern Limb. Starting point at 128 m below surface (base of crown pillar)

Using Equation 4, the critical bulking factor is around 7% such that the upward failure reaches the surface at the Eastern Limb (Figure 14). Such bulking factor is very unlikely. Based on the BGS (2015) soil classification, 7% is only achieved by very soft to soft clay or silt, this material is not recorded in LLM boreholes.

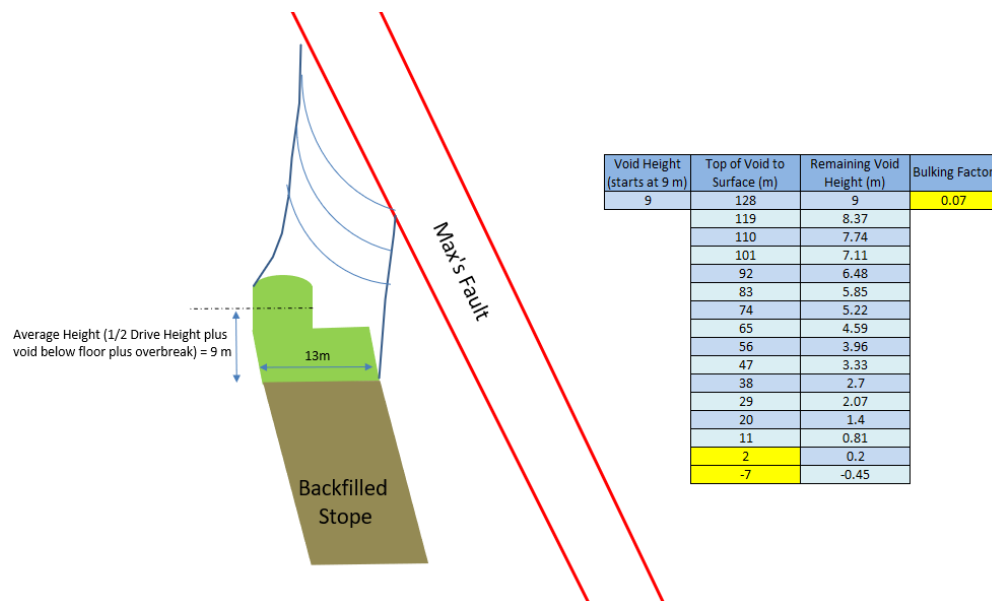


Figure 14- Schematic concept of void with filling by material from unravelling Max's Fault and chocking stage at surface at the Eastern Limb. A bulking factor of 7% applied.

The Western Limb is not proximal to major structures. In contrast to the Eastern Limb, it can be assumed that the rock mass is better (not faulted), therefore a 30% bulking factor has been applied in Equation 3. The stopes are not tight filled; hence a span of 14 m and average void height of 10 m is used. Figure 15 shows void choking

occurs at 92 m from surface. Since this failure zone has choked beneath the base of oxidation, the use of 30% bulking factor for the entire column is appropriate.

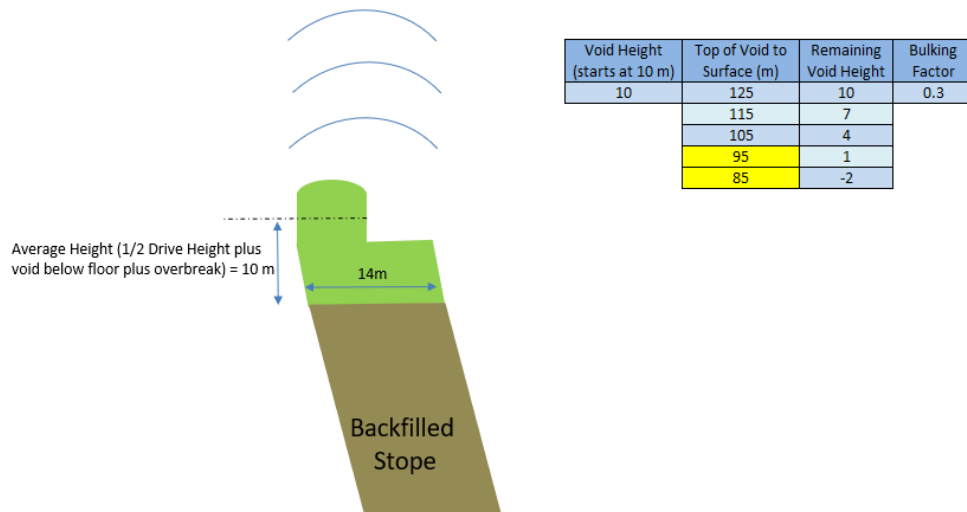


Figure 15- Schematic concept of void with filling by material from unravelling rock mass and chocking stage at 92 m below surface at the Western Limb. Starting point at 125 m below surface (base of crown pillar)

Exploring the Scaled Span Method critical cases, all crown pillars were shown to fail. The bulking of failure analysis indicated that all upward ground collapse will be arrested prior to reaching the surface.

Failure propagation would reach 38 m bgl for the Eastern Limb. A sensitivity analysis found that the bulking factor must be lower than 7% for subsidence to reach the surface and this would not occur given the material types at LLM. For the Western Limb, the upward failure is expected to choke and terminate its progression at 92 m from surface. Since NOB has been tight filled, there is no void to allow propagation of failure.

The assessment confirms no subsidence should be seen at the surface.

4.3.3 Portal and Upper Decline

The portal and upper levels of the Decline will see inevitable deterioration of the ground support in the future; therefore, a bulking failure analysis is required. The dimension of the Decline (the void) is 6m high x 6 m wide.

Based on the report 'Lady Loretta Geotechnical Factual Report Proposed Decline and Shaft' (Mining One, 2012) the extremely weathered to highly weathered material is on average 40 m below surface. For this type of rock mass, it is plausible that a bulking factor of 10% ($B = 0.1$) is applied in the analyses. Using Equation 5, it was found that where the Decline is less than 60 m deep from surface, any upward failure will reach the surface before it bulks out and self supports (Figure 16). A plot has been produced in Figure 17, which graphs likely subsidence depth according to origin of failure. Figure 17 shows an upward failure that starts at 50 m from surface (Decline backs at 50 m bgl) will produce 1 metre of subsidence at surface level. For the backs at the portal entrance ('P' in Figure 17) located around 10 m bgl, a subsidence (S) of 5 m is expected.

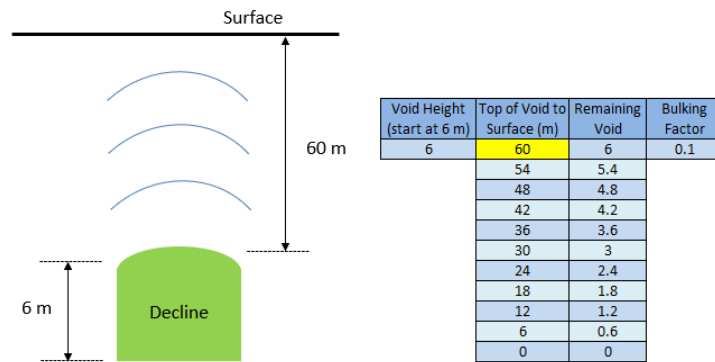


Figure 16-Schematic concept of void with filling by material from unravelling rock mass and chocking stage at surface for the Decline. Starting point at 60 m below surface.

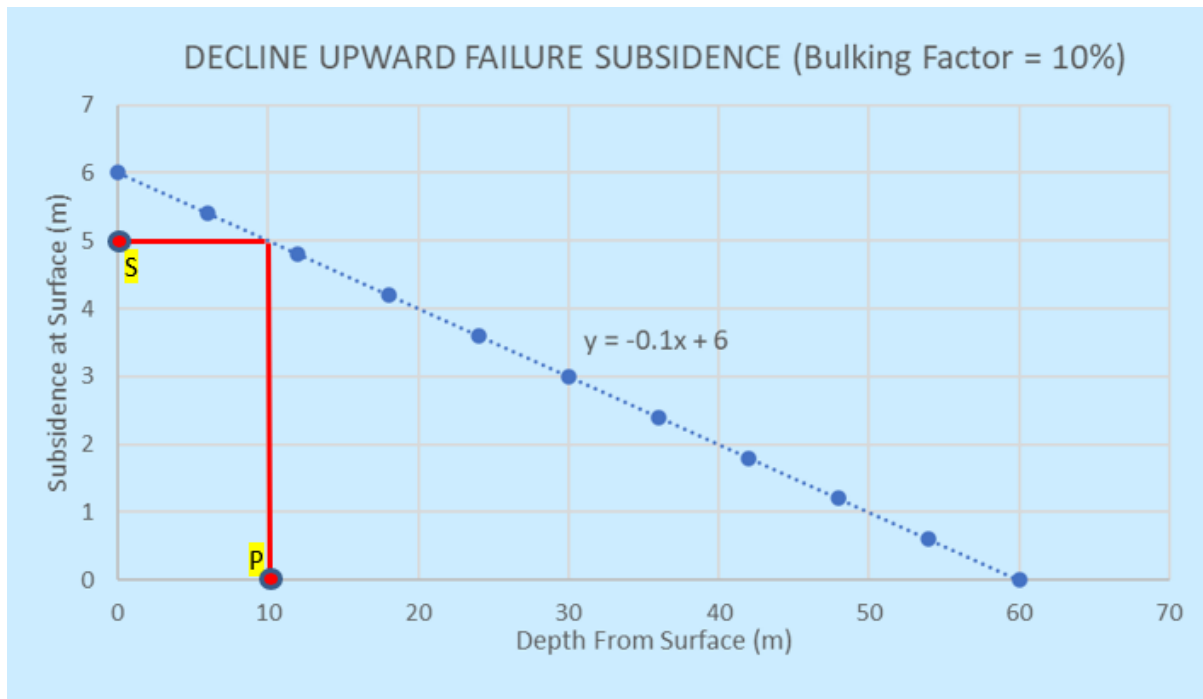


Figure 17- Subsidence metres at surface in relation to the depth from surface of the Decline. Portal backs (P) and expected subsidence (S) expected.

4.3.4 Subsidence from Voids Between Levels

As with the upper Decline, all development openings below are expected to show ground support deterioration. While the intersections along the Decline, the access drives and the footwall drives are spaced vertically every 25 m, they are positioned in a stepped layout. This stepped design will limit the available voids from one level to the other with any potential upward failure. Furthermore, based on Equation 5, in Section 4.3.1. a drive 6mH x 6mW will choke at 20 m high and subsidence on the level above will not occur. In this case a bulking factor of 30% can be applied since the uppermost level (1200 L) is approximately 100 m beneath the base of oxidation.

4.4 2D Modelling Analysis

The RS2® (formally Phase2®) 2D modelling software was chosen to examine potential subsidence on the surface. The modelling was staged from excavation and backfilling underground with “drained conditions” i.e. operational groundwater levels, to a final mine model with backfilled stopes and water recharge to the pre-mining level. Like the empirical analysis, three regions are considered: the Eastern Limb, Western Limb, and the North Ore Body (NOB). The cross sections reflect the wider crown span on the top level.

4.4.1 Rock Mass Characterisation

Material properties used in the numerical models were derived from laboratory test results presented in the GCMP, and from a review of the rock mass classification values (Q') presented in Sandy (2000). The material properties are presented in Table 13. Some values (in the GCMP) were assumed from a study conducted by AMC Consultants between 1997 and 2000, since laboratory or rock mass classification data were not available for some rock types, namely faults (AMC, 2020). Geological Strength Index (GSI) values, apart from the Fault, are based on underground observations by LLM site geotechnical engineers. A 40 m thick layer of soil was added to the model and assumed as a non-self-supporting load. Only elastic properties were considered in the model. AMC (2020) indicated that yielding with permanent change in shape occurs in stope walls following extraction, and for simplification on the method used here, the plastic properties will have little influence on surface.

Table 13- Material Properties

Unit	Friction angle (°)	Cohesion (kPa)	UCS (MPa)	E (GPa)	ν	GSI	m_i	m_b	s	a	E_r	Tensile strength (MPa)
CU			122 [#]	55	0.25	60	7	1.678	0.012	0.503	28.6	-0.854
OH			80 [#]	64	0.24	60	7	1.678	0.012	0.503	33.3	-0.560
PU			101 [#]	36	0.27	60	7	1.678	0.012	0.503	18.7	-0.707
Fault	30	20	30			30		2.00	0.0023	1		-0.023
Soil	35	50		100	0.25							-0.05
Paste	35	50	500	250	0.3							-0.05

[#]Lowest value between 1997 and 2000 study from AMC 2020; Assumed numbers are written in italics

4.4.2 In-situ stress

The in-situ stress was determined using the Western Australia School of Mines AE method. The results were presented in the GCMP. The values used in the numerical modelling based on the overall excavation orientation for each of the 3 regions are shown in Table 14.

Table 14- Stress Applied

	Horizontal to Vertical Total Stress Ratio	
	Horizontal In-plane	Horizontal Out-of-plane
Western Limb	1.77	2.12
Eastern Limb	1.993	1.956
NOB	1.993	1.956

4.4.3 Mining sequence

The mining sequence for the Eastern and Western Limbs follows a top-down order from 1200 level to 1050 level and a bottom-up order from the lowest level in the chosen section to 1025 level. For the NOB, only bottom-up sequence was adopted in LLM. These sequences were modelled in distinct stages of excavation and backfilling in each of the three models, noting that the surface level was fixed at 1340 mRL. Further, voids (5 to 8 m high) at the top of backfilled stopes at upper levels of the Eastern and Western limbs were added to simulate the lack of localised tight filled areas.

4.4.4 Groundwater

The mining stages were modelled in a drained (dry) condition, apart from the final stage, where all stopes in each model have been backfilled. In the final stage, the water table level is modelled to reach a steady state pre-mining level of 1290 mRL after complete water recharge of the underground mine. All stages are in drained conditions with rock mass porosity assumed at 1% for the main lithologies and 9% for paste and 10% for soil based on the permeability from C.M Jewel & Associates (2006) and other literature sources. The base of the soil layer was assumed above the water table, at 1300 mRL, 40 m bgl.

4.4.5 Model results and limitations

The 2D analysis results from RS2[®] are presented in Figure 18 to Figure 23. Negative values indicate settlement and positive values indicate raising/swelling relative to the pre-mining levels. For a more comprehensive visualization of the results, refer to the electronic models provided in Interpret RS2[®] for each of the three sections.

For all three sections of each of the three regions, the recorded settlement on surface increases as the mining stages progress. Notably, in the final stage, where water is recharged into the system and pore pressure acts, there is a buoyancy effect with the raising/swelling of the rock mass lifting the surface level. This buoyancy effect will increase over time as the groundwater recharges, and the lifting of the ground surface will follow.

The vertical displacement at the final stage of mining (dry mine), that created by the buoyancy effect and groundwater recharge, and the long term closure resultant displacement are shown in Table 15 for each of the three representative sections.

Table 15- Surface displacement at various stages from 2D Analysis

	At Final Stage of Mining (Dry Mine)	Buoyancy Effect (Mine Recharged)	Net subsidence from pre-mining
Eastern Limb	20 cm ↓	18 cm ↑	2 cm ↓
Western Limb	20 cm ↓	32 cm ↑	12 cm ↑
North Ore Body	19 cm ↓	9 cm ↑	10 cm ↓

At the Eastern Limb, the vertical displacement changes over time, showing a settlement of 20 cm (at final stage of mining – dry mine) followed by an 18 cm uplift from flooding (the buoyance effect). This results in a final surface 2 cm lower (resultant settlement) than from a pre-mining surface. At the Western Limb, the resultant surface level shows a 12 cm uplift and the North Ore Body, a 10 cm settlement from pre-mining stage. These subsidence and uplift magnitudes would likely go unnoticed by visual observations.

Considering the low permeability of the rock mass and high water surface runoff, water table fluctuations will have minimum effect on the modelling.

A limitation of this model is that the result is based on an elastic model. Some degree of plasticity exists in the materials. Moreover, creep behaviour for the overburden materials (loose soil and vegetation) has not been considered, which may result in delayed subsidence. As such, the model is unable to predict when in time the events shown in the model output will occur.

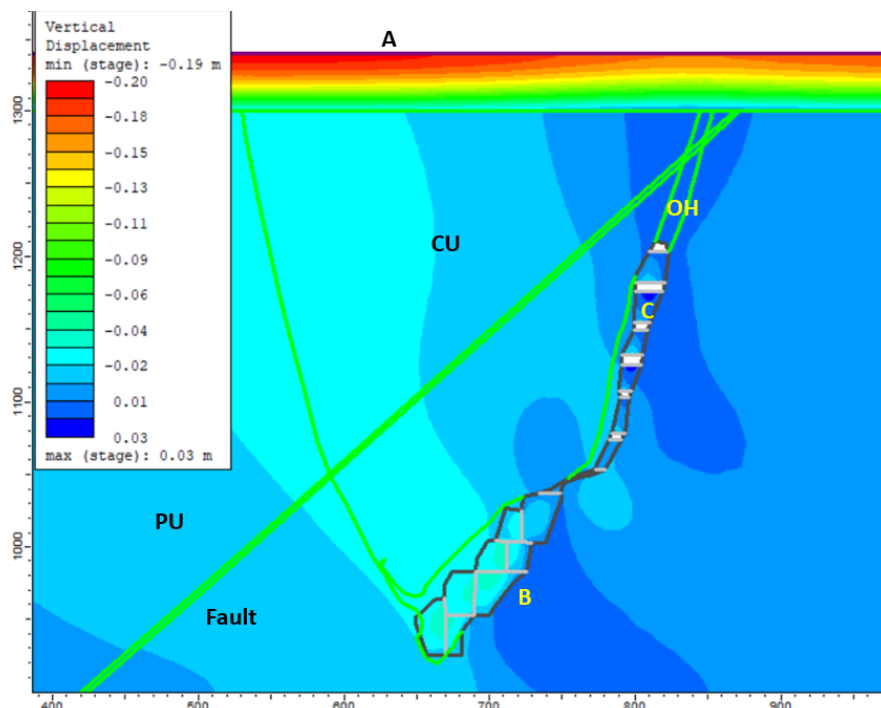


Figure 18- Eastern Limb – Final stage of mining with last stope backfilled (Dry conditions); 20 cm subsidence on surface (A), 2 cm raising at (B) and 3 cm of raising at the top of paste in (C)

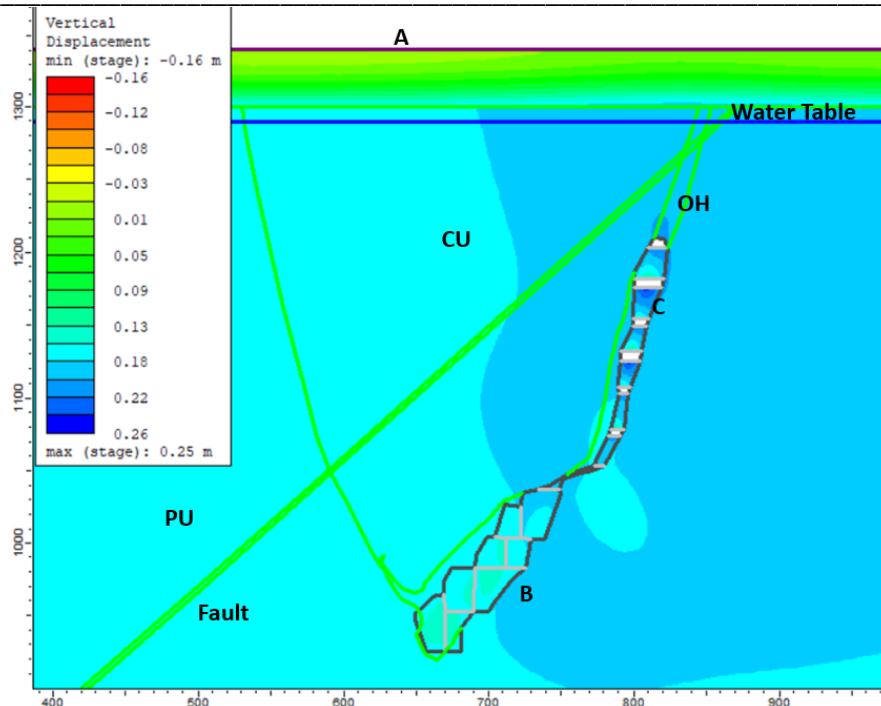


Figure 19- Eastern Limb – End of mining and water recharge completed (Flooded); 2 cm subsidence on surface (A), 18 cm raising at (B) and 24 cm raising on top of paste in 1150 L stope (C)

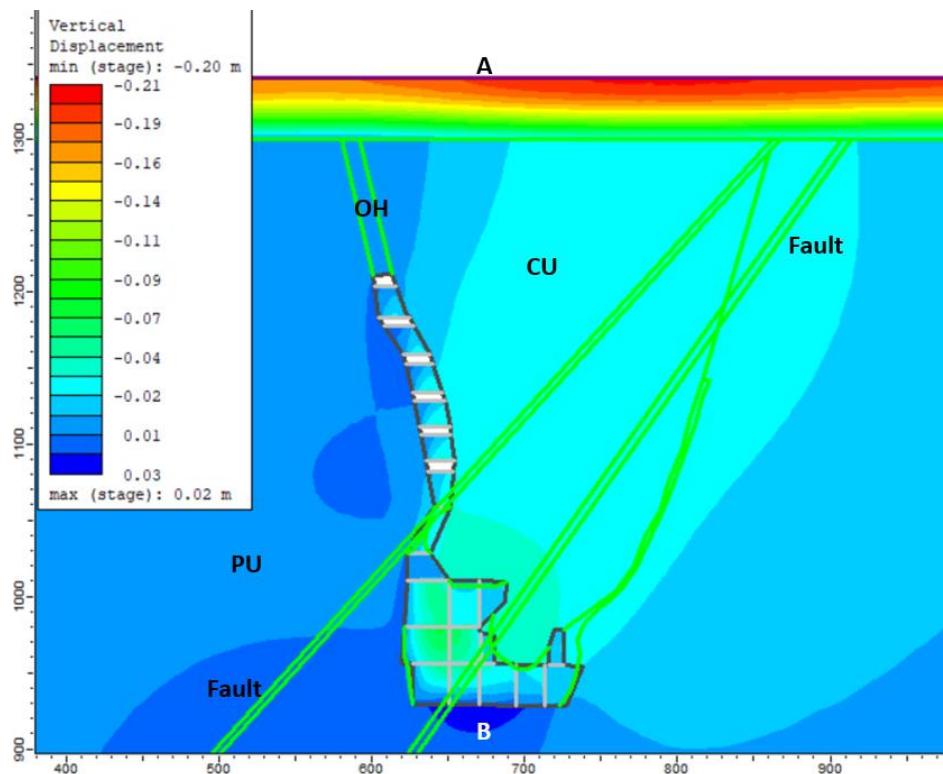


Figure 20 - Western Limb – Final stage of mining with last stope backfilled (Dry conditions); 20 cm subsidence on surface (A) and 2.4 cm raising at the base of excavation (B)

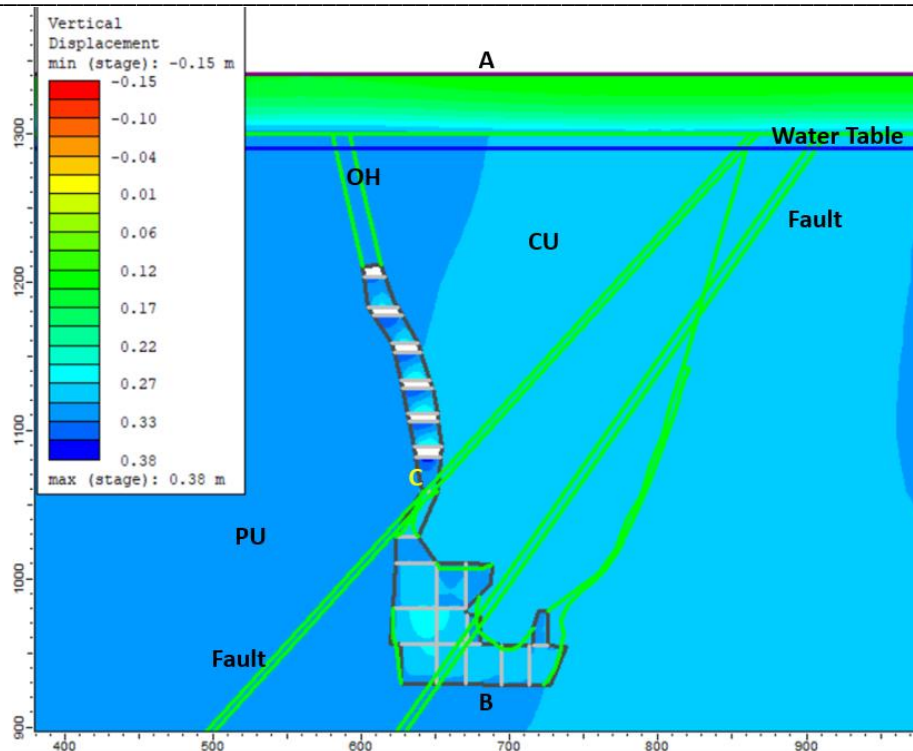


Figure 21- Western Limb – End of mining and water recharge completed (Flooded);12 cm raising on surface (A), 33 cm raising at the base of excavation (B) and 37 cm raising on top of paste in 1050 L stope (C).

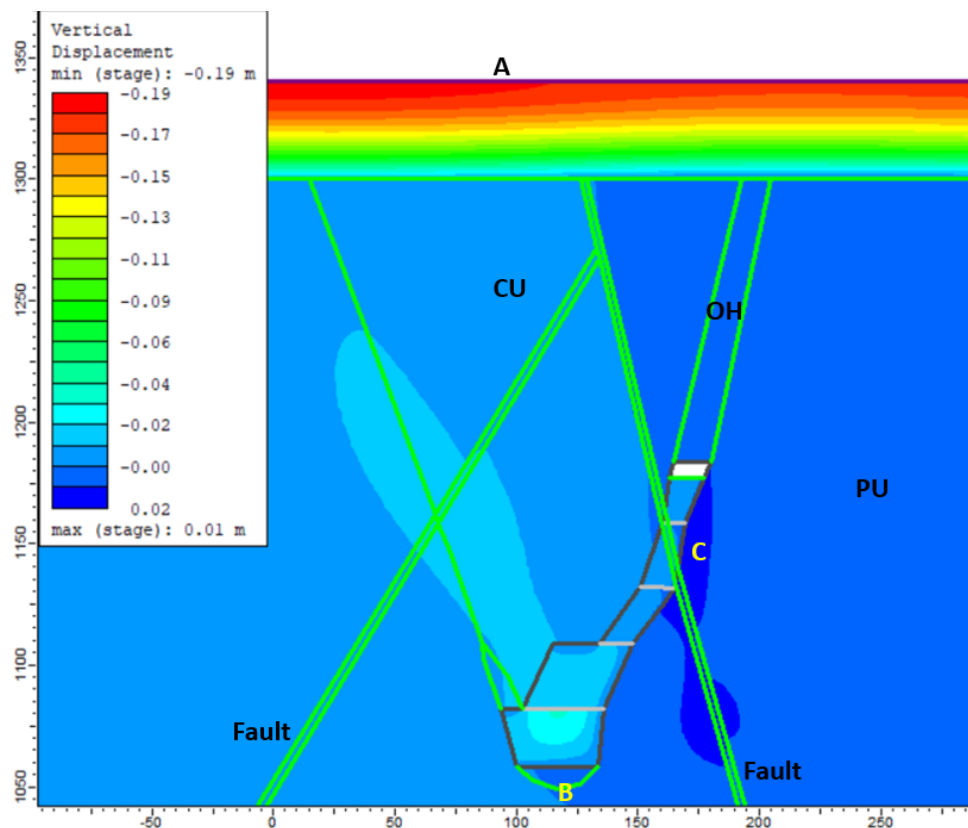


Figure 22 - NOB – Final stage of mining with last stope backfilled (Dry conditions); 19 cm subsidence on surface (A), < 1 cm subsidence at the base of excavation (B) and 1.4 cm raising (C).

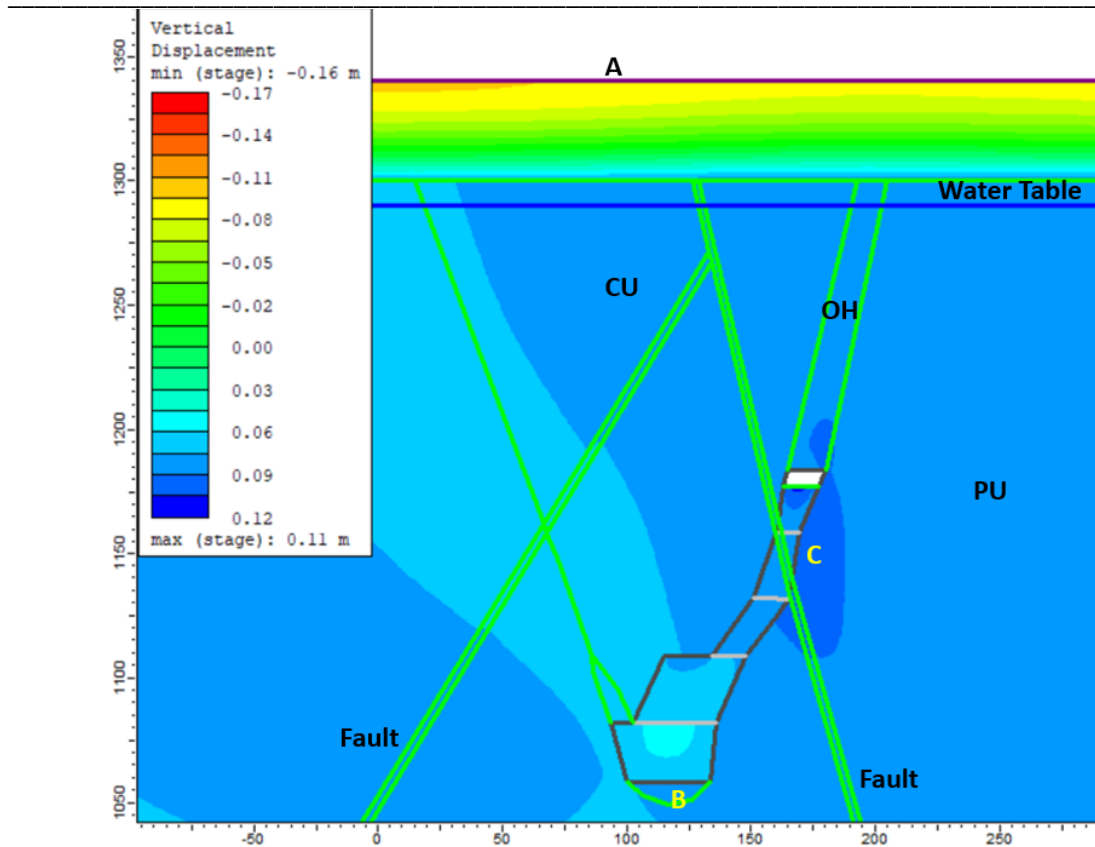


Figure 23 - NOB – End of mining and water recharge completed (Piezo line added); 10 cm subsidence on surface (A), 8 cm raising at the base of excavation (B) and 10 cm raising at (C).

4.5 Shaft Stability Assessment

There are four open shafts at LLM that require assessment, two fresh air rises (FAR) and two return air rises (RAR), one of which is also an exploration shaft. There is one additional historical (RAR) shaft, which during excavation collapsed at 30m deep. It was subsequently backfilled and another RAR location developed. Shaft locations are depicted in Figure 24.

The standard empirical method for assessing shaft stability is the McCracken-Stacey method (1989). This method modifies the standard rock mass quality Q rating by 3 additional factors to arrive at Q_R , the raise bore rock quality. LLGRD8, a 165.4m vertical diamond drill hole in the location of the fresh air rise (surface collar mine grid coordinates of 841mE, 2392mN), was logged as part of the Mining One 2012 report and considered representative of that existing ventilation shaft. The inferred location of LLGRB8 is depicted in Figure 24, in the location of 'Shaft 2 – Fresh Air'. The McCracken-Stacey methodology has been applied to this logging as an assessment of long-term shaft stability (logging is provided in Appendix B).

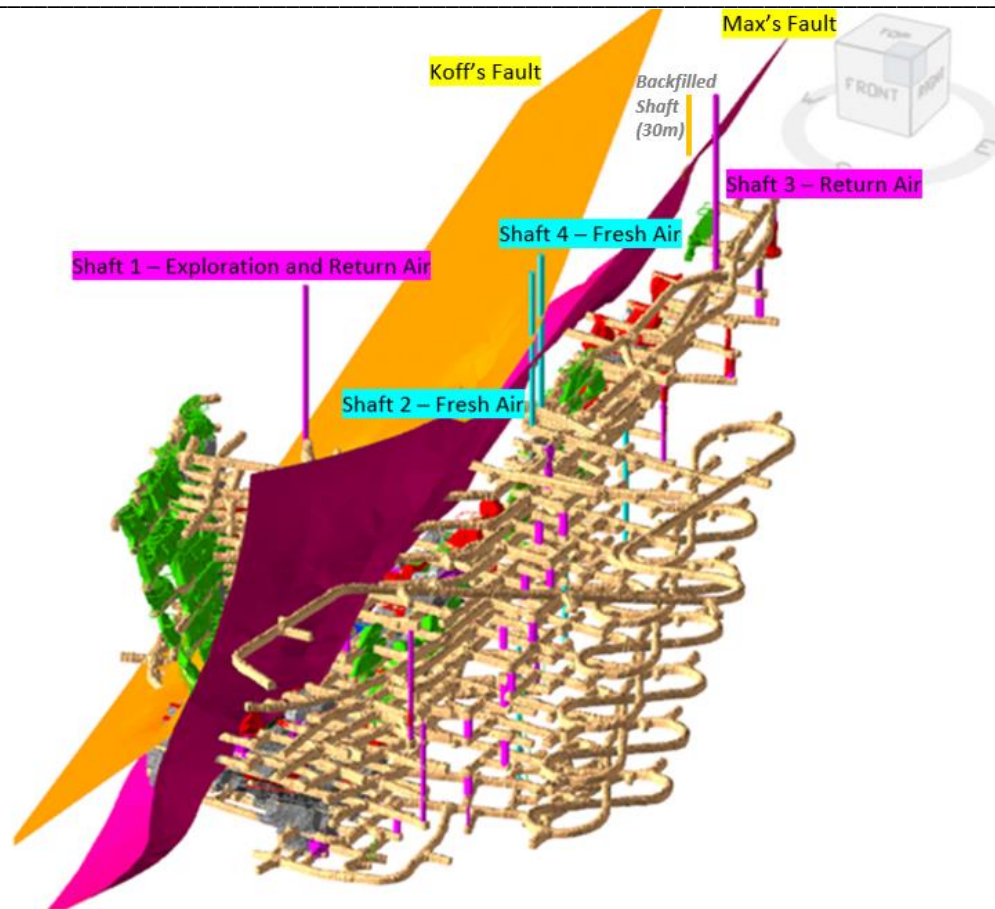


Figure 24- Location of shafts to development and faults. LLGRD8 cored hole at location of Shaft 2 – Fresh Air.

4.5.1 Assessment Assumptions

Information on discontinuity orientation was unavailable, however given most of the hole was logged as having 3 or more defect sets the Q_R orientation adjustment value of 0.85 was chosen which assumes 1 defect set with a dip 60-90° (true number of steeply dipping sets is likely to be >1 in some places which would further reduce Q_R). The poorest Q_R weathering adjustment value of 0.5 has been chosen given the long-term nature of the assessment and the fact that much of the length of the shaft will experience groundwater ingress and associated weathering over a considerable time. The Joint Water Reduction value, J_w , which was rated as 1 in the original 2012 assessment, has been reduced to 0.66 for depths below 60m which was the pre-mining depth of the water table (Douglas Partners 2012). Although hydrostatic pressure will equalise with flooding, there is not expected to be significant wash out of joint infill material, however it is expected that the presence of groundwater over the long term will reduce cohesion of joint surfaces so a reduction in stability is expected.

4.5.2 Shaft Assessment Results

Converting the calculated Q_R values to rock classes it is found that of the 165.4m hole:

- 0m to 43.9m: composed of “Extremely Poor” and completely oxidised ground.
- At 47m is the base of complete oxidation.

- 43.9 m to 113.6m: predominantly “Extremely Poor” to “Very Poor” ground, with some sections of “Poor.”
- 113.6m to 132.8m: predominantly “Exceptionally Poor” to “Extremely Poor” due to fault intercepts.
- 114.5m to 117.5m Koff’s Fault
- 131.5m to 132.8m Max’s Fault
- 132.8 m to 165.4m: predominantly “Extremely Poor” to “Very Poor” ground, with some sections of “Poor.”

To illustrate these classifications further, photos of selected core trays along with comments about classification have been included in Appendix C.

The expected stability of a shaft is relative to the shaft diameter. McCracken-Stacey’s method includes a Probability of Failure (PoF) chart shown in Figure 25 with Q_R values calculated for LLGRD8 superimposed for a 5m shaft diameter, the standard for shafts at Lady Loretta. The meterage indicated in Figure 25 is the total accumulated length of core for those PoF categories, however discontinuous along the length of the hole. Based on this chart, assuming a 5m diameter:

- The completely oxidised upper section from 0 to 43.9m has a PoF >50%,
- The fault intercept section from 113.6 to 132.8m has a PoF >50%,
- Much of the rest of the hole also has a PoF >50%, with only an accumulated 43m having a PoF 25-50% and accumulated 17.6m with a PoF 10-25%.

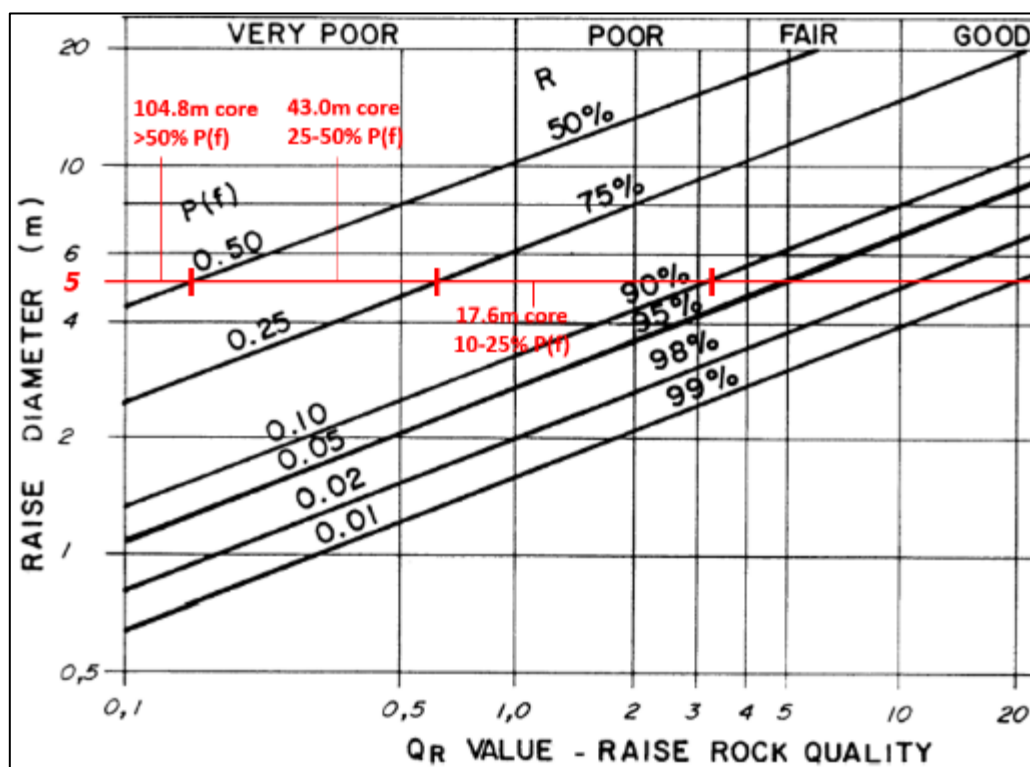


Figure 25- McCracken-Stacey (1989) Probability of Failure Chart with 5m Shaft diameter and QR results of LLGRD8 superimposed

Results indicate that pre-mining ground conditions for majority length of the 5m diameter shaft at LLM will be unstable without passive support. A concrete lining was applied during construction to address the likely failures that could occur. This support was designed to comply with the operational requirements of the mine life. The long-term functionality and necessary actions to avoid failure post mine closure will be discussed in Section 5.

4.5.3 Extrapolation to other Shafts

Similar shaft assessments have not been conducted for ground in the vicinity of the other three open shafts at Lady Loretta. Their conditions were assumed consistent to LLGRD8, as relatively poor and weathered ground persisted across the mine. LLM assumed that significant portions of the other shafts would also likely be unstable and hence all were concrete lined.

Conditions found in LLGRD8 can be confidently extrapolated to all other shafts. Section 6.3 of the LLM GCMP domains ground according to RQD values and classifies 52% of diamond drill core as 'Very Poor' to 'Fair' and 8.7% as 'Extremely Poor'. This proportion of poor ground is likely to be even higher closer to surface due to weathering. Additionally, two major faults, Max's and Koff's Fault intersect the Shaft with collars on surface (Figure 24). Both are filled with gouge and broken rock which will worsen stability.

4.6 Empirical and Modelling Results Discussion

Empirical assessment of the crown pillar stability indicates that in a most likely case there will be acceptable FoS but in critical cases, there will be unacceptable FoS. In these critical cases, FoS can be as low as 0.9 which indicates imminent failure. Generally, in critical cases FoS was around 1.3. When and if failure occurs, blocks will dislodge progressively and fall, filling the identified voids. Failure propagation (and bulking) assessment indicates that the voids left are small enough, that upwards progression will not reach the surface, and will not cause settlement. The Eastern limb at Max's Fault, was the critical scenario, where upward failure progression will reach only 38 m bgl before chocking.

2D modelling for each of the three regions show incremental surface settlement (negative values) as the mining stages progress. After mine closure as the groundwater recharges, a buoyancy effect will develop over time, causing lifting of the ground surface. Areas such as the Western Limb at this time will have a surface slightly above the pre-mining levels. The settlement and uplift of surface suggested by the modelling was minimal, and in the order of 20cm. The 2D modelling is supported by the empirical assessment.

Analysis of the upper Decline found that above 60 m bgl, a Decline failure will ravel and cause subsidence at the surface. In the area above the portal, subsidence could be seen in the order of 5 m for a failure that commences at 10 m from the surface. The shaft stability assessment revealed that ground conditions were 'Poor' to 'Extremely Poor' indicating that much of the length of the 5m diameter shafts at LLM will be unstable without passive support. This support must be functional post closure.

5 POST MINING STABILISATION OF UNDERGROUND WORKINGS

Stabilisation of underground workings that have been identified as a subsidence risk is best achieved by backfilling.

5.1 Backfilling Material Suitability

Mine waste rock material placed at the LLM waste rock dump (WRD) and used to construct the ROM pad are potential materials for use as Decline and shaft backfill with some provisions. Waste rock will be used to provide passive support to Decline and shaft walls and the Decline back. The backfilled material does not require to be self-supporting since it will not be exposed vertically or horizontally.

The advantages of using waste rock material are:

- Proximity to the mine portal and shafts,
- Relatively high strength,
- Reduction of WRD volume and assistance in surface and final site rehabilitation,
- Cost effective as opposed to imported or cemented fill.

Work commissioned by the *European Commission Directorate-General Research* (Mine Shafts: improving security and new tools for the evaluation of risks, 2013) recommended the following characteristics of the waste backfill for shafts in abandoned mines:

- Material of grain size between 20 and 120 mm (median of 100 mm), free of undersize particles,
- Compression strength of at least 30 MPa,
- Insoluble and non-flammable,
- Without toxic compounds,
- Zero risk of leaching harmful and hazardous elements,
- Meeting requirements of acceptable level of radioactivity.

The waste material stored in the LLM WRD, and ROM pad are composed of rocks sourced from the units described in Section 2.3. Notably, rocks within the Cyclic Unit (UCS = 122 MPa), Massive Unit (UCS = 83 MPa), Pyrite Unity (UCS = 101 MPa) and Lower Siderite/Dolomite Unity (UCS = 95 MPa). These units, being excavated during mine development, generally vary from slightly weathered to fresh rock. The more weathered material was excavated in the upper sections of the mine, particularly at the portal and box cut. These materials are stored in the ROM pad. Some weathered material and rocks with the friable gypsum compound were excavated in level footwall drives (PU Pyrite Unit) and are estimated at less than 5% of the WRD volume.

Additionally, as highlighted by ATC Williams report (2020), the WRD also includes paste from redevelopment and stope overbreak, which is dumped sporadically within the landform. The ATC Williams report also notes that the paste fill material stream is a process residue derived from the treatment of highly mineralised zinc and lead ores. Geochemical characterisation based on ABA (Acid Base Accounting) and single addition NAG (Net Acid Generation) testing indicates that the paste fill is unlikely to be PAF (Potentially Acid Forming) but could generate saline/neutral drainage if allowed to oxidise.

ATC Williams (2020) report undertook particle size distribution (PSD) testing of both the WRD and ROM, as reproduced in Table 16. In Table 16, sites TP2 to TP9 were from the WRD and TP11 and TP12 were from the ROM. The table indicates a large amount of silt and sand (higher percentage of smaller PSD fractions) on the WRD and more coarse material on the ROM pad. Paste has not been placed on the ROM. The PSD obtained from all sites do not meet the recommendations for backfilling the shafts, however the ROM material is preferred based on lower fines. It is therefore recommended for both the Decline and shaft sites that ROM material be utilised in the first instance.

Table 16- Waste Rock – Particle Size Distribution (TP2-TP9 = WRD and TP11-TP12 = ROM)

Sieve Size (mm)	TP2	TP3	TP5	TP6	TP8	TP9	TP11	TP12
0.075	32.2	22.5	54.8	15.6	21.2	43.6	5.7	6.6
0.15	34.1	26.1	64.0	18.8	24.0	46.0	7.1	8.3
0.3	36.3	29.4	69.1	22.3	26.0	47.9	9.0	10.6
0.425	37.6	31.1	70.3	24.2	27.2	48.9	10.2	12.0
0.6	39.3	33.2	71.5	26.7	28.9	50.1	11.8	13.7
1.18	43.5	38.2	73.8	32.7	33.2	53.3	15.8	18.2
2.36	50.4	45.9	76.6	41.1	38.9	58.3	22.2	25.3
4.75	58.0	53.5	79.8	50.7	46.7	64.6	29.8	35.0
6.7	65.0	60.0	82.0	58.7	52.6	69.6	36.9	42.1
9.5	71.5	66.7	85.0	67.8	59.9	74.5	43.8	49.8
13.2	80.4	75.7	88.3	78.0	69.5	79.7	51.4	58.7
19	84.4	84.5	91.0	87.0	75.6	86.6	62.3	65.0
26.5	92.1	91.6	93.9	93.1	83.9	92.8	72.0	74.5
37.5	98.3	97.7	96.4	99.5	94.1	98.3	80.7	84.3
63	100.0	100.0	100.0	100.0	100.0	100.0	97.8	100.0
75	-	-	-	-	-	-	100.0	-

5.2 Bulkhead Design

A Bulkhead will be applied for containing in place the waste backfill of the Decline. The bulkhead constructed will use the same specifications as the paste walls (bulkheads) currently utilised for production back filling, which are deemed suitable (Figure 26).

Bulkheads at Lady Loretta are based upon the Clune Wall Kit design. Bulkheads are constructed using two standard curved wall kits, depending upon the width of the drive. The walls kits consist of:

- Either curved wall kit: 5-6mW * 5-6mH, 5m Radius, or
- Curved wall kit: 7-8mW * 5-6mH, 7m Radius.
- 2 x Vertical Columns,
- 5 x Horizontal Cross Beams,
- Telescopic inserts for the columns and cross beams, and,
- Fixtures and fittings to secure.

The bulkhead must be constructed with a minimum fibrecrete thickness of 400mm. Fibrecrete must possess a UCS more than 15 MPA at the commencement of backfilling.

The Bulkhead needs to be free draining. This should be achieved by installing 100mm poly pipe through the bulkhead to drain potential water accumulation, reducing pressure against the structure. Poly drains should be installed at regular intervals across the entire bulkhead area, noting that lower drains will silt up quickly.

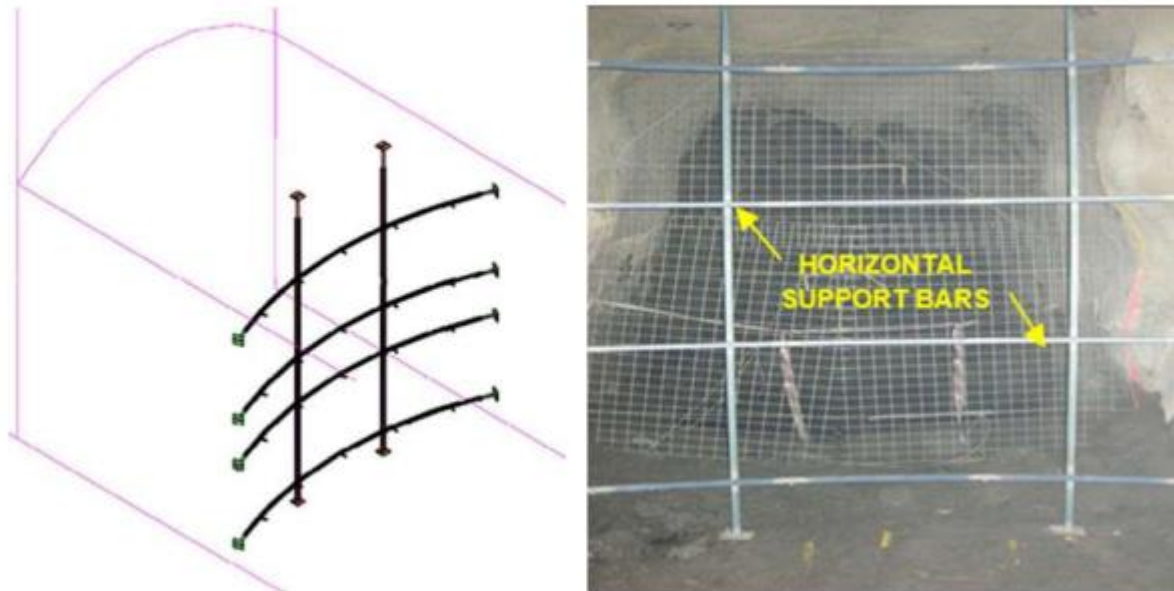


Figure 26- Clune Wall Kit Frame

5.3 Upper Decline Backfilling

As highlighted in Section 4.3.3., where the Decline is less than 60 m deep from surface, any upward failure will reach the surface before it bulks out and self supports. Considering a Decline gradient of 1: 7 and applying a 10% safety factor, the chainage to commence backfilling is 460 m from the portal as shown in Figure 27. The 10% safety factor covers eventual loss of durability in the bulkhead and collapse. Backfilling must also include stockpiles SP1 to SP4 and any crosscut in between. A “rolling bund” retreat method of placement is recommended, and this will provide the highest level of fill possible. Tight filing will be difficult to achieve, the best effort to reduce the void is required, but not essential.

A bulkhead must be installed at chainage 460 m to hold in place the waste at the start of the backfilling process. When the backfilling process is finished, a sealing bulkhead must be erected at the portal entrance. The box cut then requires backfilling to 3 m above portal backs. The material used to backfill the box cut must be geochemically benign and suitable for plant growth.

It is estimated that a total volume of around 20,500 m³ of waste will be required to backfill the upper Decline and the boxcut. The most suitable material is that sourced from the ROM.

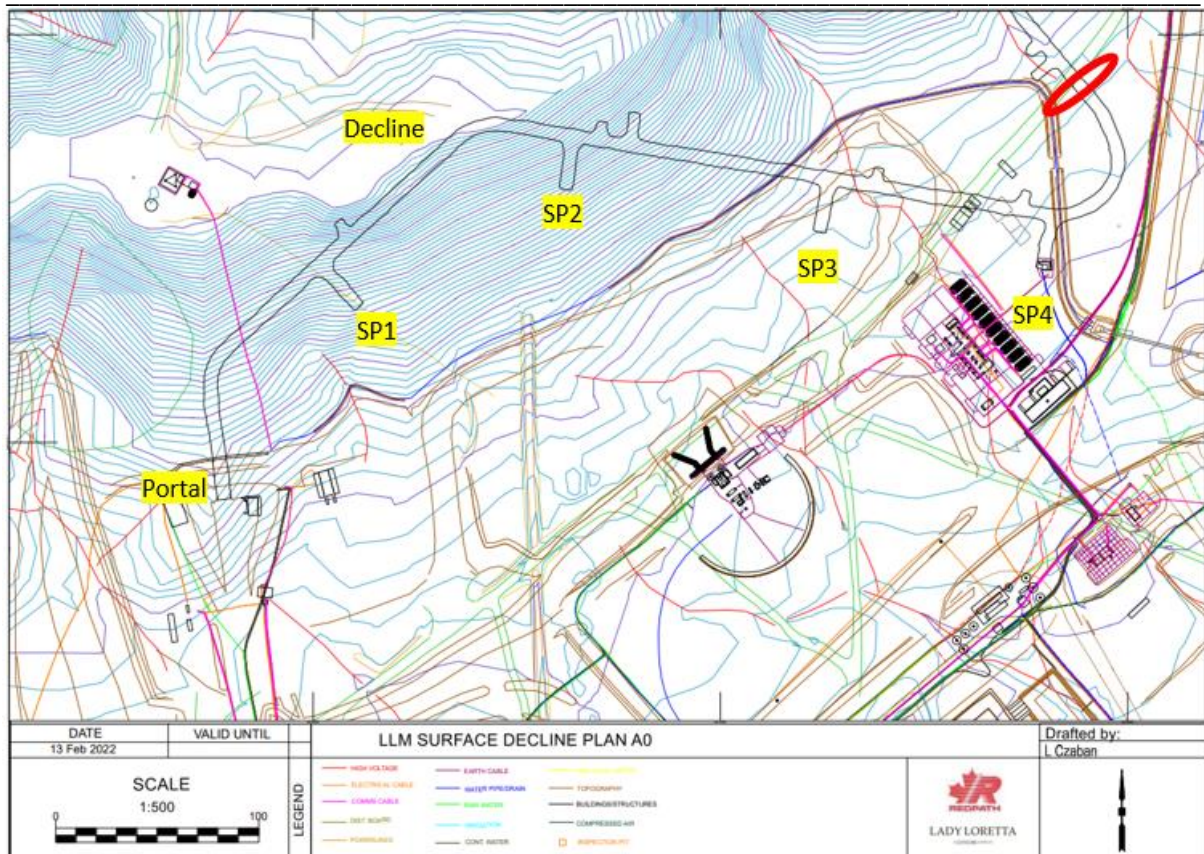


Figure 27 – Decline location on the topographic contour map showing where the backfilling towards the portal should start (Chainage 460 m in RED).

5.4 Shaft Backfilling

No bulkheads are required at the bottom of the shafts. To mitigate ongoing settlement and the lateral migration of smaller particles in the bottom of the shafts, it is recommended to use waste rock bunding. Waste rock should be placed in the underground drives, as high as possible to the backs, from the shaft brow to 10 m either side.

The most suitable material to backfill shafts are that sourced from the ROM. It is not recommended to use WRD material due to excess fines. The ROM material contains limited fines; however settlement will still occur in the shaft backfill. This will occur with progressive migration of the finer fractions to lower levels of the shaft as water percolates through voids between larger particles. To counteract this settlement, the following is required:

- Compact shaft material at the surface,
- Store additional fill material on top of the shaft, proud of the surface,
- Store additional fill material to the side of the shaft for future shaft top up,
- Monitor the settlement and top up shaft surface material as necessary, and
- Install perimeter fencing to restrict access.

It is estimated that a total of 12,000 m³ of waste will be required to backfill the four shafts linked to surface. The historical shaft that has already been backfilled should have the same settlement controls in place.

5.5 Concrete Lining and Fibrecrete Durability

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties, particularly its strength. Different concretes require different degrees of durability depending on the exposure environment and desired properties.

Concrete design has a wide range of different specifications and standards. Some recent durability evaluations conducted in Australia showed inconsistencies between the required values for design lives of 50 and 100 years (McDonnell et al., 2020). Durability of concrete is covered in Section 4 of AS 3600 Concrete Structures 3.1. The Standard applies to plain, reinforced, and prestressed concrete structures and members with a design life of 50 years $\pm$ 20% but notes that more stringent requirements would be appropriate for structures with a design life more than 50 years (e.g., monumental structures).

5.5.1 *Types and Causes of Concrete Deterioration*

Assessment of the potential causes, and factors that influence, concrete deterioration in the LLM concrete lined shafts and fibrecreted bulkheads are important to evaluate, including the suitability and potential long-term impacts on material strength.

Concrete can deteriorate for a variety of reasons, and concrete damage is often the result of a combination of factors. A comprehensive study presented by the Portland Cement Association of America is discussed here.

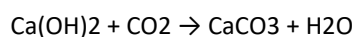
5.5.1.1 Corrosion Of Embedded Metals

Corrosion of reinforcing steel and other embedded metals is the leading cause of deterioration in concrete. When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination, and spalling. Steel, like most metals except gold and platinum, is thermodynamically unstable under normal atmospheric conditions and will release energy and revert to its natural state (iron oxide, or rust). This process is called corrosion.

The welded wire mesh of the bulkheads to be installed at the Decline, even though galvanised, can eventually corrode and weaken the fibrecreted wall. The lower bulkhead, at chainage 460 m, will be in a flooded zone of the abandoned underground mine (around 70 m below surface), and since the dry/wet cycle is not expected at this depth, the anticipated influence on the deterioration created by the acidic groundwater on the fibrecrete and consequently on the wired mesh will be slower. The concrete lining in the shafts is not reinforced.

5.5.1.2 Carbonation

Carbonation occurs when carbon dioxide from the air penetrates the concrete and reacts with hydroxides, such as calcium hydroxide, to form carbonates. In the reaction with calcium hydroxide, calcium carbonate is formed:



This reaction reduces the pH of the pore solution to as low as 8.5, at which level the passive film on the steel is not stable. Carbonation is generally a slow process. In high-quality concrete, it has been estimated that carbonation will proceed at a rate up to 1.0 mm per year. The amount of carbonation is significantly increased in concrete with a high water-to-cement ratio, low cement content, short curing period, low strength, and when highly permeable or porous. Carbonation is highly dependent on the relative humidity of the concrete. The highest rate of carbonation occurs when the relative humidity is maintained between 50% and 75%. Below 25% relative humidity, the degree of carbonation that takes place is considered insignificant. Above 75% relative humidity, moisture in the pores restricts CO₂ penetration. Lady Lorette regional humidity varies throughout the year, reaching an average of 27% in September and 53% in February (BOM, 2022 – Bureau of Meteorology). However, since the Decline and shafts will be naturally flooded, humidity will increase above the water table within these areas, exceeding 75%. Therefore, carbonation is expected to take place.

5.5.1.3 Sulphate Attack

Naturally occurring sulphates of sodium, potassium, calcium, or magnesium are sometimes found in soil or dissolved in groundwater. Sulphates can attack concrete by reacting with hydrated compounds in the hardened cement. These reactions can induce sufficient pressure to disrupt the cement paste, resulting in loss of cohesion and strength. Calcium sulphate attacks calcium aluminate hydrate and forms ettringite. Sodium sulphate reacts with calcium hydroxide and calcium aluminate hydrate forming ettringite and gypsum. Magnesium sulphate attacks in a manner like sodium sulphate and forms ettringite, gypsum, and brucite (Magnesium hydroxide). Brucite forms primarily on the concrete surface, consumes calcium hydroxide, lowers the pH of the pore solution, and then decomposes the calcium silicate hydrates.

Environmental conditions have a profound influence on sulphate attack. The attack is greater in concrete exposed to wetting-drying cycles which will occur within the LLM shafts with oscillations in the water table after the mine is flooded.

5.5.2 Expected Deterioration of Shaft Concrete Lining

At construction, all shafts except the exploration shaft were cast concrete lined for their entire length to ensure operational stability during life of mine. The concrete is without steel reinforcement. The exploration shaft, built in 1987-1988, was lined to 163 m bgl and bolt supported the remaining length to the current bottom at 318 m bgl.

It is well understood that long term exposure to mine water will have a negative effect on the strength and other material properties of concrete shaft linings. For example, Yang et al. (2017) in 'An Experimental Evaluation of the Weathering Effects on Mine Shaft Lining Materials', showed that concrete samples immersed in a simulated 'mine water' solution over a period of a year showed noticeable mass loss and decrease in uniaxial compressive strength results as well as deterioration in other strength parameters. The simulated 'mine water' solution in this study was mildly acidic and contained moderate amounts of dissolved salts (magnesium, sodium, chlorine, and sulphate). According to Douglas Partners (2012) the pre-mining groundwater in the LLM area is "acidic,

moderately saline and high in sulphate". In addition, the LLM GCMP notes (Sections 8.5 and 12.5) that 'reactive' ground conditions exist in several locations at LLM, particularly in the Pyrite unit; that exposure of this material by mining and contact with mine water produces a more aggressive solution; and this can further affect the level of deterioration that will be experienced by the shaft concrete walls.

With the flooding of the mine, it is expected that oxidation of reactive ground will continue and mixing due to entropy will occur. This will lead to residual flooded mine water with a lower pH and higher dissolved sulphates than the original groundwater.

Post closure, at and above the recharging water table level, sulphate attack will occur. The humidity created within the waste backfilled interparticle voids and capillary moisture will also prompt carbonation on the walls of the lined shafts.

The concrete lining shaft support has been effective at maintaining stability thus far, however it is expected to deteriorate. Durability is a complex topic; therefore, the concrete lining should be considered in the future to deteriorate to a point equal to total loss in functionality. Loss in functionality of the concrete lining applied in the shafts and risk of caving, will be counteracted by the passive support of the backfill.

5.5.3 Expected Deterioration of Fibrecrete Bulkhead

The recommended Decline bulkhead will be around 66 m bgl at chainage 460 m and therefore below the recharged groundwater level. The durability and inevitable deterioration will depend mostly on the groundwater composition when a steady state is reached. The speed of deterioration will be governed firstly by the corrosion of embedded metals, leading to cracking and disintegration and increased exposure and corrosion of embedded metals. Sulphate in water will also exacerbate the bulkhead deterioration by weakening the concrete and facilitating corrosion.

As previously stated, assurance of functionality is difficult. Therefore, the bulkhead in the Decline should be expected in the future to deteriorate to a point equal to total loss in functionality.

Loss in functionality of the fibrecrete bulkheads has been allowed for in the Decline backfill design. An additional 10 % of chainage metres were added down gradient to ensure that, after eventual collapse of the bulkhead, the waste backfill will immediately rill and thereafter slowly creep downhill. It is expected that only fines will continue to wash through the backfilled area and creep down gradient whilst larger blocks will remain in place. Backfilling with material from the ROM in the first instance will reduce this occurrence.

5.6 Expected Deterioration of Development Primary Support

Ore development drives are mined during stoping which are then backfilled with paste and/or waste rock. Drives below the upper Decline, which will not be backfilled, comprise the remaining of the capital development, mainly the Decline beyond chainage 460 m, the access drives and footwall drives. These drives will be naturally flooded since they will be below the post closure water table. The primary support installed during their

development comprises 75mm fibrecrete and resin bolts. As mentioned previously, the fibrecrete will deteriorate by sulphate attack and the bolts will experience corrosion. This progressive deterioration will weaken the ground support to a point of complete loss of function.

Intersection ground support, with the additional 6 m long cement grouted cable bolts, will likewise deteriorate by the combination of sulphate attack on the grout and corrosion in the embedded metal strands.

It is expected that there may be ground failure after ground support ceases to function. The occurrence of failures will be significantly minimised when drives become flooded, and passively supported by water. These drives are below the critical depth of 60 m bgl and therefore subsidence on the surface due to upward failure progression is highly unlikely.

6 MONITORING

Under section 126C(1)(j) of the *Environmental Protection Act 1994* (EP Act), the administering authority considers monitoring and maintenance necessary to decide if the progressive rehabilitation and closure plan is consistent with the requirements of the legislation. The rehabilitation planning part must contain a monitoring and maintenance program that identifies and describes the monitoring systems that will be conducted to demonstrate that set targets as per the EP Act have been achieved. As stated in the EP Act, the program must include, but is not limited to:

- Description of methodologies and standards, which could include field-based assessments and the application of new remote sensing, GIS, and other relevant emerging technologies.
- Monitoring that enables the repeatable collection of relevant statistically valid data.
- Monitoring using appropriate quality assurance and data management processes and systems.
- Regular analysis of site data including multi-year comparison trends and benchmarking against analogue/reference sites.
- Contingency strategies if monitoring data indicates milestone criteria are not being met.
- Post-closure monitoring to ensure milestone criteria has been demonstrated.
- Intent of monitoring reports, such as provision of results and key findings.

Although being in a remote area, LLM is still subject to personal, wildlife and cattle incursions. As such, it is important to monitor potential areas of subsidence in a remotely fashion. Satellite monitoring methods have evolved rapidly and can be used for long term monitoring. Other techniques of remote monitoring will likely appear in the future and be autonomous, facilitating and decreasing the costs involved. Remote monitoring not only will fulfil EP Act requirements but also create a safer environment for potential life incursions. As such, these technological advances are strongly recommended for subsidence monitoring of the surface above the upper Decline areas (from portal to chainage 460 m), around the shafts and crown pillars zones.

7 CONCLUSION

The likelihood of crown pillar collapse into remaining underground voids and consequential surface subsidence has been assessed post closure for LLM's Eastern limb, Western limb, North Ore Body, shafts, upper Decline, and the deeper development drives that will remain open post closure.

The Scaled Span Method indicates acceptable FoS for the crown pillars using the most likely scenario of ground and water condition. Most scenarios using the poorer ground conditions (1st quartile Q), which have a low likelihood of occurrence but cannot be completely discounted, had unacceptable FoS. The service life in these (and limited other) scenarios were generally of 2 to 5 years. In exploring critical cases, it was found that upwards ground collapse will arrest itself by choking, prior to reaching the surface at 38 m bgl for the Eastern Limb and 92 m bgl for the Western Limb. NOB has been tight filled and is not at risk of failure progression to these extents. The empirical assessment concluded that although crown pillar failure could occur, it would not cause settlement on the surface.

2D modelling suggests minor subsidence in the Eastern Limb and the North Ore Body and small uplift in the crown pillar above the Western Limb due to the buoyance effect, after closure and during groundwater recharge. These vertical movements would likely go unnoticed by visual observations. The flooding of the mine will have a positive outcome, creating a passive support in the voids underground. With negligible free oxygen in the underwater environment, deterioration of the rock mass will be slowed, and operational stability issues associated with the expanding gypsum crystals will not be of concern.

Ground support will ultimately deteriorate, allowing upward failures. Bulking failure method indicates that ground failure into voids at depths above 60 m bgl will not self-arrest and will reach the surface, showing subsidence. The method also indicates that failure progression from open drives of one level of the mine will not cause subsidence on the level above. The shafts are unstable if unsupported, and existing concrete lining is anticipated to deteriorate over time. As such, backfilling is important to reduce the underground voids and minimise hazards in the future.

The Decline is to be backfilled to a chainage 460 m from portal and the shafts are to be backfilled until the collar is covered. An estimated total volume of 20,500 m³ of waste will be required to backfill the upper Decline and the boxcut. It is estimated that a total of 12,000 m³ of waste will be required to backfill the four shafts linked to surface. One historical shaft has already been backfilled. The backfill material should be sourced primarily from the ROM pad due to its larger coarser fraction and limited fines. Only ROM pad material should be used to backfill the shafts. Material from the Waste Rock Dump can be used in the Decline after ROM material has been exhausted.

Areas above the portal, upper level of the Decline and around the five shafts must be barricaded and sign posted as future subsidence can occur atop these areas. Surface monitoring is recommended of these areas and proactively above the crown pillar.

8 APPENDIX A

The method of designing stable crown pillars (Carter 1992 and 2014) has been developed from a series of case studies measuring crown pillar stability. The method known as the Scaled Crown Span concept is a procedure for characterizing the geometry of a crown pillar in three dimensions and has been used to determine crown stabilities for mines in Australia and internationally. The following is verbatim from Carter, TG., 2014. "Guidelines for use of the Scaled Span Method for Surface Crown Pillar Stability Assessment; Golder and Associates."

Given the typical stope geometry and geological and rock mass conditions comprising a typical crown pillar situation, it was recognized that:

$$\text{Crown Stability} = f\left(\frac{T\sigma_h\theta}{SL\gamma u}\right)$$

where *increased stability* for any rock mass quality would be reflected by an increase in:

T , the rock crown thickness
 σ_h , the horizontal insitu stress
 and/or...in θ , the dip of the foliation or of the underlying opening, and;

where *decreased stability* for any crown would result from increases in:

S , the crown span
 L , the overall strike length of the opening
 γ , the mass (specific gravity) of the crown
 and/or...in u , the groundwater pressure.

Noting that this stability expression could be split into two, based on (a) mined opening geometry and (b) rock mass characteristics, led to the development of the basic deterministic assessment approach of comparing the dimensions of the crown pillar over the stope opening geometry, as characterized by the Scaled Crown Span (CS), against a critical rock mass competence, Q_{crit} (at which failure might be expected) as defined from the boundary between the failure cases and the stable cases.

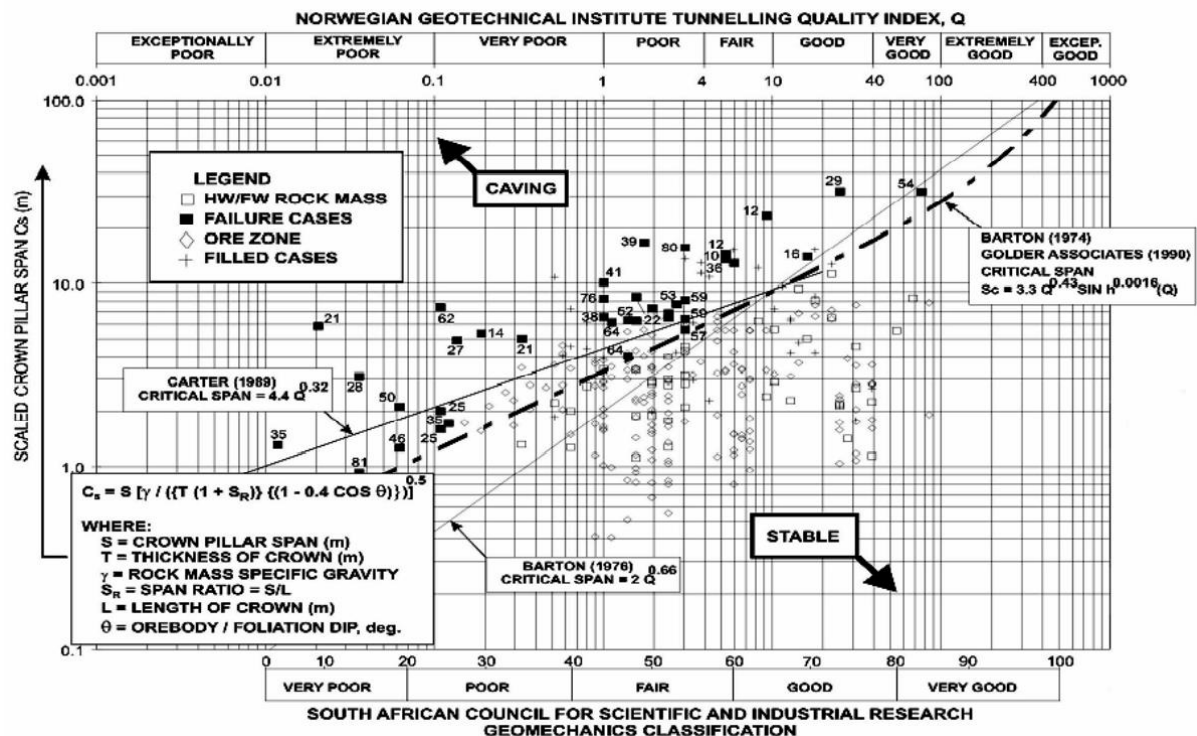
Geometry definition

In developing the three-dimensional geometry term for characterizing the overall crown pillar with respect to its actual span, S , four component terms were considered – a thickness to span ratio term, to maintain some connection with the original non-scaled "rules of thumb", – an inclination factor term, reflecting the fabric of the rock mass and typically the stope dip angle, – a term to account for the three dimensional geometry of the crown (incorporating a hydraulic radius – span ratio factor), and – a weight term to account for equivalent Terzaghi-style "rock loading" effects with respect to the size of the crown and due to any super incumbent loads – such as overburden. The final Scaled Span, CS relationship was thus defined as follows:

$$C_s = S \left(\frac{\gamma}{T(1 + S_r)(1 - 0.4 \cos \theta)} \right)^{0.5}$$

where: S = crown pillar span (m);
 γ = specific gravity (which is dimensionless but has the same numerical value as rock mass unit weight, tonnes/m³);
 T = thickness of crown pillar (m);
 θ = orebody/foliation dip, and;
 S_R = span ratio = S/L
 (crown pillar span/crown pillar strike length)

In the same manner as the Q-chart, this scaling expression, CS, is plotted on the y-axis against rock quality on the x-axis. The plot shows the original chart published in 1990, with each of the case records identified as to whether the case was an open span, or backfilled, and whether stable or not.



The Original Scaled Span Chart, showing stable and failed case records plotted as Scaled Spans versus Rock Quality

Rock mass quality definition

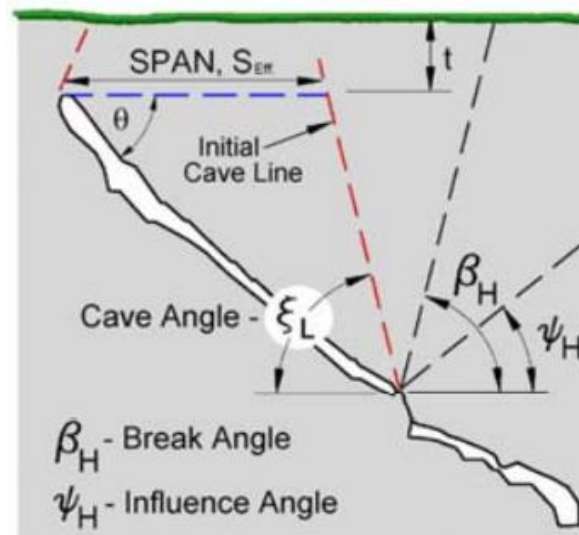
From the plot, the Scaled Spans for all the original case records have been plotted against rock quality, using both the RMR/Q classification axes, each positioned relative to each other on the basis of the well-known correlation expression; $RMR_{76} = 9 \cdot \ln(Q) + 44$, where RMR_{76} values were categorized according to the 1976 codings, thereby maintaining an equivalence with GSI. In the original work, rather than merely defining the critical rock mass quality Q_{crit} for each given case and using this for comparing with the Scaled Span, a limiting span at which failure might be expected was defined based on a regression fit to the data. As it was noted that the best fit line dividing the failed and stable case records was similar in shape and closely matched the empirical “unsupported span” curve originally proposed by Barton et al, 1974 for the tunnelling and natural cavern cases, a similar power curve regression fit was formulated to define the Critical Scaled Span (S_c or S_{crit}), at which failure might be expected; viz:

$$S_c = 3.3 \times Q^{0.43} \times \sinh^{0.0016}(Q)$$

where the hyperbolic sinh term was introduced into the expression to fit the marked trend of significant non-linearity to increased stability at high rock mass competence.

Revision

In the revision to the basic relationships published in 2002, the controlling “span” at crown level was therefore redefined to take into account the equivalent “effective” span, S_{EFF} of the hangingwall projection up to the elevation of the stope crown, as shown in the right diagram, with the extent determined from the cave line, ξ_L with the failure geometry, that might develop post-collapse of the crown and hangingwall estimated by drawing break lines up from the base of the stope.



Concept of effective span for shallow dipping stopes based on zone of influence and cave and break angles

The logic for this definition was, in concept, that the mode of failure associated with a shallow dipping stope in blocky rock, while intrinsically different from caving in coal, would still tend on a gross scale to encompass a similar extent of ground deformation, as crudely might still be postulated based on inferred cave and break angles. To apply this correction, an expression for the effective crown span (S_{EFF}) as defined as “the actual span at crown level, plus the horizontal projection of the hangingwall span-length (within the cave line extent),” was developed as follows:

$$S_{EFF} = S + L_H \left(\cos \theta - \frac{\sin \theta}{\tan \xi_L} \right)$$

where: S = actual crown span of the stope (m);

L_H = (hangingwall length of the stope (m);

ξ_L = cave angle, and;

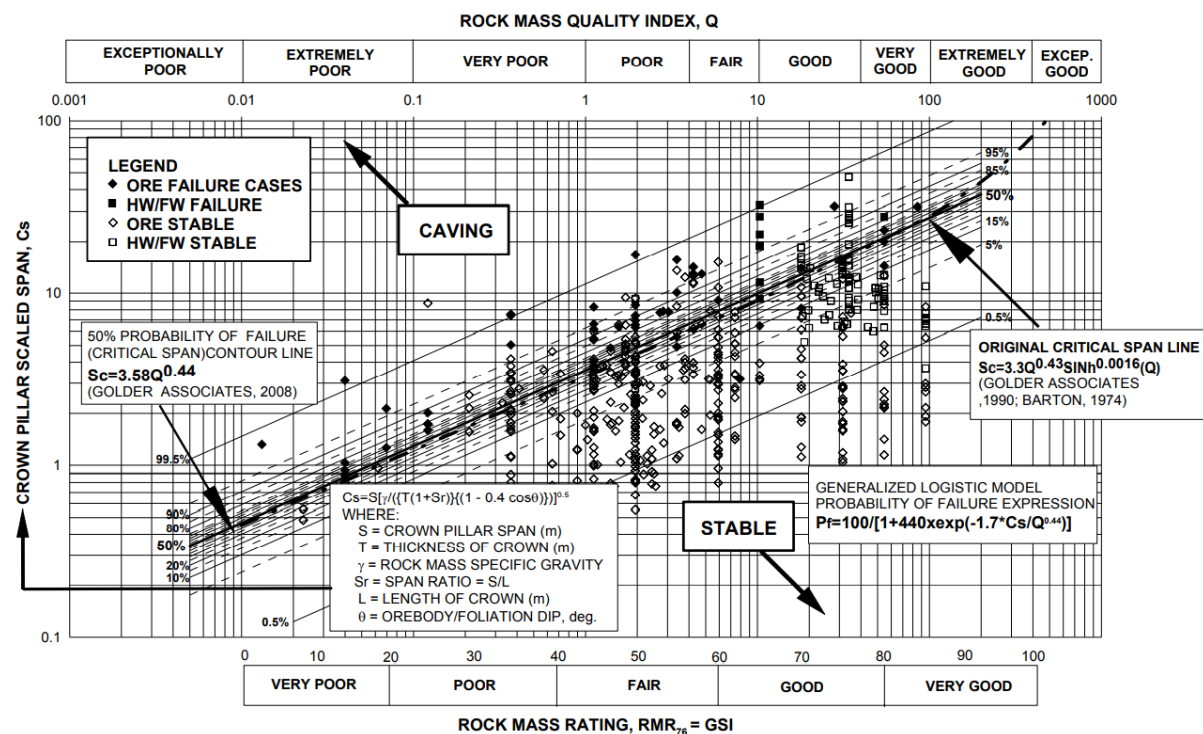
θ = stope/ore body dip

Logistic regression and the improved chart

The other significant improvement made to the Scaled Span methodology has been in improving the chart and rankings to make it easier to better address various levels of allowable risk from the perspective of different stakeholders.

Acceptable Risk Exposure Guidelines – Comparative Significance of Crown Pillar Failure

Class	Probability of Failure %	Minimum Factor of Safety	Maximum Scaled Span, $C_s (= S_c)$	ESR (Barton et al. 1974)	Design Guidelines for Pillar Acceptability/Serviceable Life of Crown Pillar				
					Expectancy	Years	Public Access	Regulatory position on closure	Operating Surveillance Required
A	50 – 100	<1	$11.31Q^{0.44}$	>5	Effectively zero	< 0.5	Forbidden	Totally unacceptable	Ineffective
B	20 – 50	1.0	$3.58Q^{0.44}$	3	Very, very short-term (temporary mining purposes only; unacceptable risk of failure for temporary civil tunnel portals)	1.0	Forcibly Prevented	Not acceptable	Continuous sophisticated monitoring
C	10 – 20	1.2	$2.74Q^{0.44}$	1.6	Very short-term (quasi-temporary stope crowns; undesirable risk of failure for temporary civil works)	2 – 5	Actively prevented	High level of concern	Continuous monitoring with instruments
D	5 – 10	1.5	$2.33Q^{0.44}$	1.4	Short-term (semi-temporary crowns, e.g. under non-sensitive mine infrastructure)	5 – 10	Prevented	Moderate level of concern	Continuous simple monitoring
E	1.5 – 5	1.8	$1.84Q^{0.44}$	1.3	Medium-term (semi-permanent crowns, possibly under structures)	15–20	Discouraged	Low to moderate level of concern	Conscious superficial monitoring
F	0.5 – 1.5	2	$1.12Q^{0.44}$	1	Long-term (quasi-permanent crowns, civil portals, near-surface sewer tunnels)	50–100	Allowed	Of limited concern	Incidental superficial monitoring
G	<0.5	>>2	$0.69Q^{0.44}$	0.8	Very long-term (permanent crowns over civil tunnels)	>100	Free	Of no concern	None required



Updated scaled span chart with probability of failure contour intervals

In its most basic form, the Scaled Span method can be applied deterministically to assess failure risk by simply comparing the Scaled Span (CS) reflecting the mined geometry, to the Critical Span (SC), reflecting the rock mass quality and calculating an approximate Factor of Safety, $F_c \approx SC/CS$. If this is done and the Scaled Span, CS exceeds the Critical Span, SC, as defined by the assumed rock quality, unless the stope had been sufficiently supported, or fill approaches had been used in mining; for any opening with F_c less than 1.0 the likelihood of failure would be predicted to be high.

While this simplistic approach is straightforward, with increasing use of the Scaled Span approach being made for checking whether abandoned mine workings might or might not need remediation, this deterministic Factor

of Safety approach wasn't found to provide sufficient discrimination for making expensive decisions, particularly at the high consequence end of the risk scale (where these needed to be made more based on estimates of the likelihood of failure). As both regulators and mine operators wished to prioritize solutions based on the severity of perceived problem excavations using risk ranking matrices, so that the likelihood of failure and potential consequences could be better assessed, attempts were made in the mid-1990's to develop a better, probabilistic assessment approach for use with the scaling expressions.

Multiple probabilistic spreadsheet analyses using @Risk with Latin Hypercube sampling were therefore conducted on case records from the database where sufficient rock quality information was available to characterize rock mass quality variability.

Plotting the SC/CS ratios as a cumulative frequency distribution from this assessment suggested that the variability was approximately normally distributed, which then allowed a crude error function fit to be formulated between the assessed probability of failure (Pf) and the SC/CS quotients, (Carter, 2000); as follows:

$$P_f = 1 - \operatorname{erf}\left[\frac{2.9F_c - 1}{4}\right]$$

where: P_f = Probability of failure;
 $F_c \approx$ an approximate Factor of Safety
 $= S_c/C_s$, and;
 $\operatorname{erf}()$ is the standard error function

The updated chart now includes iso-probability lines that define seven classes of stability state, based on their likely longevity / design; life expectancy, based on extrapolated experience from stability assessments for geotechnically controlled risks as observed not just for crown pillars but also for other underground and surface excavations.

Assessing Change in Rock Quality and Failure Risk with Time

Assessing stability state under long-term conditions remains one of the key problems for characterizing crown pillars for mine closure. The historical database provides a time history of stable and unstable cases, some of which were known to have been stable, from a general perspective point of view for many years before they failed. From the figure, the two clearly different maxima in the failure cases occur within a decade or so of original mining and then after 60 to 70 years. The reason for these two maxima is likely completely different.

The initial peak is largely thought to originate because of design problems due to the crown thickness being underestimated or the rock quality less competent than expected. The second peak is however likely related to rock competence, and degradability behaviour. This difference is of importance in assessing longevity, as although the updated Scaled Span chart and evaluation methodology can be used to rapidly assess failure risk, cognizance must always be given to the fact that longevity of a given excavation will differ dramatically dependent on the rock type and initial quality, and whether support has been designed for permanence, or not. All the case record data continues to support the 1996 observations that suggests that from the viewpoint of long-term stability, there appear to be two basic, quite different rock mass behavioural characteristics, i.e.,

- the essentially non-degradable, competent rock types (hard igneous and metamorphic types and well cemented sedimentary units) which exist, tend not to spall and hence seem to survive, and
- the degradable, weathering susceptible, weak, or highly fragmented rock types, that most commonly fail in due course of time, due to disaggregation and spalling.

These latter rock masses are of most concern when applying the Scaled Span methodology, as they are notoriously difficult to properly characterize. Of importance also is the fact that the exact timing of the second peak is not just a pure function of time (i.e. always problems happen after 60-70 years), but rather on original mined stope void space as well as crown pillar thickness, rock quality, propensity of the rock mass to degradation and also stress changes that may occur with raveling. It is recommended, therefore, that when examining the potentially degradable rock masses using the updated probability chart that some parallel evaluation also be conducted of caving mechanics, specifically checking whether bulking will be a feasible restraint on cave raveling or whether chimney caving might be problematic.

Optimizing definition of water and stress terms

As indicated previously, Q rather than Q' should be used with the Scaled Span method. However, this raises another issue of concern to ensure that “correct” definition of rock quality is achieved for crown pillar stability evaluation. This requires rational definition of what stress state and what water term should be considered when using the Q system for rock mass characterization

The Scaled Span design charts have been benchmarked to the complete Q , rather than to Q' specifically so that water and stress can be considered. Although Q and Q' both become identical numerically for many rock masses, under typical water and stress conditions, i.e. $JW = 1$, suggesting dry conditions, and $SRF = 1$, suggesting normal confinement. These may not be appropriate for many crowns where rivers and lakes exist above the crowns where JW might have a lower value than unity, or for any thin crowns or crowns with any significant degree of weathering. In all these cases an SRF of 2.5 is suggested as per Barton’s 1976 recommendations.

Accounting for overburden

In many situations, rock crown pillars exist beneath thick overburden cover. The question thus often arises, as to how one takes account of the impact that thick overburden, or high groundwater level imposes on crown stability. Utilizing the Scaled Span chart, two simple approximations have been found effective for considering these two situations. Instead of just using the natural specific gravity for the crown pillar rock mass in the geometry term for the y-axis on the Scaled Span chart, the influence of high overburden thickness or an overlying lake can be considered as a straightforward density increase in the geometry term.

9 APPENDIX B

McCracken-Stacey Method Q_R Results for LLGRD8

Interval From (m)	Interval To (m)	Core Loss (m)	Recovered (m)	Rock Type	Rock Weathering	Alteration	Strength of Core	RQD (%)	No. of Defects	No. of Defect Sets	Defect Type	Roughness	Infill	Infill Thickness (mm)	Density (T/m^3)	Sgr/Sgr ₀	UCS (Mpa)	Jw	SIF	RCD	Jr	Ja Code	Ja	Jn	Q'	Q	Wall Adjustment	Orientation Adjustment	Weathering Adjustment	Q _r	Rock Class
0	2.4	0.2	2.2	SH/SLSTN	EW	HAEM	R0	0	99	3.5	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	10	1	SF	4	12	0.21	0.08	1	0.85	0.5	0.035	EXT Poor
2.4	3.8	0	1.4	SH/SLSTN	EW	HAEM	R0	0	99	20	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
3.8	5.2	0	1.4	SH/SLSTN	EW	HAEM	R0	0	99	20	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
5.2	6.8	0	1.6	SH/SLSTN	EW	HAEM	R0	0	99	20	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
6.8	7.6	0.2	0.6	SH/SLSTN	EW	HAEM	R0	0	99	20	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
7.6	8.9	0	1.3	SH/SLSTN	EW	HAEM	R0	9	99	20	BP/JN	PS	SC	0.1	2.6	2	0.25	1	2.5	10	1	SC	2	20	0.25	0.1	1	0.85	0.5	0.043	EXT Poor
8.9	10.2	0	1.3	SH/SLSTN	EW	HAEM	R0	0	99	20	BP/JN	PS	NN	1	2.6	2	0.25	1	2.5	10	1	NN	1	20	0.5	0.2	1	0.85	0.5	0.085	EXT Poor
10.2	11.5	0.1	1.2	SH/SLSTN	EW	HAEM	R0	10	99	20	JN	PS	SF	0.1	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
11.5	13	0	1.5	SH/SLSTN	EW	HAEM	R0	17	99	20	BP/JN	SS	SF	0.1	2.6	2	0.25	1	2.5	17	3	SF	4	20	0.64	0.26	1	0.85	0.5	0.108	Very Poor
13	14.9	0	1.9	SH/SLSTN	HW	HAEM	R1	7	40	20	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
14.9	15.8	0	0.9	SH/SLSTN	HW	HAEM	R1	20	30	20	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	20	1	SF	4	20	0.25	0.1	1	0.85	0.5	0.043	EXT Poor
15.8	17.6	0.1	1.7	SH/SLSTN	HW	HAEM	R2	0	25	3	BP/JN	PS	SF	100	2.6	2	0.25	1	2.5	10	1	SF	4	9	0.28	0.11	1	0.85	0.5	0.047	EXT Poor
17.6	18.2	0	0.6	SH/SLSTN	EW	SERI/KAOL	R0	0	99	3	FLT	PK	SF	600	2.6	2	0.25	1	2.5	10	0.5	SF	4	9	0.14	0.06	1	0.85	0.5	0.024	EXT Poor
18.2	20.1	0.1	1.8	SH/SLSTN	EW	SERI/KAOL	R0	0	99	3	FLT	PK	SF	1900	2.6	2	0.25	1	2.5	10	0.5	SF	4	9	0.14	0.06	1	0.85	0.5	0.024	EXT Poor
20.1	21.8	0	1.7	SH/SLSTN	EW	HM/SER	R0	0	99	20	FLT	PK	SF	1700	2.6	2	0.25	1	2.5	10	0.5	SF	4	20	0.66	0.03	1	0.85	0.5	0.011	EXT Poor
21.8	24.2	0	2.4	SH/SLSTN	HW	HAEM	R0	10	40	20	BP/JN	PS	SC	0.1	2.6	2	0.25	1	2.5	10	1	SC	2	20	0.25	0.1	1	0.85	0.5	0.043	EXT Poor
24.2	27.3	0.2	2.9	SH/SLSTN	HW	HAEM	R1	0	50	20	BP/JN	PS	SC	0.1	2.6	2	0.25	1	2.5	10	1	SC	2	20	0.25	0.1	1	0.85	0.5	0.043	EXT Poor
27.3	29	0	1.7	SH/SLSTN	HW	HAEM	R0	0	40	20	BP/JN	PS	SF	<0.1	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
29	30.3	0.4	0.9	SH/SLSTN	EW	HAEM	R0	0	99	20	FLT	PS	SF	1300	2.6	2	0.25	1	2.5	10	1	SF	4	20	0.13	0.05	1	0.85	0.5	0.021	EXT Poor
30.3	32.1	0	1.8	SH/SLSTN	HW	HAEM	R2	15	35	3.5	BP/JN	PS	SF	0.2	2.6	2	0.25	1	2.5	15	1	SF	4	12	0.31	0.13	1	0.85	0.5	0.053	EXT Poor
32.1	34.1	0	2	SH/SLSTN	HW	HAEM	R3	50	35	3	BP/JN	PS	SF	0.2	2.6	2	0.25	1	2.5	50	1	SF	4	9	1.39	0.56	1	0.85	0.5	0.236	Very Poor
34.1	35.2	0	1.1	SH/SLSTN	EW	HAEM	R0	0	21	3.5	FLT	PK	SF	0.1	2.6	2	0.25	1	2.5	10	0.5	SF	4	12	0.1	0.04	1	0.85	0.5	0.018	EXT Poor
35.2	37.1	0.9	1	SH/SLSTN	EW	HAEM	R0	0	99	20	FLT	PK	GT	7	2.6	2	0.25	1	2.5	10	0.5	GT	12	20	0.02	0.01	1	0.85	0.5	0.003	EXC Poor
37.1	37.9	0.1	0.7	FAULT	EW	HAEM	R0	0	99	20	FLT	PK	GT	800	2.6	2	0.25	1	2.5	10	0.5	GT	12	20	0.02	0.01	1	0.85	0.5	0.003	EXC Poor
37.9	39	0	1.1	FAULT	EW	HAEM	R0	0	99	20	FLT	PK	GT	1100	2.6	2	0.25	1	2.5	10	0.5	GT	12	20	0.02	0.01	1	0.85	0.5	0.003	EXC Poor
39	41.7	0.2	2.5	SH/SLSTN	HW	HAEM	R0	41	40	20	BP/JN	PS	SF	0.1	2.6	2	0.25	1	2.5	41	1	SF	4	20	0.51	0.21	1	0.85	0.5	0.087	EXT Poor
41.7	43	0	1.3	SH/SLSTN	EW	FE	R0	0	99	3.5	BP/JN	PS	SF	0.1	2.6	2	0.25	1	2.5	10	1	SF	4	12	0.21	0.08	1	0.85	0.5	0.035	EXT Poor
43	43.9	0	0.9	SH/SLSTN	EW	FE	R0	0	99	3.5	FLT	PK	SF	900	2.6	2	0.25	1	2.5	10	0.5	SF	4	12	0.1	0.04	1	0.85	0.5	0.018	EXT Poor
43.9	45.3	0	1.4	SH/SLSTN	EW	FE	R1	43	50	3.5	BP/JN	PS	SF	2	2.6	2	0.25	1	2.5	43	1	SF	4	12	0.9	0.36	1	0.85	0.5	0.152	Very Poor
45.3	47	0	1.7	SH/SLSTN	EW	FE	R1	37	25	3.5	BP/JN	PS	SF	1	2.6	2	0.25	1	2.5	37	1	SF	4	12	0.77	0.31	1	0.85	0.5	0.131	Very Poor
47	48.4	0.1	1.3	SH/SLSTN	HW	FE	R1	18	35	3.5	BP/JN	PS	SF	0.5	2.6	2	0.25	1	2.5	18	1	SF	4	12	0.38	0.15	1	0.85	0.5	0.064	EXT Poor
48.4	51.5	0	3.1	SH/SLSTN	HW	FE	R1	40	45	3.5	BP/JN	PS	SF	0.1	2.6	2	0.25	1	2.5	40	1	SF	4	12	0.83	0.33	1	0.85	0.5	0.142	Very Poor
51.5	53.4	0.1	1.8	CARB.SH/SL	MW	SERI	R1	18	60	20	BP/JN	PS	SF	<0.1	2.6	2	0.25	1	2.5	18	1	SC	2	20	0.23	0.09	1	0.85	0.5	0.038	EXT Poor
53.4	54.8	0	1.4	CARB.SH/SL	MW	FE/SERI	R0	41	30	3.5	BP/JN	PS	SC	<0.1	2.6	2	0.25	1	2.5	41	1	SC	2	12	1.71	0.68	1	0.85	0.5	0.290	Very Poor
54.8	56	0	1.2	CARB.SH/SL	MW	FE/SERI	R0	22	30	3.5	BP/JN	PR	SF	<0.1	2.6	2	0.25	1	2.5	22	1.5	SF	4	12	0.69	0.28	1	0.85	0.5	0.117	Very Poor
56	58	0	2	CARB.SH/SL	MW	FE/SERI	R1	11	50	3.5	BP/JN	PS	SF	<0.1	2.6	2	0.25	1	2.5	11	1	SF	4	12	0.23	0.09	1	0.85	0.5	0.039	EXT Poor
58	59.1	0	1.1	SH/SLSTN	HW	HAEM	R0	0	99	20	~	PS	NN	0	2.6	2	0.25	0.66	2.5	10	1	NN	1	20	0.5	0.2	1	0.85	0.5	0.085	EXT Poor
59.1	60.5	0	1.4	SH/SLSTN	HW	QTZ-HAEM	R2	24	99	20	~	PS	NN	0	2.6	2	0.25	0.66	2.5	24	1	NN	1	20	1.2	0.48	1	0.85	0.5	0.204	Very Poor
60.5	61.6	0	1.1	SH/SLSTN	HW	QTZ-HAEM	R0	0	99	20	~	PS	NN	0	2.6	2	0.25	0.66	2.5	10	1	NN	1	20	0.5	0.2	1	0.85	0.5	0.085	EXT Poor
61.6	63	0	1.4	SH/SLSTN	HW	QTZ-HAEM	R0	28	40	20	BP/JN	PS	SC	0.1	2.6	2	0.25	0.66	2.5	28	1	SC	2	20	0.7	0.28	1	0.85	0.5	0.119	EXT Poor
63	64.1	0	1.1	SH/SLSTN	HW	HAEM	R0	0	40	20	BP/JN	PS	SC	1.1	2.6	2	0.25	0.66	2.5	10	1	SC	2	20	0.25	0.1	1	0.85	0.5	0.043	EXT Poor
64.1	65.3	0	1.2	SH/SLSTN	HW	HAEM	R1	17	99	20	~	PS	NN	0	2.6	2	0.25	0.66	2.5	17	1	SC	2	20	0.43	0.17	1	0.85	0.5	0.072	EXT Poor
65.3	66.8	0	1.5	SH/SLSTN	HW	HAEM	R2	0	0	20	BP/JN	PS	SC	0	2.6	2	0.25	0.66	2.5	10	1	SC	2	20	0.25	0.1	1	0.85	0.5	0.043	EXT Poor
66.8	68.5	0	1.7	SH/SLSTN	MW	HAEM	R2	26	30	3.5	BP/JN	PS	SF	<0.1	2.6	2	0.25	0.66	2.5	26	1	SF	4	12	0.54	0.22	1	0.85	0.5	0.092	EXT Poor
68.5	70	0	1.5	CARB.SH/SL	MW	CARB	R3	20	30	2.5	JN	PS	NN	0	2.6	2	0.25	0.66	2.5	20	1	NN	1	6	3.33	1.33	2.5	0.85	0.5	1.416	Poor
70	72.2	0	2.2	SH/SLSTN	SW	SERI	R3	34	35	3	BP/JN	PS	SF	0	2.6	2	0.25	0.66	2.5	34	1	SF	4	9	0.94	0.38	1	0.85	0.5	0.161	Very Poor
72.2	73.5	0	1.3	SH/SLSTN	SW	SERI	R2	13	30	3	BP/JN	PS	NN	0	2.6	2	0.25	0.66	2.5	13	1	NN	1	9	1.44	0.58	1	0.85	0.5	0.246	Very Poor
73.5	75.3	0	1.8	SH/SLSTN	SW	SERI	R3	43	30	3	BP/JN	PS	NN	0	2.6	2	0.25	0.66	2.5	43	1	NN	1	9	4.78	1.91	2.5	0.85	0.5	2.030	Poor
75.3	75.8	0	0.5	SH/SLSTN	SW	SERI	R3	0	99	20	BP/JN	PS	NN	NN	2.6	2	0.25	0.66	2.5	10	1	NN	1	20	0.5	0.2	1	0.85	0.5	0.085	EXT Poor
75.8	76.8	0	1	SH/SLSTN	SW	SERI	R3	0	99	3.5	BP/JN	PS	NN	NN	2.6</																

10 APPENDIX C

Selected core photos for LLGRD8 and associated Raise Bore Stability Rating Classifications

Trays 8 and 9 of LLGRD8: 23.6 – 30.3m.
Extremely Weathered material that has been
classified as “Extremely Poor”.
Includes “Exceptionally Poor” classified
ground Koff’s Fault intercept (114.5-117.5m)



Trays 34 and 35 of LLGRD8: 111.2 – 117.9m.
Includes “Exceptionally Poor” classified
ground at the Koff’s Fault intercept (114.5-
117.5m)



Trays 47 and 48 of LLGRD8: 156.7 – 163.3m.
Moderately Weathered Rock classified as
“Very Poor”



DOCUMENT INFORMATION

DOCUMENT CHANGE CONTROL

Version	Description of Changes/amendments	Author (s)	Date
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APPENDIX D CLOSURE GROUNDWATER MODELLING REPORT

Glencore Australia

Lady Loretta Mine Groundwater Closure Report

30 May 2022

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Section 1 Introduction

1.1 Background

The Lady Loretta Mine (LLM) is located approximately 140 kilometres north-west of Mount Isa in Queensland (Figure 1-1). LLM is an underground zinc-lead-silver (Zn-Pb-Ag) mine currently operating on mining lease ML5568 in accordance with Environmental Authority (EA) EPLM00982013. Redpath Australia Pty Ltd (Redpath) currently operate LLM on behalf of Glencore. The ML and EA for LLM are held by Noranda Pacific Pty Ltd (Noranda), which is a wholly owned subsidiary of Glencore. The mining lease covers around 2783 hectares with an approximate disturbance footprint of 140 hectares, and is adjacent to the Lady Annie Copper Mine located on mining lease ML90179, which is operated by Austral Resources.

A Detailed Closure Plan (DCP) has been developed and a Progressive Rehabilitation and Closure Plan (PRCP) is under development for the Lady Loretta Mine (LLM). The current campaign of mining operations is scheduled for completion in 2025. Above ground and selected below ground infrastructure is to be decommissioned and demolished. Decommissioning and demolition works are planned starting with the underground zone, shafts area and processing zone.

CDM Smith Australia Pty Ltd (CDM Smith) was engaged by Glencore Australia (Glencore) to undertake a desktop hydrogeological assessment of the Lady Loretta Mine (LLM) and surrounds to assist in closure planning and contaminant management. Specifically, Glencore requires development of a numerical groundwater flow model for prediction of groundwater system response to cessation of mining, and the potential fate of contaminants of concern (CoCs) during and after groundwater recovery. The objective of the numerical model is to assist in the development and implementation of an appropriate closure monitoring network and program.

1.2 Mine Operations

The operation produces approximately 1.6 million tonnes (MT) of high-grade Zn-Pb-Ag ore each year which is transported to Mount Isa and blended with ore from George Fisher Mine prior to processing. Zn-Pb-Ag mineralisation at LLM was indicated by a geochemical soil survey in 1968 and confirmed in 1969 by diamond drilling. Ore production from LLM commenced in September 2012 and in October 2015 production paused. The mine was placed under care and maintenance in 2015 in response to a low Zn price. Production recommenced in August 2018 and the underground mine has advanced to approximately 550 metres deep. The mine consists of four shafts and a decline whose portal is located between the Waste Rock Emplacement (WRE) and the Run of Mine (ROM) pad, which provides underground access to operational areas (Figure 1-1). The mining method at Lady Loretta is based on a mixture of transverse and longitudinal long hole open stoping with paste fill operations (Xstrata, 2012). Ore is trucked to the surface and the ROM pad where it is then crushed in a jaw crusher and stockpiled. Crushed ore is loaded and trucked to the Glencore Mount Isa processing plant for concentrating and smelting. During mining the underground workings are backfilled in stages using paste produced from tailings and cement in the paste production plant. Paste backfill is used to increase the structural integrity of mined out stopes and provide support to the underground mining operation. Following paste operations, fibrecrete is applied to the underground surfaces to assist in stabilising the rock wall material.

1.3 Mine Closure

A Detailed Closure Plan has been developed for the LLM with the aim to leave a safe, stable, non-polluting and sustainable final landform for the final land use that is consistent with the surrounding landscape (LLM, 2021a). Above ground and selected below ground infrastructure is to be decommissioned and demolished. Decommissioning and demolition works are planned to start with Underground Zone, Shafts Area, Processing Zone; with General Infrastructure Zone decommissioning, followed by Administration and Maintenance Zones.

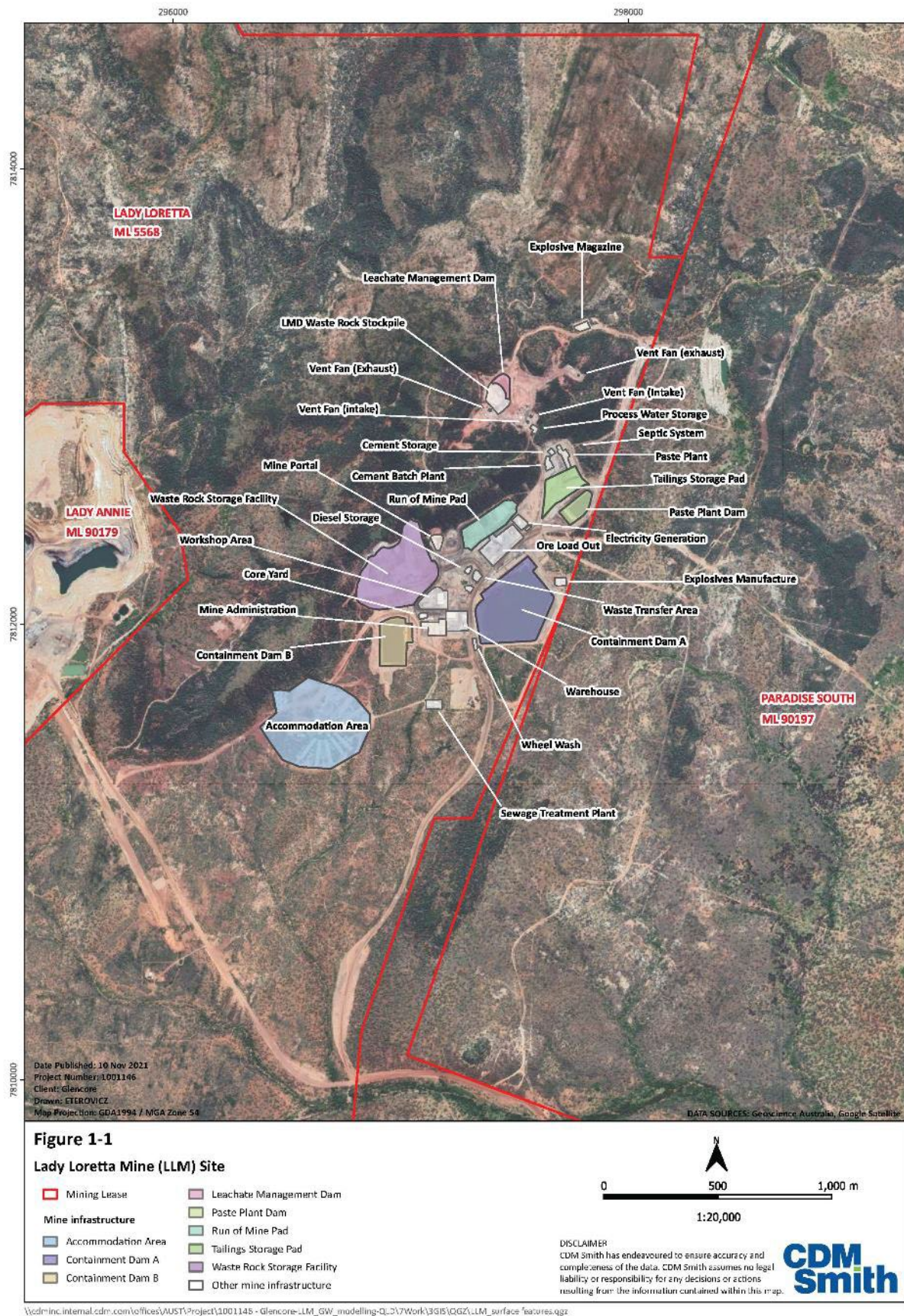


Figure 1-1 Lady Loretta Mine Site

1.4 Objectives and Scope of Work

The objective of the Lady Loretta Mine groundwater scope is to characterise the key hydrogeological features of the site, represent these in the model domain and consider Contaminants of Concern (COC) in relation to the groundwater at the site. To assist in assessing groundwater system response to mine closure it is necessary to update the hydrogeological conceptualisation and the existing numerical groundwater flow model to support CoC fate and transport predictions via solute transport modelling.

The scope of work (SOW) for this report includes the following components:

Stage 1 Hydrogeological conceptualisation and numerical groundwater flow model:

- Review of relevant reports and information describing the results of work that has previously been undertaken.
- Describe and characterise the key hydrogeological features. Identify and describe the processes that control or influence the movement and storage of groundwater and solutes in the hydrogeological system. The conceptualisation considers the physical processes and resulting heads and flows of groundwater.
- Identification of existing knowledge gaps and uncertainties relating to hydrogeological conceptualisation of LLM Study Area and its representation in a numerical groundwater flow model.
- Updating and revise the existing numerical groundwater flow model.

Stage 2 Potential fate of COC and solute transport modelling:

- Sources of identified CoCs from LLM facilities to groundwater.
- Pathways and mechanisms for CoC release from LLM facilities.
- Concentrations of potential CoCs being released from LLM facilities.
- Develop a solute transport model to assess the fate of potential CoCs in groundwater.
- Evaluation of potential impacts to groundwater resources based on conceptual and model outcomes.
- Summarise these findings to support mine closure planning.

This report summarises the studies completed to date in relation to the stages presented above.

1.5 Previous Model Studies

Previous hydrogeological conceptualisation studies were completed by Australian Groundwater and Environment (AGE) in 2015 (AGE,2015) and 2020 (AGE,2020). It has been observed that the AGE 2015 and 2020 renewed conceptual models demonstrated an evolution of conceptual thinking, with differences in terms of fault barrier conceptualisation and groundwater flow or movement between the two models identified.

AGE also updated the LLM numerical groundwater flow model in 2015 to align with the 2015 conceptualisation and to incorporate revisions to mine development and associated dewatering, and the model calibration was updated from a steady state solution to a transient calibration. It should be noted that the numerical groundwater model was not revised and updated since 2015. As such the current AGE 2020 conceptualisation does not align with the AGE 2015 numerical model construct and conceptualisation.

Due to this misalignment a revision and update to the conceptual model is required, and subsequent to this an update the numerical groundwater model to realign this model to the conceptual model is required. This realignment, developed as part of this report, will ensure that the conceptual model and numerical model have consistent hydrogeological processes represented. With both the conceptual and numerical models aligned works can progress on the development and implementation of an appropriate closure groundwater monitoring program.

This assessment details the works undertaken to revise and update the model studies and apply revised models to a solute transport model scope.

Section 2 Physical Setting

2.1 Lady Loretta Mine Key Features

2.1.1 Underground Mine

The underground mine is approximately 550 metres deep and consists of four shafts and a decline whose portal is located between the Waste Rock Emplacement (WRE) and the Run of Mine (ROM), which provides underground access to operational areas. The mining method at Lady Loretta is based on a mixture of transverse and longitudinal long hole open stoping with paste fill operations. Ore is trucked to the surface where it is then crushed in a jaw crusher and stockpiled. Crushed ore is loaded and trucked to the Glencore Mount Isa processing plant for concentrating and smelting. During mining the underground workings are backfilled in stages using paste produced from tailings and cement in the paste production plant. Paste backfill is used to increase the structural integrity of mined out stopes and provide support to the underground mining operation. Following paste operations, fibrecrete is applied to the underground surfaces to assist in stabilising the rock wall material.

2.1.2 Waste Rock Emplacement and Stockpiles

Waste rock produced by the mine is potentially acid forming (PAF) and is either used as loose fill underground or stored on the surface in the WRE.

Stockpiles at the LLM include growth medium stockpiles, the leachate management dam (LMD) stockpile and cover stockpiles. All waste rock characterised as non-acid forming (NAF) is moved to the ROM pad, which lies directly east of the decline portal and WRE. The ROM area consists of a crushing plant and is designed for surface storage of the ore extracted from the underground mine, awaiting transfer to Glencore's Mount Isa Mines (MIM) processing plant for further processing. In association with the paste plant and batch plant, the ROM is one of the key features of material transfer.

2.1.3 Water Management Infrastructure

Water management infrastructure includes four containment dams, called containment dam A (CDA), containment dam B (CDB), the paste plant dam (PPD) and the leachate management dam (LMD). CDA largely receives runoff from the ROM stockpile, crushing and loading area, decline portal, mine office and surrounding infrastructure. CDB largely receives runoff from the WRE. The PPD largely receives runoff from the paste and batch plants, and the LMD largely receives runoff from the LMD stockpile and surrounding infrastructure. Smaller unregulated sediment dams are located directly adjacent to CDA, CDB and the PPD.

2.1.4 Lady Annie East Borefield Operations

Raw water is sourced from the Lady Annie East (LAE) borefield for use in underground machinery, paste mix water, fire water, dust suppression and potable water system feed water. The annual average extraction rate of raw water from the LAE borefield is 766 mega litres per year (ML/year) (LLM, 2021a). Noranda holds a licence number 403766 to extract groundwater from the borefield at an extraction point on Lot 1 UN7 (LLM, 2021b). The borefield is located east of the Lady Loretta Mine and the current production bores are called GW15, GW17 and GW18.

2.1.5 Other infrastructure

Other mine related infrastructure includes an accommodation camp, offices and warehouses, fuel farm, explosive and chemical storage areas, emergency response buildings, water treatment plant and the communication tower. The paste plant and batch plant are located in the north-east portion of the operational area, which receives material post processing for reuse underground at LLM.

2.2 Climate

The climate at LLM is dominated by high temperatures, with a regional annual evaporation of 2954 mm/year and an annual rainfall of 414 mm/year. Rainfall is highly variable year on year with long term minimum and maximum rainfall varying between 116 and 1224 mm, respectively. Annual rainfall is concentrated in a distinct wet season from October through to March, with the highest average monthly total occurring in the months November to March (Figure 2-1). On average, monthly rainfall is always exceeded by evaporation.



Figure 2-1 Average Monthly Rainfall and Evaporation

Long term rainfall monthly cumulative deviation from the mean (CDFM) is shown in Figure 2-2, based on the rainfall data obtained from the Australian climate SILO database. Periods of below average rainfall are represented as downward trending slopes, and above average rainfall as upward trending slopes. The data show decadal long periods of below average rainfall and, typically, shorter periods of above average rainfall.

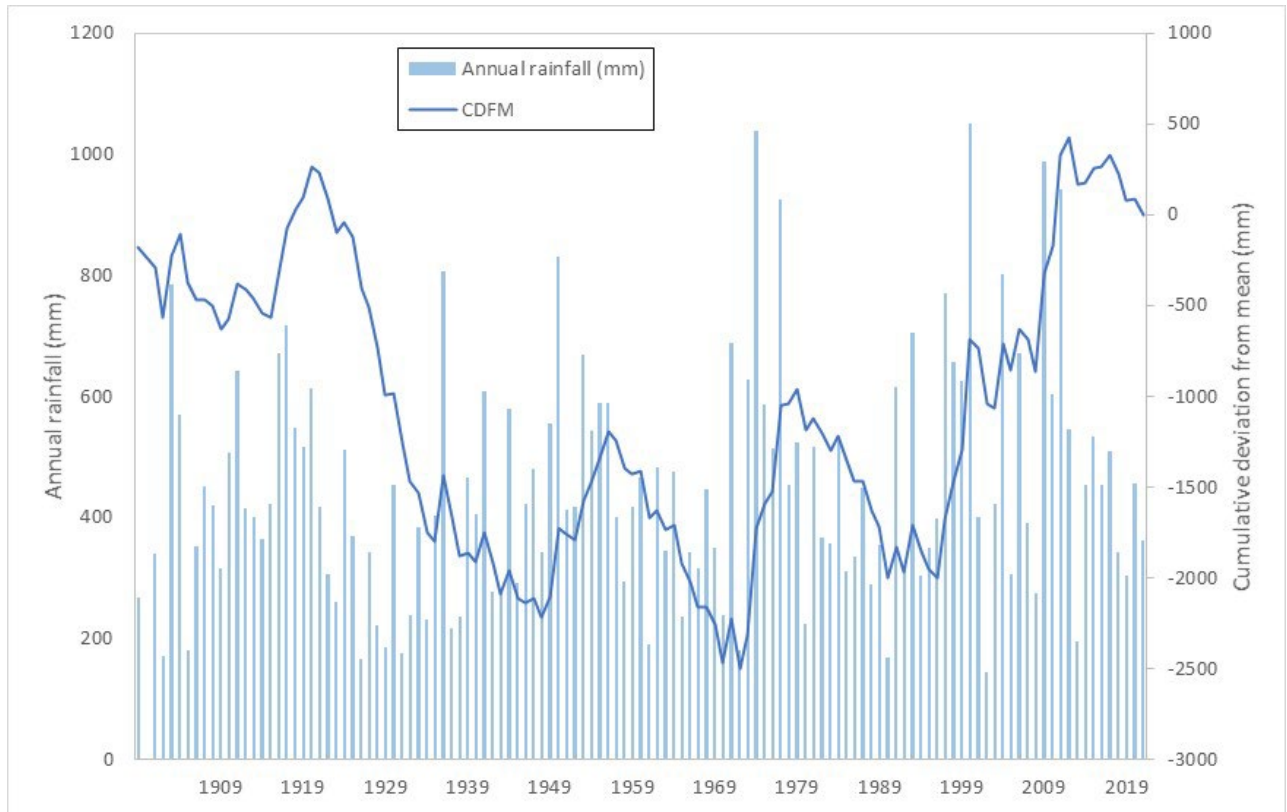


Figure 2-2 Long term Rainfall and CDFM

2.3 Topography and Hydrology

The topography in the study area ranges from approximately 300 to 390 m Australian Height Datum (AHD). The topography is characterised by higher elevation to the north of the LLM site and lower elevation to the south as shown in Figure 2-3. The major topographical feature associated with LLM is a north-east to south-west orientated ridgeline rising to 385 m AHD. The majority of LLM operations are located on the eastern flank of the ridgeline.

The LLM sits within ephemeral drainage lines that flow only in direct response to rainfall. LLM operations are located within the Leichhardt River catchment at the headwaters of Magazine and Desert Creeks. The creeks form the main ephemeral drainage lines within the immediate vicinity of the LLM. Natural surface water flow from LLM is channelled through Magazine Creek. Surface flows in the southern catchments are channelled through Desert Creek.

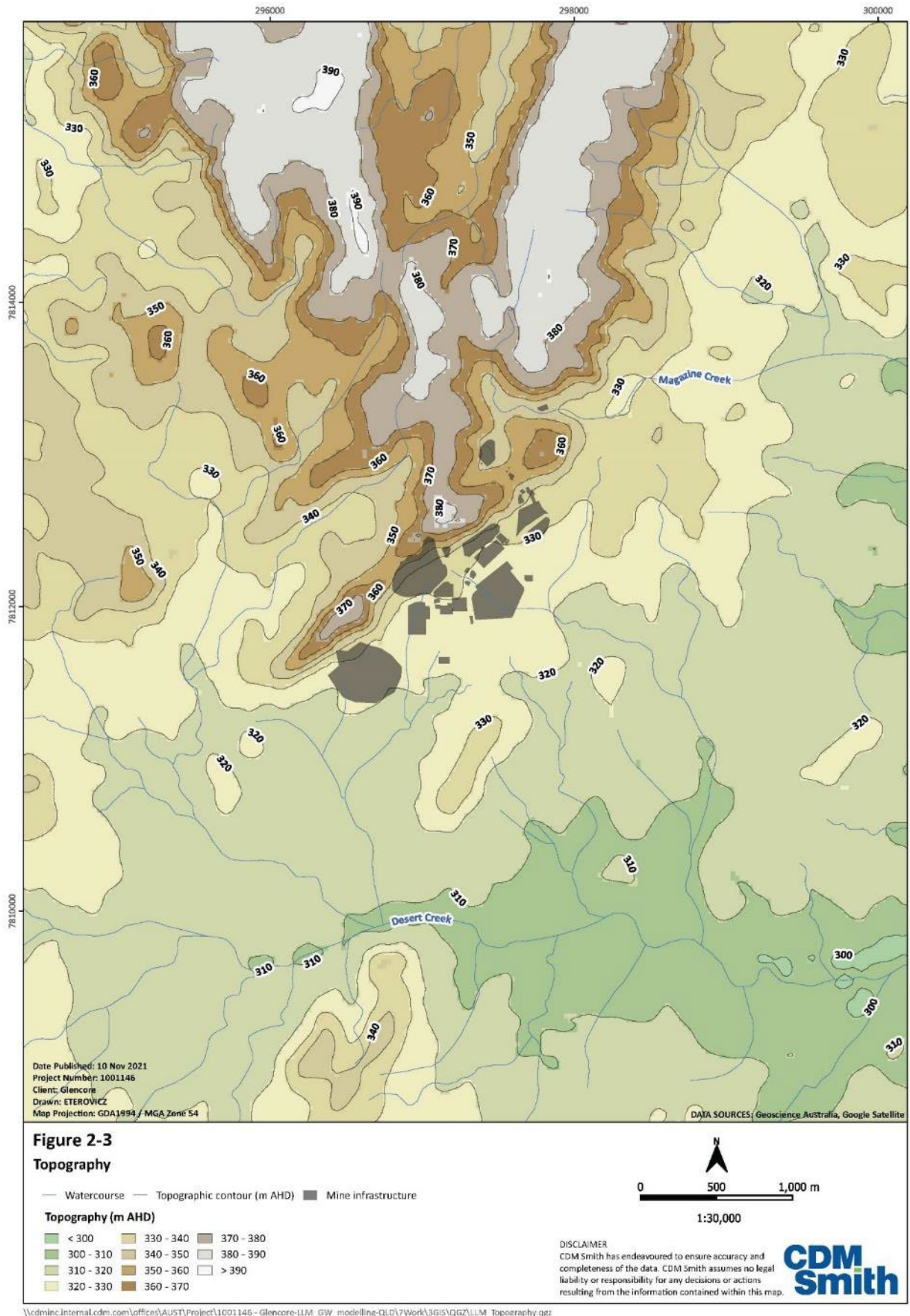


Figure 2-3 Site and Surrounds Topography

2.4 Geology

2.4.1 Lady Loretta Block

The LLM is located in the Western Fold Belt of the Mount Isa Inlier. The deposit is hosted within the Paleoproterozoic Lady Loretta Formation (Figure 2-4), which forms the uppermost outcropping unit of the McNamara Group (Valenta, 2018). The area is structurally complex and the Lady Loretta deposit is hosted in the keel of the Small Syncline, a tight north-east trending fold truncated by steep to moderately north-west dipping faults called the Koff and Max's Faults, as shown in Figure 2-5.

The LLM ore bearing zone is divided into two areas, the Big and Small Synclines. The Big Syncline contains uneconomical low base metal grades. A north-south trending fault separates the Big and Small synclines. The major Carlton Fault Zone truncates the syncline to the north-west. The Carlton Fault is associated with extensive zones, up to 200m wide, of shearing and brecciation (Hancock and Purvis, 1990). It is postulated as a feeder zone for metal rich fluids (Hancock and Purvis, 1990).

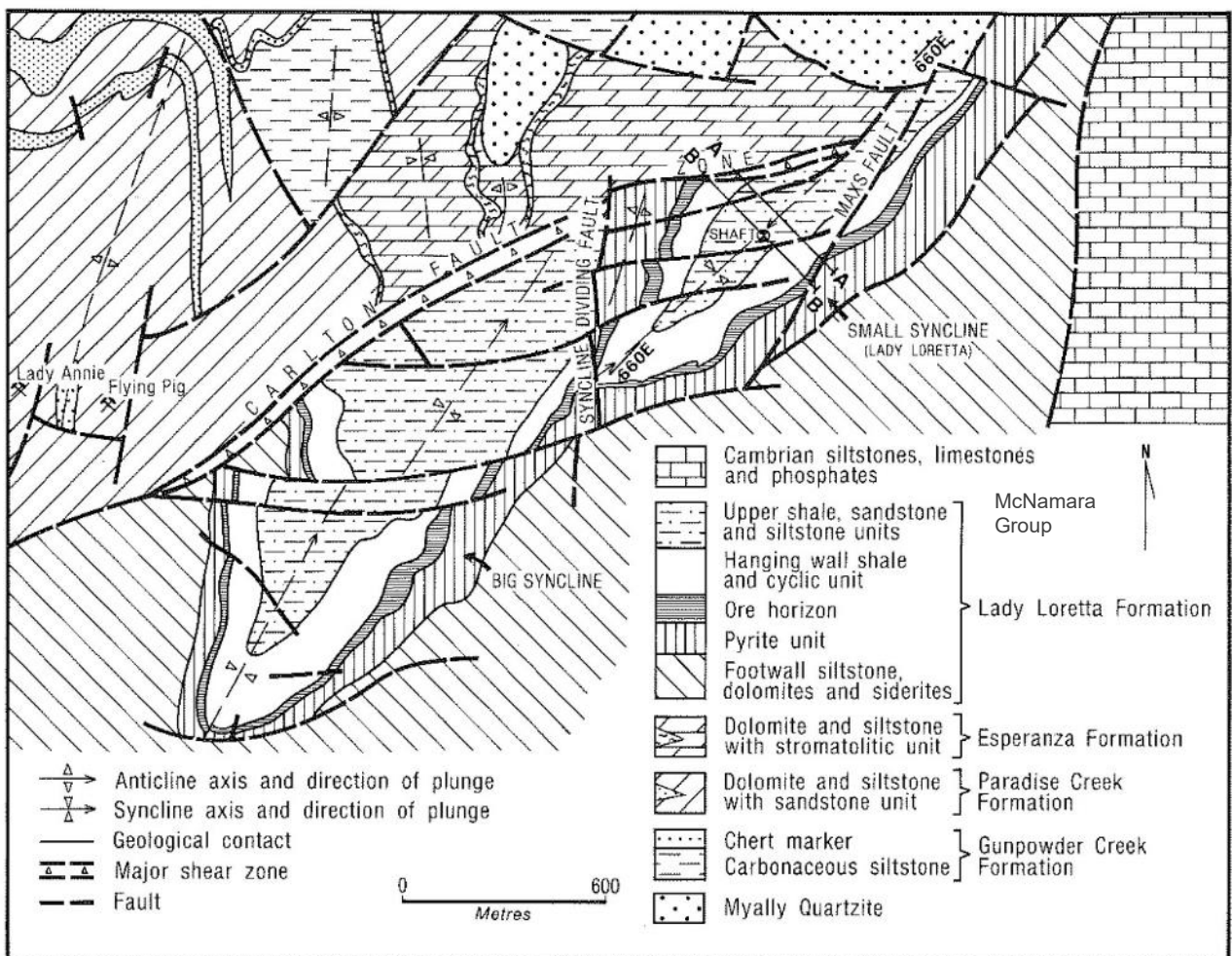


Figure 2-4 Plan View Geological Map of the Lady Loretta Deposit and Stratigraphic Column for the Lady Loretta Region (Hancock and Purvis, 1990).

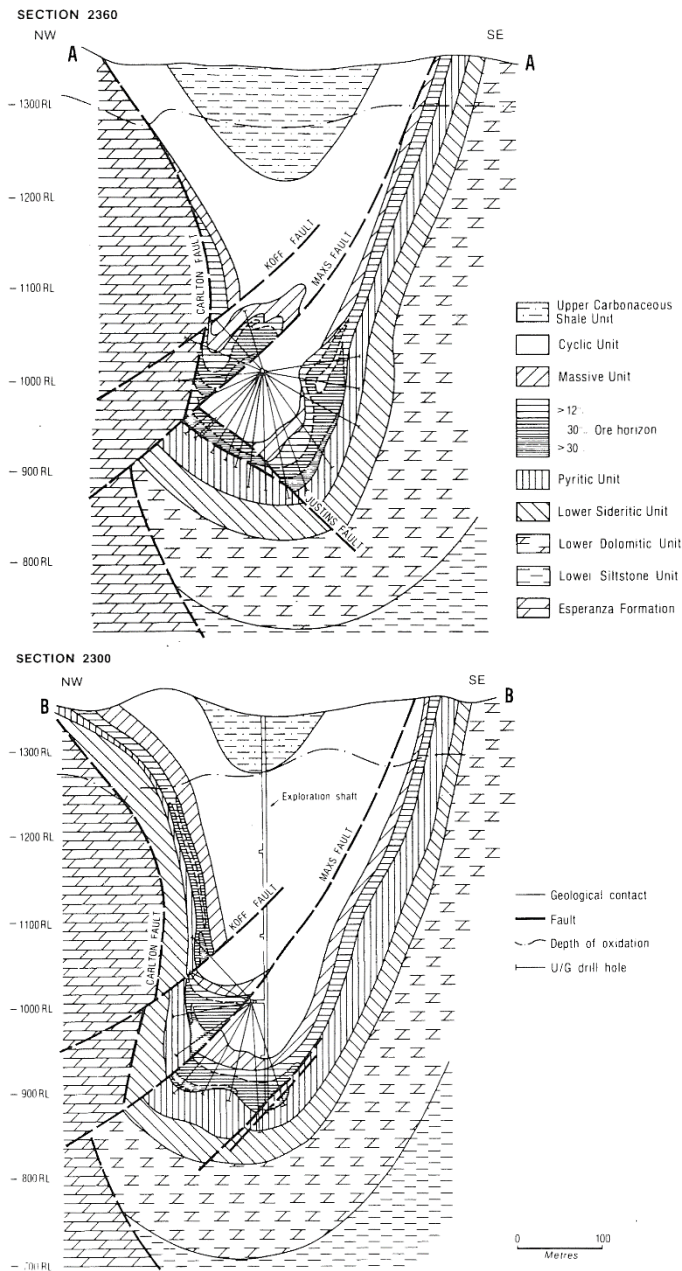


Figure 2-5 Lady Loretta Cross Sections A-A' and B-B' (Hancock and Purvis, 1990)

The surface geology is shown in Figure 2-6 and the lithology summary description is presented in Table 2-1. The ore sequence is truncated to the north-west by the north-east trending Carlton Fault zone, which juxtaposes older basin units to the north against the Lady Loretta Formation to the south (Mark, 1998). The Carlton Fault swings into convergence with the north to north-east trending Western Border Fault, which truncates Cambrian and Mesozoic cover rocks east of LLM. The Western Border Fault divides the LLM sulphide ore bearing zone from the less deformed Cambrian strata to the east, while the Carlton Fault separates the Lady Loretta Formation from the Paradise Creek Formation to the west.

The Lady Loretta Formation, one of seven that form the McNamara Group in the area, comprises dolomite, sandstone, siltstone, with chert and quartzite. The Proterozoic rocks are variably overlain by a thin layer of Mesozoic and Quaternary sediments. Although these recent sediments are not ubiquitous, they are widespread across the area (AGE, 2020).

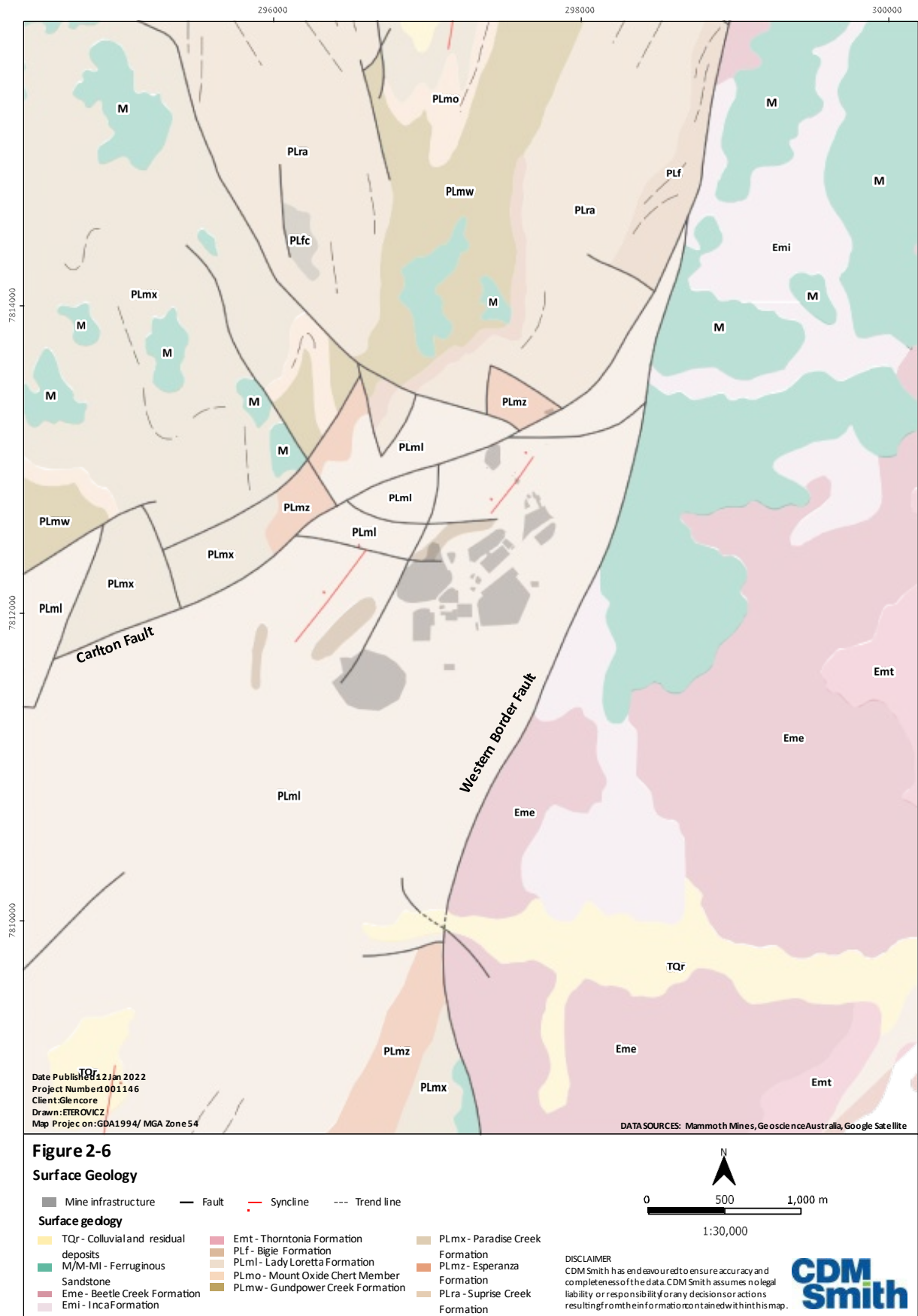


Figure 2-6 Site and Surrounds Surface Geology

Table 2-1 Site and Surrounds Stratigraphic Descriptions

Map Symbol	Age	Group	Formation	Lithology Summary
TQr	Late Tertiary - Quaternary		Alluvium and regolith	Clay, silt, sand, gravel and soil; colluvial and residual deposits (generally on older land surfaces)
M	Jurassic – Cretaceous			Ferruginous sandstone, conglomerate, siltstone and claystone
Emi	Cambrian – Early Ordovician	Narpa Group	Inca Formation	Siliceous shale and chert with limestone interbeds
Eme		Narpa Group	Beetle Creek Formation	Chert, siliceous shale with trilobite fossils, basal conglomerate
Emt		Narpa Group	Thorntonia Limestone	Thick-bedded, dolomitic limestone and dolomite with layers and nodules of chert
Emh	Neoproterozoic – Early Cambrian	Shadow Group	Mount Hendry Formation	Conglomerate, feldspathic sandstone, shale, mudstone and dolomite
PLms	Paleoproterozoic - Mesoproterozoic	McNamara Group	Shady Bore Quartzite	Flaggy to massive medium-grained orthoquartzite; interbeds of fine-grained sandstone, siltstone, and dolomite
PLml		McNamara Group	Lady Loretta Formation	Laminated stromatolitic and intraclastic dolomite, dolomitic siltstone, limestone, shale
PLmz		McNamara Group	Esperanza Formation	Stromatolitic chert and dolomite, siliceous and dolomitic sandstone
PLmx		McNamara Group	Paradise Creek Formation	Stromatolitic dolomite, dolomitic siltstone, some limestone interbeds, dolomite with chert nodules after anhydrite; minor pink to grey fine tuff
PLmo		McNamara Group	Mount Oxide Chert Member	Grey laminated chert
PLmw		McNamara Group	Gunpowder Creek Formation	Laminated siltstone, dolomitic and carbonaceous siltstone, fine-grained sandstone, feldspathic and pyritic quartzite, pebbly clayey sandstone
PLmp		McNamara Group	Torpedo Creek Quartzite	White to medium orthoquartzite, with gypsum pseudomorphs locally
PLra	Paleoproterozoic		Surprise Creek Formation	Buff, pink, white, and pale bluish grey thin-bedded fine to medium-grained labile and ferruginous feldspathic sandstone, pebbly sandstone, conglomerate, mudflake-shale pellet beds, micaceous siltstone and quartzite
PLfc			Fiery Creek Formation	Reddish brown, grey and black vesicular metabasalt and trachybasalt, locally porphyritic; purple to brown labile and micaceous sandstone, tuffaceous conglomerate; minor felsic flows and breccia
PLf			Bigie Formation	Purple-brown hematitic labile sandstone, pebbly sandstone, tuff, conglomerate and red-brown siltstone

2.4.2 Cambrian Block

To the east of the Paleoproterozoic rocks of the Mount Isa Inlier and the Western Border Fault are the Cambrian formations, which are overlain by surficial alluvium and Mesozoic sediments, varying in thickness up to 25 m. The Cambrian Block comprises four major formations as described below:

- Inca Formation underlies the surficial alluvium and Mesozoic sediments, consisting of siliceous shale and chert with limestone interbeds.
- Beetle Creek Formation consists of chert, siliceous shale with trilobite fossils, and basal conglomerate.
- Thornton Limestone consists of thick-bedded, dolomitic limestone and dolomite with layers and nodules of chert with variable thickness and predominantly outcrops in the south-east.
- Mount Hendry Formation consists of conglomerate, feldspathic sandstone, shale, mudstone and dolomite and outcrops in the south-east.

2.4.3 Paleoproterozoic Block

The Palaeoproterozoic formations to the west of the Carlton Fault are dominated by the Paradise Creek Formation, Gunpowder Creek Formation and Surprise Creek Formation. The following provides a lithology description of each formation:

- Esperanza Formation consists of stromatolitic chert and dolomite, siliceous and dolomitic sandstone.
- Paradise Creek Formation consists of stromatolitic dolomite, dolomitic siltstone, some limestone interbeds, dolomite with chert nodules.
- Gunpowder Creek Formation consists of laminated siltstone, dolomitic and carbonaceous siltstone, fine-grained sandstone, feldspathic and pyritic quartzite, pebbly clayey sandstone.
- Surprise Creek Formation consists of buff, pink, white, and pale bluish grey thin-bedded fine to medium-grained labile and ferruginous feldspathic sandstone, pebbly sandstone, conglomerate, mudflake-shale pellet beds, micaceous siltstone and quartzite.

Section 3 Hydrogeology

3.1 Hydrogeological Units

The water bearing units at the LLM site include the Lady Loretta Formation, the Cambrian Block and the Paleoproterozoic Block formations called the Esperanza and Paradise Creek units. The overlying Quaternary and Mesozoic units are rarely saturated (AGE, 2020), with the reported depth to the water table in the Cambrian Block typically more than 30 metres below ground level (mbgl). There is minimal hydrogeological information for the Esperanza and Paradise Creek Formations and only two monitoring bores in the area are screened in the Paradise Creek Formation.

The faults known as Koff and Max do not display noticeable seepage at points where they are intersected in the underground mine (AGE, 2020). Other faults not shown include Craigs Fault and Thorpedo Fault. Craigs Fault is oriented north to north-east and south to south-west and represents a narrow zone. Both Craigs Fault and Thorpedo Fault, when intersected in the underground mine, typically produce an inflow of groundwater (AGE, 2020). Koff Fault, Max Fault and Thorpedo Fault terminate at the surface, near the eastern limb of the small syncline. There is no available information or data to describe the fault structure and groundwater behaviour for the Carlton Fault or Western Border Fault. The significance of these fault structures with respect to groundwater flow is currently unknown (discussed further in Section 4).

3.2 Groundwater Monitoring Network

The LLM groundwater monitoring network includes three main types of monitoring points:

- EA-listed compliance bores.
- Internal monitoring points for background data accumulation.
- Leak detection bores which are shallow vertical groundwater bores designed to detect potential contamination from surface water infrastructure features.

The groundwater monitoring network is summarised in Table 3-1 and locations are shown in Figure 3-1. The network consists of 35 groundwater (GW) monitoring bores and 17 Leak detection (LD) sites. The LD sites are typically dry.

The LLM EA requires groundwater to be monitored on a quarterly basis at eight reference or compliance bores and six LD bores. In December 2018 Glencore received an EA amendment to remove GW07 compliance bore (as noted in Table 3-1). In 2019 monitoring bores GW02 and GW04 had collapsed and in February 2020 monitoring bore GW07 had also collapsed. In 2021 LLM augmented the groundwater monitoring network with the replacement and installation of additional bores to assist in understanding the extent of the mine depressurisation.

The monitoring network changes include the following:

- Decommissioning three failed groundwater monitoring bores as noted above.
- Installation of seven open standpipe groundwater monitoring bores at new sites GW02a, GW04a, GW07a, GW36, GW37, GW38 and GW39.

Table 3-1 LLM Groundwater monitoring network

LLM Bore ID	Description	Easting GDA94 Zone 54	Northing GDA94 Zone 54	Surveyed elevation top of casing (mAHD)	Surveyed elevation ground level (mAHD)	Total depth (m)
GW01	EA Reference	297258	7812784	346.9	345.9	70
GW02	Decommissioned	296375	7812249	331.7	331.7	30
GW02a	EA Reference	296372	7812250	331.76	330.91	126
GW03	EA Reference	298760	7813355	320.5	319.9	73
GW04	Decommissioned	298816	7810667	304.8	304.1	65.5
GW04a	EA Compliance	298815	7810670	304.09	303.15	42.8
GW05	Removed from EA	297472	7809978	-	315	38.5
GW06	Removed from EA	297518	7813285	-	344	89.5
GW07	Decommissioned	297943	7813358	331.8	331.6	61
GW07a	EA Compliance	298181	7813222	326.12	325.12	105
GW08	EA Compliance	297017	7811217	316.3	315.6	120
GW09	EA Reference	293773	7814701	311	310.3	90
GW10	Internal monitoring	298707	7814109	328.1	327.4	120
GW11	EA Reference	296393	7813439	342.5	341.9	120
GW12	Internal monitoring	296460	7809836	308.7	308.1	160
GW13	Internal monitoring	295706	7810452	311	310.3	120
GW14	Internal monitoring	296309	7812089	333.4	332.7	73
GW15	Drawdown only	298238	7812164	316.8	316.2	69.9
GW16	Drawdown only	298574	7812908	329.5	328.7	73
GW17	Drawdown only	297914	7810834	307.9	307.5	58.00
GW18	Removed from EA	299022	7814060	-	303	-
GW19	Drawdown only	297936	7811092	310.1	309.3	121.36
GW20	Drawdown only	297375	7809678	303.6	303.2	81.5
GW21	Internal monitoring	297916	7811931	315.9	315.3	-
GW34	Internal monitoring	297936	7812848	-	339	144
GW35	Internal monitoring	298083	7812352	329.3	328.6	74
GW36	Internal monitoring	296728	7811760	324.11	323.18	93
GW37	Internal monitoring	296292	7810890	310.73	309.68	76
GW38	Decommissioned	297724	7811869	-	-	-
GW39	Internal monitoring	298245	7812924	334.18	333.18	50.9
LD01	EA Reference	297824	7812634	332.3	331.6	52
LD02	EA Compliance	297715	7812383	325.6	325	30
LD03	EA Reference	297321	7812193	327.4	326.8	52
LD04	EA Compliance	297661	7811987	319.5	318.7	30
LD05	EA Reference	297050	7812086	328.6	327.9	52
LD06	EA Compliance	296915	7811738	321.7	321	30
LD07	Internal monitoring	297020	7811937	-	361	-

LLM Bore ID	Description	Easting GDA94 Zone 54	Northing GDA94 Zone 54	Surveyed elevation top of casing (mAHD)	Surveyed elevation ground level (mAHD)	Total depth (m)
LD08	Internal monitoring	297017	7811840	-	332	-
LD09	Internal monitoring	296908	7811841	-	304	-
LD10	Internal monitoring	296907	7811928	-	327	-
LD11	Internal monitoring	297591	7812209	-	335	-
LD12	Internal monitoring	297622	7812167	-	336	-
LD13	Internal monitoring	297659	7812095	-	335	-
LD14	Internal monitoring	297596	7811942	-	337	-
LD15	Internal monitoring	297470	7811914	-	351	-
LD16	Internal monitoring	297400	7811912	-	328	-
LD17	Internal monitoring	297759	7812452	-	344	-

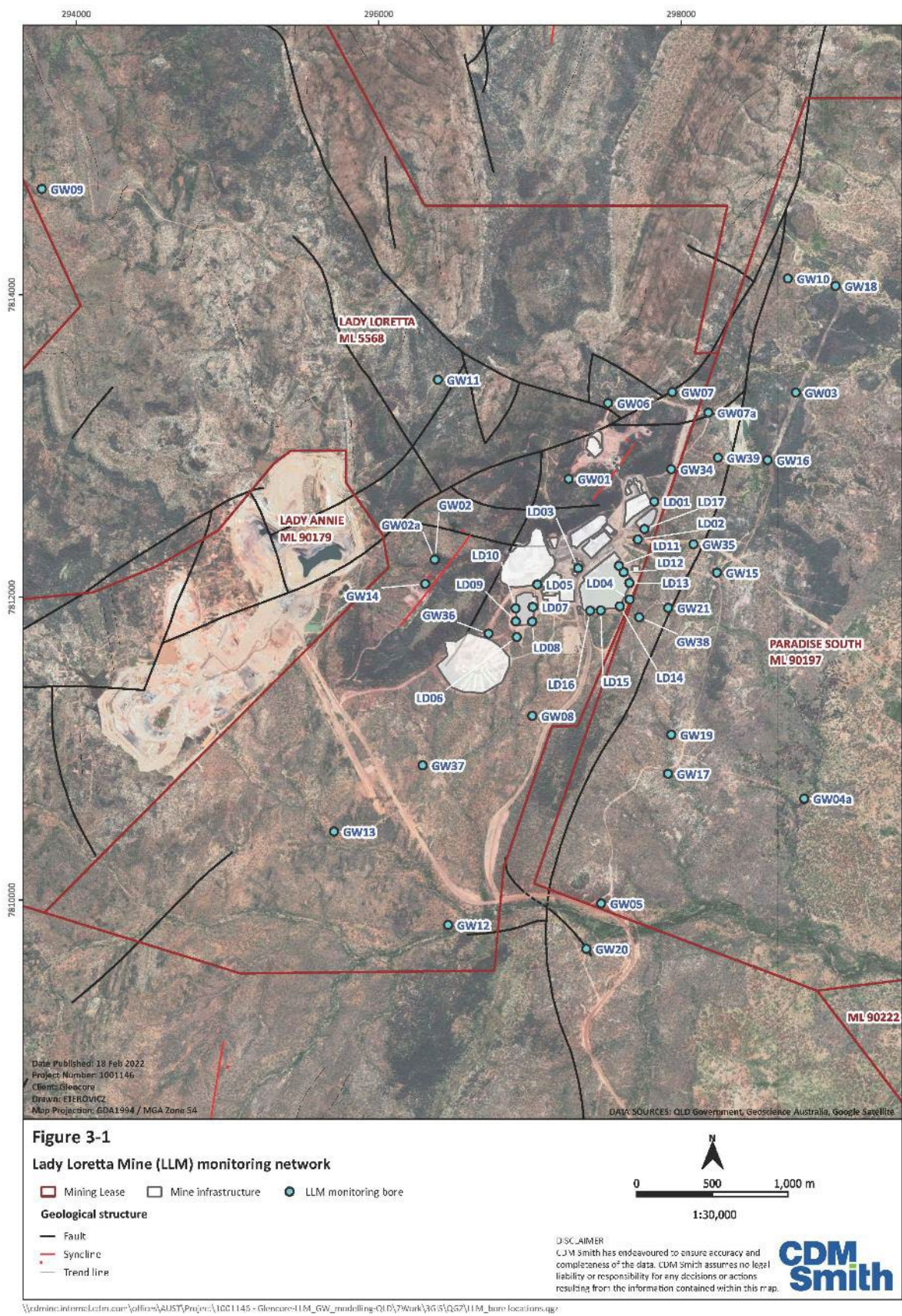


Figure 3-1 Lady Loretta Mine Monitoring Network

3.3 Hydraulic Properties

3.3.1 Paleoproterozoic - Lady Loretta Block

Douglas Partners in 2012 completed a review of the hydrogeological information and data for LLM based on previous investigations as shown in Table 3-2. A summary of the main hydrogeological information is provided below:

- Rock units of the Lady Loretta synclinal structure hosting the orebody are extensively fractured.
- Permeability of the surrounding rock mass outside fracture/fault zones is likely to be low.
- Bulk rock mass hydraulic parameters are estimated to be in the following ranges:
 - Transmissivity 0.2 to 3.0 m²/day
 - Hydraulic Conductivity 5.0E-04 to 2.0E-02 m/day
 - Storativity 4.5E-04 to 2.0E-03

Table 3-2 Lady Loretta Previous Investigation Permeability Results

Description	Golder Associates (1985, 1986a & 1986b)	Hardcastle & Richards (1987)
Transmissivity (m ² /day)	3.0	0.2 to 0.5
Storativity	4.5E-04	1.0E-03 to 2.0E-03
Hydraulic Conductivity (m/day)	2.0E-02	5.0E-04 to 1.3E-03

AGE (2021) completed slug testing on recently completed monitoring bores, a summary of the results is provided in Table 3-3. The testing was undertaken using a standard technique, where a solid slug was inserted into the bore, resulting in a displaced raised water level. The slug testing program comprised conventional rising and falling head tests and the data was analysed using the Bouwer and Rice method (Bouwer & Rice, 1976) to provide estimates of hydraulic conductivity, which shows the permeability of Lady Loretta Block rocks is generally low ranging from around 9.0E-04 to 2.4E-01 m/day.

Table 3-3 2021 Permeability and Hydraulic Conductivity Results

Bore ID	Hydraulic Conductivity (m/day)	Transmissivity (m ² /day)
GW02a	9.0E-04	
GW07a	1.0E-03	
GW07a	9.0E-04	
GW36	5.0E-03	2.00E-03
GW37	2.4E-01	

3.3.2 Cambrian Block

A literature review completed by AGE in 2020 analysed the data from 25 bores with relevant hydraulic properties (AGE, 2020). Table 3-4 lists hydraulic properties derived from pumping tests for the bores screened in the Cambrian Block. In summary, the hydraulic conductivity values obtained from pumping tests range from 2.46 to 123 m/day.

Table 3-4 Cambrian Block Permeability and Hydraulic Conductivity Results (AGE, 2020)

Bore ID	Rate (L/sec)	Airlift yield (L/sec)	Aquifer thickness ^a (m)	Hydraulic Conductivity ^a (m/day)	Transmissivity ^a (m ² /day)	Storativity ^a (m-1)	Specific storage (m ⁻¹)
GW17	1.6	1.2 ; 1.0 ^b ; 0.8 ^c	18	123	2,210		
GW18	1.4	1.25 ^c					
GW03		1.1	12	2.46	29.5	1.39E-08	
GW10		0.2					
GW15		3	20	55.3	1,110		1.73E-06
GW20		5	18	10.8	194	2.60E-06	

Notes: a All data is from the most recent report by Rob Lait & Associates (2013), unless otherwise noted.

b Douglas Partners (2007).

c obtained from bore report for bore RN 146130.

3.3.3 Paleoproterozoic Block

There is minimal hydrostratigraphic information and permeability data for the Paleoproterozoic Block located west of the Carlton Fault. Yield data obtained from the Queensland groundwater database of registered bores indicates air lift yields range from 0.1 to 2.2 L/sec as shown in Table 3-5. The bore log lithology descriptions are similar to the Lady Loretta Formation and the fractured rock is likely to have variable permeability. Representative values of hydraulic conductivity and specific yield are 8.0E-04 m/day and 12%, respectively based on siltstone (Domenico and Schwartz, 1990 and Morris and Johnson, 1967).

Table 3-5 Queensland Groundwater Database - Reported Bore Yields

QLD RN Bore ID	LLM Monitoring Bore	Air Lift Yield	Bore Log Listed Formation
146844	GW11	0.10 L/sec at 47 m 0.10 L/sec at 54 m 0.20 L/sec at 73 m	Paradise Creek Formation
146847	GW09	0.10 L/sec at 36 m 0.20 L/sec at 68 m 2.20 L/sec at 76 m	Paradise Creek Formation

3.4 Groundwater Heads and Flow Direction

3.4.1 Lady Loretta Block

Groundwater head data is available for the Lady Loretta Block bores from August 2013 to July 2021. The groundwater head elevations typically show a declining trend (Figure 3-2). The groundwater monitoring data shows there are variable drawdown rates within the bores over the monitoring period. The highest decline rate is recorded at bore GW13 at 1.5 m/year and GW7, GW8 and GW12 at approximately 0.6 m/year. The lowest decline rate is recorded at bore GW14 at approximately 0.1 m/year and minimal change at GW34 at approximately 0.07 m/year.

Higher elevation areas in the north have higher hydraulic heads for example GW6 and GW7 while lower elevation areas typically have lower hydraulic heads; for example GW8, GW12 and GW13, indicating the natural (pre-mine) groundwater flow direction is inferred as south towards Desert Creek consistent with ephemeral drainage lines and topography. However, the pre-mine groundwater flow field has been altered due to mine dewatering, and flow direction is now generally towards the LLM underground workings. Considering the reported GW14 groundwater heads, which is located between the LLM and the Lady Annie mine pit, there does not appear to be significant dewatering interference between the two mines.

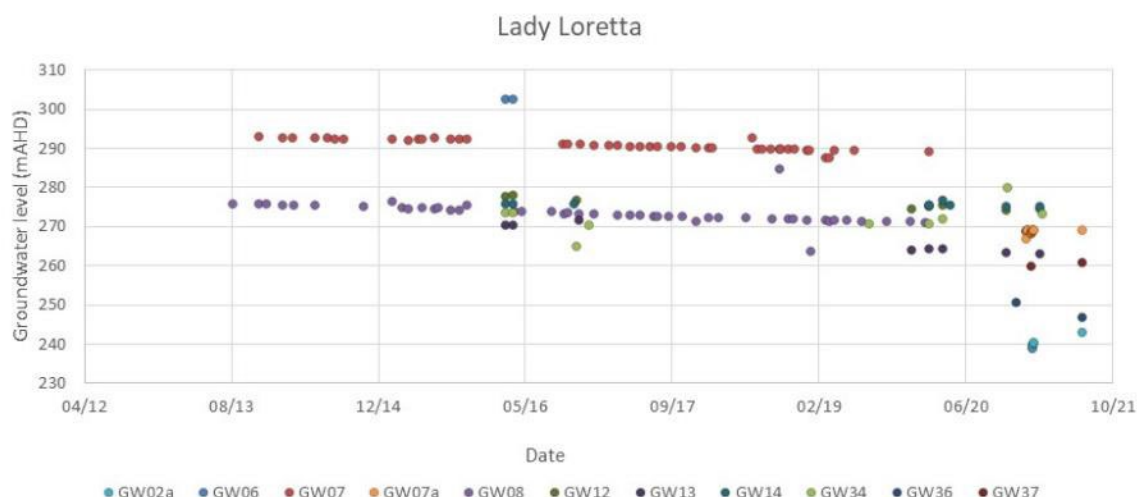


Figure 3-2 Lady Loretta Block Groundwater Heads

3.4.2 Cambrian Block

Groundwater head data is available for the Cambrian Block bores from July 2013 to March 2021 (Figure 3-3). All the groundwater monitoring bores show a declining groundwater level trend over the monitoring period. The groundwater heads are approximately 269 to 273 mAHD, with the lowest at GW15 at approximately 268.5 mAHD (possibly in response to pumping from GW15). There are no obvious seasonal recharge responses to annual rainfall evident in the groundwater heads and there is a visible rate of groundwater decline since 2018, despite an increasing slope in CDFM data for the same period.

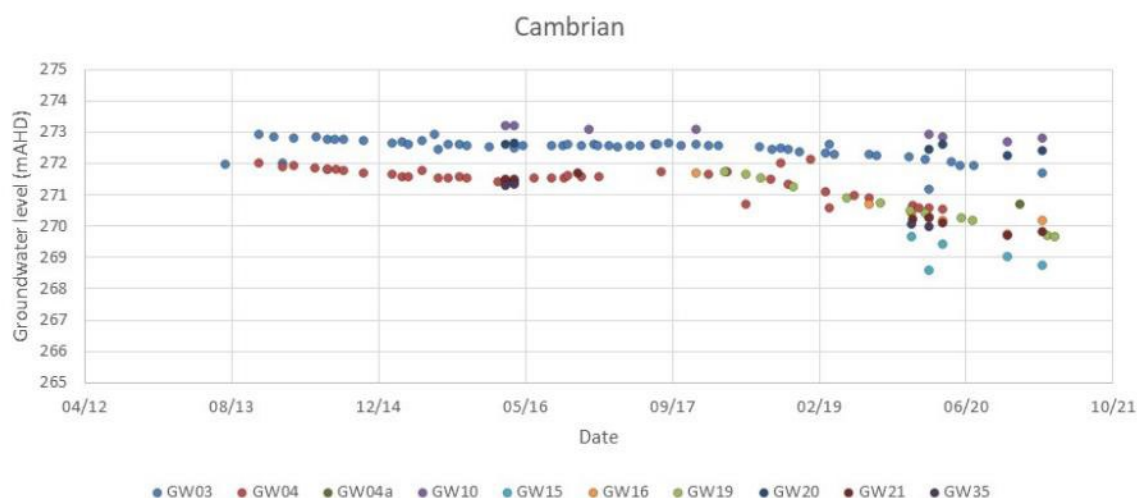


Figure 3-3 Cambrian Block Groundwater Heads

Table 3-6 shows groundwater head statistics and Figure 3-4 shows the average groundwater head over the monitoring period. Groundwater head decline is greatest at monitoring bore GW15. The groundwater heads show a drawdown and flow direction towards the monitoring bore GW15 from the north and south. The groundwater decline is likely to be attributed in part to the LAE borefield. Whilst there is little west to east spread of water head datapoints, the available initial/earliest data suggests the natural (pre-mine) groundwater flow direction inferred as east, consistent with ephemeral drainage lines and topography.

Table 3-6 Groundwater Head Statistics

Bore ID	Minimum Head mAHD	Mean Head mAHD	Maximum Head mAHD	Count
GW10	272.7	273.0	273.2	8.0
GW03	271.2	273.3	319.9	57.0
GW16	269.7	270.6	271.7	9.0
GW15	268.6	269.7	271.4	7.0
GW21	269.7	270.6	271.7	8.0
GW19	269.7	270.7	271.7	12.0
GW04	270.5	271.5	272.1	41.0
GW20	272.3	272.5	272.6	6.0

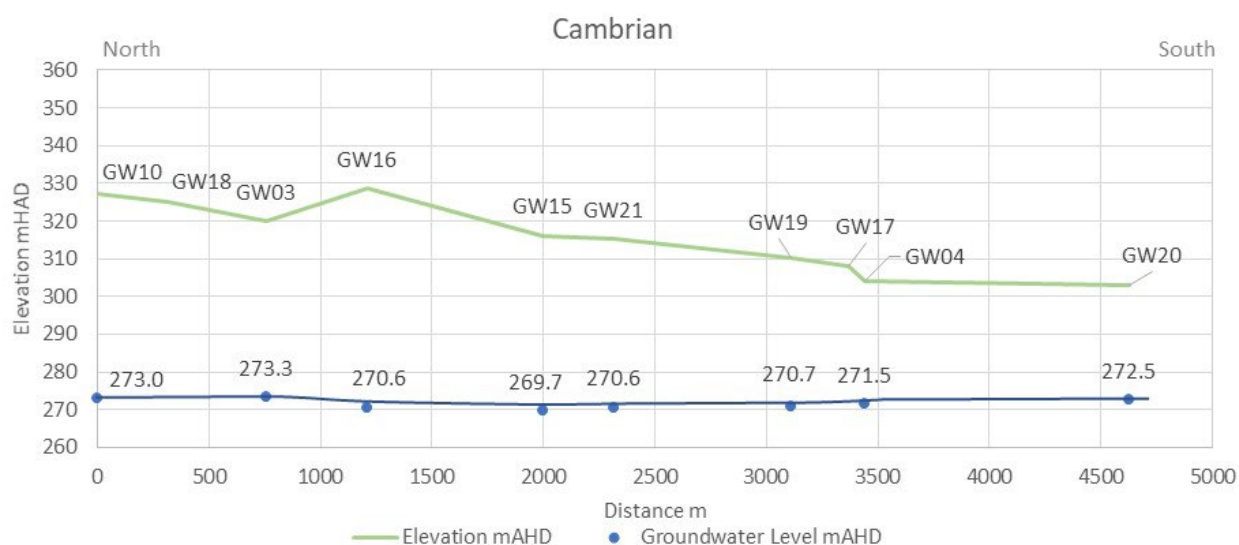


Figure 3-4 Cambrian Block Average Groundwater Heads

3.4.3 Paleoproterozoic Block

There are two groundwater monitoring bores located in the Paleoproterozoic Block west of LLM and the Carlton Fault (Figure 3-5). The groundwater level measurements over the monitoring period are relatively consistent and show minor change since 2013 despite a variable slope in CDFM data for the same period and no evident recharge response to rainfall. Bore GW11 is located greater than 1 kilometre from LLM and GW09 greater than 4 kilometres. The natural (pre-mine) groundwater flow direction is inferred as west based on the topography and groundwater head data for bores GW09 and GW11.

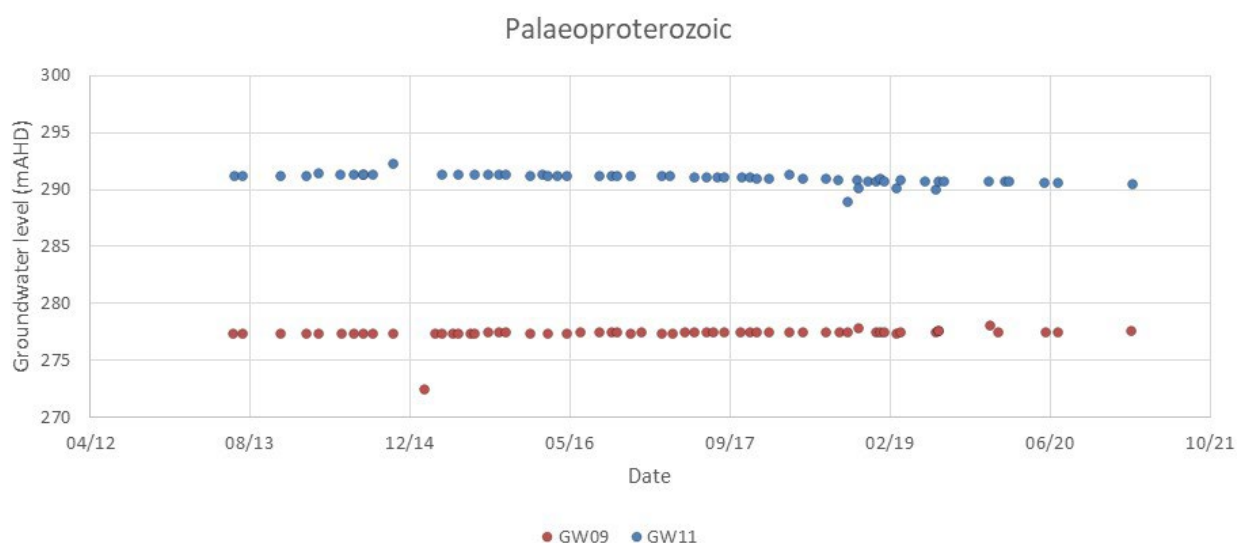


Figure 3-5 Palaeoproterozoic Block Groundwater Heads

3.5 Groundwater Potentiometric Contours

Figure 3-6 shows the average observed groundwater heads and interpreted head contours based on monitoring bore data for the project area. Shown inferred contour lines are drawn by hand without sophisticated software and are not representative of calculated fault permeability or behaviour. The observed groundwater heads to the east of the Western Border fault show a minimum of 269.7 mAHD in GW15 and a maximum elevation of 273.3 mAHD in GW03. All the other monitoring bores located to the east of the fault show groundwater heads within this range.

Carlton and Western Border Faults are expected to exert a major control on groundwater flow fields, with groundwater contours also influenced by drawdowns that develop in response to mine dewatering and borefield production. Because of these influences it is not possible to clearly attribute groundwater contours to specific fault controls, so a quantification of the specific influence of faults cannot be made at this time. However, there is a hydraulic gradient towards the LAE borefield and to the LLM site. Overall, on the Lady Loretta Block there is evidence of localised groundwater flow towards LLM due to dewatering within the underground mine workings, a cone of depression has developed, drawing groundwater toward the central part of the site operations. The cone of depression extends south to south-west along the axis of the syncline, toward bore GW13 and there is minimal depressurisation evident in the west around GW14. This contour assessment is considered further as part of the reconceptualisation presented in Section 4.

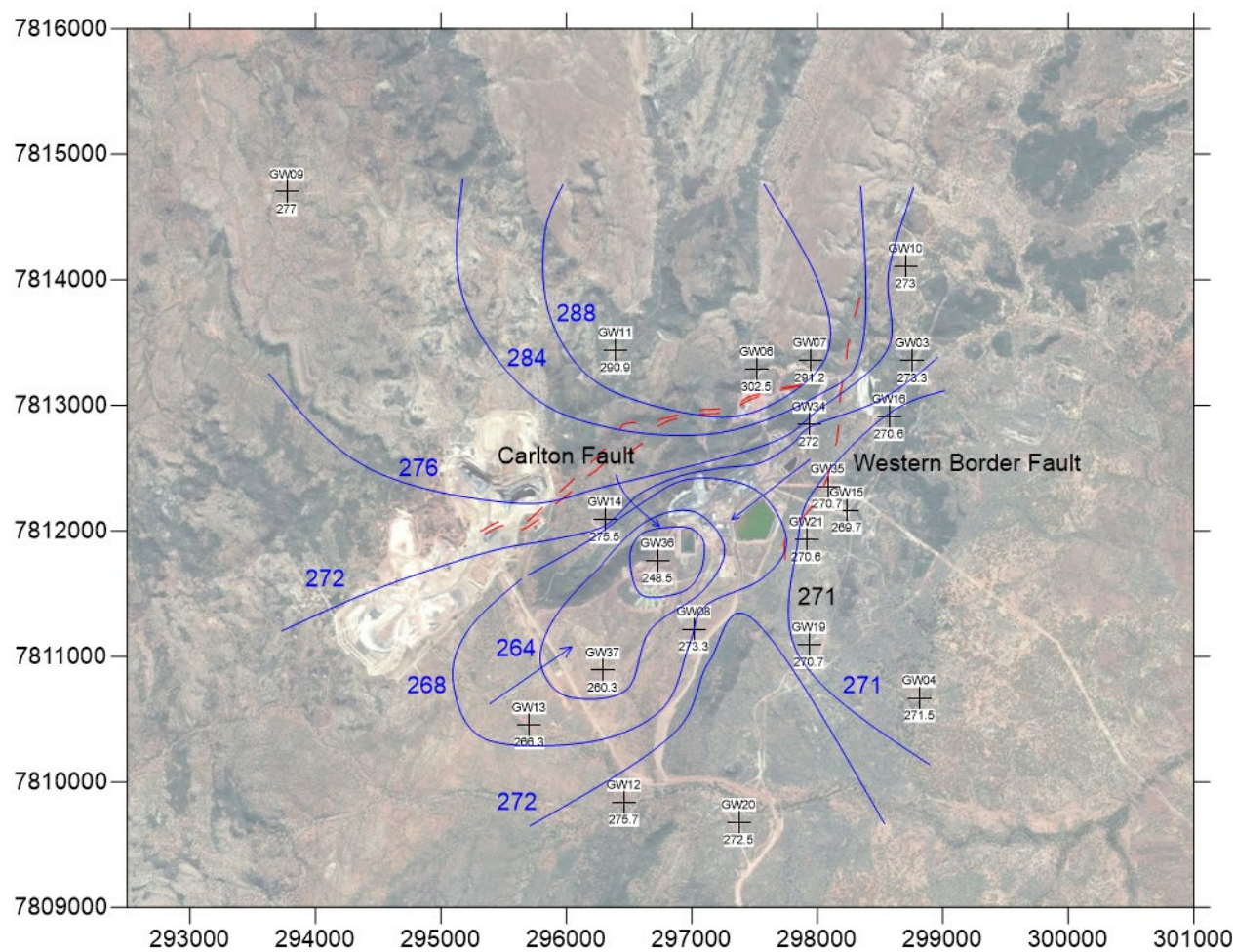


Figure 3-6 Average Observed Groundwater Levels and Contours (mapped fault locations cannot be exact or precise)

3.6 Groundwater Quality

Proportional abundances of major cations and anions are shown on the piper diagram Figure 3-7 for monitoring bores across the site. Piper Plots explain the classification type of water facies on the basis of its interaction with rock and soil minerals. The diamond plot at the centre is a blend of two trilinear plots on the two sides of the diamond. Different quadrants of the diamond show the different type of water on the basis of ion concentration dominance.

Based on the Piper Plot all formations have calcium-bicarbonate dominated groundwater except for the Paleoproterozoic Block, which has calcium-chloride dominated groundwater in some locations. The Paleoproterozoic Block bores located furthest from the LLM to the north-west indicates calcium as the dominant cation and chloride as the dominant anion. Groundwater with calcium as the dominant cation and bicarbonate the dominant anion is typically consistent across the site.

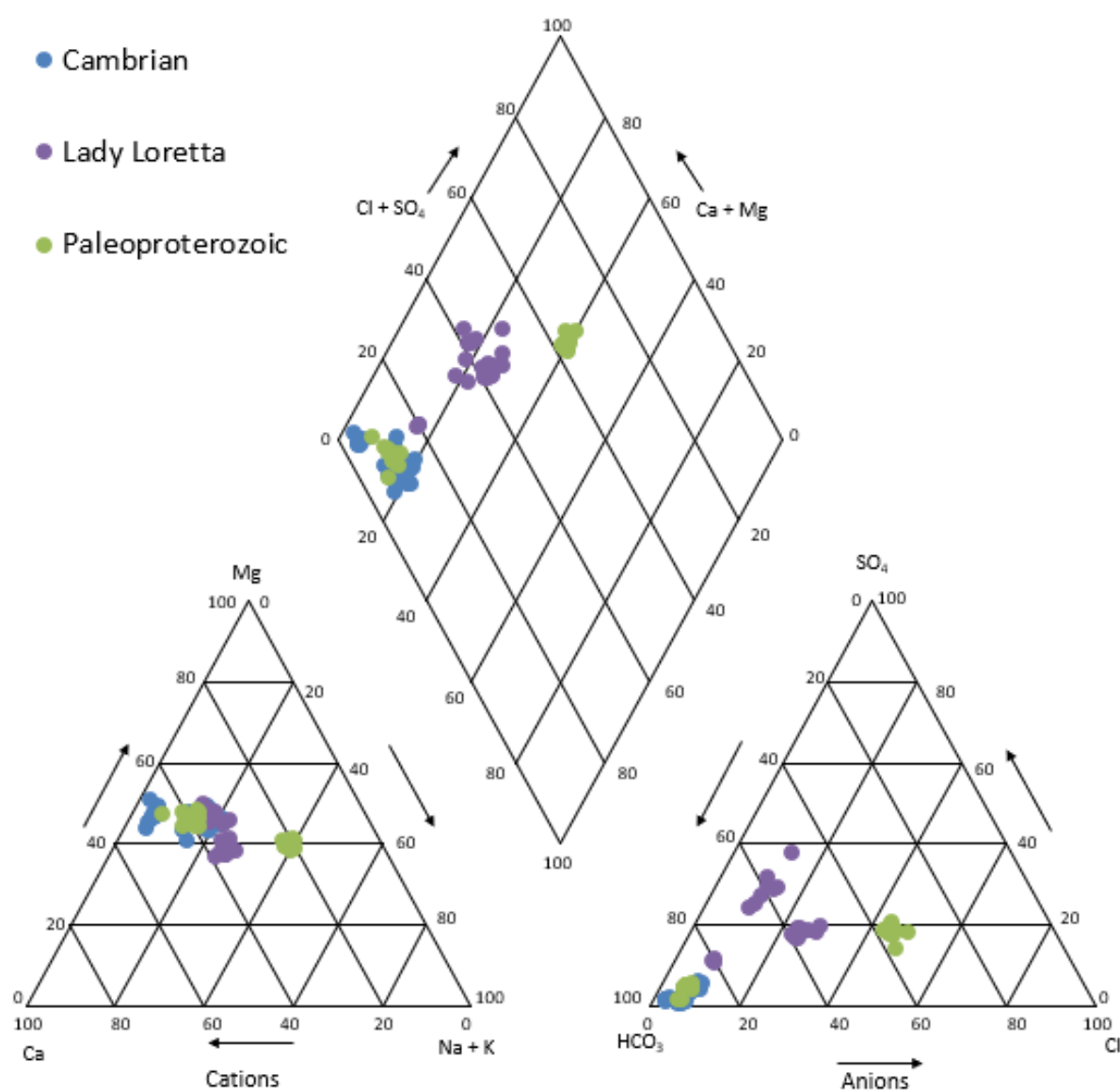


Figure 3-7 Piper Diagram for all Selected Groundwater Samples

The cations versus chloride proportional abundances are shown in Figure 3-8 for monitoring bores across the site. Based on Figure 3-8 the cations versus chloride plots indicate that groundwaters are similar. All formations have calcium -bicarbonate dominated groundwater except for monitoring bore GW09, which has calcium-chloride dominated groundwater. GW09 located furthest from the LLM to the north-west shows calcium as the dominant cation and chloride as the dominant anion.

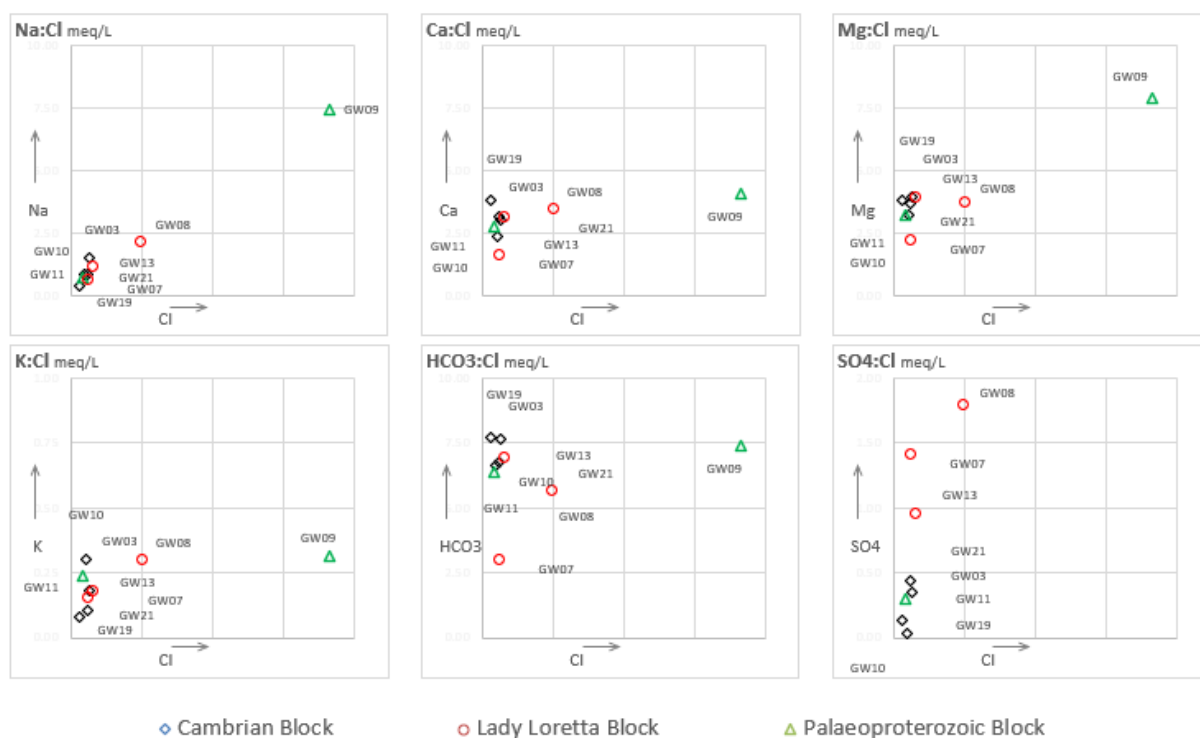


Figure 3-8 Major Ion and Chloride Ratio Plots for Selected Groundwater Samples

Figure 3-9 to Figure 3-11 show electric conductivity (EC) for monitoring bores across the site. The groundwater samples indicate EC values of less than 1000 $\mu\text{S}/\text{cm}$, with the exception of GW09 which reports an EC of almost 2000 $\mu\text{S}/\text{cm}$. Notably, the bores located on the eastern and western side of the Carlton Fault and Western Border Fault show comparable EC values.

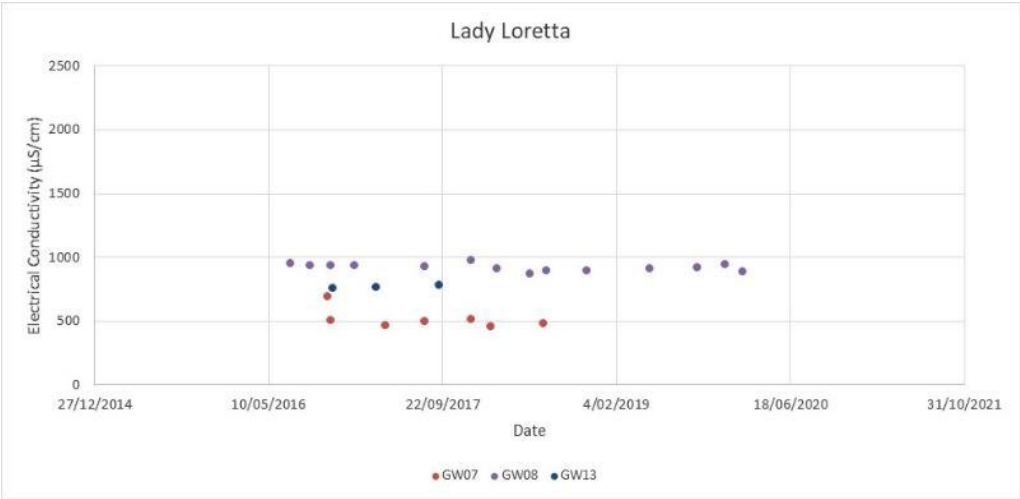


Figure 3-9 Lady Loretta Block EC

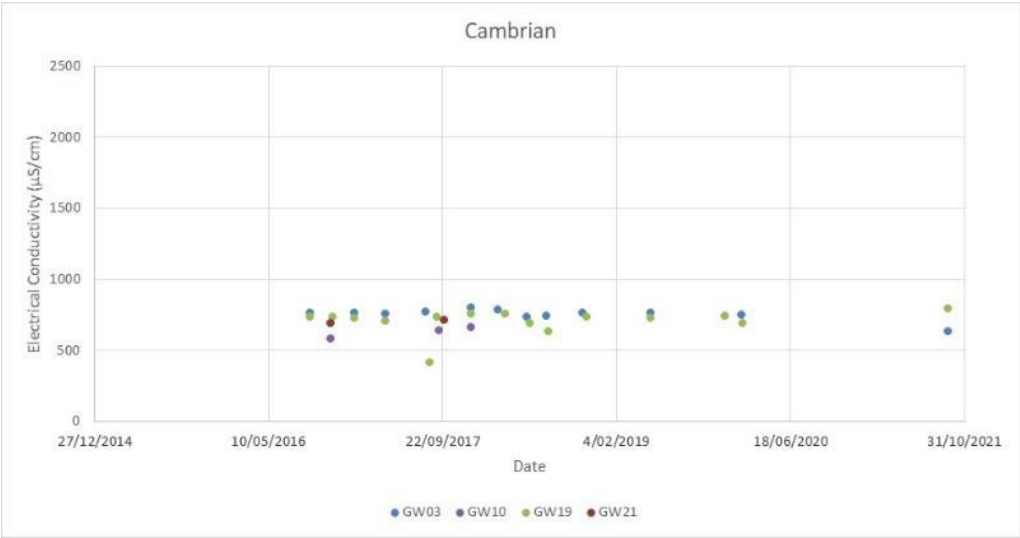


Figure 3-10 Cambrian Block EC

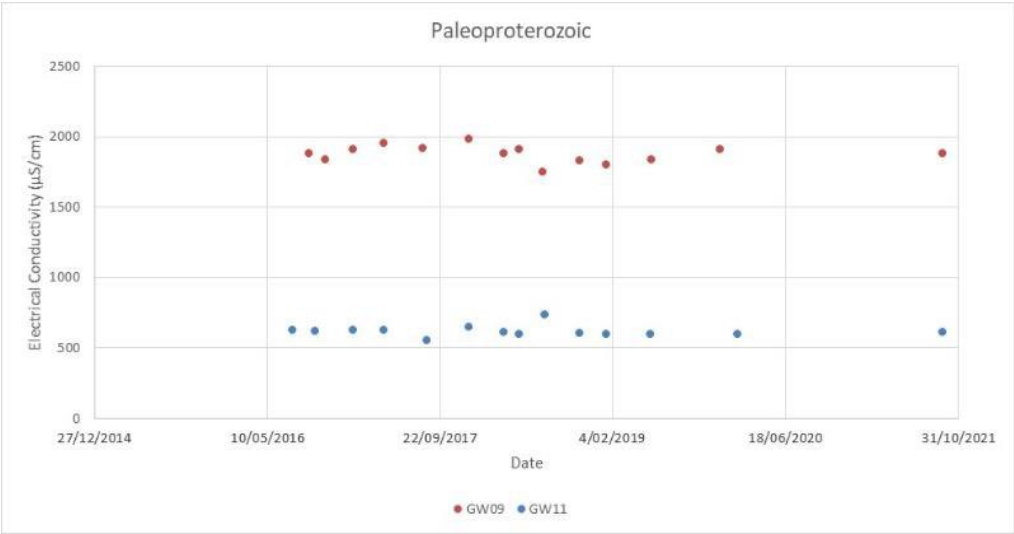


Figure 3-11 Paleoproterozoic Block EC

3.6.1 Hydrochemistry Assessment

Salient Solutions Pty Ltd completed an assessment of the hydrochemistry of the groundwater in and around LLM as an independent constraint on the site conceptualisation (Appendix A). The assessment used cations and anion chemistry together with water quality parameters to:

- Assess possible fault fracture groundwater connectivity between the Cambrian, Lady Loretta and Proterozoic blocks through application of hydrochemical analysis.
- Potentially evaluate the degree of connectivity/permeability between the blocks through the fault network that could be inferred by the hydrochemistry assessment findings.
- Evaluate the findings of the assessment relative to the other work scopes, and establish if the hydrochemistry of the site supports the understanding of groundwater flows at the site.

The following subsections summarises the findings (Appendix A: Evans, 2022).

3.6.1.1 LLM Blocks

Two primary potential sources of chemical constituents measured in the groundwater in the region of LLM are considered:

- The first is from salts depositing either via rainfall or via dryfall (dust) mechanisms.
- The second is associated with mineral dissolution, both under natural conditions and under conditions imposed due to mining activities.

Groundwater in the Lady Loretta Block is considered oxidised to mildly reducing. This suggests that the sulphidic mineralisation has the potential to be oxidised as groundwater flows through the strata. Dewatering associated with mining operations has induced hydraulic gradients towards the mine, and this has meant that there is a greater supply of oxidised groundwater available for oxidation processes. Conversely, samples from GW08 show that under near natural conditions, the groundwater can become mildly reduced.

The chloride concentration in groundwater across the site indicates locally differing recharge rates within the block, and these concentrations are preserved, indicating a degree of compartmentalisation within the Lady Loretta Block. This compartmentalisation via chloride concentrations can also be seen in the Proterozoic Block, indicating this compartmentalisation occurs at a regional scale within blocks, and is not unique to Lady Loretta. The sulphate findings at Lady Loretta also suggest compartmentalisation as well as informing the distribution of sulphidic mineralisation within the bedrock and indicate that sulphur is being contributed to the groundwater from mineral dissolution (or oxidation) processes (as discussed above) and this could be considered compartmentalised in the vicinity of the underground workings. This intra-block compartmentalisation, particularly in the vicinity of the underground workings is a key finding in relation to closure planning.

There are differences between the metal concentrations recorded in samples collected of the underground groundwater versus regional groundwater samples:

- Arsenic generally is at higher concentrations in the regional water and is mostly non-detectable in the underground seepage of groundwater.
- Lead concentrations are low, but there are detectable levels in all samples whereas lead is mostly below detection limits in the regional groundwater.
- Molybdenum and cadmium concentrations are essentially at the same levels between the two groundwaters (underground seepage versus regional groundwater).
- Cobalt, nickel and zinc are at much higher levels in the underground seepage of groundwater when compared to the more regional groundwater, with zinc being 20 to 50 times higher.

- Regional groundwaters (that is, groundwater outside of the influence of direct impacts of mining) show background levels of some metals that are well above detection limits, confirming that natural weathering processes in metalliferous terrains produce higher than usual background metal contents. The occurrence of a large number of outliers in the metals data for the Lady Loretta Block and the Proterozoic Block also supports the hypothesis that groundwater in these two Blocks can be compartmentalised, that is, they are not well-mixed.

3.6.1.2 Regional Conclusions

From a regional perspective there is little evidence from the water quality study to support broad scale mixing between groundwaters from different geological blocks in the vicinity of LLM, considering the results of the major ion chemistry assessment. The chemical types of the Cambrian Block groundwater are sufficiently different from those in the groundwater of the Lady Loretta Block to indicate that if flow across the Western Boundary Fault is possible, it is of a small magnitude. Alternatively, the hydrochemical advective “front” of Cambrian Block groundwater chemistry has not had sufficient time to reach the groundwater monitoring locations and analysed. Differing concentration of metals further emphasises the difference between groundwater in the Cambrian Block compared to groundwater from the other Blocks.

3.7 Groundwater Recharge and Discharge

3.7.1 Groundwater Recharge

Recharge to the groundwater system is likely to occur through rainfall infiltration. The recharge rate is expected to vary spatially across the project area and is highly likely to be related to lithology type (AGE, 2020) and the degree to which outcrop occurs. The rate of rainfall infiltration is likely to be low, due to the climate setting where evaporation rates are higher than rainfall rates across the seasons. Estimates of recharge between 1 to 5 % of rainfall are typical in this type of environment (AGE, 2020), consistent with the fresh-brackish levels of salinity. The Thornton Limestone is identified as the most likely pathway for groundwater recharge into the aquifers and formations targeted by the LAE Borefield (AGE, 2015). Douglas Partners (2007) also state that recharge is likely to be enhanced in proximity to the Western Border Fault due to increased fracturing along this structural feature.

3.7.2 Groundwater Discharge

The major discharge from LLM is inflow to the underground mine workings. Regional aquifer through-flow is also considered a discharge mechanism for the Cambrian Block groundwater system in the study area, with groundwater flow inferred to be toward the east.

3.7.2.1 Mine Discharge

Douglas Partners in 2012 completed a hydrogeological assessment to determine likely inflows to LLM underground workings. The analysis undertaken provided the data listed in Table 3-7.

Table 3-7 Mine Groundwater Inflows

Description	Inflow L/sec
Mine areas and crosscuts	5
Development drives	10 to 20
The decline	10
High volume, short term inflows from intersected faults and old boreholes	Unknown
Total inflows to the Lady Loretta mine	25 to 35

AGE in 2020 estimated that the typical recorded groundwater inflow to the underground workings during care and maintenance was approximately 8 L/sec. During operations, the volume of water pumped from the mine reaches approximately 15 L/sec (AGE, 2020), which includes around 7 L/sec of water introduced to the mine from the surface.

Total mine inflow estimates range from 8 to 35 L/sec, dependant on the mining activities and geology intersected.

3.7.2.2 LAE Production

There are three production bores called GW15, GW17 and GW18. The annual average extraction rate of raw water from the LAE borefield is 766 ML per year, which equates on average to approximately 24 L/sec (LLM, 2021b). There are no known landholders in the area that extract groundwater from groundwater bores.

Section 4 Hydrogeological Conceptualisation

4.1 AGE Conceptualisations 2015 and 2020

4.1.1 AGE Previous Conceptual Models and Fault Behaviour

Previous hydrogeological conceptualisation studies were completed by Australian Groundwater and Environment (AGE) in 2015 (AGE,2015) and 2020 (AGE,2020). It has been observed that the AGE 2015 and 2020 conceptual models demonstrated an evolution of conceptual thinking, with differences in terms of fault barrier conceptualisation and groundwater flow or movement between the two models identified.

AGE in 2015 updated the LLM numerical groundwater model to incorporate the mine development and associated dewatering, and the model calibration was updated from a steady state solution to a transient calibration. The following observations were noted in the AGE 2015 report in relation to the groundwater conceptualisation of the Western Border Fault (AGE, 2015).

- *The bores located on the eastern and western side of the fault show comparable EC values which confirms that the fault is unlikely act as a barrier to groundwater flow.*
- *The bores located immediately west of the fault record groundwater levels between 271 mAHD (GW35) and 280 mAHD (GW12). These bores show marginally higher groundwater levels in comparison to groundwater levels to the east of the fault. Therefore, while the fault appears to separate the groundwater system into two zones, the hydraulic disconnect between the two zones is not significant.*

The AGE 2015 numerical model defined the hydraulic parameter for the Carlton and Western Border Fault as a horizontal permeability or hydraulic conductivity value of 0.02 m/day illustrating that AGE considered this a barrier.

AGE in 2020 updated and renewed only the groundwater conceptual model, with no numerical model works completed. The following points are summarised from the AGE 2020 report.

- *The hydraulic gradients and temporal trends reinforced the conceptualisation that the Western Border Fault acts as a barrier to flow.*
- *The Palaeoproterozoic Block was separated from the Lady Loretta Block by the Carlton Fault, with lithological and hydraulic evidence indicating that the fault acts as a barrier to hydraulic connection between the two zones.*
- *The groundwater quality for the Cambrian block shows no indications of mixing with source waters from LLM. This observation fits with the understanding of the Western Border Fault acting as a barrier to flow.*
- *The Western Border Fault acts as a barrier to groundwater flow, and there is negligible interference between the Lady Loretta Block and the Cambrian Block.*

4.1.2 Review of AGE Conceptualisation

The AGE 2020 concept of barrier to flow is shown below where there is nearly no flow across faults (Figure 4-1).

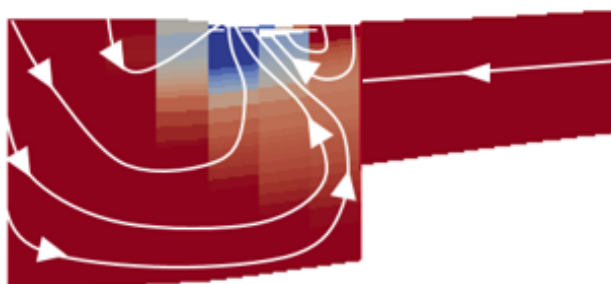


Figure 4-1 Cross Section of Barrier Fault Flow Lines (McCallum et al., 2018)

Faults can broadly exhibit three behaviours in a fluid flow context these behaviours are (Figure 4-2):

- A barrier to both along and across fault flow.
- A conduit to both along and across fault flow.
- A conduit to along fault flow and a barrier to across fault flow.

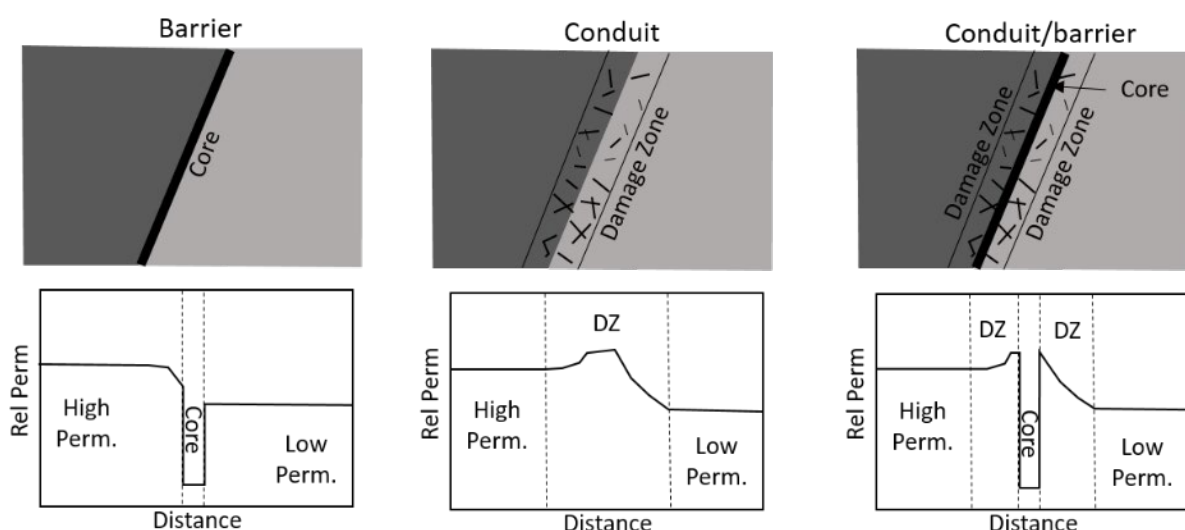


Figure 4-2 Three Conceptual Models of how Fault Zones Impact Fluid Flow Properties (McCallum et al., 2018)

Ideally, to represent the faults within the context of the conceptual conduit-barrier system, details of the physical characteristics of the fault zones need to be represented. This includes the widths and permeabilities of the fault core and the damage zone (McCallum et al., 2018). There are insufficient site data or information to inform fault permeabilities and determine the fault behaviour to groundwater flow. Ideally, a site field and data collection program (possibly including groundwater isotopic studies) would inform the fault behaviour and this information would inform the regional numerical model.

However, since this conceptualisation and parameterisation is not possible based on the available information and data, it is necessary to test each of the possibilities in a sensitivity analysis or calibration exercise. It is important that each of the three scenarios is tested in the numerical analysis to consider the likely fault behaviour. The use of the recently developed modelling technique PESTPP-IES (White, 2018) that can run numerical groundwater models stochastically in a highly efficient manner will be used to assess the knowledge gap for the hydraulic properties of the faults and fault behaviour.

4.1.3 Re-conceptualisation of Study Area Hydrogeological Interactions

A simplified revised conceptual cross section is shown in Figure 4-3 based on the available hydrogeological information and assessment works completed above.

Key features of the hydrogeological conceptualisation are as follows:

- The Western Border Fault divides the LLM sulphide ore bearing zone from the less deformed Cambrian Block to the east, while the Carlton Fault separates the Lady Loretta Block from the Paleoproterozoic Block to the west. There is no Cambrian block to the west of Western Fault.
- The major Carlton Fault Zone truncates the syncline to the north-west. The Carlton Fault is associated with extensive zones (up to 200m wide) of shearing and brecciation.
- The major faults (Carlton Fault and Western Border Fault) are considered to exert a major control on flow patterns in the topography driven and structurally controlled hydrogeological system. However, it is difficult to different fault control on flow given other influences on groundwater flow at this time (e.g mine dewatering).
- The natural groundwater flow direction is likely structurally controlled in an unstressed environment and is assumed to follow the ephemeral drainage lines and site topography.
- The groundwater head decline is likely to be attributed to both the LAE borefield (Cambrian Block) and mining activities (Lady Loretta Block). Constant groundwater inflow rate to underground workings is about 252 ML/year and the annual average extraction rate of raw water from the LAE Borefield is 766 ML per year.
- A hydraulic gradient towards the LAE borefield and to the LLM site has been identified. Overall, on the Lady Loretta Block there is evidence of localised groundwater flow towards LLM due to dewatering within the underground mine workings - a cone of depression has developed, drawing groundwater toward the central part of the site operations.
- Cambrian Block hydrostratigraphy hydraulic conductivity values range from 2.5 to 123 m/day, whilst Lady Loretta Block hydrostratigraphy permeability values are low ranging from around 0.001 to 0.25 m/day. There is minimal hydrostratigraphy information and permeability data for the Paleoproterozoic Block and representative values for the lithology are likely in the range 0.001 m/day. Regardless of the hydraulic properties of the Western Boundary Fault, the hydraulic conductivity contrast between the Cambrian and Lady Loretta Blocks will influence the distribution of hydraulic gradients across the fault.
- The chloride concentration in groundwater across the site indicates locally differing recharge rates within the block, and these concentrations are preserved, indicating a degree of flow compartmentalisation within the Lady Loretta Block at least. The intra-block compartmentalisation seen in the Lady Loretta Block is also exhibited in the Proterozoic Block, showing this intra-block compartmentalisation is not unique to Lady Loretta and is occurring at a regional scale (Appendix A: Evans, 2022).
- From a regional perspective there is little evidence to support broad scale mixing between groundwaters from different geological blocks in the vicinity of LLM considering the results of the major ion chemistry assessment completed. The chemical types of the Cambrian Block groundwater are sufficiently different from those in the groundwater of the Lady Loretta Block to indicate that if flow across the Western Boundary Fault is possible, it is of a small magnitude. Alternatively, the advective hydrochemical “front” of Cambrian Block groundwater has not had sufficient time to reach the observation points and be sampled.
- There does not appear to be substantial drawdown or water head differences across the Carlton Fault.
- There is insufficient data to definitively determine how the faults may influence fluid flow based on the desktop assessment works completed (considering active dewatering in the study area). However, numerical modelling approaches are to be used to further assess fault behaviour.

Section 4 Hydrogeological Conceptualisation

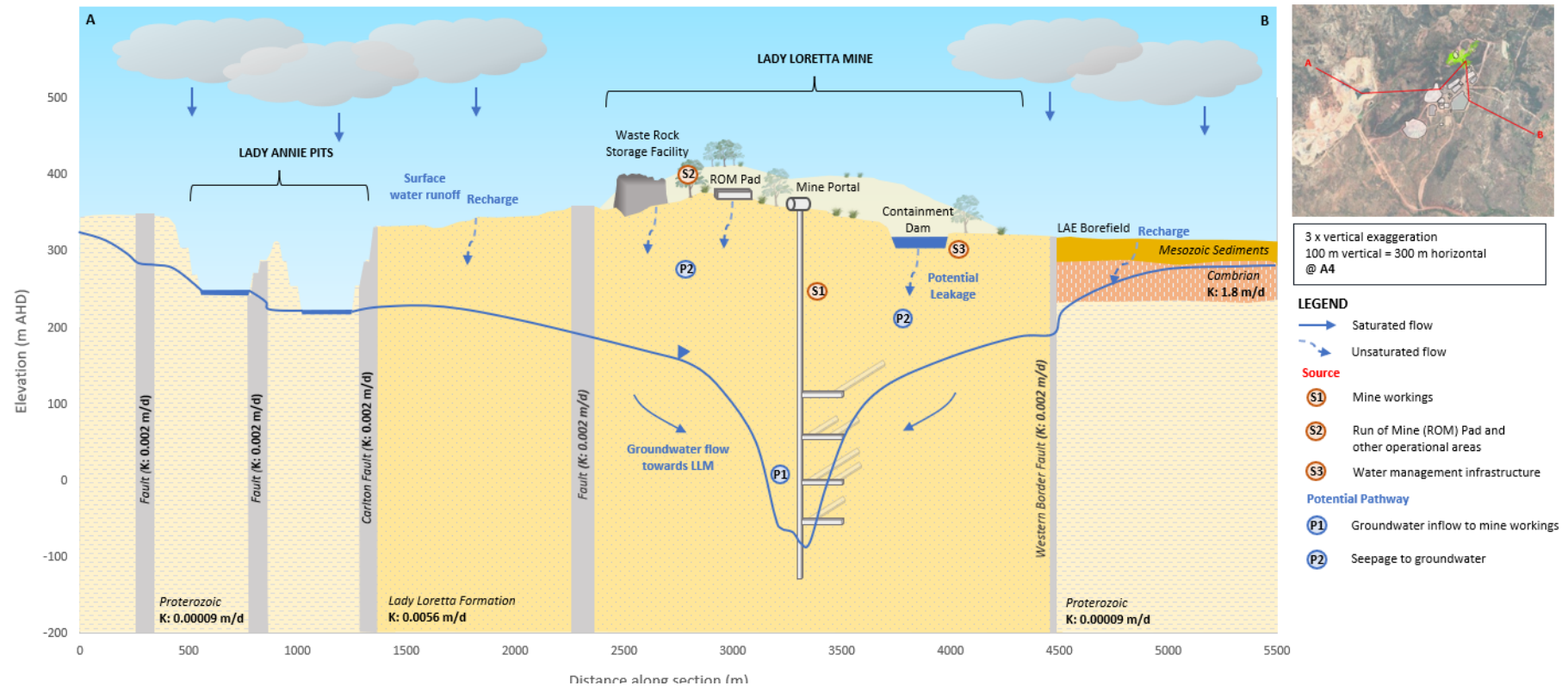


Figure 4-3 Conceptual Hydrogeological Model Schematic – Operating Mine

Section 5 Numerical Groundwater Modelling

Following the revision of the conceptual hydrogeological model this project involves the development of a numerical groundwater model for the prediction of groundwater system response to cessation of mining, and to assist in understanding the potential fate of CoCs during and after groundwater recovery. The overall objective of the numerical model is to assist in the development and implementation of an appropriate closure monitoring network and groundwater monitoring program.

This section focuses on groundwater flow modelling for assessing an after-closure scenario considering the updated conceptualisation for the site and surrounds. Section 7 describes the solute transport modelling that was undertaken to assess and map the potential fate of identified CoCs sourced from LLM operations.

The original LLM groundwater model (AGE, 2013; AGE, 2015) was used as a basis for representing the updated hydrogeological conceptualisation described in the earlier sections of this report. The updated LLM groundwater model is referred to as the LLM2021 model herein.

5.1 Model Objective

The objective of the LLM2021 groundwater flow model is to:

- Assess groundwater flow fields during mining operation, closure recovery and long-term new quasi-equilibrium.
- Estimate groundwater flux to the underground workings over time after the cessation of mining.

The potential transport and fate of CoCs during and after groundwater recovery is assessed using solute transport modelling (Section 7).

5.2 Model Construction

The LLM2021 groundwater model was upgraded from the original model (AGE, 2015) with the latest hydrogeological conceptualisations as reported in the earlier sections of this report. This section highlights the key changes that have been made to the model for this scope. In addition, a brief description of model settings that remain unchanged from the original model (AGE, 2015) is provided herein for completeness.

5.2.1 Numerical Code

The original groundwater model (AGE, 2015) was developed in MODFLOW-SURFACT (Panday and Huyakorn, 2008), a legacy numerical code that is gradually being phased out and replaced by MODFLOW-USG (Panday et al., 2013). MODFLOW-USG inherits most, if not all, capabilities from MODFLOW-SURFACT and is freely available and well maintained by the United States Geological Survey (USGS).

MODFLOW-USG was selected as the numerical code for the development of the LLM2021 groundwater flow model. Groundwater Vistas version 8 (ESI, 2020) and the Python module FloPy (Bakker et al., 2016) were used for the pre- and post-processing of model data.

5.2.2 Spatial Discretisation

The LLM2021 model domain (Figure 5-1) and grid (Figure 5-2) are consistent with the original model (AGE, 2015). The model domain was discretised into rectangular cells comprising 661 rows and 297 columns. There are 196,317 cells in each layer with the cell dimension varying from 10 x 10 m covering the LLM site and LAE borefield to 100 x 100 m outside the area of interest. The model grid was rotated from north 20 degrees to the east to align the cells parallel to the LAE borefield that is consistent with the principal groundwater flow direction.

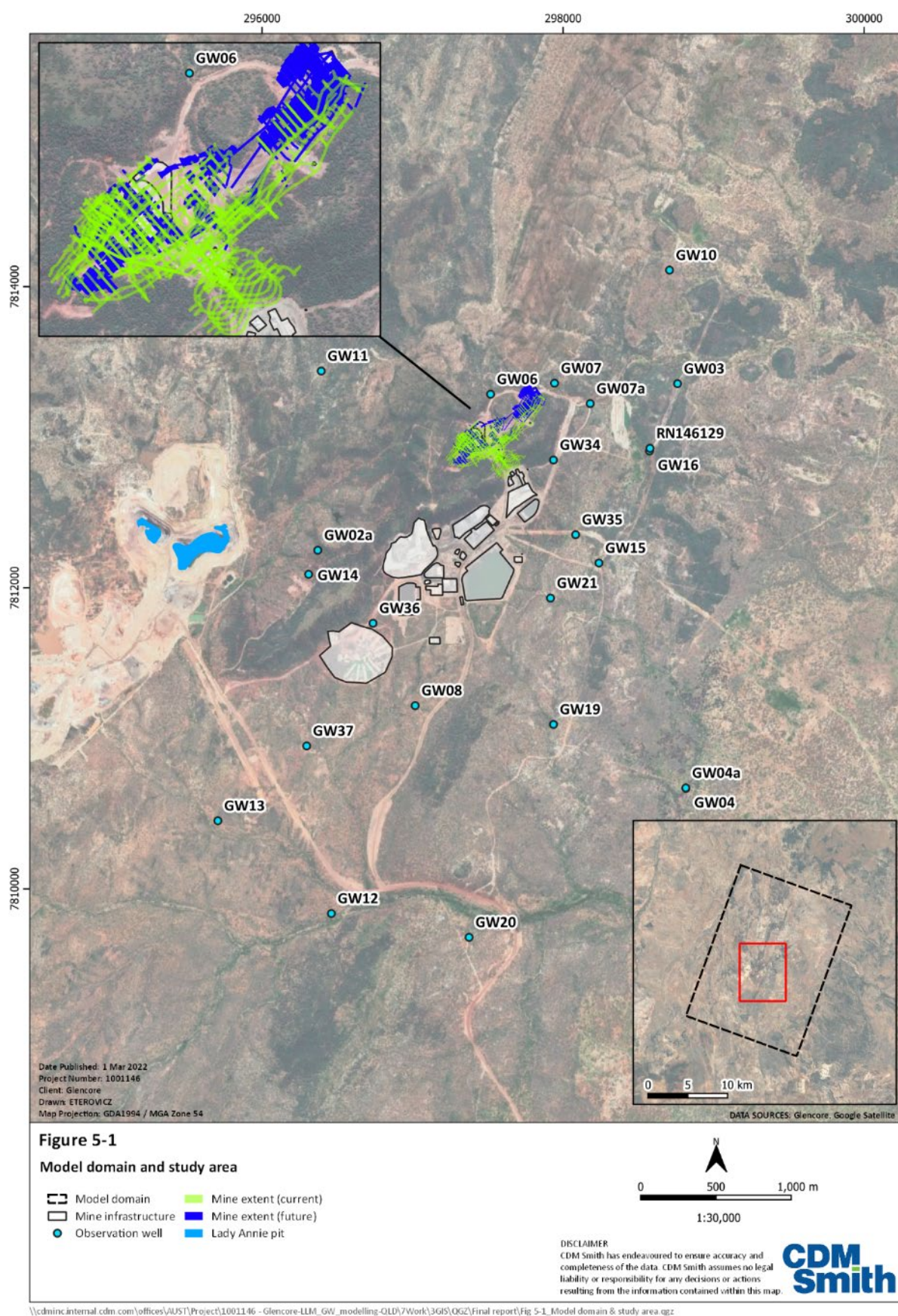


Figure 5-1 Model Domain and Study Area

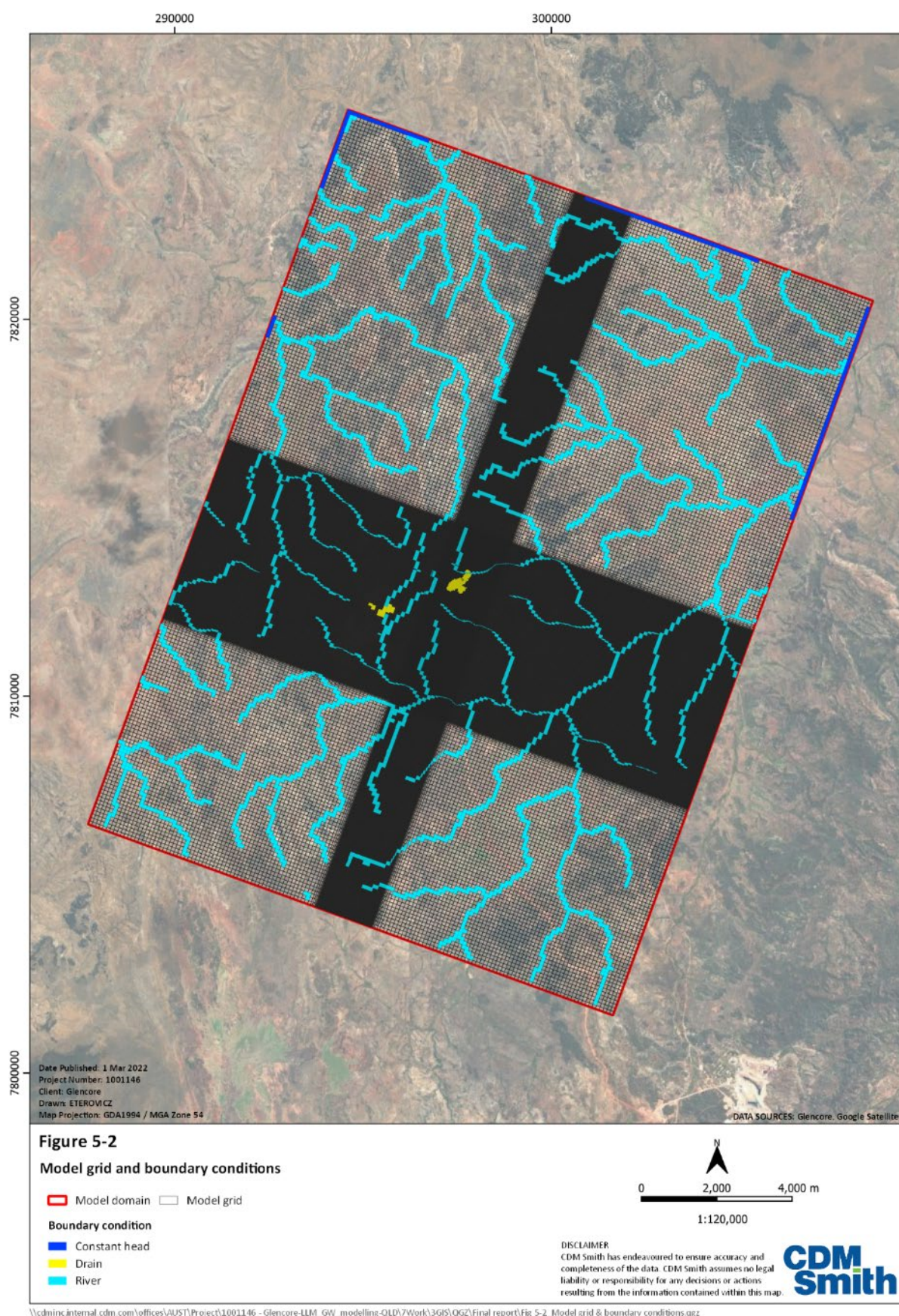


Figure 5-2 Model Grid and Boundary Conditions

The total model extent is approximately 20 km in the northeast and southwest direction and approximately 15 km wide in the northwest to southeast direction, covering an area of approximately 300 km².

5.2.3 Model Layers and Elevation Surfaces

The original groundwater model (AGE, 2015) has six layers with the bottom layer completely inactivated. As the numerical code does not compute groundwater level for inactive cells, this inactive layer was removed from the LLM2021 model to enhance the model agility (i.e. reduce model file size and hence processing time), resulting in a total of five model layers.

As part of this work, we attempted to use the existing geological Leapfrog model to set the elevation surfaces for the LLM2021 model. However, this was found to not be feasible due to missing data (i.e. the geological block to the northwest of Western Fault) and the very limited extent of the geological model. As such, the update of elevation surfaces was simplified as follows.

The top elevation surface (Figure 5-4) represents the land surface, and is consistent between the LLM2021 model and the original model (AGE, 2015). While not documented in AGE (2015), this elevation surface is believed to be sourced from the ELVIS database with a spatial resolution of 30 x 30 m. Following the original model (AGE, 2015), a constant thickness approach was adopted for the LLM2021 model due to the lack of data for finer parameterisation.

Figure 5-3 and Table 5-1 show the model layer setup with two key differences compared to the original model (AGE, 2015):

- The original model (AGE, 2015) contains a hydraulic parameter zone in the top layer to represent the Cambrian block to the west of Western Fault. However, our hydrogeological conceptualisation review shows that there is no Cambrian block to the west of Western Fault. Therefore, this zone was changed to represent the Lady Loretta Formation in the LLM2021 model and extended to all layers.
- Based on our hydrogeological conceptualisation review, the thickness of model layer 1 was increased from 50 m in the original model (AGE, 2015) to 80 m in the LLM2021 model. This is to account for the nominal thickness of 50 m for the Cambrian block and 30 m for the overlying surficial sediments. The thicknesses of other model layers were also adjusted as shown in Table 5-1.

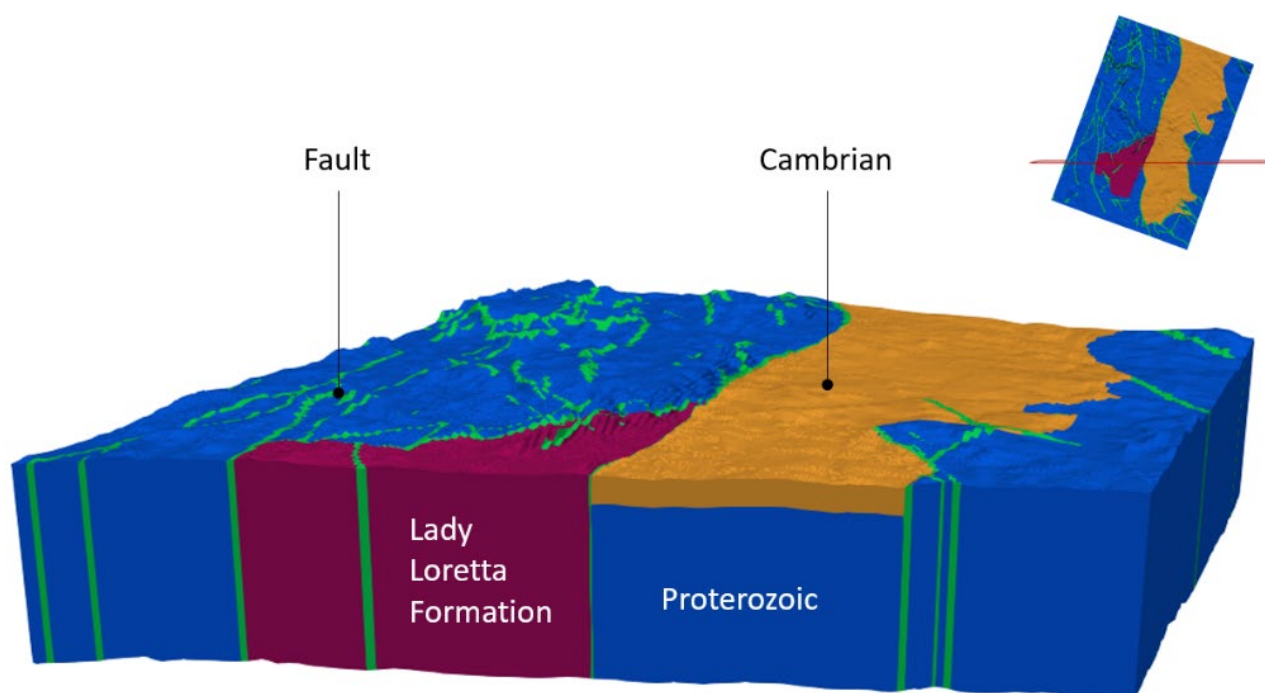


Figure 5-3 Model Cross-section

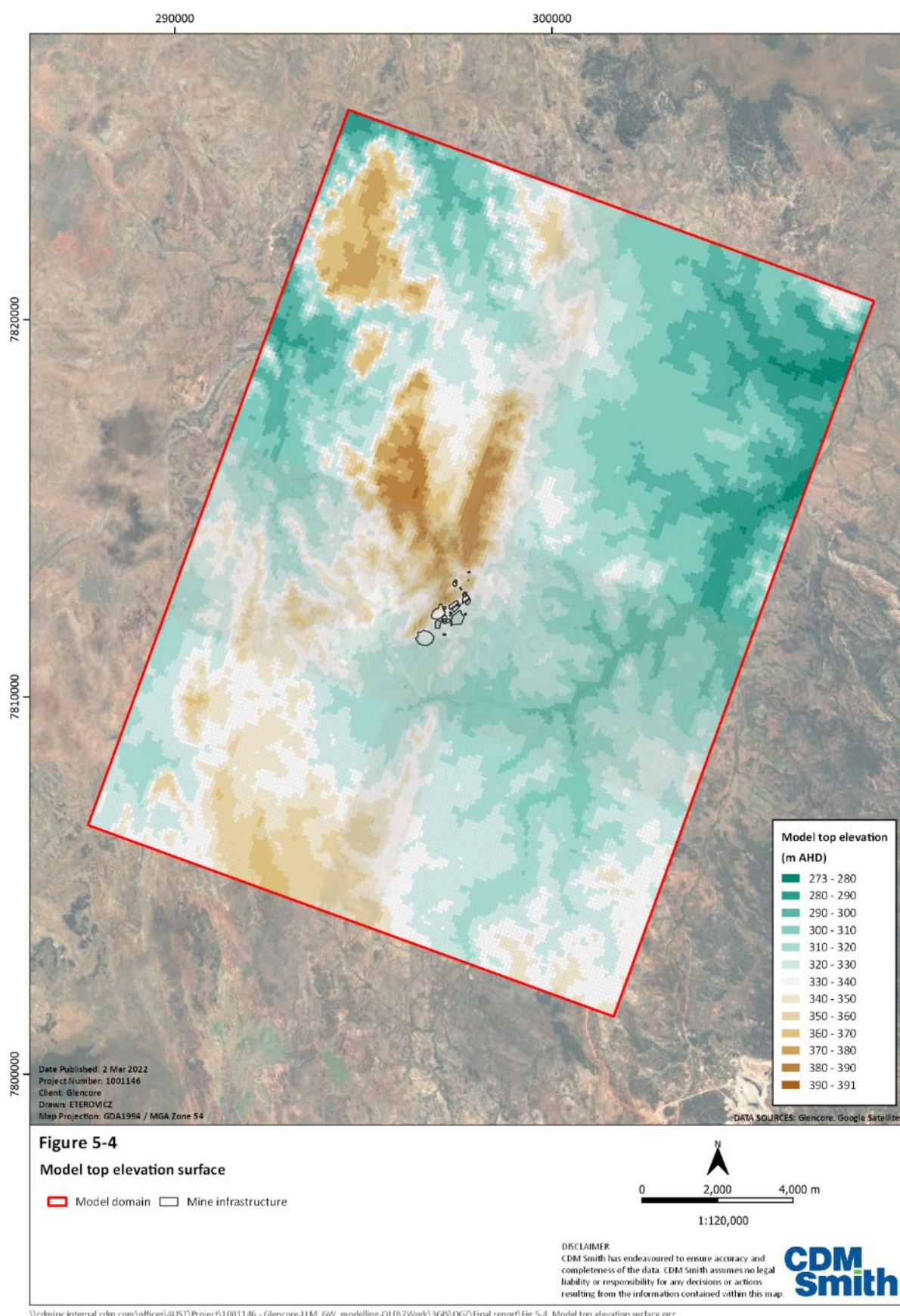


Figure 5-4 Model Top Elevation Surface

Table 5-1 Model Layer Setup

Model layer	Hydrostratigraphy	Thickness (m)
1	Lady Loretta Formation, Cambrian, Proterozoic and faults	80
2	Lady Loretta Formation, Proterozoic and faults	100
3		120
4		140
5		160

5.2.4 Boundary Conditions

Model boundary conditions represent the key physical processes of a given groundwater system. For the LLM2021 model, the key processes simulated include:

- Regional groundwater flows
- Surface drainage
- Rainfall recharge
- Groundwater evapotranspiration
- Mine dewatering
- Borefield production

5.2.4.1 Regional Groundwater Flows

Regional groundwater flows across the model domain edges are represented using the constant head boundary (Figure 5-2). The constant head value is spatially and temporally constant, and the value of 275 m AHD from the original model remains unchanged in the LLM2021 model (the selection of head value is not fully explained in AGE 2015). Assuming groundwater flow conforms to the topography (Figure 5-4), the constant head cells were assigned to the northeastern portion of the model domain in the top layer to represent regional groundwater outflows.

5.2.4.2 Surface Drainage

The ephemeral drainage features within the model domain mostly flow only in direct response to rainfall that produces runoff. This process is simulated in the LLM2021 model using the MODFLOW RIV Package (Figure 5-2). Consistent with the original model (AGE, 2015), the river stage and bottom elevation were both set to the DEM values, such that the river cells only act as a groundwater draining feature and do not produce any recharge to the groundwater system.

Riverbed conductance controls the magnitude of groundwater discharge through the river cells. Different from the original model, the riverbed conductance for the LLM2021 model was estimated through model calibration (but was found to be insensitive after the calibration). The riverbed conductance is spatially and temporally constant.

5.2.4.3 Rainfall Recharge

A portion of rainfall percolates through the soil and eventually reach the water table, becoming groundwater recharge. This process is simulated in the LLM2021 model using the MODFLOW RCH Package. There are two parts to the recharge setup, including rainfall rate and rainfall-to-recharge ratio.

The rainfall rate is based on the Camooweal Township weather station (37010; Figure 2-1 and Figure 2-2) and was set to be time-varying but spatially uniform in the LLM2021 model. The rainfall-to-recharge ratio represents the portion of rainfall that becomes recharge and was estimated through model calibration. The ratios were initially zoned based on surface geology (Figure 5-5), with further spatial heterogeneity added through the use of pilot point calibration.

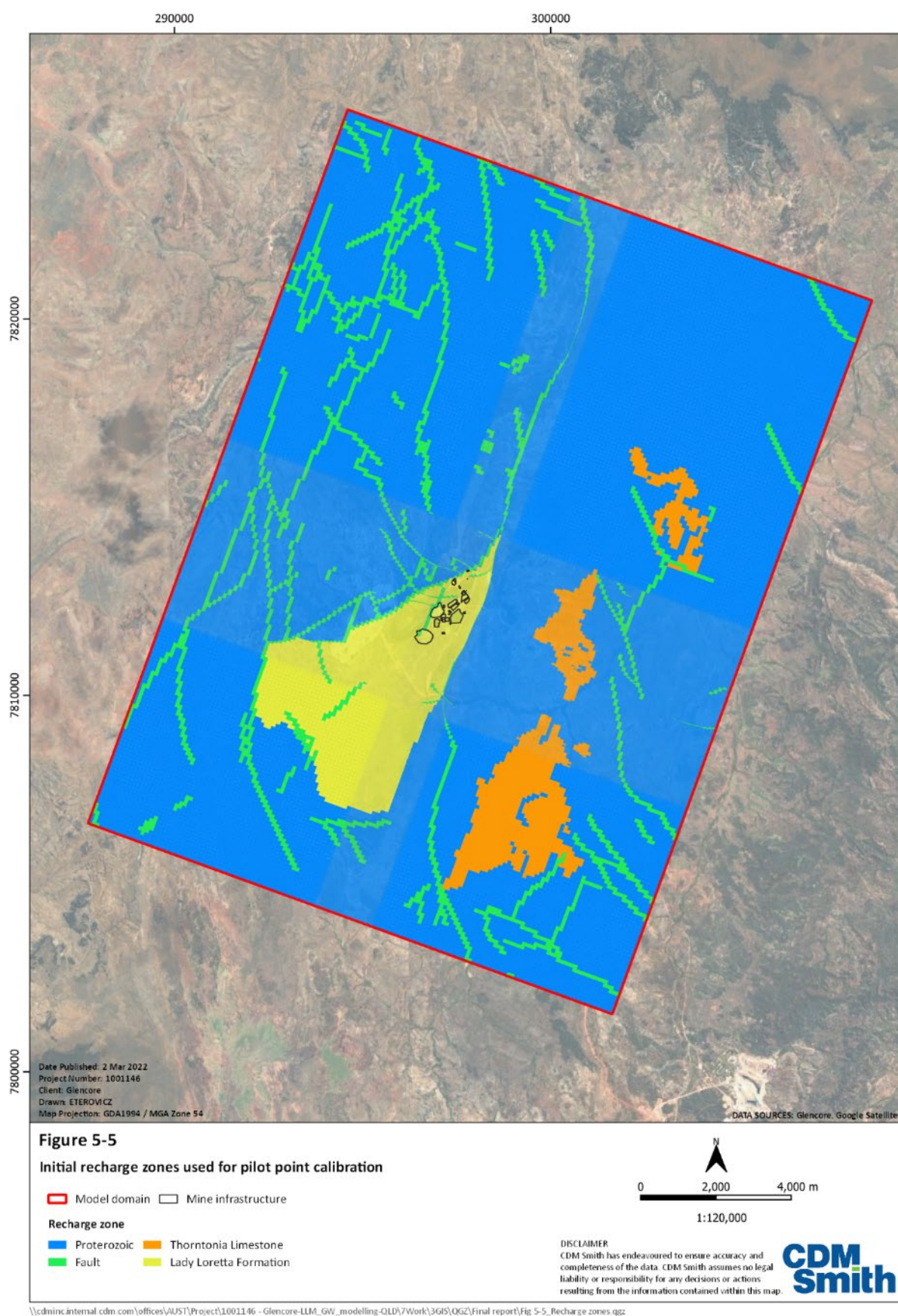


Figure 5-5 Initial Recharge Zones Used for Pilot Point Calibration

5.2.4.4 Groundwater Evapotranspiration

Shallow groundwater can be lost to the atmosphere through evapotranspiration (ET), either via plants whose roots access the capillary fringe or shallow water tables. This process is represented in the LLM2021 model using the MODFLOW EVT Package. This package takes two inputs, including potential ET rate and extinction depth.

The potential ET rate refers to the groundwater ET rate that would occur if the water table was at the land surface. In the LLM2021 model, the potential ET rate is based on the Camooweal Township weather station (37010; Figure 2-1) from the SILO database. Pan evaporation is considered too high to be used as the potential ET rate as it assumes unlimited water availability. Instead, the potential ET rate is based on the FAO56 estimates (Allen et al., 1998), which is the reference ET rate that takes temperature, relative humidity, wind speed and solar radiation into account. The potential ET rate for the LLM2021 model is time-varying but spatially uniform.

Extinction depth defines the depth threshold below which no groundwater ET occurs. The extinction depth for the LLM2021 model was set to the conventional value of 2 m and remains spatially and temporally constant. Within the model domain, most groundwater ET is expected to occur in low-lying areas (Figure 5-4) where the water table is generally shallower.

5.2.4.5 Mine Dewatering

Mining at the LLM commenced in 2012 and the current campaign of mining operations is scheduled for completion in 2025, with dewatering continued (in parallel with the Resource Development program to review potential to extend the Ore Reserve) until the end of 2032. Mine dewatering (i.e. abstractions of water from within the mine) is represented in the LLM2021 model using the MODFLOW DRN Package (Figure 5-2). The spatial extent and elevations of the historical and future mine plan (activated after Q1 2022) were provided by Glencore. However, due to the lack of timing information

(i.e. how the mine extent and elevations change over time), the historical and future mine extent and elevations are assumed to be constant throughout their corresponding simulation periods. This approach has the potential to introduce bias into the calibration but is considered a compromise that needs to be made given the data availability. This approach ensures the impact of mining is not underestimated and is therefore considered a conservative assumption.

The elevation data for mine levels are spatially variable and can be as low as -145 m AHD. These elevation values were used to set the drain stage and assign model layer for each drain cell. The magnitude of groundwater discharge to the mine is controlled by the drain conductance, which was set to be spatially and temporally constant, and estimated through model calibration.

Mine dewatering is scheduled to discontinue from 2033 onwards. The mine will be backfilled at the end of the Commercial Proposition period with material from surface. The backfilling activity as per the closure plan is defined as backfilling the upper section of the mine decline and upper section of the ventilation shafts only. Given the other sources of uncertainty (e.g. structural and parameter uncertainty), detailed simulation of backfilling is not considered to be warranted at this time, and is unlikely to add much value to the modelling outcomes. This process is represented in the LLM2021 model by deactivating the drain cells. It is acknowledged that backfilling is not an instantaneous process and its representation in the model is simplified.

The neighbouring Lady Annie pit is simulated in a similar manner using drain cells (Figure 5-2). The spatial extent and pit bottom elevations were provided by Glencore, with a nominal elevation of 241.4 m AHD for the western pit and 214 m AHD for the eastern pit. These elevations and the drain conductance were set to be spatially and temporally constant. The drain conductance for the Lady Annie pit was estimated through model calibration separately from the LLM drain conductance. Given its relatively early commencement in 2007, the Lady Annie pit is assumed to be active throughout the simulation period.

5.2.4.6 LAE Borefield Production

Groundwater discharge through LAE borefield production is represented in the LLM2021 model using the MODFLOW WEL Package. The spatial location (Figure 5-2) and time-series pumping rates of the three production wells GW15, GW17 and GW18 were provided by Glencore.

Using the capability of MODFLOW-USG, the LLM2021 model was instructed to automatically reduce pumping rates to prevent the hosting cells from becoming dry. For numerical modelling purposes the LAE borefield production is scheduled to cease operation by December 2025 in alignment with the proposed mine closure schedule.

5.2.5 Hydraulic Properties

Model parameters that control the hydraulic properties of the LLM2021 model include hydraulic conductivity, specific storage and specific yield. Hydraulic conductivity describes how easily water can pass through a given porous medium, while the specific storage and specific yield relate to the amount of water that can be released from or stored in the porous medium in response to changes in hydraulic head under confined and unconfined conditions, respectively.

Aquifer test and literature values reported in Section 3.3 were used as the basis to set the lower and upper bounds for the hydraulic properties of the LLM2021 model. The hydraulic properties were then refined through model calibration where the parameters were adjusted within their lower and upper bounds until a good fit to the field observations is achieved. The hydraulic parameters were initially zoned (Figure 5-6), with further spatial heterogeneity added through the use of pilot point calibration (see Section 5.3.1).

5.2.6 Temporal Discretisation

Time discretisation defines the simulation period and the temporal resolution of the model. A stress period is defined as a period of time where stresses (e.g. pumping) on a given groundwater system remain constant. The stress period setup for the LLM2021 model is provided in Table 5-2.

Table 5-2 Model Stress Period Setup

Stress period	Start date	Stop date	Period length	Description
1	-	31/12/2011	-	A steady-state period to represent the long-term average conditions without any mining activities. This period provides the initial conditions for the subsequent transient periods.
2 - 42	1/01/2012	31/03/2022	Quarterly (90 - 92 days)	These transient periods represent the historical calibration period. Mining activities commenced in Sep 2012.
43 - 78	1/04/2022	31/12/2250	Gradually increases from quarterly to 20-yearly	These transient periods represent the future prediction period. Future mine plan is assumed to commence in Apr 2022 and cease to operate by the end of Dec 2025. Mine dewatering is scheduled to cease operation from 2033 onwards and the mine will be backfilled, with backfilling defined as backfilling the upper section of the mine decline and upper section of the ventilation shafts only. This period is extended to approximately 230 years into the future to assess any long-term impact of mining.

The model starts with a steady-state period to represent the long-term average conditions without any LLM mining activities, with the aim to provide the initial conditions for the subsequent transient periods. The transient periods are quarterly for the historical calibration period and gradually increase to 20-yearly for the future prediction period. Historical mining commenced in September 2012 while the future mine plan is assumed to commence in April 2022 and cease to operate by the end of December 2025. Mine dewatering is scheduled to cease operation from 2033 onwards and the mine will be backfilled, with backfilling defined as backfilling the upper section of the mine decline and upper section of the ventilation shafts only. The future period is extended hundreds of years into the future to

Section 5 Numerical Groundwater Modelling

assess any long-term impact associated with water level recovery within the backfilled mine voids and surrounding groundwater system.

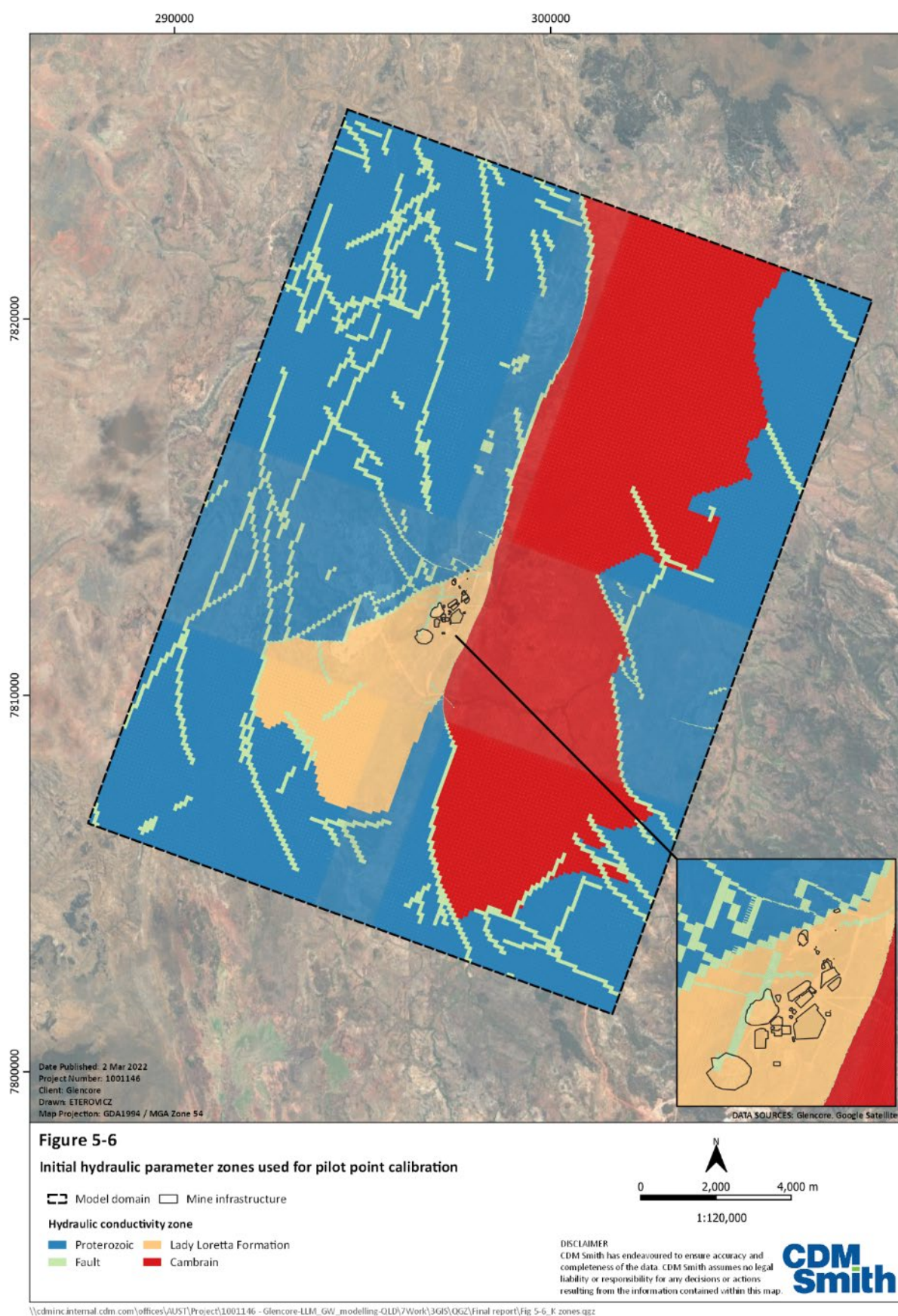


Figure 5-6 Initial Hydraulic Property Zones Used for Pilot Point Calibration

5.3 Model Calibration and Sensitivity Analysis

Model calibration is a process of tuning model parameters to fit field observations. This process, however, is non-unique in that there can be numerous combinations of parameters that fit the field observations similarly well. Traditional groundwater modelling generally employs a deterministic approach where a single calibrated model is developed to make predictions. However, due to non-uniqueness, a model that can fit the field observations does not necessarily mean the model represents the 'truth'. Instead, that model just represents one of numerous realisations that can fit the field observations (a realisation represents a possible combination of model parameters).

It is a better approach to capture as many model realisations as possible that can fit the field observations. However, this generally requires a stochastic approach where multiple models are developed, calibrated and used to make predictions, which can be extremely time consuming and hence not as commonly applied as the deterministic approach. This limitation has been overcome by the recently developed modelling technique PESTPP-IES (White, 2018) that can run numerical groundwater models stochastically in a highly efficient manner. In this study, 100 model realisations were developed and calibrated, enabling probabilistic predictions and a more robust uncertainty analysis.

5.3.1 Calibration Approach

The LLM2021 model was calibrated to 23 observation wells (Figure 5-1) with their water level measurements averaged to the quarterly stress periods, resulting in a total of 226 water level targets. In addition, as it is generally good modelling practice to include multiple types of calibration targets, a flux target was included for the recorded groundwater ingress to the underground workings of 8 L/sec (approximately 700 m³/d) during the care and maintenance period (Section 3.7.2.1).

The model parameters that were calibrated include horizontal hydraulic conductivity, vertical anisotropy of hydraulic conductivity (i.e. K_h / K_v), specific storage, specific yield, rainfall-to-recharge ratio, drain conductance (separately for the LLM and Lady Annie pit) and riverbed conductance (see Table 5-3). The boundary conductance terms are assumed to be spatially and temporally constant, while the hydraulic parameters were calibrated using the pilot point technique (Doherty et al., 2010) where parameter values are estimated at the pilot point locations and then interpolated to all model cells. This study used a highly parameterised approach with a total of 9,140 pilot points set up and calibrated.

PESTPP-IES (White, 2018) excels at calibrating highly parameterised models as its computational time is independent of the number of parameters to calibrate. Instead, its run time depends on the number of calibrated model realisations to be generated, which was set to 100 model realisations in this study given the model complexity. These 100 model realisations were initially developed in a random manner within the bounds provided in Table 5-3, calibrated to the field observations simultaneously, and then used together for the prediction forecasts. This approach provides insights into the different possible parameter combinations that are supported by the field observations and the resulting predictions.

Table 5-3 summarises the settings of model parameters used for the calibration, where the initial values are based on either site knowledge or the geometric mean of the upper and lower bounds. For each parameter, the initial value was used to determine the centre of a log-normal distribution that was used to draw random values for the realisations. The spread of the distribution is controlled by standard deviation and it is assumed that ± 2 standard deviations cover 95% of values.

Section 5 Numerical Groundwater Modelling

Table 5-3 Settings of Initial Hydraulic Parameters for Calibration

Parameter	Description	Initial value	Lower bound	Upper bound
Hydraulic conductivity (m/d)	Lady Loretta Formation	1×10^{-2}	1×10^{-4}	1×10^0
	Cambrian	5×10^0	1×10^0	5×10^1
	Proterozoic	1×10^{-4}	1×10^{-6}	1×10^{-2}
	Fault	1×10^{-3}	1×10^{-4}	1×10^{-1}
Vertical anisotropy (K_h / K_v)	Lady Loretta Formation	1×10^0	1×10^0	1×10^2
	Cambrian	1×10^0	1×10^0	1×10^2
	Proterozoic	1×10^0	1×10^0	1×10^2
	Fault	1×10^0	1×10^0	1×10^2
Specific storage (m^{-1})	Lady Loretta Formation	3×10^{-6}	1×10^{-6}	1×10^{-5}
	Cambrian	3×10^{-6}	1×10^{-6}	1×10^{-5}
	Proterozoic	3×10^{-6}	1×10^{-6}	1×10^{-5}
	Fault	1×10^{-5}	1×10^{-6}	1×10^{-4}
Specific yield (-)	Lady Loretta Formation	3×10^{-3}	1×10^{-3}	1×10^{-2}
	Cambrian	3×10^{-3}	1×10^{-3}	1×10^{-2}
	Proterozoic	3×10^{-3}	1×10^{-3}	1×10^{-2}
	Fault	3×10^{-3}	1×10^{-3}	1×10^{-2}
Rainfall-to-recharge ratio (%)	Lady Loretta Formation	1×10^{-2}	1×10^{-4}	5×10^{-2}
	Cambrian	1×10^{-2}	1×10^{-4}	5×10^{-2}
	Proterozoic	1×10^{-2}	1×10^{-4}	5×10^{-2}
	Fault	1×10^{-2}	1×10^{-4}	5×10^{-2}
Drain conductance (m^2/d)	LLM	1×10^2	1×10^1	1×10^3
	Lady Annie pit	1×10^2	1×10^1	1×10^3
Riverbed conductance (m^2/d)	Surface creeks	1×10^0	1×10^{-1}	1×10^1

5.3.2 Calibration Performance

5.3.2.1 Calibration Statistics

A scatter plot comparing the observed and simulated groundwater levels is shown in Figure 5-7. The black data points represent the mean while the blue error bars represent the range of simulated groundwater levels from the 100 calibrated model realisations. The blue error bars indicate the uncertainty associated with the simulated groundwater levels, which varies between observations. The diagonal 1:1 reference line represents the ideal situation where the simulated groundwater levels fit the observations perfectly. Data points that are closer to the 1:1 reference line indicate a better calibration performance, and vice versa.

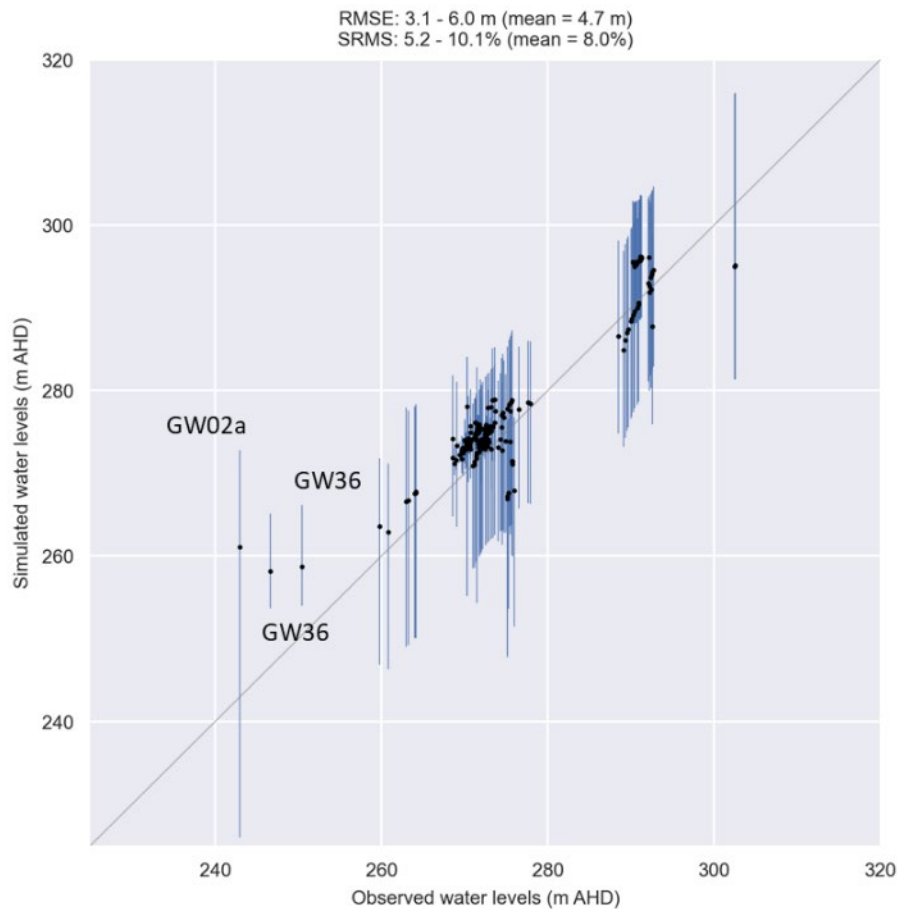


Figure 5-7 Comparison of Observed and Simulated Water Levels

Figure 5-7 shows an overall satisfactory calibration performance where the cloud of data points centre around the 1:1 reference line, indicating little systematic bias towards overestimation or underestimation. The 100 calibrated realisations show a root mean squared error (RMSE) of 3.1 – 6.0 m (mean: 4.7 m) and a scaled root mean squared (SRMS) error of 5.2% - 10.1% (mean: 8.0%), suggesting all the 100 calibrated realisations have achieved a reasonable fit to the observations.

The results show a considerable discrepancy for GW02a with a large uncertainty. This well was recently drilled in 2021 and its water level continued to increase from 208.5 to 242.9 m AHD between Jan and Jul 2021, suggesting a slow recovery that is not intended for the model to replicate. Two water level measurements from GW36 also show a notable discrepancy, where none of the 100 realisations can fit the observed values (i.e. the blue error bars do not intersect with the 1:1 reference line). Review of daily drilling reports and field notes reveals that there were development issues with this well, which have the potential to influence the water level measurements.

5.3.2.2 Calibrated Groundwater Flux to Mine

Figure 5-8 shows the probability distribution of simulated groundwater flux to the mine during the care and maintenance period from the 100 calibrated model realisations. The probability distribution resembles a normal distribution with the peak (i.e. the most likely value) at the flux target of 700 kL/d, suggesting an acceptable calibration performance. The probability distribution also provides insights into the uncertainty associated with the flux estimate, where more than 95% of the realisations lie between 600 and 800 kL/d. The RMSE is relatively small and ranges between 0.8 and 135.8 kL/d with a mean of 33.8 kL/d. It should be acknowledged that the mine is represented in a simplified manner in the model (Section 5.2.4.5), and therefore there is uncertainty associated with the mine flux calibration from a conceptual point of view.

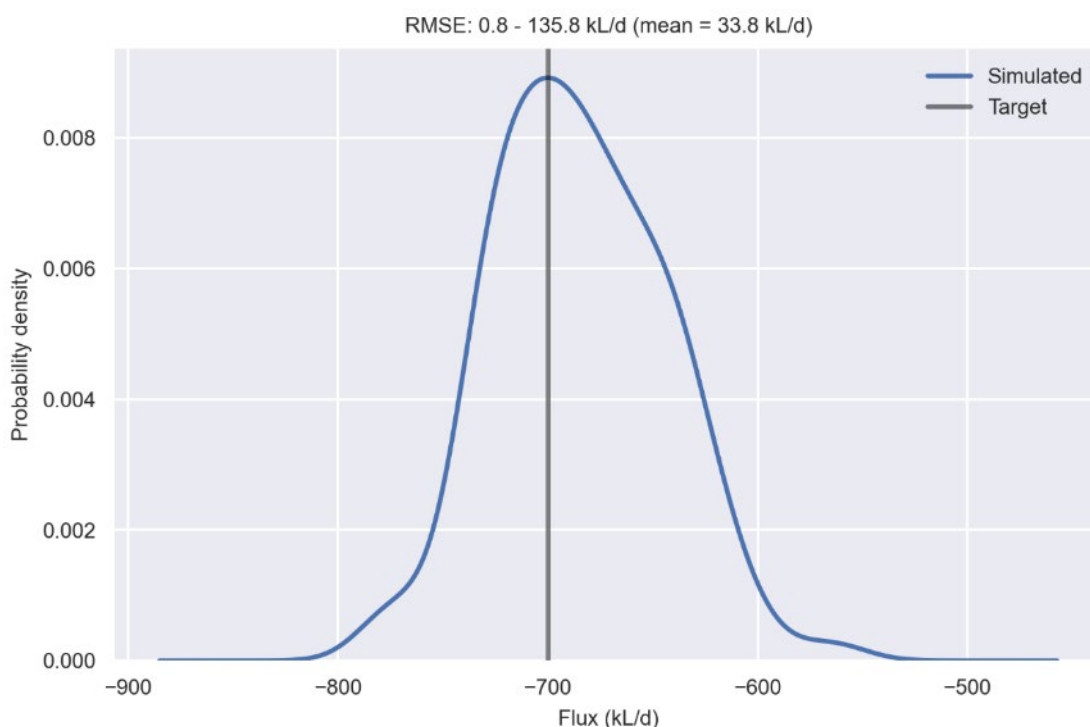


Figure 5-8 Probability Distribution of Simulated Flux to the Mine During the Care and Maintenance Period

5.3.2.3 Calibrated Hydrographs

A subset of observed hydrographs is compared with the modelled water levels in Figure 5-9 and Figure 5-10. These hydrographs were selected based on their length of historical records and spatial location. The full set of hydrographs are provided in Appendix B. In general, Figure 5-9 and Figure 5-10 show a reasonable match between the observed and simulated water levels. Some discrepancies can be attributed to the fact that the historical mine extent and elevations are assumed to be constant throughout the calibration period due to the lack of data for finer parameterisation.

Some observation wells such as GW03 shows a small variation in the modelled water levels across the 100 realisations (i.e. smaller uncertainty), while some observation wells such as GW07, GW12 and GW13 show a large variation in the modelled water levels (i.e. larger uncertainty). This information provides insights into how much confidence we can have on model results in different areas.

5.3.3 Calibrated Parameters

Table 5-4 shows a high-level view of the calibrated parameter statistics based on the geometric mean across the 100 model realisations. The spatial distributions of the calibrated parameters are shown in Figure 5-11 to Figure 5-15.

One key knowledge gap is the hydraulic properties of the faults. Following AGE (2015), the faults were implemented into the model as semi-vertical features, where the spatial distribution of faults is assumed to be the same across the model layers. The faults are represented in the model as a separate hydraulic parameter zone, the values of which were determined through model calibration in a stochastic manner. Through PESTPP-IES, the conceptualisation of faults was initially randomised. For a given fault, some realisations conceptualised the fault as a barrier to groundwater flow (i.e. low K) while some other realisations conceptualised the fault as a conduit (i.e. high K). After fitting to the field observations, these realisations converged to the conclusion that the faults are generally more permeable than the Proterozoic and less permeable than the Cambrian, and the fault permeability is generally in the same order of magnitude as the Lady Loretta Formation permeability. The faults do not act as impermeable barriers, and likely have low permeability.

Section 5 Numerical Groundwater Modelling

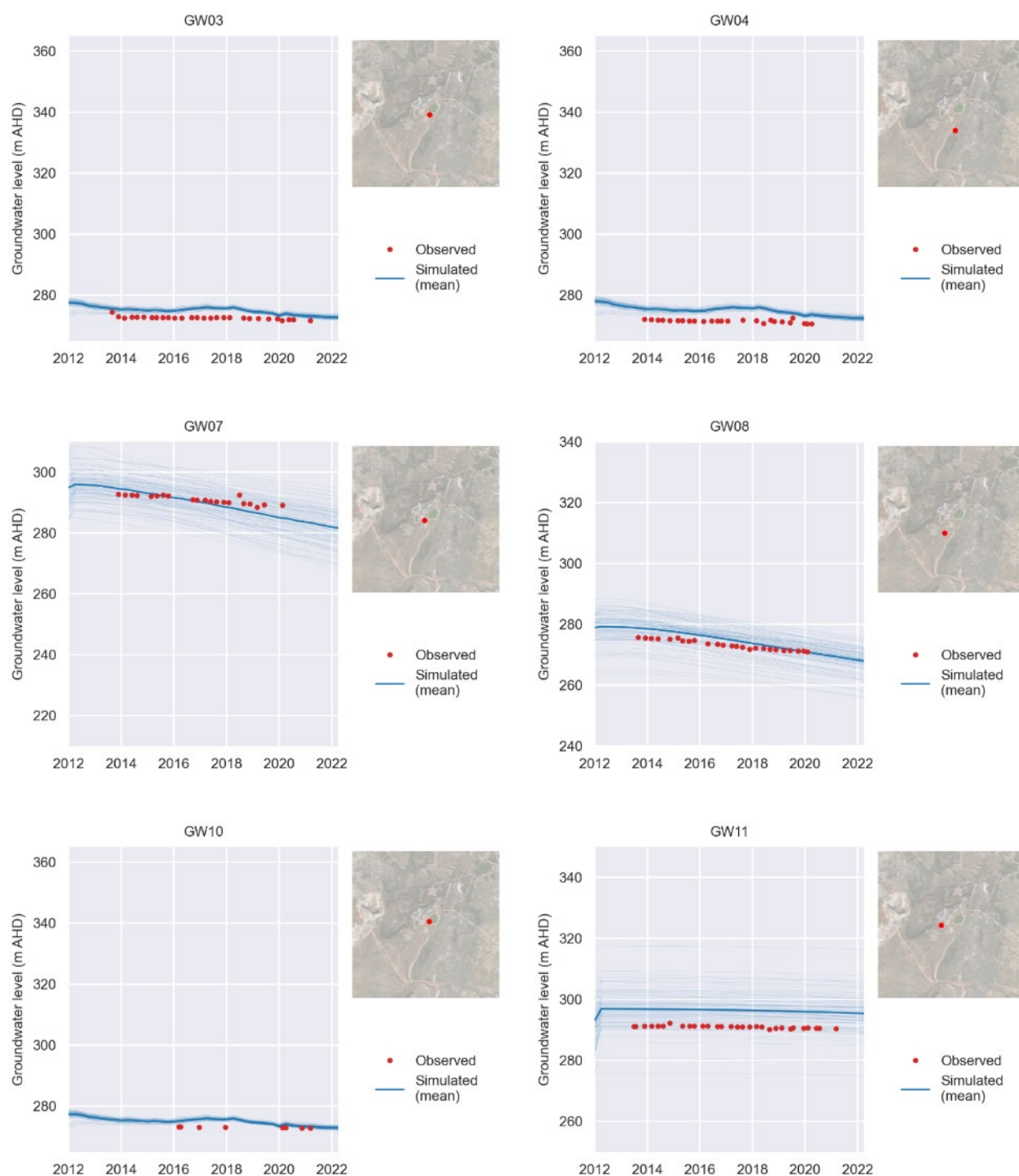


Figure 5-9 Hydrograph Comparisons (Set 1)

Section 5 Numerical Groundwater Modelling

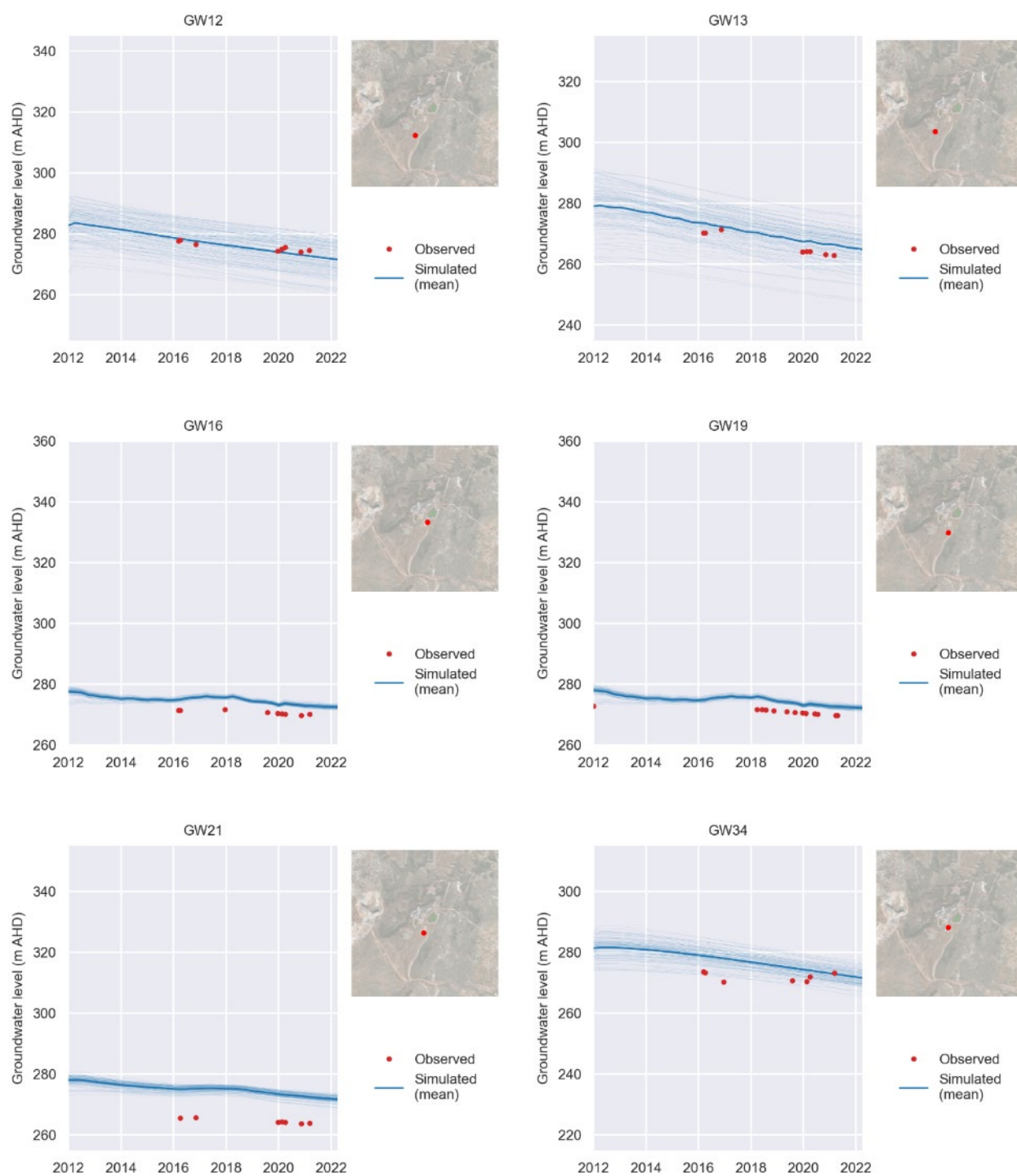


Figure 5-10 Hydrograph Comparisons (Set 2)

Section 5 Numerical Groundwater Modelling

Table 5-4 Calibrated Parameter Statistics Based on the Geometric Mean of Each Realisation

Parameter	Description	Geometric mean	Minimum	Maximum	Uncertainty (expressed as std)
Hydraulic conductivity (m/d)	Lady Loretta Formation	5.6×10^{-3}	1.5×10^{-3}	1.4×10^{-2}	2.1×10^{-1}
	Cambrian	1.8×10^1	1.1×10^1	2.7×10^1	7.4×10^{-2}
	Proterozoic	8.7×10^{-5}	3.7×10^{-5}	1.7×10^{-4}	1.3×10^{-1}
	Fault	2.0×10^{-3}	8.6×10^{-4}	4.0×10^{-3}	1.4×10^{-1}
Vertical anisotropy (K_h / K_v)	Lady Loretta Formation	7.8×10^0	3.0×10^0	1.4×10^1	1.5×10^{-1}
	Cambrian	2.0×10^0	1.3×10^0	3.2×10^0	8.4×10^{-2}
	Proterozoic	2.1×10^0	1.3×10^0	3.1×10^0	6.9×10^{-2}
	Fault	2.6×10^0	1.5×10^0	5.4×10^0	1.0×10^{-1}
Specific storage (m^{-1})	Lady Loretta Formation	2.0×10^{-3}	3.8×10^{-4}	6.7×10^{-3}	2.3×10^{-1}
	Cambrian	3.2×10^{-3}	1.1×10^{-3}	7.1×10^{-3}	1.3×10^{-1}
	Proterozoic	5.9×10^{-3}	2.8×10^{-3}	1.1×10^{-2}	1.2×10^{-1}
	Fault	3.3×10^{-3}	1.1×10^{-3}	6.1×10^{-3}	1.7×10^{-1}
Specific yield (-)	Lady Loretta Formation	3.8×10^{-6}	2.1×10^{-6}	6.9×10^{-6}	1.3×10^{-1}
	Cambrian	3.3×10^{-6}	2.0×10^{-6}	4.9×10^{-6}	7.1×10^{-2}
	Proterozoic	3.3×10^{-6}	2.7×10^{-6}	4.1×10^{-6}	3.8×10^{-2}
	Fault	5.8×10^{-6}	3.2×10^{-6}	9.6×10^{-6}	1.2×10^{-1}
Rainfall-to-recharge ratio (%)	Lady Loretta Formation	2.6×10^{-1}	1.7×10^{-1}	3.4×10^{-1}	7.9×10^{-2}
	Cambrian	3.4×10^{-1}	2.3×10^{-1}	5.3×10^{-1}	8.2×10^{-2}
	Proterozoic	2.6×10^{-1}	1.9×10^{-1}	3.7×10^{-1}	5.5×10^{-2}
	Fault	4.0×10^{-1}	3.1×10^{-1}	5.3×10^{-1}	5.4×10^{-2}
Drain conductance (m^2/d)	LLM	2.2×10^2	5.3×10^1	8.6×10^2	3.1×10^{-1}
	Lady Annie pit	2.7×10^2	2.6×10^1	9.6×10^2	3.1×10^{-1}
River conductance (m^2/d)	Surface creeks	4.0×10^{-1}	1.0×10^{-1}	2.1×10^0	3.1×10^{-1}

Uncertainty is expressed as the standard deviation of the log-transformed parameters, where a larger value suggests a larger spatial heterogeneity and hence the geometric mean in Table 5-4 being less representative. For instance, assuming the log-transformed parameters are normally distributed, a standard deviation of 0.25 means 95% of values are within an order of magnitude of the geometric mean.

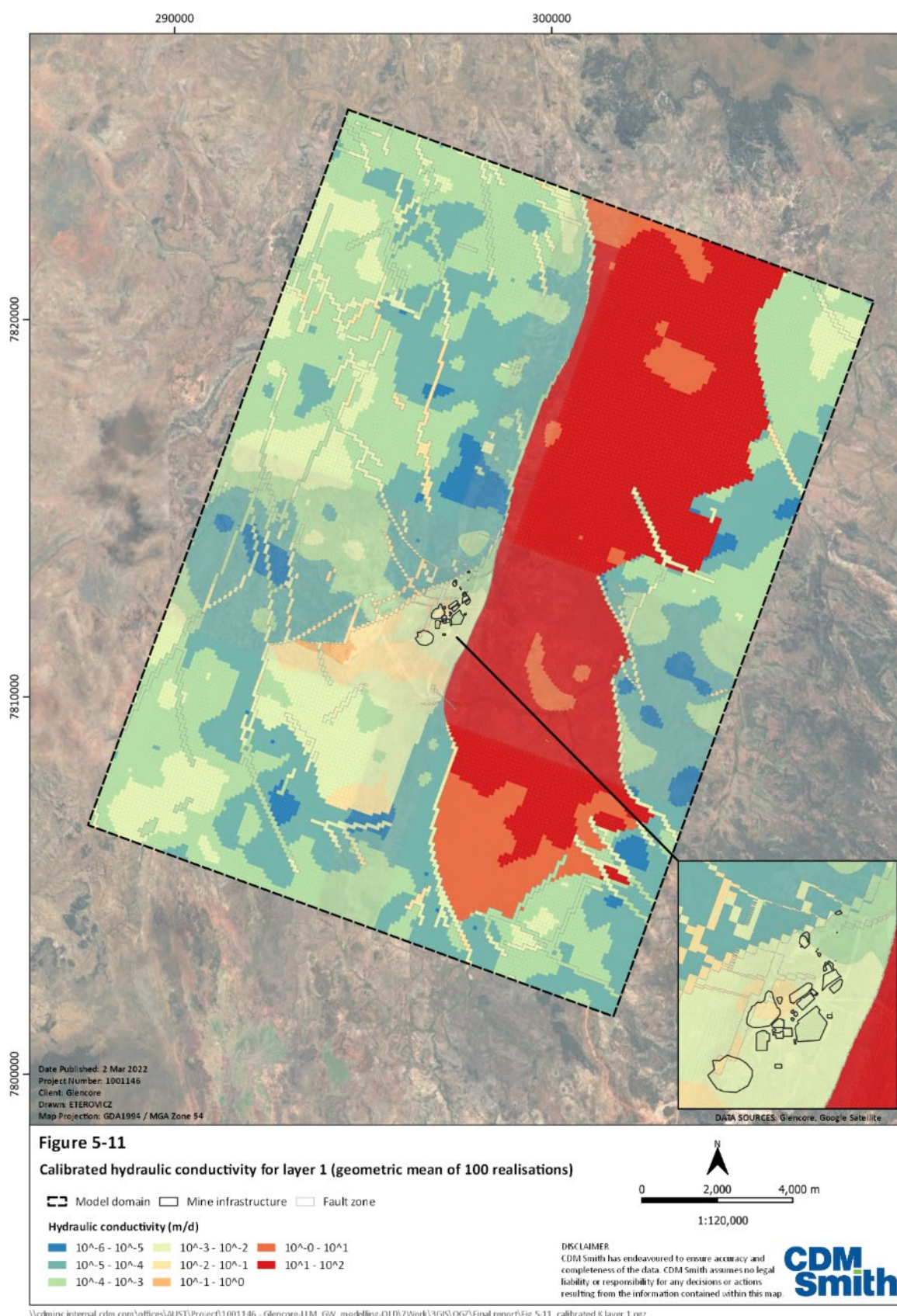


Figure 5-11 Calibrated Hydraulic Conductivity for Layer 1 (Geometric mean of 100 realisations)

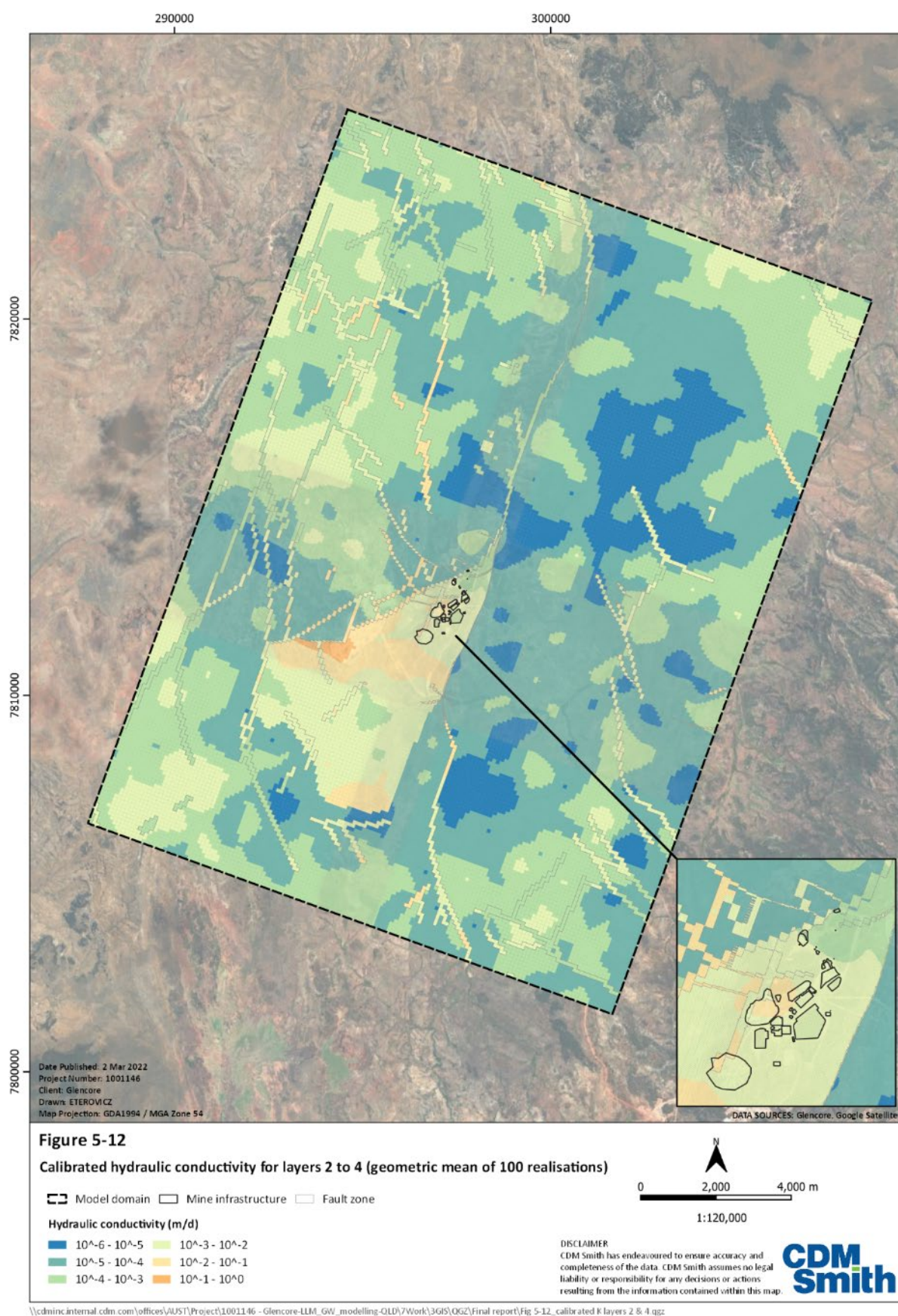


Figure 5-12 Calibrated Hydraulic Conductivity for Layers 2 to 4 (Geometric mean of 100 realisations)

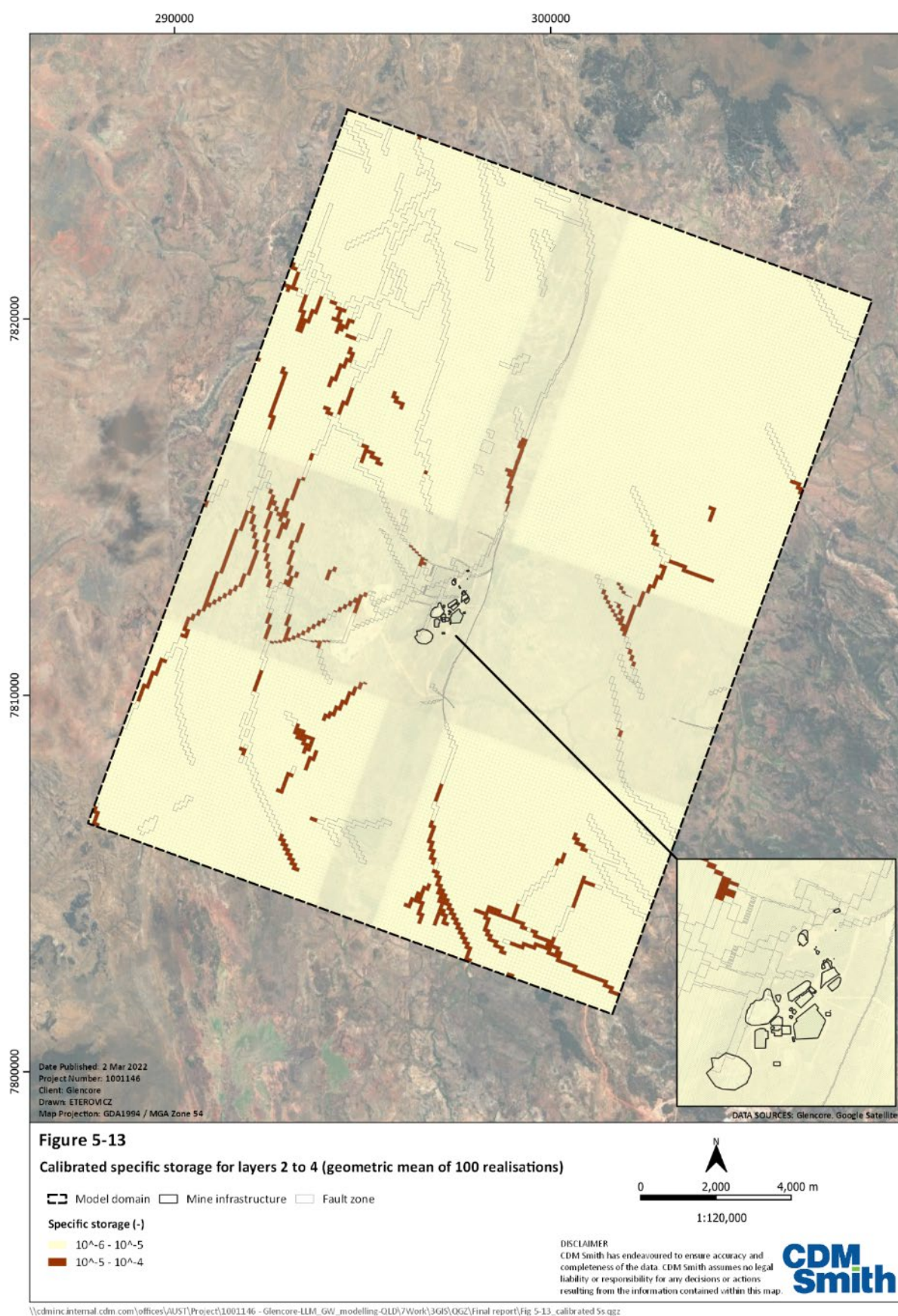


Figure 5-13 Calibrated Specific Storage for Layers 2 to 4 (Geometric mean of 100 realisations)

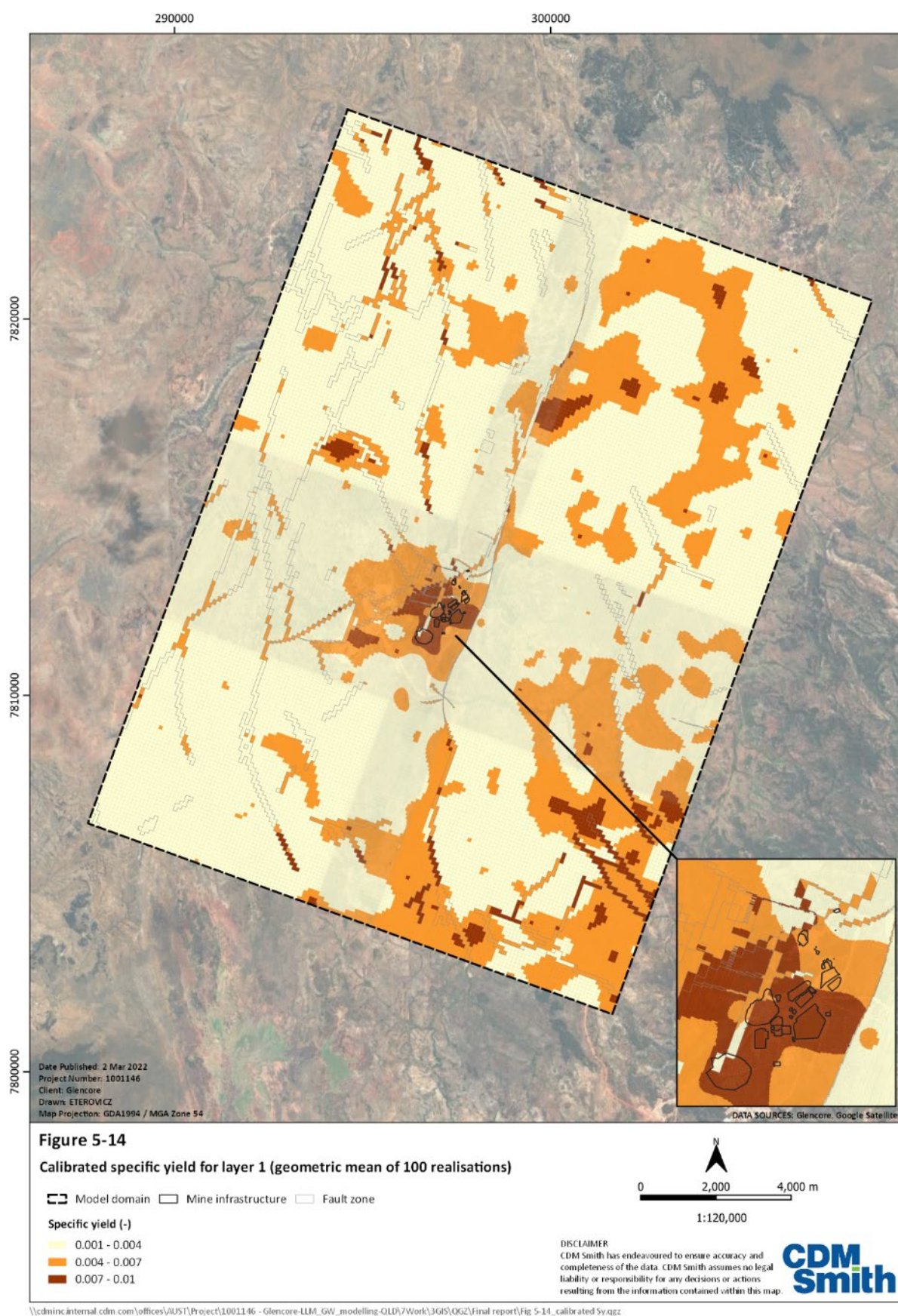


Figure 5-14 Calibrated Specific Yield for Layer 1 (Geometric mean of 100 realisations)

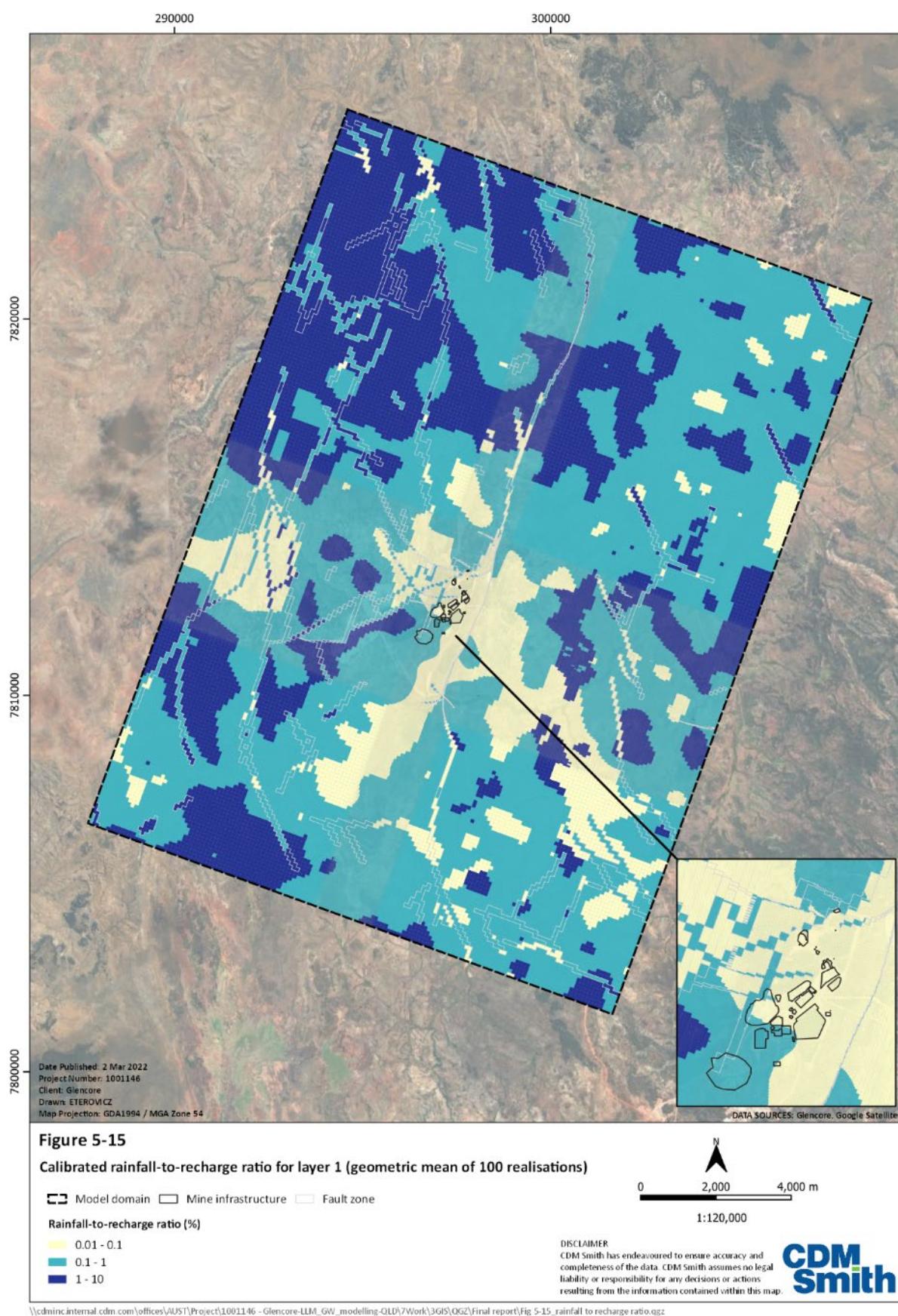


Figure 5-15 Calibrated Rainfall-to-Recharge Ratio for Layer 1 (Geometric mean of 100 realisations)

5.3.4 Calibrated Model Results

5.3.4.1 Calibrated Groundwater Level Contours

The calibrated groundwater levels (mean of 100 realisations) at the end of calibration period for layers 1 and 4 are shown in Figure 5-16 and Figure 5-17 respectively.

Both figures show that the relatively low fault permeability (Figure 5-11 and Table 5-3) has limited the majority of groundwater drawdown impact within the Lady Loretta Formation. The layer 1 contours show more influence from topography, while the layer 4 contours show a considerably lower water level as this layer hosts the majority of mining (i.e. larger drain cell extent and lower drain stages).

5.3.4.2 Calibrated Model Mass Water Balance

The calibrated model mass water balance (mean of 100 realisations) for the pre-mining period and at the end of calibration period is shown in Table 5-5. For the pre-mining period, inflows are dominated by rainfall recharge while outflows are dominated by groundwater ET and regional outflows (i.e. constant head fluxes). Most of the groundwater ET is expected to occur in low-lying areas where the water table is generally shallower. Groundwater discharge to the Lady Annie pit is relatively small, and river leakage is nil as groundwater levels are suppressed by ET.

At the end of calibration period, rainfall recharge is still the dominant inflow, albeit lower than the pre-mining period due to yearly fluctuations. There is also a notable increase in storage (note that storage inflow is a MODFLOW convention that actually represents reduction in groundwater storage) and regional groundwater inflows. The outflows are dominated by ET and groundwater extraction, with a notable increase in drain outflows due to the LLM underground workings and a decrease in regional groundwater outflows.

The model results show a mass balance percentage discrepancy of less than 1% for all times throughout the mining operation and post-mining period, which is acceptable based on requirements of the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Table 5-5 Calibrated Mass Water Balance for the Pre-mining Period and at the End of Calibration (Mean of 100 realisations)

Inflow (kL/d)	Pre-mining period (31/03/2012)	End of calibration (31/03/2022)
Storage	500	822
Constant head	29	432
Recharge	5336	3594
Total	5865	4849
Outflow (kL/d)		
Storage	828	80
Constant head	1511	110
Wells	0	1582
Drains (LLM)	0	615
Drains (Lady Annie)	279	180
River leakage	0	0
ET	3249	2286
Total	5867	4853
Percent discrepancy	-0.03%	-0.08%

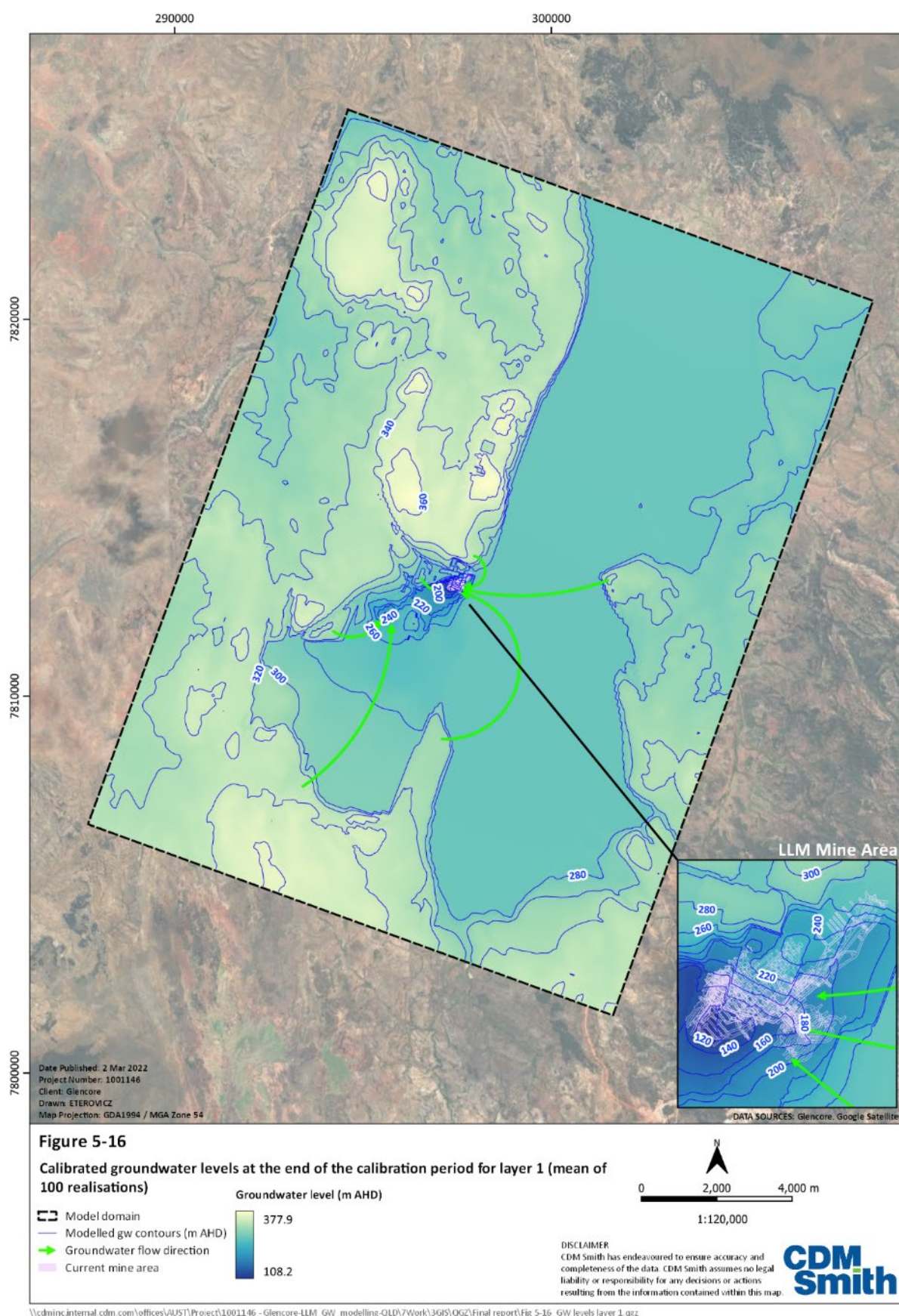


Figure 5-16 Calibrated Groundwater Levels at the end of Calibration Period for Layer 1 (Mean of 100 realisations)

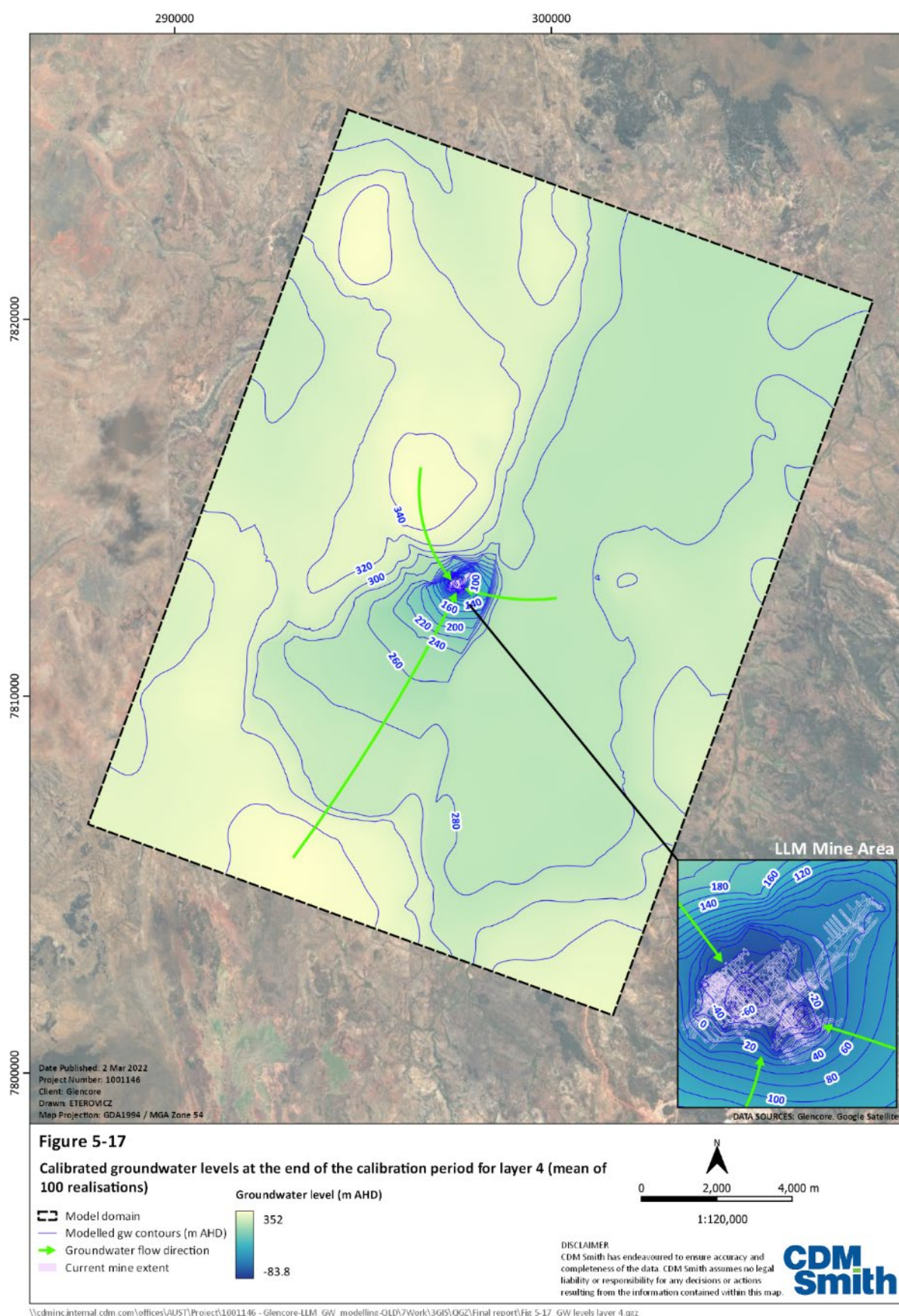


Figure 5-17 Calibrated Groundwater Levels at the end of Calibration Period for Layer 4 (Mean of 100 realisations)

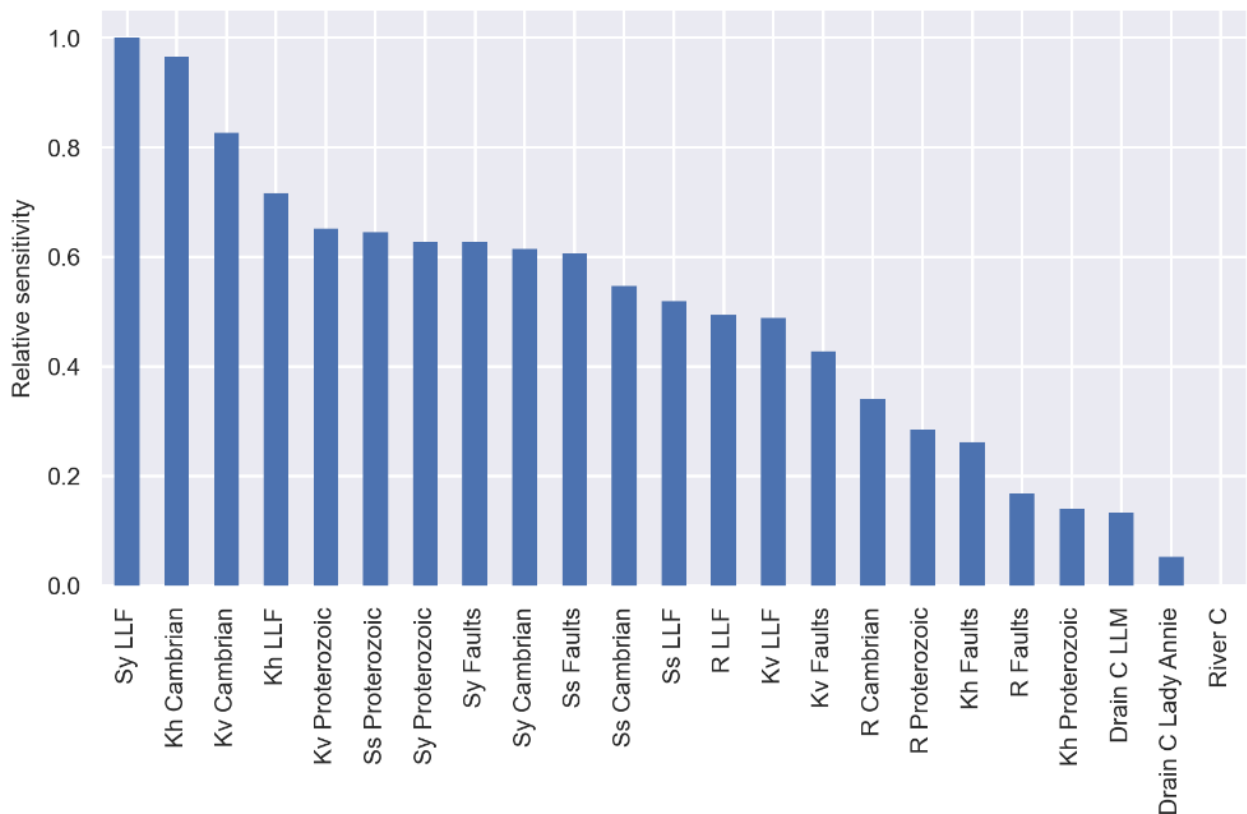
5.3.5 Sensitivity Analysis

Due to the stochastic approach adopted in this study, sensitivity analysis needs to be undertaken in a different manner using the concept of relative uncertainty reduction of parameter (Manewell and Doherty, 2021) that is defined as follows:

$$r_i = 1 - \frac{\sigma_i^{post}}{\sigma_i^{prior}}$$

where r_i is the relative uncertainty reduction of parameter i , σ_i^{prior} is the prior uncertainty of parameter i (i.e. the standard deviation of parameter i across the 100 realisations before calibration), and σ_i^{post} is the posterior uncertainty of parameter i (i.e. the standard deviation of parameter i across the 100 realisations after calibration). This approach is based on the rationale that the uncertainty (i.e. the standard deviation across the 100 realisations) of a more sensitive parameter would be reduced more by the calibration, and vice versa.

The min-max normalised parameter sensitivities are shown in Figure 5-18. The specific yield of Lady Loretta Formation (LLF) was found to be the most sensitive, possibly due to its control on the LLF response to the LLM underground workings and the inclusion of a flux calibration target. The hydraulic conductivity of Cambrian and LLF were also found to be sensitive, which is expected as these formations host the majority of groundwater level observation wells.



Kh = Horizontal hydraulic conductivity, Kv = Vertical anisotropy of hydraulic conductivity, Ss = specific storage, Sy = specific yield, R = rainfall-to-recharge ratio, C = Conductance, LLF = Lady Loretta Formation

Figure 5-18 Min-max Normalised Parameter Sensitivities

5.4 Model Predictions and Uncertainty Analysis

5.4.1 Prediction Approach

As discussed in Section 5.1, the Stage 1 objective of the LLM2021 groundwater flow model is to assess the groundwater flow fields during mining operation (already provided in Figure 5-16 and Figure 5-17), closure recovery and long-term new quasi-equilibrium. In addition, the LLM2021 model is to be used to estimate groundwater flux to the underground workings over time.

The scenario setup involves the following:

- Using the future mine plan between April 2022 and Dec 2025. Dewatering from the underground mine is scheduled to continue (to allow additional demolition waste from regulated dams to be disposed underground) until the end of 2032 and the mine is backfilled from 2033 onwards.
- Extending the latest pumping rates to December 2025, after which the pumping wells are deactivated for the post-mining period.
- Setting the future climate, including rainfall and ET rates, based on the average of last five years.
- A budget zone was set up for the LLM drain cells to estimate groundwater flux to the underground workings over time, especially for the post-dewatering period where the LLM drain cells are deactivated.

The stochastic modelling approach adopted in this study enables a more robust uncertainty analysis. Our approach is mathematically complex in that it involves sampling the posterior prediction space, which is a non-linear technique that is not subject to any linear assumptions between the model parameters and outputs. Despite the mathematical complexity, the uncertainty associated with the flux-to-mine estimates is presented in a straightforward manner where realisation results are shown individually to indicate the range of plausible possibilities that are supported by the field observations.

5.4.2 Prediction Groundwater Flow Fields

The predicted groundwater flow fields at the end of future dewatering (December 2032) and at the post-mining equilibrium (year 2250) are shown in Figure 5-19 and Figure 5-20 respectively.

Figure 5-19 shows that groundwater levels at LLM can be as low as -2 m AHD at the end of future dewatering, with the majority of drawdown impact limited to the Lady Loretta Formation.

Figure 5-20 shows that after more than 200 years into the future, the cone of depression caused by the LLM mining is predicted to be completely dissipated, with a groundwater level of approximately 280 m AHD in the vicinity of the former mine. In comparison, the Lady Annie pit is predicted to behave as a local groundwater sink where the groundwater level can be as low as 214 m AHD. The regional groundwater flow fields appear to follow the topography again.

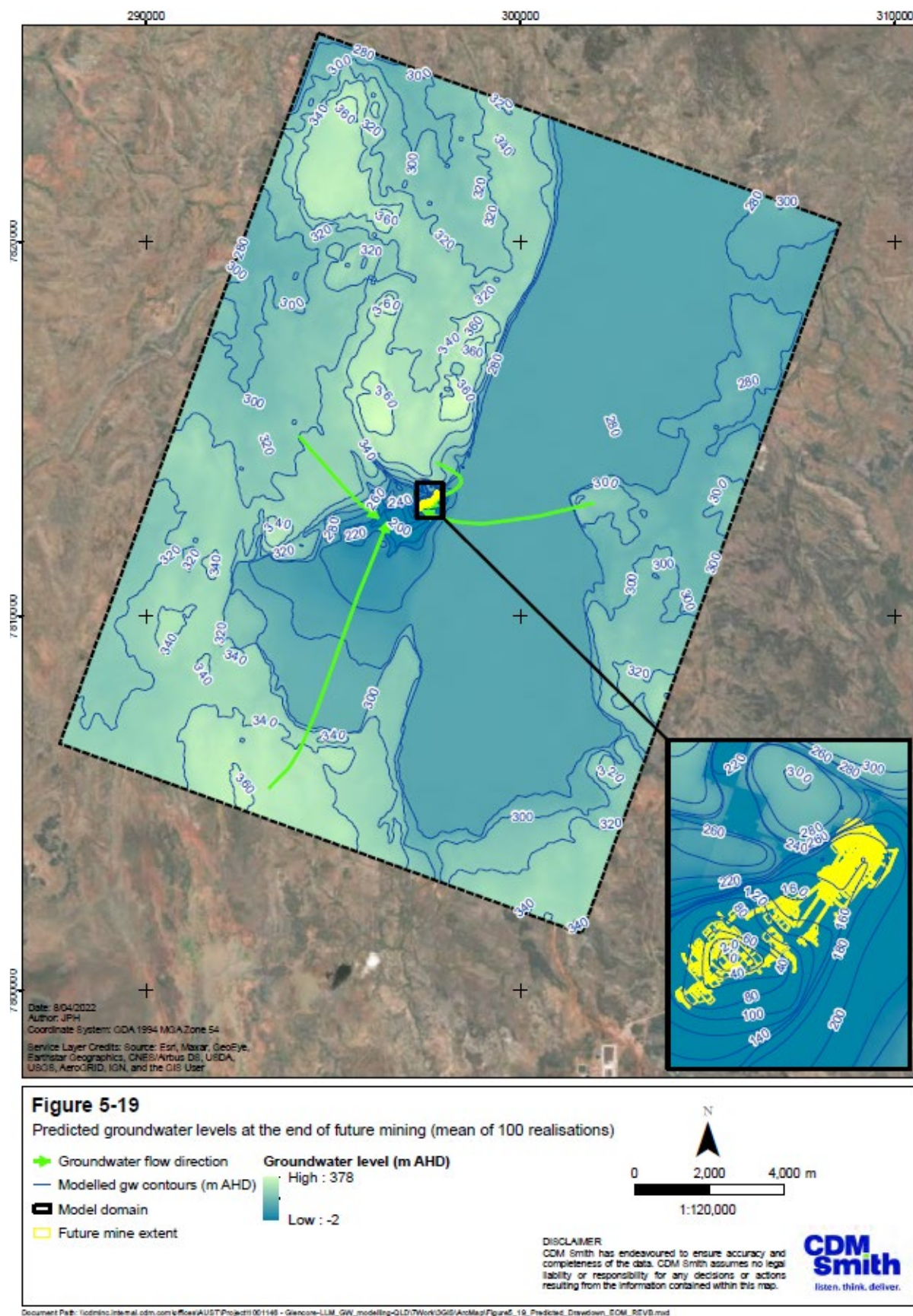


Figure 5-19 Predicted Groundwater Flow Fields at the end of Future Dewatering (Mean of 100 realisations)

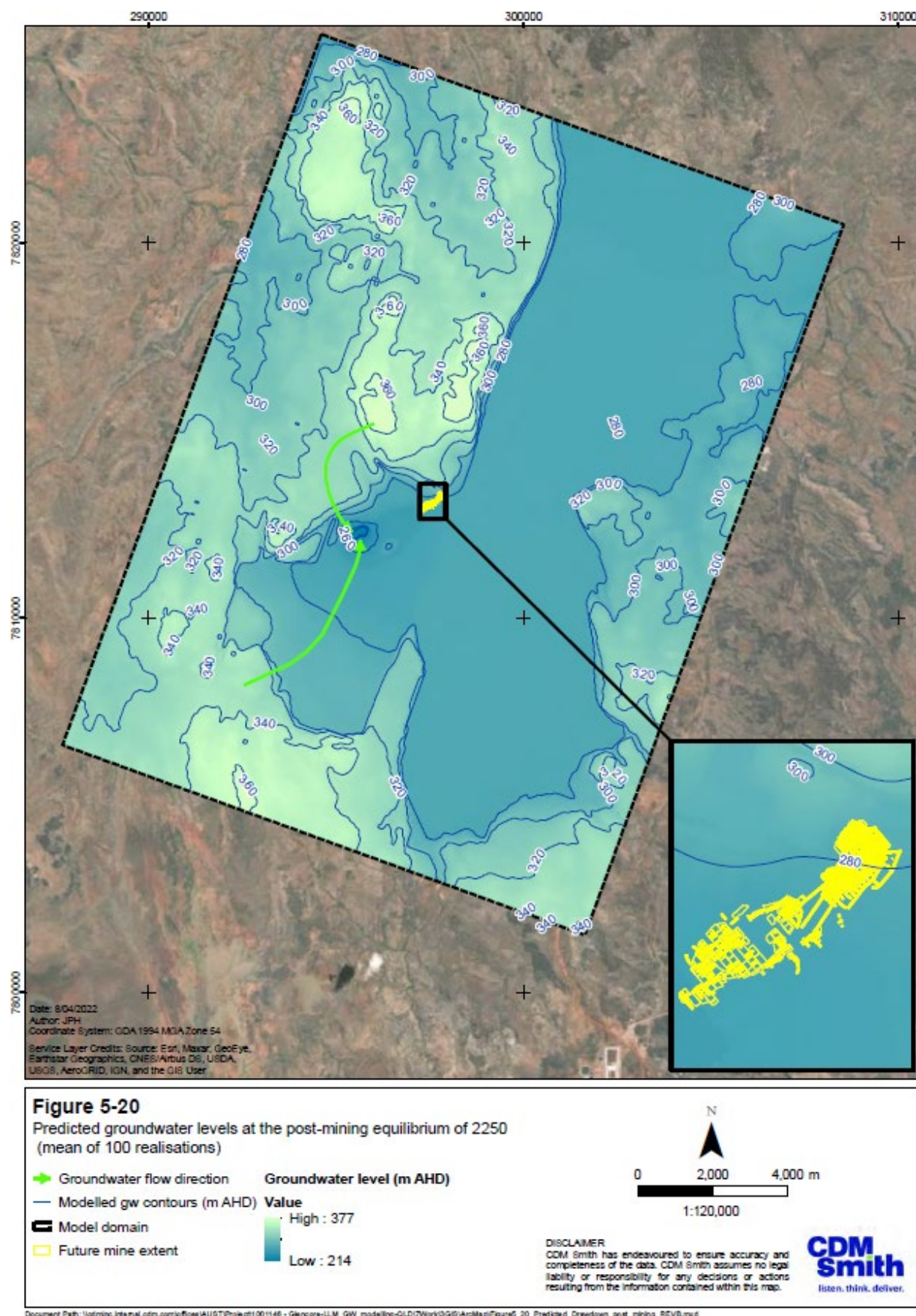


Figure 5-20 Predicted Groundwater Flow Fields at the Post-mining Equilibrium of 2250 (Mean of 100 realisations)

5.4.3 Predicted Groundwater Flux to Underground Workings

Groundwater fluxes to the underground mine workings over time predicted by the 100 calibrated realisations are shown in Figure 5-21. The semi-transparent lines represent the realisations individually and are an indicator of predictive uncertainty, while the solid line represents the mean of the realisations. The time axis is based on the number of years elapsed since the cessation of mining (Dec 2025).

The modelled flux is predicted to be approximately 630 kL/d at the cessation of mining, reducing over time as dewatering continues. As mine dewatering ceases to operate, groundwater inflow to the mine decreases rapidly as the heads in the backfilled mine voids rises. The modelled flux becomes stabilised at approximately 5 kL/d 50 to 60 years after the cessation of mining. A detail breakdown of modelled flux is shown in Table 5-6.

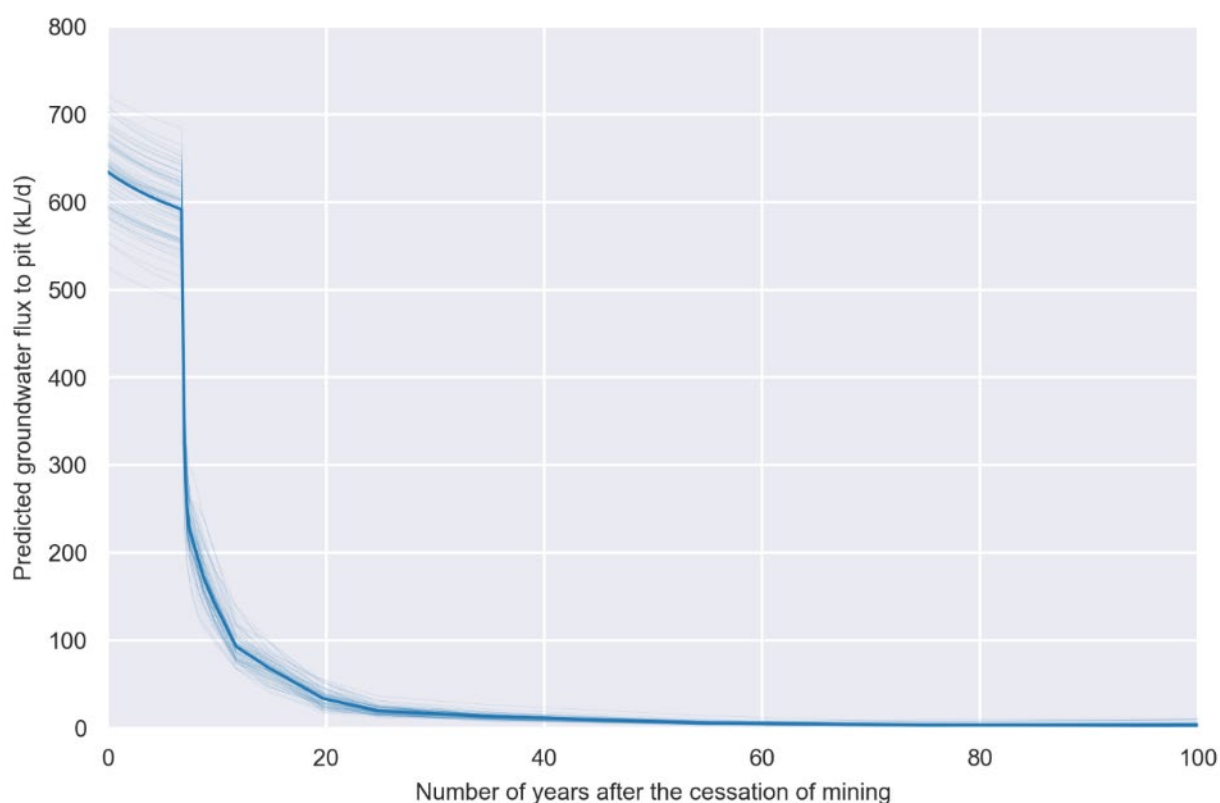


Figure 5-21 Predicted Groundwater Flux to the Underground Workings Over Time

A post closure conceptual model is shown in Figure 5-22 based on the available hydrogeological information and the numerical model results for post closure. Key features being:

- After more than 200 years into the future, the cone of depression caused by the LLM mining is predicted to be completely dissipated.
- Groundwater levels in the vicinity of the former LMM approximate 280 m AHD.
- The Lady Annie pit is predicted to behave as a local groundwater (evaporative) sink where the groundwater level can be as low as 214 m AHD.
- The regional groundwater flow fields appear to follow the topography (in a subdued manner).

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Table 5-6 Predicted Groundwater Flux to the Underground Workings from the 100 Calibrated Realisations

Years elapsed since the cessation of mining	Mean flux (kL/d)	Minimum flux (kL/d)	Maximum flux (kL/d)
0	636.5	527.4	723.2
1	627.8	519.7	715.5
2	620.1	512.9	708.9
3	613.2	506.9	703.0
4	607.0	501.6	697.8
5	601.4	496.9	693.0
7	591.5	488.8	684.9
8	214.7	149.6	291.2
9	172.7	114.9	241.2
10	142.9	98.3	203.6
12	93.2	67.7	139.0
15	69.1	40.9	99.6
20	33.9	17.4	56.2
25	20.2	12.1	36.7
35	13.6	8.4	27.0
55	6.2	3.1	14.5
75	3.9	1.6	9.8
95	3.9	1.1	10.9

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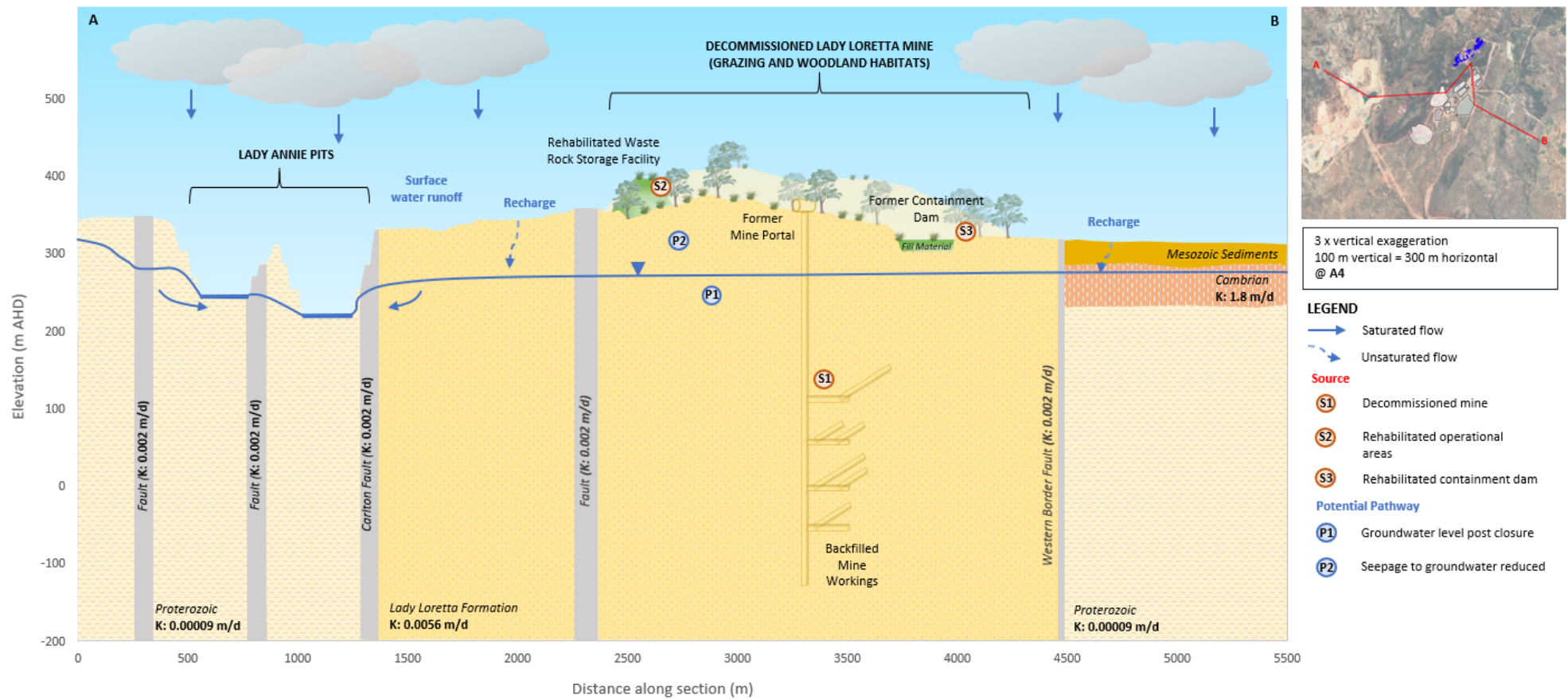


Figure 5-22 Conceptual Model – Post Closure

Section 6 Environmental Values and Contaminants of Concern

6.1 Environmental Values

The Environmental Values (EV) of waters and wetlands are protected under the Environmental Protection Water and Wetland Biodiversity Policy 2019. LLM is located within the Leichardt River water catchment plan, and the EVs for the project area are determined in accordance with Section 6 of the EPP Water and Wetland Biodiversity Policy. The identified EVs for the LLM receiving environment are:

- aquatic ecosystem protection.
- cultural and spiritual values.
- waters that may be used for agricultural purposes.
- waters that may be used for drinking water.
- industrial use of water.

The below subsections describe the assessed site EVs.

6.1.1 Aquatic Ecosystem Protection

A search of the Queensland Globe and Queensland Wetland Maps shows no listed Groundwater Dependent Ecosystems mapped in the area or within 10 kilometres of LLM. The Queensland GDE mapping and Wetland Maps are developed through consultation and the integration of expert knowledge with detailed spatial data.

Based on this review there are no mapped:

- Ecosystems dependent on the surface expression of groundwater (surface expression GDEs).
- Ecosystems dependent on the sub-surface presence of groundwater (terrestrial GDEs).
- Ecosystems dependent on the subterranean presence of groundwater (subterranean GDEs).

A search of the Bureau of Meteorology National Atlas Groundwater Dependent Ecosystems (GDE) shows two low to moderate potential aquatic GDE types, to the southeast of LLM (Figure 6-1). The GDE Atlas was released in 2012 and was produced by conducting a national scale assessment using remote sensing and GIS rules-based analysis, which mapped the potential for groundwater/ecosystem interaction.

The two potential GDE locations are located over four kilometres southeast of LLM. No data is available in the area to directly assess the groundwater table and GDEs. Based on the available information the Cambrian units are overlain by surficial alluvium and Mesozoic sediments, varying in thickness up to 25 m. The depth of the groundwater is assumed to be greater than 30 m below surface and the overlying Quaternary and Mesozoic units are likely rarely saturated.

6.1.2 Cultural and Spiritual Values

Cultural and spiritual values may include custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities. No cultural and spiritual values have been identified for groundwater in the project area.

Section 6 Environmental Values and Contaminants of Concern

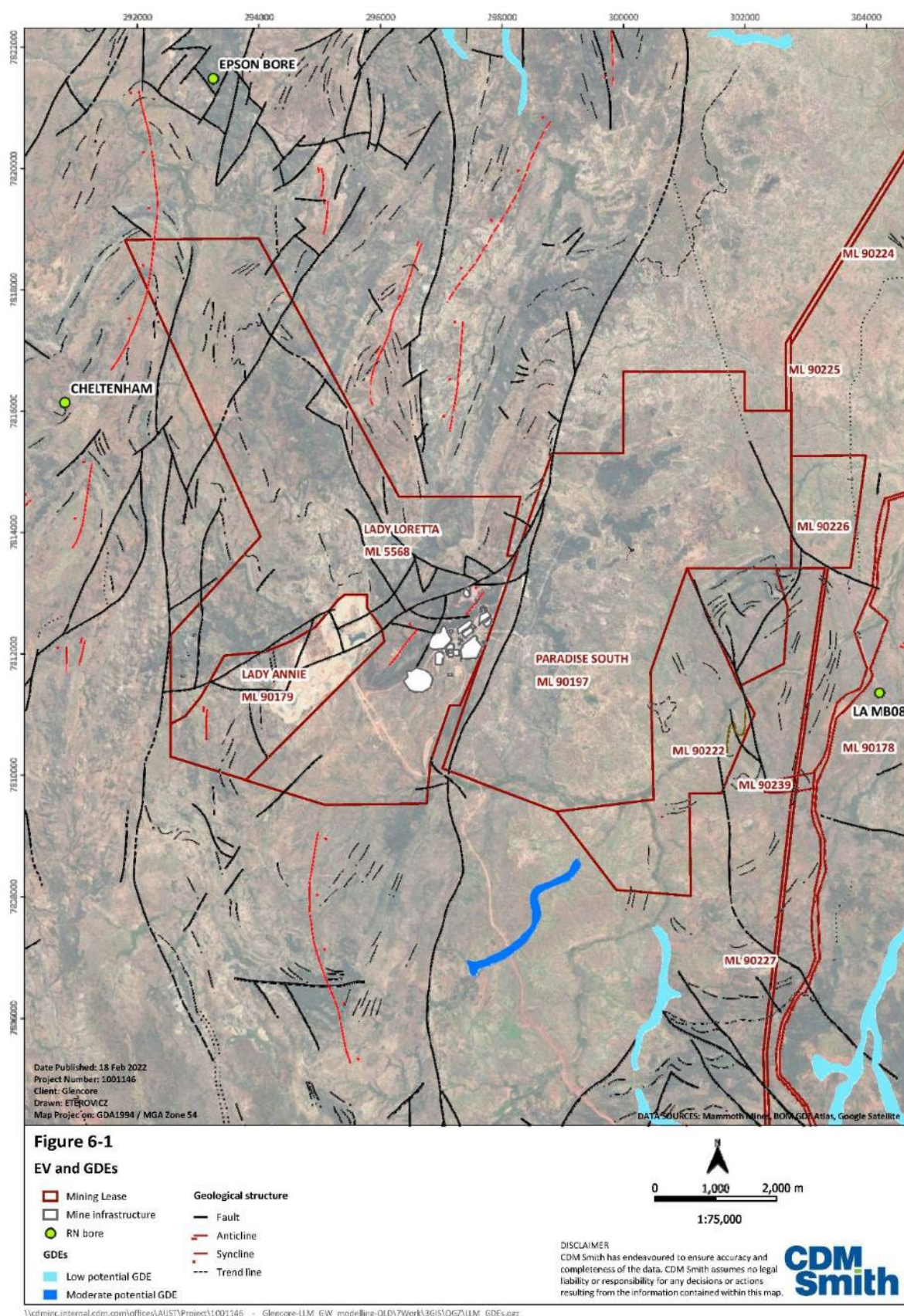


Figure 6-1 Environmental Values and Potential Groundwater Dependent Ecosystems

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6.1.3 Agricultural / Industrial Use and Potable Water

A search of the Queensland Government groundwater database of registered bores within 10 kilometres of the LLM site was conducted:

- Within 5 km of LLM, there are 42 registered groundwater bores, with 39 bores listed or identified as related to mining activities and 3 abandoned. As such, there are no known or identified registered water supply stock or domestic bores within 5 kilometres of the LLM site.
- Between 5 and 10 kilometres of the LLM site there are three registered bores (RN32777 Epson bore and RN51356 Cheltenham bore to the northeast, and RN146610 LAMB08 to the west). The two registered bores RN32777 and RN51356 have no listed role shown in the registered bore report and RN146610 LAMB08 is listed as mine monitoring.

The two main users of groundwater for industrial use in the area are LMM and Lady Annie Mine. LLM sources raw water from the LAE bore field for use in the process, underground, paste mix water, fire water, dust suppression and potable water system feed water.

In addition, potable water for the site is produced at the LLM reverse osmosis water treatment plant for use across the mine and camp operation as drinking and sanitary purposes.

6.2 Environmental Values - Potential Risks

The potential environmental risks to EVs due to LLM's operations and closure have been considered and include the following:

- Operational and Closure Risk of seepage of contaminated water to underlying groundwater from water management infrastructure including Containment Dam A (CDA), Containment Dam B (CDB), the Paste Plant Dam (PPD) and the Leachate Management Dam (LMD).
- Operational Risk of seepage of contaminated water to underlying groundwater from Run of Mine (ROM) Pad and other operational areas.
- Operational and Closure Risk of acidic metalliferous drainage (AMD) developing in response to oxidation of sulphides in the underground mine workings, Waste Rock Emplacement (WRE), Leachate Management Dam (LMD) stockpile and legacy PAF mine waste.

6.3 Contaminants of Concern Sources and Water Quality

6.3.1 Surface Contaminants of Concern Sources

LLM containment structures have been assessed in accordance with the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures resulting in a 'significant' consequence category on the basis that both, failure to contain overtopping and dam break failure scenarios result in general environmental harm of the downstream receiving environment (LLM, 2021b). All LLM containment structures therefore meet the criteria of a 'Regulated Structure' (dam) and must be designed, constructed and operated in accordance with the Manual and Schedule D of the LLM EA (LLM, 2021b). The Regulated Dams at LLM include:

- Containment Dam A (CDA)
- Containment Dam B (CDB)
- Paste Plant Dam (PPD)
- Leachate Management Dam (LMD)

Section 6 Environmental Values and Contaminants of Concern

The sources of potential contaminants of concern (COCs) for each containment structure are shown in Table 6-1.

Table 6-1 Potential COC Sources for each Containment Structure (LLM, 2021b)

Containment Structure	Potential Contaminants
Containment Dam A	Metal ore, AMD, hydrocarbons.
Containment Dam B	PAF waste rock, AMD, hydrocarbons.
Paste Plant Dam	Tailings, AMD, cement, batch plant reagents, hydrocarbons.
Leachate Management Dam	PAF waste rock, acid and metalliferous mine drainage.

According to Glencore's internal LLM Detailed Closure Plan, once the dams are no longer required during the rehabilitation process they will be decommissioned and rehabilitated subject to final landowner or third party user agreements (LLM, 2021a). As the containment dams are regulated structures under the environmental authority, each will require a decommissioning plan (LLM, 2021a). As part of the LLM closure strategy, the regulated dams will be decommissioned. LMD is planned for decommissioning in 2028 and the remaining regulated dams are planned for decommissioning in 2044. Decommissioning and rehabilitation of CDA, CDB and PPD can only occur after major works are completed in the catchments generating mine-affected waters and dewatering of the underground workings has been discontinued. Closure works have been completed within the LMD catchment, which has involved rehandling and removal of the LMD Stockpile to the Waste Rock Emplacement, as well as excavation and removal of additional mineralised material and placement of inert fill followed by revegetation works within the legacy mine area. Mine affected waters within the LMD catchment area have been reduced and once works have been effective in mitigating the risks presented in the receiving environment the dam can be decommissioned.

The decommissioning process for the dams will include:

- Removal of any accumulated sediments and HDPE liners.
- Assessing the contaminated land risk and where necessary implementing remediation measures.
- Removal of leak detection system, piezometers, monitoring equipment (if present).
- Lowering the invert level of the emergency spillways.
- Pushing in sides and partial recontouring of the containment embankments to achieve the Final Landform profile.
- The above decommissioning process will ensure dams are no longer a source of COC.

6.3.2 Water Class and Water Quality

LLM has established water classes to define the different types and quality of water encountered at LLM (LLM, 2021b). The below subsections describe the established water classes.

6.3.2.1 Process Water

Process water describes water sourced from Containment Dam A for use as paste mix water and dust suppression within the LLM containment area. The water held in CDA is sourced from:

- Stormwater runoff within the CDA catchment.
- Brine from the CDA Water Treatment Plant (WTP) and potable water reverse osmosis plant.
- Water transfers from other site water storages - Containment Dam B and the Paste Plant Dam.
- Underground dewatering and water discharged from site oil water separators.

Section 6 Environmental Values and Contaminants of Concern

- Wheel wash wastewater and clean in clean out laundry wastewater.

The water quality contained in the CDA is characterised by elevated electrical conductivity and sulphate concentration and total metals including Aluminium, Cobalt, Lead, Nickel, Zinc and Iron (Table 6-2).

Table 6-2 CDA Water Quality Results (COCs)

Analyte	Units	Minimum	Mean	Maximum	Sample Count
pH	n/a	5.9	7.2	8.0	10
EC	µS/cm	3580.0	4468.0	5170.0	10
TSS	mg/L	10.0	37.9	73.0	10
Sulfate	mg/L	2420.0	3116.0	3580.0	10
Chloride	mg/L	58.0	66.0	74.0	10
Calcium	mg/L	576.0	647.4	741.0	10
Magnesium	mg/L	254.0	350.9	428.0	10
Sodium	mg/L	105.0	130.6	160.0	10
Potassium	mg/L	77.0	86.8	96.0	10
Aluminium	mg/L	0.02	0.44	1.07	10
Arsenic	mg/L	0.002	0.006	0.018	10
Cadmium	mg/L	0.010	0.040	0.080	10
Chromium	mg/L	<0.001	<0.001	<0.001	10
Cobalt	mg/L	0.103	0.221	0.310	10
Copper	mg/L	0.002	0.013	0.027	10
Lead	mg/L	0.076	0.359	1.530	10
Molybdenum	mg/L	0.004	0.010	0.031	10
Nickel	mg/L	0.038	0.074	0.107	10
Selenium	mg/L	<0.01	<0.01	<0.01	10
Zinc	mg/L	7.480	24.878	45.200	10
Boron	mg/L	0.120	0.154	0.200	10
Iron	mg/L	0.200	3.958	8.840	10
Mercury	mg/L	<0.0001	<0.0001	<0.0001	10

6.3.2.2 Waste Rock Leachate

PAF waste rock produced by mining operations that cannot be placed in underground voids is transferred to the surface and placed in the WRE. The WRE has been engineered to safely store PAF waste rock, limit seepage and direct runoff and leachate to Containment Dam B. PAF waste placed on the WRE is treated with hydrated lime and compacted in 1 metre lifts to limit oxidation processes and neutralise acid production. Water held in CDB is periodically transferred to CDA in accordance with the transfer rules stipulated in the Regulated Dam Operational Plan.

The water quality contained in the CDB is characterised by elevated electrical conductivity and sulphate concentration and total metals including Aluminium, Arsenic, Cadmium, Chromium, Cobalt, Copper, Lead, Nickel, Zinc and Iron (Table 6-3).

Section 6 Environmental Values and Contaminants of Concern

Table 6-3 CDB Water Quality Results (COCs)

Analyte	Units	Minimum	Mean	Maximum	Sample Count
pH	n/a	1.8	3.6	8.6	47
EC	µS/cm	3040.0	9081.5	33300.0	47
TSS	mg/L	5.0	46.9	813.0	46
Sulfate	mg/L	1380.0	8272.8	40600.0	47
Chloride	mg/L	24.0	133.6	400.0	47
Calcium	mg/L	286.0	522.7	793.0	47
Magnesium	mg/L	81.0	973.9	5050.0	47
Sodium	mg/L	23.0	121.6	349.0	47
Potassium	mg/L	1.000	76.021	251.000	47
Aluminium	mg/L	0.02	190.3	1240.0	47
Arsenic	mg/L	0.001	0.084	0.798	47
Cadmium	mg/L	0.001	1.032	6.770	47
Chromium	mg/L	0.001	0.042	0.327	47
Cobalt	mg/L	0.003	2.617	16.700	47
Copper	mg/L	0.003	2.586	19.400	47
Lead	mg/L	0.015	0.924	3.900	47
Molybdenum	mg/L	0.001	0.006	0.052	45
Nickel	mg/L	0.007	1.339	8.890	47
Selenium	mg/L	0.010	0.034	0.520	44
Zinc	mg/L	0.222	722.865	4610.000	47
Boron	mg/L	0.050	0.279	0.630	46
Iron	mg/L	0.050	943.212	5610.000	47
Mercury	mg/L	0.0001	0.0001	0.0002	44

6.3.2.3 Mine Dewatering

LLM mine dewatering activities results in approximately 1 ML/d of water pumped to the surface for storage in either CDA or PPD. Due to the high suspended solids loads produced, all mine dewatering is directed to either the CDA or PPD sediment dams to remove solids prior to entering either water storage. Water held in PPD is periodically transferred to CDA in accordance with the transfer rules stipulated in Regulated Dam Operational Plan.

The water quality contained in the PPD is characterised by elevated electrical conductivity and sulphate concentration and total metals including Aluminium, Arsenic, Cadmium, Chromium, Cobalt, Copper, Lead, Nickel, Zinc and Iron (Table 6-4).

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Table 6-4 PPD Water Quality Results (COCs)

Analyte	Units	Minimum	Mean	Maximum	Sample Count
pH	n/a	4.5	6.8	7.9	23
EC	µS/cm	2330.0	4006.1	8560.0	23
TSS	mg/L	5.0	6764.6	135000.0	20
Sulfate	mg/L	1510.0	2798.7	6350.0	23
Chloride	mg/L	25.0	54.6	164.0	23
Calcium	mg/L	314.0	512.6	717.0	23
Magnesium	mg/L	150.0	347.3	1320.0	23
Sodium	mg/L	34.0	79.8	234.0	23
Potassium	mg/L	20.0	72.0	181.0	23
Aluminium	mg/L	0.01	45.6	1000.0	22
Arsenic	mg/L	0.001	3.029	69.6	23
Cadmium	mg/L	0.005	0.338	7.100	23
Chromium	mg/L	0.001	0.086	1.700	20
Cobalt	mg/L	0.049	0.801	15.000	23
Copper	mg/L	0.001	2.341	53.700	23
Lead	mg/L	0.002	47.163	1080.000	23
Molybdenum	mg/L	0.001	0.083	1.730	23
Nickel	mg/L	0.018	0.235	4.020	23
Selenium	mg/L	0.010	0.015	0.100	20
Zinc	mg/L	2.280	186.589	3870.000	23
Boron	mg/L	0.050	0.162	0.450	23
Iron	mg/L	0.050	770.859	16700.000	22
Mercury	mg/L	0.0001	0.0001	0.0010	20

6.3.3 Subsurface Contaminant Sources

The subsurface contaminant sources are the mine workings (backfilled with paste produced from tailings), the base of the modern WRE, and the base of the legacy PAF storage.

The water quality contained in the LMD is characterised by elevated electrical conductivity and sulphate concentration and total metals including Aluminium, Arsenic, Cadmium, Chromium, Cobalt, Copper, Lead, Nickel, Zinc and Iron (Table 6-5).

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Table 6-5 LMD Water Quality Results (COCs)

Analyte	Units	Minimum	Mean	Maximum	Sample Count
pH	n/a	2.3	2.6	3.0	6
EC	µS/cm	1750.0	11358.3	39500.0	6
TSS	mg/L	9.0	179.6	1460.0	14
Sulfate	mg/L	935.0	14521.7	86900.0	14
Chloride	mg/L	5.0	49.0	170.0	14
Calcium	mg/L	93.0	318.3	720.0	14
Magnesium	mg/L	48.0	947.2	5400.0	14
Sodium	mg/L	2.0	31.2	112.0	14
Potassium	mg/L	1.0	6.4	24.0	14
Aluminium	mg/L	35.0	711.6	4400.0	14
Arsenic	mg/L	0.010	0.547	5.650	14
Cadmium	mg/L	0.199	3.602	18.100	14
Chromium	mg/L	0.004	0.077	0.539	14
Cobalt	mg/L	0.231	4.328	23.900	14
Copper	mg/L	0.581	8.917	55.500	14
Lead	mg/L	0.009	0.184	0.412	14
Molybdenum	mg/L	0.001	0.018	0.105	14
Nickel	mg/L	0.154	2.869	16.500	14
Selenium	mg/L	0.010	0.179	1.050	14
Zinc	mg/L	108.000	2494.643	12500.000	14
Boron	mg/L	0.050	0.541	5.000	14
Iron	mg/L	38.200	847.800	4430.000	14
Mercury	mg/L	0.0001	0.0003	0.002	14

According to the LLM supplied information, selected below ground infrastructure is to be decommissioned in accordance with the demolition study. Backfilling of the underground working will begin from 2033 onwards, with backfilling defined as backfilling the upper section of the mine decline and upper section of the ventilation shafts only.

6.4 Potential Exposure Pathways from COC Sources to Receptors

A potential exposure pathway is the route along which a COC might move through the environment from its source to a receptor. Potential pathways considered for the site are presented in Table 6-6. In summary, four pathways are considered relevant with respect to connection of the source (exposed containment structures, waste rock, underground workings) to EVs.

Section 6 Environmental Values and Contaminants of Concern

Table 6-6 Identified Pathways

Pathways (P)	Description
P1	Groundwater inflow to the underground workings and contact of water with exposed oxidised rock / materials.
P2	Vertical or lateral migration of solutes from the underground workings to the external groundwater.
P3	Abstraction and use (environmental values) of groundwater external to the mine infrastructure.
P4	Seepage of contaminated water from waste landforms and containment dams to underlying groundwater.

Post closure, the regulated dams will be decommissioned. LMD is planned for decommissioning in 2028 and the remaining regulated dams are planned for decommissioning in 2044. The primary aquifer recharge mechanisms will consist of direct infiltration via rainfall and infiltration associated with any surface water flow paths. Discharge mechanisms will remain unchanged, with any changes associated with groundwater flow related to any changes in mining activities occurring such as the Lady Annie site. The changes relating to future mining activities cannot be quantified at this time.

The development of the source-pathway-receptor model included assessment of the following:

- Sources of contamination or site activities that can cause contamination.
- Pathways by which contaminants can or may infiltrate to the local water table and then migrate via groundwater flow pathways.
- Receptor of the pollution who or what could be affected due to LLMs operations and closure.

The summary shown in Table 6-7 has been colour coded with:

- Orange indicating an open path based on the site setting and activities there is the potential for this pathway to be open.
- Green indicating the pathway is closed with either of the source, pathway and receptor elements closed. However long term monitoring of the groundwater monitoring and seepage detection bores will be required to confirm the success of the rehabilitation and removal of all source contaminants.

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Table 6-7 Source, Pathway and Groundwater Receptor Summary

Current Operations			Post Closure ¹		
Source	Pathway	Groundwater Receptor	Source	Pathway	Groundwater Receptor
Mine workings, the base of the modern WRE, Leachate Management Dam stockpile and the base of the legacy PAF storage.	Groundwater inflow to the underground workings and contact of water with exposed oxidised rock / materials. Vertical or lateral migration of solutes from the underground workings to the external groundwater Abstraction of groundwater external to the mine infrastructure.	Industrial Use and Drinking Water Stock Water Aquatic Ecosystem Protection	Below and above ground infrastructure is to be decommissioned and the shafts and portal will be backfilled with suitable material, and demolition waste and sealed with a concrete plug.	Groundwater inflow to the underground mine workings reduced due to decommissioning and no longer possible through the modern WRE and PAF storage as the site has been successfully rehabilitated and all COC sources removed.	Industrial Use and Drinking Water Stock Water Aquatic Ecosystem Protection
Run of Mine (ROM) Pad and other operational areas.	Seepage of contaminated water to underlying groundwater. Abstraction of groundwater external to the mine infrastructure.	Industrial Use and Drinking Water Stock Water Aquatic Ecosystem Protection	Stockpiles, ROM and pads, roads etc removed and land rehabilitated so site activities benign.	Seepage of potential contaminants into groundwater no longer possible as site has been successfully rehabilitated and all COC sources removed.	Industrial Use and Drinking Water Stock Water Aquatic Ecosystem Protection
Seepage of contaminated water to underlying groundwater from water management infrastructure including CDA, CDB, PPD and LMD.	Seepage of contaminated water to underlying groundwater. Abstraction of groundwater external to the mine infrastructure.	Industrial Use and Drinking Water Stock Water Aquatic Ecosystem Protection	According to the LLM Detailed Closure Plan once the dams are no longer required during the rehabilitation process they will be decommissioned and rehabilitated.	Seepage of potential contaminants into groundwater no longer possible as site has been successfully rehabilitated and all COC sources removed.	Industrial Use and Drinking Water Stock Water Aquatic Ecosystem Protection

¹ Closure evaluation assumes all materials will be removed from site and there is no contaminant leachate at depth

Section 7 Solute Transport Modelling

7.1 Model Selection and Assumptions

The solute transport modelling objective is to predict the potential fate and transport of COCs in groundwater underlying the storage and backfilled underground areas, that have been identified as potential source of contamination, including:

- Containment Dam A (CDA)
- Containment Dam B (CDB)
- Paste Plant Dam (PPD)
- Leachate Management Dam (LMD)
- Backfilled underground galleries

The transport modelling is conducted with MODFLOW USG Transport (Panday, 2019). The transport component is added onto the predictive model scenario comprising mining operation and post-mining operations (cf. section 5.4). The aquifers parameters are from the best calibrated groundwater flow model (section 5.3) which estimated plausible aquifer hydraulic properties as well as recharge and discharge processes.

The transport approach is normalised. In a normalised approach, the individual concentrations are not provided in an absolute value (i.e. concentration in mg/L), but they are expressed as a percentage of the source concentration. The benefit of the normalised approach is that it is not COC species specific and can be applied to any non-reactive inorganic CoC. The normalised approach is suitable for the adopted conservative approach as some retardation or decay processes that could be specific to some chemical species are neglected. For the simplification of the normalised approach the background concentration (i.e. the natural pre-mining concentration of contaminant in groundwater) is set to zero. For a potentially present COC as background concentration, the normalised approach provides results that are an offset to the background concentration (i.e. the 0% contour reflects the background concentration and the 100% represents the source concentration which can be interpreted as being the background concentration plus an “added contamination concentration”. All the percentile contours are representing the residual of the “added contamination concentration”).

The physical and chemical processes that affect the fate and transport of dissolved groundwater contaminants include advection, hydrodynamic dispersion, molecular diffusion, adsorption, dilution and degradation. The combined effect of those processes controls how long a contaminant plume will grow, remain stable, or shrink. The processes can be described briefly as:

- Advection is the component of solute movement attributed to transport by the flowing groundwater. Advection is typically the dominant factor in transporting dissolved COCs.
- Hydrodynamic dispersion is a physical process whereby dissolved constituents spread at the pore-scale level, leading to larger-scale macroscopic spreading, both horizontally and vertically away from the centre of the plume mass. Dispersion is controlled by aquifer heterogeneity, temporal variations in the hydraulic gradient and the size and location of the initial plume. Dispersion is stronger in the direction of flow (the longitudinal dispersion) than in direction normal to the flow line (transverse dispersion). Though dispersion in the transverse direction is a much weaker process than dispersion in the longitudinal direction, at low velocities where molecular diffusion is the dominant dispersive mechanism, the coefficients of longitudinal and transverse dispersion can approach each other, i.e. become nearly equal.
- Molecular diffusion is a physical process whereby molecules move from an area of higher concentration to an area of lower concentration, and the rate of diffusion is typically overshadowed by advective and dispersive forces. However, molecular diffusion is often a significant factor in the pore-scale transfer of COC mass, and in

certain low permeability geologic formations with very slow advective movement, and correspondingly slow dispersive forces.

- Adsorption is a chemical process whereby dissolved COCs interact with and are 'captured' on the surface of solids. Adsorption of dissolved constituents onto subsurface materials is a phenomenon known to retard plume movement relative to groundwater. Adsorption is often described by the retardation factor which quantifies how many times slower a dissolved constituent moves relative to the average linear groundwater velocity.
- Dilution is the mixing of contaminated water with water of lower concentration leading to a reduction of concentration.
- Degradation processes are biological and chemical processes that decrease the mass of some dissolved constituents. These processes include the effects of biodegradation, photolysis, oxidation-reduction, and hydrolysis. They are generally grouped into either biologic or abiotic (chemical) degradation processes.

The modelling approach adopted in this assessment is considered conservative as it does not take into account all the aforementioned attenuation processes that reduce the concentration of COCs along the groundwater flow path. A conservative approach does not aim at making exact predictions, but aims at overestimating the potential impact related to the predictions. Conservative approaches are often adopted within impact assessments as it keeps the predictive uncertainty on the side of overestimation. Therefore, whenever the overestimated impacts remain within acceptable bounds, as in, no valued assets (i.e. environmental) are likely not to be affected by the project, the results can be considered reliable and do not require more detailed analyses

As part of the conservative approach the model is predicting advective and dispersive transport, with these processes tending to slow or reduce the contamination. Diffusion is not considered further as it is a small component of the overall fate and transport (Panday, 2019). Any adsorption and degradation processes have also not been considered further due to the conservative model approach.

Other conservative assumptions associated with this model comprise:

- The dam construction are not captured in the model development. The dam construction consists of CDA, CDB and PPD being HDPE lined and LMD is GCL lined. The dams therefore do have engineering containment features which the modelling excludes based on the conservative approach adopted. There is no evidence to show there is any contamination coming from the surface water dams, storage facilities or stockpile area so the contribution from this source is extremely conservative.
- For the source of contamination located at ground surface (CDA, CDB, PPD, LMD) the source of contamination was set directly at the water table, with the transport processes within the unsaturated zone not considered further. This is a conservative assessment as it assumes that the contamination crosses the unsaturated zone without delay nor decay.
- The sources of contamination are assumed constant for the whole simulation (running 220 years post-mining). For the surface water dams, the persistence of contamination release post-mining is conservative as site rehabilitation post-mining will reduce (if not completely remove) the potential release of contamination. For the underground workings, the source of contamination is also assumed constant in time for the duration of the whole simulation. This is a conservative assessment as it assumes no exhaustion of the contamination potency of materials post closure. It is understood that due to the planned decommissioning of the site infrastructure and rehabilitation of the site, the source of contamination to the water table will progressively decline, and consequently that the predicted long-term plume is predominantly an overestimation of the likely outcome.
- As this is a conservative transport model assessment the entirety of the underground workings is assumed to be a potential source of contamination (from the deepest point to the highest point). The water chemistry of the underground working is oxidised to mildly reducing. This suggests that sulphidic mineralisation has the potential to be oxidised as groundwater flows through the strata. The groundwater recovery post closure in the backfilled underground workings is likely to result in the reactive material being under water cover, which has proven to be a highly effective method for AMD control. Water cover is an effective barrier to the gaseous diffusion of oxygen.

The role of redox processes in limiting metals transport once the new groundwater flux equilibrium is reached is important, the redox processes would work to limit the future movement of contaminants that respond to changes in redox conditions.

7.2 Model Parameters and Boundary Conditions

The relevant transport parameters for the reference scenario are summarised in Table 7-1. Conservative assumptions were assumed to choose the parameters as describes in the following sub-sections.

Table 7-1 Assumed Transport Parameters

Parameter	unit	value
Longitudinal dispersivity	m	100
Transversal dispersivity	m	10
Vertical dispersivity	m	10
Porosity	-	Sy (heterogeneous)

7.2.1 Effective Porosity

In addition to the specific yield (Sy) for flow, MODFLOW requires the assignment of a separate porosity parameter, $\emptyset$, used for the mass transport solution. The value of $\emptyset$ (porosity) is larger than Sy, as porosity measures the amount of water stored within the pores or fissures of the aquifer, while Sy is a measure of gravity drainage (a portion of the porosity). The difference between the porosity and the specific yield is the specific retention. To be conservative in this modelling, the porosity for mass transport is assumed to be equal to the specific yield, so therefore the analysis will be conservative (travel times are faster) In fractured rock aquifers effective porosity might approximate Sy due to the nature of flow in fractured rock systems.

The effect of variation of effective porosity on the transport predictions is considered in the sensitivity analysis.

7.2.2 Dispersivity

The dispersivity parameters have units of length. Field-scale dispersion in aquifers is understood to be scale dependent, where the magnitude of the dispersion coefficient is observed to be larger at larger scales of mass transport. This phenomenon is a result of larger plumes capturing progressively larger scales of heterogeneity (not represented in the flow modelling) which may lead to progressively larger spreading of the plume. Relationships between reported estimates of dispersivity and the field scales of investigations were reviewed critically by Gelhar et al. (1992). Results from the Gelhar et al. review (Figure 7-1) can be used to provide guidance on reasonable choices of values for these transport parameters. Thus, for a plume of scale 1 to 10 km existing estimates of longitudinal dispersivity are typically 10 to 100 m and estimates of horizontal transverse dispersivity are typically 1 to 10 m.

As a rule-of-thumb, the value of longitudinal dispersivity should not be much less than the typical length dimension of the model cells. Smaller values of dispersivity may cause numerical instabilities and failure of the simulation.

Larger values of dispersivity can also be regarded as conservative as they tend to enhance the size of the contamination plume. For the simulation a longitudinal dispersivity of 100 m and transverse and vertical dispersivity of 10 m was chosen. The effect of variation of dispersivity on the transport predictions is considered in the sensitivity analysis.

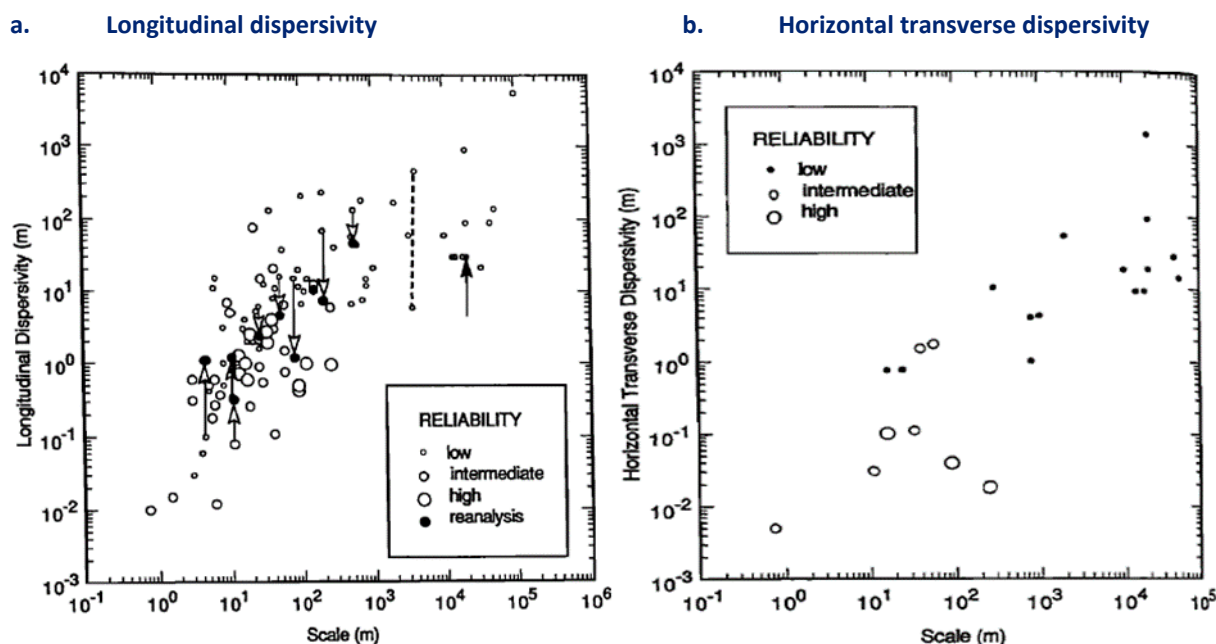


Figure 7-1 Field-scale Dispersivity Values (after: Gelhar et al. 1992)

7.2.3 Boundary Conditions

The release of contamination is controlled by a constant concentration boundary condition (BC). The constant concentration boundary condition acts as a contaminant source providing solute mass to the model domain in the form of a known concentration. The constant concentration BC is defined on layer 1 across the model nodes representing the CDA, CDB, PPD and LMD (Figure 7-2). The constant concentration is defined directly at the water table (in layer 1).

This is a conservative assumption, as the delay and attenuation represented by the transfer through the unsaturated zone is assumed to be instantaneous. It should be noted that the model does not account for potential water table mounding associated with seepage beneath the respective dams. Dams are HDPE lined, and through this approach it is expected that this will minimise leakage, with the dams to be decommissioned at the end of operations.

For a conservative approach, the sources of contamination from the dams are assumed to persist post-mining operation and for the whole simulation (running for the 12 years of mining operation and 220 years post-mining). As previously stated, it is understood that the source of contamination to the water table will progressively falter following the site rehabilitation and consequently that the predicted long-term plume is suitable for the impact assessment as it provides a clear overestimation of the potential contamination.

The constant concentration BC representing the source of contamination associated with the underground workings is defined at all the nodes that are representing the underground mine across layer 2 to 5. For the backfilling of the mine workings, the source of contamination is also assumed constant in time for the duration of the whole simulation. It is conservative as it assumes no exhaustion of the contamination potency of the backfill materials or exposed rock.

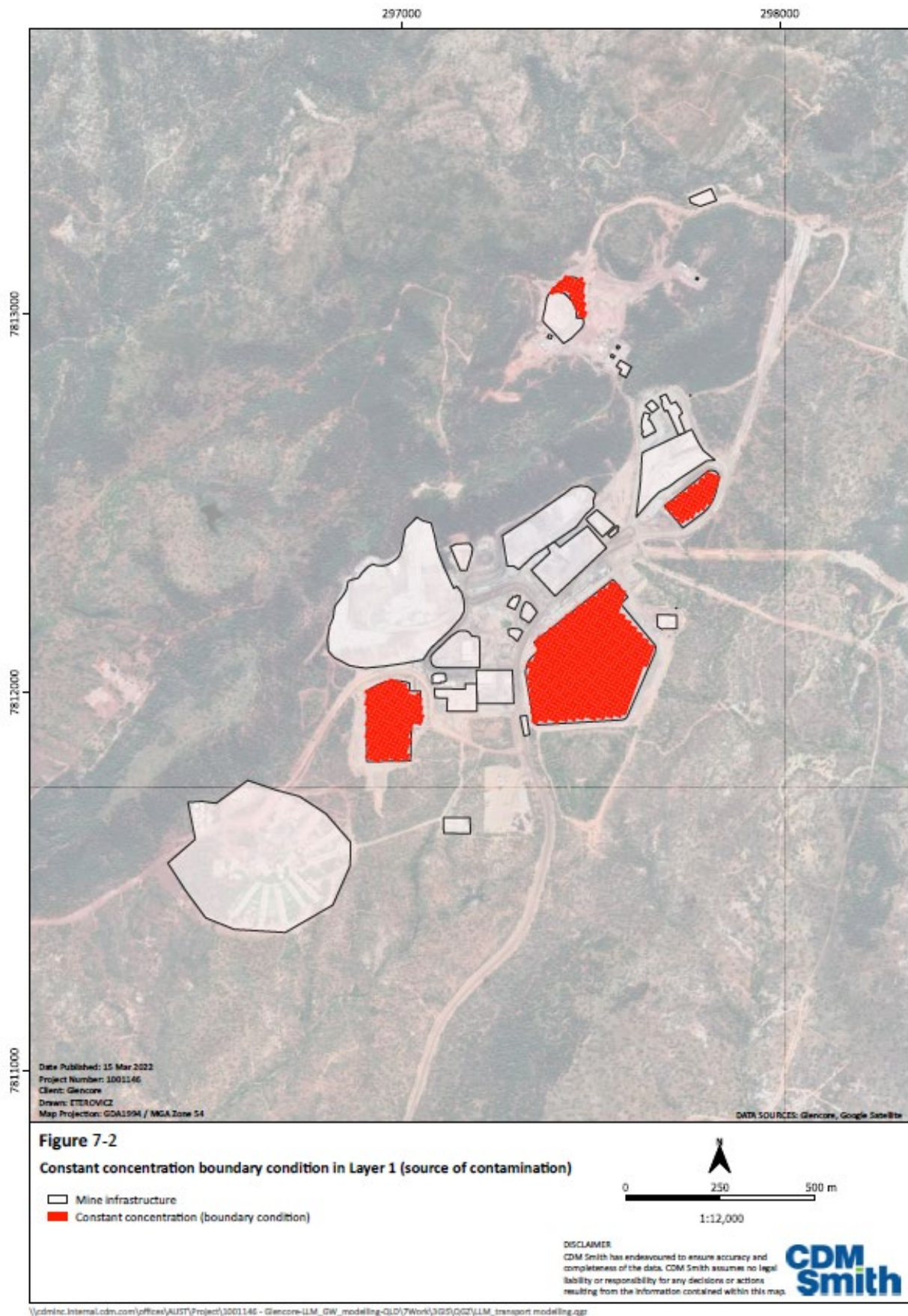


Figure 7-2 Constant Concentration BC in Layer 1 (source of contamination)

7.3 Model Results

The predictive simulation of mass transport uses the flow field from the calibrated groundwater flow model. The initial condition for the transient calibration, is provided by the first steady state stress period representing the aquifer in pre-mining condition (no contaminant is released during the pre-mining condition as background concentrations are assumed to be nil). As a normalised contamination transport was assumed, the modelling results represent the concentration as a percentage of the source concentration.

At 220 years post-mining, the concentration of any contaminant 300 m away from the sources is predicted to be less than 10% of the source concentration (Figure 7-3). For the mine workings, after 220 years, no contamination higher than 10% of the source concentration is predicted beyond 500 m of the mine.

At approximately 1,000 years post-mining, the 10% of source concentration limit is predicted to move around 20 m further from the source (Figure 7-4 to Figure 7-6) reflecting of the limited displacement within the aquifer once pre-mining condition have been re-established, which occurs approximately 200 years post-mining.

According to Glencore's internal LLM Detailed Closure Plan once the dams are no longer required during the rehabilitation process they will be decommissioned and rehabilitated subject to final landowner or third party user agreements (LLM, 2021a). As the containment dams are regulated structures under the environmental authority, each will require a decommissioning plan (LLM, 2021a). The regulated dams will be decommissioned with LMD planned for decommissioning in 2028 and the remaining regulated dams are planned for decommissioning in 2044.

As noted earlier the transport model method and approach is considered conservative. The sources of contamination from the dams are assumed to persist post-mining operation and for the whole simulation (running for the 12 years of mining operation and 220 years post-mining). However, this is highly unlikely to be realistic and the decommissioning will result in the structures not being present for the time period 220 years post mining.

Under these conservative modelling assumptions, at 220 years post-mining, the concentration of any contaminant will be less than 300 m away from the sources is predicted to be less than 10% of the source concentration and less than 350 m away from the sources is predicted to be less than 5%

7.4 Model Results Interpretation

The transport modelling does not discuss COCs individually and it is assumed that all COCs will behave similarly as a constituent in the model. The table below shows the normalised transport approach calculation for four common COCs: sulphate, cobalt, lead and zinc for each containment dam at 5% of initial concentration.

Table 7-2 CDA Water Quality Results (COCs)

Analyte	Units	Mean initial concentration	5% of mean initial concentration
Sulfate	mg/L	3116.0	155.8
Cobalt	mg/L	0.22	0.01
Lead	mg/L	0.36	0.02
Zinc	mg/L	24.9	1.2

Table 7-3 CDB Water Quality Results (COCs)

Analyte	Units	Mean initial concentration	5% of mean initial concentration
Sulfate	mg/L	8272.8	413.6
Cobalt	mg/L	2.6	0.13
Lead	mg/L	0.9	0.05
Zinc	mg/L	722.9	36.1

Table 7-4 PPD Water Quality Results (COCs)

Analyte	Units	Mean initial concentration	5% of mean initial concentration
Sulfate	mg/L	2798.7	139.9
Cobalt	mg/L	0.8	0.04
Lead	mg/L	47.2	2.36
Zinc	mg/L	186.6	9.3

Table 7-5 LMD Water Quality Results (COCs)

Analyte	Units	Mean initial concentration	5% of mean initial concentration
Sulfate	mg/L	14521.7	726.1
Cobalt	mg/L	4.33	0.22
Lead	mg/L	0.18	0.01
Zinc	mg/L	2494.6	124.7

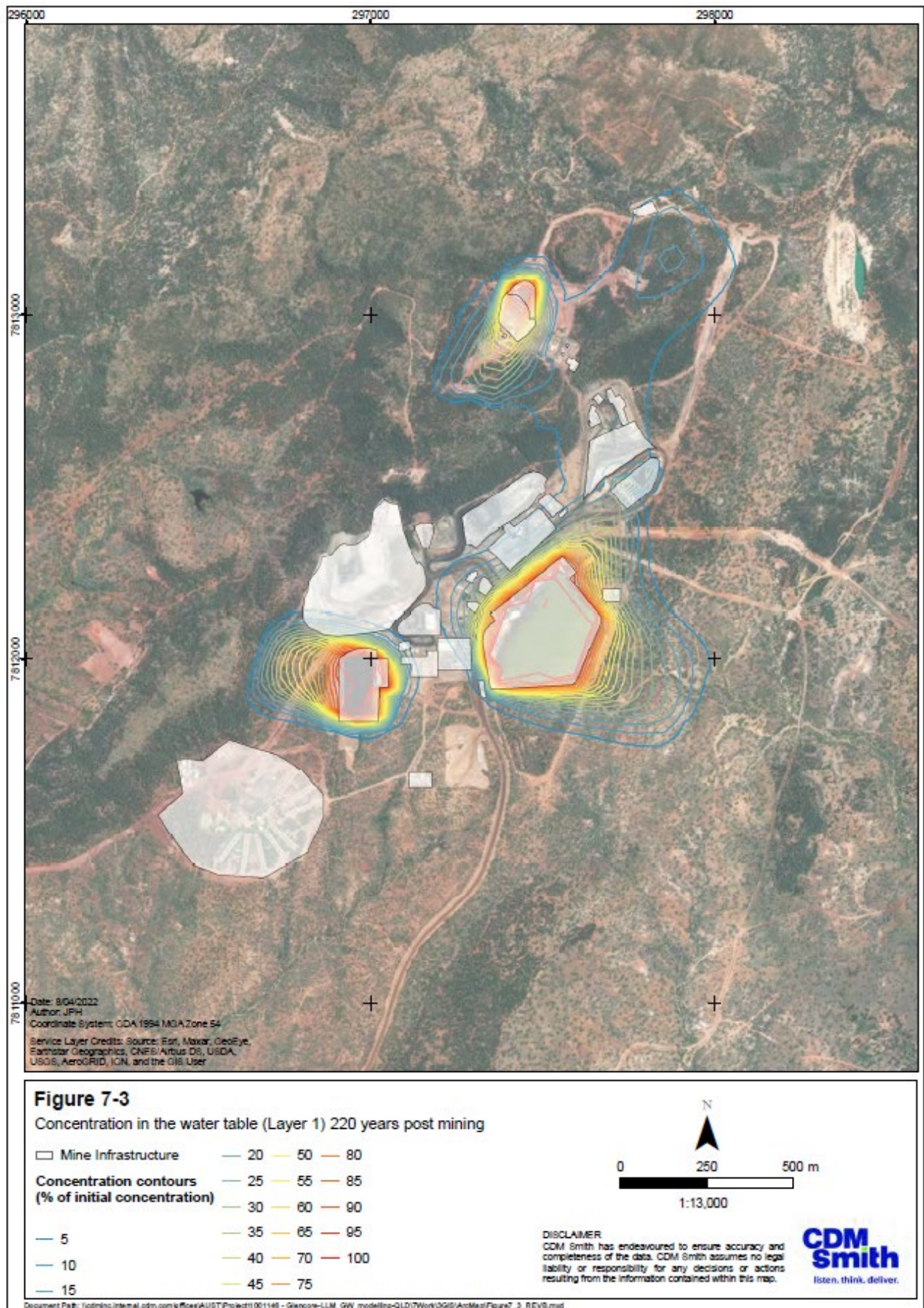


Figure 7-3 Predicted Concentration in the Water Table (Layer 1) - 220 years post-mining

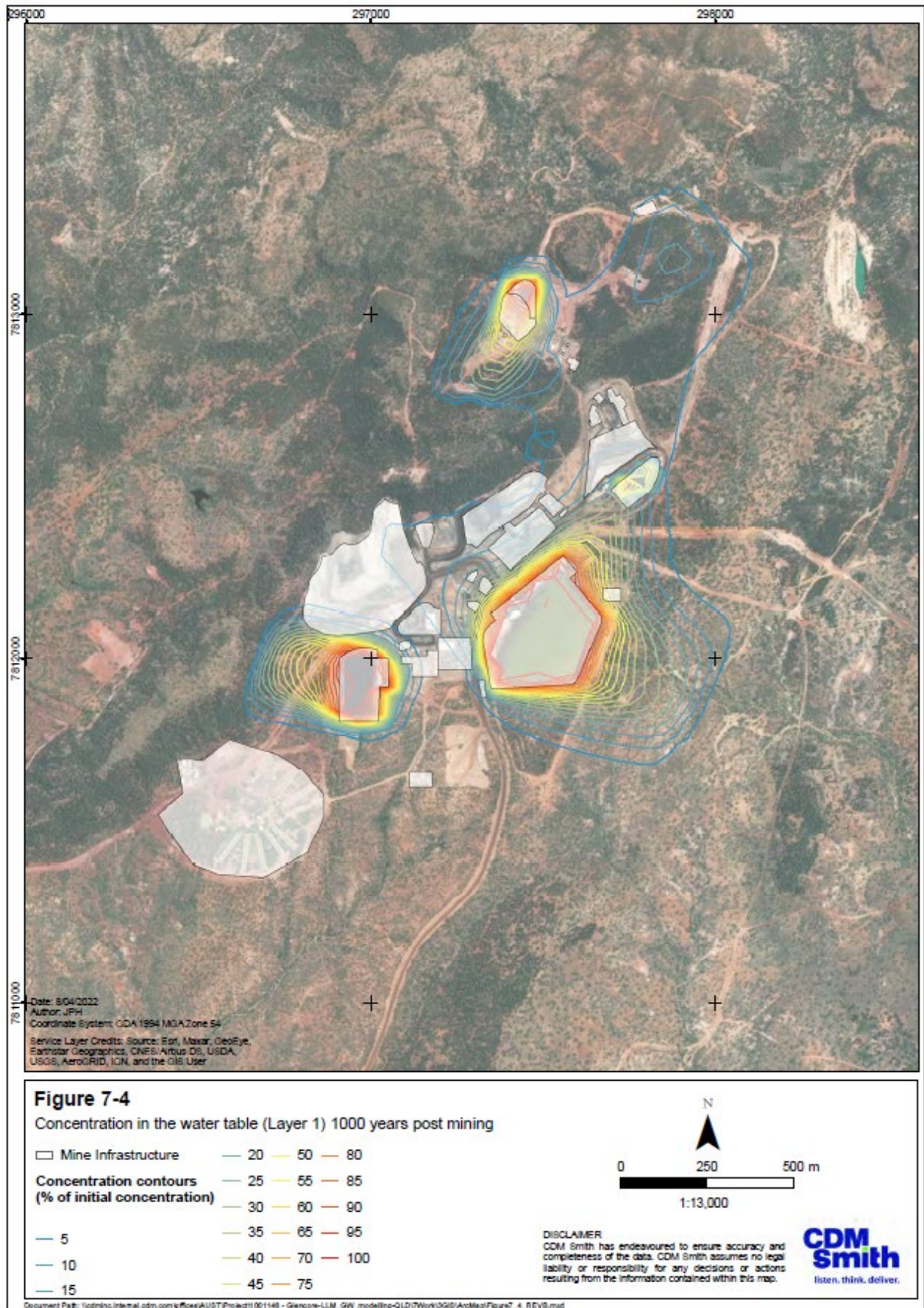


Figure 7-4 Predicted Concentration in the Water Table (Layer 1) - 1000 years post-mining

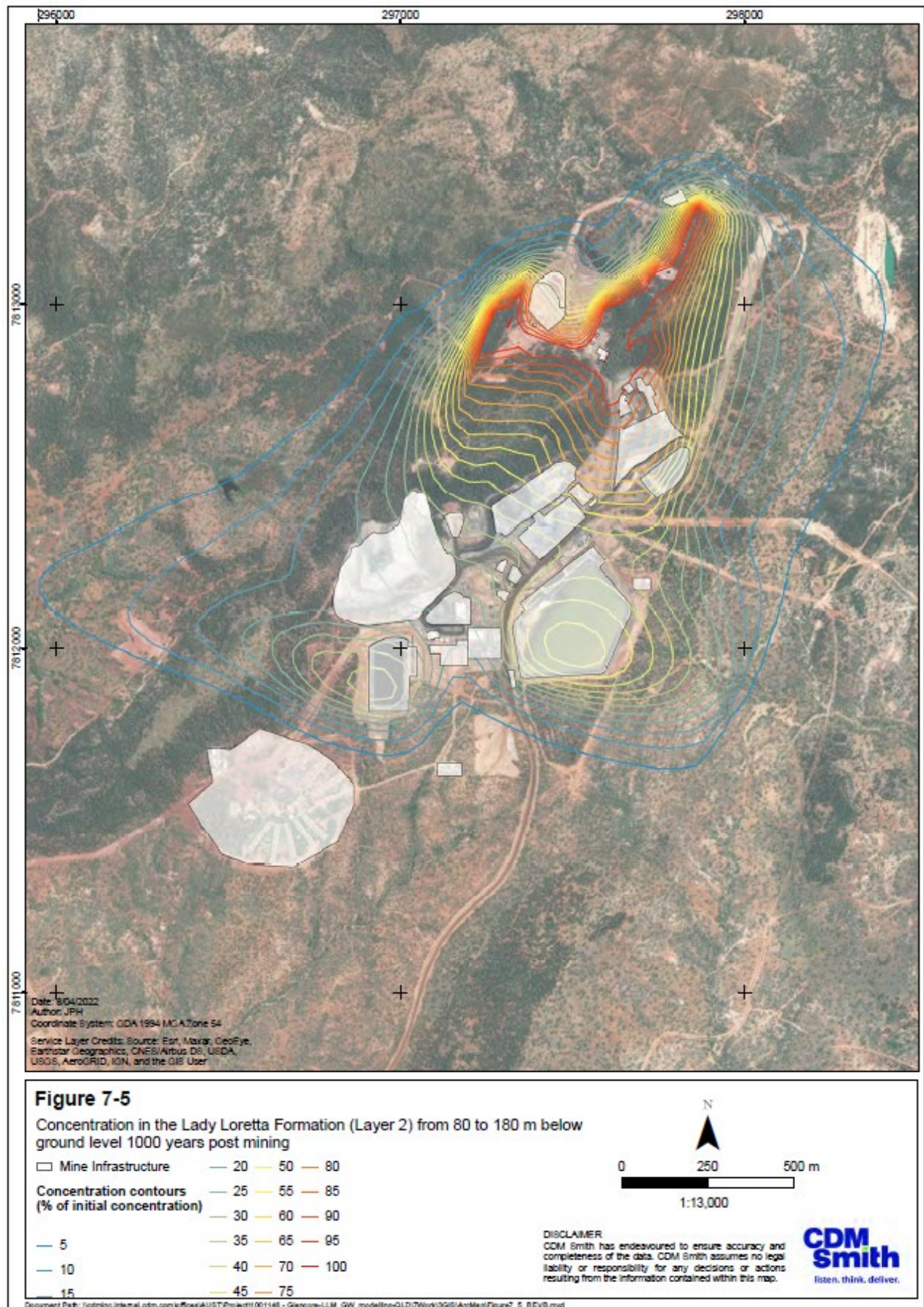


Figure 7-5 Concentration in the Lady Loretta Formation Between 80 to 180m Beneath Ground Level (layer 2)

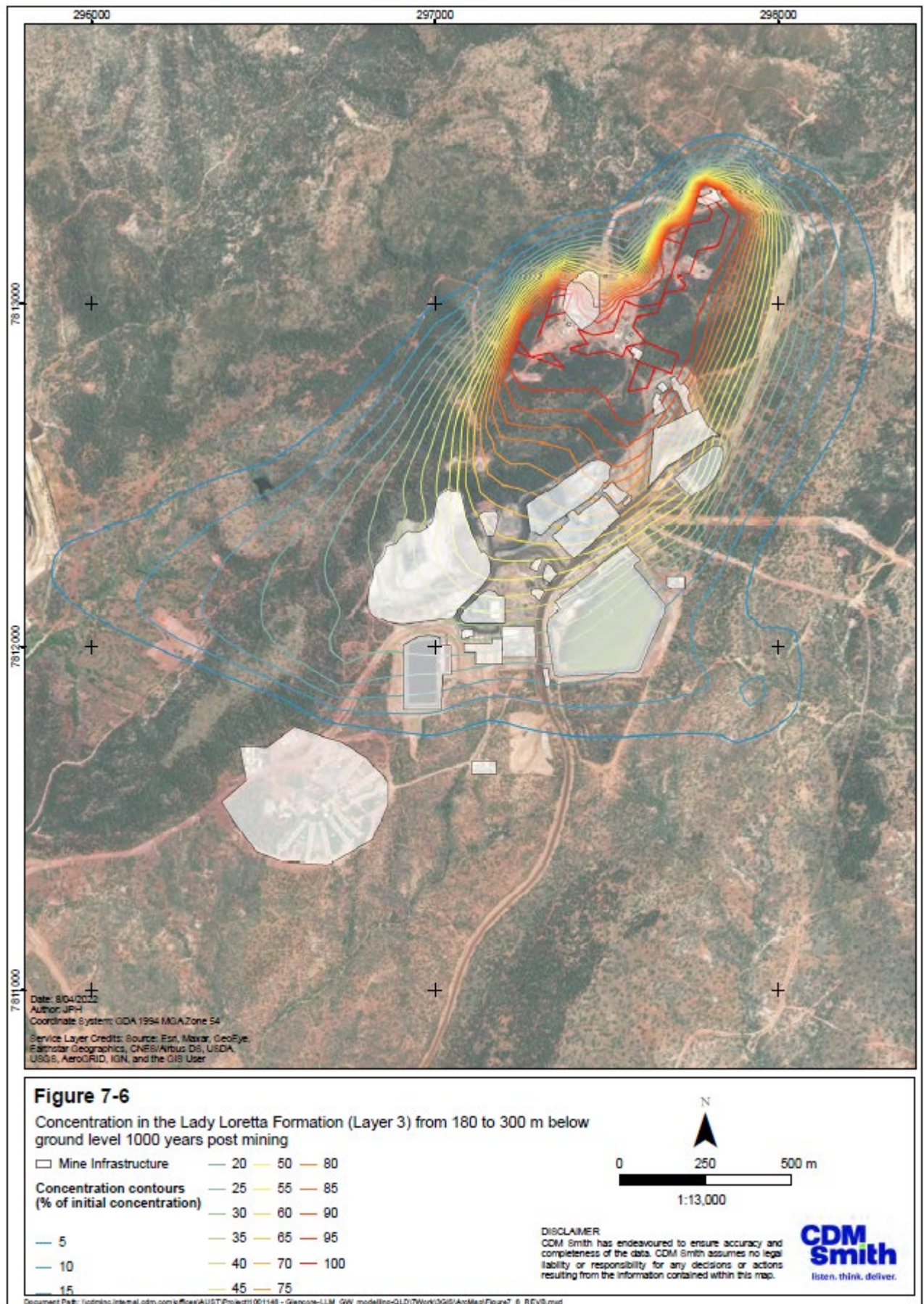


Figure 7-6 Concentration in the Lady Loretta Formation Between 180 to 300m Beneath Ground Level (layer 3)

7.5 Sensitivity Analysis

The sensitivity analysis explores the level of constraint of the model prediction and involves changing a model parameter (one at the time) to establish how the contamination propagation is affected by that change. Sensitive parameters generate a significant change while insensitive parameters generate little predictive change. The sensitivity analysis allows identification of which parameters are most controlling the propagation of the plume, and which would therefore require the most scrutiny to reduce predictive uncertainty. Insensitive parameters indicate that parameter error is of limited consequence.

Three sensitivity scenarios were designed and the method of varying parameters for the sensitivity analysis is summarised in Table 7-6. As the adopted dispersivity parameters are conservative, the sensitivity run explores the influence of lower dispersivity parameters (Sensitivity scenario 1) and no dispersivity (sensitivity scenario 2). The reference scenario assumed that the transport of contaminant uses the same pore spaces than flow, and the sensitivity scenario 3 explores the influence of lesser pore space for contaminant movement than for water flow. Results of the sensitivity analysis are illustrated in Figure 7-7. The analysis shows that a reduced dispersivity parameter considerably reduces plume propagation. No sensitivity scenario with a higher value of dispersivity was selected because the reference model scenario adopted a conservative value of dispersivity (overestimated). Sensitivity 3 scenario also shows a reduced plume propagation than the reference scenario.

Table 7-6 Sensitivity Run Parameters

Parameter	unit	Reference run	Sensitivity 1	Sensitivity 2	Sensitivity 3
Longitudinal dispersivity	m	100	10	No dispersivity	100
Transversal dispersivity	m	10	1	No dispersivity	10
Vertical dispersivity	m	10	1	No dispersivity	10
Porosity	-	Sy (Calibrated array ¹)	Sy (Calibrated array ¹)	Sy	0.8 x Sy

Note: 1. Sy is heterogeneous

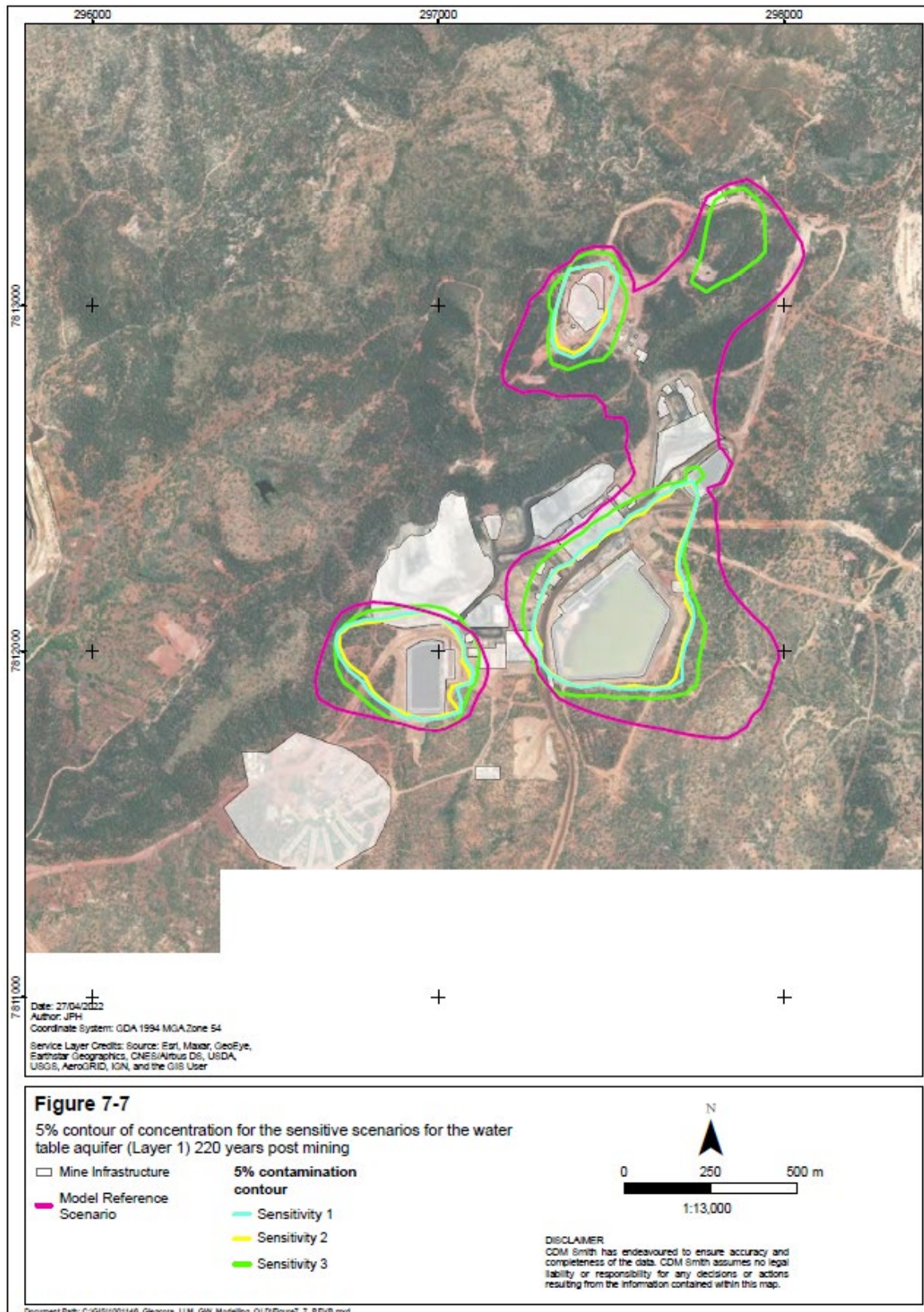


Figure 7-7 5% contour of contamination for the sensitive scenarios for the water table aquifer (Layer 1) (under conservative modelling assumptions)

Section 8 Evaluation of Potential Impacts to GW Resources

The likelihood of adverse impact on receptors is considered low given the current understanding of potential pathways identified and modelling results, namely:

- The major faults (Carlton Fault and Western Border Fault) are considered to exert a major control on flow patterns in the topography driven hydrogeological system. The water quality suggests a level of compartmentalisation in the Lady Loretta block and in the vicinity of the underground workings. This intra-block compartmentalisation, particularly in the vicinity of the underground workings is a key finding in relation to closure planning. The transport contamination plume is fully contained within the compartmentalisation in the Lady Loretta block.
- The regional groundwater flow fields appear to follow the topography in a subdued manner and the model contaminant plume propagation shows a dispersion in all directions from the various sources of contamination with a preferential extension toward the west in the regional flow gradient toward the Lady Annie pit. After 220 years post-mining, the concentration of any contaminant 300 m away from any of the sources is predicted to be less than 10% of the source concentration. At 1,000 years post-mining, the predicted plume extent remains little changed from that predicted 220 years post-mining.
- The transport model is highly conservative. The decommissioning will result in the dams not being present for the time period 220 years post mining. Under these conservative modelling assumptions, at 220 years post-mining, the concentration of any contaminant will be less than 300 m away from the sources is predicted to be less than 10% of the source concentration.
- The dams construction are not captured in the model development. There is no evidence to show there is any contamination coming from the surface water dams, storage facilities or stockpile area so the contribution from this source is extremely conservative. The dam construction consists of CDA, CDB and PPD being HDPE lined and LMD is GCL lined.
- EVs (stockwatering or ecological) have not been identified within the predicted transport model plume extent considering the current groundwater use.
- It should be noted that for future groundwater use:
 - Current water quality indicates that untreated groundwater is unsuited to the following uses – drinking water, stock water and industrial applications.
 - In order for future users to access groundwater, approval will need to be sought from the appropriate regulatory authority prior to accessing groundwater.
 - The absence of current groundwater users in the area (no bores within 5km, with the exception of the current LAE borefield) would indicate that accessing groundwater for use is not preferred by local stakeholders, with other water supply options (rainfall dams, surface water etc) in use for local supply.
- No groundwater receptors have been identified to date in the course of this study, with no known or identified registered water supply stock or domestic bores within 5 kilometres of the LLM site (outside of the to be decommissioned LAE borefield). Given the sites location and considering the points above future use of groundwater at the site is considered unlikely at this time.

Considering the above, while within the pre closure setting, pathways to receptors exist, the hydrogeological controls of COC from the sources is such that the likelihood of that pathway being realised is low. Therefore, the potential likelihood of impact to groundwater receptors is considered to be low. From a closure perspective, and considering the rehabilitation plan for the site, it is expected that EV exposure to potential COCs will also be low.

Section 8 Evaluation of Potential Impacts to GW Resources

Given the fact that the dam construction consists of CDA, CDB and PPD being HDPE lined and LMD is GCL lined and there is no evidence to show there is any contamination coming from the surface water dams, storage facilities or stockpile area the closure strategy risk is expected to be even lower, and could be considered as a no risk situation.

In summary, given the current understanding of groundwater flow, containment dam management, EVs (potential GDEs) and absence of nearby groundwater users, there is a low risk of potential impact. A conceptual cross section summarising these findings is shown in Figure 8-1 based on the available hydrogeological information, numerical model results and solute transport model results to illustrate the groundwater situation as it is currently understood.

Section 8 Evaluation of Potential Impacts to GW Resources

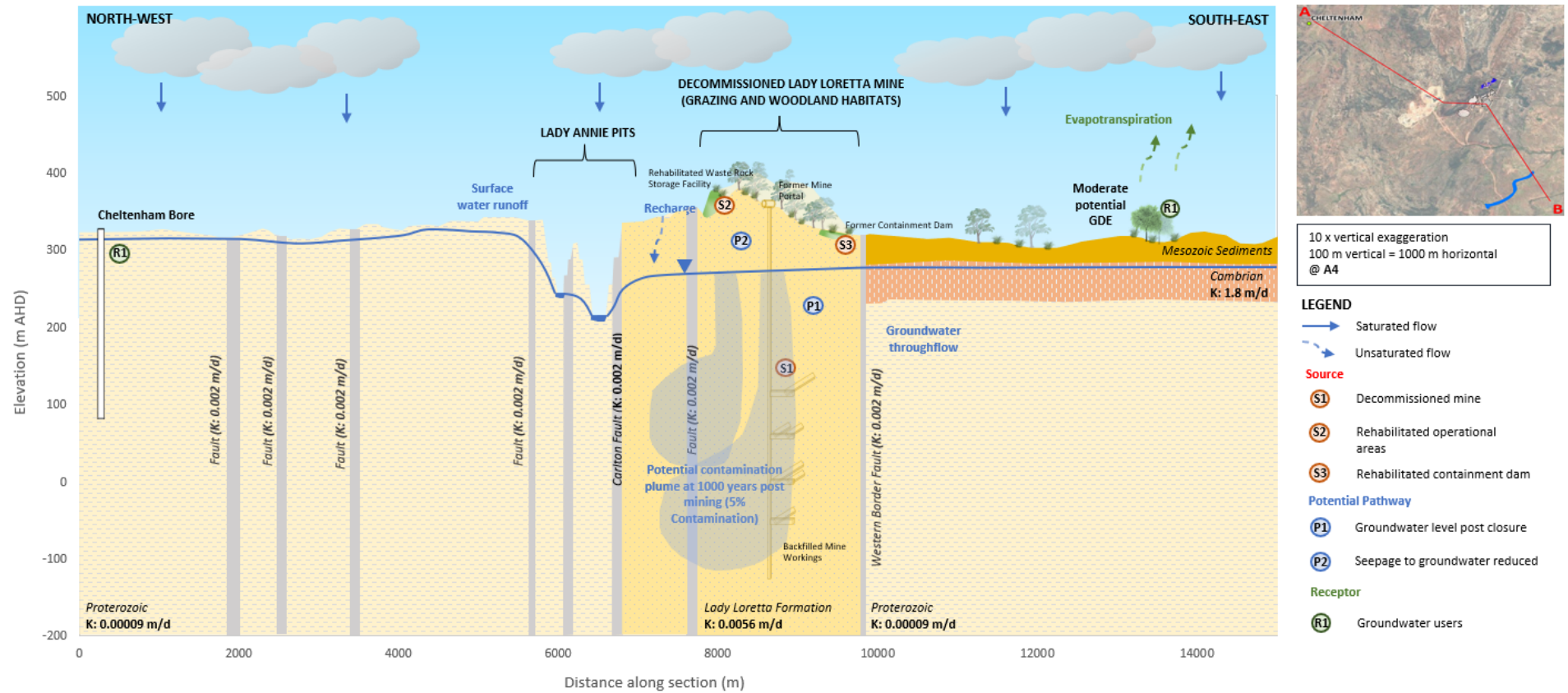


Figure 8-1 Conceptual Model – Post Closure showing Solute Transport Model Results and Receptors

Section 9 Conclusions

9.1 Conceptual Model

The conclusions for the Conceptual Model are listed below:

- The major faults (Carlton Fault and Western Border Fault) are assumed to exert a major control on flow patterns in the topography driven hydrogeological system. The Western Border Fault divides the LLM sulfide ore bearing zone from the less deformed Cambrian Block to the east, while the Carlton Fault separates the Lady Loretta Block from the Paleoproterozoic Block to the west. The major Carlton Fault Zone truncates the syncline to the north-west. The Carlton Fault is associated with extensive zones (up to 200m wide) of shearing and brecciation.
- Cambrian Block hydrostratigraphy hydraulic conductivity values range from 2.5 to 123 m/day, whilst Lady Loretta Block hydrostratigraphy permeability values are low ranging from around 0.001 to 0.25 m/day. There is minimal hydrostratigraphy information and permeability data for the Paleoproterozoic Block and representative values for the lithology are likely in the range 0.001 m/day. Regardless of the hydraulic properties of the Western Boundary Fault, the hydraulic conductivity contrast between the Cambrian and Lady Loretta Blocks will influence the distribution of hydraulic gradients across the fault.
- There has been identified a hydraulic gradient towards the LAE borefield and to the LLM site. Overall, on the Lady Loretta Block there is evidence of localised groundwater flow towards LLM due to dewatering within the underground mine workings. A cone of depression has developed, drawing groundwater toward the central part of the site operations.
- The chloride concentration in groundwater across the site indicates locally differing recharge rates within the block, and these concentrations are preserved, indicating a degree of flow compartmentalisation within the Lady Loretta Block at least. The compartmentalisation seen in the Lady Loretta block is also exhibited in the Proterozoic Block, showing this intra-block compartmentalisation is not unique to Lady Loretta and is occurring at a regional scale (Appendix A: Evans, 2022).
- The sulphate findings at Lady Loretta also suggest compartmentalisation as well as informing the distribution of sulphidic mineralisation within the bedrock and this could be considered compartmentalised in the vicinity of the underground workings. This intra-block compartmentalisation, particularly in the vicinity of the underground workings is a key finding in relation to closure planning.
- From a regional perspective there is little evidence from the water quality study to support broad scale mixing between groundwaters from different geological Blocks in the vicinity of the Lady Loretta mine, considering the results of the major ion chemistry assessment completed. Differing concentration of metals further emphasises the difference between groundwater in the Cambrian Block compared to groundwater from the other Blocks.
- There is insufficient data to definitively determine how the faults may influence fluid flow based on the desktop assessment works completed (considering active dewatering in the study area). However, numerical modelling approaches were used to further assess fault behaviour, and are summarised below.

9.2 Groundwater Numerical Model

The original groundwater model (AGE, 2015) was upgraded to the LLM2021 model with the following key highlights:

- The modelling platform was upgrade from the legacy code MODFLOW-SURFACT to MODFLOW-USG that is technically more robust and accessible.
- The model hydrostratigraphy was updated based on insights from the Leapfrog geological model. In particular, the Lady Loretta Formation is represented in the LLM2021 model as a separate hydraulic property zone that is extended to all model layers.

- The Lady Annie pit was implemented in the LLM2021 model using the MODFLOW Drain Package.
- This study used a stochastic approach to develop 100 different possible combinations of hydraulic parameters that are fitted to the field observations. This approach better addresses the issue of non-uniqueness and enables probabilistic predictions and a more robust uncertainty analysis.

The key findings from this modelling work include:

- One key knowledge gap is the hydraulic properties of the faults. Through PESTPP-IES, the conceptualisation of faults was initially randomised. For a given fault, some realisations conceptualised the fault as a barrier to groundwater flow (i.e. low K) while some other realisations conceptualised the fault as a conduit (i.e. high K). After fitting to the field observations, these realisations converged to the conclusion that the faults are generally more permeable than the Proterozoic and less permeable than the Cambrian, and the fault permeability is generally in the same order of magnitude as the Lady Loretta Formation permeability. The faults do not act as impermeable barrier and likely have low permeability.
- Groundwater level at the LLM is predicted to be as low as -2 m AHD at the end of future dewatering, with the majority of drawdown impact limited to the Lady Loretta Formation. After more than 200 years into the future, the cone of depression caused by the LLM mining is predicted to be completely dissipated, with a groundwater level of approximately 280 m AHD in the vicinity of the former mine. In comparison, the Lady Annie pit is predicted to behave as a local groundwater sink where the groundwater level can be as low as 214 m AHD. The regional groundwater flow fields appear to follow the topography again.

9.3 Solute Transport Model

The transport modelling conducted in this assessment was designed conservatively, and it provides an overestimation of the contamination movement or propagation. The model conservative assumptions include:

- Neglecting the adsorption and degradation processes that would reduce the contamination propagation.
- A constant release of contamination within the aquifer during the whole modelling period.
- Neglecting transport through the unsaturated zone and assuming a contamination release directly in the groundwater aquifer.
- Extensive zone of contamination release within the underground galleries.
- Conservative dispersive and porosity parameters.
- A coarse grid discretisation tending to numerically overestimate dispersion.
- There is no evidence to show there is any contamination coming from the surface water dams, storage facilities or stockpile area so the contribution from this source is extremely conservative.
- One non-conservative assumption concerns the water table mounding that would be generated by seepage from the respective dams. Though, this assumption is not likely to outweigh the other conservative assumptions and the results are therefore still conservative.

The resulting contamination propagation shows a dispersion in all direction around the various source of contamination with a preferential extension toward the west in the regional flow gradient toward the Lady Annie pit. Under these conservative modelling assumptions, at 220 years post-mining, the concentration of any contaminant 300 m away from the sources is predicted to be less than 10% of the source concentration. For the mine workings, after 220 years, no contamination higher than 10% of the source concentration is predicted beyond 500 m of the mine. At approximately 1000 years post-mining, the 10% of source concentration limit is predicted to move around 20 m further from the source reflecting of the limited displacement within the aquifer once pre-mining condition have been re-established.

According to Glencore's internal LLM Detailed Closure Plan once the dams are no longer required during the rehabilitation process, they will be decommissioned and rehabilitated subject to final landowner or third-party user agreements (LLM, 2021a). As part of the LLM closure strategy, the regulated dams will be decommissioned. LMD is planned for decommissioning in 2028 and the remaining regulated dams are planned for decommissioning in 2044.

The transport model method and approach is conservative. The sources of contamination from the dams are assumed to persist post-mining operation and for the whole simulation (running for the 12 years of mining operation and 220 years post-mining). However, this is highly unlikely to be realistic and the decommissioning will result in the dams not being present. Under these conservative modelling assumptions, at 220 years post-mining, the concentration of any contaminant will be less than 300 m away from the sources is predicted to be less than 10% of the source concentration.

9.4 Groundwater Summary

- The major faults (Carlton Fault and Western Border Fault) are considered to exert a major control on flow patterns in the topography driven hydrogeological system, with flow across the faults considered limited.
- The nature of these fault controls at the regional scale has been confirmed via water quality/chemistry analysis results, and are also confirmed via numerical model findings that the faults do not act as impermeable barrier and likely have low permeability. In support of this interpretation there is little evidence from the water quality study to support broad scale mixing between groundwaters from different geological blocks further demonstrating the low permeability of the faults.
- Overall, on the Lady Loretta Block there is evidence of localised groundwater flow towards LLM due to dewatering within the underground mine workings. This dewatering together with other aquifer stresses creates difficulties in further assessing fault control on groundwater flow, hence the reliance on hydrochemistry and numerical modelling outcomes to characterise the fault flow regime and conclude the faults likely have a low permeability.
- The hydrochemistry assessment works also indicates locally differing recharge rates within the LL block, and these concentrations are preserved, indicating a degree of flow compartmentalisation within the Lady Loretta Block. This intra-block compartmentalisation, particularly in the vicinity of the underground workings is a key finding in relation to closure planning.
- Numerical modelling outputs also support this intra-block compartmentalisation, and help constrain drawdowns and also recovery. After more than 200 years into the future, the cone of depression caused by the LLM mining is predicted to be completely dissipated.

9.5 Potential Impacts Summary

- Environmental Values and a source pathway receptor assessment indicate that:
 - There are no listed Groundwater Dependent Ecosystems mapped in the area or within 10 kilometres of LLM. There are no known or identified registered water supply, stock or domestic bores within 5 kilometres of the LLM site (outside of the LAE borefield).
 - The LAE borefield provides groundwater for industrial use / potable supply (following processing) for the LLM and Lady Annie Mine. This borefield is planned for decommissioning as part of the mine closure.
 - For future groundwater use the current water quality indicates that untreated groundwater is unsuitable as a water supply and approval will need to be sought from appropriate stakeholders prior to any future access to groundwater. In addition, the absence of current groundwater users in the area would indicate that accessing groundwater for use is not preferred by local stakeholders, with other water supply options (rainfall dams, surface water etc) in use for local supply.

- Routine groundwater monitoring will continue to be conducted for a period of time to build a dataset that provides statistically valid trends. This will allow measurement of groundwater level recovery and water quality for comparison against the groundwater model predictions.
- Environmental risk at the site is governed by potential seepage of contaminated mine waters to underlying groundwater from mine water management infrastructure including dams, ROM pad and AMD from waste rock emplacements, legacy PAF dumps and management dams. Closure planning approaches intend for mine water management infrastructure to be decommissioned and sites rehabilitated, leaving no ongoing risks from these structures. Legacy seepage at depth beneath these structures may still be present following closure. However, the nature of dam construction and the use of liners, as well as operational controls such as leak detection monitoring limit the potential for undetected seepage to occur during operations. Primary COCs typically are elevated sulphate concentrations and total metals concentrations including aluminium, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, zinc and iron.
- Primary pathways connecting COCs to groundwater are through water inflows into the underground workings or surrounds from surface (seepage) and vertical or lateral migration of solutes from the underground workings to external groundwater.
- Post closure the risk profile in regards to groundwater and groundwater receptors is considered low as:
 - Mine infrastructure will be decommissioned and removed, with the site rehabilitated as needs, thereby removing the majority of contaminant sources.
 - Potentially contaminated groundwater flows into the mine workings/surrounding area/from the mine workings into the local aquifer will be reduced with COC sources removed.
 - There are no recognised receptors in relation to groundwater in the vicinity of the site.
- Considering the above, the consequence of potential impact to groundwater receptors is considered to be low. From a closure perspective, and considering the rehabilitation plan for the site, it is expected that EV exposure to potential COCs will also be low.
- Given the fact that the dam construction consists of CDA, CDB and PPD being HDPE lined and LMD is GCL lined and there is no evidence to show there is any contamination coming from the surface water dams, storage facilities or stockpile area the closure strategy risk is expected to be even lower.

In summary, given the current understanding of groundwater flow, the conceptual and numerical modelling works completed, current and potential future EVs and absence of nearby groundwater users, proposed containment dam management, and the outcomes of solute transport modelling it can be concluded that there is a low risk of potential environmental impact at this time in relation to LLM following post closure decommissioning and rehabilitation activities.

Section 10 Limitations

The limitations of the study are outlined below:

- The exact location of the Carlton and Western Border fault is uncertain, and there is some uncertainty on the location, depth, direction and thickness of the faults.
- There is insufficient fault testing data or information to inform the Carlton and Western Border fault behaviour and permeability.
- Carlton and Western Border fault behaviour has been inferred based on groundwater head assessment and chemistry analysis completed as part of this scope.
- Assumptions were made on the formation locations and thicknesses for the Lady Loretta Block, Cambrian Block, and the Paleoproterozoic Block due to limitations in the available geological data provided.
- There are only two groundwater monitoring bores located in the Paleoproterozoic Block west of LLM and the Carlton Fault.
- The authors did not have access to accurate monitoring data or information available for the Lady Annie Mine. The assessment does not consider or include data or information on groundwater quality from the Lady Annie Mine.
- The Lady Annie Mine Closure Plan or Current Operations Plan is unknown to the authors. The numerical groundwater model and solute transport model includes the Lady Annie open cut pit and the location is predicted to behave as a local groundwater depression.
- The major limitation is the constant mining extent and elevations that were used for the calibration due to the lack of timing information.
- The 100 model realisations are unlikely to capture all the possibilities. The stochastic approach of using 100 model realisations is superior to the traditional deterministic approach where only one model is used, and these 100 model realisations provide useful insights into the predictive uncertainty and hydraulic properties of the faults.
- The water quality dataset is considered to be of a limited quality for this type of assessment, with inconsistent data collection periods, as well as periods within the time period though which no data was collected. Also of note is that water quality data was limited along the Carlton Fault, and this impacted hydrochemistry informing the conceptualisation in this area.
- The location of monitoring bores also influences the water quality assessment, as bores located in more distal locations from faults are less likely to present with clear geochemical signatures demonstrating connection between the relevant blocks through the faults.
- The numerical groundwater model and solute transport models are built on provided and specified dates for the mine operations, dewatering actives and backfill operations. Changes in the closure planning including dates, dewatering periods may result in changes to the model results.
- The transport model is highly conservative. The transport model does not include dates of the dam rehabilitation or decommissioning. The rehabilitation and decommissioning will result in the dams not being present. In addition, the dam construction details such as the HDPE and GCL liner are not included in the transport model development and results.

Section 11 Disclaimer

This report has been prepared by CDM Smith Australia Pty Ltd (CDM Smith) at the request of Glencore Australia for the purpose of assisting in closure planning and contaminant management.

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If further information becomes available, or additional assumptions need to be made, CDM Smith reserves its right to amend this report.

Section 12 References

- Australasian Groundwater and Environmental Consultants (AGE), 2015. Lady Loretta Model Update, Project G1656A. Prepared for Rob Lait and Associates Pty Ltd. August 2015.
- Australasian Groundwater and Environmental Consultants (AGE), 2020. Hydrogeological Conceptual Model 2020 Update. Prepared for Glencore. September 2020.
- Australasian Groundwater and Environmental Consultants (AGE), 2021. Lady Loretta Mine Drilling Observation. August 2021.
- Bakker, M. et al., 2016. Scripting MODFLOW model development using Python and FloPy. *Groundwater*, 54(5): 733-739.
- Barnett, B. et al., 2012. Australian Groundwater Modelling Guidelines, Waterlines report, National Water Commission, Canberra.
- Bense, V.F., Gleeson, T., Loveless, S.E., Bour, O., Scibek, J., 2013. Fault zone hydrogeology. *Earth-Science Rev.* 127, 171–192.
- Bower, H., & Rice, R. (1976). The Bower and Rice slug test - an update. *Groundwater*, no.3, 304-309.
- Bureau of Meteorology, 2012. National Groundwater Dependent Ecosystems (GDE) Atlas. Bioregional Assessment Source Dataset. Viewed November 2021.
- Childs, C., Manzocchi, T., Walsh, J.J., Bonson, C.G., Nicol, A., Schöpfer, M.P.J., 2009. A geometric model of fault zone and fault rock thickness variations. *J. Struct. Geol.* 31, 117–127.
- DIP, 2010. North West Regional Plan. Planning for a stronger, more liveable and sustainable community. August 2010.
- DNRM, 2018. Mammoth Mines Surface Geology Sheet 6758 Compilation Map, Australia 1:100000 Geological Compilation Series.
- Doherty, J.E., Fienen, M.N., Hunt, R.J., 2010. Approaches to highly parameterized inversion: Pilot-point theory, guidelines, and research directions. US Geological Survey scientific investigations report, 5168: 36.
- Domenico, P.A. and F.W. Schwartz, 1990. *Physical and Chemical Hydrogeology*, John Wiley & Sons, New York, 824 p.
- Douglas Partners, 2007. Report on Long-term Yield Assessment for the Lady Annie East Borefield Lady Loretta Project via Mt Isa, Northwest Queensland. A report commissioned by Noranda Pacific Pty Ltd. June 2007.
- Douglas Partners, 2012. Development of a Dewatering Strategy & Groundwater Management Plan for Lady Loretta Mine Project. 79899.00. Report prepared for Xstrata Zinc. July 2012.
- DSD, 2018. Preparation of a program for environment protection and rehabilitation (PEPR) for metallic and industrial minerals (excluding coal and uranium) in South Australia. Minerals Regulatory Guidelines MG2b. Mineral Resources Division, Department for Energy and Mining, South Australia, Adelaide. August 2018.
- ESI, 2020. Guide to Using Groundwater Vistas version 8.
- Evans, R, 2022. Lady Loretta Mine Hydro-chemical Assessment. Salient Solutions Australia.
- Garven, 1995. Continental-scale groundwater flow and geologic processes. *Annual Review of Earth and Planetary Sciences*, V24, p89-117.
- Garven, G, Bull S, Hopkins, J, 1998. Numerical modelling of fluid flow systems in the McArthur Basin. University and the Centre for Ore Deposit Research.
- Gelhar L. W., Welty, C. and Rehfeldt K. R. 1992. A Critical Review of Data on Field-Scale Dispersion in Aquifers. *Water Resources Research*, 28(7), 1995-1974.

- Gillespie, P. a., Howard, C.B., Walsh, J.J., Watterson, J., 1993. Measurement and characterisation of spatial distributions of fractures. *Tectonophysics* 226, 113–141.
- Hancock, M.C., Purvis, A.H., 1990. Lady Loretta Silver-Lead-Zinc deposit: in Hughes F E (Ed.), *Geology of the Mineral Deposits of Australia & Papua New Guinea The AusIMM*, Melbourne Mono 14, v1, 943-948
- Hutton, L and Wilson, I, 1985. Mammoth Mines Region, Queensland 1:100,000 geological map
- LLM, 2021a. Lady Loretta Mine Detailed closure plan. Prepared by ERM.
- LLM, 2021b. Lady Loretta Mine, Z-LLM-OPS-PLN-Water Management Plan.
- Manewell, N., Doherty, J., 2021. Rapid Data Assimilation Using an Appropriately Complex Model, A GMDSI worked example report. National Centre for Groundwater Research and Training, Flinders University, South Australia.
- Mark, 1998. Gravity, Magnetic and Radiometric Evidence for the Geological Setting of the Lady Loretta Pb-Zn-Ag Deposit-A Qualitative Appraisal. *Economic Geology* Vol. 93, 1998, pp. 1295-1306.
- McCallum J., Simmons C., Mallants D., Batelaan O.2018. Simulating the groundwater flow dynamics of fault zones. National Centre for groundwater research and training.
- McConachie , B, Barlow, M, Dunster, J, Meaney, R, and Schaap, A, 1993. The Mount Isa Basin-definition, structure and petroleum geology. *Australian Petroleum Exploration Association (APEA) Journal*, V33, p237-257.
- McGoldrick, 1993a. DEPOSIT HALOS, Geology of the Lady Loretta deposit: review, new developments, and implications for ore genesis, in CODES: AMIRA/ARC Project P384 Proterozoic sediment-hosted base metal deposits. October 1993.
- Morris, D.A. and A.I. Johnson, 1967. Summary of hydrologic and physical properties of rock and soil materials as analyzed by the Hydrologic Laboratory of the U.S. Geological Survey, U.S. Geological Survey Water-Supply Paper 1839-D, 42p.
- Panday, S., 2019; USG-Transport Version 1.4.0: The Block-Centered Transport Process for MODFLOW-USG, GSI Environmental, [http:// http://www.gsi-net.com/en/software/free-software/USG-Transport.html](http://www.gsi-net.com/en/software/free-software/USG-Transport.html)
- Panday, S., Huyakorn, P.S., 2008. MODFLOW SURFACT: A state-of-the-art use of vadose zone flow and transport equations and numerical techniques for environmental evaluations. *Vadose Zone Journal*, 7(2): 610-631.
- Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., Hughes, J.D., 2013. MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation. 2328-7055, US Geological Survey.
- Rob Lait and Associates Pty Ltd (RLA), 2013. Lady Loretta Groundwater Investigation May - July 2013 – Briefing for Australasian Groundwater and Environmental Consultants Pty Ltd.
- Walsh, J.J., Watterson, J., 1988. Analysis of relationship between displacement and dimensions of faults. *J. Struct. Geol.* 10, 239–247.
- White, J.T., 2018. A model-independent iterative ensemble smoother for efficient history-matching and uncertainty quantification in very high dimensions. *Environmental Modelling & Software*, 109: 191-201.
- Valenta, R, 2018. NW Queensland Mineral Province Deposit Atlas Prototype Report, the Mount Isa and Ernest Henry Deposits. DNRME-GSQ Commissioned study and report.
- Xstrata, 2011. Xstrata Resources and Reserves Statement, as of 31 December 2011.
- Xstrata, 2012. Xstrata Resources and Reserves Statement, as of 31 December 2012.

Appendix A Lady Loretta Mine Hydrochemical Assessment

Salient Solutions Pty Ltd



Lady Loretta Mine

Hydrochemical Assessment

FINAL

4 March 2022

Ray Evans

Salient Solutions Australia Pty Ltd

For CDM Smith

Lady Loretta Mine Hydrochemistry

The following sets out an assessment of the hydrochemistry of the groundwater in and around the Lady Loretta Mine as an independent constraint on the site conceptualisation.

The objectives of this hydrochemical review and assessment include:

- Assessment of possible fault fracture groundwater connectivity between the Cambrian, Lady Loretta and Proterozoic blocks through application of hydrochemical analysis;
- Possible evaluation of the degree of connectivity/permeability between the blocks through the fault network that could be inferred by the hydrochemistry assessment findings;
- To evaluate the findings of the assessment relative to the hydrogeological conceptualisation and the numerical groundwater model findings, and establish if the hydrochemistry of the site supports the understanding of groundwater flows at the site.

This assessment considers rainfall recharge to the aquifers but excludes surface water/shallow groundwater interaction linked to mining activities or any assessment of surface activities or processes post closure from a hydrochemical perspective that may impact groundwater across the site.

Site Contaminants of Concern and Site Environmental Values

While the primary focus of this assessment is to evaluate the hydrochemistry of the groundwater at the site in relation to the site conceptualisation and possible groundwater flow regimes there are key contaminants of concern and environmental values in relation to groundwater that are of particular interest from an environmental and mine closure planning perspective.

The following contaminants of concern have been identified for the Lady Lorretta mine that need to be considered as part of this scope:

Subsurface Contaminants of Concern (COC) / Sources

The subsurface contaminant sources are the mine workings (backfilled with paste produced from tailings). PAF waste rock produced by mining operations that cannot be placed in underground voids is hauled to the surface and placed in the LLM waste rock storage facility (WRSF). The mine dewatering is characterised by pH, high electrical conductivity, suspended solids, sulphate and total metal concentrations such as zinc, cadmium, iron and lead, with these constituents forming the COC.

According to the LLM Detailed Closure Plan all infrastructure (both above and below ground) is to be decommissioned and demolished in general accordance with the demolition study. From a subsurface perspective there are four shafts, a decline portal and numerous bores located across the mine lease. The shafts and mine portal will be backfilled with suitable material, including demolition waste (subject to an EA amendment which is in progress), and sealed with a concrete plug. Select monitoring bores may be kept for closure monitoring purposes.

The Environmental Values (EV) of waters and wetlands are protected under the Environmental Protection Water and Wetland Biodiversity Policy 2019. LLM is located within the Leichardt River water plan catchment and the EVs are determined in accordance with section 6 of the EPP Water and Wetland Biodiversity Policy. The identified EVs for the LLM receiving environment are:

- aquatic ecosystem protection
- cultural and spiritual values

- waters that may be used for agricultural purposes
- waters that may be used for drinking water
- industrial use of water

Data

A number of Excel files were supplied from the client, and these were combined into one master dataset. Chemical analyses were selected according to the following:

1. Duplicates were removed;
2. Analyses that did not contain at least a full set of major ions (Ca, Mg, Na, K, Cl, Total Alkalinity and SO_4) were removed. This included a large number of data points that reported field observations only;
3. Analyses that met the criteria of being within a 10% charge balance were retained, all others removed. The charge balance was calculated as the difference between the total anions and total cations divided by the sum of the total anions and cations, expressed as a percentage. Totals were derived as milli-equivalents per Litre. The seven major ions were used in this calculation;
4. Some underground metal analyses were not used as the sampling location and circumstances of sampling were not adequately documented.

The data cleaning resulted in a data set of 166 analyses spread across 14 bores (up to 172 samples for some metals data). The data spans the period from January 2012 to September 2021, with bore GW03 having 29 different analyses and a number of bores only one.

It should be noted that the dataset is considered to be of a poor quality for this type of assessment, with inconsistent data collection periods, as well as periods within the time period though which no data was collected. Also of note is that water quality data was limited along the Carlton Fault, and this impacted hydrochemistry informing the conceptualisation in this area. The location of monitoring bores also influences the assessment, as bores located in more distal locations from faults are less likely to present with clear geochemical signatures demonstrating connection between the relevant blocks through the faults.

Total Alkalinity (as CaCO_3 mg/L) was used as the measure of the CO_2 - H_2O system activity in each sample (as opposed to carbonate and bicarbonate). Further data limitations (where applicable) are detailed further in the relevant sections below.

Laboratory TDS

No analyses have recorded laboratory TDS measurements. For future reference this should be rectified and TDS by evaporation at 180° added as a standard measurement as part of future analysis suites.

Electrical Conductivity

A number of samples have both field and laboratory measurements of electrical conductivity. These are plotted in Figure 1. The data shows a good correlation, but it does not have a slope of 1, indicating that field EC is higher than the laboratory measurement at higher EC values. This discrepancy may reflect field meter calibration issues which may need to be followed up with field staff prior to any future sampling.

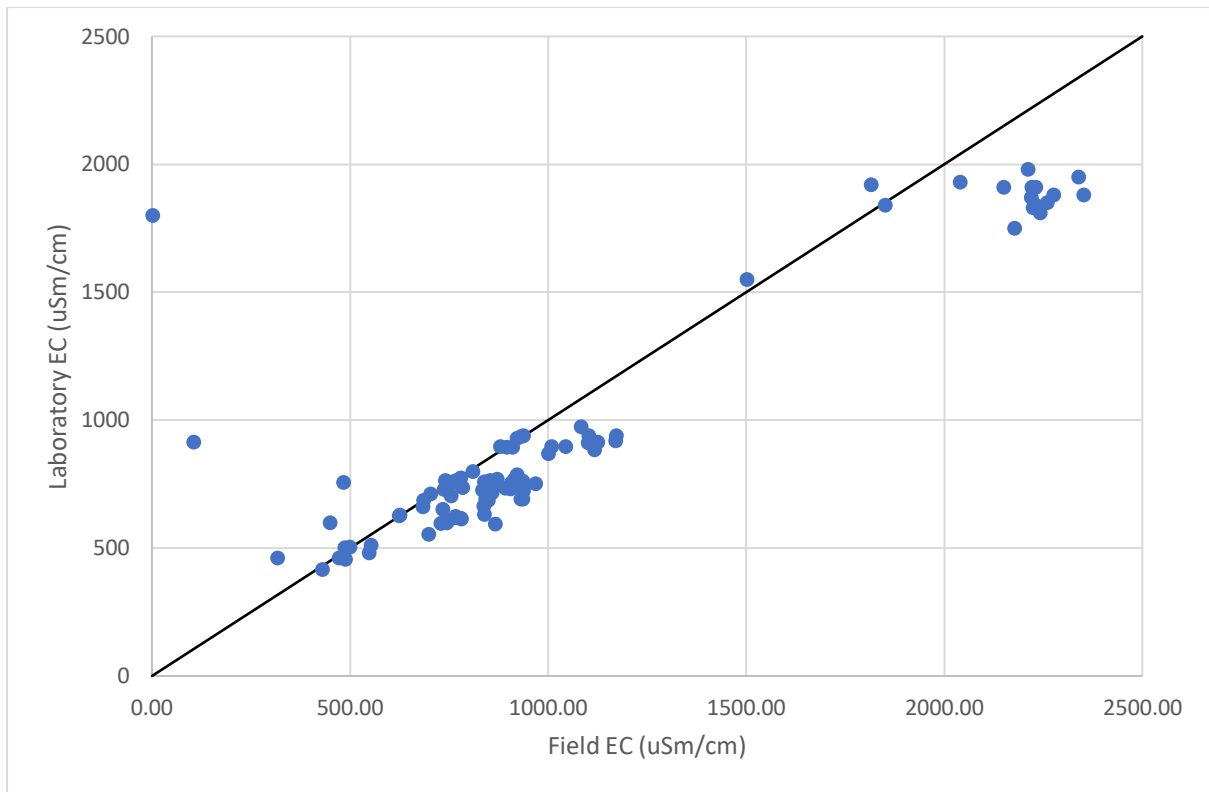
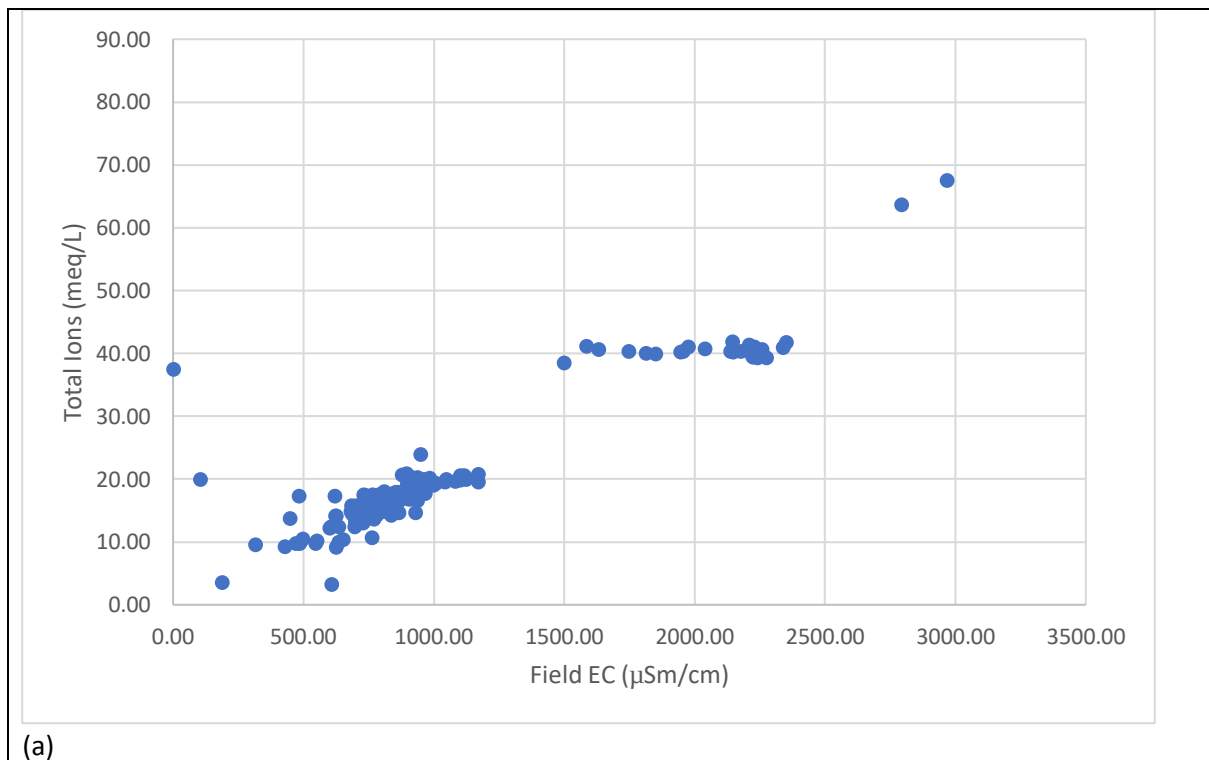


Figure 1: Field Electrical Conductivity versus Laboratory Electrical Conductivity (in $\mu\text{Sm}/\text{cm}$)



(a)

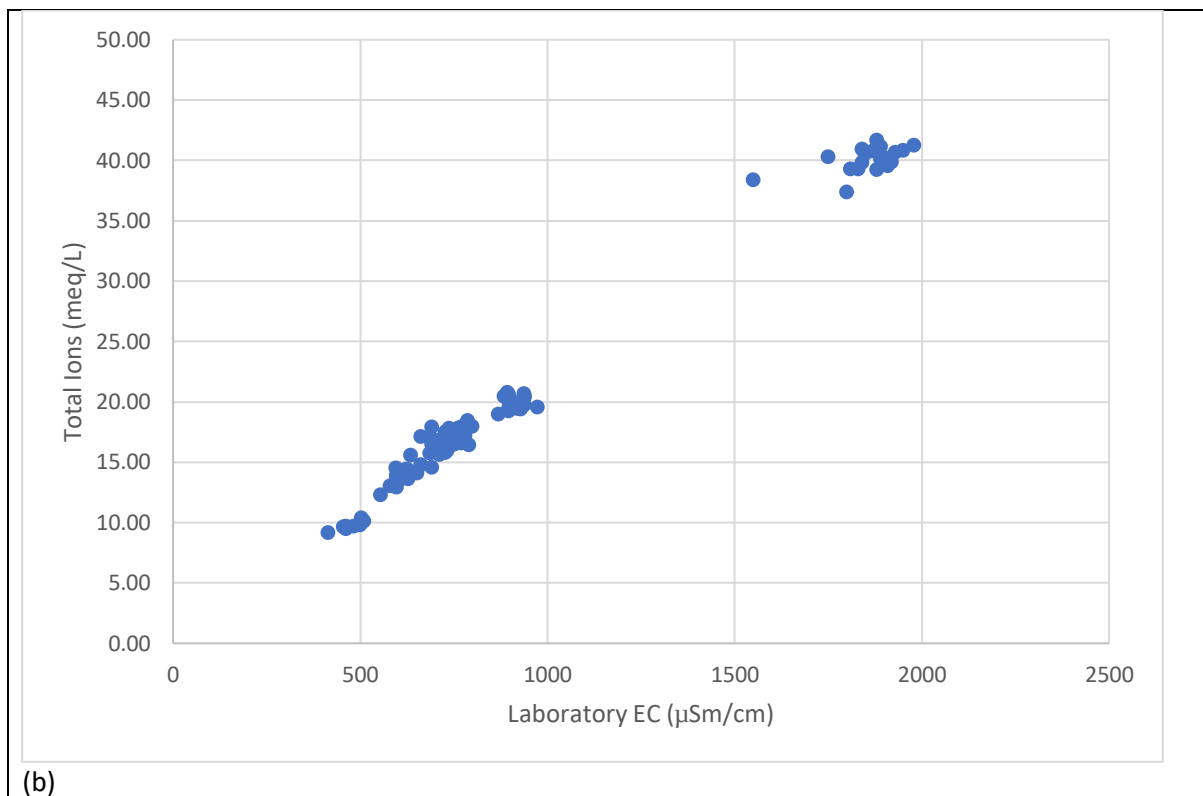


Figure 2: Electrical Conductivity versus Total Ions (a) Field EC vs Total Ions, and (b) Laboratory EC vs Total Ions

Total Ions, calculated as the sum of the major ions as milliequivalents per Litre (meq/L), were plotted against both laboratory and field EC measurements (Figure 2a and b). The plot of laboratory EC vs Total Ions (b) shows a good correlation, but the Field EC plot (a) shows a number of areas of poor correlation. This suggests that the field EC measurement may not be correct, and this could be a function of instrument error (calibration, etc). The almost linear correlation in Figure 2 (b) provides confidence that Total Ions can be used as a surrogate for TDS (or total salinity).

pH

Field pH and laboratory pH are only sporadically measured, with 96 samples collected where both parameters were measured. Moving forward these should be measured and reported on all occasions. A plot of pH field versus laboratory is presented in Figure 3. This shows a poor relationship between the two measurements with laboratory measurements consistently higher than their respective field reading. Usually, this relationship indicates that CO_2 has degassed in the sample bottle after sampling but prior to measurement, indicating that the holding period prior to analysis has been exceeded. In cases where the pH readings are more than one pH unit different between the two measurements, poor calibration of field equipment may be the issue impacting results. Disagreement between field and laboratory pH measurements places a question mark over the reported concentrations of ions that are biologically involved, such as HCO_3^- , SO_4^{2-} , and Ca (Yesertener, 2010¹).

Ordinarily, such poor correlation between the two measurements would invalidate further assessment. However, this would result in few samples being available for further study. One

¹ Yesertener, C. 2010 – Hydrogeochemical assessment of the Surficial Aquifer, Perth Metropolitan Area. WA Dept of Water, Report No. HG37

outcome from this lack of correlation is that the results of any assessment of pH driven chemical reactions would be uncertain, and as such, are not undertaken.

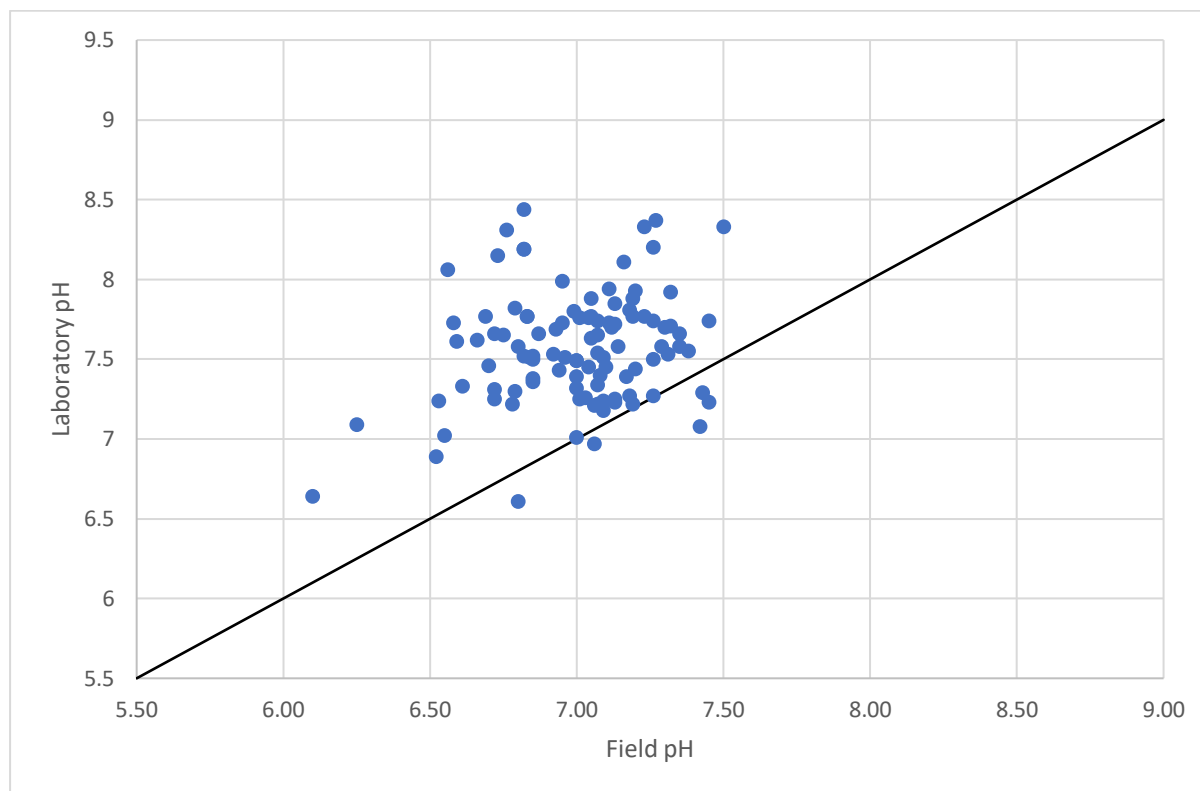


Figure 3: Field pH versus laboratory pH (1:1 line shown)

Field pH versus Field Redox

Redox and pH measured in the field were plotted to describe the likely Eh/pH relationships. The plot (Figure 4) shows that the measured values lie in a generally tight grouping showing neutral to slightly acid pH and oxidised to slightly reduced redox potential.

The lowest redox potential values are all from bore GW08. These values might indicate that the waters in GW08 are reduced and that dissolved sulfur might be speciated into H_2S or HS^- . Field observations recorded at the time the sample was taken note a strong sulfur smell. Thus, depending on the laboratory analytical methods used to measure sulfur, and the chemical evolution of the sample in the bottle during transit, the reported sulphate concentrations may be a minimum only.

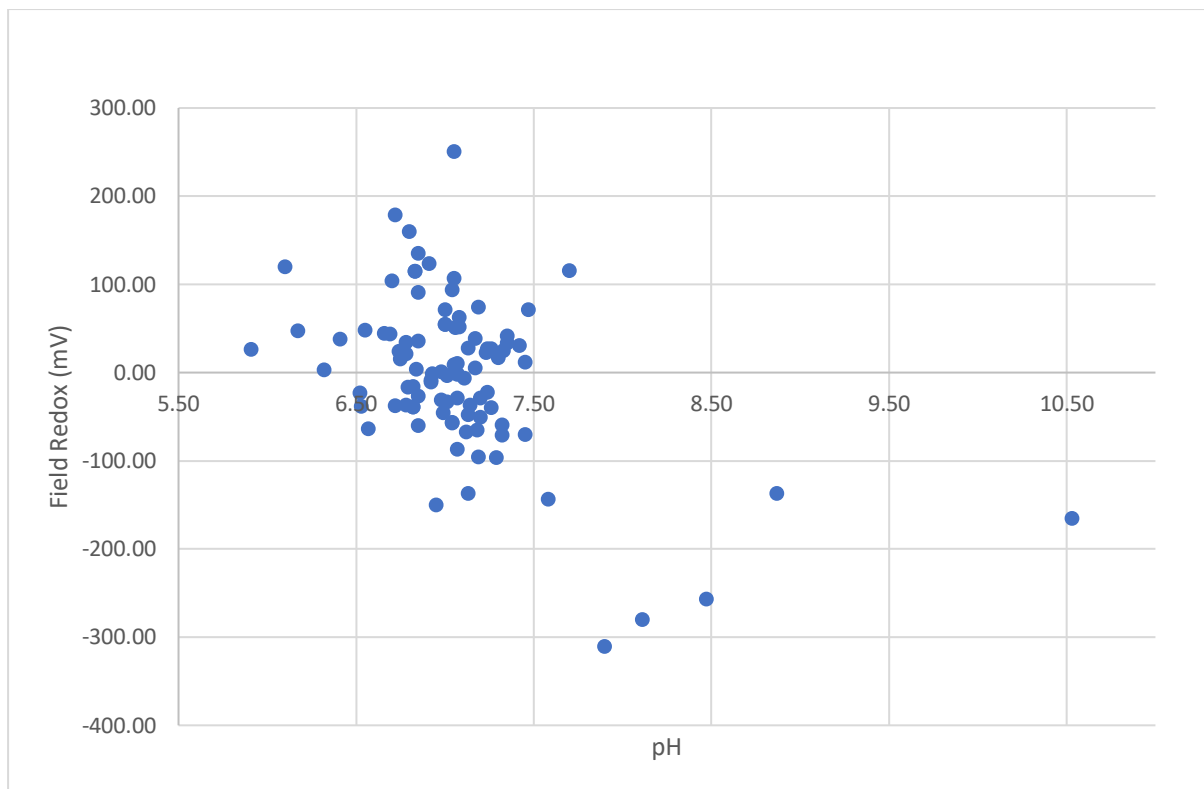


Figure 4: Field pH versus Field Redox

Data Analysis

As mentioned above, there were no measurements of TDS in the laboratory reported in the data. Total Ions (as milli-equivalents/L) were used as a surrogate of total salinity.

Sources of Ionic species

There are two primary potential sources of chemical constituents measured in the groundwater in the region of the Lady Loretta Mine. The first is from salts depositing either via rainfall or via dryfall (dust) mechanisms.

The first group could comprise salts from a continental origin or salts from an oceanic origin. Given that recharge is from monsoonal rainfall during the wet season, it is assumed here that the majority of salt from diffuse recharge sources has an oceanic origin.

The second is from mineral dissolution. In this latter group, there are three main mineral systems to be considered – all are present in the LLM area:

- primary alumino-silicate minerals;
- carbonates (limestone/calcite and dolomite); and
- sulfidic minerals (such as pyrite and those associated with mineralisation).

Other mechanisms/processes may influence the chemical make-up of the groundwater, but these are seen as minor. These include, ion exchange (both in the soil zone and in the weathered parts of the aquifer), sorption and desorption, and degradation of organic or carbonaceous materials.

Chloride is considered the most conservative of all of the major ions found in groundwater, especially at low ionic strength (low TDS). It is assumed here that chloride concentration is driven by the cycling of oceanic aerosols/salts through the aquifer. This may be a complex process due to local storage of salts in the unsaturated zone and/or local flow within compartmentalised blocks of

bedrock. Elevated levels of chloride might indicate halite dissolution as a potential source of salt, but the overall character of the groundwaters in the LLM area are dilute, and no halite has been recorded in the local bedrock sequences.

The distribution of Chloride in groundwater in the LLM area is generally simple at the broad scale, but can be complex at the local scale (Figure 5). Generally, groundwater in the Cambrian and Lady Loretta Blocks have low overall Chloride concentrations, whereas the limited data for groundwater in the Paleoproterozoic Block indicate higher levels of Chloride (except for groundwater sampled at bore GW07 – which is discussed in detail below). This distribution tends to suggest that infiltrating water undergoes little concentration due to evapotranspiration in the LL and Cambrian Blocks, when compared to the Paleoproterozoic Block.

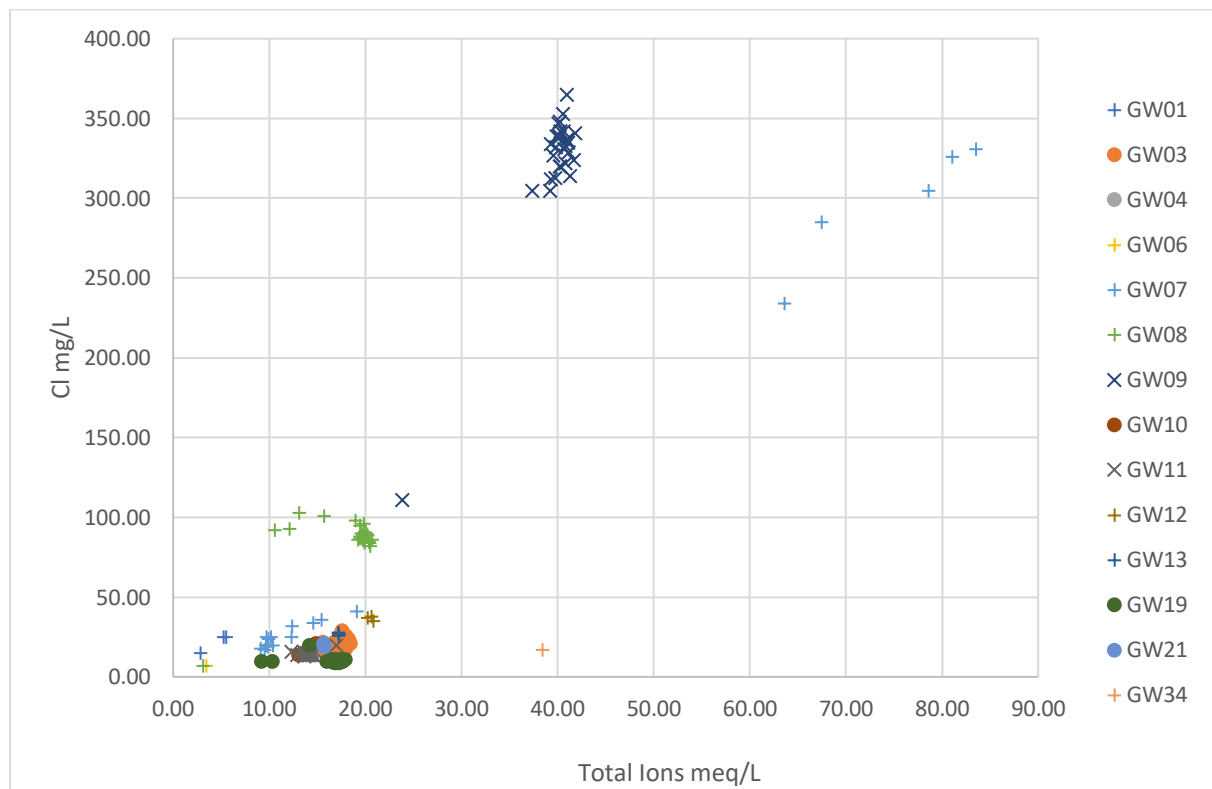


Figure 5: Chloride versus Total Ions. (+ - Lady Loretta Block, o - Cambrian Block, x - Paleoproterozoic Block)

At the detailed scale Chloride concentration for groundwater sampled at GW08 is about twice the Chloride concentration for groundwater from the LL and Cambrian Blocks. This may indicate that this groundwater is more highly concentrated during recharge at this particular location. It can also be concluded, if this is the case, that there is no major mixing of groundwaters within the LL Block following recharge, and therefore groundwater flow can be seen as compartmentalised within this section of the block.

If all the Chloride concentration in groundwater is from oceanic aerosols from rainfall, then one might expect that the Na/Cl weight ratio may reflect seawater values, assuming that Sodium behaves conservatively. Figure 6 shows the Na/Cl ratio for groundwaters plotted against Total Ions. The seawater ratio is also shown. Note that groundwater from bore GW09 falls on the seawater ratio line and indicates that at least the sodium and chloride conform with a simple diffuse recharge from oceanic salt sources. Some of the samples of groundwater from GW07 lie on the same ratio. However, most sampled groundwater shows a trend of increasing Na/Cl ratio for a given Total Ion value. This may indicate that sodium is preferentially added to the groundwater during recharge,

probably due to ion exchange process in the shallow soil/regolith. Note that there is no trend with increasing Total Ion value. The flow system, as it can be deduced, does not support increasing Cl values down the flow path. Thus, the data in Figure 6 show that this ratio is inherited probably shortly after recharge, and is then maintained within that part of the aquifer compartment. This further supports a conceptualisation of the aquifer within the blocks being compartmentalised in specific areas, with little interchange between compartments.

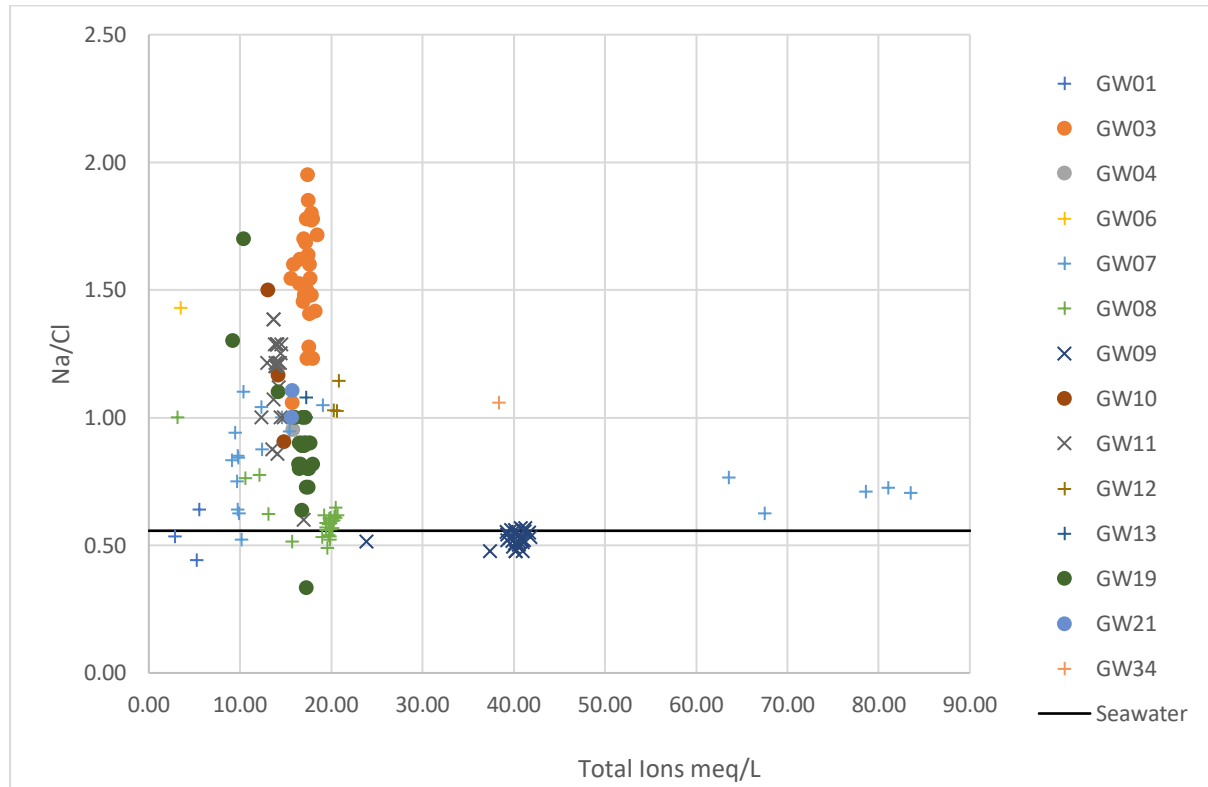


Figure 6: Na/Cl weight ratio vs Total Ions (+ - Lady Loretta Block, o – Cambrian Block, x – Paleoproterozoic Block)

Sulphate

Sulphate plotted against Total Ions (Figure 7) shows that:

- Sulphate concentration in the Cambrian Block groundwater is always low;
- Groundwater in the Lady Loretta Block has variable sulphate levels, including extremely high levels at times in bore GW07; and
- There is both low and high sulphate concentrations in groundwaters of the Paleoproterozoic Block.

These findings are consistent with the understanding of the distribution of sulphidic mineralisation within the bedrock, and indicate that sulfur is being contributed to the groundwater from mineral dissolution (or oxidation) processes. These oxidation processes are consistent with the measured redox potential (as discussed above).

The low sulphate content of groundwater within the Cambrian Block also indicates that the rocks are dominated by carbonates/dolomites, and not by gypsum.

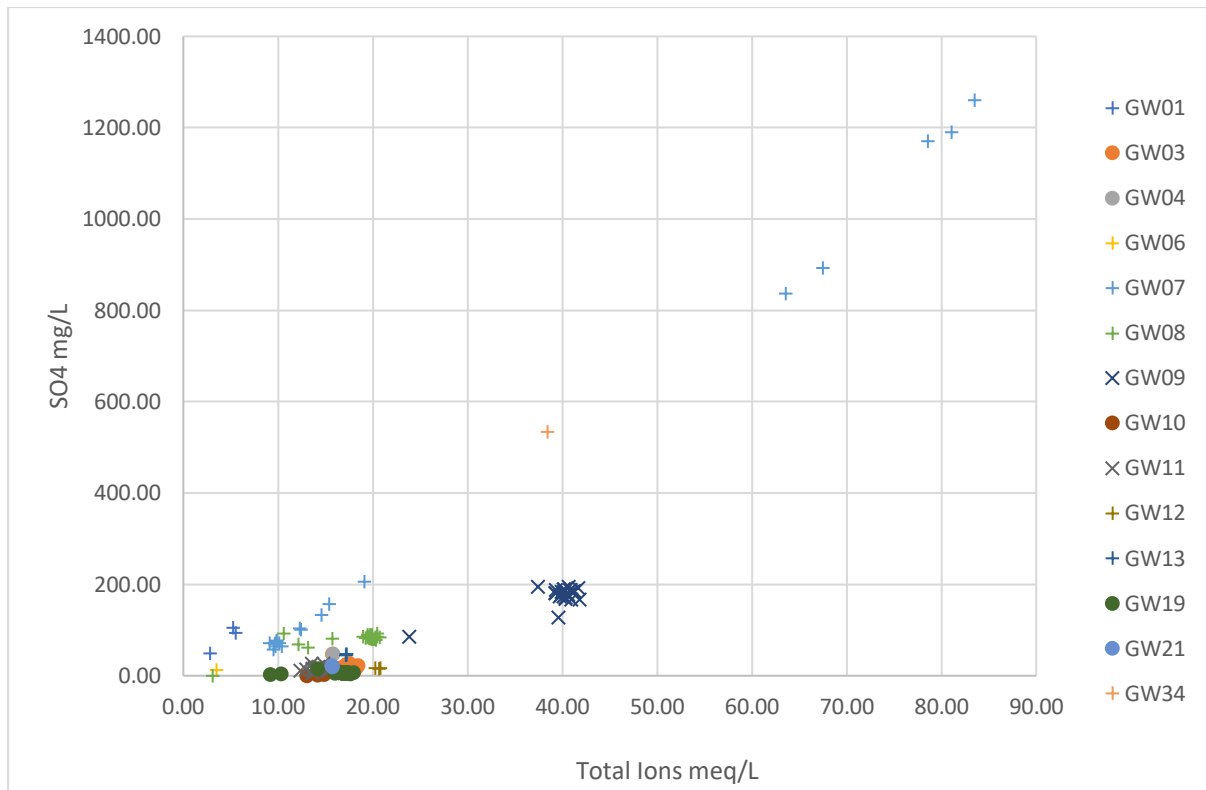


Figure 7: Sulphate versus Total Ions (+ - Lady Loretta Block, o – Cambrian Block, x – Paleoproterozoic Block)

Total Alkalinity

Total Alkalinity is reasonably constant across the different Block groundwaters, with values generally between 300 and 450 mg/L (Figure 8), though the proportion of Total Ions varies, with the Cambrian Block groundwaters having a larger proportion of Total Alkalinity when compared to groundwater sampled from bore GW07 in particular.

Total Alkalinity is most likely derived from two sources in the Lady Loretta area. Firstly, it is produced via the dissolution of carbonates (and dolomites), and secondly, it is produced via the dissolution of aluminosilicates.

Groundwater from bore GW11 (located in the Proterozoic block), GW12 and GW13 (located in the Lady Loretta block) have the same Total Alkalinity and Total Ion values as groundwater from the Cambrian Block. The piezometry of the site precludes any movement of groundwater from the Cambrian Block to the site of GW11, but there may be some limestone layers present at that site. Movement of groundwater may be occurring from the Cambrian Block to the site of GW12 and GW13, but more detailed piezometry would be required to confirm this. It is also possible that there are carbonate layers present in these bores.

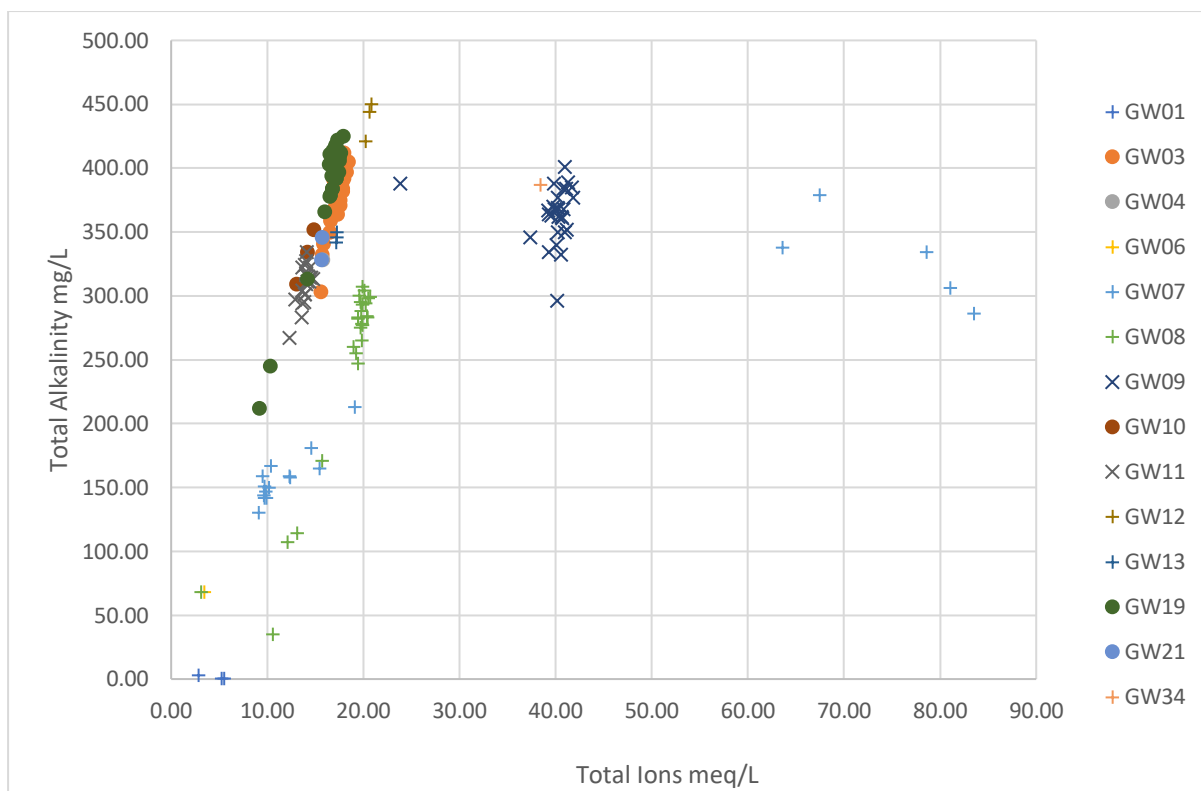


Figure 8: Total Alkalinity versus Total Ions (+ - Lady Loretta Block, o – Cambrian Block, x – Paleoproterozoic Block)

To further understand the geochemistry of the Cambrian Block groundwater, the molar ratio of Total Alkalinity to Calcium plus Magnesium was plotted against Total Ions (Figure 9).

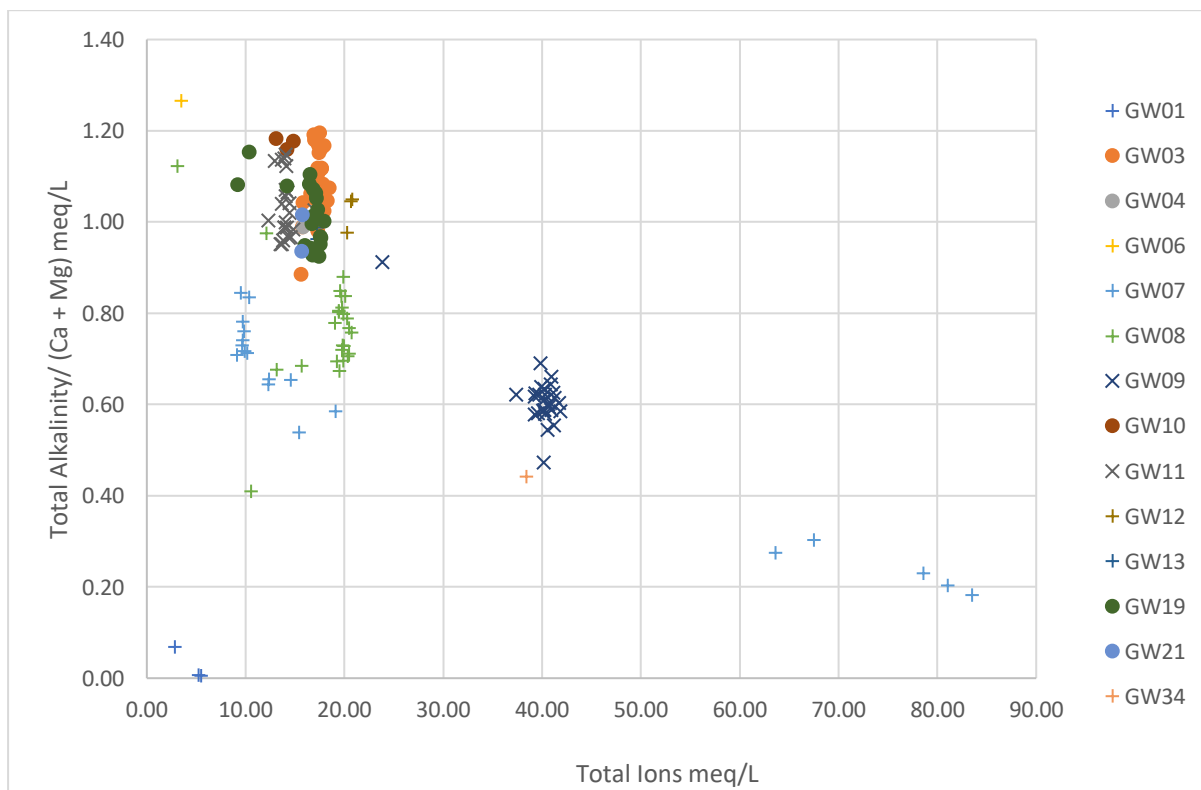


Figure 9: Molar ratio of Total Alkalinity/Ca plus Mg versus Total Ions (meq/L) (+ - Lady Loretta Block, o – Cambrian Block, x – Paleoproterozoic Block)

If dolomitic dissolution were the primary driver on the Total Alkalinity and, Calcium and Magnesium system, then one might expect that the ratio of those constituents would be unity. Figure 9 shows that the ratio for the Cambrian Block groundwater is close to one in all cases.

Interestingly, some of the non-Cambrian Block groundwater plots in the same space; namely, GW11, GW12 and GW13, as well as some early samples from GW08.

Temporal Variability of Water Chemistry

Changes in water chemistry for groundwaters sampled at bores GW03, GW07 and GW08 is discussed below within the context of understanding how dewatering of the aquifer affects chemical constituents, either through mine leakage or through borefield extraction. The focus of discussion is confined to changes in sulfate concentration and to changes in the molar ratio of Total Alkalinity to Calcium plus Magnesium.

Bore GW03

Bore GW03 samples groundwater from the Cambrian Block.

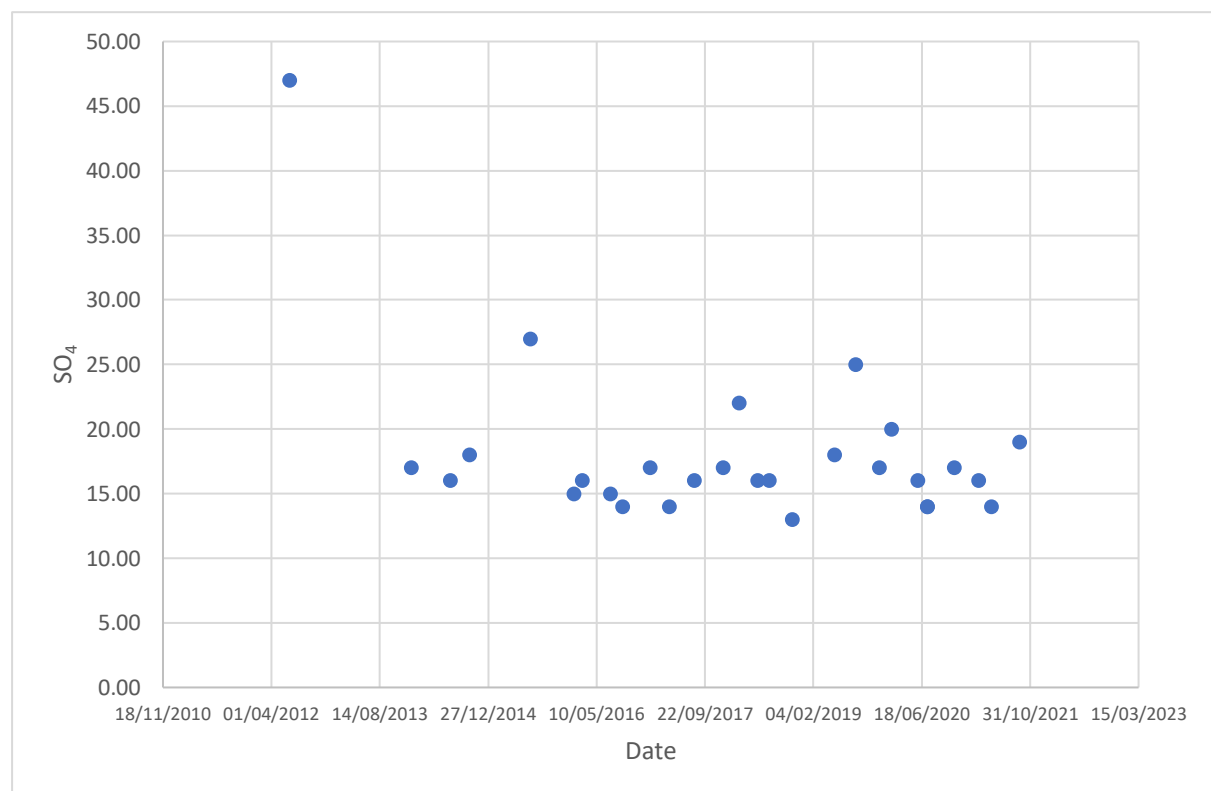


Figure 10: Sulfate concentration over time for GW03

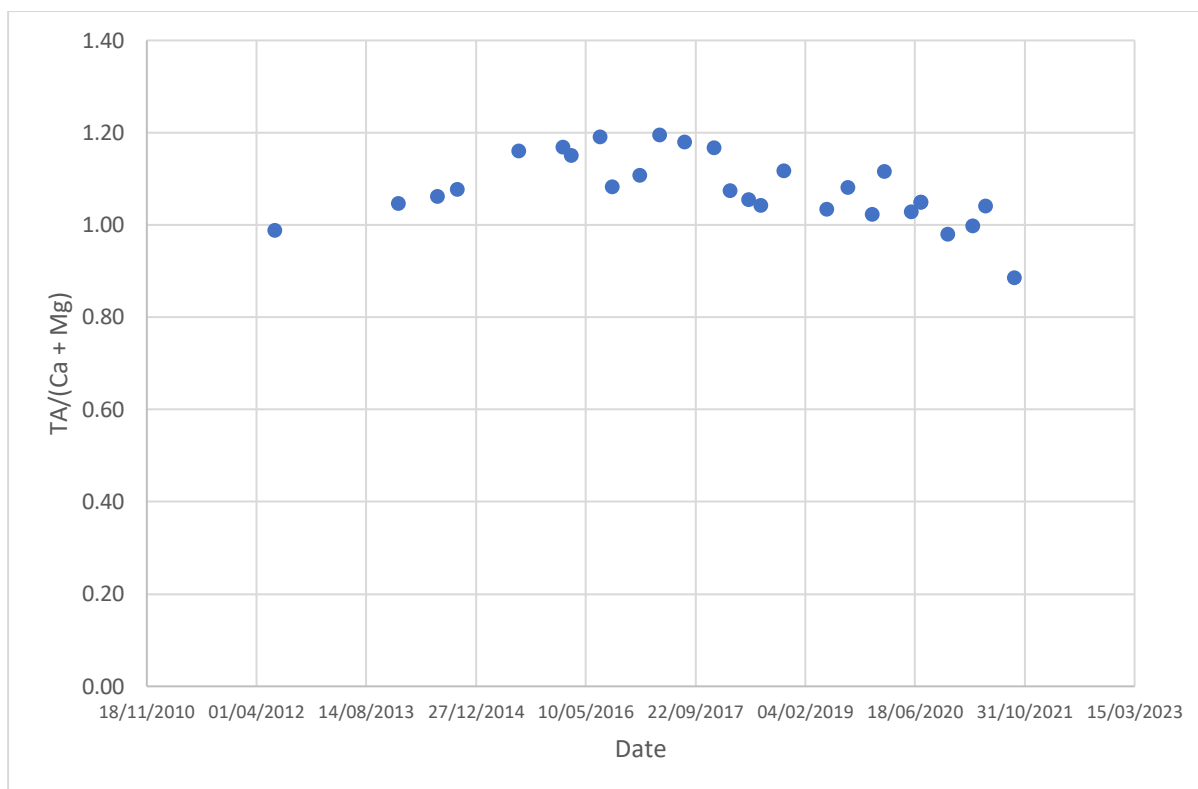


Figure 11: Molar ratio of Total Alkalinity/(Ca plus Mg) versus time for bore GW03

Figure 10 and Figure 11 show temporal changes in SO_4 and the ratio $\text{TA}/(\text{Ca} + \text{Mg})$ respectively. The trends with time are reasonably stable and indicate that as groundwater extraction from the borefield locally increases hydraulic gradients, the water chemistry is uniform. There appear to be no major water chemical reactions taking place at the temporal scale of the data.

Bore GW07

Bore GW07 samples groundwater from the Paleoproterozoic Block to the north of the Lady Loretta mine, and lies up gradient. The bore is situated very close to the Carlton Fault.

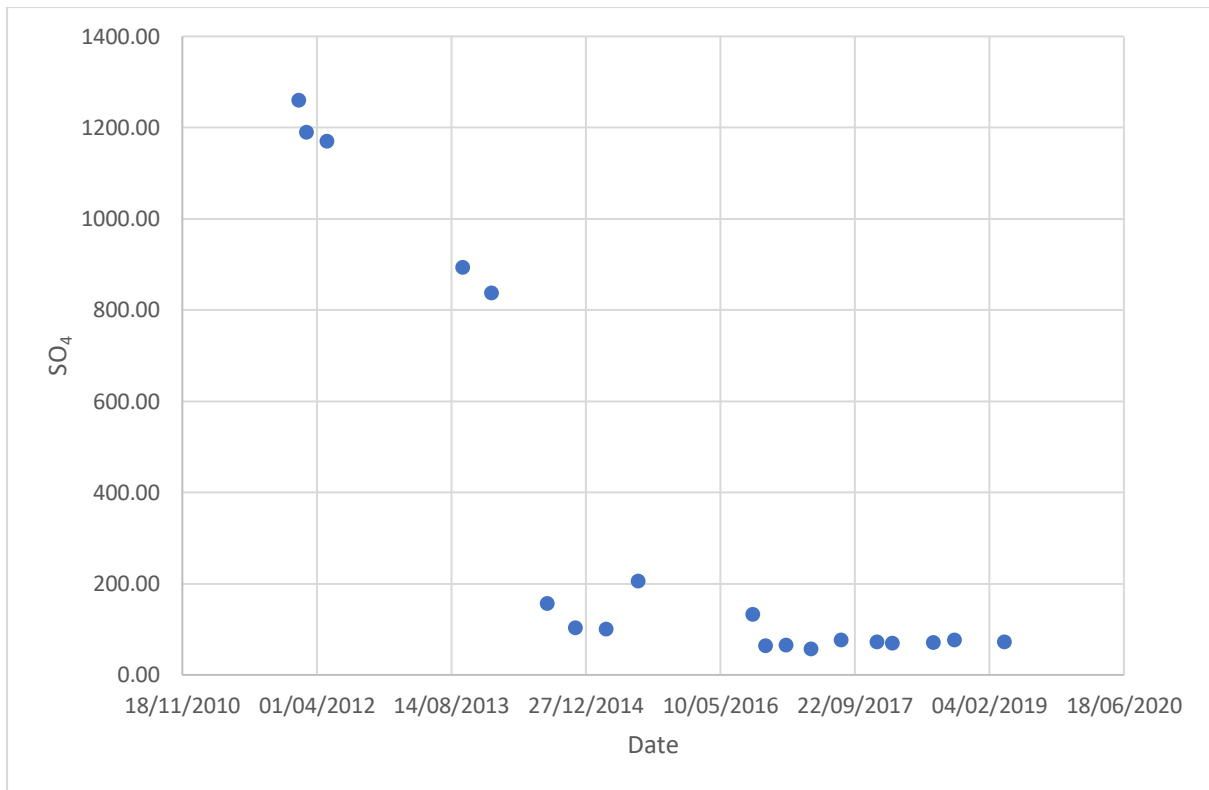


Figure 12: Sulfate concentration over time for GW07

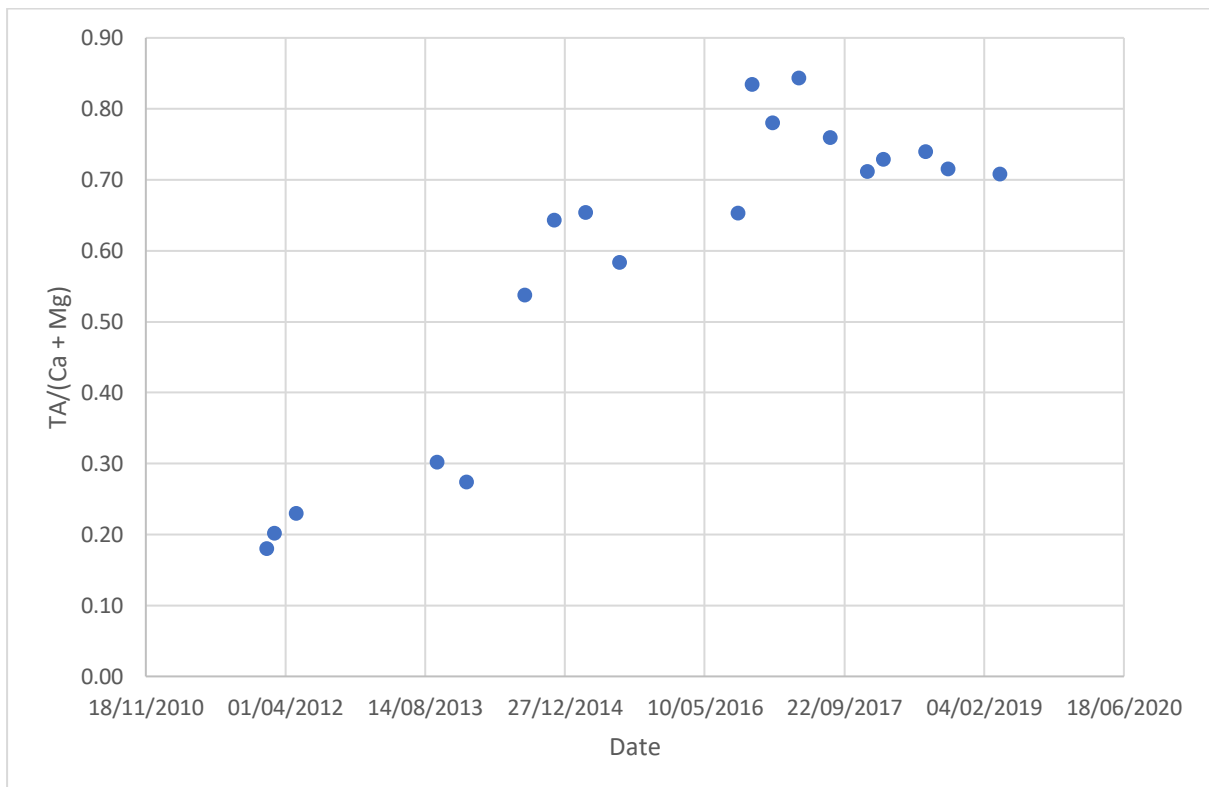


Figure 13: Molar ratio of Total Alkalinity/(Ca plus Mg) versus time for bore GW07

Changes in water chemistry for GW07 show that as the mine dewatering proceeds, there is a rapid decrease in SO₄ concentrations, and a correlated increase in the ratio of TA/(Ca + Mg) (Figure 12 and Figure 13). In mid-2016 the two plots reach a dynamic equilibrium. The sulfate decrease is probably

indicative of the rate of oxidation of sulphidic minerals locally to the sampling point. As the hydraulic gradients increase and flow increases towards the mine, the newly arriving groundwater is unable to oxidise sufficient sulphides to maintain the original concentration. This potentially indicates very low storage in the aquifer, and high local groundwater velocity. The Total Alkalinity to Calcium plus Magnesium ratio increases substantially, but never reaches greater than about 0.8. This increase may be due to silicate dissolution processes, or the dissolution of carbonates, or a combination of both.

Bore GW08

Bore GW08 samples groundwater from the Lady Loretta Block and lies to the south east of the Lady Loretta mine.

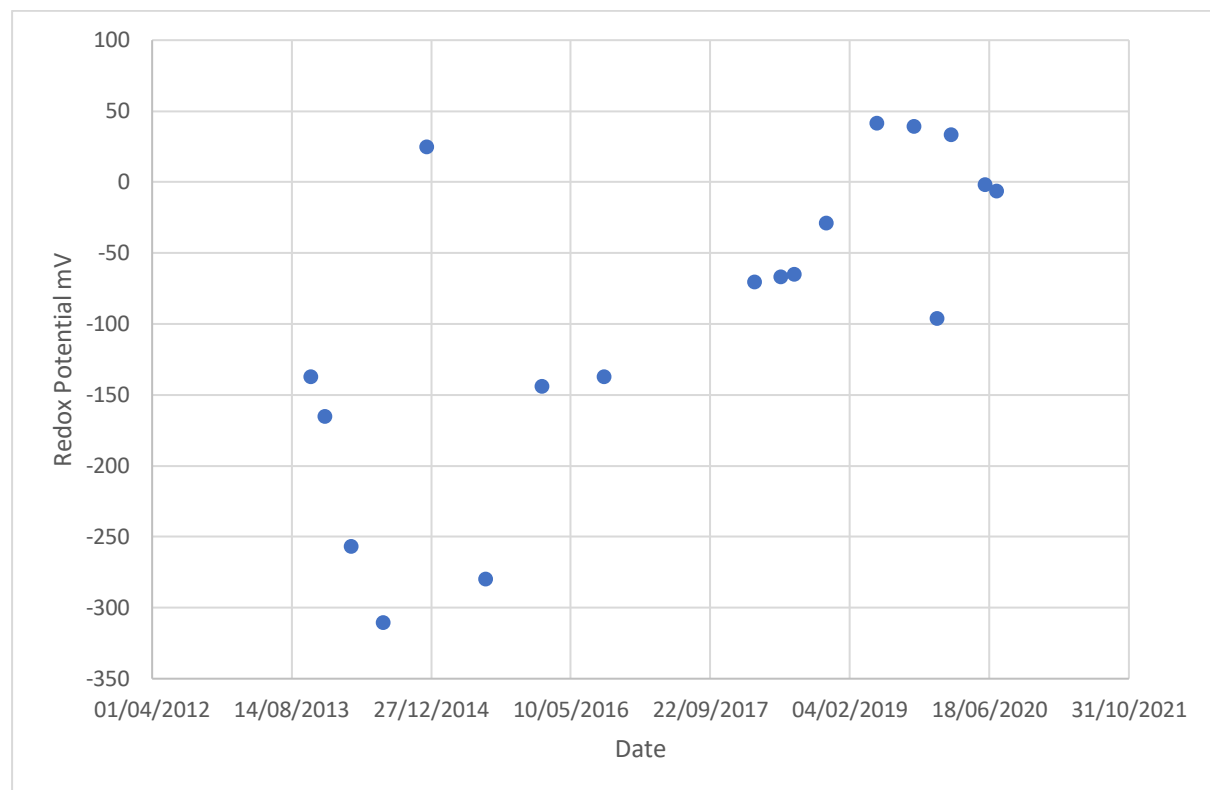


Figure 14: Redox potential variability over time for GW08

The redox potential for bore GW08 increases to mildly oxidised levels by early 2019 (Figure 14). This is a typical response of a system that is of low storage (buffer volume) and the introduction of oxygenated groundwaters. Figure 15, however, shows that sulfate concentration didn't change in response to this increase in oxidation, potentially indicating that either the kinetics of the oxidising process are stable under the flow conditions, or this is a larger store of dissolved sulfate within the vicinity of the bore.

The molar ratio of TA/(Ca + Mg) decreases over time (Figure 16), also indicating that silicate dissolution processes are most likely dominant, but the early data may indicate that there are carbonate rocks within the vicinity of the bore.

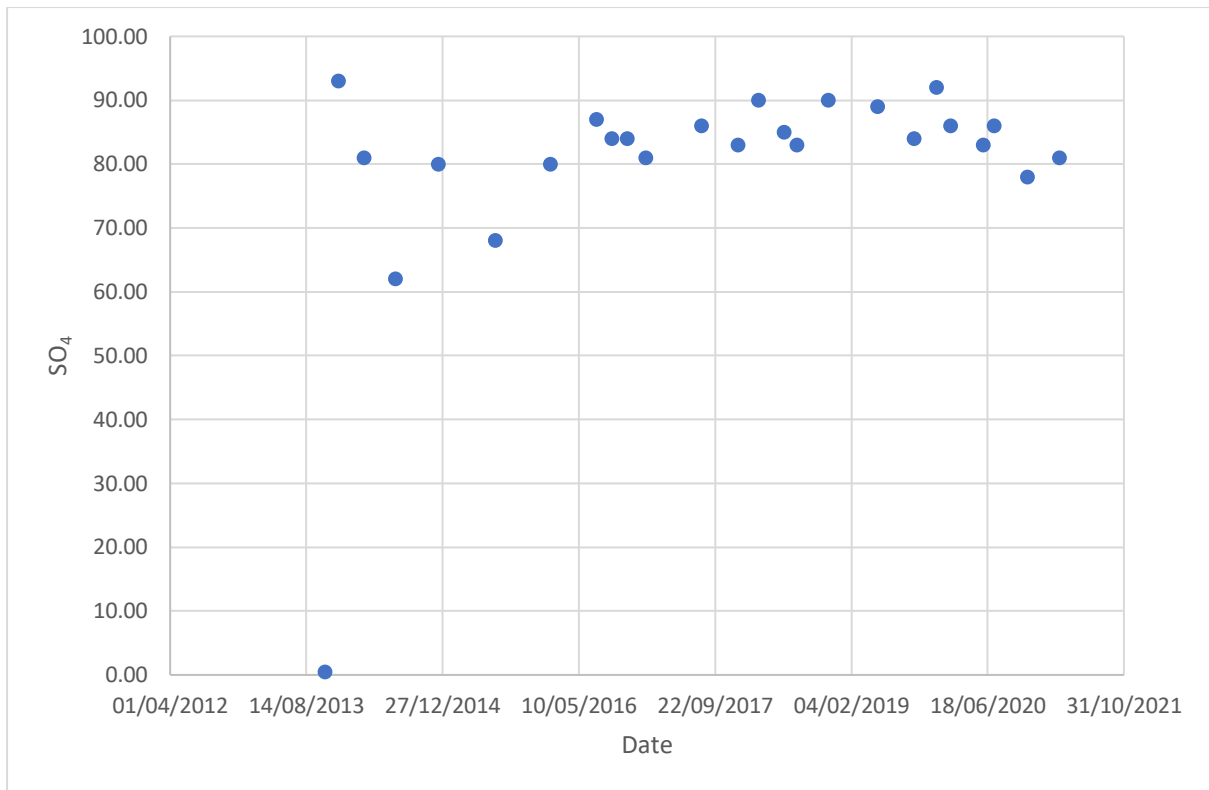


Figure 15: Sulfate concentration over time for GW08

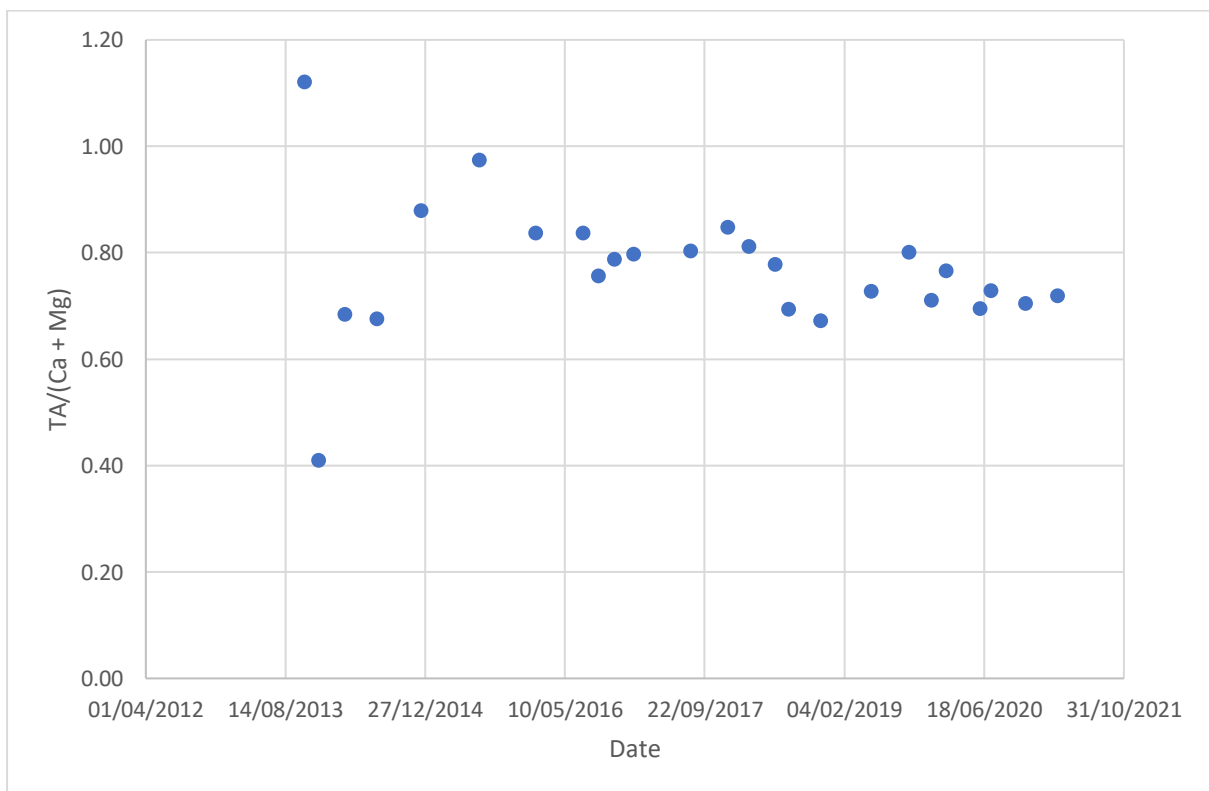


Figure 16: Molar ratio of Total Alkalinity/(Ca plus Mg) versus time for bore GW08

Water Chemistry of Underground Working Leakage

A number of water samples were taken from seepages in the mine over the period August 2019 to March 2020.

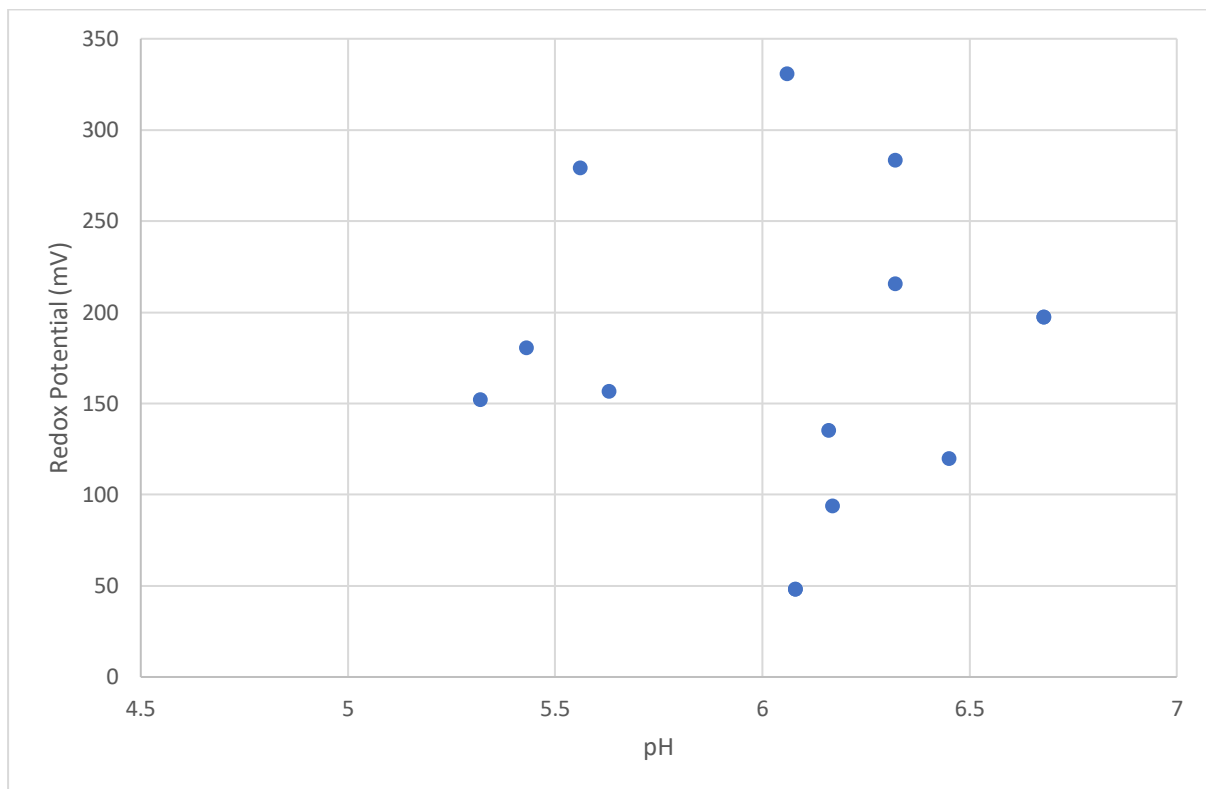


Figure 17: pH versus Redox Potential of Underground Leakage samples

The pH – Redox potential field (Figure 17) shows that the leakage water is slightly acid and oxidised. The oxidation state is similar to the regional samples (Figure 4), however, the pH is lower by about one pH unit. This is consistent with the level of sulphidic content of the mine sequence of rocks, and indicates its acid forming potential.

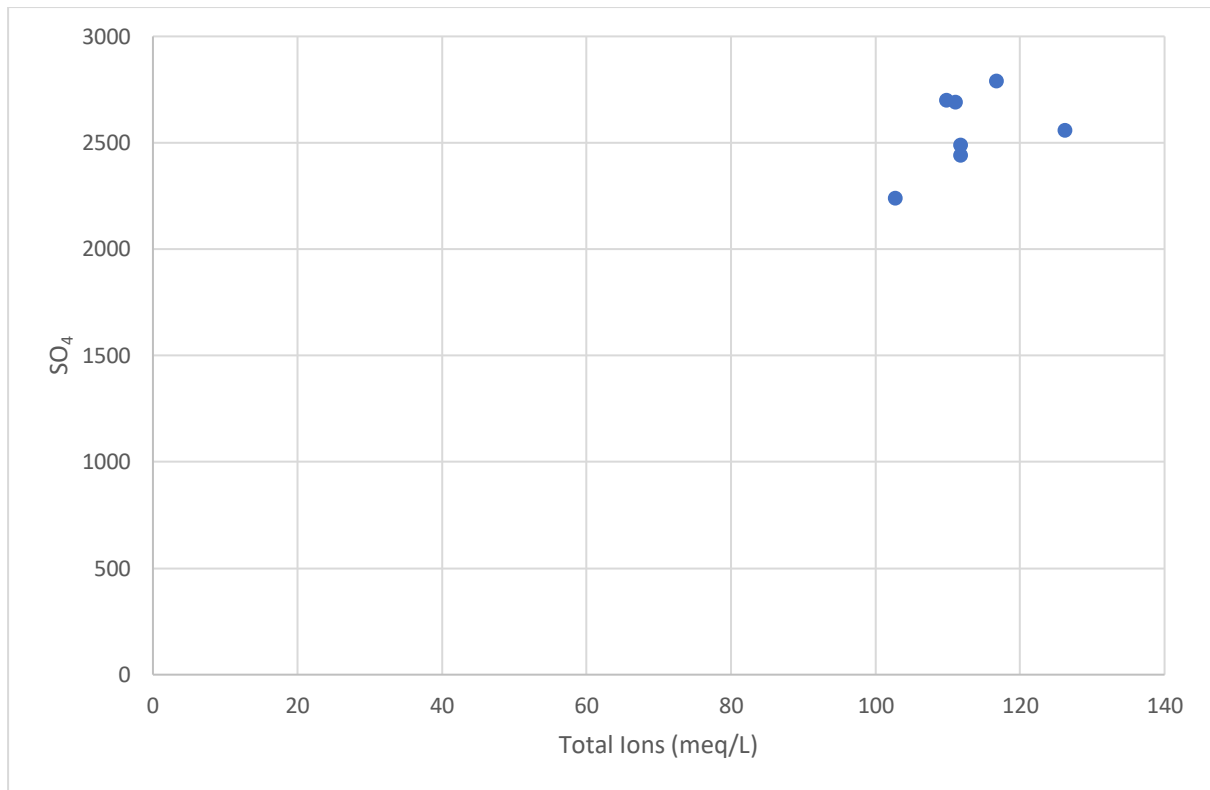


Figure 18: Sulfate versus Total Ions, Underground Leakage samples

Leakage samples are more saline (higher Total Ion values) and have higher Sulfate concentrations than the surrounding groundwater (Figure 18).

The molar ratios of Total Alkalinity to Calcium plus Magnesium () for underground leakage samples are small compared with all other samples and indicates that carbonate dissolution is not a controlling dissolution process close to the mine workings. Concentration of both divalent cations (Calcium and Magnesium) is high when compared to Total Alkalinity. It is unknown at this time what process is responsible for these values.

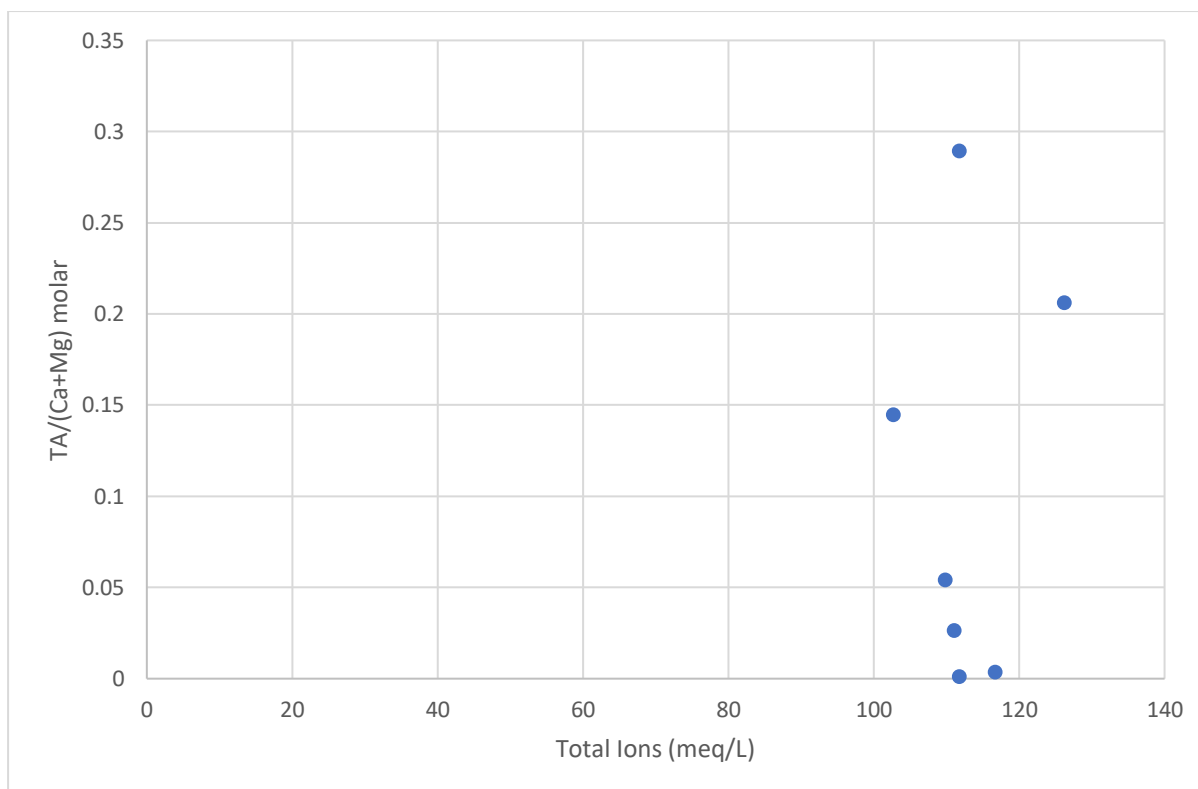


Figure 19: Molar ratio of Total Alkalinity/(Ca plus Mg) versus Total Ions (meq/L) for Underground Leakage samples

Major Ion Discussion

In an effort to further differentiate the groundwaters between Blocks, the molar ratio of Total Alkalinity to Calcium plus Magnesium was plotted against Sulphate (mg/L) (see Figure 20). The plot shows that groundwater from the Cambrian Block has a TA/(Ca+Mg) ratio of around 1, and low Sulphate, whereas groundwater from the Lady Loretta Block has a TA/(Ca+Mg) ratio approaching but never reaching 1, and increasing concentration of Sulphate. Groundwater from GW09 is consistent with the Lady Loretta character, but groundwater from GW11 is consistent with groundwater from the Cambrian Block. Groundwater from bores GW12 and GW13 show a transitional character between the two Blocks.

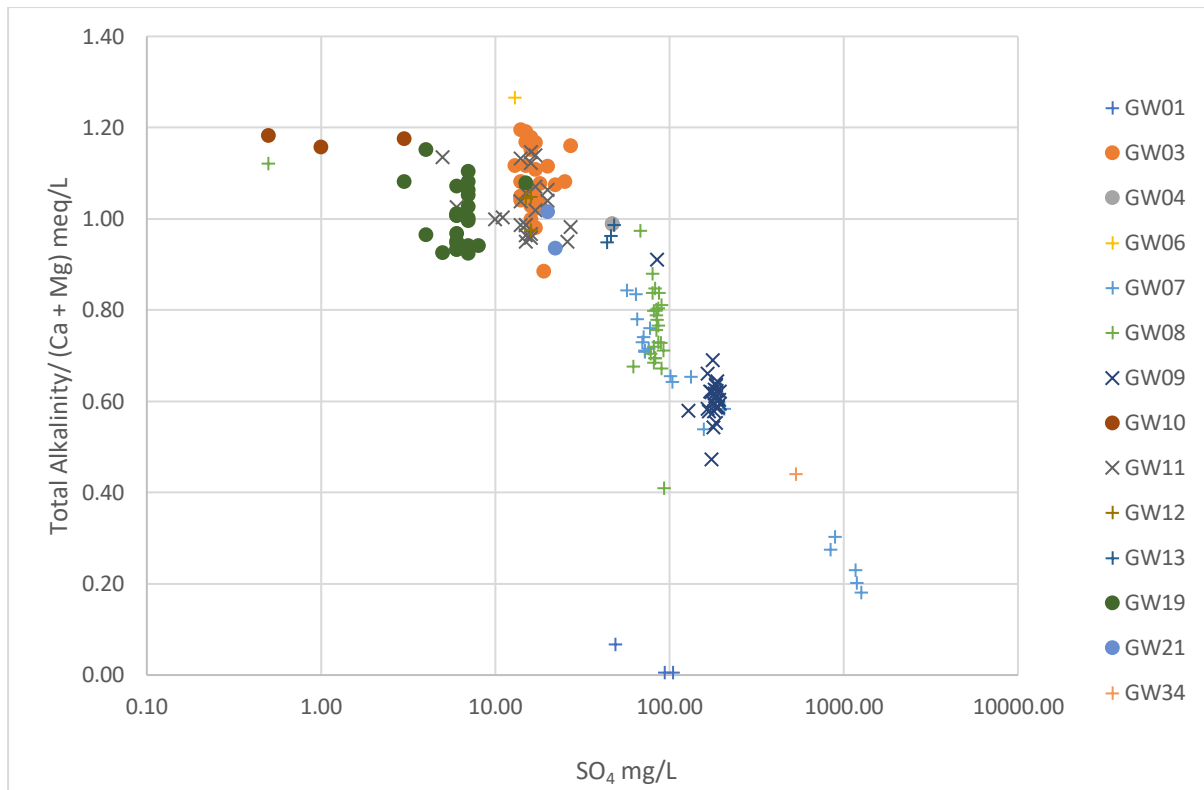


Figure 20: Molar ratio of Total Alkalinity/Ca plus Mg versus Sulphate (mg/L) (+ - Lady Loretta Block, o - Cambrian Block, x - Paleoproterozoic Block) Note the logarithmic scale on the X-axis.

One conceptual model of the Lady Loretta area is that the two main faults (the Western and Carlton Faults) are not barriers to lateral flow and that groundwater from the Cambrian Block is able to flow towards the Lady Loretta mine void consistent with the current understanding of hydraulic gradients in the area. From a hydrochemical point of view, this lateral flow can be tested by examining groundwater samples from bores completed in the Lady Loretta Block to see if they show signs of attaining a chemical signature similar to that from groundwater in the Cambrian Block. This is predicated, though, by where the “breakthrough” front of Cambrian groundwater has progressed. That is, once drawdown conditions were established at the mine void, actual particle flow across the fault will take time to reach the void. It is probable that, according to the conceptual model of fault character, the advective front is still somewhere between the Western Fault and the mine void. For the groundwater sampled at the intervening bores to show a Cambrian Block signature, the advective front will have to have reached the bores sampled.

Bores GW08, GW12, GW13 and GW34, located in the Lady Loretta Block, lie in these transitional areas. Piezometry appears to preclude flow from the Cambrian Block towards GW08, GW12 and GW13. However, there are hydrochemical signatures in these bores consistent with the typical chemical makeup of groundwater in the Cambrian Block. It is unclear if this indicates the advective front has reached these bores, or whether similar hydrochemical reactions are producing similar water chemistry.

Groundwater from GW34 is categorically not related to the Cambrian Block groundwater chemistry character.

Interestingly, groundwater sampled in GW06, GW07 located in the Lady Loretta Block and GW11 located in the Proterozoic Block all show similar character to Cambrian Block groundwater, but it is almost impossible for Cambrian Block groundwater to be found at these sites due to the large

groundwater gradient in the opposite direction. This indicates that some local geo-chemical features related to detailed bore lithology can produce similar results across the site.

Another consideration within which to assess the groundwater chemistry is whether there is hydrochemical evidence of the groundwater flow field prior to mining. That is, the site would have been in dynamic equilibrium prior to mining, and the groundwater would have been flowing according to the prevailing hydraulic gradients. These are unknown, but early groundwater level data suggests that the flow was from north-west to southeast. There is no chemical evidence to suggest or not suggest that groundwater was flowing from the Lady Loretta Block into the Cambrian Block. Bore GW21 is located very close to the mapped Western Border Fault, and is completed in the Cambrian strata. Groundwater at this site has the second highest level of Sulphate, indicating a potential influence or signature from the Lady Loretta Block. Bore GW04 has the highest sulphate content of the Cambrian Block and it is the furthest bore from the Western Border Fault.

There is expected to be a three to four order of magnitude change in hydraulic conductivity between the Lady Loretta Block (lower hydraulic conductivity) and the Cambrian Block (higher). This indicates a potential mass flux across the Western Fault that would be very small. Based on this consideration, it may be impossible to observe a change in water chemistry due to flow across the Western Fault in an easterly direction (that is, from the Lady Loretta to the Cambrian Block) within the accuracy of the chemical analyses undertaken.

The lateral flow of water between the Paleoproterozoic Block to the Lady Loretta block through the Carlton Fault has not been able to be assessed at this time from a hydrochemical perspective as there is insufficient data to complete the detailed assessment, and the Paleoproterozoic Block is inferred to be up hydraulic gradient from the Lady Loretta block, so no groundwater is expected to flow from the Lady Loretta mine site to this Block.

Compartmentalisation within the Blocks

Chloride results as shown in Figure 5 shows that there is local compartmentalisation within the blocks, with results from select bores in the Lady Loretta and the Proterozoic blocks demonstrating this. In addition, sulphate findings also suggest compartmentalisation (Figure 10) as well as informing the distribution of sulphidic mineralisation within the bedrock, and indicate that sulfur is being contributed to the groundwater from mineral dissolution (or oxidation) processes and this could be considered compartmentalised in the vicinity of the underground workings.

Distribution of Metals in groundwater in the LLM region

The distribution of selected metals in groundwater across the Lady Loretta area was assessed as an aid to understanding what information can be inferred from their distribution and concentration and how this may constrain the existing conceptual model. The assessment also provides useful background information for consideration of Constituents of Concern during Stage 2 of the study.

The metals analysed in groundwater samples at the LLM, and assessed as part of this part of the project included Aluminium, Arsenic, Cadmium, Chromium, Cobalt, Copper, Lead, Mercury, Molybdenum, Nickel, Selenium and Zinc. In addition, Boron and Iron were also analysed; these are not considered here.

Constituents were analysed for both dissolved and total concentrations. It is assumed that the field sampling procedures were appropriate for both types of laboratory analysis. Table 1 provides the percentage of samples for each constituent that were below the detection limit for both dissolved and total constituents.

Table 1: Percentage of Samples that had Detectable Levels of selected Metals

Metal	Total number of analyses	Detection limit (mg/L)	% of samples below detection limit for dissolved metals	% of samples below detection limit for total metals
Aluminium	167	0.01	80.2	44.9
Arsenic	168	0.001	37.5	33.1
Cadmium	164	0.0001	81.7	76.6
Chromium	167	0.001	91.0	71.1
Cobalt	169	0.001	33.1	27.5
Copper	170	0.001	72.9	52.1
Lead	165	0.001	93.3	75.4
Molybdenum	165	0.001	32.7	27.6
Nickel	170	0.001	38.8	39.5
Selenium	162	0.01	99.4	98.8
Zinc	171	<0.005	2.9	6.6
Mercury	162	0.0001	99.4	99.4

The difference between dissolved and total concentrations for specific constituents is due to the presence of particulate matter with associated metal content. The presence of particulates can be caused by inefficient filtering during the sampling operation, or particulates of a size smaller than the filter paper used at the time of sampling. Particulates may represent a phase that is mobile within the groundwater flow system and thus represent part of the transport process, or they may represent gels or films that have been dislodged from the bore casing or immediate surrounds of the bore during the disruptions from purging and sampling. In this latter case, the additional metals bound to these particles are not available for transport and do not constitute a component of the metal flux. There is not enough information to conclude what role the particulate portion of the total concentration has within this context, and as a result only dissolved concentrations will be considered further.

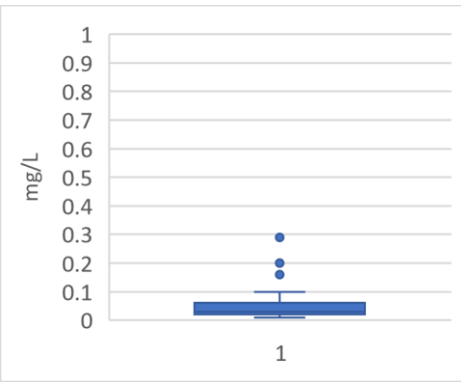
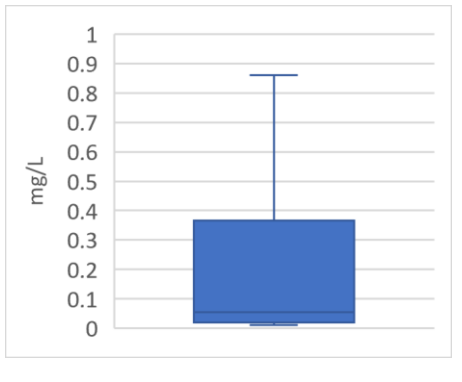
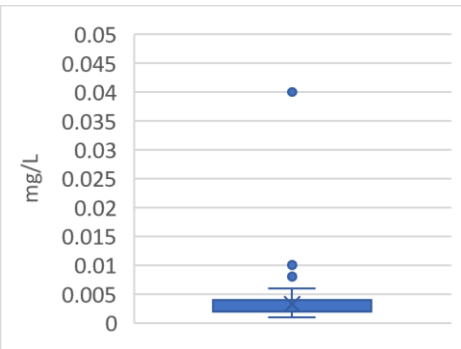
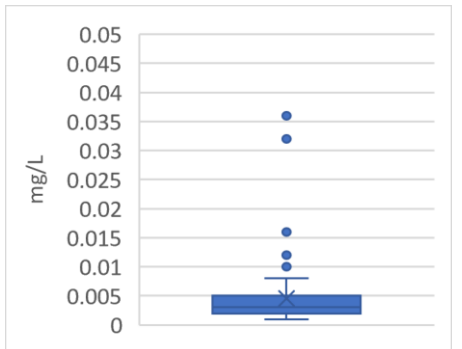
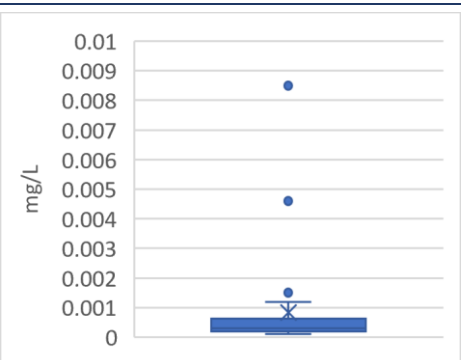
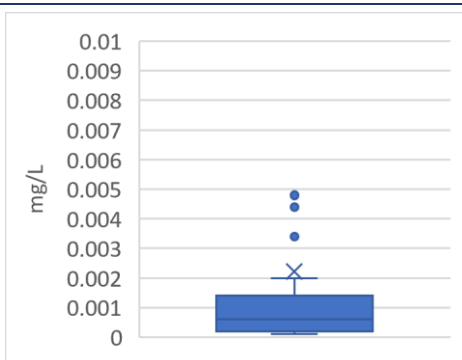
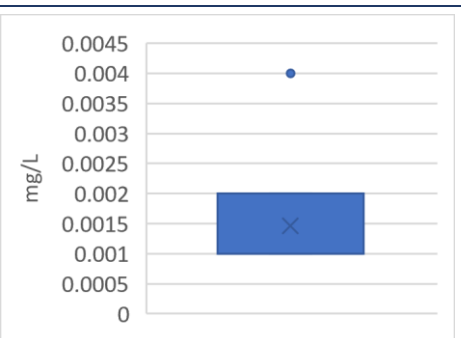
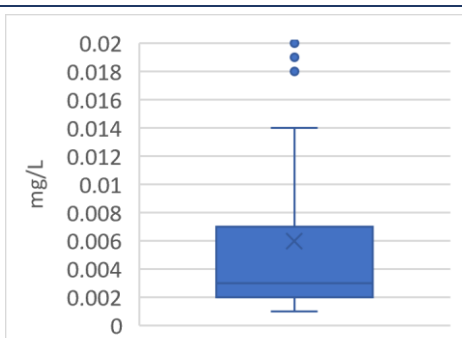
Table 1 shows that a large proportion of elements have concentrations below the detection limit. The exception is Zinc, where nearly all samples have a detectable concentration. Mercury, Selenium, Lead and Chromium are below detection limit in more than 90% of samples for dissolved species. Arsenic, Cobalt, Molybdenum and Nickel (in addition to Zinc) are below the detection limit for less than 40% of samples for dissolved species. This establishes a default background constituent presence as the groundwater samples represented in the Table are for observation bores some distance from the mine. That is, the rock mass at the bore sites have not been mechanically altered by mining, and have only undergone some dewatering due to mining operations.

Table 2 provides information for the levels of constituents above the detection limit. That is, the concentration values that fall below the detection limit have been removed, and summary statistics for detected only concentrations are provided. The data is displayed in the form of box and whisker plots. The inner box represents the 25th percentile value (the base of the box) and the 75th percentile value (the top of the box). The whiskers (the lines above and below the box) identify the smallest (below) and largest (above) values that are not considered outliers. The dots represent outlier values

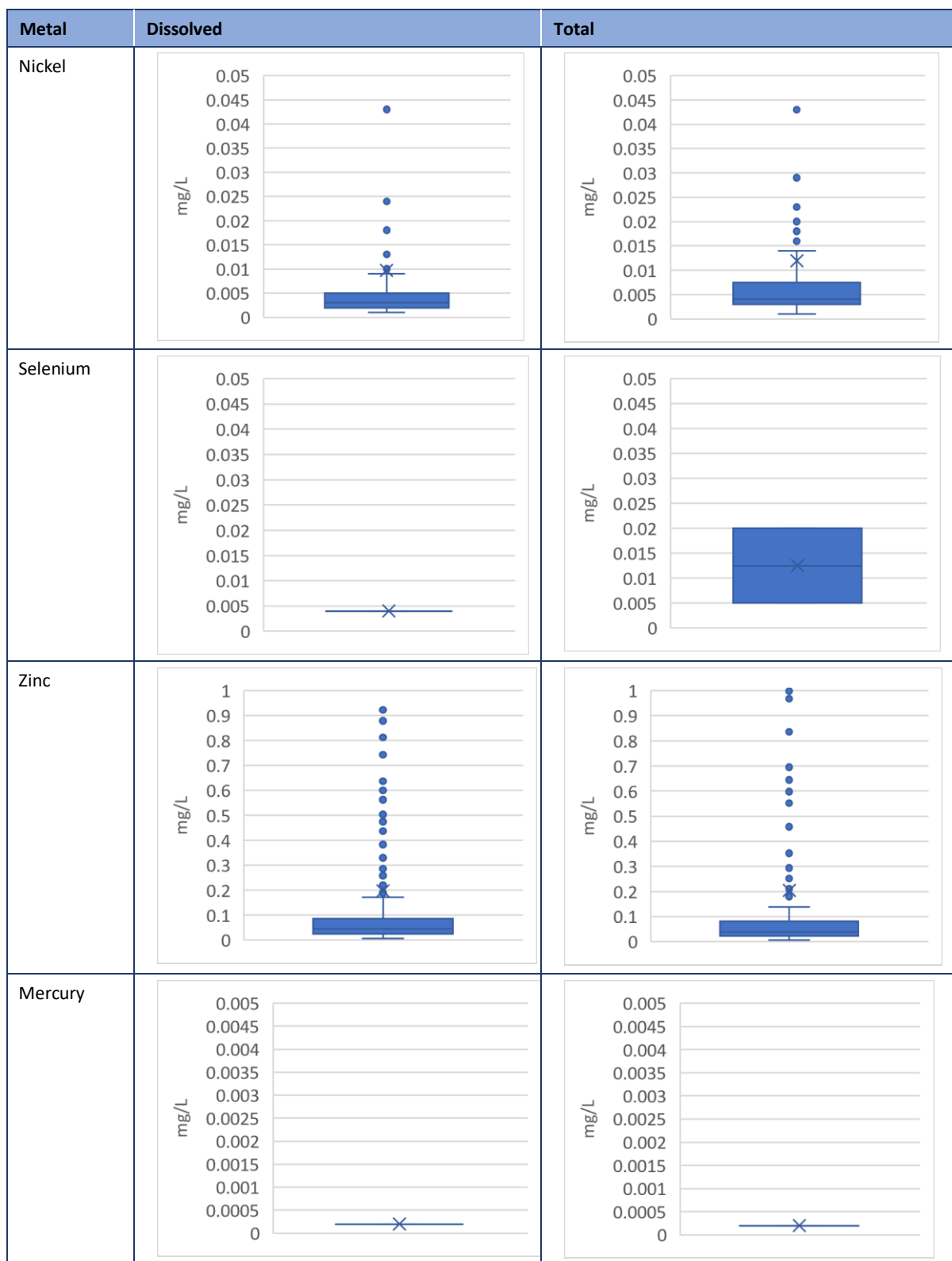
determined by being outside what is termed the inter-quartile distance. The line in the box is the 50th percentile value (the median) and the X is the mean value.

The data represents the background levels of metals in the groundwater and is not unexpected for a metalliferous terrain. Note also that the data is for all of the three geological blocks.

Table 2: Box and Whisker Plots of Selected Detected Metal Concentrations

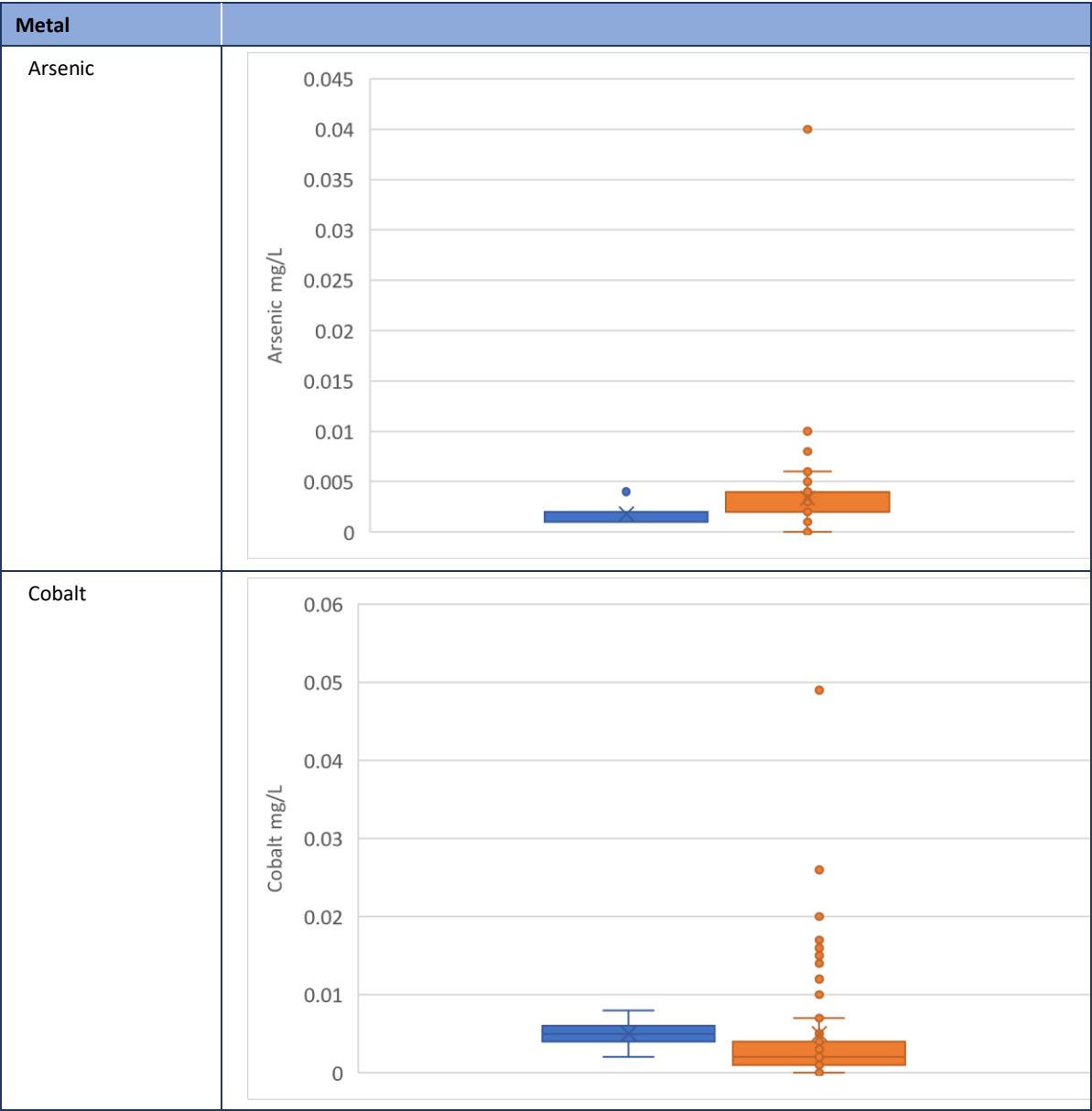
Metal	Dissolved	Total
Aluminium		
Arsenic		
Cadmium		
Chromium		

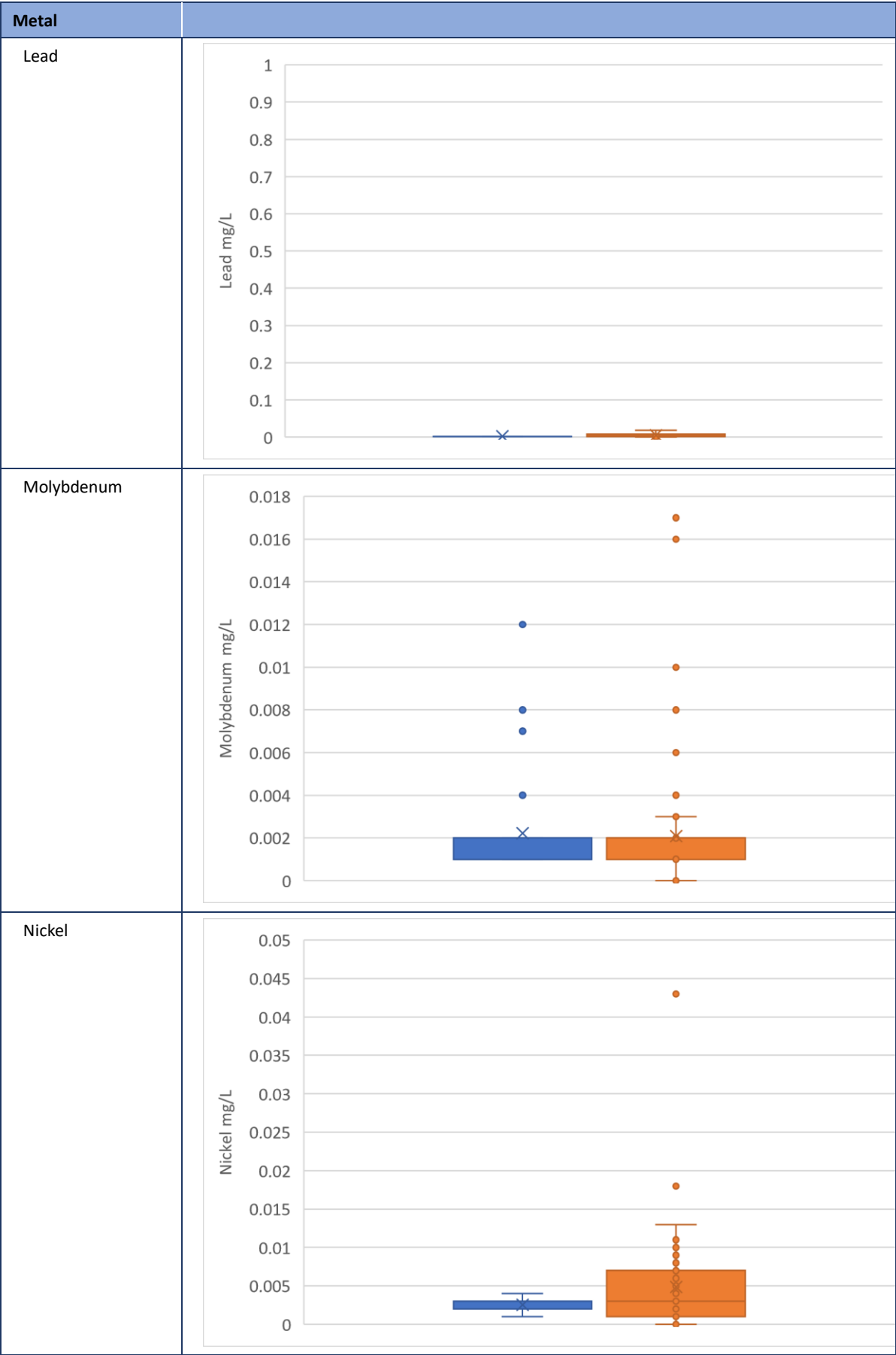
Metal	Dissolved	Total
Cobalt		
Copper		
Lead		
Molybde-num		

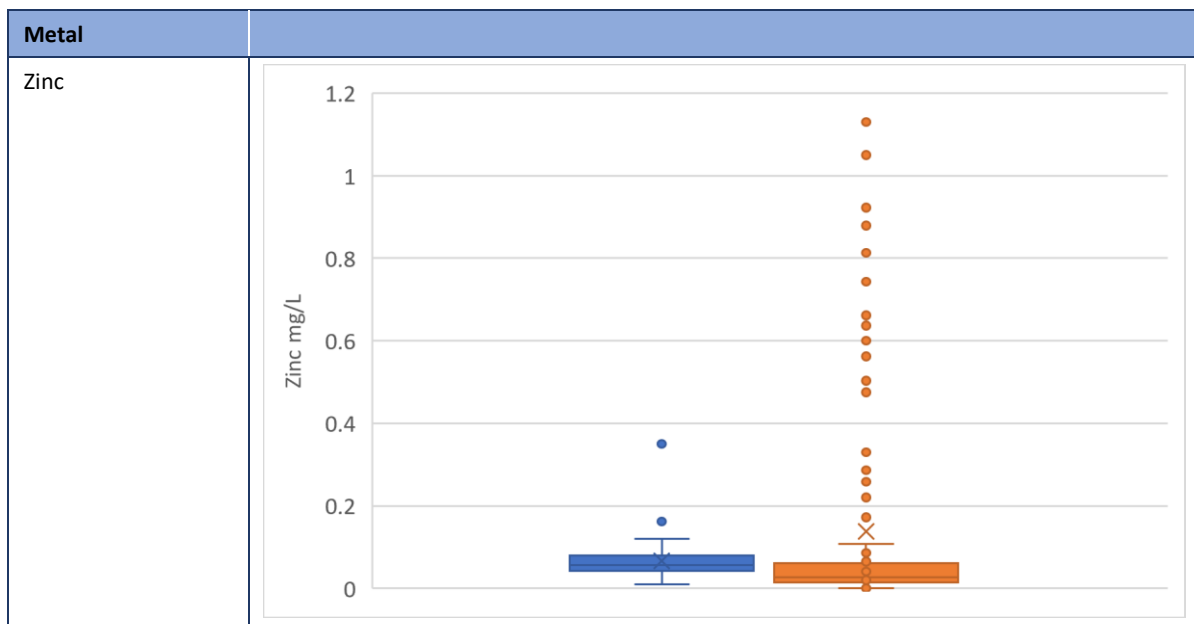


The difference between groundwater sampled from the Cambrian Block and the other two Blocks (Paleoproterozoic and Lady Loretta) is further explored by considering box and whisker plots of dissolved Arsenic, Cobalt, Lead, Molybdenum, Nickel and Zinc (the main elements that have substantial detectable concentrations; Lead has been included as it is a potential CoC; see Table 3).

Table 3: Box and Whisker plots for selected dissolved metals for Cambrian Block (blue) and Lady Loretta plus Paleoproterozoic Blocks (orange)







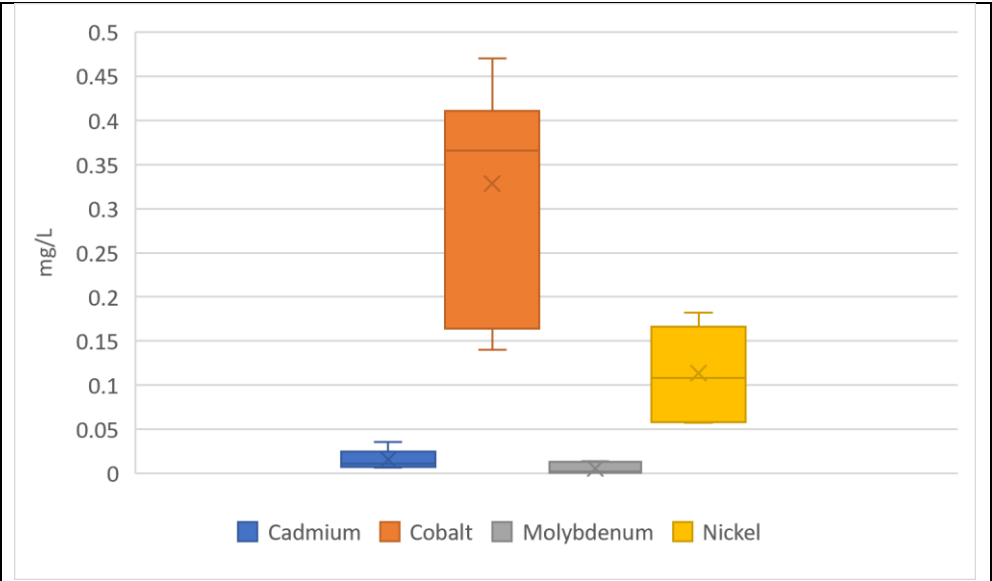
The plots show that the inter-quartile range (the width of the Box) is similar between the Cambrian and other Blocks. The median values are generally the same, but the means are different. The main difference though is that groundwater samples from the Lady Loretta and Paleoproterozoic Blocks have metal concentrations more likely to be outliers than for the Cambrian Block. That is, the concentration distribution is more likely to be uniform for the Cambrian Block, whereas, a number of samples provide concentrations that are more than the interquartile distance above the mean. This is particularly pronounced for Zinc.

Lead shows very low concentrations for all sampled groundwater.

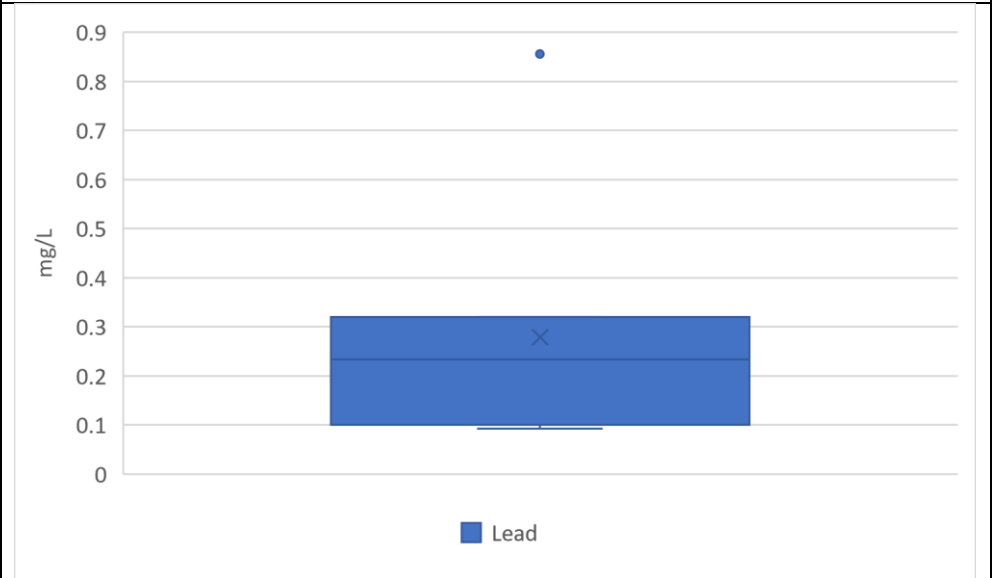
One interpretation of this data distribution is that the Cambrian Block groundwaters are comparatively more well mixed than the other groundwaters in the area, and that the Cambrian Block strata contains lower overall levels of these metals. Conversely, the plots show that the Lady Loretta and Paleoproterozoic Block strata have areas of high metal content, and that groundwaters within these areas are not mixing with adjoining areas to produce more uniform concentrations of the dissolved metals.

Concentration of Metals in underground mine seepage

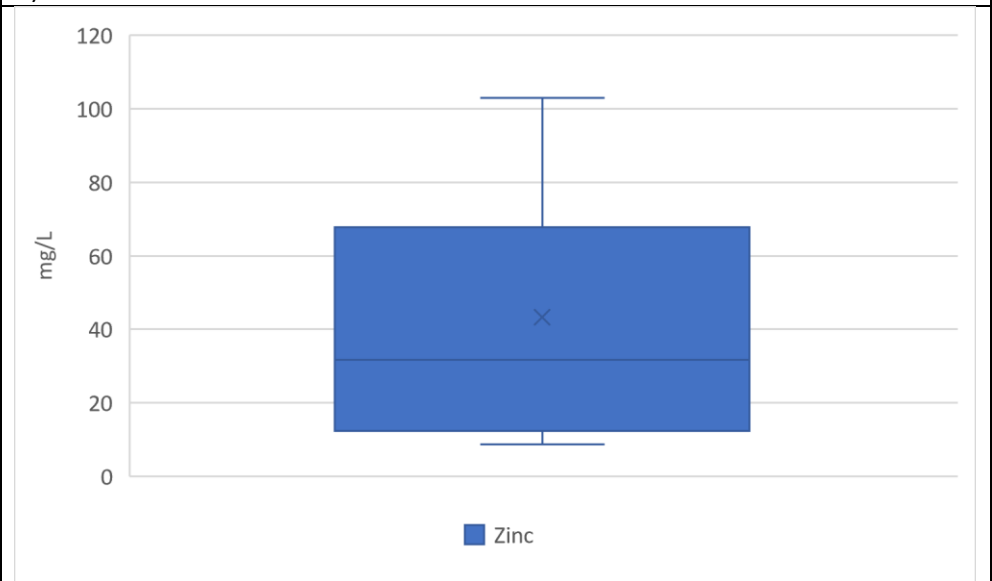
Some data (seven samples) is available for groundwater that has egressed into the mine over a seven-month period in late 2019 to early 2020. The metals content of the groundwater is slightly different to that of groundwater from the broader study area. Arsenic, Chromium, Copper and Mercury levels are either very close to or below detection for all samples. Cadmium, Cobalt, Lead, Molybdenum, Nickel and Zinc are above detection limits (Figure 21a, b and c).



a)



b)



c)

Figure 21: Box and Whisker Plots for dissolved Metals analysed in Underground Mine Seepage

There are some distinct differences between the Metal concentrations in the Underground Seepage groundwater and the more regional groundwater. These include:

- Arsenic generally is at higher concentrations in the regional water and is mostly non-detectable in the underground seepage groundwater;
- Lead concentrations are low, but there are detectable levels in all samples (though only 7 in total) whereas Lead is mostly below detection limits in the regional groundwater;
- Molybdenum and Cadmium concentrations are essentially at the same levels between the two groundwaters (underground seepage versus regional groundwater);
- Cobalt, Nickel and Zinc are at much higher levels in the underground seepage groundwater when compared to the more regional groundwater, with Zinc being 20 to 50 times higher.

Conclusions

- Hydrochemical data quality is an issue with the current dataset, with potential issues attached to analysis suites and field measurement approaches identified.
- In addition, the regular scheduling of a standardised groundwater sampling suite should be considered to enable consistent detailed hydrochemical assessments to be undertaken that also include seasonal variability (recharge) influences.
- Two primary potential sources of chemical constituents measured in the groundwater in the region of the Lady Loretta Mine are considered:
 - The first is from salts depositing either via rainfall or via dryfall (dust) mechanisms;
 - The second is associated with mineral dissolution, both under natural conditions and under conditions imposed due to mining activities.

Lady Loretta Block Conclusions

Groundwater in the Lady Loretta Block is oxidised to mildly reducing. This suggests that sulphidic mineralisation has the potential to be oxidised as groundwater flows through the strata. The mine void has increased hydraulic gradients towards the mine and this has meant that there is a greater supply of oxidised groundwater available for oxidation processes. Conversely, samples from GW08 show that under near natural conditions, the groundwater can become mildly reduced. This is an important consideration for post-mining planning.

The Chloride concentration in groundwater across the site indicates locally differing recharge rates within the block, and these concentrations are preserved, indicating a degree of flow compartmentalisation within the Lady Loretta Block at least.

Regional groundwaters (that is, groundwater outside of the influence of direct impacts of mining) show background levels of some metals that are well above detection limits, confirming that natural weathering processes in metalliferous terrains produce higher than usual background metal contents.

The occurrence of a large number of outliers in the metals data for the Lady Loretta Block and the Proterozoic Block also supports the hypothesis that groundwater in these two Blocks can be compartmentalised, that is, they are not well-mixed.

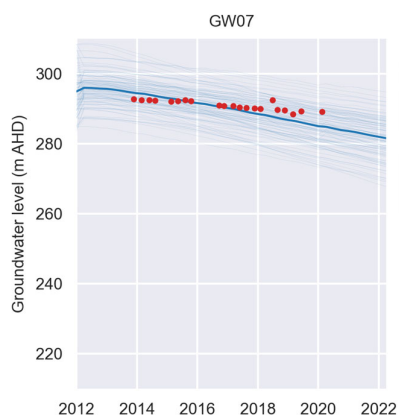
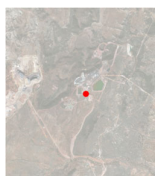
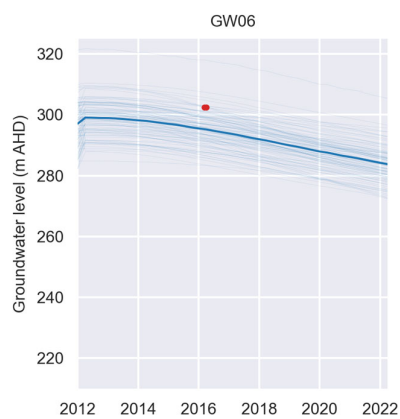
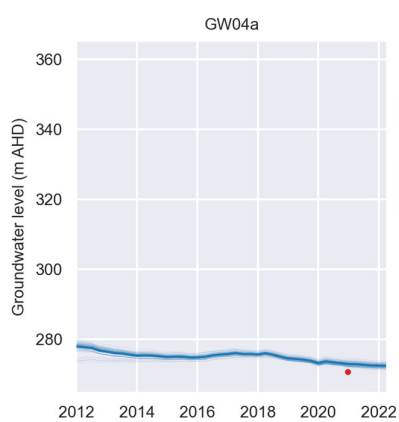
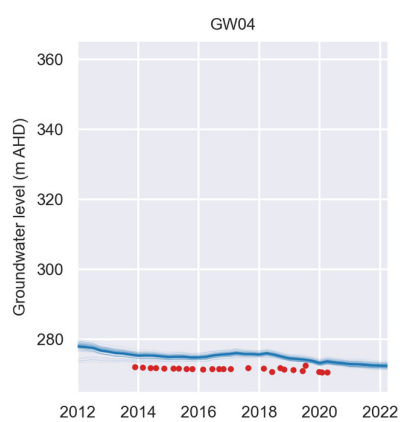
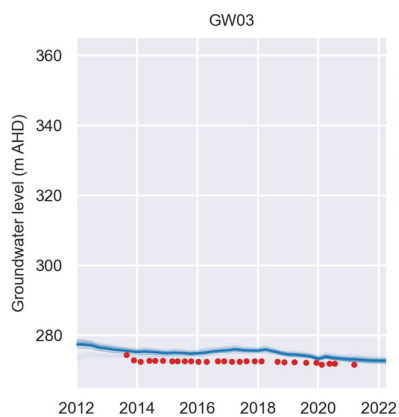
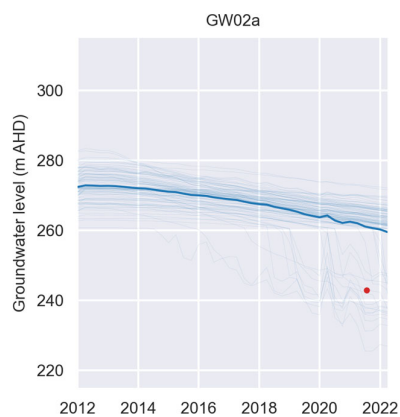
Regional Conclusions

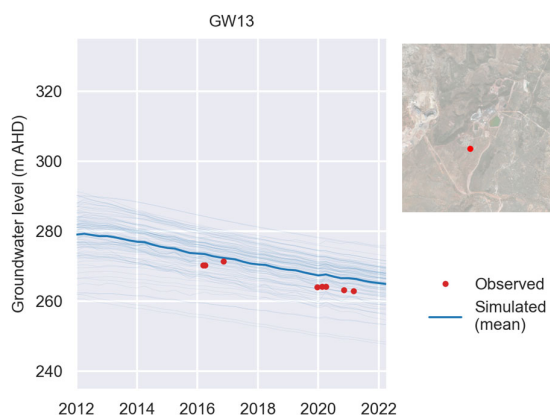
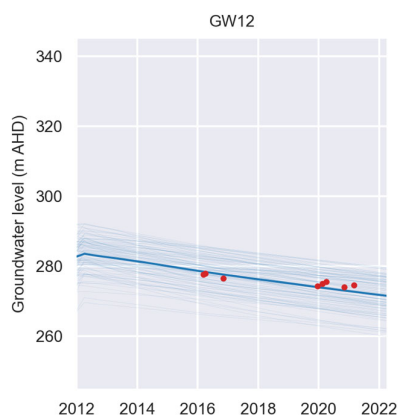
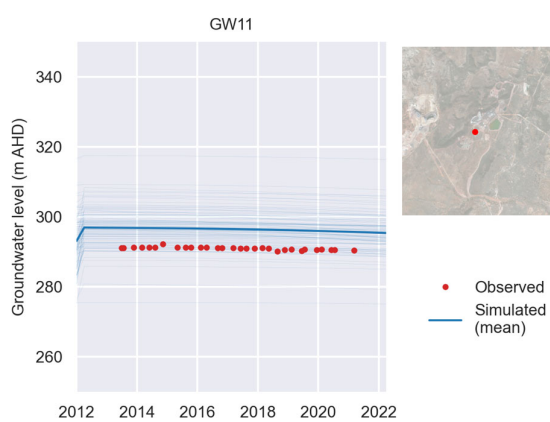
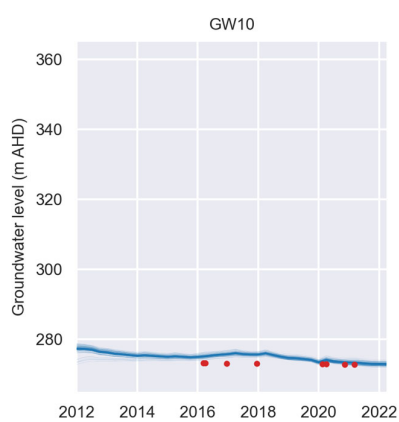
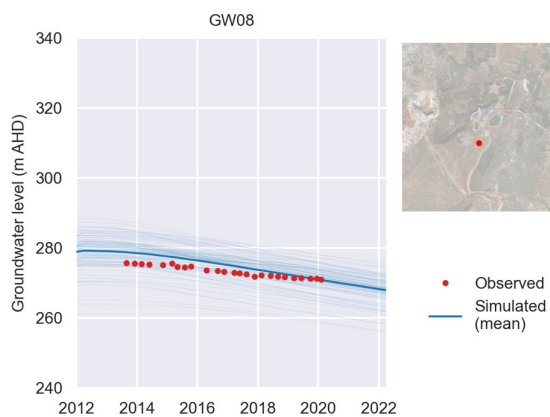
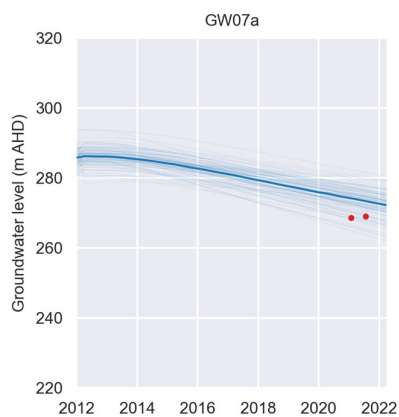
From a regional perspective there is little evidence to support broad scale mixing between groundwaters from different geological Blocks in the vicinity of the Lady Loretta mine considering the results of the major ion chemistry assessment completed. The chemical types of the Cambrian

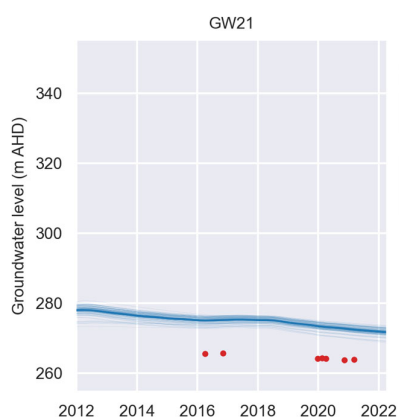
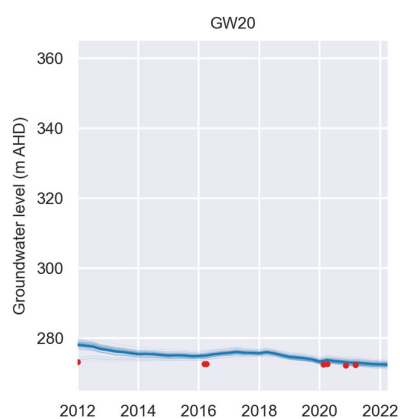
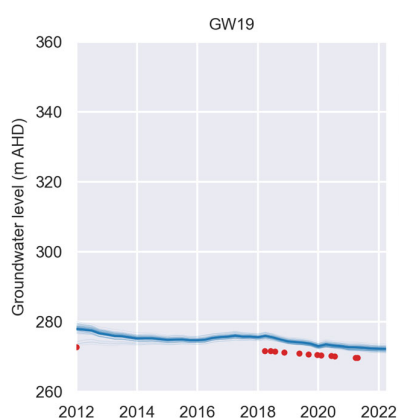
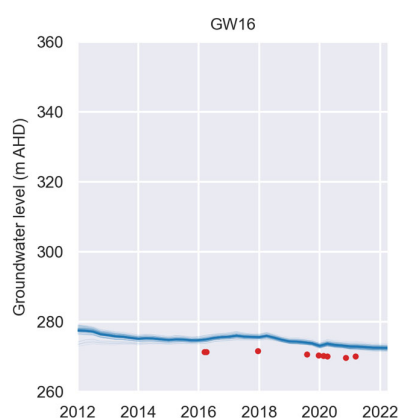
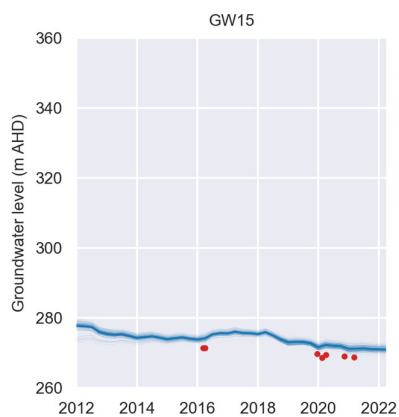
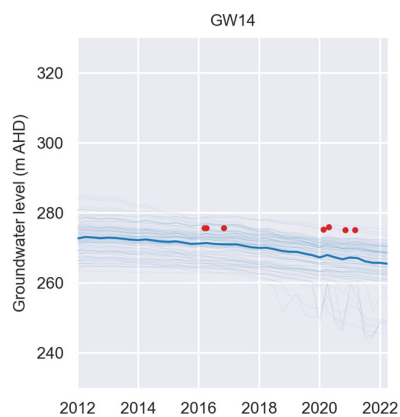
Block groundwater are sufficiently different from those in the groundwater of the Lady Loretta Block to indicate that if flow across the Western Boundary Fault is possible, it is of a small magnitude. Alternatively, the advective “front” of Cambrian Block groundwater has not had sufficient time to reach the observation points and be sampled.

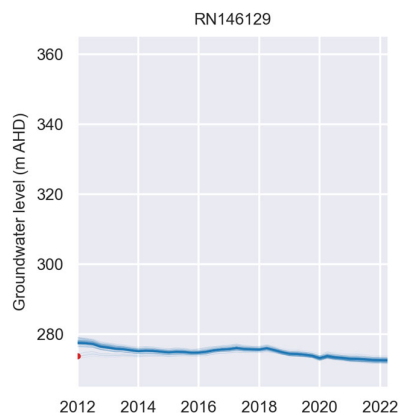
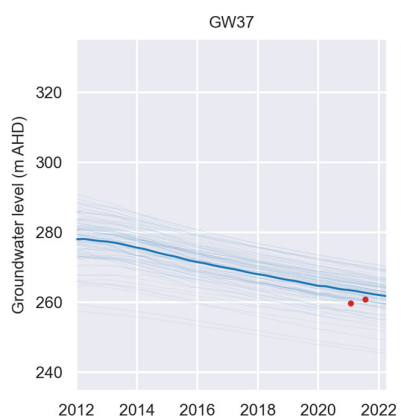
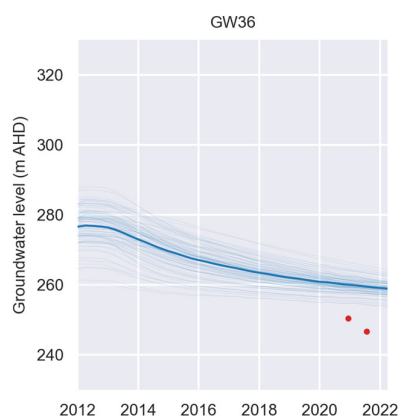
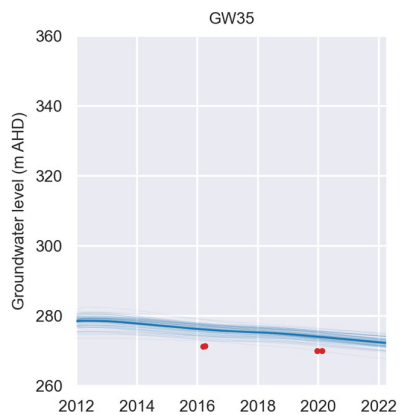
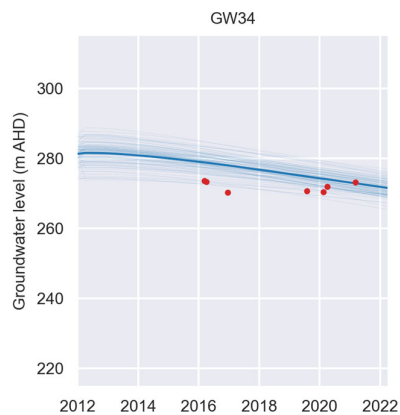
Differing concentration of metals further emphasises the difference between groundwater in the Cambrian Block compared to groundwater from the other Blocks, and supports the notion of a lack of mixing between the Cambrian and Lady Loretta Blocks.

Appendix B Bore Hydrographs









APPENDIX E PRCP PLAN SCHEDULE

Post-mining land uses (PMLU)										
Rehabilitation area				RA1						
Relevant activities				Waste Rock Emplacement						
Total rehabilitation area size (ha)				10.2						
Commencement of first milestone: RM2				10/12/2033						
PMLU				Native Habitat						
Date area is available	10/12/33	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	10.2									
Milestone completed by	10/12/37	10/12/50	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM2	10.2									
RM6	4.7									
RM8	4.7									
RM9		4.7								
RM11		10.2								
RM12			10.2							

- 1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
- 2) Insert new columns to the blue table to match rehabilitation milestone dates.
- 3) Insert new rows to the blue table to include additional rehabilitation milestone references.
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Post-mining land uses (PMLU)										
Rehabilitation area				RA2						
Relevant activities				Topsoil Stockpiles						
Total rehabilitation area size (ha)				5.7						
Commencement of first milestone: RM4				10/12/2035						
PMLU				Low Intensity Cattle Grazing						
Date area is available	10/12/35	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	5.7									
Milestone completed by	10/12/38	10/12/50	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM4	5.7									
RM7	5.7									
RM10		5.7								
RM13			5.7							

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Post-mining land uses (PMLU)										
Rehabilitation area				RA3						
Relevant activities				Leachate Management Dam (LMD) and Erosion and Sediment Control Facility						
Total rehabilitation area size (ha)				0.9						
Commencement of first milestone: RM5				10/12/2025						
PMLU				Native Habitat						
Date area is available	10/12/25	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	0.5	0.9								
Milestone completed by	10/12/28	10/12/45	10/12/55	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM5	0.5	0.9								
RM6	0.5	0.9								
RM7	0.5	0.9								
RM9			0.5							
RM12				0.9						

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- 3) Insert new rows to the blue table to include additional rehabilitation milestone references.
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Post-mining land uses (PMLU)										
Rehabilitation area				RA4						
Relevant activities				CDA, CDB, PPD, Sediment Dams and Erosion and Sediment Control Facilities						
Total rehabilitation area size (ha)				13						
Commencement of first milestone: RM5				10/12/2039						
PMLU				Low Intensity Cattle Grazing						
Date area is available	10/12/39	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	13									
Milestone completed by	10/12/52	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM5	13									
RM6	13									
RM7	13									
RM13		13								

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3) Insert new rows to the **blue table** to include additional rehabilitation milestone references.
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Post-mining land uses (PMLU)										
Rehabilitation area				RA5						
Relevant activities				Infrastructure - waste disposal trench, LMD area, explosive magazine						
Total rehabilitation area size (ha)				11.8						
Commencement of first milestone: RM6				10/12/2025						
PMLU				Native Habitat						
Date area is available	10/12/25	10/12/32	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	0.7	8	11.8							
Milestone completed by	10/12/28	10/12/35	10/12/50	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM1		0.8								
RM4		8								
RM6	0.7	8								
RM7	0.7	8								
RM9			11.8							
RM12				11.8						

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- 3) Insert new rows to the blue table to include additional rehabilitation milestone references.
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Post-mining land uses (PMLU)										
Rehabilitation area				RA6						
Relevant activities				Infrastructure						
Total rehabilitation area size (ha)				35.4						
Commencement of first milestone: RM1				10/12/2032						
PMLU				Low Intensity Cattle Grazing						
Date area is available	10/12/32	10/12/39	10/12/44	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	15.7	29.4	35.4							
Milestone completed by	10/12/35	10/12/41	10/12/2046	10/12/50	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM1	6.5	20.4	35.4							
RM4	15.7	29.4	35.4							
RM6	15.7	29.4	35.4							
RM7	15.7	29.4	35.4							
RM10				29.4						
RM13					35.4					

- 1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
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- 3) Insert new rows to the blue table to include additional rehabilitation milestone references.
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Post-mining land uses (PMLU)										
Rehabilitation area				RA7						
Relevant activities				Run of Mine (ROM) Pad, Paste Plant and Batch Plant						
Total rehabilitation area size (ha)				10.1						
Commencement of first milestone: RM1				10/12/2032						
PMLU				Low Intensity Cattle Grazing						
Date area is available	10/12/32	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	10.1									
Milestone completed by	10/12/35	10/12/50	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM1	10.1									
RM4	10.1									
RM6	10.1									
RM7	10.1									
RM10		10.1								
RM13			10.1							

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- 3) Insert new rows to the blue table to include additional rehabilitation milestone references.
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Post-mining land uses (PMLU)										
Rehabilitation area				RA8						
Relevant activities				Exploration, Roads and tracks						
Total rehabilitation area size (ha)				15.7						
Commencement of first milestone: RM6				10/12/2032						
PMLU				Native Habitat						
Date area is available	10/12/32	10/12/59		10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	1	14.3	15.7							
Milestone completed by	10/12/35	10/12/38	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM6	1	14.3								
RM7	1	14.3								
RM12			15.2							

- 1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
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- 3) Insert new rows to the blue table to include additional rehabilitation milestone references.
- 4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area					RA9					
Relevant activities					Exploration, Roads, tracks and Haul Road					
Total rehabilitation area size (ha)					24.7					
Commencement of first milestone: RM6					10/12/2032					
PMLU					Low Intensity Cattle Grazing					
Date area is available	10/12/32	10/12/35	10/12/39	10/12/44	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	2.1	2.8	3.2	3.9	24.7					
Milestone completed by	10/12/35	10/12/38	10/12/42	10/12/45	10/12/60	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM6	2.1	2.8	3.2	3.9						
RM7	2.1	2.8	3.2	3.9						
RM13					24.7					

- 1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
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- 3) Insert new rows to the blue table to include additional rehabilitation milestone references.
- 4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area				RA10						
Relevant activities				Underground Openings - Shafts, decline, portal						
Total rehabilitation area size (ha)				0.6						
Commencement of first milestone: RM3				10/12/2032						
PMLU				Native Habitat						
Date area is available	10/12/35	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx	10/12/xxxx
Cumulative area available (ha)	0.6									
Milestone completed by	10/12/45	10/12/60		xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx	xx/xx/xxxx
Milestone Reference	Cumulative area achieved (ha)									
RM3	0.6									
RM12		0.1								

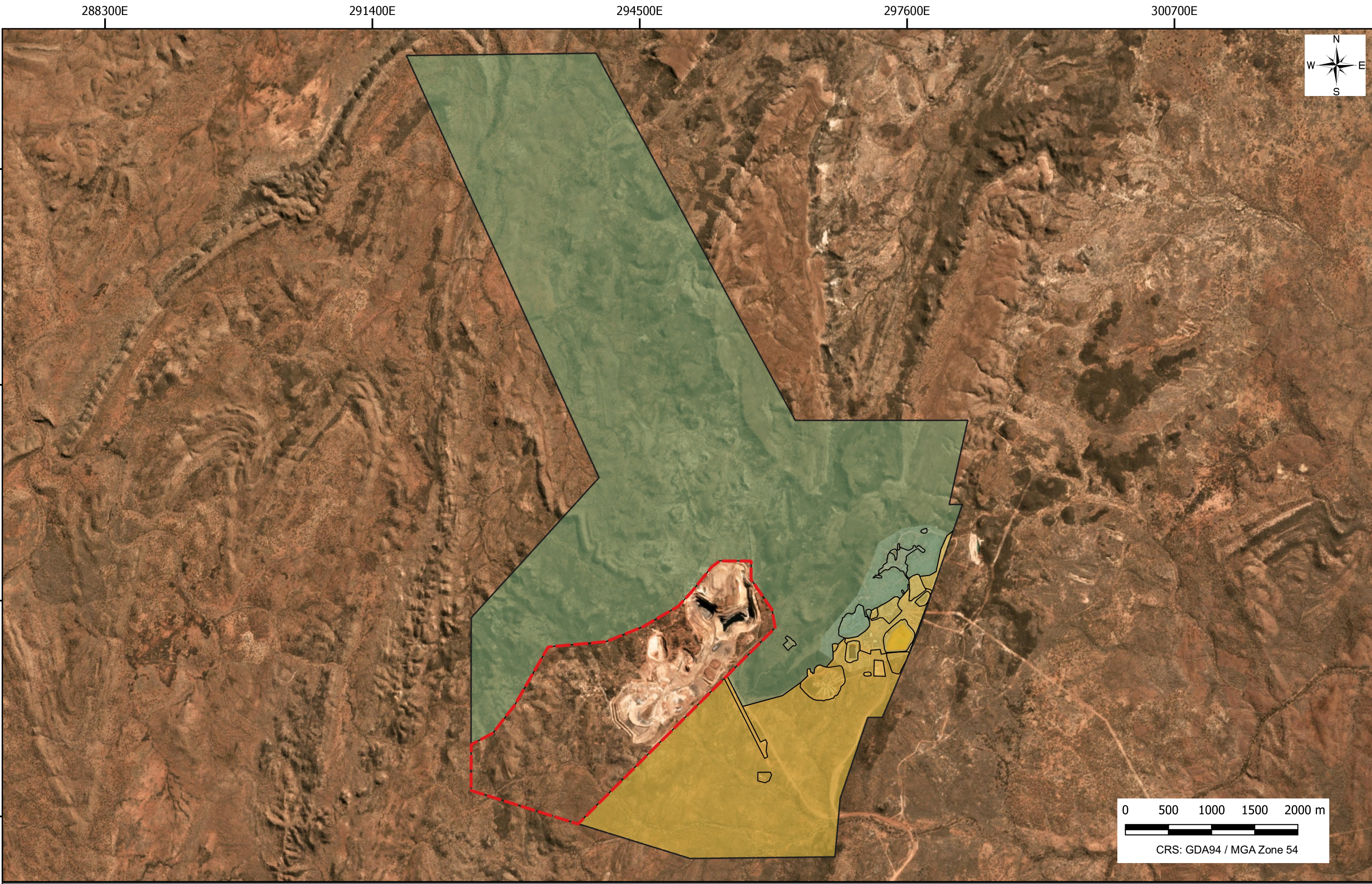
- 1) Insert new columns to the **yellow table** to include further rehabilitation milestone dates.
- 2) Insert new columns to the **blue table** to match rehabilitation milestone dates.
- 3) Insert new rows to the **blue table** to include additional rehabilitation milestone references.
- 4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Milestone reference	Rehabilitation milestone	Milestone criteria
RM1	Infrastructure decommissioning and removal (Fixed Plant)	a) Services disconnected (excluding services agreed with stakeholders for retention) b) Surface fixed plant and infrastructure including foundations (excluding that required for drainage or otherwise agreed with stakeholders for retention) has been removed ## c) Drillholes are capped / plugged and decommissioned in accordance with ESR/2016/1985 ## NOTE: Criteria transitioned from Land Outcome Document (Post Mine Land Use Plan, dated August 2018).
RM2	Installation of cover system (WRE)	a) Batter and crest treatments have been applied, and monitoring stations installed consistent with the WRE engineering design. b) A suitably qualified and experienced person has prepared an As-Constructed Report that details the works undertaken, and certified that construction and encapsulation works met the design intent
RM3	Landform development and reshaping / re-profiling (Underground Openings)	a) Upper sections of ventilation shafts have been backfilled with ROM borrow material to preclude access to underground workings b) Surface subsidence generated depression as determined by subsidence monitoring is no greater than > 500 mm c) Upper section of mine decline has been backfilled with ROM borrow material to preclude access to underground workings d) Portal sealed and box-cut backfilled with inert material to form a free draining final surface e) A suitably qualified and experienced person has prepared an As-Constructed Report that details the works undertaken, and certified that construction and backfilling of underground openings met the design intent
RM4	Landform development and reshaping / re-profiling (ROM Pad, Paste Plant and Batch Plant and Infrastructure Area, Topsoil Stockpiles)	a) Terrain has been reprofiled with disturbed slopes not steeper than 4 H : 1 V and verified by an appropriately qualified person
RM5	Landform development and reshaping / re-profiling (Regulated Dams and Erosion and Sediment Control Facilities)	a) Recommendation by suitably qualified and experienced engineer that Regulated Dam status can be rescinded. b) Terrain has been reprofiled with disturbed slopes not steeper than 4 H : 1 V and verified by an appropriately qualified person c) Erosion and sediment control facilities (excluding facilities agreed with stakeholders for retention) decommissioned and left free draining
RM6	Surface Preparation	a) A suitably qualified person has assessed the characteristics of the soil and growth media and defined requirements for ameliorants and other treatments necessary to achieve the PMLU b) Ameliorants and other treatments (including application of stockpiled growth media) have been applied, as recommended by suitably qualified person. c) Final surface has been deep ripped on surfaces, with the exception of WRE (RA1) d) Placement of maximum thickness of 100mm of growth media at ROM, Paste Plant and Batch Plant Area (RA7), subject to recommendations by suitably qualified person.
RM7	Revegetation (all disturbed areas excluding WRE)	a) Complete seeding to the WRE crest area using seed mix and sowing rates described in Table 16 of the PRC Plan, or based on more recent seed mix and sowing rates as recommendations by suitably qualified person
RM8	Revegetation (WRE)	a) Complete seeding to the WRE crest area using seed mix and sowing rates described in Table 16 of the PRC Plan, or based on more recent seed mix and sowing rates as recommendations by suitably qualified person

RM9	Achievement of surface requirements - Vegetation on Developmental Trajectory (Native Habitat areas)	a)Corrective actions that are recommended by a suitably qualified persons identified through the rehabilitation monitoring methodology has been implemented. b)Corrective action arising from the routine inspections program have been undertaken to include weed control, erosion repair, livestock exclusion. c)Ecosystem Function Analysis index scores compared to equivalent reference sites are: -Stability > 50 % of reference -Infiltration > 40 % of reference -Nutrient Cycling > 20 % of reference -Species Richness > 40 % of reference -Vegetation Dynamics > 20 % of reference -Habitat Complexity > 20 % of reference
RM10	Achievement of surface requirements - Vegetation on Developmental Trajectory (Low Intensity Cattle Grazing areas)	a)Corrective actions that are recommended by a suitably qualified persons identified through the rehabilitation monitoring methodology has been implemented. b)Corrective action arising from the routine inspections program have been undertaken to include weed control, erosion repair, livestock management. c)Ecosystem Function Analysis index scores compared to equivalent reference sites are: -Stability > 50 % of reference -Infiltration > 40 % of reference -Nutrient Cycling > 20 % of reference -Vegetation Dynamics > 20 % of reference d)The basal area of grasses is > 30 % of reference
RM11	Achievement of surface requirements - WRE	a)A suitably qualified person has assessed the performance monitoring data for the WRE and verified that: -No rill/gully erosion > 500 mm -Water flux into contained waste is < 10 % of rainfall
RM12	Achievement of post-mining land use to stable condition (Native Habitat areas)	a)Ecosystem Function Analysis index scores compared to Native Habitat reference sites are: -Stability Index > 80 % of reference -Infiltration > 60 % of reference -Nutrient Cycling > 60 % of reference -Species Richness > 60 % of reference -Vegetation Dynamics > 40 % of reference -Habitat Complexity > 40 % of reference b)Proportion of Category 3 restricted invasive plant species is not >10% of total vegetation groundcover** c)Weed densities will be similar to surrounding reference sites## d)No unrepai red active gullies (i.e. showing active sediment deposition and sides/floor devoid of cover) > 1 m deep## e)Surface water quality at downstream compliance points to meet contaminant limits defined in the current EA## f)Assessment and validation by suitably qualified person that the long-term risks presented by groundwater contamination do not preclude the PMLU g)Evidence in rehabilitation report that appropriate risk assessment for geotechnical stability at the WRE and Underground Openings has been undertaken and control measures are in place## h)Contaminated land investigation completed by suitably qualified person i)Contaminated Land Site Investigation verifies residual contamination presents no unacceptable risk to achieving the PMLU j) Backfill of ventilation shaft complete to pose no unacceptable safety risks to humans or wildlife k)Underground opening certified as safe by a suitably qualified geotechnical engineer (this only applies to RA10) *Defined by Biosecurity Act 2014

RM13	Achievement of post-mining land use to stable condition (Low Industry cattle Grazing areas)	a)Assessment by suitably qualified and experienced person that pasture is sufficiently productive to support low intensity cattle grazing b)Ecosystem Function Analysis index scores compared to equivalent reference sites are: -Stability > 80 % of reference -Infiltration > 60 % of reference -Nutrient Cycling > 60 % of reference -Vegetation Dynamics > 40 % of reference c)The basal area of grasses is > 60 % of reference d)Proportion of Category 3 restricted invasive plant species is not >10% of total vegetation groundcover** e)Weed densities will be similar to surrounding reference sites## f)No unrepai red active gullies (i.e. showing active sediment deposition and sides/floor devoid of cover) > 1 m deep## g)Evidence in rehabilitation report that appropriate risk assessment for geotechnical stability at the ROM, Paste Plant and Batch Plant, Infrastructure and Water Dam areas has been undertaken and control measures are in place## h)Surface water quality at downstream compliance points to meet contaminant limits defined in the current EA## i)Groundwater quality to meet contaminant limits defined in the current EA## j)Assessment and validation by suitably qualified person that the long-term risks presented by groundwater contamination do not preclude the PMLU being sustained k)Contaminated land investigation completed by suitably qualified person l)Contaminated Land Site Investigation verifies residual contamination presents no unacceptable risk to achieving the PMLU *Defined by Biosecurity Act 2014
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- 1) Insert new rows below the table to record more Rehabilitation Area Milestones for the project
- 2) Ensure all Rehabilitation Milestones recorded in this table align with those included in the RA sheets in this form.
- 3) See the PRCP guideline before developing site-specific Rehabilitation Area Milestones



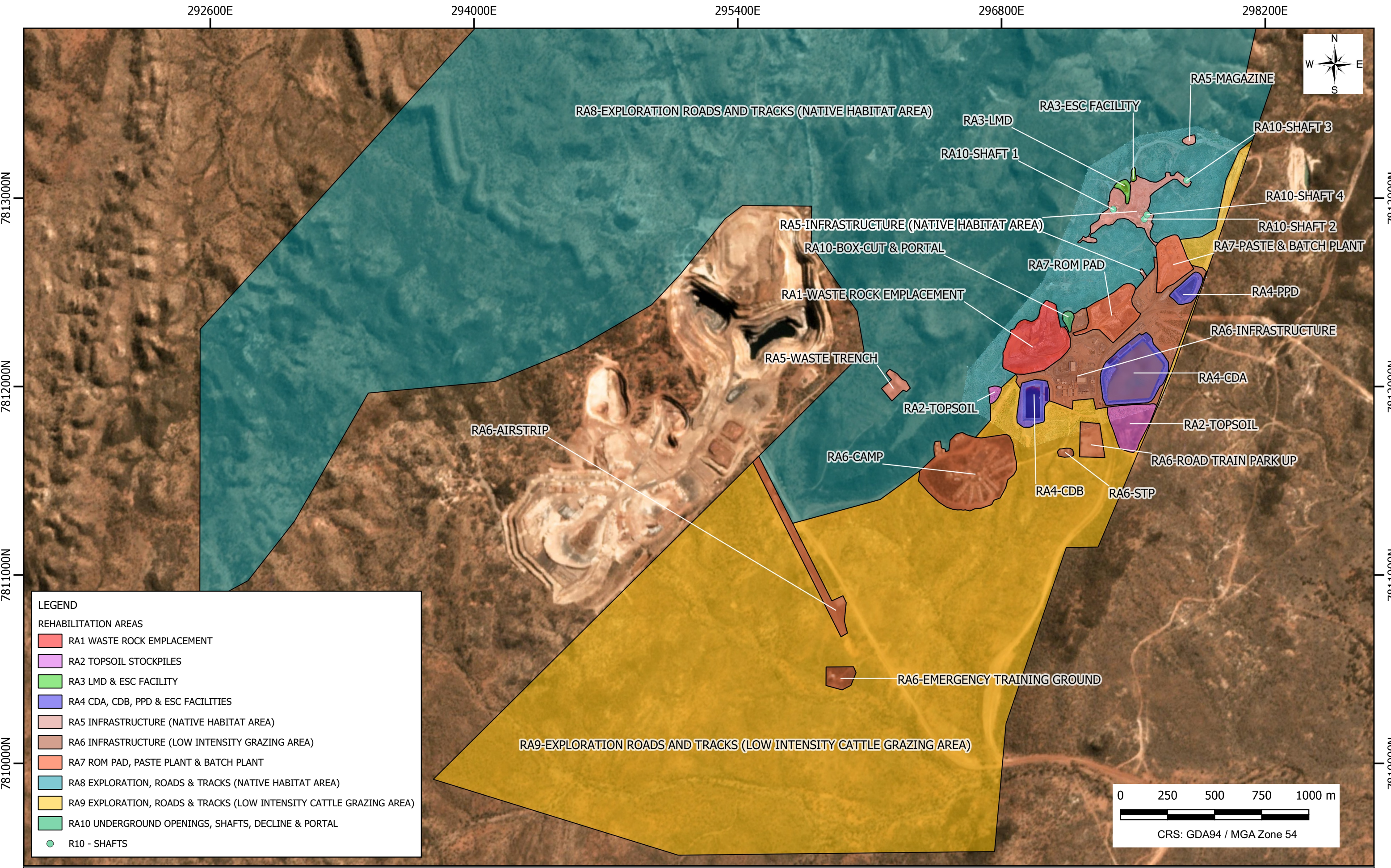
- LEGEND
- | | |
|---------------------------|--|
| LADY LORETTA MINE LEASE | LOW INTENISTY CATTLE GRAZING AREA (567 HA) |
| LADY ANNIE LEASE BOUNDARY | NATIVE HABITAT AREA (2206 HA) |
| REHABILITATION AREAS | |

NORANDA PACIFIC PTY LIMITED

LADY LORETTA MINE
FINAL SITE DESIGN



FIGURE 016
112009-04
DATE: 2022-05-27



APPENDIX F FINAL LANDFORM 3D MODEL (DIGITAL SUBMISSION)