

# Water Management Plan

## McArthur River Mine

McArthur River Mining Pty Ltd



## DOCUMENT PROPERTIES

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Prepared by	MRM Environment Department
Reviewed by	MRM Management Team
Comment/s	

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# 1 Introduction

## 1.1 Background

The McArthur River Mine (the Mine) is an Open Pit zinc, lead and silver mining operation in the Northern Territory (NT) located approximately 700 kilometres (km) south east of Darwin, and approximately 45 km south west of the township of Borroloola (Figure 1).

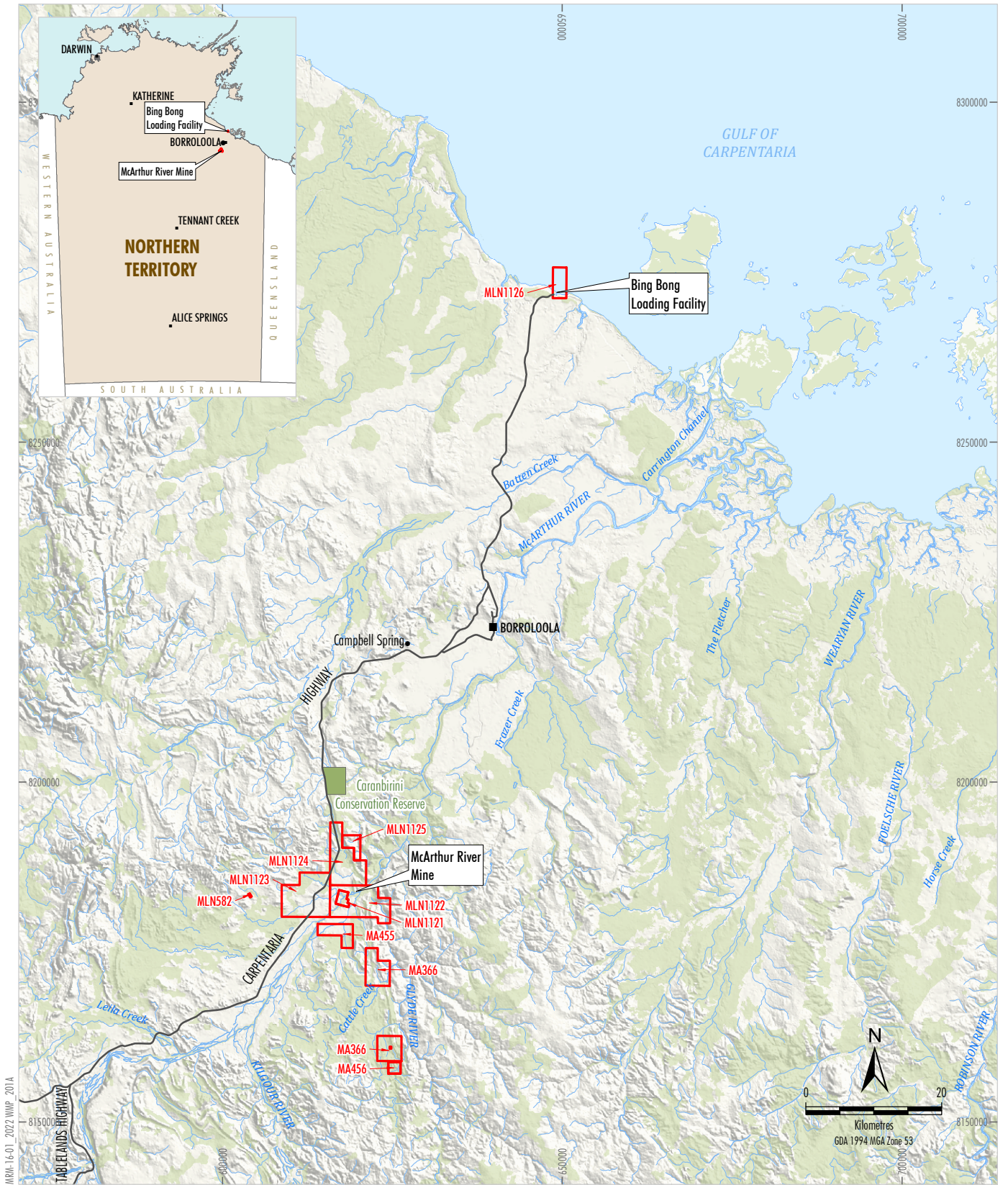
In addition to mining activities, the operations include an on-site concentrator and processing plant (the Concentrator), and barge loading and shipping activities at the Bing Bong Loading Facility (BBLF) located in the Gulf of Carpentaria approximately 95 km north-northeast of the Mine (Figure 1).

McArthur River Mining Pty Ltd (MRM) is the operator of the Mine and is a wholly owned subsidiary of Glencore. MRM is the world's largest producer of zinc in bulk concentrate form.

MRM operates in compliance with its current Mining Management Plan (and associated amendments) approved by the Department of Industry, Tourism and Trade. On-site mining and processing activities are conducted within Mineral Lease Northern (MLN) 1121, MLN 1122, MLN 1123, MLN 1124 and MLN 1125 (Figure 2).

A summary of key MRM operations is as follows:

- Mining and transport of ore within the Open Pit using conventional blast, load and haul methods to the run-of-mine (ROM) pad for stockpiling and processing.
- Mining of and transport of waste rock within the Open Pit using conventional blast, load and haul methods to the Overburden Emplacement Facilities (OEFs).
- Processing of ore via crushing, heavy media separation, grinding, flotation, lead oxidation, dewatering and concentrate handling and storage.
- Thickening of tailings generated by ore processing and piping of tailings for disposal at the Tailings Storage Facility (TSF).
- Transport of concentrate products by road train along the Carpentaria Highway to the BBLF, where the product is barged offshore for transfer to ships in the Gulf of Carpentaria.
- Other ancillary activities, such as dam construction, flood protection works, rehabilitation and excavation of borrow material for construction activities.



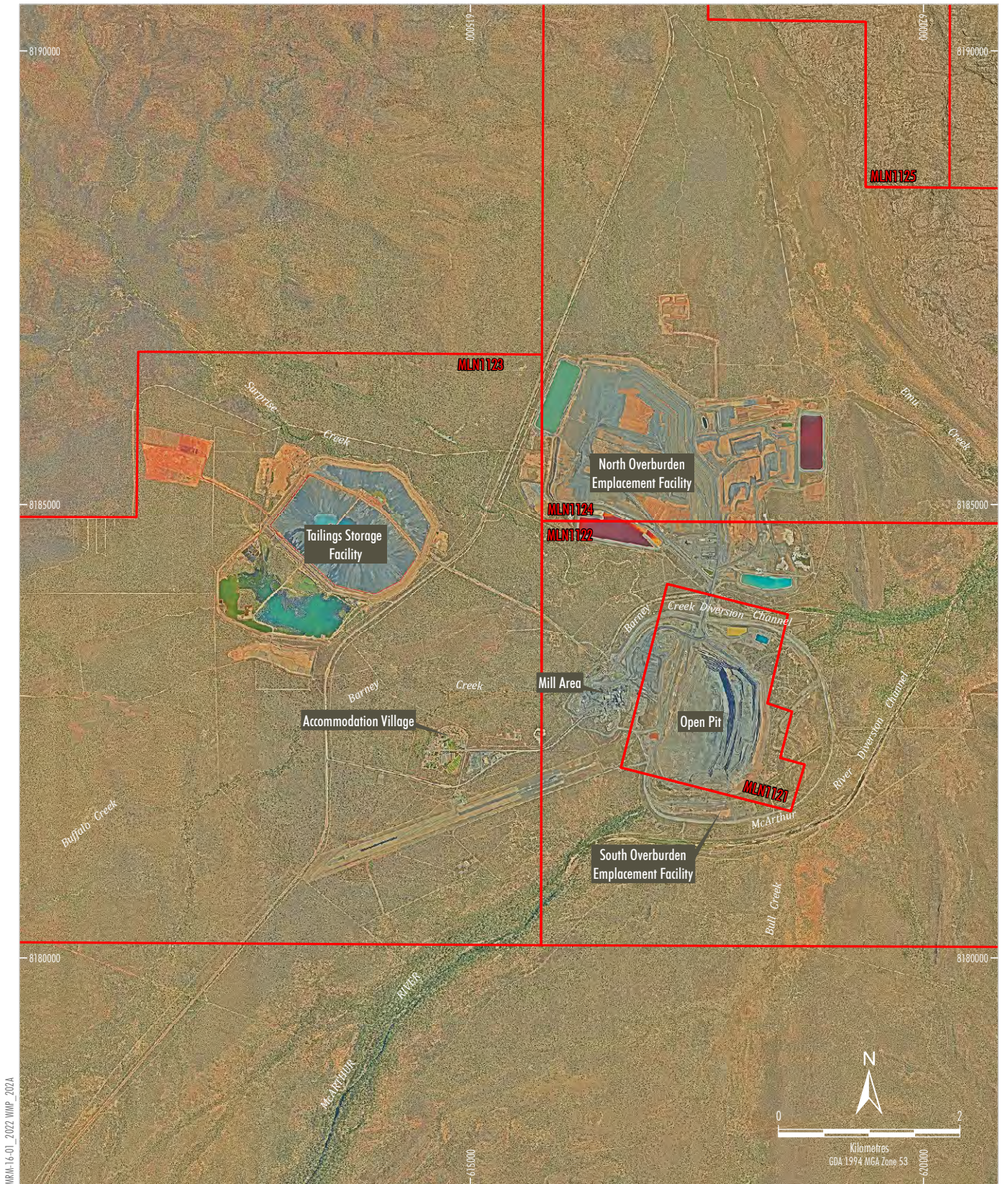
**LEGEND**

- Mineral Lease/Exploration
- Major Road
- River/Creek

Source: Geoscience Australia - Topography (2006);  
 Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
 Regional Locality

**Figure 1**



MRM-16-01\_2022 WMP\_202A

**LEGEND**  
 Mineral Lease

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

McARTHUR RIVER MINE  
 Mine Site

Figure 2

## 1.2 Purpose and Scope

The Water Management Plan (WMP) is a component of the overarching Adaptive Management Plan (AMP) and provides detailed technical information with regard to surface water and groundwater management on-site. The purpose of the WMP is to:

- provide transparency for operational water management at the Mine, including key objectives and strategy;
- outline the surface water and groundwater related monitoring programs and performance criteria; and
- fulfil the requirements of key approval and licence conditions.

The WMP excludes the BBLF. Water management at the BBLF is covered in the *Bing Bong Loading Facility Environmental Management Plan*. The WMP also excludes management of potable water. For information on potable water management, refer to the *McArthur River Mine Health and Hygiene Management Plan 2019-2024*.

For information regarding the adaptive management concept and framework for the Mine, including the key environmental objectives and the operational Trigger Action Response Plans (TARPs) relevant to performance criteria, refer to the AMP.

## 1.3 Structure and Composition

The WMP is structured as follows:

- Section 2: Presents the climatic, hydrological, hydrogeological and aquatic environments relevant to water management at the Mine.
- Section 3: Presents the Mine water classification system, considerations for water management at the Mine, key water management objectives, a site water management overview, groundwater and surface water extraction and management tools.
- Section 4: Describes the current water monitoring programs and performance criteria.
- Section 5: Outlines the contingency responses that may be implemented to an exceedance of a performance criteria or environmental objective.
- Section 6: Provides the process for reviewing and updating this WMP.
- Section 7: References.

## 1.4 Roles and Responsibilities

Roles and responsibilities relevant to the WMP are as follows:

- **General Manager:** implementation of the WMP, ensuring that risk mitigation measures are included as a component of mine planning, and that appropriate contingency responses are implemented if necessary.
- **Manager – Health, Safety, Environment and Community:** implementation of the WMP.
- **Environment Team:** implementation and revision of the WMP, including the water monitoring program and performance criteria.
- **Environment Technicians:** collection of monitoring data, maintenance of monitoring equipment and quality assurance of data.
- **Water Team:** implementation of the water balance strategy, including management of water storage levels, inventories and associated TARPs.
- **Mine and TSF Operators:** implementation of risk mitigation measures and contingency responses.

## 1.5 Regulatory Framework

### 1.5.1 Legislation

The following legislation is relevant to the WMP:

#### Commonwealth Legislation

- *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and Environment Protection and Biodiversity Conservation Regulations 2000.*
- *National Environment Protection Council Act 1994.*

#### Key Northern Territory Legislation

- *Mining Management Act 2001 and Mining Management Regulations 2001.*
- *Water Act 1992 and Water Regulations 1992.*
- *Waste Management and Pollution Control Act 1998 and Waste Management and Pollution Control (Administration) Regulations 1998.*
- *Environment Protection (National Pollutant Inventory) Objective 2004.*
- *Mineral Titles Act 2010 and Mineral Titles Regulations 2011.*
- *McArthur River Project Agreement Ratification Act 1992.*
- *Northern Territory Aboriginal Sacred Site Act 1989 and Northern Territory Aboriginal Sacred Sites Regulations 2004.*

## 1.5.2 Guidelines

The following guidelines have been considered in the preparation of the WMP.

### **Australian Guidelines**

- Guidelines for Water Quality (*Australian and New Zealand Guidelines for Fresh and Marine Water Quality* [ANZG, 2018]).
- Guidelines on the Environmental Management of Dams (Australian National Committee on Large Dams, 2001).
- Preventing Acid and Metalliferous Drainage Guidelines (Department of Industry, Innovation and Science, 2016).
- Guidelines for Groundwater Quality Protection in Australia (Department of Agriculture and Water Resources, 2013).

### **Northern Territory Guidelines**

- Environmental Assessment Guidelines – Acid and Metalliferous Drainage (Northern Territory Environment Protection Authority [NT EPA], 2013a).
- Guidelines on Mixing Zones (NT EPA, 2013b).
- Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015).
- Guidance on Adaptive Management (NT EPA, 2018).

### **International Guidelines**

- A practical guide to catchment-based water management for the mining and metals industry (International Council on Mining & Metals, 2017).
- Global Acid Rock Drainage Guide (The International Network for Acid Prevention, 2009).

### **Corporate Guidelines**

- Glencore water management guidelines.

## 1.5.3 Licences, Certifications and Authorisations

The following Commonwealth and NT approvals and regulatory obligations are currently relevant to the WMP:

- Variation of Authorisation 0059 and the approved Mining Management Plan;
- Waste Discharge Licence (WDL) 174;
- Commonwealth EPBC Approvals (2003/954 and 2014/7210); and
- Aboriginal Areas Protection Authority (AAPA) Certificates.

## 1.6 Community Values and Beneficial Uses

### 1.6.1 Community Values

Community values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, health, safety or welfare, and requires protection from the effects of stressors.

In accordance with the ANZG (2018), MRM has identified the following community values for the McArthur River receiving waters downstream of the Mine:

- aquatic ecosystems (slightly to moderately disturbed);
- primary industries including stock drinking water, irrigation and general water uses;
- recreation and aesthetics; and
- cultural and spiritual values.

Typically, the most stringent water quality objectives are associated with the protection of aquatic ecosystems. Where more stringent water quality guidelines have been identified for other McArthur River community values (e.g. primary industry), these have been adopted in preference to those related to the protection of aquatic ecosystem values.

### 1.6.2 Beneficial Uses

WDL 174 lists the following beneficial uses as declared under the *Water Act 1992* (NT) and the sensitivity of the surrounding land use and environment in the vicinity of the Mine. These include:

- Declared beneficial uses and/or water quality objectives:
  - McArthur River Area: aquatic ecosystem protection, recreational water quality and aesthetics (Gazette references G9 11 March 1998 and G20 27 May 1988); and
  - McArthur River Catchment Area: environment, cultural and riparian (Gazette reference G10 14 March 2001).
- Sites of conservation significance (SOCS):
  - Sir Edward Pellow Island group (SOCS No. 33);
  - McArthur River coastal floodplain (SOCS No. 34); and
  - Borroloola area (SOCS No. 35).

## 1.7 Objectives of the WMP

The key environmental and operational objectives supported by the WMP and strategy are:

1. Protect the McArthur River beneficial uses and community values from mining impacts.
2. Facilitate development of the ecosystems and their functions along the McArthur River Diversion Channel for terrestrial and aquatic flora and fauna.
3. Achieve a recovering trend in the water quality and ecosystem function in creeks on the Mine site within 20 years of cessation of mining.

4. Manage water resources to ensure continuous water supply for mining and ore processing operations whilst minimising water abstraction and maximising water recycling.
5. Manage the operational risk of Open Pit inundation to ensure continuous mining operations and protection of the Mine's assets.
6. Ensure water management is conducted in accordance with MRM's regulatory obligations, including the Mining Management Plan, WDL 174, and EPBC Approvals 2003/954 and 2014/7210.

The operational strategies that support these objectives are aligned with the waste water management hierarchy which aims to preferentially apply strategies in the order of avoidance, reuse and reduction of waste. The hierarchy aims, where practical, to reduce the requirement to dispose of waste water through discharge to the receiving environment.

## 2 Site Setting

### 2.1 McArthur River Catchment

The McArthur River catchment is located within the Gulf of Carpentaria drainage division (see Plate 1), which is one of 12 drainage divisions defined by ANZG (2018).

Flow in the McArthur River adjacent to the Mine is highly seasonal, with flow occurring predominantly during the wet season. Complete cessation of flow is common during the dry season, although a number of permanent pools subsist year-round along the river. These pools have an important ecological function, acting as refugia for aquatic biota during the dry months. The duration of the dry phase is variable and depends on the magnitude of the previous wet season, which recharges the shallow groundwater responsible for catchment baseflow. The catchment adjacent the Mine is classified as temporary waters (intermittent/recurrent) in accordance with ANZG (2018).

The condition of the McArthur River outside of the MRM mineral leases is considered a 'slightly to moderately disturbed system' due to the influence of pastoralism and grazing throughout the catchment. The ANZG (2018) guidelines generally recommend that a 95 percent (%) species protection level should be applied to freshwater toxicants in slightly to moderately disturbed systems, as is the case for the McArthur River in the vicinity of the Mine.

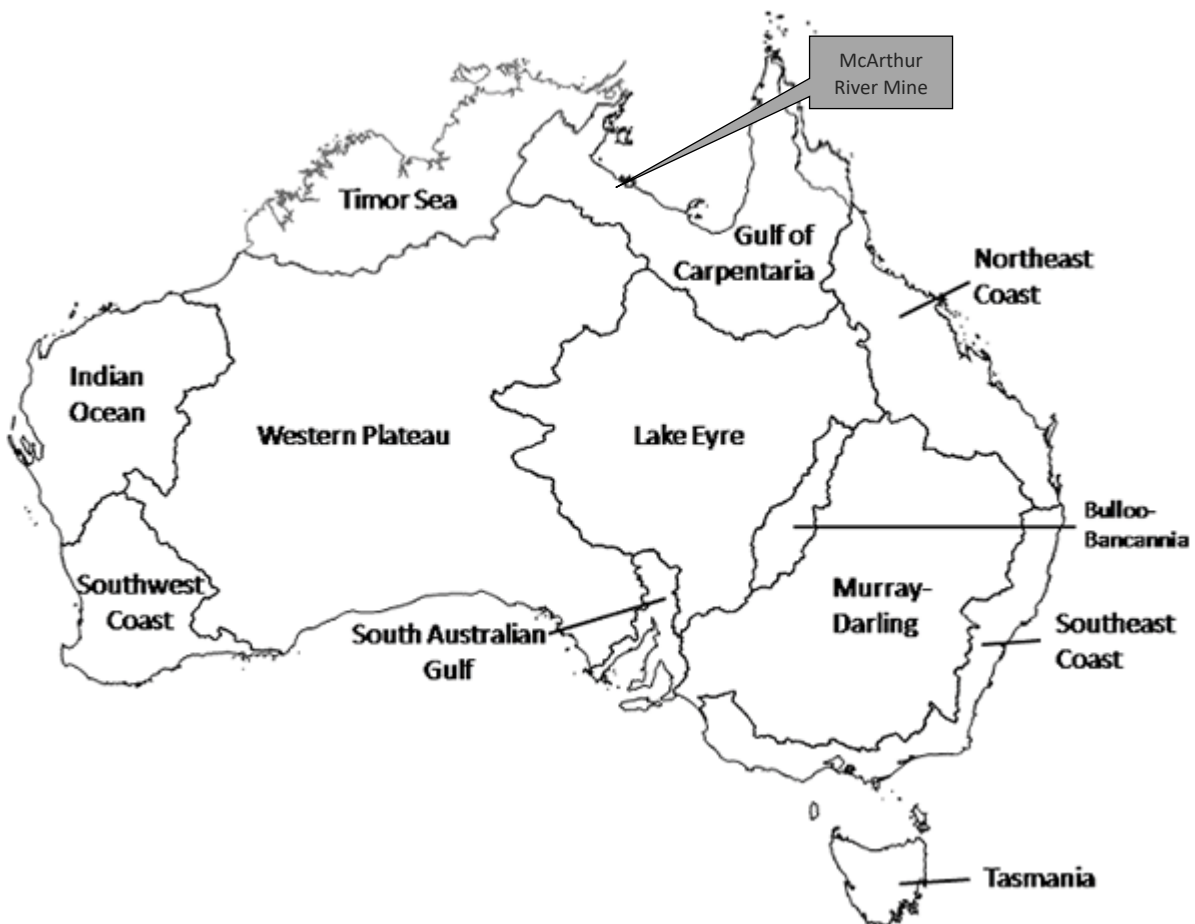


Plate 1: Australia's Inland Water Drainage Divisions (ANZG, 2018)

## 2.2 Climate

The McArthur River catchment experiences a monsoonal climate regime, which is strongly seasonal with distinct wet and dry seasons. The average daily minimum and maximum temperatures at the Mine range between 12°C (in July) and 39°C (in November).

Rainfall and evaporation data was obtained from the Queensland Climate Change Centre of Excellence SILO Patched Point Data Service. The SILO Patched Point Data have been derived from climate data recorded at the MRM Airport (Station No. 14704). Table 1 shows the mean monthly and annual rainfall and pan evaporation data based on the available 132 years of data (1889 to 2021).

**TABLE 1: SILO PATCHED POINT MEAN MONTHLY RAINFALL AND EVAPORATION AT MRM AIRPORT**

Month	Mean monthly rainfall (mm)	Mean monthly pan evaporation (mm)
July	1.3	185.0
August	0.4	220.0
September	3.1	258.8
October	15.2	303.7
November	44.7	295.2
December	111.9	275.0
January	192.6	233.4
February	172.2	192.6
March	140.1	210.7
April	31.8	209.6
May	7.4	196.0
June	5.0	171.8
<b>Annual</b>	<b>725.8</b>	<b>2,752.1</b>

Note: mm = millimetres

Plate 2 shows the mean monthly and cumulative monthly rainfall at the Mine in addition to monthly and cumulative rainfall for the July 2020 to June 2021 period.

The average monthly rainfalls at the Mine exhibit distinct wet (November to April) and dry (May to October) seasons during the year, with a dry season low of 0.4 millimetres (mm) in August to a wet season high of 192.6 mm in January. The wet season average monthly rainfalls (31.8 mm to 192.6 mm) are significantly higher than the equivalent dry season monthly rainfalls (0.4 mm to 15.2 mm). The recorded mean annual rainfall at the Mine over the period 1889 to 2021 is approximately 726 mm.

The average annual pan evaporation at the Mine is estimated to be approximately 2,752 mm, which is approximately 3.8 times the average annual rainfall. The evaporation rate is high throughout the year, with highest evaporation rates occurring in the months between August and January. Mean monthly evaporation is generally much higher than mean monthly rainfall in all months of the year, except January and February.

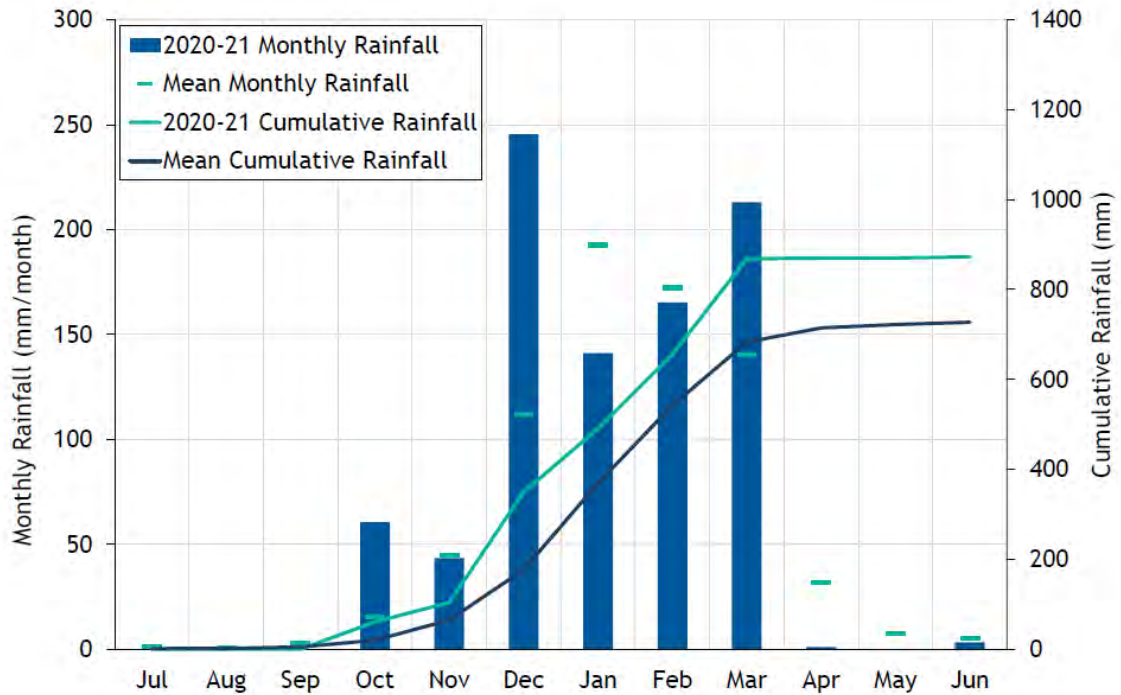


Plate 2: Monthly and Cumulative Monthly Rainfall at the Mine

## 2.3 Surface Water

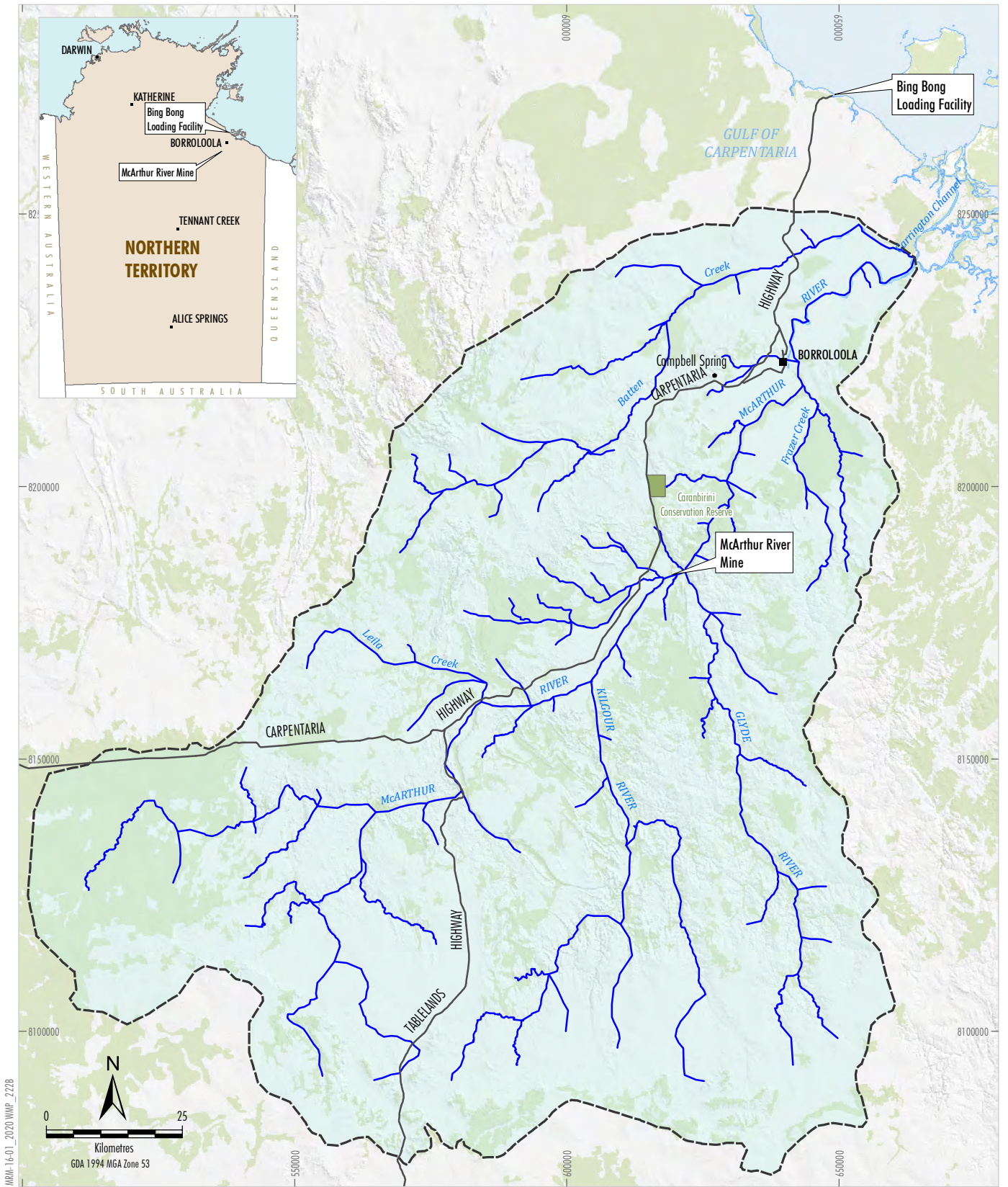
### 2.3.1 Regional Hydrology

The McArthur River is the major surface water feature in the region and originates in the Barkly Ranges and flows in a northeast direction before discharging into the Gulf of Carpentaria near the Sir Edward Pellew Group Islands. The river falls more than 250 metres (m) over its 330 km length. The total catchment area of the McArthur River is approximately 26,000 square kilometres (km<sup>2</sup>).

Figure 3 shows the drainage network of the McArthur River catchment and its major tributaries, including Batten Creek, Scrubby Creek, Tooganginie Creek, the Kilgour River, the Glyde River, Barney Creek and Rocky Creek. The catchment is bounded by the Limmen Bight River and Rosie River catchments to the west and northwest, the Wiso and Barkly Basins to the south and the Robinson River catchment to the east. The catchment is sparsely populated with isolated communities, including the township of Borroloola.

The Mine is located adjacent to the McArthur River, between its confluences with the Glyde and Kilgour rivers in the middle reaches of the catchment. The Glyde River, which has a catchment area of approximately 2,440 km<sup>2</sup>, originates 95 km southeast of the Mine and joins the McArthur River approximately 6.9 km downstream of the Mine. The Kilgour River, which originates approximately 112 km south of the Mine, has a catchment area of approximately 3,100 km<sup>2</sup> and joins the McArthur River approximately 20.7 km upstream of the Mine.

The McArthur River bed level in the reach adjacent to the Mine is between 16 metres above Australian Height Datum (m AHD) and 21 m AHD.



- LEGEND**
-  Major Road
  -  Major Watercourse
  -  McArthur River Catchment

**McARTHUR RIVER MINE**  
**Regional Surface Water Drainage Features**

Source: Geoscience Australia - Topography (2006);  
 Department of Environment and Natural Resources (2016)

**Figure 3**

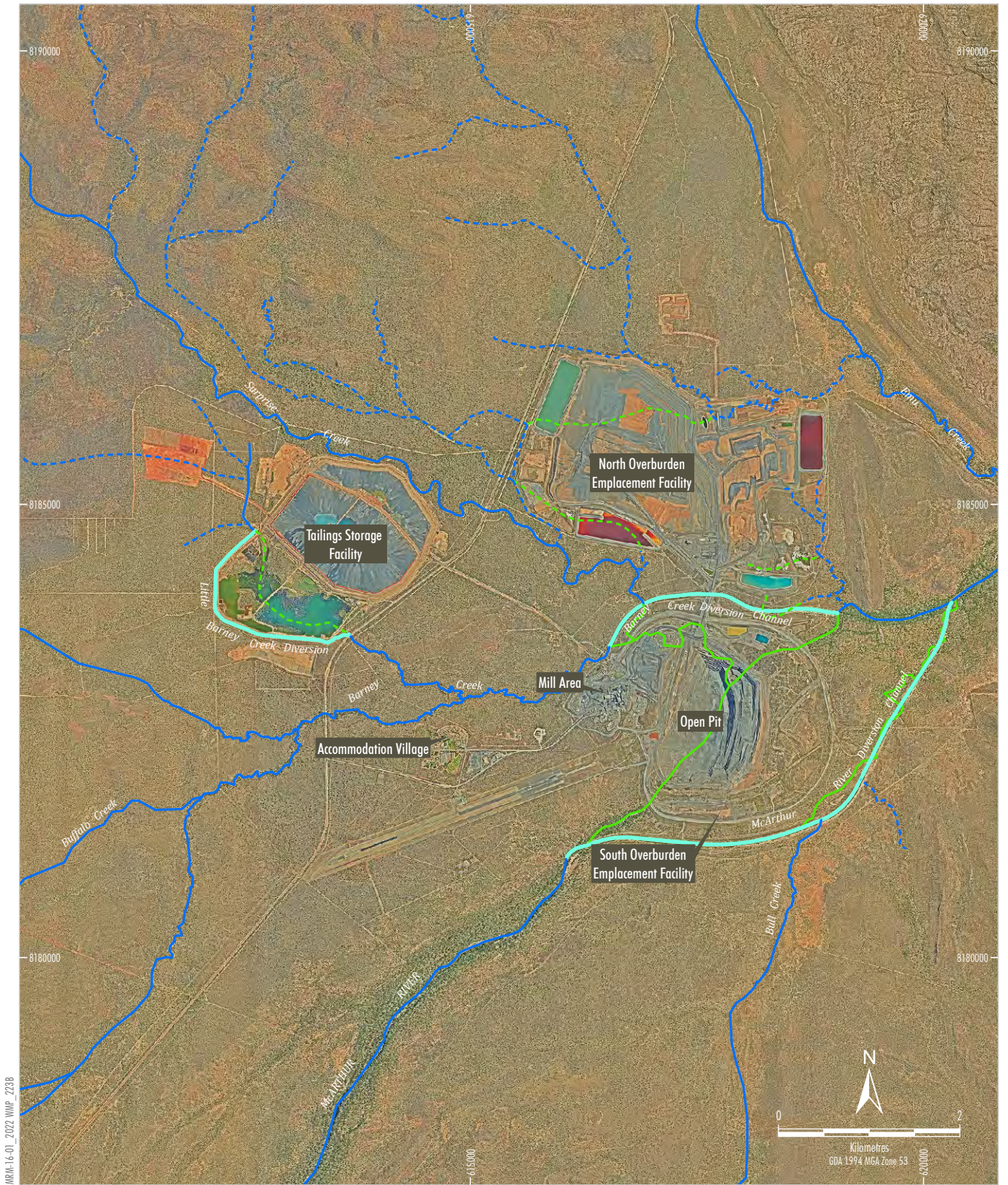
### 2.3.2 Local Hydrology and Topography

Figure 4 shows the local drainage network in the vicinity of the Mine, while Figure 5 shows the surface topography.

The Mine area lies mostly within the McArthur River floodplain. Surface drainage of the waterways in the vicinity of the Mine generally occur from the west towards the McArthur River in the east.

The McArthur River, Barney Creek and Little Barney Creek have been realigned within the Mine to allow for mining activities (Figure 4). In addition, a flood protection levee has been constructed to protect the Open Pit and Mine infrastructure from periodic flooding. Bull Creek is intercepted by the McArthur River Diversion Channel. Surprise Creek is intercepted by the Barney Creek Diversion Channel. The catchment areas for the key watercourses is provided in Table 2 with a summary given below:

- The McArthur River is a major surface water feature of the region.
- McArthur River Diversion Channel was completed in 2009 and consists of a 5.5 km diversion. The works have allowed open cut mining to the ore deposits beneath the river. The river was diverted to the east around the proposed footprint of the Open Pit. To protect the Open Pit from floodwater, a levee wall has been constructed between the Open Pit and the diverted river.
- Barney Creek is an ephemeral (fleeting) waterway, only flowing during the wet season following large episodic rainfall. Barney Creek flows west to east and intersects the Carpentaria Highway to the south of the TSF.
- Barney Creek Diversion Channel is a 2.5 km diversion of lower Barney Creek to allow construction of the northern section of the levee wall. The diversion begins to the north of the Concentrator and cuts between the Open Pit and the North Overburden Emplacement Facility (NOEF). The junction of Barney Creek Diversion Channel and the Old McArthur River is seasonally inundated. During peak flow events, backwater from the McArthur River can extend upstream along the Barney Creek Diversion Channel.
- Little Barney Creek Diversion Channel is a 2.9 km diversion of Little Barney Creek around the southern side of the TSF complex (including the Water Management Dam). The diversion re-joins Little Barney Creek and flows easterly to join Barney Creek. A culvert has been constructed to allow Little Barney Creek to flow under the Carpentaria Highway.
- Surprise Creek is also an ephemeral (fleeting) waterway, only flowing during the wet season following large episodic rainfall. The waterway originates to the northwest of the site and meanders to the north of the TSF before intersecting the Carpentaria Highway. Downstream of the highway, Surprise Creek continues to flow south of the NOEF, converging with the Barney Creek Diversion Channel between the Open Pit and the NOEF.
- Bull Creek was intersected by the McArthur River Diversion Channel and flows into the diversion channel from the south. The Bull Creek catchment is not impacted by the Mine.
- Emu Creek flows southward along the western edge of the Bukalara Plateau. The creek flows past the northern extent of the NOEF and joins the McArthur River upstream of the Glyde River confluence.
- Glyde River originates in the sandstone ranges to the east of the Mine and converges with the McArthur River downstream and to the northeast of the Mine. The Glyde River catchment is not impacted by the Mine.

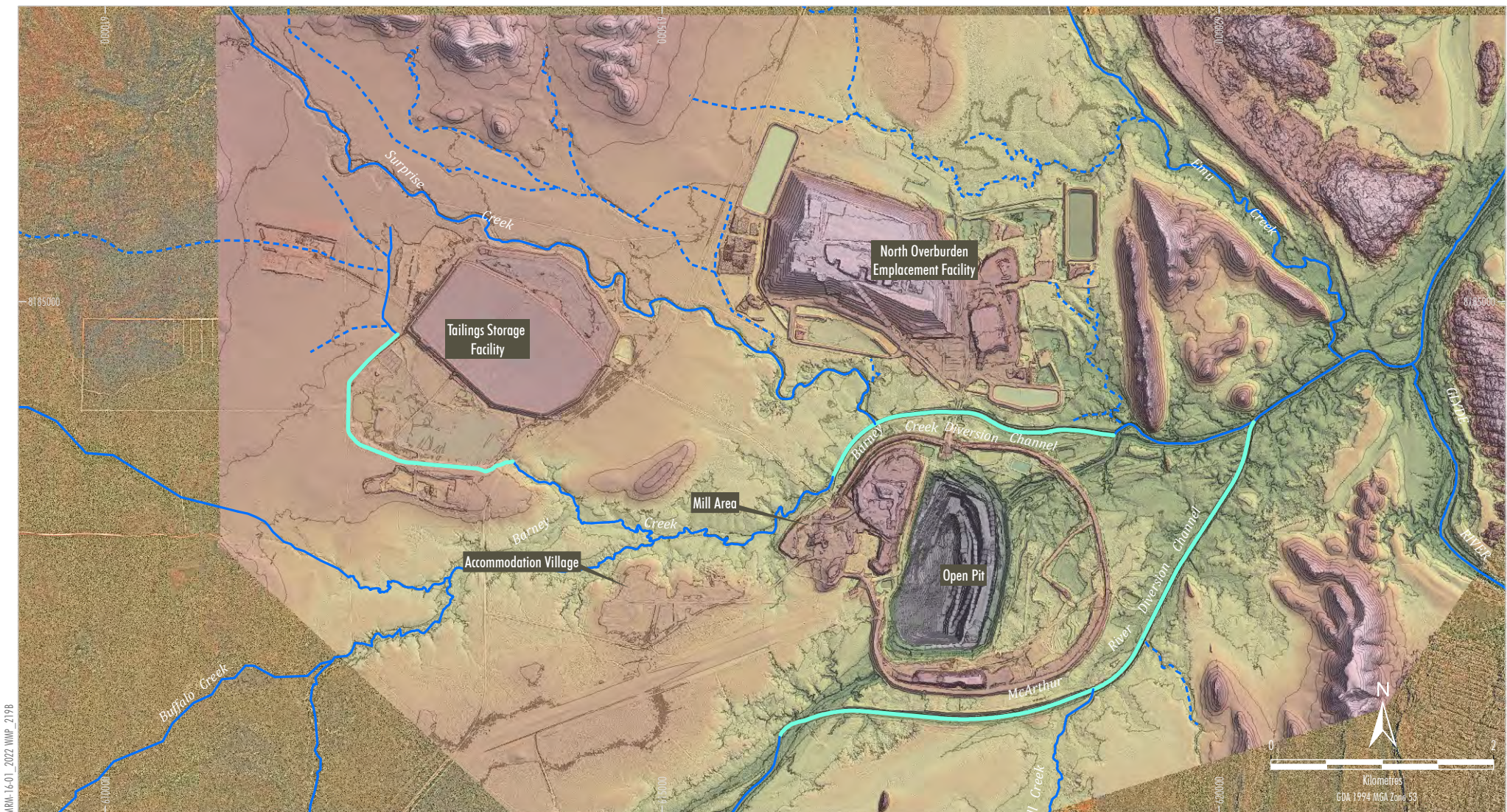


- LEGEND**
- - - Minor Drainage
  - Major Drainage
  - Existing Diversion
  - - - Pre-diversion Minor Drainage
  - Pre-diversion Major Drainage

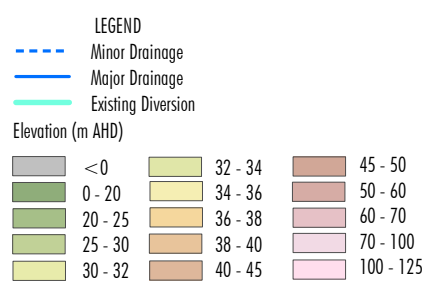
**McARTHUR RIVER MINE**  
Local Surface Water Drainage Features

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

**Figure 4**



/MRM-16-01\_2022 WMR\_2198



Source: Orthophoto MRM (2018); Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
Surface Topography and Drainage

**Figure 5**

**TABLE 2: CATCHMENT AREAS OF WATERCOURSES IN THE VICINITY OF THE MINE**

Watercourse	Catchment Area (km <sup>2</sup> )
McArthur River at upstream of the Mine	9,600
Glyde River at the McArthur River junction	2,440
Barney Creek at the McArthur River junction	700
Surprise Creek at Barney Creek junction	100
Emu Creek at the McArthur River junction	65
Bull Creek at the McArthur River junction	115
McArthur River downstream of the Glyde River junction	12,920

### 2.3.3 Background Surface Water Quality

MRM implements a comprehensive natural surface water quality monitoring program (detail provided in Section 4.3) in the vicinity of the Mine to assess background water quality in the McArthur River and its local tributaries. Background water quality is heavily influenced by the seasonal cycle of the wet-dry tropics.

#### 2.3.3.1 Wet Season

Background surface water quality in the McArthur River catchment during the wet season is typified by low total dissolved solids, hardness, alkalinity and electrical conductivity (EC), all associated with surface water dilution from catchment runoff and frequent rainfall events. The pH typically ranges from 6.5 – 8 during the wet season.

Wet season flood pulses have high erosive forces, transporting catchment sediment downstream. The sediment laden water contains high concentrations of total suspended sediments including fine colloidal material which results in turbid waters. The fine colloids also cause elevated concentrations of metals associated with catchment regolith including aluminium and iron.

Background water quality during flood pulses can also be influenced by the erosion of mineralised zones (Figure 6) which occur at surface in the McArthur River catchment. These mineralised zones can result in naturally elevated total concentrations of metals such as copper, lead and zinc.

First flush and flood pulse events in the McArthur River catchment often result in the rapid mobilisation of catchment organic matter. The bacterial decomposition of this material often causes low dissolved oxygen concentrations during these events. Similarly, the mobilisation of partially decomposed organic matter can also cause naturally elevated concentrations of nitrate.

#### 2.3.3.2 Dry Season

Background surface water quality in the McArthur River catchment during the dry season is typified by high concentrations of total dissolved solids and alkalinity, and moderate concentrations of hardness and electrical conductivity. These parameters are associated with the influence of mineral rich groundwater derived baseflow on the surface water quality. As a result, the pH typically ranges higher during the dry season from 7.5 to 8.5.

Flow in the McArthur River adjacent the Mine and the local tributaries occurs predictably every wet season, with cease to flow conditions common during the dry season. Recessional flow during the dry season is dictated by the catchment size and the magnitude of the previous wet season, which recharges the shallow groundwater systems responsible for sustaining baseflow. The local tributaries, including Barney, Surprise and Emu Creeks contain fleeting waters that typically cease to flow early in the dry season. Flow in the McArthur River is sustained for longer periods.

The cease to flow conditions and eventual drying of sections of the waterways influence water quality through the evapo-concentration of major solutes. The electrical conductivity in background McArthur River waters can range up to 2.2 millisiemens per centimetre (mS/cm) during these conditions. The background dry season water is bicarbonate dominant. Suspended sediments and total metal concentrations in background water during the dry season are typically low, with the exception of iron associated with expression of anoxic groundwater in some background catchments. The low flow and cease to flow conditions are susceptible to influence from upstream pastoral activities, including faecal material from cattle.

There are a number of zones of natural mineralisation (Figure 6) present across the catchment and on the mineral leases, which influence water quality during the dry season. These occur in the areas to the east of the Open Pit which are intersected by and outcrop in the McArthur River Diversion Channel, and in the area around Barney Creek between the Concentrator and the TSF. Elevated concentrations of sulphate, lead, zinc, and copper in surface water have been experienced in these areas.

## 2.4 Geology and Mineralisation

### 2.4.1 Stratigraphy

The Mine is situated within the McArthur River floodplain, where the weathered and fresh bedrock of the Proterozoic McArthur Group are overlain by a variable thickness of Quaternary alluvial sediments of up to 18 m in thickness in some parts. The McArthur Group is a sequence of Proterozoic formations that are extensive and predominantly dolomitic. These sequences are generally thicker than 4 km and consist of interbedded dolostones, siltstones, shales and sandstones. The McArthur Group is overlain by the Batten Subgroup that consists of shallow marine deposits, dolomitic sandstones, pyritic shale, quartz sandstone, and evaporites (URS, 2012).

Naturally occurring sulphide-rich lithologies, referred to as mineralized zones, occur within the HYC deposit in the open pit as well as satellite deposits to the east of the pit, north of the NOEF (near Emu Creek) and in the area around Barney Creek (between the mill and the TSF) (Figure 6). These zones have an influence on groundwater quality and have been defined by Logan and Associates (2018) based on consideration of pre-mining soil and sediment geochemistry as well as historic and recent drilling results.

The immediate Mine area geology includes the Barney Creek Formation and various identified dolomites (Teena, Mitchell Yard and Mara Dolomite). Table 3 summarises the stratigraphy, geology and hydrogeological characteristics of the Mine.

Directly east of the Mine is the Bukalara Plateau, which rises 20 m to 100 m above the surrounding land surface and is comprised mainly of lower Cambrian Bukalara Sandstone (Klohn Crippen Berger Ltd [KCB], 2017a).

**TABLE 3: SUMMARY OF STRATIGRAPHY, LITHOLOGY AND HYDROGEOLOGY**

Period	Geological Formation	Member/unit name	Lithological description	Hydrogeological characterisation
Quaternary	Alluvium	Alluvium	Unconsolidated granular and fines material deposited under fluvial and flood conditions, often reworked	Productive unconfined aquifer where saturated
		Palaeochannel	Mostly gravel and coarse sand deposited in the McArthur River Palaeochannel	High yielding aquifer
Proterozoic	Barney Ck Formation	Weathered bedrock	Weathered bedrock, variable depth and nature dependent on host lithology	Variable, can be considered aquifer where permeability is laterally pervasive
		HYC Pyritic Shale	Pyritic Shale	Poor aquifer
		Main Talus Breccia (Cooley Dolomite Breccia)	Chaotic breccias with clasts that occur from a few millimetres until a few metres in size	Poor aquifer
		HYC Pb-Zn Ore	Thin-bedded to laminated dolomitic siltstone characterised by high carbonaceous content	Can yield groundwater if fractured
		W-fold Shale	Green and red dolomitic siltstone and shale with interbeds of green vitric tuff	Poor aquifer
	Teena Dolomite	Coxco	Massive dark grey and sometimes vaguely bedded dolostone with numerous interbeds of weathering mudstones	Fractures, joints, and other geologic structures in these otherwise competent rocks can be conduits through which groundwater flows
		Lower Teena	Very thin bedded, massive, dark pink and grey dolomite	
Palaeo-proterozoic	Emmerugga Dolostone	Mitchell Yard Dolostone	Dark grey weathering, uniform, massive, karstic dolomite which has undergone extensive vadose alteration	Variably saturated karstic/fractured rock aquifer. Fractures and vughs dominantly control groundwater flow
		Mara Dolostone	Laminated dololomite, interbedded with thin beds of flake and randomly orientated intra clast breccias, occasional recessive fine dolomitic sandstone, dolomitic siltstone and silty massive dololomite. The silty units sometimes contain chert.	



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- LEGEND**
- HYC Ore Body
  - Cooley Prospects
  - Ridge Prospects

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
**Mineralisation at the Mine**

**Figure 6**

## 2.4.2 Structural Geology

Six dominant geological structures within the Mine area have been identified and are shown on Figure 7. A summary of each of the features is included in Table 4.

**TABLE 4: SUMMARY OF DOMINANT STRUCTURAL FEATURES**

Structure	Description
Emu Fault	<ul style="list-style-type: none"> <li>Major regional north-northwest fault about 1.5 km east of the orebody.</li> <li>Characterised by horst blocks of Masterton Sandstone, displaced upwards from the base of the McArthur Group.</li> <li>Seismic data suggest the fault comprises several near vertical faults, about 150 m wide, is deeply weathered, has a low density and is porous with respect to the surrounding rocks (Golder Associates, 2004).</li> <li>Available data suggests that the Emu Fault has low permeability at a relative shallow depth (MRM, 2018).</li> </ul>
Western Fault	<ul style="list-style-type: none"> <li>Series of north-south trending thrusts, which dip steeply towards the east.</li> <li>It abuts the Cooley Dolomite with the HYC Pyritic Shale, the latter host to the bedded lead and zinc mineralisation. The Cooley Dolomite comprises of the Western Fault Block, which is bounded on the west by the Western Fault and on the east by the Emu Fault.</li> <li>Previous drilling programs have indicated that the Western Fault is of low permeability below the base of weathering (Logan and Associates, 2018).</li> <li>The Western Fault is coincident with the Cooley Breccia, interpreted to be a tectonic breccia formed along the reverse fault planes. The breccia matrix has been interpreted to be a sedimentary chemical precipitate rather than true matrix sediment.</li> <li>The Cooley Breccia texture has primarily been re-healed by carbonates and has low hydraulic conductivity.</li> </ul>
Barney Trend	<ul style="list-style-type: none"> <li>Dominant east-west trending fault corridor, which dislocates the Western Fault, but probably not the Emu Fault. Interpreted to comprise a series of north side down steps.</li> <li>Cooley-style brecciation and alteration, and lead and zinc mineralisation occur along the corridor in outcrop and drill hole.</li> <li>The corridor passes beneath the TSF and the NOEF.</li> <li>The 2016 ERI data suggest that the faults are conductive, inferring they are porous and/or permeable (GHD Pty Ltd [GHD], 2017).</li> </ul>
Whelans Fault	<ul style="list-style-type: none"> <li>Trends north-south, with an east side down sense of movement.</li> <li>It is at a high angle to bedding in the southern wall of the Open Pit. It appears to migrate into the bedding planes of the steeply dipping clay beds of the Teena and W-Fold Shale in the northern end of the Open Pit (Logan and Associates, 2017).</li> </ul>
Woyzbun Fault	<ul style="list-style-type: none"> <li>Exposures of the Woyzbun Fault in the Open Pit, underground mine, and drill hole intersections show a narrow tight fault with minimal gouge or infill.</li> <li>This normal fault, which dips between 75 degrees (°) to 85° to the south-east, has a throw of approximately 100 m, with the south block down (Logan and Associates, 2017).</li> </ul>
Woyzbun Parallel	<ul style="list-style-type: none"> <li>Located near the southern end of the pit.</li> <li>Woyzbun parallel faults have been identified in several of the historical geophysical data sets (Logan and Associates, 2017). Further work is required to confirm their geometry and significance.</li> </ul>
Myrtle Fault	<ul style="list-style-type: none"> <li>Located between the Western and Emu Faults, east of the Open Pit.</li> <li>It is an east side up structure, strikes north-south and thrusts the Myrtle Shale over younger dolomites. It has an interval of fault gouge and rubble which appears open and permeable, with radial flow (Logan and Associates, 2018).</li> </ul>



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**LEGEND**  
 - - - - - Interpreted Fault

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
**Geological Structures at the Mine**

**Figure 7**

## 2.5 Groundwater

### 2.5.1 Hydrostratigraphic Units

Three main hydrostratigraphic units are present, as categorised by the host lithologies and their hydraulic properties of how readily they transmit water (transmissivity, permeability/hydraulic conductivity) as well as how much water they hold per unit volumes (storativity/specific yield). The aquifer types according to these criteria are summarised in Table 5.

**TABLE 5: HYDROSTRATIGRAPHIC UNITS**

Geology unit	Description	Characteristics
Alluvium	Coarse-grained alluvium – Current McArthur River Channel. Unconfined	Significant aquifer zone with clean sands, gravels and cobbles, typically less than 5 m thick, at the base of the current river channel. High permeability, high (unit) storage aquifer expected to display unconfined to semi-confined responses.
	Coarse-grained alluvium – McArthur River Palaeochannel. Unconfined.	Major aquifer zone with multiple relatively thin interbeds of sands, gravels and cobbles concentrated within the bottom 5 – 10 m of the palaeochannel. High permeability, high (unit) storage aquifer expect to display unconfined to semi-confined responses. Relatively large total storage of groundwater given extent (up to 800 m width and 3,500 m length).
	Coarse-grained alluvium – Other. Unconfined, locally perched	Similar to above but characterized by smaller scale and extent associated with Barney Creek and smaller drainage tributaries. Minor aquifer zone and not present outside drainage channel areas.
Weathered Bedrock	Vuggy-karstic dolomite. Localised, unconfined, or semi-confined.	Major aquifer zone restricted to dolomitic lithologies where degree and extent of weathering and mineral dissolution has caused vugs and small cavities to develop along pre-existing weaknesses such as joints, bedding, veins and faults. Typically high but variable permeability and specific yield. Considered to be most prevalent to the north east of the open pit in association with the Cooley Dolomite in between the Western and Myrtle Faults the east.
	Jointed-faulted (non-dolomitic) bedrock. Localised, unconfined, or semi-confined.	Minor aquifer zones considered to have minor to moderate permeability and low unit storage. Often enhanced and extended in areas associated with faulting and folding. Within the weathering profile, shale bedrock does not constitute even a minor aquifer zone.
Fresh Bedrock	Jointed-faulted bedrock.	Considered individually as minor aquifer zones where jointing and faulting within fresh rock mass can provide enhanced permeability (but very low storage) through partly open fractures. Permeability typically decreases with increasing depth below about 100 m.

### 2.5.2 Local Groundwater Gradients

Figures 8 and 9 present the groundwater levels for the 2020/21 wet season and dry season, respectively.

Groundwater gradients trend from west to east, and locally towards the creeks. Localised drawdown is observed around the dewatered Open Pit and underground workings and around the abstraction bore fields. No major changes in gradient directions have been observed between the end of the wet and dry seasons.

Groundwater levels exhibit a moderate to strong response to seasonal changes, with large fluctuations in groundwater levels between the wet and dry seasons, in particular at locations near surface water drainage features.

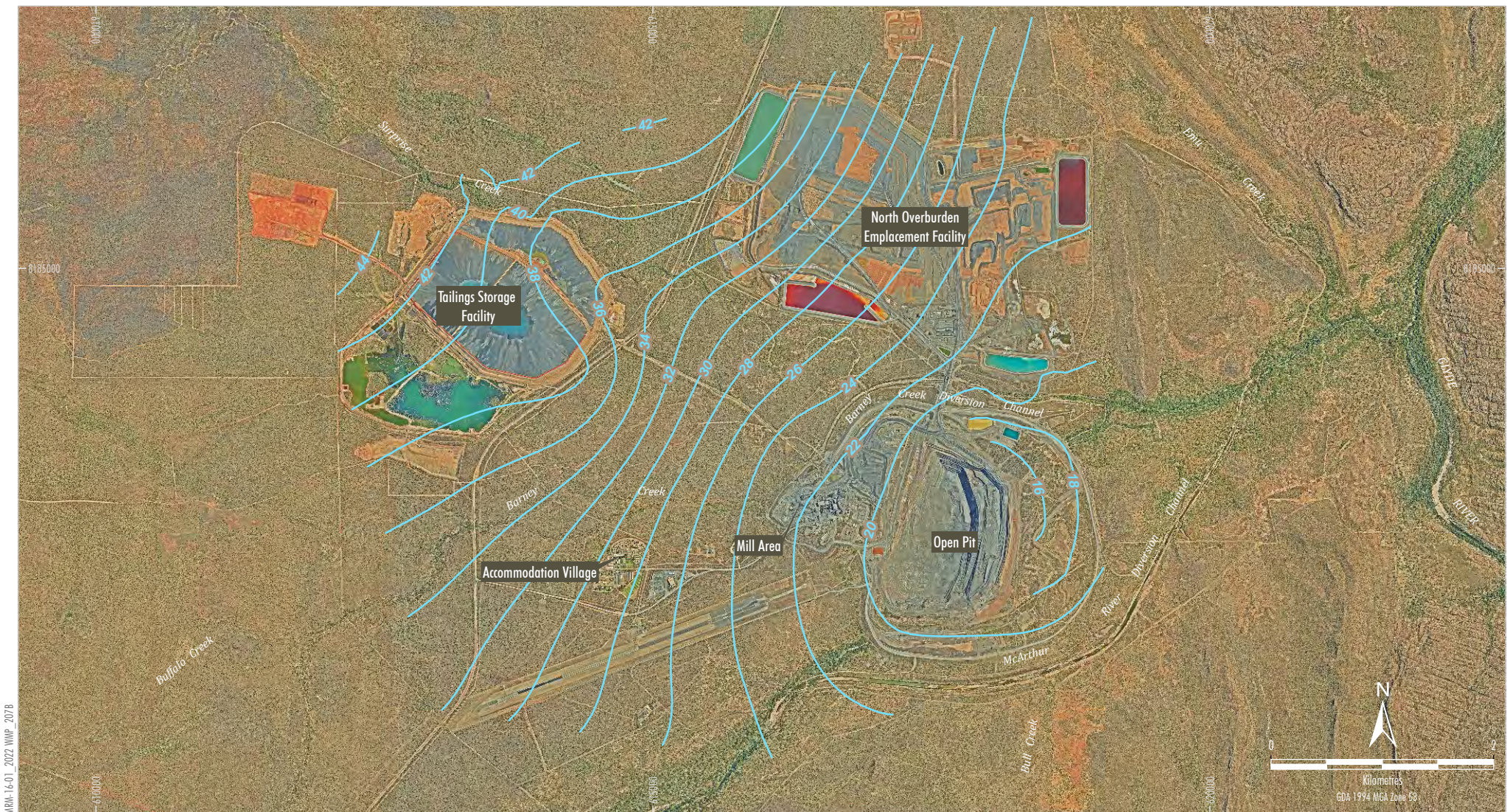
### 2.5.3 Background Groundwater Quality

There is significant variability in the groundwater quality across the Mine. Groundwater is neutral to slightly alkaline in pH. Groundwater quality is generally dolomitic (i.e. calcium/magnesium bicarbonate water type), influenced by the variability in geology. Natural mineralisation (Figure 6) in the area results in elevated sulphate, metals and electrical conductivity in certain locations.

### 2.5.4 Groundwater – Surface Water Interactions

The groundwater and surface water systems surrounding the Mine are highly connected, with one system often influencing the other. The key mechanisms that facilitate interaction between groundwater and surface water at the Mine are summarised below:

- **Recharge/infiltration:** during and following rainfall, some of the water that falls on or flows onto the surface (including in creeks and rivers) can soak into the soil or rock. The water that infiltrates the surface and does not evaporate or transpire through plants back into the atmosphere is known as groundwater recharge. Groundwater recharge is the mechanism by which the groundwater levels within the hydrostratigraphic units are fed additional water. Infiltration also occurs into constructed features such as the OEFs, the TSF or the water management dams.
- **Toe and basal seepage:** seepage is a general term used to describe the water that has infiltrated a body of material and under the influence of gravity is moving. This can be in the form of basal seepage (at the bottom of a facility) or toe seepage (at the edge of a facility). Basal seepage migrates vertically until it reaches the groundwater table. Once it reaches the groundwater, the seepage water can migrate horizontally and might report to surface water systems distant from the source. Toe seepage mainly is collected in drains and sumps as required.
- **Baseflow:** baseflow describes the discharge of groundwater into the surface water system. This occurs when groundwater levels in an area around a creek or river are higher compared to those within the creek or river, resulting in a hydraulic flow gradient towards the surface water feature. Where groundwater is impacted from the Mine or natural mineralisation, baseflow has the potential to contribute contaminants to the McArthur River and creeks at the Mine. However, the majority of Mine-impacted groundwater is predicted to flow towards the Open Pit and is not expected to influence the receptors. In addition, drawdown of the groundwater table has the potential to reduce baseflow into waterholes within the McArthur River.



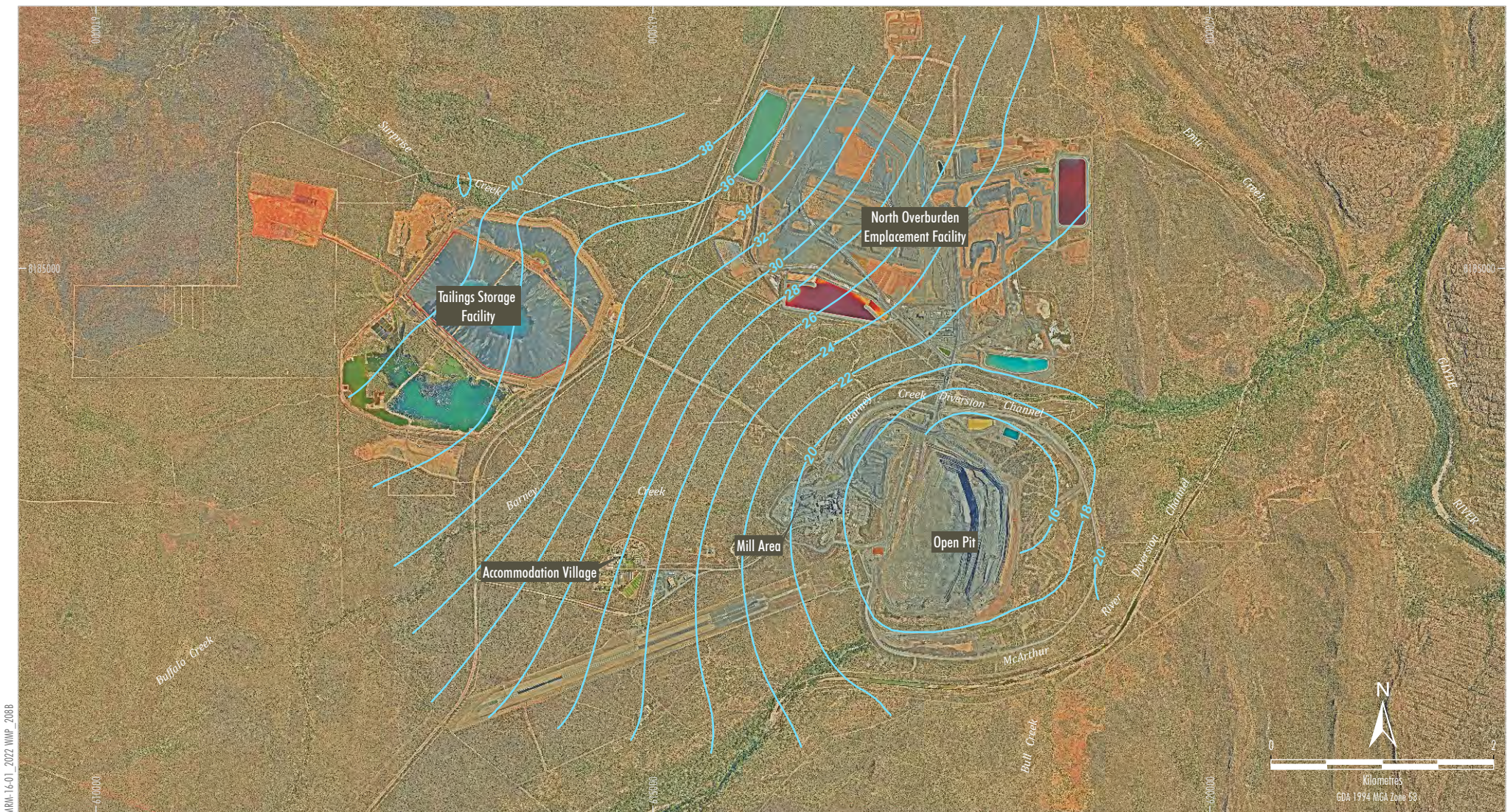
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**LEGEND**  
 Groundwater Contour (m AHD)

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
**Groundwater Elevation Contours -**  
**Wet Season**

**Figure 8**



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**LEGEND**  
 Groundwater Contour (m AHD)

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
**Groundwater Elevation Contours -**  
**Dry Season**

**Figure 9**

## 2.5.5 Site Hydrogeological Models

### 2.5.5.1 Conceptual Hydrogeological Model

A summary of the current hydrogeological conceptual model is provided below:

- Groundwater enters the system via wet season rainfall recharge mechanisms and upgradient through-flow. Groundwater flow is from west to east across the Mine through the overburden (alluvium), weathered bedrock and shallow fractured bedrock.
- Groundwater levels exhibit a moderate to strong response to seasonal changes, with large fluctuations in groundwater between the wet and dry seasons.
- Groundwater provides baseflow to the watercourses and diversions across the Mine. This occurs during the wet season and where groundwater is generally shallow and persists into the dry season until the water levels have receded.
- Groundwater leaves the system via discharge to watercourses and diversions, abstraction bores (Section 3.5) and shallow evapotranspiration.
- Natural mineralisation is present in a number of areas which results in elevated analyte concentrations (e.g. sulphate, metals) within the groundwater.
- Sources of contaminants include seepage and associated loads to groundwater from mining infrastructure (e.g. TSF, NOEF and water storages), which have the potential to influence groundwater levels and quality.
- Environmental receptors are identified as the Djirrinmini Waterhole and surface water receptors which are fed by groundwater.

The hydrogeological conceptual model of the Open Pit and NOEF areas are summarised on the cross-sections in Plates 3 and 4 (both adapted from KCB 2017a) respectively. Contaminated seepage from the NOEF is not predicted by the groundwater model to reach the Barney Creek Diversion Channel until after mining has ceased.

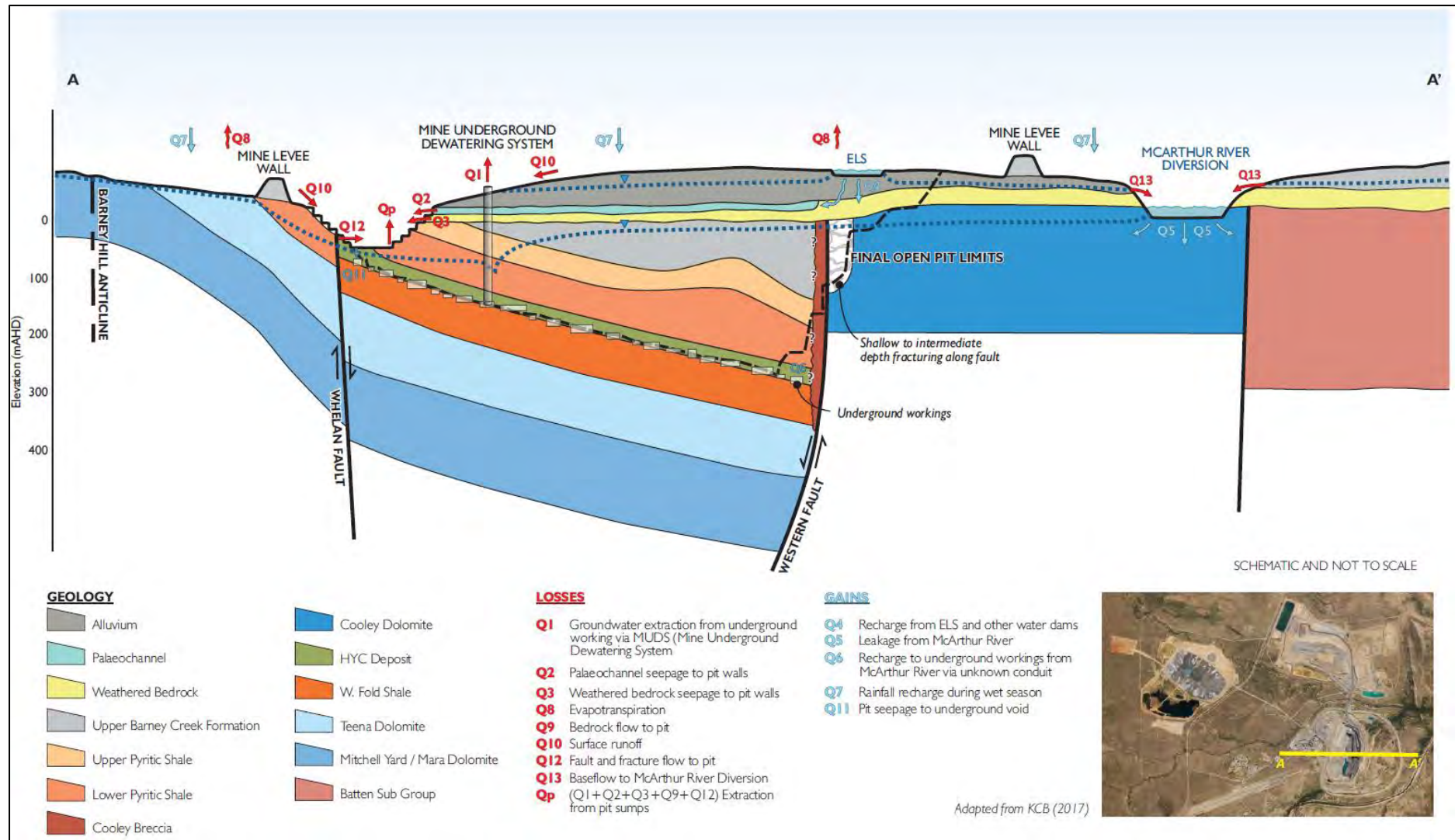


Plate 3: Hydrogeological Conceptual Model – Open Pit Cross-Section

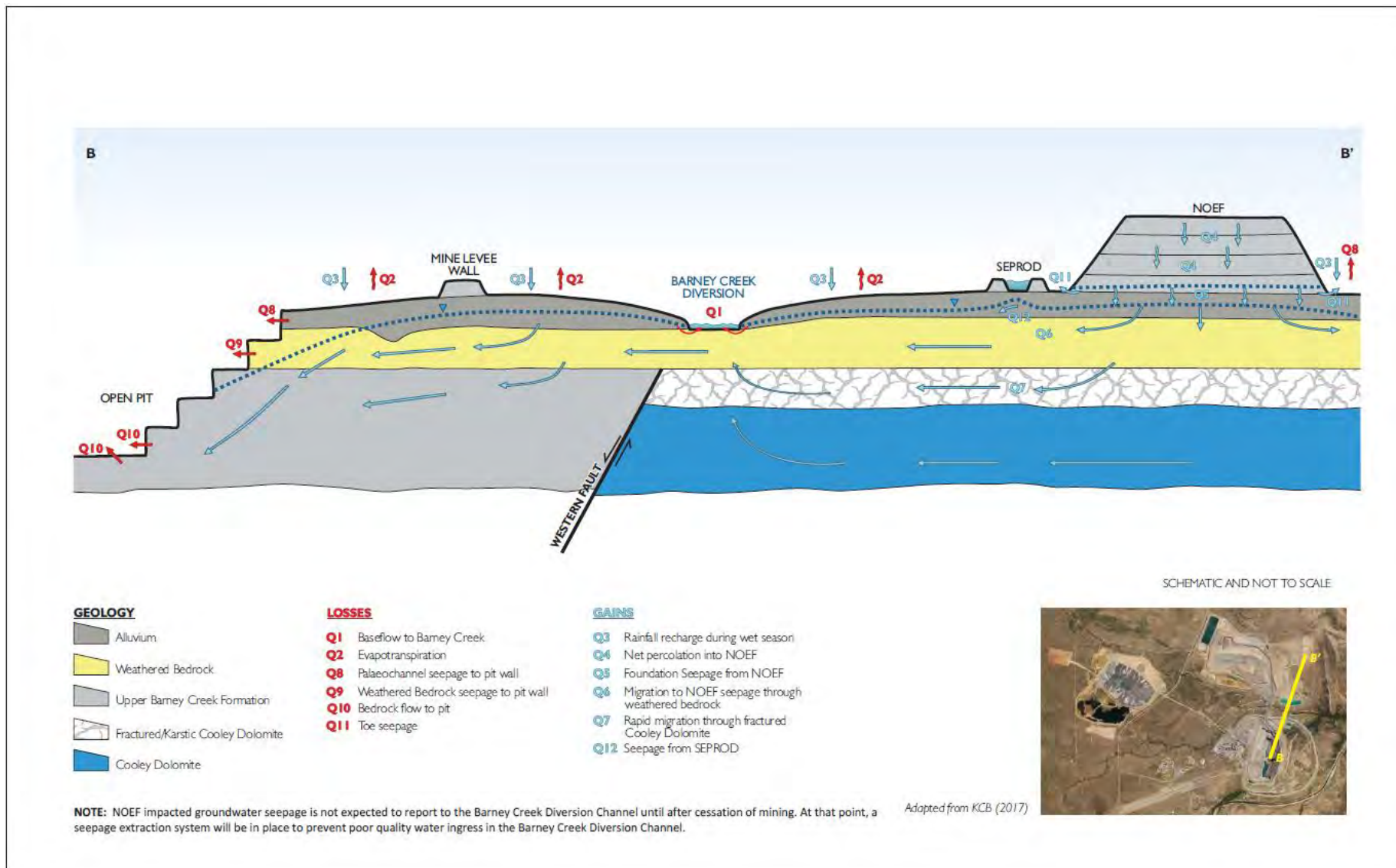


Plate 4: Hydrogeological Conceptual Model – NOEF Cross-Section

### 2.5.5.2 Numerical Groundwater Model

A site-wide numerical groundwater flow model was developed as part of the OMP EIS.

The model simulates groundwater responses to mining operations, closure and post-closure conditions. Sources of elevated contaminants were also simulated within the model. Details of the model setup, calibration, predictions and review process are provided below.

#### Numerical Model Construction

The site-wide numerical groundwater model was developed using the MODFLOW SURFACT version 4.0 modelling software and Groundwater Vistas (Version 6.83) visualisation software.

The model domain extends 12.0 km west-to-east and 11 km south-to-north and covers an active area of approximately 100 km<sup>2</sup> (Figure 10). The model is based on a 50 x 50 m grid with 240 columns and 219 rows across 14 model layers vertically discretised to represent different hydrostratigraphic units, identified potential sources and mining features.

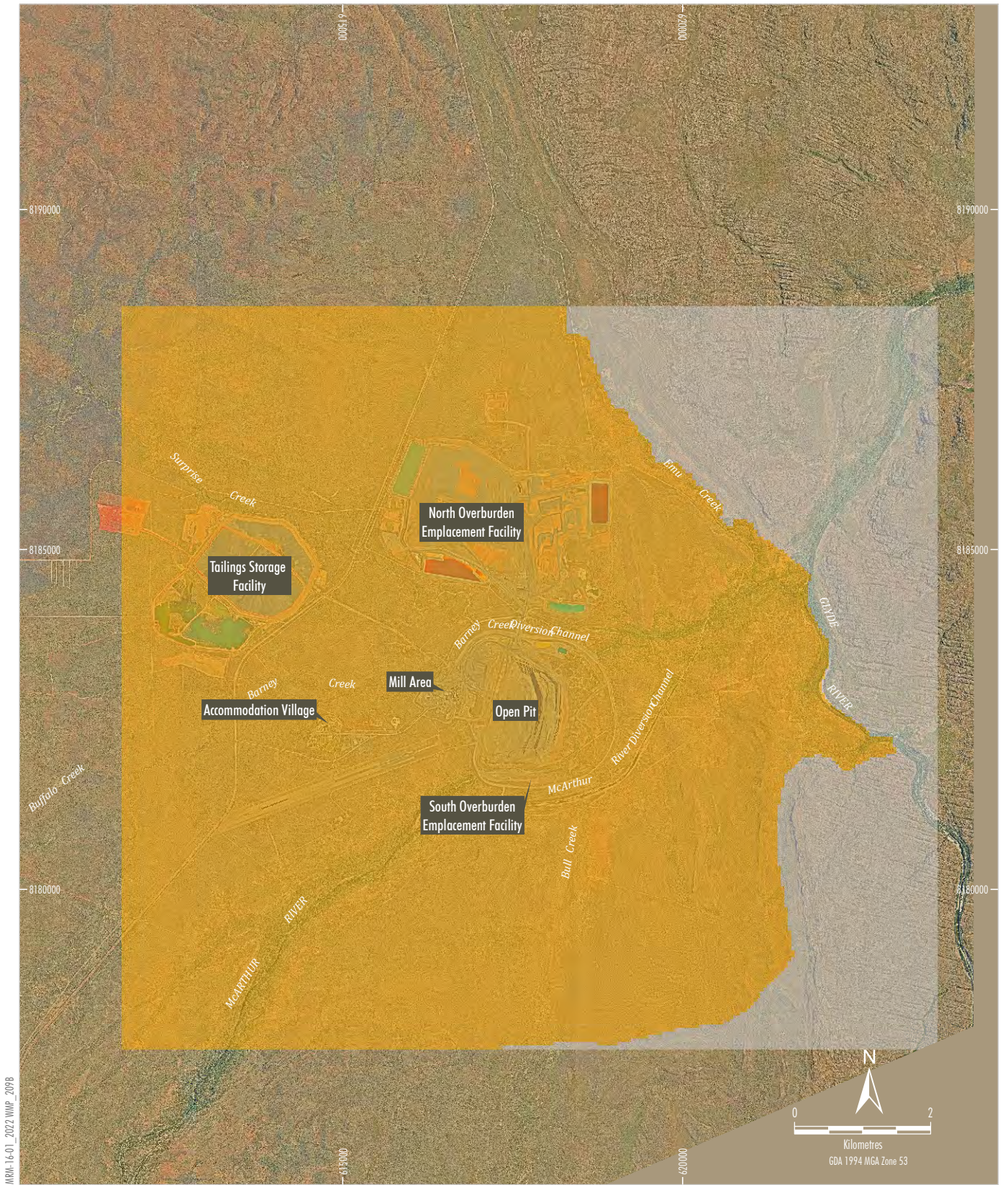
#### Numerical Model Review and Update

The site-wide groundwater model will continue to be reviewed following significant changes to the physical environment at the Mine and following additional data becoming available to ensure it remains relevant and accurate.

If a review determines that the model is no longer fit for purpose, a model update will be completed. Model updates will be completed in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012) and may include the following:

- Improvement of the model architecture (e.g. model layers, hydraulic properties and structural features);
- Improvement of the model calibration;
- Addition of new data from monitoring and field investigations; and
- Update of the hydrogeological conceptual model on which the numerical model is based.

The predictions and results of the updated numerical model will be used in conjunction with the conceptual hydrogeological model and in-field monitoring results to inform MRM's long-term groundwater management strategy.



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**LEGEND**

- Active Cell
- Non-Active Cell

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
**Numerical Model Groundwater Area**

**Figure 10**

## 2.6 Aquatic Ecology Setting

### 2.6.1 Reach and Riparian Habitat

The McArthur River reach above the Mine is characterised by a low sinuosity channel with many anabranches within a broad level floodplain. Outcropping rock supporting riffle habitats occur at several locations. Long deep pools separated by glides/runs and riffles are common. Edge habitats are present as near vertical banks with root masses formed by fringing riparian vegetation.

The original McArthur River overlying the main ore body was characterized by a single uniform channel with low sinuosity. Broad depositional levees, tributary gullies and discontinuous flood channels were present. Instream habitat commonly included pools separated by shallow glides/runs with near vertical banks. Following construction of the McArthur River Diversion Channel, the Mine reach is characterised by the remnants of the original McArthur River and substrates are dominated by fine silt and mud. The downstream section of the McArthur River is contained by the sandstone ridges of the Bukalara Range, emerging onto a broad alluvial plain approximately 20 km downstream of the Mine. Instream habitats in this area include long shallow runs and occasional pools, with riffle habitats occurring intermittently below the Bukalara Range.

The Mine area and the Diversion Channels occur within a surrounding matrix of continuous savanna woodland, forest and sandstone escarpment habitats and cattle grazing is the principal local and regional land use. Vegetation within the study area ranges from tall riparian forest and woodland along the McArthur River to low open woodland with tussock grassland and spinifex ground layers in non-riparian areas. Riparian forest and riparian woodland vegetation types form a band of riparian vegetation up to 700 m wide upstream of the Mine and 350 m wide at downstream sites.

Pronounced wet and dry seasons influence flow regime throughout the catchment. Considerable flows throughout the main McArthur River channel are experienced during the wet season, often with periods of flooding. During dry season lengths of the main McArthur River channel can cease to flow and become dry, with groundwater-fed pools becoming important habitat.

### 2.6.2 Aquatic Fauna of National Significance

A search using the Australian Government Department of the Environment and Energy Protected Matters Search Tool and the Species Profile and Threats Database indicated that four species of national conservation significance under the EPBC Act may be present in aquatic habitat within the Mine area or adjacent to it. These include:

- **Fish species, *Pristis pristis* (Freshwater Sawfish), which is listed as vulnerable and migratory;**

The Freshwater Sawfish is a large fish that breeds in marine and estuarine waters but migrates as juveniles into the upper freshwater reaches of rivers, where they develop away from the threat of predators. This species has been the subject of extensive targeted surveys within the McArthur River, including an ongoing monitoring program and a tagging program, designed to investigate the movements of sawfish through the river system and McArthur River Diversion Channel.

- **Reptile species, *Elseya lavarackorum* (Gulf Snapping Turtle), which is listed as endangered;**

The Gulf Snapping Turtle is a freshwater turtle confined to the larger river systems of the Gulf of Carpentaria. It occurs within the Nicholson River, Gregory River, Calvert River and Robinson River (all east of the McArthur River), as well as in the Roper River and Limmen Bight River (west of the McArthur River). This species has never been recorded within the McArthur River system.

- **Reptile species, *Crocodylus johnstoni* (Freshwater Crocodile), which is listed as marine; and**

Freshwater Crocodiles are common in the mid and lower McArthur River catchment and tributaries of the McArthur River. The Freshwater Crocodile is generally observed in non-tidal freshwaters with a number of records collected from waters on or adjacent the MRM lease.

- **Reptile species, *Crocodylus porosus* (Estuarine Crocodile), which is listed as a marine and migratory species.**

Estuarine Crocodiles are common in the lower McArthur River catchment and nearby coastal areas. Small numbers occasionally move upstream to the vicinity of the Mine.

### 2.6.3 Aquatic Fauna Recorded in the McArthur River Catchment

The species that have been recorded during aquatic fauna surveys over the period 2013 to 2018 are provided in Table 6.

**TABLE 6: AQUATIC SPECIES RECORDED DURING SURVEYS IN THE MCARTHUR RIVER CATCHMENT BETWEEN 2013 AND 2018**

Species	2013	2014	2015	2016	2017	2018
<i>Ambassis macleayi</i>	X	X	X	X	X	X
<i>Ambassis spp.</i>	X	X		X	X	X
<i>Amniataba percoides</i>	X	X	X	X	X	X
<i>Anodontiglanis dahli</i>					X	
<i>Arrhamphus sclerolepis</i>	X	X	X		X	X
<i>Brachirus selheimi</i>	X	X	X	X	X	X
<i>Carcharhinus leucas</i>	X	X	X		X	X
<i>Chanos chanos</i>		X	X			X
<i>Craterocephalus stercusmuscarum</i>	X	X	X			X
<i>Elops hawaiiensis</i>		X				
<i>Gerres filamentosus</i>			X			X
<i>Glossamia aprion</i>	X	X	X	X	X	X
<i>Glossogobius spp.</i>	X	X	X	X	X	X
<i>Hephaestus fuliginosus</i>	X	X	X	X	X	X
<i>Lates calcarifer</i>	X	X	X	X	X	X
<i>Leiopotherapon unicolor</i>	X	X	X	X	X	X
<i>Liza alata</i>	X	X	X	X	X	X
<i>Megalops cyprinoides</i>	X			X	X	X
<i>Melanotaenia splendida</i>	X	X	X	X	X	X
<i>Mogurnda mogurnda</i>			X			

Species	2013	2014	2015	2016	2017	2018
<i>Nematalosa erebi</i>	X	X	X	X	X	X
<i>Neoarius berneyi</i>	X	X	X	X	X	X
<i>Neoarius graeffei</i>	X					
<i>Neoarius leptaspis</i>					X	
<i>Neoarius paucus</i>	X	X	X	X	X	X
<i>Neosilurus ater</i>	X	X		X	X	X
<i>Neosilurus hyrtlii</i>	X	X	X	X	X	X
<i>Oxyeleotris selheimi</i>	X	X	X	X	X	X
<i>Pristis pristis</i>		X		X	X	X
<i>Pisodonophis boro</i>	X			X	X	
<i>Rhinomugil nasutus</i>	X	X	X			
<i>Scatophagus argus</i>	X	X	X		X	X
<i>Scomberoides commersonianus</i>	X	X	X		X	X
<i>Scortum ogilbyi</i>	X		X	X	X	X
<i>Selenotoca multifasciata</i>					X	
<i>Strongylura krefftii</i>	X	X	X	X	X	X
<i>Toxotes chatareus</i>	X	X	X	X	X	X
<i>Valamugil buchanani</i>	X					
<i>Urogymnus dalyensis</i>			X			
<i>Zenarchopterus novaeguineae</i>	X	X	X			X
Total Species	31	29	29	23	30	30

\* *Glossogobius* spp.' refers collectively to *Glossogobius giurus* and *Glossogobius aureus*.

## 3 Operational Water Management

The water management systems at the Mine require sufficient flexibility to manage water during pronounced wet and dry seasons, in addition to significant rainfall variations from year to year. This means that the water management systems must accommodate both shortages and surpluses of water over the life of the Mine. The following sections present how the Mine water systems manage these issues.

### 3.1 Water Classification System

A water classification system has been adopted at the Mine since the beginning of the 2015/2016 reporting period and is an operational tool that helps optimise the management of water on-site. The current classification system has six water classes based on water quality. A Mine water source study was undertaken to develop the water classes based on water quality data recorded at various artificial water storages at the Mine and expected water sources generated during future mining operations. Wherever possible, water at the Mine is to be managed in a way that separates different water classes to minimise the volume of poor quality water and process water produced and maximise the end use opportunities for cleaner water classes.

Table 7 describes the six water classes adopted at the Mine, typical sources of this water and the concentration range of the limiting contaminant relative to the WDL 174 site-specific trigger values. The classes include:

- **Class 1** – diverted (clean) water. This water class is typically sourced from upstream catchments that are unaffected by mining. Wherever practical, controls are put in place to divert this water away from mining activities without impacting its quality.
- **Class 2** – surface water. This water class is typically sourced from cleared areas and benign stockpile areas. Runoff from these areas is required to go through a sediment management structure to capture and settle sediment prior to releasing it passively through the structure or dewatering once the sediment particles have settled out. Class 2 water is not considered wastewater, and consequently can be released to the receiving environment separate from conditions of WDL 174.
- **Class 3** – treated water permeate. This water class is permeate from the reverse osmosis (RO) Water Treatment Plant (WTP). Class 3 water is released in accordance with conditions of WDL 174.
- **Class 4** – managed release water. This water class is typically sourced from surface runoff from cleared areas with some exposed/capped non-benign material and/or mine water treated with bulk hydrated lime. This water typically has sulphate and/or metal concentrations that are higher than downstream compliance point trigger values specified in the WDL 174 conditions. This water can be used for a number of end uses on site. This water can also be released to the McArthur River when there is sufficient river flow for dilution and in accordance with the WDL 174 conditions.
- **Class 5** – poor quality water. This water class is typically affected by seepage from the TSF and NOEF, runoff from areas with exposed non-benign material and/or underground void water. This water class is generally contained within the Mine water management system.
- **Class 6** – process water. This water class is typically water used within the Concentrator and TSF as well as other process streams including brine from the water treatment plant. This water class is contained within the Mine water management system.

The water quality criteria relevant to the water classes is inherently linked to the site-specific trigger values in the WDL as shown in Table 7.

For simplicity, water which is of Class 4, 5 or 6 is collectively referred to as 'Mine water' throughout this document.

The water classification system is dynamic and will continue to be reviewed periodically and updated if required to ensure the class system is representative of the range of water qualities and uses within the Mine water management system and WDL 174 conditions.

**TABLE 7: MCARTHUR RIVER MINE WATER CLASSIFICATION SYSTEM**

Class	Class Description	Description of Typical Sources	Water Quality – Number of Times Above the WDL 174 Site-Specific Trigger Values <sup>a</sup>	
			Sulphate & EC	Other WDL analytes
Class 1	Diverted water	Upstream catchments unaffected by mining	<1	<1
Class 2	Surface water	Cleared areas and clay/topsoil stockpiles	<1	<1
Class 3	Treated permeate	Permeate from the WTP	<1	<1
Class 4	Managed release water	-	-	-
- Sub- class a	<i>Best quality</i>	Runoff from cleared areas and clay/topsoil stockpiles and treated by sediment dams, raw water	1 - 3	1 - 4
- Sub- class b	<i>Good quality</i>	Surface runoff from cleared areas with some exposed/ capped LS-NAF <sup>c</sup> waste material, raw/intercepted groundwater	3 - 5	4 - 20
- Sub- class c	<i>Medium quality</i>	Surface runoff from cleared areas with some capped and/or exposed MS-NAF <sup>d</sup> waste material	5 - 25	20 - 50
Class 5	Poor quality water	Seepage from the TSF and NOEF, water stored in the underground void	25 - 30	50 - 1,000
Class 6	Process water	Water used within the Concentrator and other process streams, seepage from ore stockpiles	>30	>1,000

ML/day = megalitres per day.

<sup>a</sup> The number of times of exceedance shown is based on the limiting analyte. Concentrations of other analytes may be lower compared with the WDL 174 trigger values.

<sup>b</sup> Indicative only.

<sup>c</sup> LS-NAF – low salinity non-acid forming.

<sup>d</sup> MS-NAF – metalliferous saline non-acid forming.

## 3.2 Key Operational Factors

### 3.2.1 Surface Water Inflow Variability

Significant surface water inflows to the Mine can occur during the wet season. Based on the *2021/22 Annual Site Water Balance for the McArthur River Mine* (Appendix A), wet season rainfall runoff inflows to the Mine water management system are estimated to be 3,580 megalitres (ML) for a median rainfall year and range from 1,493 ML for a dry (90<sup>th</sup> percentile) year to 6,909 ML for a wet (10<sup>th</sup> percentile) year. For the historically wettest rainfall year, rainfall runoff inflows to the Mine water management system were estimated to be 15,561 ML. The water management system therefore needs to cater for a significant proportion of annual rainfall runoff inputs occurring within a matter of weeks. As the Mine footprint increases in the future, the Mine water management system will be required to manage additional amounts of surface runoff inputs.

### 3.2.2 Groundwater Inflow Variability

Significant groundwater inflows to the Open Pit and underground mine voids may occur as mining progresses. Annual groundwater inflows into the Open Pit and underground voids are estimated to be 2,249 ML for a median rainfall year and range from 2,049 ML for a dry (90<sup>th</sup> percentile) year to 2,463 ML for a wet (10<sup>th</sup> percentile) year. For the historically wettest rainfall year, groundwater inflows to the Open Pit and underground void are estimated to be 3,292 ML.

### 3.2.3 Flooding

Most of the existing Mine infrastructure, the TSF, the Open Pit and the NOEF are located within the McArthur River floodplain and without appropriate mitigation, could potentially be affected by McArthur River, Barney Creek and/or Surprise Creek floodwaters.

### 3.2.4 Water Quality Changes

The open cut mining process involves the removal of large quantities of overburden to access the orebody located deeper beneath the surface. The characteristics of the overburden varies with depth and location within the Open Pit. Some overburden may have potential impacts on the environment if it is not managed correctly, whereas others are environmentally benign and provide useful resources for construction and rehabilitation.

MRM's target ore is a base metal sulphide deposit that has a relatively high proportion of sulphide minerals (including pyrite) in the rocks. Consequently, overburden may also contain a high proportion of sulphide minerals and base metals.

Sulphide minerals can oxidise when exposed to oxygen and water, generating sulphuric acid and secondary oxidation products in the process. The generation of acid liberates metallic oxides, sulphates and other major ions, which may be soluble to varying degrees, depending on the pH of the water. Certain types of overburden are also at risk of spontaneous combustion. Spontaneous combustion is the propensity of some sulphide and carbon-rich rocks to self-heat due to rapid oxidation. It is characterised by high temperatures and the emission of gases, in particular sulphur dioxide.

At the Mine, the term Acid and Metalliferous Drainage (AMD), is used to refer to all possible impacts from sulphide oxidation, including saline drainage (SD), neutral metalliferous drainage (NMD) and acid drainage (AD). These broad sub-categories reflect differing behaviours, environmental risks/impacts, mitigation measures and remediation strategies:

- Saline Drainage (SD): refers to drainage characterised by elevated salinity, with circumneutral pH, and metal concentrations similar to background levels.
- Neutral Metalliferous Drainage (NMD): refers to drainage characterised by circumneutral pH waters with elevated metal concentrations and potentially elevated salinity.
- Acid Drainage (AD): specifically refers to drainage characterised by acidic pH, and potentially elevated salinity and elevated metal concentrations.

Rainwater infiltration and net percolation into the underlying overburden emplaced at the NOEF can express horizontally at the toe of the NOEF or enter groundwater vertically through basal seepage. Similarly, basal seepage can also occur from the storage of artificial surface waters in the NOEF, TSF and Mill domains when damaged dam liners or inoperable underdrains allow stored waters to enter groundwater. These artificial waters can include products of SD, NMD and AD. If uncaptured, both toe seepage and impacted groundwater can potentially discharge to surface water features, such as local creeks, which can then act as downstream transport mechanisms allowing contaminants from the Mine site to enter the McArthur River.

As the NOEF reaches its full footprint and the cover system is progressively implemented, rainwater infiltration and net percolation into the underlying waste material of the NOEF will decrease, reducing volumes of both basal and toe seepage. However, the available water quality data and modelling undertaken to date suggest this seepage will be of low quality and will require long-term management.

Surface runoff from the rehabilitated areas of the NOEF will be better-quality when compared to the seepages/drainages. Geochemical modelling indicates that after placement of NOEF cover system material, runoff water quality from the rehabilitated sections of the NOEF will meet water quality criteria for offsite release. This runoff will eventually be released to the receiving environment on a routine basis following treatment through a sediment trap to reduce suspended sediments loads and confirmation of suitable water quality.

Another substantial influence on water quality changes at the Mine site is the operation of the lead oxidation circuit (PbOx). This process creates an acidic and metalliferous waste water with similar characteristics to AD. This water currently has limited treatment options. This waste water stream is segregated from other water types at the Mine to prevent cross contamination. However, it currently occupies a significant portion of the Mine site's total dam storage volume. As of 1 October 2021, the NOEF East Perimeter Runoff Dam (EPROD) contained approximately 1,059 ML of PbOx affected water. MRM currently plans to build a gypsum plant to treat this waste water stream, with commissioning tentatively planned for 2023.

### 3.3 Key Operational Water Management Objectives

The key operational objectives of the MRM water management system and the principal strategies used to achieve them are outlined below:

- 1. Protect the McArthur River beneficial uses and community values from mining impacts.**
  - a. comply with WDL site-specific trigger values at the McArthur River downstream compliance point, SW11;
  - b. operate in accordance with the NT EPA Guidelines on Mixing Zones (NT EPA, 2013b); and
  - c. operate in accordance with the ANZG for Fresh and Marine Water Quality (ANZG, 2018).
- 2. Achieve a recovering trend in the water quality and ecosystem function in creeks on the Mine site within 20 years of cessation of mining:**
  - a. operate all water storages at their target operating levels to mitigate the risk of uncontrolled overflows;
  - b. intercept toe seepage from the TSF and NOEF in sumps and drains and store in lined water storages;
  - c. control basal and toe seepage from water storage infrastructure by maximising the use of lined structures;
  - d. install fixed pumping infrastructure to allow the rapid transfer of water between storages as required to mitigate the risk of uncontrolled overflows;
  - e. optimise tailings deposition in the TSF to reduce the central decant pond size and provide an adequate tailings beach around the perimeter of the dam against the walls. This reduces seepage and the risk of overflow, as well as reducing the risk of geotechnical failure, all of which may affect surface water quality;
  - f. implement water treatment as required to manage potential contaminant loads in managed release water;

- g. intercept impacted groundwater and surface water on the operational Mine site as required to maintain McArthur River surface water quality below the WDL 174 trigger values at the downstream compliance point;
  - h. operate sediment traps and bunds to collect sediment runoff; and
  - i. utilise the Open Pit as an ultimate fall-back for water storage to maintain McArthur River surface water quality below the WDL 174 trigger values at the downstream compliance point.
- 3. Manage water resources to ensure continuous water supply for mining and ore processing operations whilst minimising water abstraction and maximising water recycling:**
- a. conserve water as necessary, including minimising the surface area of stored water and the associated loss to evaporation. This includes the transfer of mine waters into the underground void for storage and later reuse;
  - b. manage groundwater abstraction to balance Open Pit dewatering requirements and water security for the operation;
  - c. prioritise water recycling within the process water circuit by re-use of poor-quality water; and
  - d. segregate different water classes to minimise the volume of poor quality water and process water produced and maximise the end use opportunities for cleaner water classes.
- 4. Manage the operational risk of Open Pit inundation to ensure continuous mining operations and protection of the Mine's assets:**
- a. limit the area of surface disturbance, thus limiting the volume of water generated at the Mine;
  - b. intercept clean surface water and groundwater from around the Open Pit before it contacts mineralised zones;
  - c. ensure there is no material change in flood immunity or erosion potential on the Carpentaria Highway, Mine Levee Wall or key infrastructure without risk mitigation measures; and
  - d. use sprinklers, evaporation fans and irrigation in suitable areas to enhance evaporation losses when necessary.
- 5. Ensure water management is conducted in accordance with all MRM's regulatory obligations:**
- a. comply with conditions of WDL 174; and
  - b. comply with conditions of Variation of Authorisation 0059.

The operational strategies that support these objectives are aligned with the waste water management hierarchy which aims to preferentially apply strategies in the order of avoidance, reuse and reduction of waste. The hierarchy aims, where practical, to reduce the requirement to dispose of waste water through discharge to the receiving environment.

## 3.4 Water Management Infrastructure

### 3.4.1 Class 1 Diverted Water Management Infrastructure

Class 1 runoff drains direct runoff from undisturbed upstream catchments around potentially disturbed and/or areas of the Mine site. The Class 1 runoff drains are required for both construction and operational stages of the Mine.

### 3.4.1.1 Class 1 Diverted Water Management Infrastructure

The Class 1 diverted water management infrastructure at the Mine includes:

- the McArthur River Diversion Channel that directs McArthur River flow around the southern and eastern boundary of the Open Pit;
- the Barney Creek Diversion Channel that directs Surprise Creek and Barney Creek flows around the northern boundary of the Open Pit;
- the Little Barney Creek Diversion Channel that directs catchment runoff around the western boundary of the Water Management Dam;
- a flood protection levee around the perimeter of the Open Pit;
- flood protection levees around the perimeter of the NOEF; and
- surface water drains to the west and north of the NOEF that direct surface runoff to Surprise Creek and Emu Creek.

### 3.4.2 Class 2 Surface Water Management Infrastructure

Class 2 runoff generated at the Mine is managed by constructing Class 2 runoff drains that collect and direct runoff from benign catchments to sediment management structures. Class 2 water is not considered wastewater, and consequently can be released to the receiving environment (either passively or pumped) separate from conditions of WDL 174. Sediment ponds can be used to control sediment in Class 2 runoff. A typical sediment pond cross-section is presented in Plate 5. Where possible, sediment ponds are located in old drainage channels such as old or abandoned creek channels that have been isolated due to mining activities to minimise the amount of excavation required for the storage and allow water to overflow/be drawn down into a natural downstream channel after sediment removal.

Selection of the most appropriate type of sediment management structure (sediment pond or otherwise) is undertaken as part of the design process. In some cases, such as clay borrow pits, the area where the Class 2 water accumulates also acts as the sediment management structure.

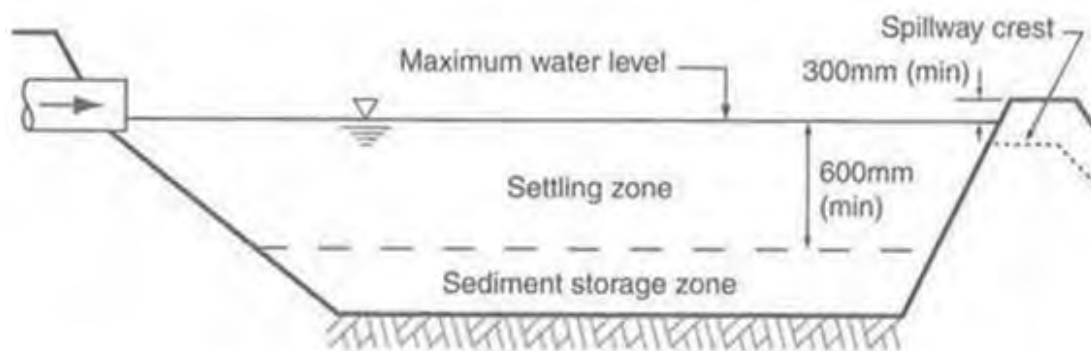


Plate 5: Typical Sediment Pond Cross-Section

### 3.4.2.1 Class 2 Water Management Infrastructure

The Class 2 surface water management infrastructure at the Mine includes numerous sediment management structures located strategically across the Mine to remove suspended sediment from Class 2 runoff prior to discharging to the natural waterways. These include:

- the South West Sediment Trap, which is positioned on the south western side of the NOEF to reduce suspended sediment from Class 2 surface water runoff from cleared areas and benign stockpiles;
- bunds, drains and re-contouring within the mine levee wall area that directs clean water away from the Open Pit; and
- clay borrow pits and benign rock quarries around the Mine and TSF domains that accumulate Class 2 water from direct rainfall input.

## 3.4.3 Flood Control Infrastructure

### 3.4.3.1 Mine Levee Wall

The Open Pit is located on the floodplain of the McArthur River and is protected from McArthur River floodwaters by a flood protection levee called the Mine Levee Wall. This Mine Levee Wall has been constructed to provide the Open Pit immunity from a McArthur River flood event of up to 0.2 % annual exceedance probability (AEP) (500 year average recurrence interval [ARI]). The minimum crest level of the Mine Levee Wall is approximately 44 m AHD.

### 3.4.3.2 NOEF Flood Protection

Flood protection levees have been constructed around the perimeter of the NOEF to limit the potential risk of waste rock inundation from the McArthur River and its tributaries. The levees constructed around the perimeter of the NOEF provide between 5 % AEP and 1 % AEP flood immunity from McArthur River flooding.

Further detail on the NOEF flood protection infrastructure is available in the *North Overburden Emplacement Facility Management Plan* (MRM, 2022).

## 3.4.4 Class 4, 5 and 6 Water Storage Facilities (Dams and Sumps)

The artificial surface water monitoring program (Section 4) is a key control used when transferring water between water storage facilities at the Mine. Different water classes are segregated to minimise the contamination of waters. Segregation is a key component of the waste water management hierarchy.

Water is not transferred from any water storage structure until water quality analysis has been received and interpreted and the results confirm that the water is suitable for the destination.

### 3.4.4.1 Open Pit Water Management Infrastructure

This section describes the primary water management infrastructure at the Open Pit and Mill domains that manages Class 4, 5 and 6 artificial waters. They included:

#### Open Pit

Active mining pit that collects runoff from the Open Pit catchment within the mine levee wall, in addition to groundwater inflows.

#### Underground Void

The decommissioned underground mine void that collects runoff from the Open Pit, as well as groundwater inflow.

### Mining Underground Dewatering System

Consists of 3 shafts (UGB1 Hole H, UGB2 Hole B and UGB3 Hole G) located on the northeast side of the Open Pit. The shafts were specifically drilled to intersect the underground voids. Dewatering pumps are installed in each MUDS shaft, and are used to dewater the Underground and Open Pit (UG&OP) water to Pete's Pond.

### Pete's Pond

An out-of-pit mine water dam that collects water pumped out from the (UG&OP). It is a distribution point for water from the UG&OP, including for water cart use.

### Concentrator Runoff Pond

A pond that collects runoff and overflows from the Mill catchment, return water from the TSF Cell 2 and pumped inflows from distributions points such as Pete's Pond. The pond supplies the Mill process water demands. The Concentrator Runoff Pond was desilted in 2018, however, has since experienced further siltation.

### Anti-Pollution Pond

A pond that collects runoff from areas of the Mill catchment, including the heavy media plant. It also receives pumped inflows from distribution points such as Pete's Pond and Van Duncan's Dam. The Anti-Pollution Pond supplies Mill process water demands.

### Van Duncan's Dam

A dam that collects runoff from the Western Overburden Emplacement Facility (WEOF) ROM pad. The Van Duncan's Dam supplied water cart use until late 2015. Van Duncan's Dam receives overflows from the water cart quick-fill tank and the Concentrator Runoff Pond.

### Lake Archer

A pond that collects runoff from the WEOF ROM pad and other areas within the Mill catchment. Lake Archer is the distribution point for excess leach water from the lead oxidation circuit (PbOx) at the Concentrator.

### Raw Water Tank

A tank that receives bore water pumped from the MIMEX, Emu and Southern Extension production bore fields to supply Mill process demands and truck wash facilities.

### Pond 2

A pond with no external catchment that is as a distribution point for Class 4 water. Pond 2 is typically used to transfer treated water from the Mine to the Water Management Dam for storage. Pond 2 is also a source location for authorised discharges to the McArthur River under the WDL.

### Bench Sumps

There are a number of sumps located on high-walls and benches of the Open Pit that collected groundwater inflow, including from horizontal depressurisation bores. The bench sumps transfer water to other ponds or dams (primarily Pete's Pond or Pond 2) depending on water quality results and water class.

## **3.4.4.2 Tailings Storage Facility Water Management Infrastructure**

This section describes the primary water management infrastructure at the TSF domain that manage Class 4, 5 and 6 artificial waters. They included:

### TSF Cell 1

A TSF cell that was recommissioned in 2019 to store fine rejects from the Concentrator. Water collected in TSF Cell 1 is dewatered to TSF Cell 2.

### TSF Cell 2

A TSF cell that stores fine rejects from the Concentrator. The Cell 2 decant pond is used to return excess water in tailings to the Concentrator Runoff Pond or Mine for reuse.

### TSF Interception Trench

An interception trench constructed to the north of TSF Cell 1, which collects seepage from the TSF cells. Seepage is transferred along the trench via gravity and bore pumps to a sump, which is dewatered to TSF Cell 1.

### Water Management Dam

A water-storage that was constructed through the damming of Little Barney Creek. The Water Management Dam is the primary storage location for Class 4 waters awaiting reuse or discharge. The Water Management Dam is a source location for authorised discharges to the McArthur River under the WDL and Variation of Authorisation 0059.

### **3.4.4.3 North Overburden Emplacement Facility Water Management Infrastructure**

This section describes the primary water management infrastructure at the NOEF domain that manage Class 4, 5 and 6 artificial waters. They included:

#### Southern Perimeter Runoff Dam

A containment dam that collects runoff from the southern section of the NOEF. The Southern Perimeter Runoff Dam is also used to store water from a number of toe sumps.

#### South-Eastern Perimeter Runoff Dam

A containment dam that is used to store and treat mine water through the addition of bulk hydrated lime. The water transferred for treatment is sourced from various locations, including the UG&OP, toe sumps, NOEF runoff, TSF decant and PbOx leach.

#### Western Perimeter Runoff Dam

A containment dam that collects runoff and seepage from the western section of the NOEF. The Western Perimeter Runoff Dam also receives pumped inflows from TSF decant.

#### Eastern Perimeter Runoff Dam.

A containment dam with no external catchment. The Eastern Perimeter Runoff Dam is currently used to store acidic and metalliferous wastewater from the PbOx leach circuit.

### Toe Sumps

There are a large number of sumps located at the toe of various stages of the NOEF. The toe sumps are used to collect and transfer AMD seepages from the NOEF.

### **3.4.4.4 Dam and Pond Levels**

Water storages at the Mine (for Class 4, 5 and 6 water) are operated following defined TARPs based on water levels/volumes to limit operational risk and uncontrolled overflows. Plate 6 shows the adopted design configuration for water storages at the Mine. The Full Supply Level, Maximum Operating Level, Upper Operating Level and Lower Operating Level storage volumes for each Mine water storage is provided in Appendix B *Water balance modelling for the McArthur River Mine in support of the 2021/22 wet season TARP*. In addition:

- water storages are appropriately sized to capture and retain runoff from the contributing catchments;
- water storage spillways are appropriately sized; and

- water storages are appropriately sealed or lined to limit seepage through the base and wall of the dam, as dictated by risk and the class of the stored water.

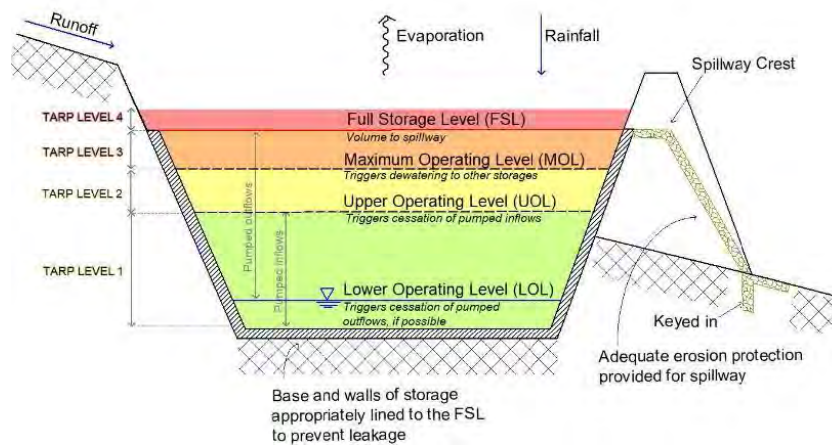


Plate 6: Typical Mine Water Storage Cross-Section

### 3.4.5 2021/22 Water Management System

Plate 7 shows the 2021/22 configuration of the Mine site water management system and infrastructure, including land use types, pipeline and drainage routes. Plate 8 shows a schematic of the 2021/22 to 2024/25 Mine water management system.

Table 8 provides a list of Mine water storages and their storage capacities at Full Supply Level, liner types, expected water class and if the storage is authorised to receive AMD under the Variation of Authorisation 0059.

Details of the changes to the water management system for the period 2021/2022 to 2024/2025 are presented in Appendix A *2021/22 Annual Site Water Balance for the McArthur River Mine*.

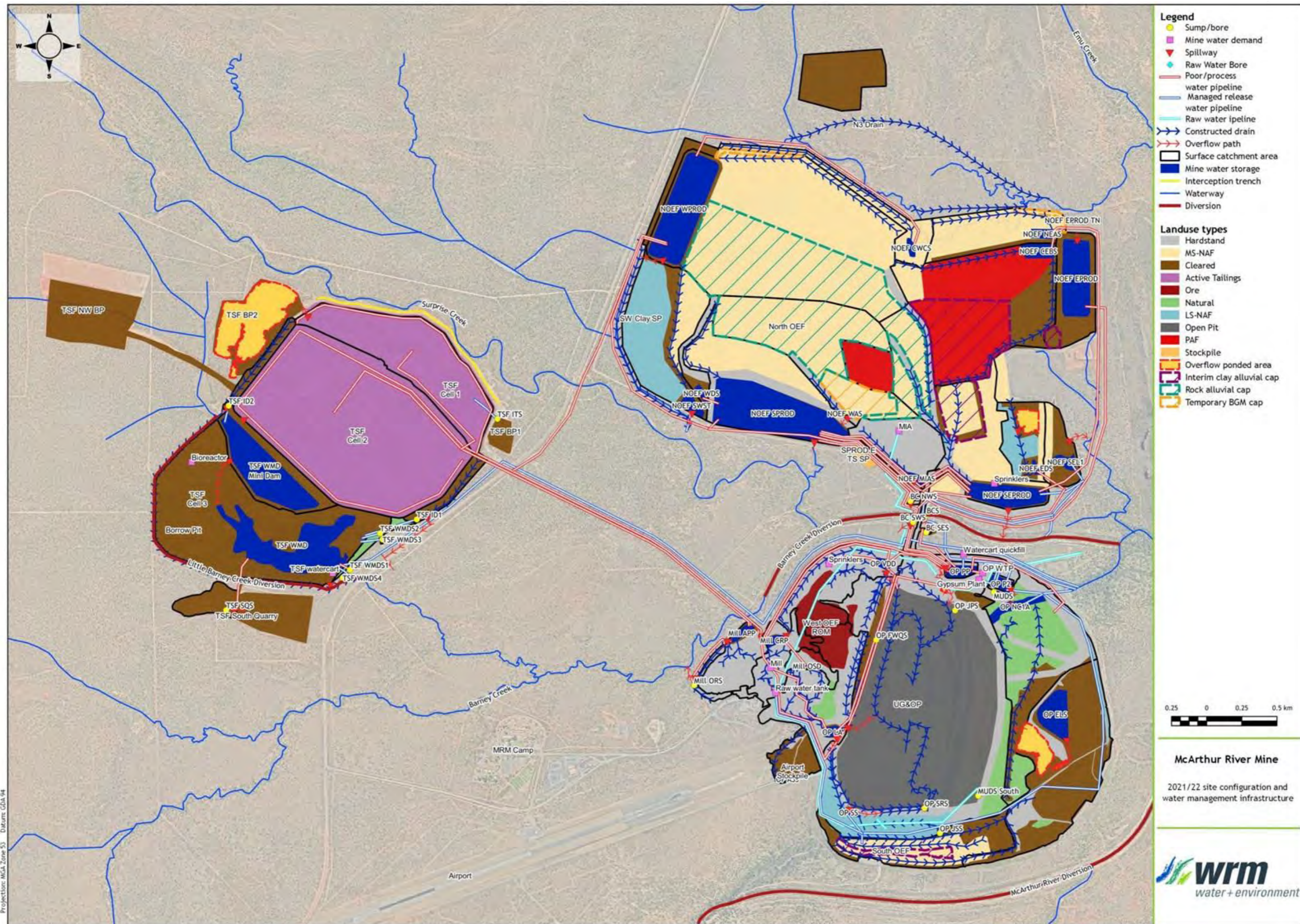


Plate 7: McArthur River Mine 2021/22 Site Configuration and Water Management Infrastructure

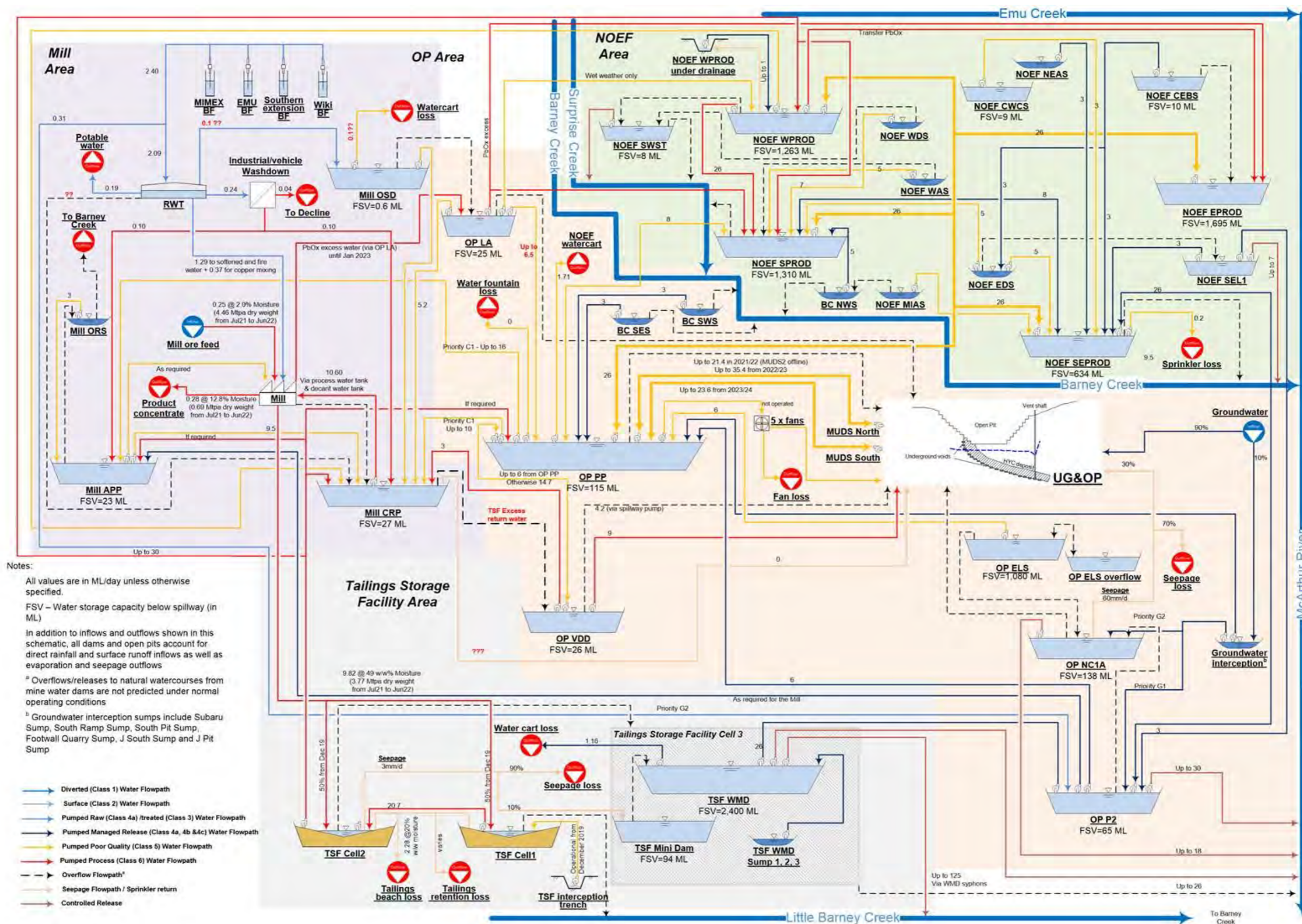


Plate 8: Schematic of the 2021/22 - 2024/25 McArthur River Mine Water Management System

**TABLE 8: MINE WATER STORAGE CAPACITIES, LINER TYPE AND EXPECTED WATER CLASS**

Storage Name	Storage Capacity at FSL (ML)	Liner (none, CCL, HDPE)	Expected Water Class	Authorised to place AMD <sup>a</sup>
<i>Current</i>				
<b><i>Open Pit and Mill</i></b>				
Anti-Pollution Pond (Mill APP)	23	CCL	5/6	Yes
Concentrator Runoff Pond (Mill CRP)	27	CCL	6	Yes
East Levee Storage (OP ELS)	1,080	None	4	No
Footwall Quarry Sump (OP FWQS)	5	None	4	No
J Pit Sump (OP JPS)	5	None	2-4	No
J South Sump (OP JSS)	5	None	4	No
Lake Archer (OP LA)	25	HDPE	5/6	Yes
North Crossing 1A (OP NC1A)	138	None	1-4	No
Old ROM Sump (Mill ORS)	2.9	None	5	No
Old Stores Dam (Mill OSD)	0.6	HDPE	5	Yes
Pete's Pond (OP PP)	115	HDPE	5/6	Yes
Pond 2 (OP P2)	65	HDPE	4	Yes
South Ramp Sump (OP SRS)	5	None	4	No
Underground and Open Pit (UG&OP)	1,362 <sup>b</sup>	n/a	5/6	n/a
Van-Duncans Dam (OP VDD)	26	None	5/6	Yes
<b><i>North Overburden Emplacement Facility</i></b>				
East Drain Sump (NOEF EDS)	97	None	5/6	Yes
East Perimeter Runoff Dam (NOEF EPROD)	1,695	HDPE	5/6	Yes
Mine Infrastructure Area Sump (NOEF MIAS)	15	HDPE	5	Yes
South-East Levee 1 (NOEF SEL1)	343	None	4	No
South-East Perimeter Runoff Dam (NOEF SEPROD)	634	CCL	4/5	Yes
South Perimeter Runoff Dam (NOEF SPROD)	1,249	HDPE	5/6	Yes
South-West Sediment Trap (NOEF SWST)	8	None	2	No
West A Sump (NOEF WAS)	0.2	HDPE	5/6	Yes
West D Sump (NOEF WDS)	38.1	HDPE	5/6	Yes
West Perimeter Runoff Dam (NOEF WPROD)	1,263	HDPE	5/6	Yes
<b><i>Barney Creek</i></b>				
Barney Creek North-West Sump (BC NWS)	1.4	None	4	No
Barney Creek South-East Sump (BC SES)	4.8	None	4	No
Barney Creek South-West Sump (BC SWS)	1.8	None	4	No

Storage Name	Storage Capacity at FSL (ML)	Liner (none, CCL, HDPE)	Expected Water Class	Authorised to place AMD <sup>a</sup>
<b><i>Southern Overburden Emplacement Facility</i></b>				
SOEF Sump	TBC	HDPE	5/6	Yes
<b><i>Tailings Storage Facility</i></b>				
TSF Cell 2 (TSF Cell 2)	1,086 to 1,263	None	6	n/a
TSF Cell 1 (TSF Cell 1)	376 to 430	None	6	n/a
TSF Mini Dam (TSF Mini Dam)	94	None	4	No
TSF Water Management Dam (TSF WMD)	2,400	None	4	No
TSF WMD Sumps 1, 2 & 3	TBC	None	4	No
<b><i>Planned / Under Construction</i></b>				
<b><i>North Overburden Emplacement Facility</i></b>				
Central-East Bravo Sump (NOEF CEBS)	400	CCL (current) & BGM (planned)	5/6	Yes
North-East Alpha Sump (NOEF NEAS)	10	CCL (current) & BGM (planned)	5/6	Yes
North-East Stilling Basin (NOEF NESB)	TBC	TBC	5/6	Yes
North-West Sump (NOEF NWS)	TBC	TBC	5/6	Yes
South-East Alpha Sump (NOEF SEAS)	TBC	CCL & BGM	5/6	Yes
South Sediment Dam (NOEF SSD)	TBC	TBC	2/4	No
South Stilling Basin (NOEF SSB)	TBC	TBC	5/6	Yes
<b><i>Eastern Overburden Emplacement Facility</i></b>				
EOEF Sump (EOEFS)	TBC	TBC	5/6	Yes

<sup>a</sup> Under Variation of Authorisation 0059

<sup>b</sup> to the geotechnical limit of 9,791 mRL (20 m lower than the dry season Open Pit base target level of 9,811 mRL).

<sup>c</sup> SOEF = Southern Overburden Emplacement Facility

## 3.5 Groundwater Extraction

Groundwater is extracted at the Mine site for mining and ore processing operations and to provide potable water. The NT *Water Act 1992* was recently updated to remove exemptions that mining activities had been previously provided to certain sections of the Act. MRM will seek the appropriate licences required for groundwater extraction.

### 3.5.1 Open Pit and Underground Void Dewatering

Prior to the start of Open Pit mining, the HYC orebody and waste materials were removed through underground mining activities. The old access passages and stopes from the underground mining left an array of connected works (voids) beneath the current Open Pit shell (see Plate 9). The underground voids are in hydraulic connection to the Open Pit and provide a water storage capacity of approximately 1.4 gigalitres (GL).

The underground void works are an integral component of the water management infrastructure at the Mine. MRM can divert excess water into the voids for storage, later extraction and reuse. Other water inputs to the underground voids include local groundwater inflows that primarily seep into the Open Pit, direct rainfall within the Open Pit footprint, and rainfall runoff from the catchment inside the Mine Levee Wall. Groundwater inflows include those from horizontal depressurisation bores, which are installed and operated to manage the geotechnical stability of the Open Pit walls. Water entering the Open Pit drains into the underlying underground voids, resulting in the floor of the Open Pit remaining dry as long as excess storage is available in the voids.

Water is extracted from the underground voids for operational uses and to control the level of water at the floor of the Open Pit for mining access. Water is extracted from the underground voids from 3 shafts on the northeast side of the Open Pit. The three shafts are named the Mining Underground Dewatering System (MUDS). The shafts were specifically drilled and installed to intersect the underground voids. In addition, water is also collected and pumped from a series of sumps located on the upper benches of the Open Pit. This extraction is known as high-wall interception. The bench sumps are also used to capture and dewater groundwater inflow from a number of horizontal depressurisation bores. During periods of Open Pit inundation (flooding), water loss from the system also occurs through direct dewatering of the Open Pit (e.g. pontoon pumps) and from surface evaporation.

Due to the mineralised nature of the regional geology and HVC orebody, all water stored and extracted from the underground void, including groundwater, is contaminated with heavy metals, including zinc. Water collected from the high-wall sumps is typically of better quality.

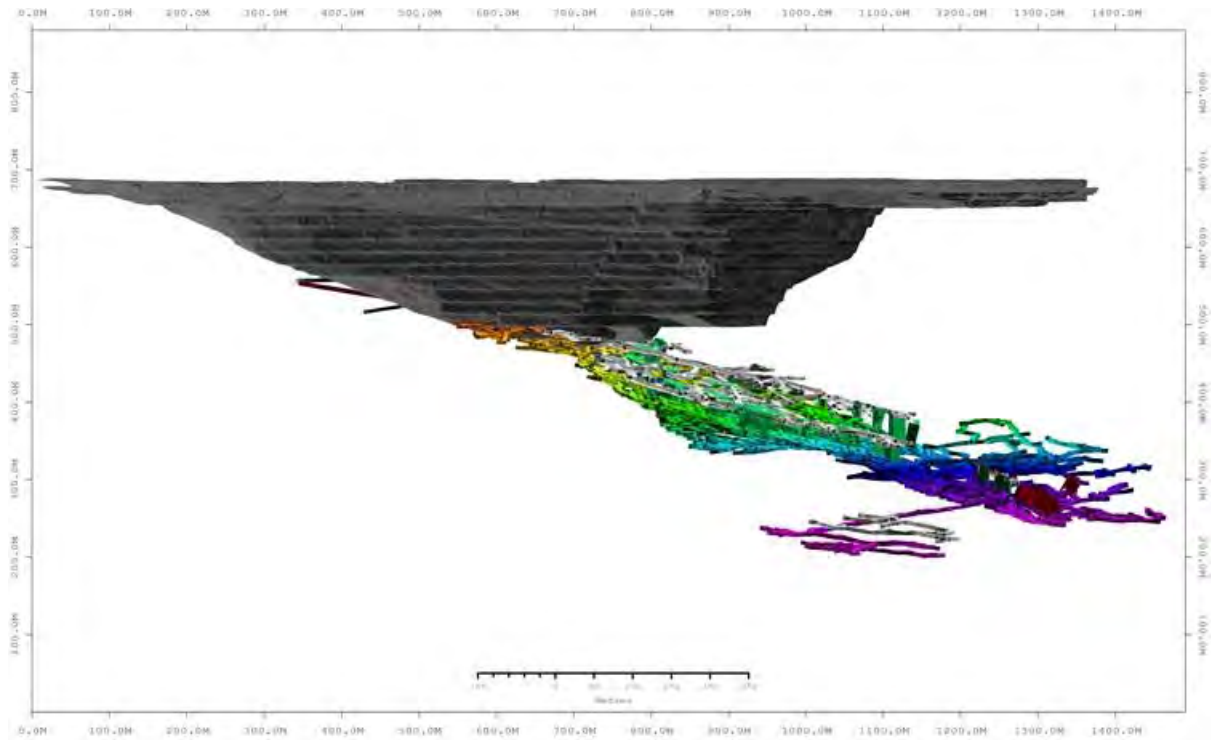


Plate 9: Underground Voids (coloured areas) beneath the Open Pit.

### 3.5.2 Groundwater Borefields

In addition to the dewatering of the UG&OP, MRM also operates five production borefields for groundwater extraction purposes (Figure 11):

- **Emu Borefield**, located to the southeast of the NOEF;
- **MIMEX Borefield**, located south of the airport;

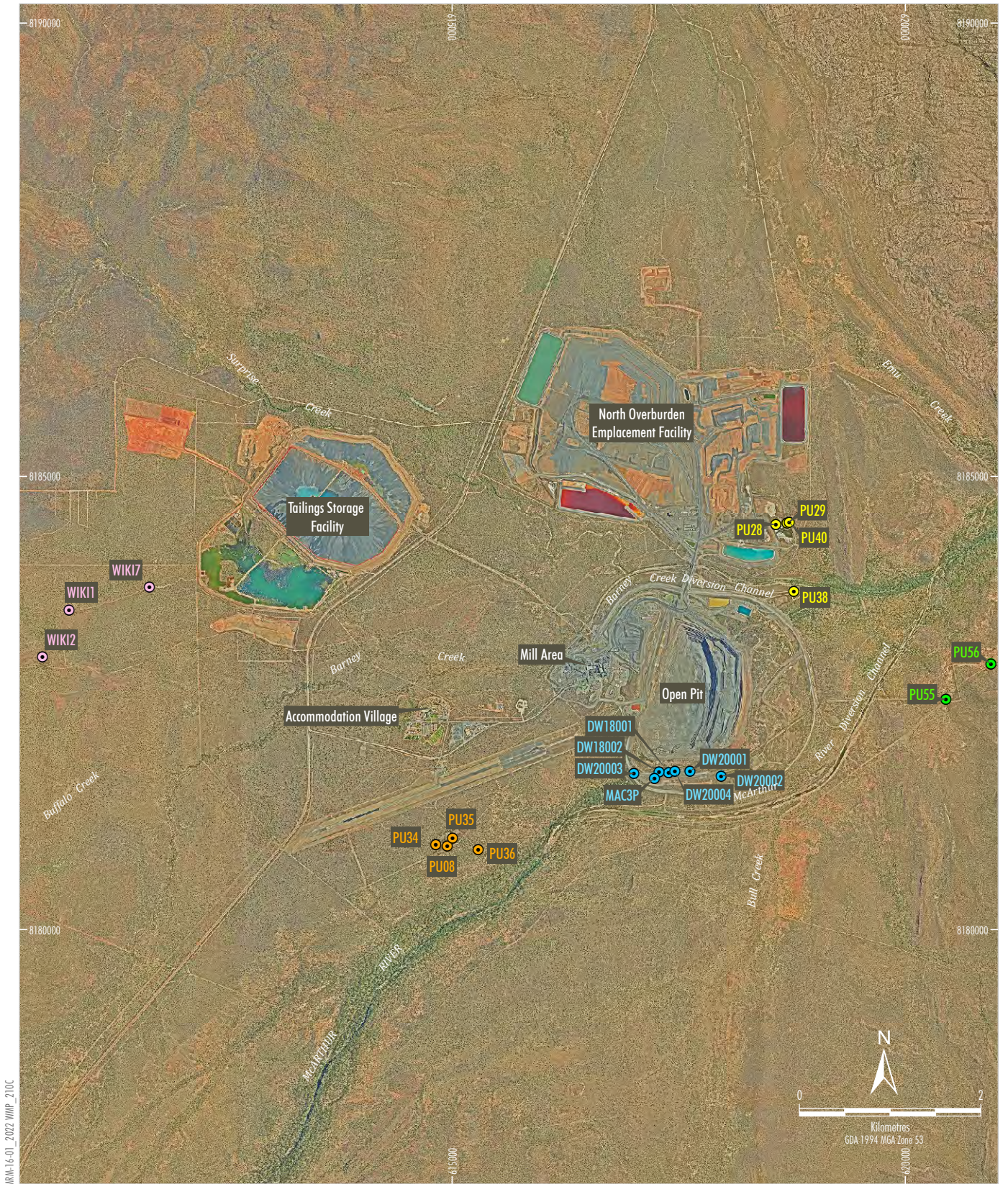
- **Donkey Borefield**, located east of the McArthur River diversion;
- **Southern Extension Borefield**, located between the Mine levee wall and the Open Pit; and
- **Wiki Borefield**, located west of the TSF domain.

Groundwater extracted from the production borefields is used for specific applications which require a better quality of water (low salinity, hardness and dissolved metal content) than the water obtained from the UG&OP. These uses include reagent mixing in the Concentrator, gland water, raw water for firefighting, potable water, camp water and irrigation for rehabilitation.

Details of the borefields are provided in Table 9.

**TABLE 9: PRODUCTION BOREFIELDS AT THE MINE**

Bore Field	Site	Easting	Northing	Volume Monitoring	Quality Monitoring
EMU	PU28	618572	8184470	Yes - when bore is operational	Quarterly - when bore is operational
	PU29	618695	8184481		
	PU38	618771	8183728		
	PU40	618722	8184490		
MIMEX	PU08	614948	8180920		
	PU34	614820	8180939		
	PU35	615006	8181010		
	PU36	615288	8180882		
Southern Extension	DW18001	617390	8181734		
	DW18002	617284	8181739		
	MAC3P	617233	8181671		
	DW20001	617627	8181747		
	DW20002	617969	8181696		
	DW20003	617006	8181722		
	DW20004	617458	8181748		
Donkey	PU55	620452	8182542		
	PU56	620948	8182932		
Wiki	WIKI1	610772	8183527		
	WIKI2	610478	8183004		
	WIKI7	611661	8183777		



**LEGEND**

**Abstraction Bores**

- Donkey Borefield
- Emu Borefield
- MIMEX Borefield
- Southern Extension Borefield
- Wiki Borefield

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); MRM (2019)

**McARTHUR RIVER MINE  
Groundwater Abstraction Locations**

**Figure 11**

## 3.6 Surface Water Extraction

Surface water extraction activities may include risk mitigation measures or contingency responses where extraction is required to protect the beneficial uses and community values of the McArthur River, including:

- extraction from the Barney Creek Diversion Channel or Old McArthur River to intercept mine-affected baseflow;
- extraction from Surprise Creek through interception trench use; and
- extraction from on lease waterways due to contamination caused by an environmental incident such as a hydrocarbon spill or Mine water pipeline leak.

During risk mitigation measures or contingency responses, sumps or bunds may also be constructed in the waterway to aid in extraction of the target waters. Surface water that is extracted is pumped to the mine water system dependent on water chemistry and water class.

MRM will seek the appropriate licences required for surface water extraction under the *Water Act 1992*.

## 3.7 Water Treatment

### 3.7.1 Hydrated Lime Water Treatment

This treatment process occurs in the Southern Perimeter Runoff Dam via the application of a hydrated lime slurry using a lime mixing plant. The general treatment methodology involves the continuous input of mine affected water (either Class 5 or 6) in conjunction with a lime slurry into the dam. The high residency time of the waters in the dam (> 15 days) is used to allow for settlement of particulates before extraction of treated water from the dam.

The treatment aims to improve the water quality to a Class 4 status for transfer to and storage in the Water Management Dam or other suitable structures for subsequent release in accordance with WDL 174. Zinc is typically the limiting contaminant in the mine-affected waters. A pH of 8.7 is targeted with treatment, which effectively precipitates the majority of zinc from solution as zinc hydroxide. The target zinc concentration is < 0.8 milligrams per litre (mg/L), as this allows discharge using existing infrastructure at typical McArthur River dilution ratios.

### 3.7.2 Reverse Osmosis Water Treatment Plant

Construction of the RO water treatment plant was completed in August 2018. The first stage of commissioning was completed in September 2018 with the successful production of permeate. Partial modification and redesign of the pre-treatment infrastructure was undertaken throughout 2019. Reliability testing continues to be undertaken prior to final commissioning of the plant.

The RO water treatment process consists of pH adjustment, oxidation, precipitation, coagulation and clarification for removal of coarse and fine solids, as well as the bulk of the dissolved metals including zinc, lead, iron and manganese. This pre-treatment step is followed by ultra-filtration prior to passing through the RO membranes for removal of major ions and residual dissolved metals.

The plant has the capability to operate at a nominal capacity of up to approximately 6 ML/day, producing approximately 4.4 ML/day of RO permeate and approximately 1.6 ML/day of waste. The waste is output in two streams:

1. 0.12 ML/day of clarifier sludge, which is produced by the chemical pre-treatment stage that removes the bulk of the metals by pH adjustment, oxidation, precipitation, coagulation and clarification. The contaminants are present as solids (1.5 % wt).

2. 1.5 ML/day of brine, which is produced by the RO membrane and is hypersaline but contains low metals.

The management strategies for the water treatment plant output streams include:

- RO permeate:
  - storage in the TSF WMD prior to managed release in accordance with WDL 174 conditions;
  - storage in OP P2 prior to managed release in accordance with WDL 174 conditions; and
  - utilisation in other areas within the lease to offset new water requirements.
- Clarifier sludge:
  - filtration and disposal of the metalliferous solids into the TSF Cell 1 or Cell 2, and transfer of the filtered water into the process water circuit.
- RO Brine:
  - treatment by gypsum precipitation and transfer to the TSF WMD.

## 3.8 Mine Water Managed Releases

Managed releases from the Mine are undertaken in compliance with WDL 174, Variation of Authorisation 0059, and PRO-2200035 *Waste Discharge Procedure* (Appendix C). The WDL provides conditional approval from the NT regulator for the controlled discharge of wastewater to the McArthur River. The WDL prescribes strict environmental controls to minimise the risk of harm to the beneficial uses and community values of the McArthur River. The WDL controls include compliance with water quality site-specific trigger values at the McArthur River downstream compliance point, SW11.

The WDL allows MRM to proactively manage its onsite water inventories through managed releases to help mitigate the risk of Open Pit inundation and uncontrolled overflows from water storages. Mine water managed releases are generally restricted to Class 3 and Class 4 waters. Managed releases are timed to occur during periods of flow in the McArthur River to ensure appropriate dilution to ensure that the site-specific trigger values at the downstream compliance point are not exceeded.

Releasing water during the wet season also reduces the likelihood of having to store significant volumes of low quality water in Mine site storages during the drier months. This limits the potential for seepage from Mine water storages during periods when there is limited natural dilution.

All managed releases are carried out in accordance with the approved WDL 174 and PRO-2200035 *Waste Discharge Procedure* (Appendix C). The procedure utilises a dilution calculator to determine the discharge flow rate to be applied to achieve compliance with the site-specific trigger values at SW11. To align the discharge regime and management of the McArthur River mixing zones with the Mine's key environmental objectives, the procedure also requires that dilution calculations are completed using flow conditions in the McArthur River directly adjacent the Mine. Conservatively, compliance at SW11 is therefore met before considering the additional flow and diluting capacity of the Glyde River.

PRO-2200035 *Waste Discharge Procedure* (Appendix C) also describes the following:

- positions that can authorise a discharge of wastewater off-site;
- general infrastructure and monitoring checks to be completed in the lead up to the wet season and a discharge event;
- mixing calculation theory;
- use of the dilution calculator and the steps to request discharge approval; and

- steps to initiate a discharge once discharge approval has been granted.

MRM's current WDL, including any updated or amended site-specific trigger values, is available from the NT regulator at: <https://ntepa.nt.gov.au/your-business/public-registers/licenses-and-approvals-register/waste-discharge-licences/mining/mrm>

An electromagnetic flow meter or other measuring device is used to monitor managed releases. For each managed release event, the following information is recorded:

- the time discharge commenced and duration of the discharge;
- the discharge rate of flow; and
- the total discharge volume.

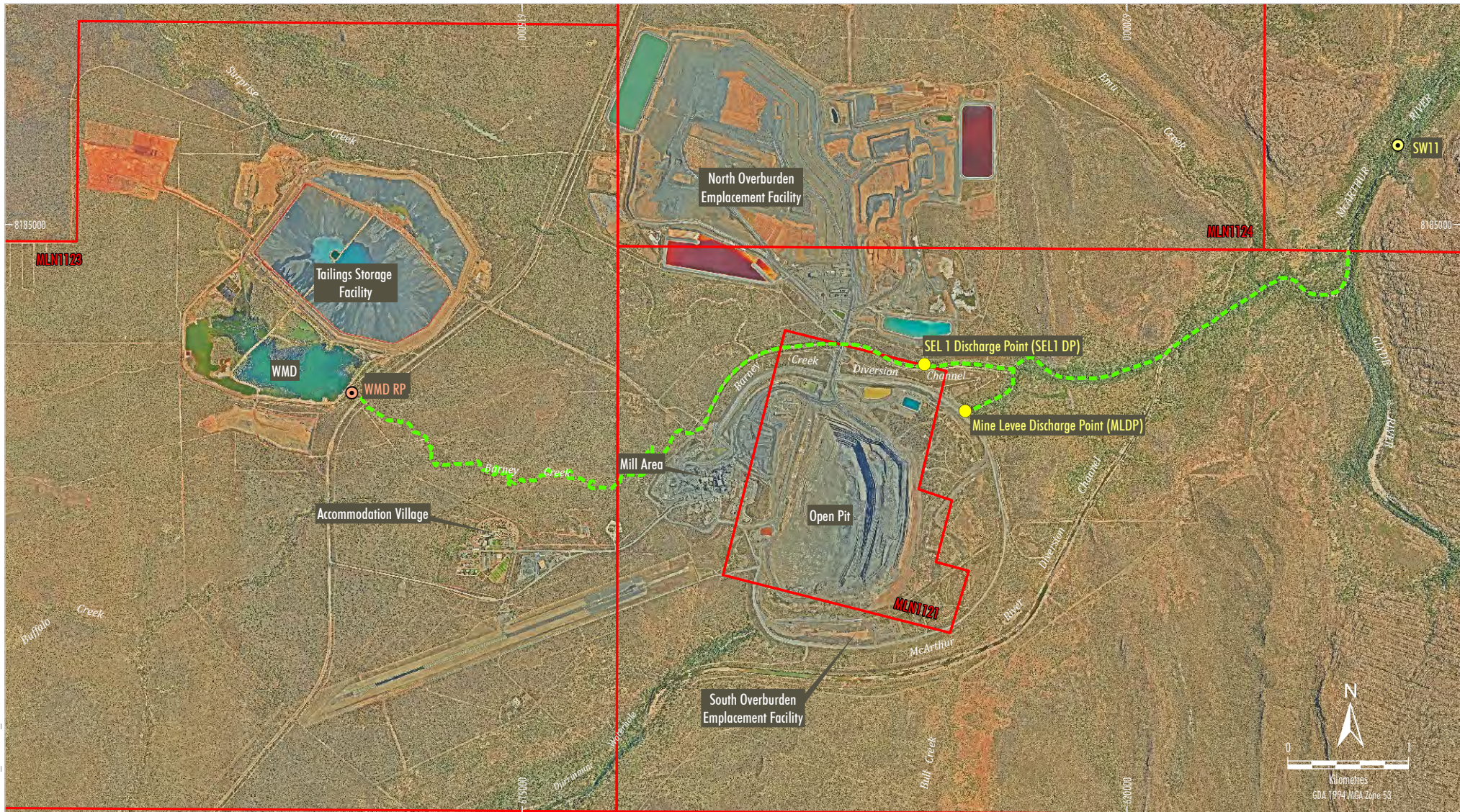
### 3.8.1 Authorised Discharge Points

WDL 174 details the authorised discharge points for the Mine. These points are outlined below in Table 10 and shown on Figure 12.

**TABLE 10: WDL 174 AUTHORISED DISCHARGE POINTS**

Authorised Discharge Point	Description	Location
Mine Levee Discharge Point(s) (MLDP) (Mine levee pumping outlets)	<p>Discharges through Mine Levee Discharge Point (MLDP) include:</p> <ol style="list-style-type: none"> <li>1. Rain water collecting in the old McArthur River Channel (NC1A) inside the Mine levee.</li> <li>2. Groundwater from dewatering bores around main pit collected in and then discharged from Pond 2 (P2).</li> <li>3. Water from the water management dam.</li> <li>4. Treated water from the Water Treatment Plant that will be stored in (P2) prior to discharge from the MLDP.</li> </ol> <p>Waters discharged at Mine Levee Discharge Point are pumped over the mine levee wall and flow into the Old McArthur River channel upstream of the McArthur River and Glyde River confluence.</p>	Easting 618661 Northing 8183459
South-East Levee 1 Discharge Point (SEL 1 DP)	<p>Rain water collecting inside the South Eastern Levee and separated from all contaminated seepages. Discharges are pumped via pipe line to Barney Creek and then flow into the McArthur River. Discharge can only occur when flow as measured in the McArthur River at the downstream gauging station is in excess of 20m<sup>3</sup>/s.</p>	Easting 618332 Northing 8183859
McArthur River Diversion Channel Discharge Point(s) (MRDC DP)	<p>Discharges through McArthur River Diversion Channel Discharge Point(s) (MRDC DP) include:</p> <ol style="list-style-type: none"> <li>1. Groundwater from dewatering bores around main pit collected in and then discharged from Pond 2 (P2).</li> <li>2. Water from the water management dam.</li> <li>3. Treated water that will be stored in (P2) prior to discharge from the MRDC DP.</li> </ol> <p>Waters discharged at the McArthur River Diversion Channel Discharge Point(s) are pumped into the McArthur River Diversion Channel upstream of the McArthur River and Glyde River confluence.</p>	Easting 619595 Northing 8182573

In addition, pursuant to the NT *Mining Management Act 2001* and permissible under Variation of Authorisation 0059, MRM is authorised to release wastewater from the Water Management Dam Release Point (see Figure 12). The Water Management Dam Release Point consists of a series of siphons that discharge water directly into the Little Barney Creek. Water is then conveyed along Barney Creek to the McArthur River.



- LEGEND**
- Mineral Lease
  - Authorised Discharge Point
  - ⊙ Authorised Release Point
  - ⊙ Compliance Monitoring Location
  - - - Mixing Zone

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); MRM (2019)

**McARTHUR RIVER MINE**  
**Authorised Discharge and Release Points and Mixing Zone**

**Figure 12**

## 3.8.2 Mixing Zones

Mixing zones are specifically defined areas where the water quality may be below that required to protect community values and beneficial uses (NT EPA, 2013b). Mixing zones allow for a designated zone of impact between the wastewater release points and the compliance point. Nonetheless, environmental controls are still required to minimise risk to mixing zones. These controls are outlined in the NT Guidelines on Mixing Zones (NT EPA, 2013b).

The Mine site's mixing zone extends along the McArthur River from the McArthur River Diversion Channel Discharge Point, past the end of the McArthur River Diversion Channel (Barney Creek and McArthur River confluence), finishing at the northern (downstream) boundary of MLN 1122.

In the operational areas of the Mine, managed releases are also conveyed along Little Barney Creek and Barney Creek (including the Barney Creek Diversion Channel). However, these reaches are highly ephemeral, are not considered important refugia for the persistence of any aquatic species, nor do they provide a major ecological role within the wider McArthur River catchment. For these reasons, the Little Barney Creek and Barney Creek reaches are not afforded mixing zone status or the same level of protection as that applied to the mixing zones of the McArthur River.

The Mine's mixing zones are shown in Figure 12.

## 3.9 Management Tools

### 3.9.1 Water Balance Model

A water balance for the Mine site is undertaken annually to assess the historical performance of the water management system as well as outline the strategy and forecast performance over a forward period. The water balance model is an essential risk management tool for the Mine site.

MRM and WRM have developed the site-wide water balance model using GoldSim® software to simulate the performance of the Mine's water management system. The forecast water balance model uses 120 years of historical climate data (using SILO rainfall and evaporation data) to predict the likely performance of the water management system for a large range of possible climatic conditions. The model has been validated against monitoring data dating back to 2010.

The annual site water balance assessment is undertaken to determine:

- the ability to meet water supply requirements for Mine water demands such as Mill makeup water, dust suppression, clay conditioning, etc;
- the risk of Open Pit inundation and the ability to dewater the Open Pit over consecutive wet seasons within an acceptable time frame (1 to 6 months);
- the annual volume of Class 5 (poor) and Class 6 (process) water that would require treatment to balance the inventory and risk;
- the annual volume of Class 4 (managed release water) that would require discharge to the McArthur River to balance the inventory and risk; and
- the risk of uncontrolled overflow from Class 5 and Class 6 water storages.

The *2021/22 Annual Site Water Balance for the McArthur River Mine* is provided in Appendix A.

### 3.9.2 Water Storage TARPs

MRM uses a TARP process to operate and manage the key water storages at the Mine site. The TARP takes into consideration the catchment areas and pumping infrastructure to determine set operating levels for the water storages based on risk. The TARP process aims to ensure that water storages are operated in a manner that meets or exceeds external commitments regarding the probability of uncontrolled overflow to the receiving environment.

MRM's current commitments require the AEP of uncontrolled off-site releases from poor quality (Class 5) on-site storages to be less than 5 % and process water (Class 6) on-site storages to be less than 1 %.

The water storage TARPs are developed annually prior to wet season to reflect current water management conditions. The report *Water balance modelling for the McArthur River Mine in support of the 2021/22 wet season TARP* is provided in Appendix B.

The water storage TARP operating level definitions were updated for the 2021/22 wet season. These are provided in Table 11.

**TABLE 11: DEFINITIONS FOR WATER STORAGE TARP AND OPERATING LEVELS**

TARP Level	Description
Level 1	Stored volume is less than the Upper operating level (UOL). Normal operations - pumped inflows and outflows can occur at this level as required for operations.
Level 2	Stored volume is greater than UOL and less than Maximum Operating Level (MOL). Early warning - cease pumped inflows from other storages unless otherwise specified in the individual dam TARP. Pumped outflows should be commenced if the receiving storage is below its UOL if possible.
Level 3	Stored volume is greater than MOL but less than Full Storage Level (FSL). Imminent risk - commence pumped outflows immediately as specified in the individual dam TARP.
Level 4	Stored volume is greater than FSL. Uncontrolled discharge of mine water - undergo monitoring and reporting procedures.

### 3.9.3 Geotechnical Inspections of Water Storages

MRM has engaged GHD to be the Engineer of Record for the primary water storages in the TSF, Mill and Mine domains. Under this arrangement, an Annual Dam Safety Assessment, including annual inspections, is undertaken and reported by GHD for the following:

Mine dams:

- Eastern Perimeter Runoff Dam;
- South Eastern Perimeter Runoff Dam;
- Southern PAF Run Off Dam;
- Western PAF Run Off Dam;
- South East Levee 1;
- North Crossing 1A;
- Pete's Pond; and
- Pond 2.

Mill and TSF dams:

- TSF Cell 1;
- TSF Cell 2;
- Water Management Dam; and
- Mill Anti-Pollution Pond.

The scope for the Annual Dam Safety Assessment completed by GHD includes the following requirements:

- review of consequence classification;
- summary of construction/raise works and quality assurance and quality control results;
- instrumentation and monitoring results;
- stability of structure review;
- incident reporting; and
- recommendations for “dam safety” requirements and recommendations for “improvement of practices”.

For the 2021 calendar year, the Mill and TSF Dams Inspection Report was finalised on 22 February 2022 (GHD, 2022a). The Mine Dams Inspection Report was finalised on 29 March 2022 (GHD, 2022b).

## 4 Monitoring Programs

MRM maintains an Environmental Monitoring Schedule (Appendix D) that outlines the most up-to-date water monitoring plans for the Mine site. To ensure monitoring remains relevant and consistent with the WMP's key environmental and operational objectives, the monitoring schedule is updated on a routine basis in response to changing site needs, amendments to regulatory documents and revisions to risk assessments.

An overview of the water monitoring programs is provided in the following sections, noting that individual monitoring sites may be added or removed from the overarching monitoring schedule as discussed above:

- Surface water monitoring program (Section 4.1);
- Fluvial sediment monitoring (Section 4.2);
- Surface water flow monitoring (Section 4.3);
- Artificial surface water monitoring (Section 4.4);
- Mine derived loads monitoring (Section 4.5);
- Groundwater monitoring (Section 4.6); and
- Freshwater ecology monitoring program (Section 4.7).

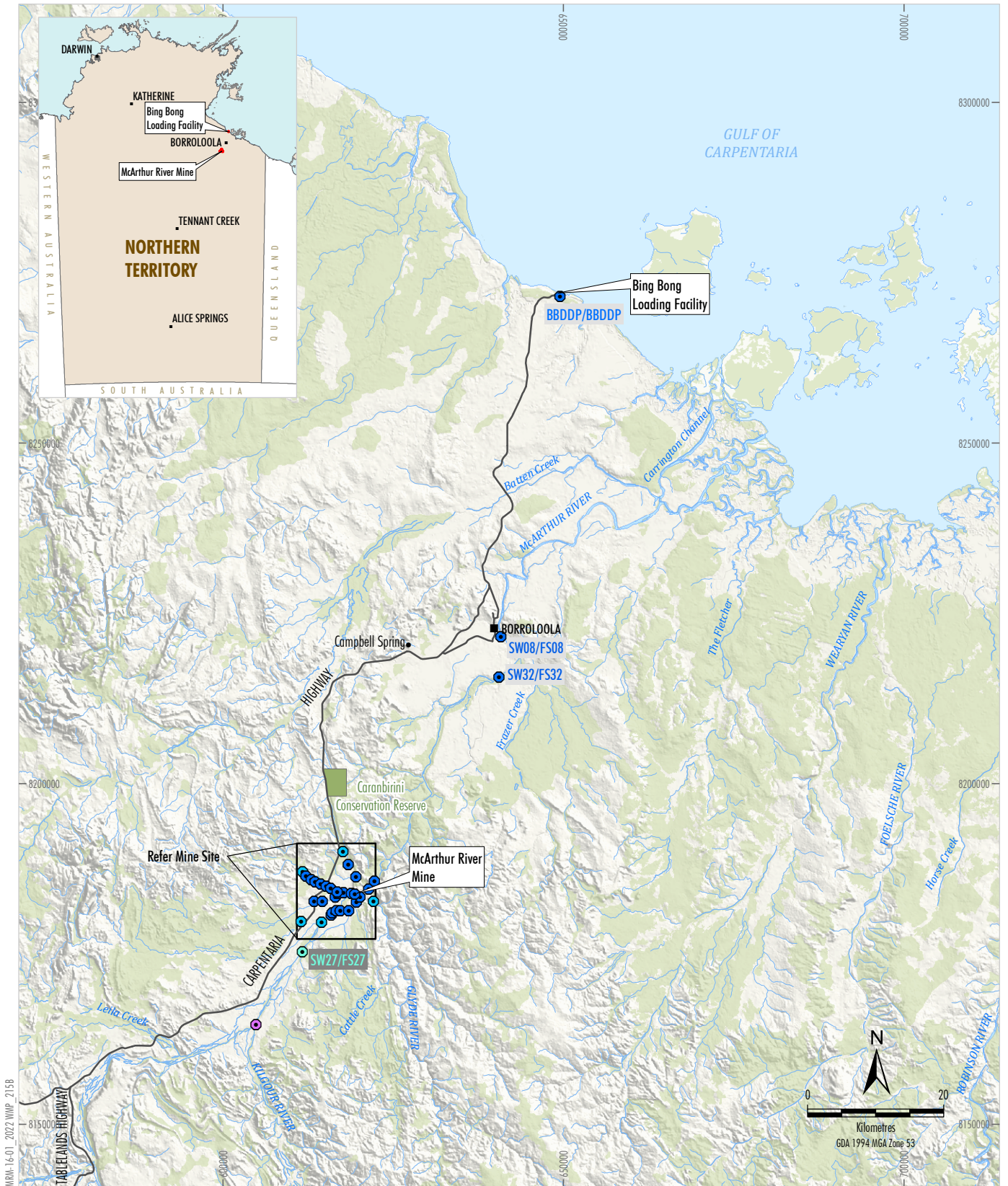
### 4.1 Surface Water Monitoring

#### 4.1.1 Overview

MRM has developed a natural surface water monitoring program that specifies the sampling requirements and procedures for the monitoring of waterways around the Mine site including the McArthur River, Glyde River, Barney Creek, Surprise Creek and Emu Creek. The objectives of the monitoring are to:

- characterise water quality at monitoring sites upstream and downstream of Mine operations;
- assess the potential impacts on the receiving waters from mine operations;
- assess the measured surface water quality against site-specific trigger values to verify compliance;
- identify the potential sources of contamination measured at water monitoring sites; and
- assess the efficacy of controls implemented by MRM to prevent contamination of receiving waters downstream of the site in the McArthur River.

The natural surface water monitoring network for the Mine consists of approximately 30 monitoring sites along local waterways (Figure 13 and Figure 14).



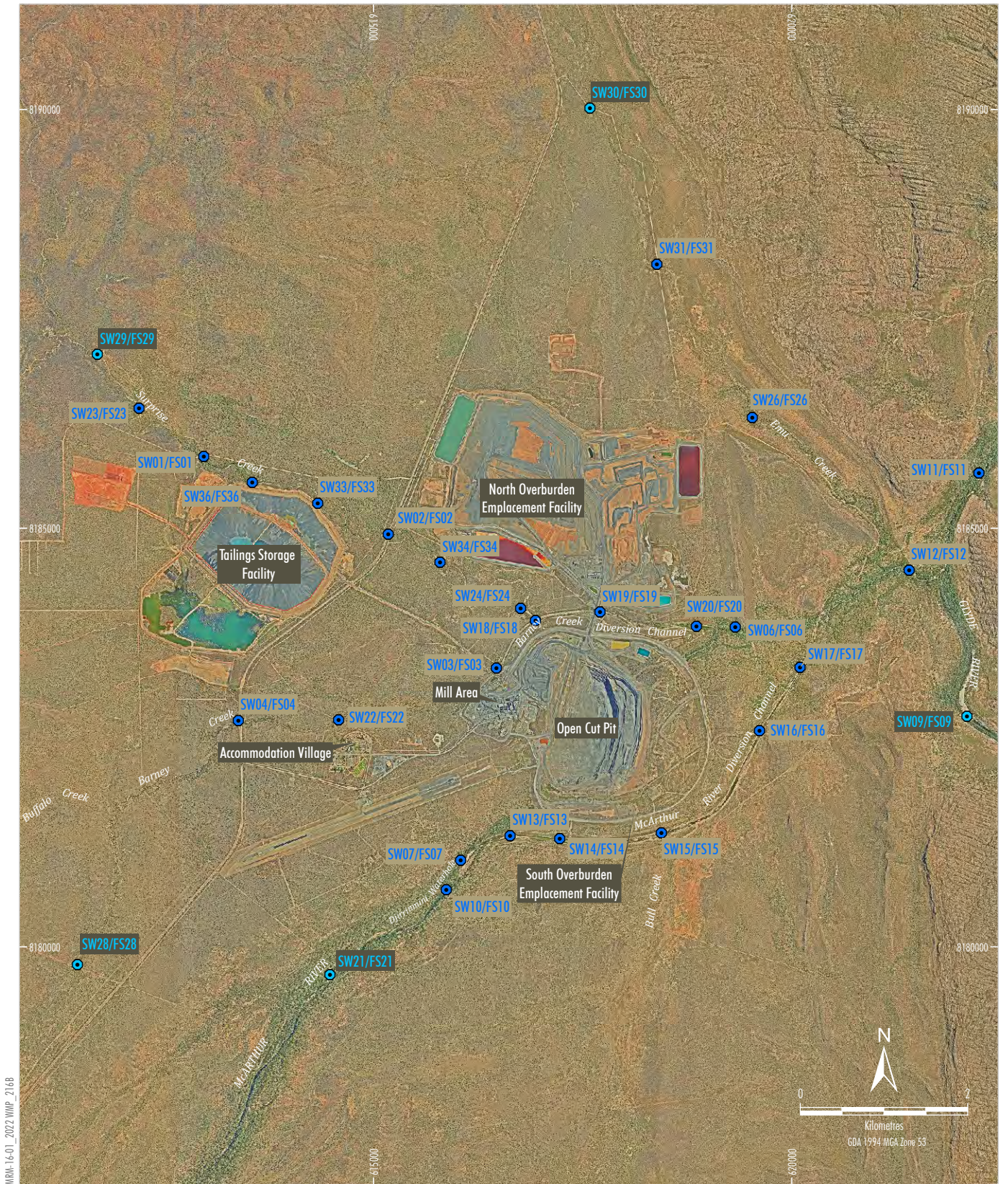
**LEGEND**

- Major Road
- River/Creek
- Control
- Early Warning Flood Station
- Potential Impact
- Upstream

Source: Geoscience Australia - Topography (2006);  
Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
**Regional Surface Water and**  
**Fluvial Sediment Monitoring Sites**

**Figure 13**



**LEGEND**  
 ● Control  
 ● Potential Impact

Source: Orthophoto MRM (2018); Department of Environment and Natural Resources (2016); MRM (2018)

**McARTHUR RIVER MINE**  
**Local Surface Water and Fluvial Sediment Monitoring Sites**

**Figure 14**

The monitoring sites are categorised into:

1. **Control and Upstream sites** located upstream of the Mine or in unaffected catchments, which are used to:
  - identify background water quality concentrations upstream of the Mine so that the performance of downstream sites can be assessed; and
  - identify trends in background water quality that may influence the water quality on-site and downstream of the Mine.
2. **Potential Impact sites** located onsite or downstream of the Mine which are used to:
  - confirm compliance with the site-specific trigger values specified in the WDL 174 (at monitoring site SW11) in consideration of the influence of background concentrations;
  - identify elevated concentrations near key Mine water storages or infrastructure; and
  - identify trends along reaches of the McArthur River or its tributaries which may indicate the onsite water management systems are not performing as expected.

The sites of potential impact have been selected to identify adverse or unexpected water quality trends in the vicinity or downstream of the Mine infrastructure.

The WDL compliance point is surface water monitoring site SW11. This site is located on the McArthur River downstream of MLN 1122 and is considered to represent the quality of water leaving the mineral leases at the Mine. In accordance with conditions of the WDL 174, site-specific trigger values are applied to the water quality measured at the SW11 monitoring site.

The typical suite of analytes monitored at natural surface water sites is listed in Table 12. Samples are generally taken weekly with flow at each surface water monitoring site.

**TABLE 12: SURFACE WATER QUALITY ANALYTE SUITE**

Category	Analytes		
Physico-chemical Parameters	pH	Sulphate (SO <sub>4</sub> )	Bromide (Br)
	EC	Calcium (Ca)	Nitrate (NO <sub>3</sub> ),
	Dissolved oxygen	Magnesium (Mg)	Ammonia (NH <sub>3</sub> )
	Temperature	Sodium (Na)	Total nitrogen (N)
	Oxidation reduction potential	Potassium (K)	Total phosphorous (P)
	Turbidity	Fluoride (F)	Hardness
	Total dissolved solids	Chloride (Cl)	Alkalinity
	Metals and Metalloids (total and filtered)	Aluminium (Al)	Chromium (Cr)
Antimony (Sb)		Cobalt (Co)	Selenium (Se)
Arsenic (As)		Copper (Cu)	Silver (Ag)
Barium (Ba)		Nickel (Ni)	Thallium (Tl)
Beryllium (Be)		Iron (Fe)	Uranium (U)
Boron (B)		Lead (Pb)	Vanadium (V)
Bismuth (Bi)		Manganese (Mn)	Zinc (Zn)
Cadmium (Cd)		Mercury (Hg)	
Hydrocarbons <sup>1</sup>		Benzene	Total petroleum hydrocarbons (TPH) (C <sub>6</sub> -C <sub>36</sub> )

<sup>1</sup> Monitored at select sites

Surface water quality samples are collected in accordance with MRM Natural Surface Water Monitoring Procedure (PRO-2200023). The following information is recorded for each surface water sample collected and analysed:

- date on which the sample was collected;

- time at which the sample was collected;
- location at which the sample was collected;
- name of the person who collected the sample;
- chain of custody forms relating to the sample;
- field measurements (if any) and analytical results (if any) relating to the sample; and
- laboratory quality assurance and quality control documentation.

In addition to the surface water samples and field readings, electrical conductivity loggers are also used at select surface water monitoring sites to provide a continuous record of conductivity over the wet season. The loggers are placed at monitoring sites in accordance with WDL 174 and Variation of Authorisation 0059 requirements. The updated list of sites requiring continuous electrical conductivity monitoring is provided in the MRM Monitoring Schedule.

#### 4.1.2 Performance Triggers

The performance triggers for natural surface water monitoring are applied to the McArthur River compliance Point, SW11. These triggers are defined in Tables 13 and 14.

**TABLE 13: NATURAL SURFACE WATER PERFORMANCE TRIGGERS DURING MANAGED RELEASE**

TARP Level	Description
Level 1	SW11 analyte predicted or measured less than 90% of Site-Specific Trigger Value due to the managed release.
Level 2	SW11 analyte predicted or measured greater than or equal to 90% of Site-Specific Trigger Value due to the managed release.
Level 3	Monitoring indicates: <ol style="list-style-type: none"> <li>1. SW11 analyte greater than Site-Specific Trigger Value on three consecutive sampling occasions;</li> <li>2. SW11 analyte equal to or greater than 3 x Site-Specific Trigger Value; or</li> <li>3. subsequent consecutive exceedances of Site-Specific Trigger Value described in 1 and 2 above.</li> </ol>

**TABLE 14: NATURAL SURFACE WATER PERFORMANCE TRIGGERS**

TARP Level	Description
Level 1	SW11 analyte measured less than 90% of Site-Specific Trigger Value.
Level 2	SW11 analyte measured greater than or equal to 90% of Site-Specific Trigger Value.
Level 3	Monitoring indicates: <ol style="list-style-type: none"> <li>1. SW11 analyte greater than Site-Specific Trigger Value on three consecutive sampling occasions;</li> <li>2. SW11 analyte equal to or greater than 3 x Site-Specific Trigger Value; or</li> <li>3. subsequent consecutive exceedances of Site-Specific Trigger Value described in 1 and 2 above.</li> </ol>

## 4.2 Fluvial Sediment Monitoring

### 4.2.1 Overview

MRM has developed a fluvial sediment monitoring program that specifies the sampling requirements and procedures for the monitoring of sediments in the McArthur River, Glyde River, Barney Creek, Surprise Creek and Emu Creek. The objectives of the monitoring are to:

- identify potential variations in physico-chemical parameters of fluvial sediments, in particular heavy metals;
- identify with the use of guidelines, sediments where analyte concentrations are likely to result in adverse effects on sediment ecological health;
- identify sediments with the potential for remobilisation of analytes in the water column and/or into the aquatic food chains; and
- identify the potential sources of any contaminants detected in fluvial sediments.

The fluvial sediment monitoring network at the Mine is aligned with the natural surface water sample sites and consists of approximately 30 monitoring sites along local waterway (Figures 13 and 14). The monitoring sites are categorised into:

1. control and upstream sites located upstream of the Mine or in unaffected catchments; and
2. potential impact sites located onsite or downstream of the Mine.

Potential impact sites have been selected to identify adverse or unexpected sediment quality trends in the vicinity or downstream of the Mine infrastructure.

The typical suite of analytes monitored at fluvial sediment sites is listed in Table 15. Samples are generally taken annually following cessation of the wet season.

**TABLE 15: FLUVIAL SEDIMENT MONITORING ANALYTE SUITE**

Category	Analytes		
Physico-chemical Parameters	Sediment moisture content pH paste EC paste Total sulphur PSD	Soluble ions: Calcium (Ca) Magnesium (Mg) Sodium (Na) Potassium (K)	Chloride (Cl) Sulphate (SO <sub>4</sub> )
Metals and Metalloids (total and filtered)	Aluminium (Al) Antimony (Sb) Arsenic (As) Barium (Ba) Beryllium (Be) Boron (B) Bismuth (Bi) Cadmium (Cd)	Chromium (Cr) Cobalt (Co) Copper (Cu) Nickel (Ni) Iron (Fe) Lead (Pb) Manganese (Mn) Mercury (Hg)	Molybdenum (Mo) Selenium (Se) Silver (Ag) Thallium (Tl) Uranium (U) Vanadium (V) Zinc (Zn)
Isotopes	Lead isotopes ( <sup>207</sup> Pb/ <sup>206</sup> Pb, <sup>208</sup> Pb/ <sup>206</sup> Pb)		

Fluvial sediment samples are wet sieved with deionised water and oven dried prior to acid digestion. Both a weak acid digest and strong acid digest are completed separately on the sediments. Data is presented based on the analysis of the <63 µm sediment fraction in accordance with MRM Fluvial Sediment Sampling Procedure (PRO-2200029) and national guidelines.

## 4.2.2 Performance Triggers

The performance triggers for fluvial sediment monitoring are applied to all potential impact sites located on-site or downstream of the Mine. The performance triggers are based on national sediment quality guideline values taken from a Sediment quality assessment: a practical guide (Simpson and Batley, 2016) (Table 16). The performance triggers are outlined in Table 17.

Following the recommendations of Simpson and Batley (2016), MRM compares the <63µm sediment metal concentrations analysed by dilute acid extraction (representing the bioavailable concentrations of metals in the sediment) to the sediment quality guideline values.

**TABLE 16: SEDIMENT QUALITY GUIDELINE VALUES (SIMPSON AND BATLEY, 2016)**

Contaminant	Sediment Quality Guideline Value	Sediment Quality Guideline - High
	<i>Metals/metalloids (mg/kg dry weight)</i>	
Arsenic	20	70
Cadmium	1.5	10
Copper	65	270
Lead	50	220
Zinc	200	410

mg/kg = milligrams per kilogram

**TABLE 17: FLUVIAL SEDIMENT QUALITY PERFORMANCE TRIGGERS**

TARP Level	Description
Level 1	Fluvial sediment analyte less than or equal to the <i>Sediment Quality Guideline Value</i> .
Level 2a	Fluvial sediment analyte greater than the <i>Sediment Quality Guideline Value</i> and less than or equal to the <i>Sediment Quality Guideline - High</i> .
Level 2b	Fluvial sediment analyte greater than the <i>Sediment Quality Guideline - High</i> .
Level 3	Fluvial sediment analyte greater than the <i>Sediment Quality Guideline – High</i> for 4 consecutive quarterly results.

## 4.3 Surface Water Flow

### 4.3.1 Overview

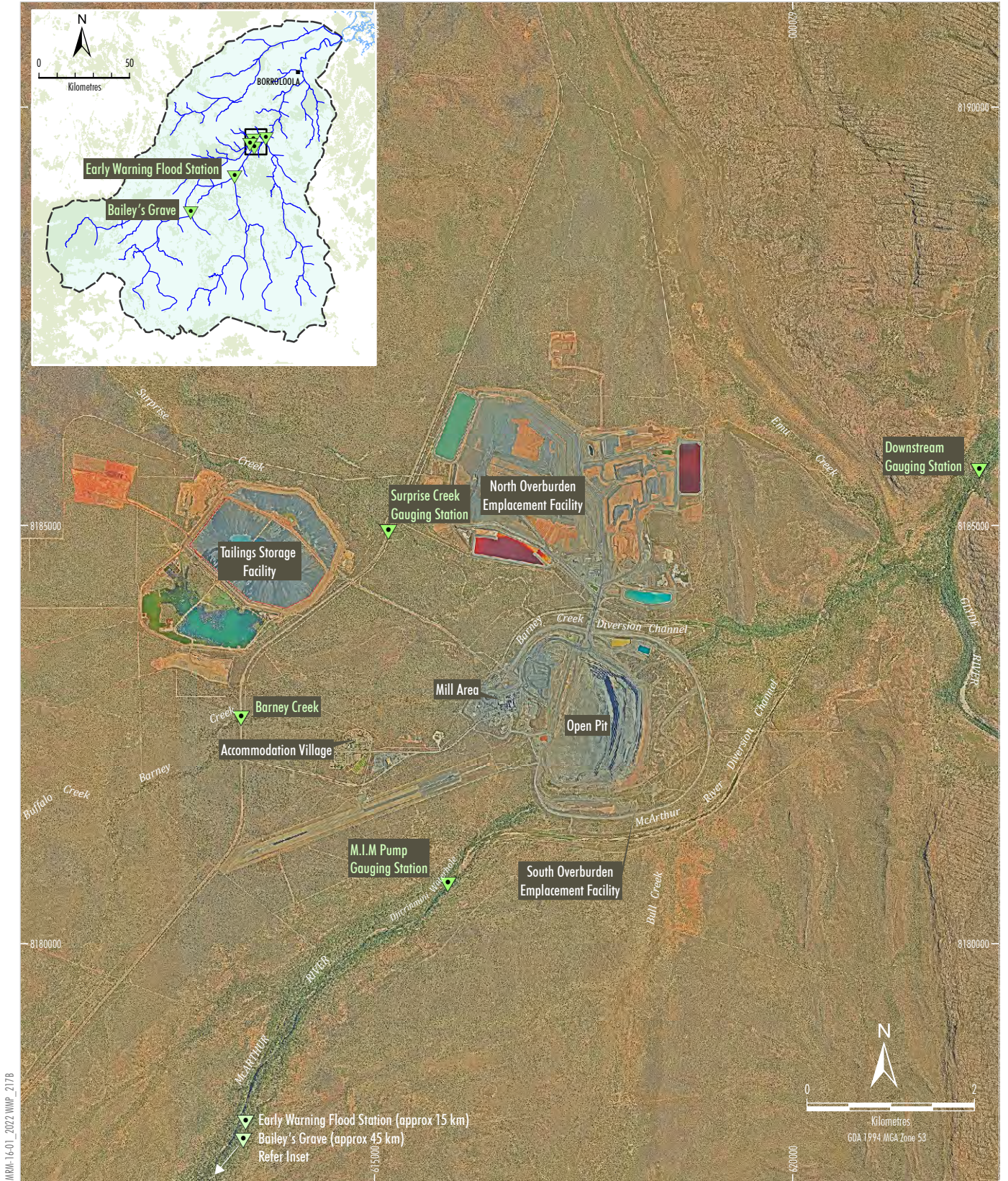
MRM monitors surface water flow in the McArthur River catchment at a number of gauging stations to provide information for flood assessments, engineering designs and waste discharge calculations. MRM owns and maintains a number of the stations, with the NT Department of Environment, Parks and Water Security (DEPWS) also operating stations in the catchment.

There are six primary gauging stations in the McArthur River catchment in the vicinity of the Mine (Figure 15):

- McArthur River Bailey's Grave Gauging Station (G9070142) operated by DEPWS and located upstream of the McArthur River and Kilgour River confluence;
- McArthur River Early Warning Flood Station (EWFS) located on the McArthur River 21 km south-west (upstream) of the Mine and downstream of the Kilgour River confluence;
- McArthur River M.I.M Pump Gauging Station (G9070132) operated by DEPWS and located just upstream of the Mine;
- McArthur River Downstream Gauging Station (DSGS) located at SW11, downstream of the confluence with the Glyde River;
- Surprise Creek Gauging Station (SCGS) located at the Carpentaria Highway crossing; and
- Barney Creek Gauging Station (BCGS) located at the Carpentaria Highway crossing.

The McArthur River M.I.M Pump Gauging Station (G9070132) operated by DEPWS has the longest and most reliable data record for the McArthur River near the Mine.

In addition to the real-time gauging stations, pressure transducer loggers are also used at select surface water monitoring sites to provide a continuous record of water level over the wet season. The loggers are placed at monitoring sites in accordance with WDL 174 and Variation of Authorisation 0059 requirements. The updated list of sites requiring continuous water level monitoring is provided in the MRM Monitoring Schedule.



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**LEGEND**  
 Gauging Station

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); MRM (2018)

McARTHUR RIVER MINE  
 Principal Gauging Station Network

Figure 15

## 4.4 Artificial Surface Water Monitoring

### 4.4.1 Overview

MRM has developed an artificial surface water monitoring program which specifies the sampling requirements and procedures for monitoring of water in designated water storage structures (Figure 16a). The objectives of the artificial monitoring program are:

- identify potential contamination in water to determine risk and appropriate management options;
- identify suitable water storage options, and whether offsite discharge is a viable disposal option; and
- collect data to assess environmental performance and provide information for contamination source investigations.

The artificial surface water monitoring network at the Mine consists of approximately 50 routine monitoring sites (Figure 16b). The frequency of sampling is dictated by data use and statutory requirements such as WDL 174. Sampling frequency varies from site to site and includes weekly, monthly and event based (e.g. commencement of waste discharge, rainfall events) sampling. The typical suite of analytes monitored at artificial surface water sites is listed in Table 18.

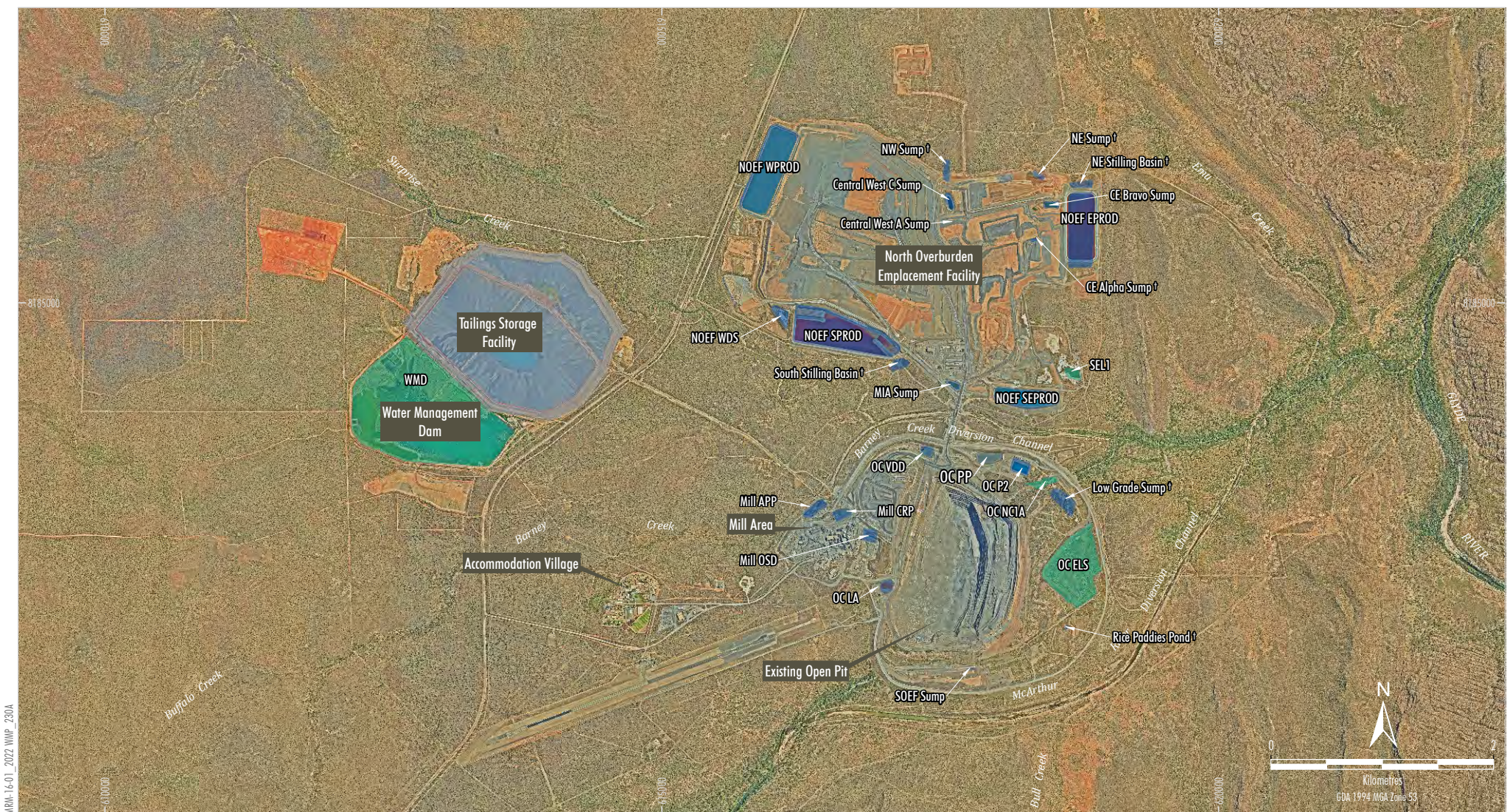
**TABLE 18: ARTIFICIAL SURFACE WATER QUALITY ANALYTE SUITE**

Category	Analytes		
Physico-chemical Parameters	pH	Sulphate (SO <sub>4</sub> )	Bromide (Br)
	EC	Calcium (Ca)	Nitrate (NO <sub>3</sub> )
	Dissolved oxygen	Magnesium (Mg)	Ammonia (NH <sub>3</sub> )
	Temperature	Sodium (Na)	Total nitrogen (N)
	Oxidation reduction potential	Potassium (K)	Total phosphorous (P)
	Turbidity	Fluoride (F)	Hardness
	Total dissolved solids	Chloride (Cl)	Alkalinity
	Metals and Metalloids (total and filtered)	Aluminium (Al)	Chromium (Cr)
Antimony (Sb)		Cobalt (Co)	Selenium (Se)
Arsenic (As)		Copper (Cu)	Silver (Ag)
Barium (Ba)		Nickel (Ni)	Thallium (Tl)
Beryllium (Be)		Iron (Fe)	Uranium (U)
Boron (B)		Lead (Pb)	Vanadium (V)
Bismuth (Bi)		Manganese (Mn)	Zinc (Zn)
Cadmium (Cd)		Mercury (Hg)	
Hydrocarbons <sup>1</sup>		Benzene	Total petroleum hydrocarbons (TPH) (C <sub>6</sub> -C <sub>36</sub> )

<sup>1</sup> Monitored at select sites

Artificial surface water quality samples are collected in accordance with MRM Artificial Surface Water Monitoring Procedure (PRO-2200025).

In addition to the water quality samples, the changes to water storage inventories at the Mine is also monitored at key artificial water locations. This monitoring is undertaken on a routine basis and includes water storage transfer volumes (including source and destination), water levels and storage volumes. The data is used for comparisons with the dam TARPs to inform water storage and pumping operations. The monitoring is undertaken by the Mining Department and reported on a daily basis.



/MRM-16-01\_2022 WMP\_230A

**LEGEND**

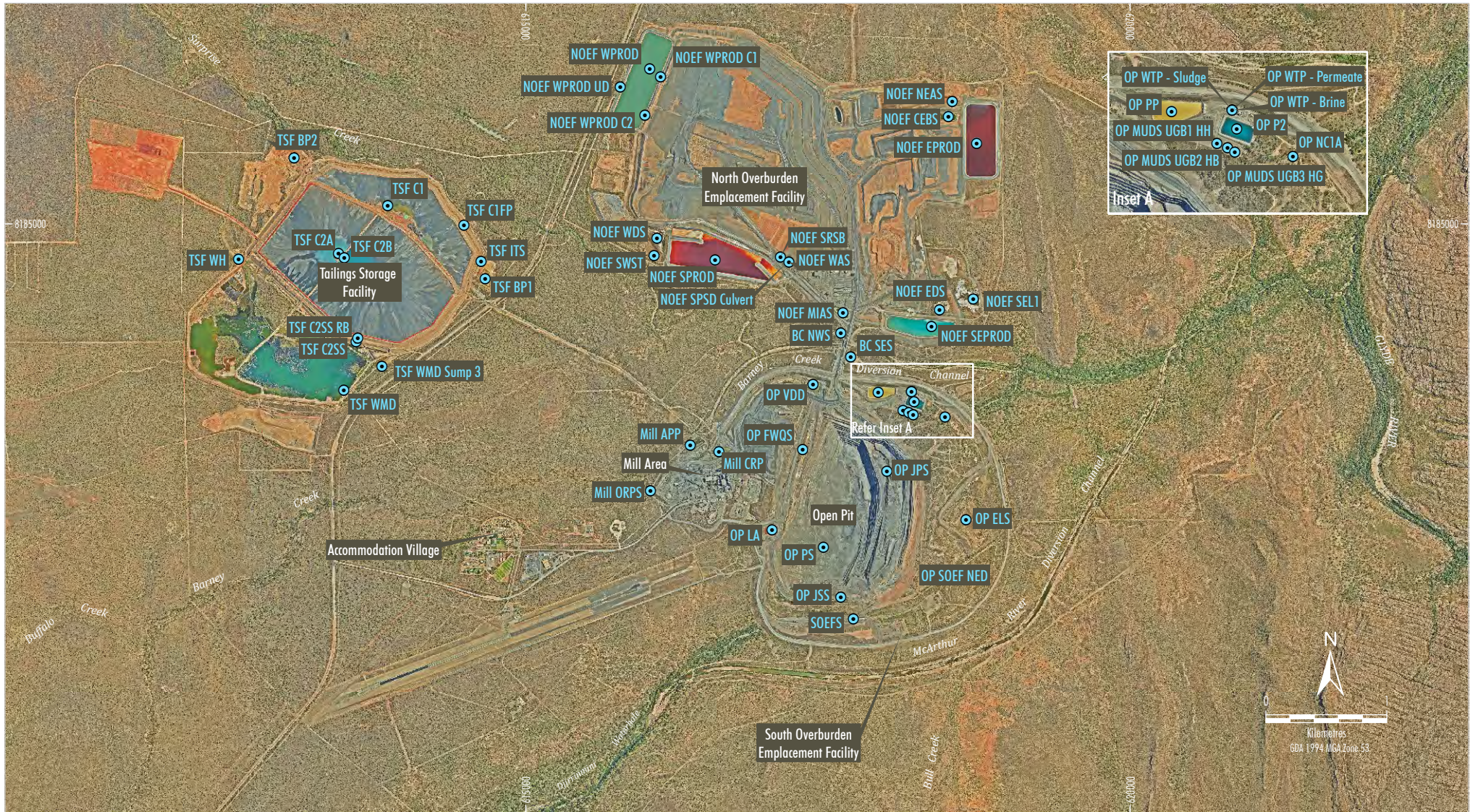
- Water Storage\*
- Non-AMD Water Storage
- Tailings Storage Facility

Note: \* AMD water may be stored in this water storage at times.  
 † This storage has not yet been developed.

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016)

**McARTHUR RIVER MINE**  
**Mine Tailings Storage Facility and Water Storages**

**Figure 16a**



MRM-16-01\_2022\_WMP\_231A

- LEGEND**
- Artificial Surface Water Site

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); MRM (2018)

**McARTHUR RIVER MINE**  
**Artificial Surface Water Monitoring Sites**

**Figure 16b**

## 4.4.2 Performance Triggers

The performance triggers for artificial surface water monitoring are applied to the water quality of sediment traps that release to the receiving environment. These triggers are defined in Table 19.

**TABLE 19: SEDIMENT TRAP PERFORMANCE TRIGGERS**

TARP Level	Description
Level 1	Sediment trap water quality = Class 2 or better (lower) based on median concentrations over the reporting period (as detailed in the WMP).
Level 2	Sediment trap water quality = Class 4 based on median concentrations over the reporting period (as detailed in the WMP).
Level 3	Sediment trap water quality $\geq$ Class 5 based on median concentrations over the reporting period (as detailed in the WMP).

## 4.5 Mine Derived Loads Monitoring

### 4.5.1 Managed Release

Lead and zinc loads are estimated in managed release on a daily basis using measured discharge volumes and managed release water quality. The estimation of managed release loads can be expressed by the equation below:

$$\text{managed release load} = \text{source volume} \times \text{source concentration}$$

Managed release flowrates from the authorised discharge and release points (Figure 12) are metered using electromagnetic or other style flowmeters. Metered flow rates in litres per second are converted to daily volumes for the load estimations.

The daily lead and zinc loads are estimated by multiplying the daily managed release volumes and the concentration data for each of the managed release points. The loads discharged from all release points are then be summed for the reporting period, which represent the annual mine derived loads contribution from managed releases.

Condition 108 of the MRM Variation of Authorisation requires that "... annual loads of lead and zinc discharged to the McArthur River in future years (July to June) do not exceed the loads discharged in 2017-2018...". The estimated 2017-2018 managed release loads are detailed in Table 20.

**TABLE 20: 2017-2018 MANAGED RELEASE LOADS**

Source	Total Lead (kg)	Total Zinc (kg)
Managed release from authorised discharge/release points	15.8	3,429

## 4.5.2 Mine Affected Baseflow

Condition 17(a)(iii) of Variation of Authorisation 0059 requires a plan that includes:

*iii. methodology to calculate contaminant loads and contaminant concentrations entering creeks and the McArthur River using system modelling that must:*

*a. use suitable site-specific data collected as part of Condition 26;*

*...*

*c. detail specific assumptions to be tested including but are not limited to:*

*i. groundwater flow paths;*

*ii. attenuation of metals from mine-derived wastes;*

Additionally, Condition 27(b)(ii) of Variation of Authorisation 0059 requires this plan to:

*ii. quantify impacts to water quality and trends in groundwater to determine that objectives and targets are being met, including the effectiveness of source control to reduce loads to as low as reasonably practicable;*

System modelling is used to estimate groundwater loads, calculated for each of the surface water zones using results from MRM's routine groundwater monitoring and an analytical approximation for groundwater flow.

Groundwater flows for various different surface water reaches were estimated to coincide with surface water reach sections identified by WRM Water and Environment Pty Ltd (WRM) and used for EIS reporting (KCB 2017a; 2017b; WRM 2017).

A groundwater flow estimate for each reach was calculated using Darcy's law, with representative hydraulic properties for the shallow groundwater units likely to contribute to surface water baseflow used to define the input parameters.

Darcy's law was applied as follows:

$$Q = TiL$$

$$T = kb$$

Where Q is flow; T is transmissivity; i is the hydraulic gradient; L is the length of watercourse; k is hydraulic conductivity and b is the thickness of active flow (i.e. between the piezometric surface and creek invert).

Estimated loads were obtained by multiplying the estimated groundwater flow to each reach by the recorded concentrations of lead and zinc from the groundwater quality records to calculate the load of these contaminants entering the watercourse. Where a range of plausible gradients exists from measured water levels, this range is considered in the calculations.

The processes outlined above were conducted separately for the wet and dry seasons to account for the change in groundwater loads due to the seasonal variation in groundwater flux to the various watercourses. Groundwater monitoring values between the late March and April of the respective year are used to represent the wet season loads, while monitoring values between September and October were used to represent the dry season.

Using these representative values, the cumulative loads were then estimated for both seasons by multiplying the values by a representative number of days; annual values were calculated as the sum of the two seasonal loads (Table 21).

**TABLE 21 MONITORING TIMESERIES REPRESENTING WET AND DRY SEASON PERIODS**

Season	Period	Seasonal Multiplier
Dry	April – October	180 days
Wet	October – April	185 days

Groundwater monitoring was used from a select number of monitoring bores on the basis of representing the shallow groundwater in each creek section/surface water zone. Monitoring bores were selected for each of the surface water zones and, where possible, the selection of bores aimed to have bores evenly spaced throughout the zone and on both banks of each watercourse. Since the groundwater quality is variable, a range of representative values from each reach is used to provide an envelope of calculated loads.

The location of monitoring bores used, and the associated surface water zones have been illustrated in Plate 10. Groundwater monitoring data was not available for zones 16\_1, 11, 14, 15, 18\_3, 18\_2, Glyde and Bull 19 (highlighted maroon in Plate 10). These zones contain no mining-associated infrastructure, and no groundwater loads were calculated for these zones.

Mass model loads for lead and zinc were both extracted from the calibrated groundwater model and calculated based on the methodology above for each of the surface water zones illustrated in Plate 10. The correlation between the model and manual loads were assessed to validate the methodology used for manual calculation.

The estimated 2017-2018 loads are detailed in Table 22.

**TABLE 22: ESTIMATED 2017-2018 BASEFLOW LOADS**

Source	Total Lead (kg)	Total Zinc (kg)
Estimated 2017-2018 Baseflow Loads	0.5	47.8

Following the estimation of loads for each year, the process will be refined using the data collected, including through testing of assumptions regarding:

- groundwater flow paths; and
- attenuation of metals from mine derived wastes.

### 4.5.3 Mine-derived Loads Performance Triggers and Trend Analysis

The performance triggers applied to mine derived loads entering the McArthur River are outlined in Table 23.

**TABLE 23: MINE-DERIVED LOAD PERFORMANCE TRIGGERS**

TARP Level	Description
Level 1	The total discharge/release and baseflow loads are 90 % or less of the following limits: <ul style="list-style-type: none"> <li>• Lead: Annual Defined Limit = 16.3 kg.</li> <li>• Zinc: Annual Defined Limit = 3,476.8 kg.</li> </ul>
Level 2	The total discharge/release and baseflow loads are greater than 90% but less than 100% of defined limit.
Level 3	The total discharge/release and baseflow loads are greater than 100% of defined limit.

Comparison of annual baseflow loads between years would be undertaken to quantify trends and compare baseflow loads to the 2018 EIS predictions.



## 4.6 Groundwater Monitoring

### 4.6.1 Groundwater Monitoring Network

Groundwater monitoring commenced in 1995 and has been expanded to a network of over 350 monitoring locations, targeting the major hydrostratigraphic units across the different domains.

The groundwater monitoring network has been sub-divided into “performance indicator bores” and “investigative bores”. Details of the purpose of each category are provided in Table 24.

**TABLE 24: DESCRIPTION OF MONITORING TYPE BORES PURPOSE**

Category	Purpose of Bores
Performance indicator bores	<ul style="list-style-type: none"> <li>Identify changes to groundwater conditions in the areas adjacent to groundwater receptors;</li> <li>Indicate trends that have the potential to cause an impact to the downstream receptors; and</li> <li>Identify variation from model predictions that have the potential to pose a risk to downstream receptors.</li> </ul>
Investigative bores	<ul style="list-style-type: none"> <li>To assist in closing knowledge gaps and further defining the hydrogeological conceptual model for the Mine.</li> <li>Bores within Mine facilities (e.g. bores within the TSF and NOEF) and adjacent to water storage facilities (e.g. adjacent to the PRODs and current/proposed water management dams); and</li> <li>Bores associated with management and mitigation measures (e.g. adjacent to the interception trench proposed to be installed at the TSF).</li> </ul>

Performance indicator bores will be assessed annually and reported in the MRM Environment Monitoring Report (EMR). Data from the investigative bores will be analysed as part of the relevant investigation and the analysis process might vary with the ongoing requirements of each study.

### 4.6.2 Groundwater Quality Performance Monitoring Program

The key objectives of the groundwater quality performance monitoring program are:

- Characterisation of water quality at monitoring sites upstream of Mine operations and in zones of natural mineralisation;
- Identification of adverse or unexpected trends in groundwater quality that may harm the receiving beneficial uses and community values;
- Assessment of measured groundwater quality against predicted groundwater impacts;
- Validation of the SPR model; and
- Assessment of the efficacy of controls implemented by MRM to prevent contamination from the sources identified.

The groundwater quality performance monitoring network locations target the vicinity of the identified sources of contaminants, the vicinity of surface water pathways to the receptor (on-lease creeks), and towards the downstream McArthur River. Groundwater quality upstream of the Mine operations and in zones of natural mineralisation is also monitored.

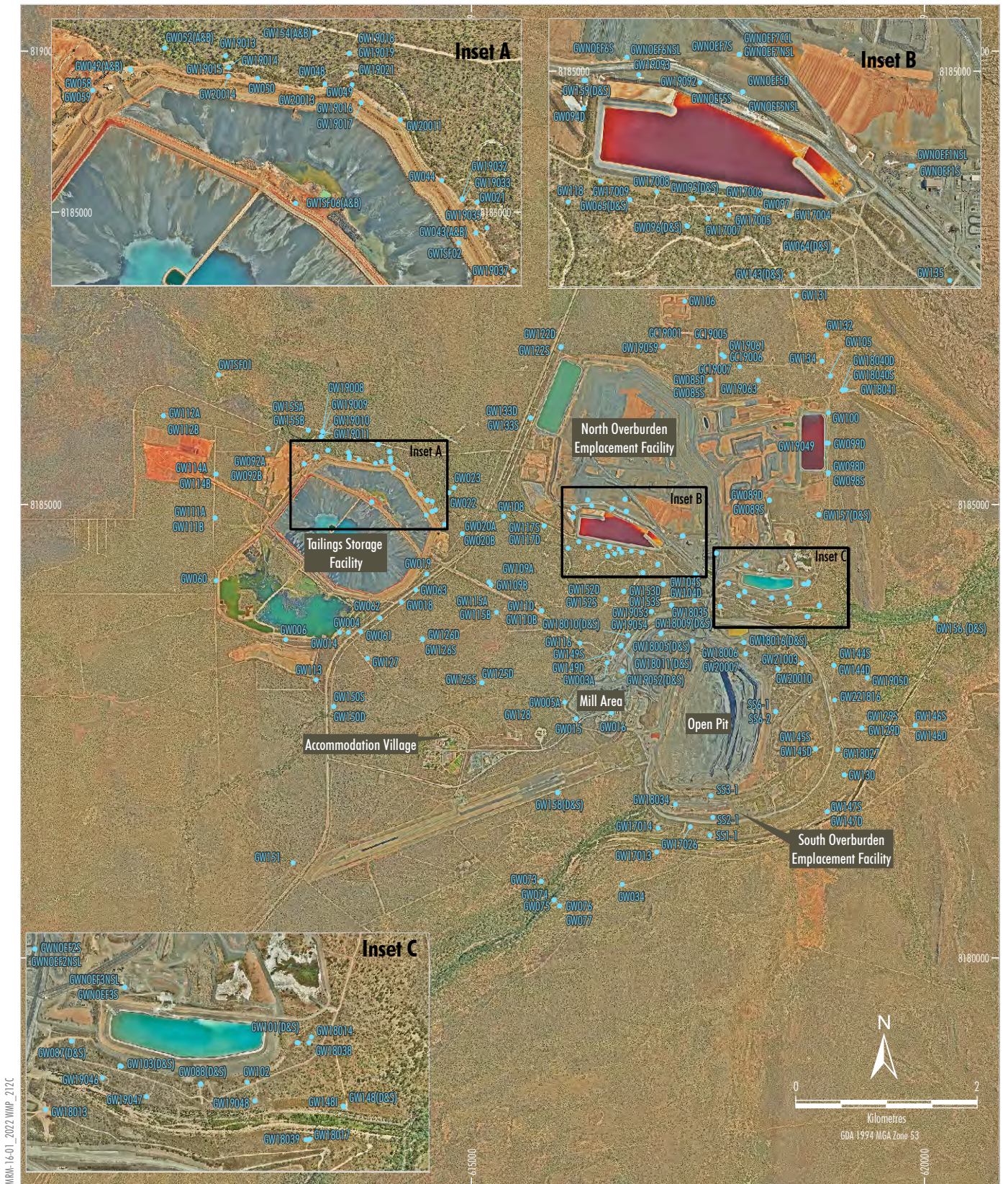
The typical suite of analytes monitored at groundwater monitoring sites is listed in Table 25 and sites are shown on Figure 17.

**TABLE 25: GROUNDWATER QUALITY ANALYTE SUITE**

Category	Analytes			
Physico-chemical Parameters	pH	Sulphate (SO <sub>4</sub> )	Bromide (Br)	
	EC	Calcium (Ca)	Nitrate (NO <sub>3</sub> ),	
	Dissolved oxygen	Magnesium (Mg)	Ammonia (NH <sub>3</sub> )	
	Temperature	Sodium (Na)	Total nitrogen (N)	
	Oxidation reduction potential	Potassium (K)	Total phosphorous (P)	
	Turbidity	Fluoride (F)	Hardness	
	Total dissolved solids	Chloride (Cl)	Alkalinity	
	Metals and Metalloids	Aluminium (Al)	Chromium (Cr)	Molybdenum (Mo)
Antimony (Sb)		Cobalt (Co)	Selenium (Se)	
Arsenic (As)		Copper (Cu)	Silver (Ag)	
Barium (Ba)		Nickel (Ni)	Thallium (Tl)	
Beryllium (Be)		Iron (Fe)	Uranium (U)	
Boron (B)		Lead (Pb)	Vanadium (V)	
Bismuth (Bi)		Manganese (Mn)	Zinc (Zn)	
Cadmium (Cd)		Mercury (Hg)		
Hydrocarbons <sup>1</sup>		Benzene	Total petroleum hydrocarbons (TPH) (C <sub>6</sub> -C <sub>36</sub> )	

<sup>1</sup> Monitored at select sites

Groundwater quality samples are collected in accordance with MRM's Groundwater Monitoring Procedure (PRO-2200024) (MRM, 2021b).



**LEGEND**  
 ● Groundwater Monitoring Site

**McARTHUR RIVER MINE**  
**Groundwater Monitoring Network**

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); MRM (2022)

**Figure 17**

### 4.6.3 Groundwater Level Monitoring Program

The objectives of groundwater level monitoring program are:

- assess the magnitude of Mine derived drawdown and mounding of the groundwater table;
- identify relevant changes in groundwater gradients near the Open Pit and mining infrastructure;
- provide data for future refinements of the conceptual and numerical model; and
- provide information for investigations into relevant knowledge gaps such as investigations into surface water-groundwater interactions and investigations into the Open Pit inflow processes.

Manual groundwater level measurements are recorded periodically (at least six-monthly) at all monitoring bores using an electronic dip meter. In addition to manual level measurements, high frequency level measurements (at least every four hours) are collected by automated pressure transducers in approximately 150 bores. The majority of these bores are part of the investigative monitoring network and slight variations in the location and number of these bores might occur based on the ongoing investigation requirements. Groundwater pressures are also recorded at different depths at approximately 50 vibrating wire piezometers across the Mine (Figure 18).

The complete groundwater monitoring dataset is assessed annually and reported in the MRM EMR.

Groundwater level monitoring with continuous loggers is undertaken in accordance with MRM Groundwater Data Logger and Download Procedure (PRO-2200019) (MRM, 2021c).

#### 4.6.3.1 Wurrini Groundwater Level Monitoring

To determine whether impacts of groundwater drawdown are observed in the Wurrini Waterhole, a groundwater level performance monitoring program is undertaken. The objective of this program is to ensure early detection of drawdown that may negatively impact the Wurrini Waterhole.

The monitoring network around the Wurrini Waterhole consists of five monitoring bores, located along the eastern and western side of the waterhole targeting the different hydrogeological units. These bores include GW073, GW074, GW075, GW076 and GW077 (Figure 18).

##### *Wurrini Groundwater Level Indicators*

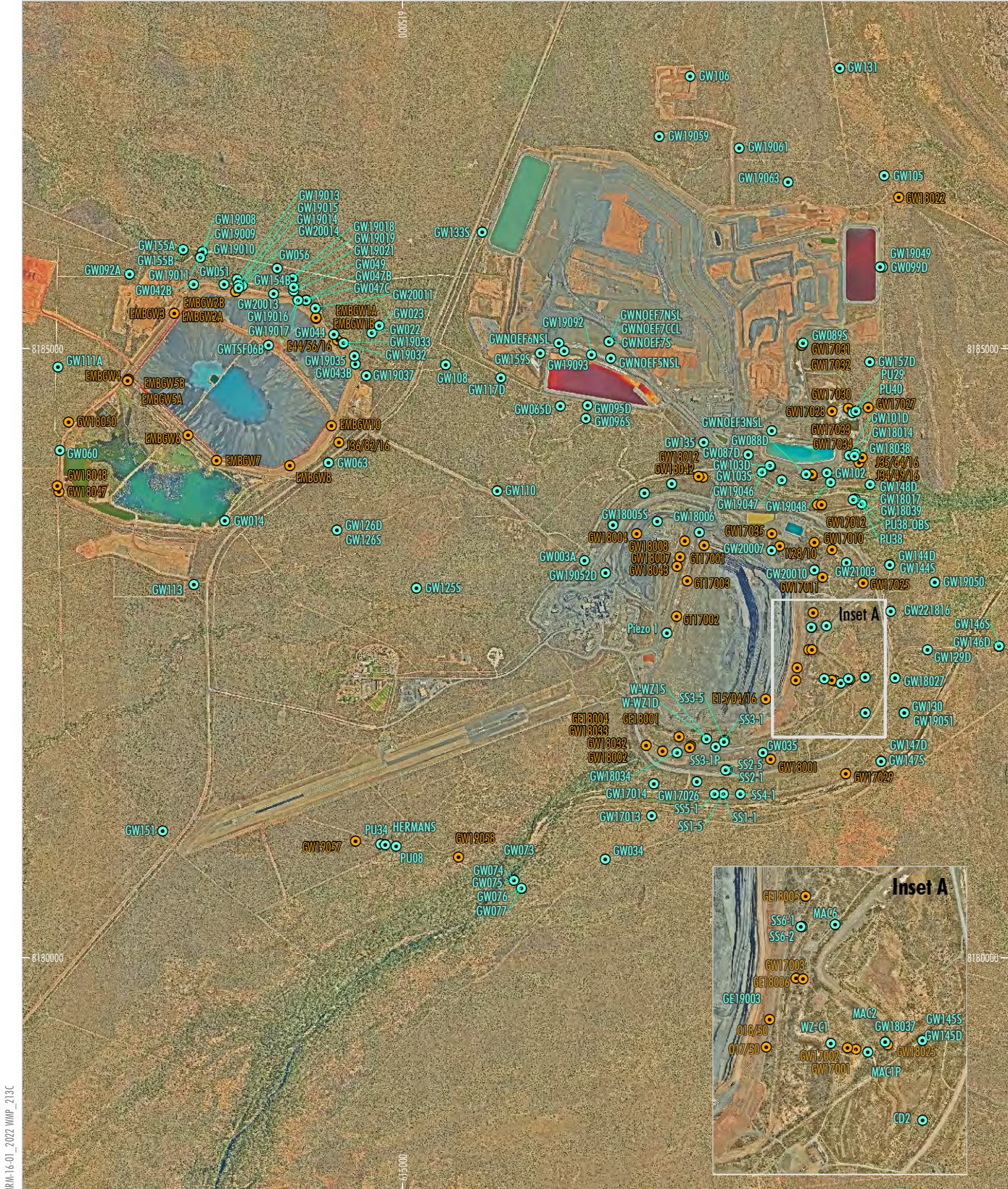
Bore specific leading indicator levels were derived for monitoring bores adjacent to the Wurrini Waterhole.

Due to the highly seasonal responses in the water levels, a statistical determination of the mean and standard deviation is not appropriate to determine groundwater level control chart levels as this may result in false triggering of leading indicators due to the inclusion of the high water levels (coinciding with the wet season). To avoid false triggering, the bore specific groundwater level data from the start of monitoring until the end of 2017 was reviewed to identify the lowest recorded water levels. Once these were identified (coinciding with December 2016), climate data was reviewed to confirm climate conditions at the time. December 2016 corresponds to the end of the dry season in a year that experienced one of the lowest annual rainfall totals (470 mm) in the rainfall record (from 1994 to 2018). The groundwater levels for December 2016 have therefore been used to calculate the bore specific groundwater level indicators for the Wurrini Waterhole bores.

The three control limits are set as follows:

- **Normal limit:** lowest recorded water level;
- **Control limit:** lowest recorded water level – 0.5 m; and
- **Critical limit:** lowest recorded water level – 0.7 m.

Where a water level exceeds the control or critical limit, MRM will implement the TARP as described in the AMP.



- LEGEND**
- Groundwater Level Monitoring
  - Vibrating Wire Piezometer

McARTHUR RIVER MINE  
Continuous Groundwater Level Monitoring

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); MRM (2022)

Figure 18

#### **4.6.3.2 Underground Workings Water Level Monitoring**

The water level in the underground workings is recorded daily at the MUDS (Figure 11).

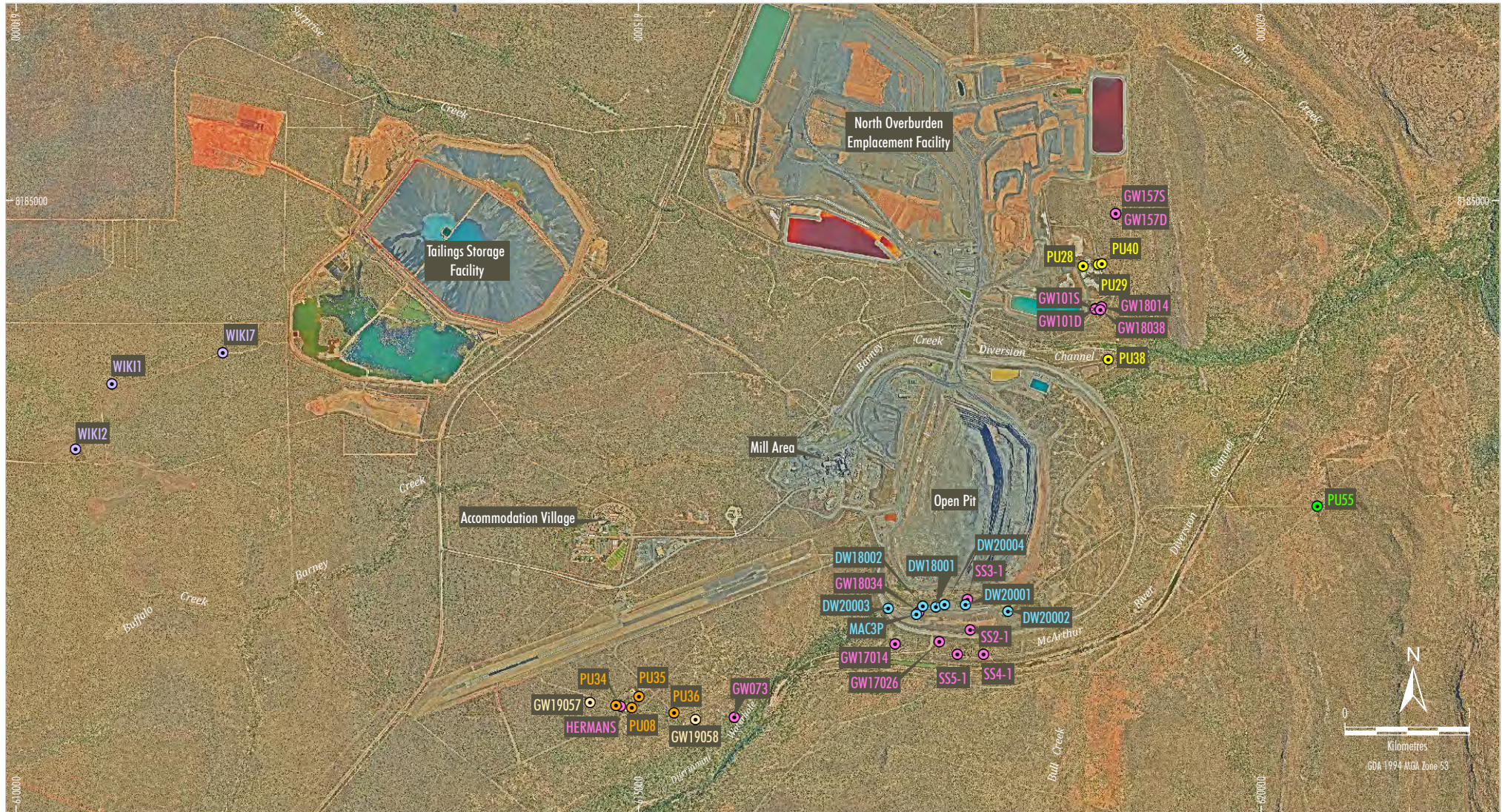
#### **4.6.4 Raw Water Monitoring**

The objectives of the raw water monitoring program are to:

- define the abstraction volumes from the bore fields;
- define the extent of drawdown around the abstraction bore fields; and
- identify variations in physico-chemical parameters that may be indicative of deterioration of groundwater around the abstraction bore fields.

The raw water monitoring program comprises monitoring of abstraction volumes and water quality at the abstraction bores as detailed in Table 9. It also comprises monitoring of levels and quality at the surrounding monitoring bores. Raw water monitoring locations are shown in Figure 19.

MRM-16-01\_2022 WMRP\_214C



**LEGEND**

- Groundwater Monitoring Bores
- Vibrating Wire Piezometer

**Abstraction Bores**

- Donkey Borefield
- Emu bore field
- MIMEX bore field
- Southern extension bore field
- Wiki Borefield

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); MRM (2022)

**McARTHUR RIVER MINE**  
**Raw Water Groundwater**  
**Monitoring Locations**

**Figure 19**

## 4.7 Freshwater Ecology Monitoring

MRM has undertaken freshwater ecology monitoring since 2006. There are currently four monitoring programs undertaken:

- Macroinvertebrate Monitoring (Section 4.7.1);
- Diversity and Abundance of Aquatic Fauna (Section 4.7.2);
- Freshwater Sawfish and Barramundi Acoustic Monitoring (Section 4.7.3); and
- Metals in Aquatic Fauna (Section 4.7.4).

The objectives across the four monitoring programs are:

- monitor fish populations in permanent and semi-permanent pools;
- monitor populations of *Pristis pristis* (Freshwater Sawfish);
- monitor fish diversity in temporary or semi-permanent pools and riffles;
- monitor fish passage success through the McArthur River Diversion Channel by:
  - Continuing tagging of key fish species.
  - Assessing temporal migration patterns of the fishes within the river and determining habitat associations and the utilisation of the McArthur River Diversion Channel.
  - Sampling of key sites within, upstream and downstream of the McArthur River Diversion Channel.
- compare the diversity and abundance of fishes present in the original section of the McArthur River adjacent to the Mine to those present in the McArthur River Diversion Channel;
- collate data on sightings and the capture/re-capture of Freshwater Sawfish including information on the growth rates and movements of re-captured individuals;
- compare the abundance of *Macrobrachium spp.* (Cherabin) present within the McArthur River Diversion Channel to those occurring upstream/downstream of the McArthur River Diversion Channel as a potential indicator of habitat complexity;
- assess the effectiveness of adding large woody debris to the McArthur River Diversion Channel as a key rehabilitation strategy;
- collect size and distribution data on aquatic reptiles known to occur in the McArthur River including the *Acrochordus arafurae* (Arafura File Snake) and *Emydura worrelli* (Worrell's Turtle);
- compare the diversity and abundance of fish species within the original section of the McArthur River and the McArthur River Diversion Channel over time; and
- monitor the diversity and distribution of species within Surprise and Barney Creeks.

### 4.7.1 Macroinvertebrate Monitoring

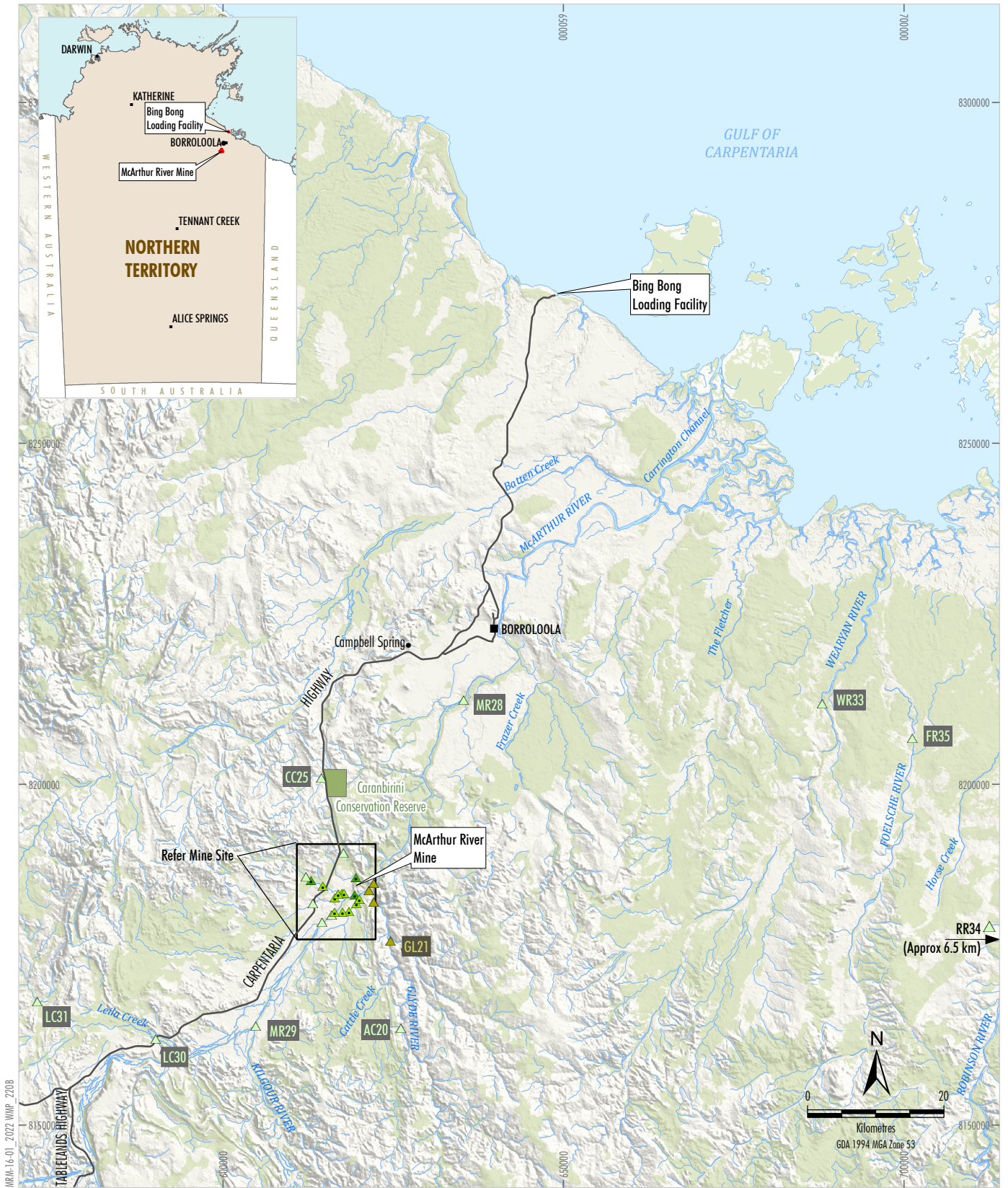
The macroinvertebrate monitoring program aims to identify changes in the receiving environment that could lead to adverse impacts to aquatic ecosystems in the vicinity of the Mine. The objectives of the macroinvertebrate monitoring program are to:

- identify changes in macroinvertebrate communities near the Mine and downstream that may be related to Mine operations; and
- monitor the development of instream habitats within the McArthur River and Barney Creek Diversion Channels.

The macroinvertebrate monitoring site locations are shown on Figures 20 and 21. Reference sites have been selected to correspond with performance identification sites and at least five performance identification sites have been selected to assess the performance of the Mine to provide statistical robustness. At each monitoring site, a macroinvertebrate sample is collected at a standard edge habitat and a riffle macroinvertebrate sample will be collected if this habitat type is present at that site.

Sampling is undertaken annually, with macroinvertebrate collection timed to coincide with the recessional flow period four to six weeks after the last wet season storm flush. This enables sampling that integrates the effects of wet season flows while allowing time for macroinvertebrate populations to recover following flood disturbance. The sampling regime has been designed to minimise the effects of the extreme seasonality that influences aquatic macroinvertebrate abundance, diversity and composition in the wet-dry monsoonal tropics, while allowing for between year comparisons for sampled habitats within the selected season. In addition to macroinvertebrate sampling, a surface water quality sample is also collected at each site.

Further detail on the Macroinvertebrate Monitoring Program is provided in Appendix E – *Macroinvertebrate Monitoring Program*.



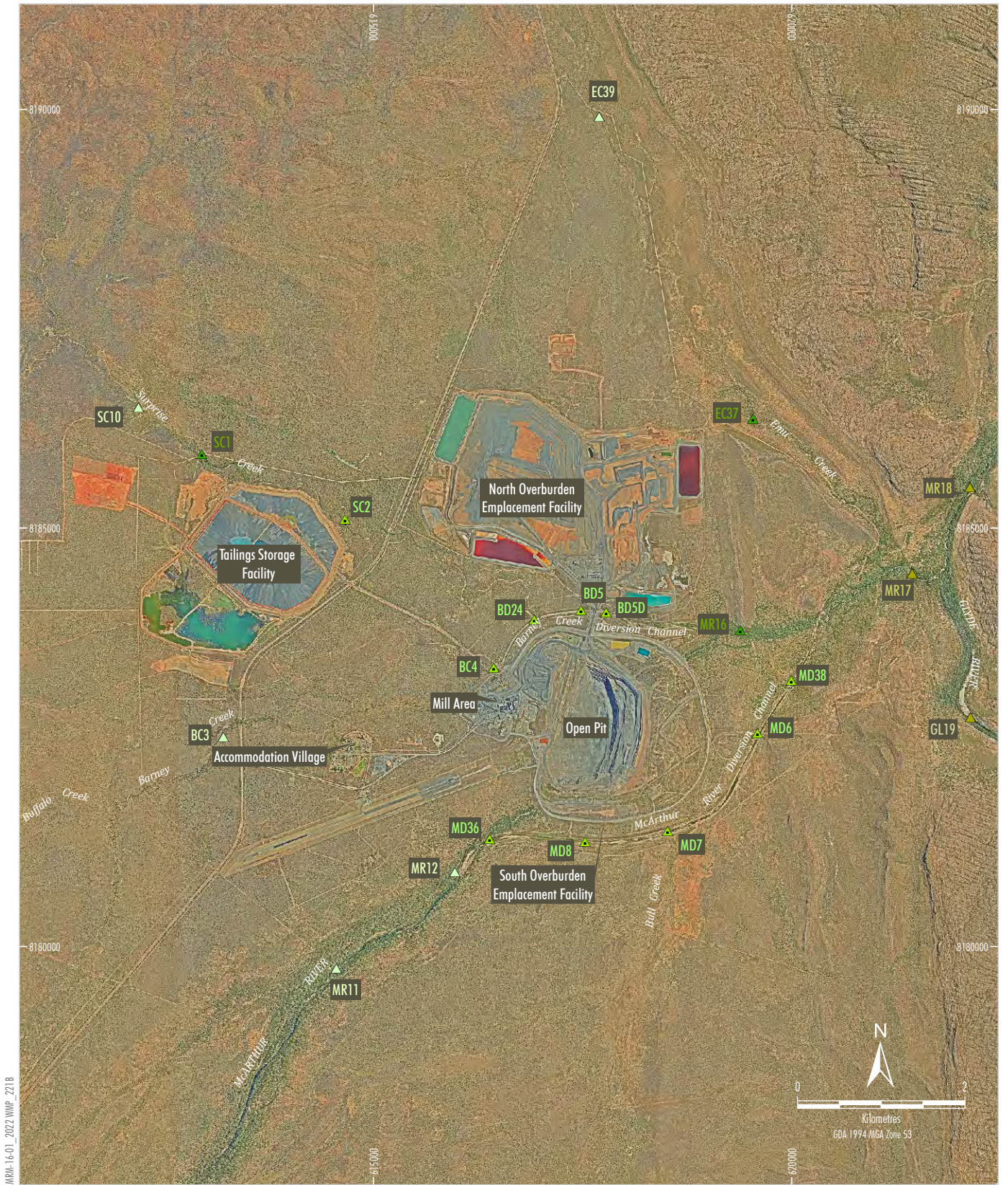
**LEGEND**

- Major Road
- River/Creek
- Performance Identification Site (Edge & Riffle)
- Performance Identification Site (Edge)
- Reference Site (Edge & Riffle)
- Reference Site (Edge)

**McARTHUR RIVER MINE**  
Regional Macroinvertebrate  
Monitoring Sites

Source: Geoscience Australia - Topography (2006);  
Department of Environment and Natural Resources (2016)  
EMS (2019); MRM (2019)

**Figure 20**



MRM-16-01\_2022 WMP\_221 B

**LEGEND**

- ▲ Performance Identification Site (Edge & Riffle)
- ▲ Performance Identification Site (Edge)
- ▲ Reference Site (Edge & Riffle)
- ▲ Reference Site (Edge)

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); EMS (2019); MRM (2019)

**McARTHUR RIVER MINE**  
**Local Macroinvertebrate**  
**Monitoring Sites**

**Figure 21**

## 4.7.2 Aquatic Fauna Abundance and Diversity

The aquatic fauna abundance and diversity monitoring program aims to identify whether the Mine is impacting aquatic fauna within the wider McArthur River catchment area, and whether the McArthur River is providing suitable habitat for aquatic fauna. The program includes:

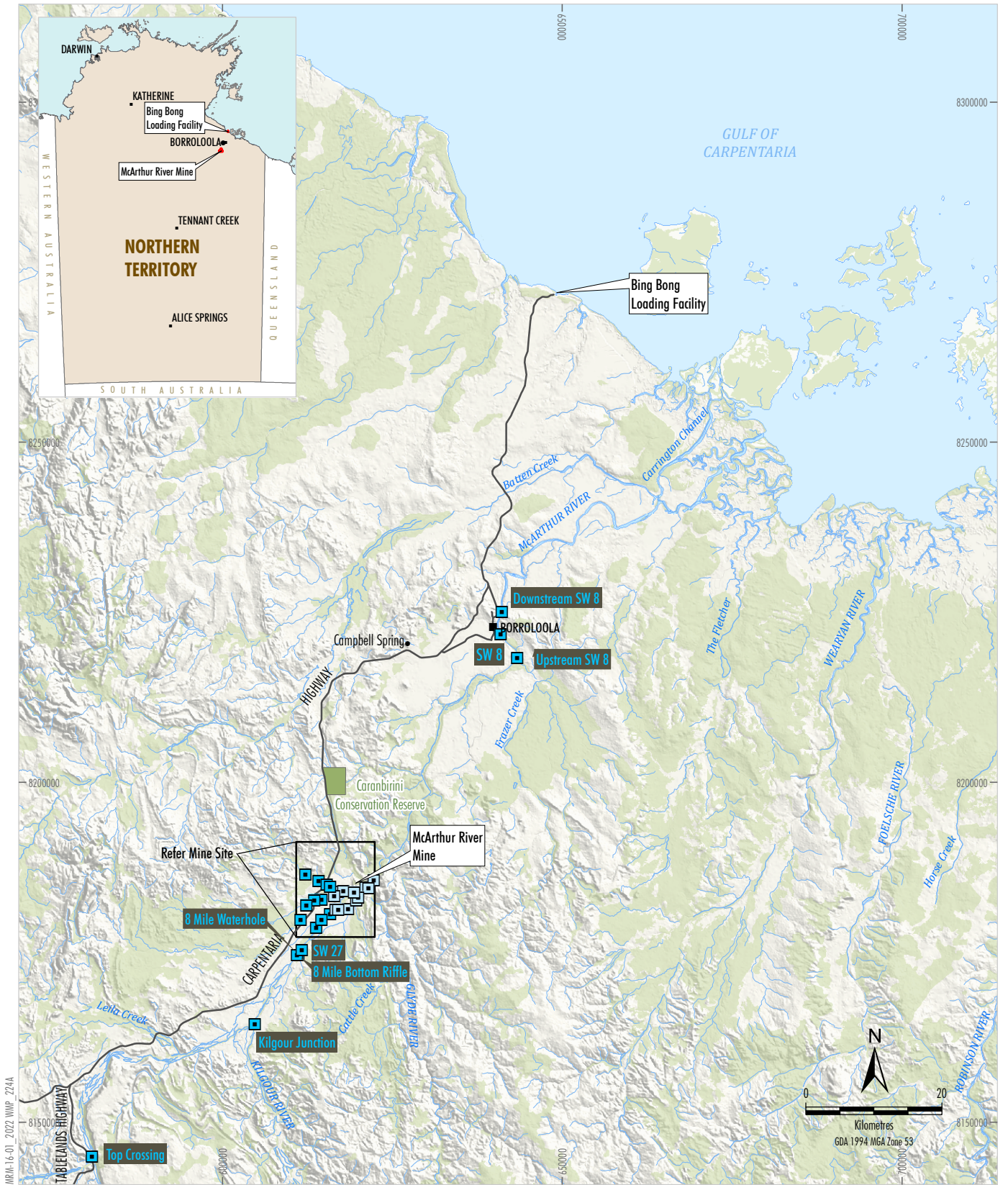
- monitoring fish populations in permanent and semi-permanent pools;
- monitoring fish diversity in temporary or semi-permanent pools and riffles;
- monitoring populations of Freshwater Sawfish, listed as vulnerable under the EPBC Act;
- monitoring fish passage success through the McArthur River Diversion Channel by:
  - implementing a tagging program of key fish species;
  - assessing temporal migration patterns of the fish within the river and determining habitat associations and the utilisation of the McArthur River Diversion Channel; and
  - sampling of key sites within the McArthur River Diversion Channel as well as both upstream and downstream.
- monitoring the diversity and distribution of species within Surprise and Barney Creeks;
- assessing the effectiveness of adding large woody debris to the McArthur River Diversion Channel as a key rehabilitation strategy; and
- assessing the effectiveness of mitigation strategies in preventing contamination of the McArthur River.

Aquatic fauna abundance and diversity is conducted during the early dry season at a number of sites in the vicinity of the Mine (Figures 22 and 23), including:

- **Reference Sites** which have been selected to provide data at locations which are considered to be outside the influence of mining operations and therefore representative of background or natural conditions. These sites are used to confirm whether background conditions are influencing performance in the vicinity of the Mine.
- **Performance Identification Sites** which have been selected to determine whether the Mine is impacting on sites in McArthur River Diversion Channel or downstream McArthur River.

Sampling of fauna is undertaken via a number of methods including gill netting, fyke netting, seine netting, electrofishing and line fishing. Selected species are also tagged using dart or cattle tags to monitor the individuals broad scale movement through the catchment.

Further detail on the program is provided in Appendix F - *Aquatic Fauna Abundance and Diversity Program*.

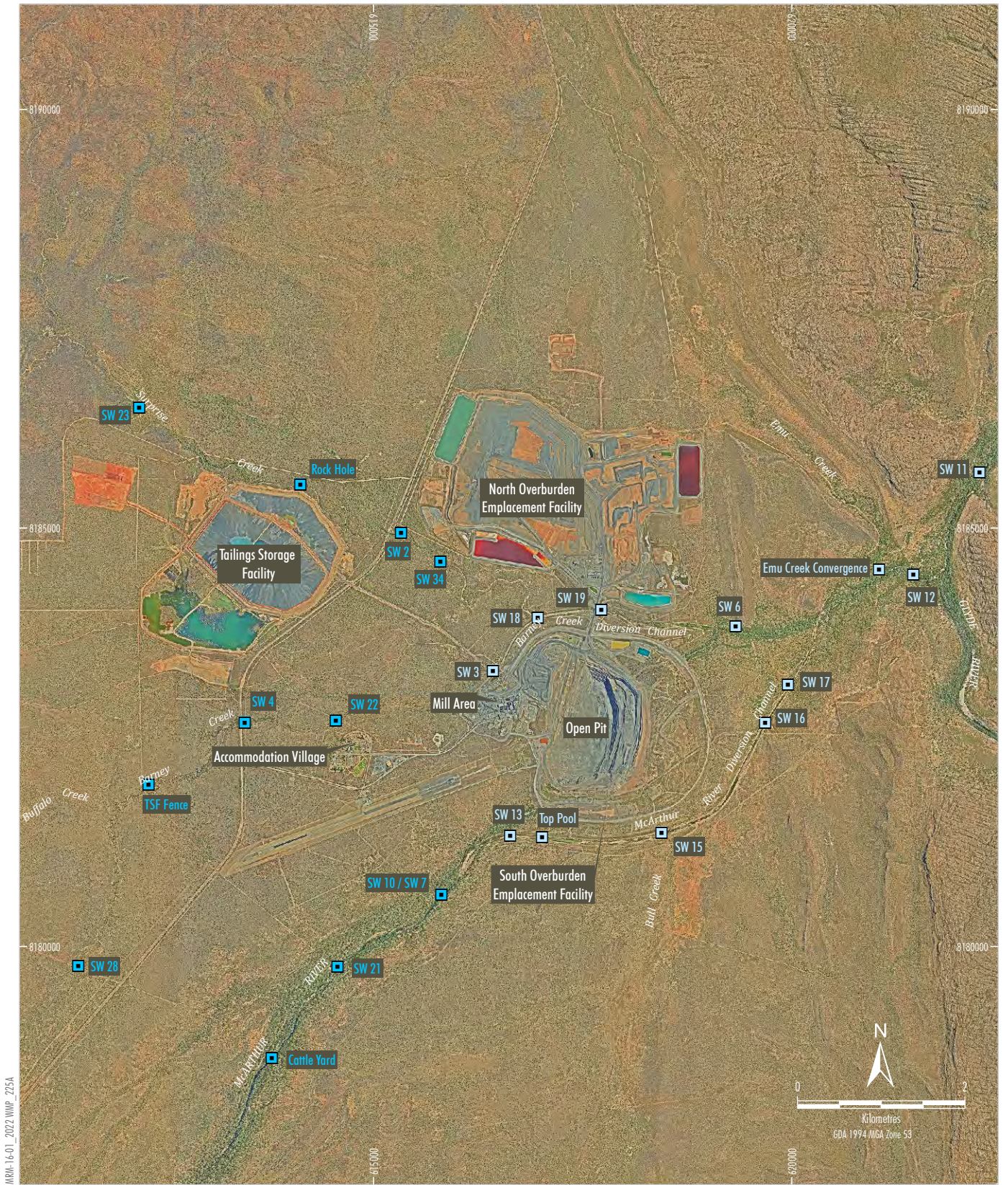


- LEGEND**
- Major Road
  - River/Creek
  - Performance Identification Site
  - Reference Site

McARTHUR RIVER MINE  
Regional Aquatic Fauna  
Monitoring Sites

Source: Geoscience Australia - Topography (2006);  
Department of Environment and Natural Resources (2016)  
EMS (2019); MRM (2019)

Figure 22



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**LEGEND**

- Performance Identification Site
- Reference Site

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); EMS (2019); MRM (2019)

**McARTHUR RIVER MINE**  
Local Aquatic Fauna  
Monitoring Sites

**Figure 23**

### 4.7.3 Freshwater Sawfish and Barramundi Acoustic Monitoring Program

The overarching aim of this Monitoring Program is to monitor populations of migratory fish species, primarily Freshwater Sawfish, within the McArthur River. These objectives to achieve this aim include;

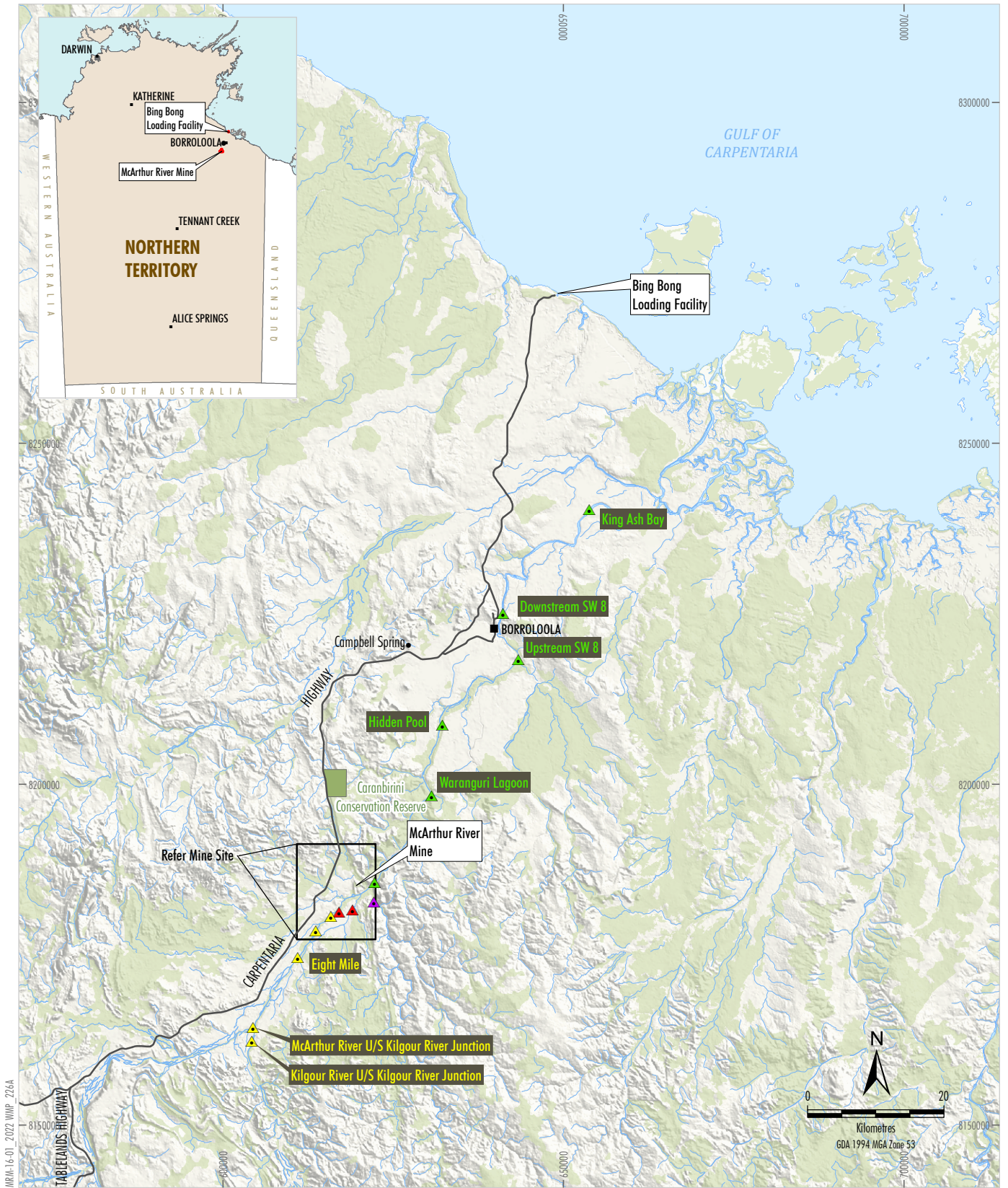
- Collect longitudinal data on Freshwater Sawfish and Barramundi utilising permanent refuge pools, seasonal habitats and migratory routes;
- Establish whether the McArthur River Diversion Channel maintains the ecological integrity of the McArthur River's fish fauna and permits fish passage;
- Increase the general public's awareness of the significance of the Freshwater Sawfish, its current status and its legal protection through general education, erection of signs at popular locations throughout the catchment and dissemination of current information at public events.

Captured Freshwater Sawfish and Barramundi are implanted with acoustic transmitter tags which are individually coded and cattle style tags for easy identification on recapture. By the end of June 2019, a total of 16 individual Freshwater Sawfish and 26 individual Barramundi had been fitted with acoustic tags.

Eleven acoustic receiver sites, presented in Figure 24 and 25, are located along the main McArthur River channel as far upstream as the confluence with the Kilgour River, in the vicinity of the Mine with specific focus on the McArthur River Diversion Channel, and downstream as far as King Ash Bay.

When a tagged animal is within approximately 250 m of an acoustic receiver, a date, time, and tag number is recorded. This data allows for the location of the individual animal to be tracked throughout the catchment, and can determine residence time periods within certain pools or time taken to migrate between acoustic receivers. This data can be used to determine whether the Diversion Channel is suitable for fish movement.

Further details on the Freshwater Sawfish monitoring program is provided in Appendix G – *Freshwater Sawfish Monitoring Program*.



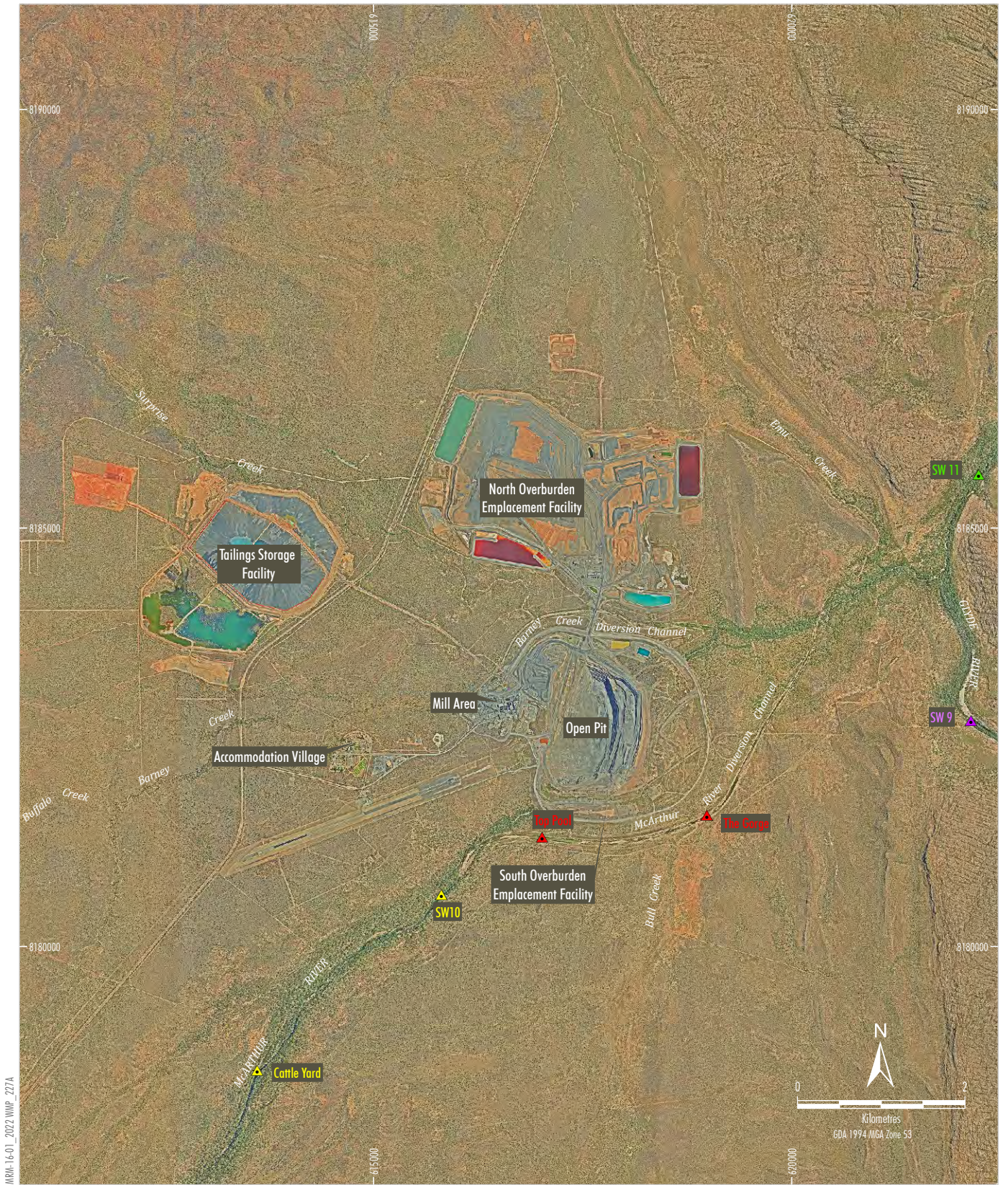
**LEGEND**

- Major Road
- River/Creek
- Downstream of Diversion Channel
- Upstream of Diversion Channel
- Within Diversion Channel
- Glyde River

**McARTHUR RIVER MINE**  
**Regional Acoustic Receiver**  
**Monitoring Sites**

Source: Geoscience Australia - Topography (2006);  
 Department of Environment and Natural Resources (2016)  
 EMS (2019); MRM (2019)

**Figure 24**



**LEGEND**

- ▲ Downstream of Diversion Channel
- ▲ Upstream of Diversion Channel
- ▲ Within Diversion Channel
- ▲ Glyde River

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); EMS (2019); MRM (2019)

McARTHUR RIVER MINE  
Local Acoustic Receiver Monitoring Sites

Figure 25

#### 4.7.4 Metals in Aquatic Fauna

MRM undertakes monitoring of metals and lead isotope ratios in fish, crustaceans and molluscs of the Limmen, McArthur and Robinson River catchments. Monitoring of metals in aquatic fauna has been conducted since 2005.

The objective of the metals in aquatic fauna monitoring program is to identify whether metals and metalloids are entering the aquatic food chain as a result of MRM’s mining activities through the collection and analysis of biota tissues. The species which are sampled are divided into:

- **Environmental indicator species**, including:
  - Spangled Perch (*Leiopotherapon unicolor*), Chequered Rainbowfish (*Melanotaenia splendida*) and Bony Bream (*Nematalosa erebi*).
- **Commonly consumed species**, including:
  - Barramundi (*Lates calcarifer*), Sooty Grunter (*Hephaestus fuliginosus*) and Archer Fish (*Toxotes chatareus*).
  - Cherabin (*Macrobrachium spinipes*), and the Freshwater Mussel (*Velesunio angasi*) are also collected. These two species are known to be commonly consumed and are also considered as environmental indicator species.

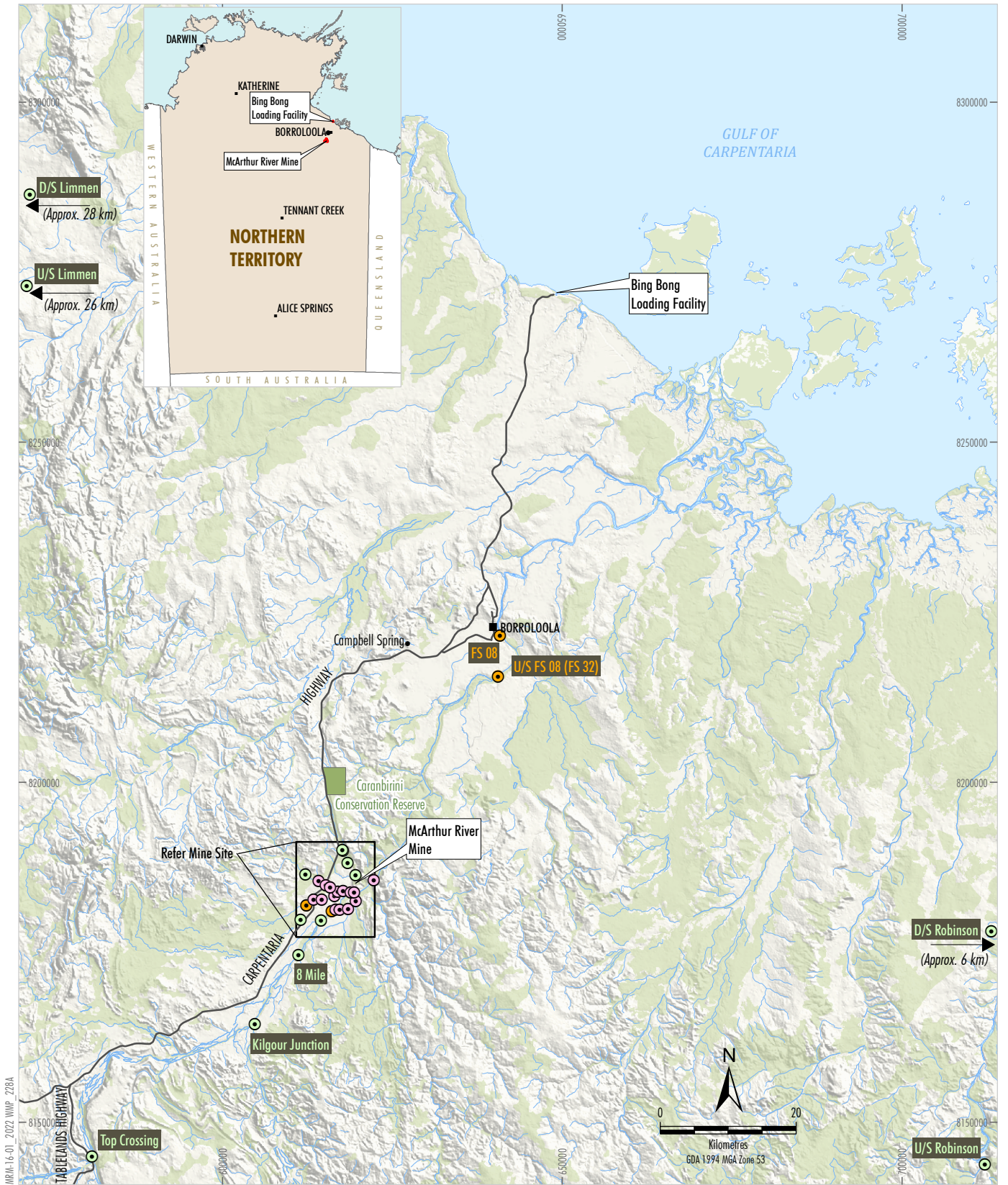
The monitoring locations are presented in Figures 26 and 27.

Metal tissue concentrations of each species are compared to the maximum permitted concentration (MPC) of contaminants in Schedule 19 of Standard 1.4.1 (Maximum Levels of Contaminants and Natural Toxicants) in the *Australian and New Zealand Food Standards Code* (Food Standards Australia and New Zealand [FSANZ], 2016). Where no maximum permitted concentration is defined, metal tissue concentrations will be compared to historical levels and analysed for any obvious trends. The maximum levels relevant to the species considered in this monitoring program are provided in Table 26.

**TABLE 26: MAXIMUM PERMITTED CONCENTRATIONS OF METAL CONTAMINANTS IN AQUATIC SPECIES**

Contaminant	Food		Maximum level (mg/kg)
	Category	Relevant Species	
Cadmium	Molluscs	Freshwater Mussel	2
Lead	Fish	Barramundi, Sooty Grunter, Archer Fish, Spangled Perch, Chequered Rainbowfish and Bony Bream	0.5
	Molluscs	Freshwater Mussel	2

Details on the Metals in Aquatic Fauna monitoring program is provided in Appendix H – *Monitoring of Metal Concentrations within Freshwater Fish, Crustaceans and Molluscs of the McArthur River*.



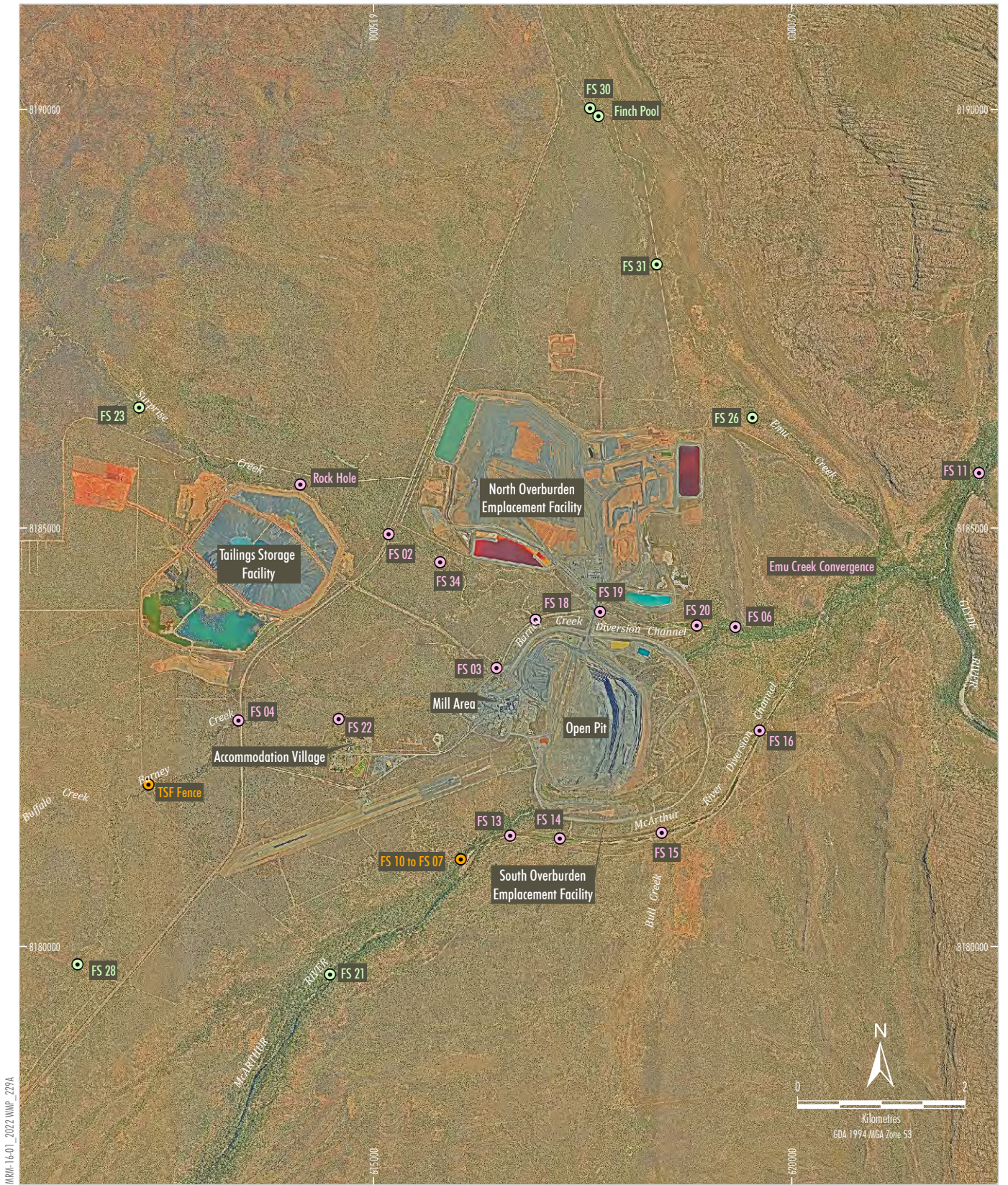
**LEGEND**

- Major Road
- River/Creek
- Performance Identification Site
- Reference Site
- Reference Site / Performance Identification Site

**McARTHUR RIVER MINE**  
**Regional Metals in Aquatic Fauna**  
**Monitoring Sites**

Source: Geoscience Australia - Topography (2006);  
 Department of Environment and Natural Resources (2016)  
 EMS (2019); MRM (2019)

**Figure 26**



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**LEGEND**

- Performance Identification Site
- Reference Site
- Reference Site / Performance Identification Site

Source: Orthophoto MRM (2021); Department of Environment and Natural Resources (2016); EMS (2019); MRM (2019)

**McARTHUR RIVER MINE**  
**Local Metals in Aquatic Fauna**  
**Monitoring Sites**

**Figure 27**

#### 4.7.5 Aquatic Fauna Monitoring Performance Triggers

The use of a static trigger level, such as a fixed value of change (percentage), is of limited use when monitoring dynamic natural environments (IPE, 2018). This is due to the fact that natural variation can be significant and driven by numerous factors (including a number which may be unknown) and which may unequally affect the range over which the environment is being monitored (IPE, 2018).

Effective monitoring of a natural environment requires an understanding of the scale of variation which can occur from both a spatial and temporal perspective. As such, an impact can only be identified when the change in the environment at a specific location is outside the bounds of that which is considered to be natural variation. The inclusion of reference sites is therefore critical in programs which monitor the natural environment to provide a comparison for sites which may be considered to be potentially impacted upon (IPE, 2018).

Performance triggers have been developed to:

- identify adverse or unexpected trends which could lead to impacts on upstream or downstream aquatic ecology or the ecological function of the McArthur River and determine the effectiveness of mitigation strategies; and
- confirm key objective 1 '*Protect the McArthur River beneficial uses and community values from mining impacts*' is being met (Section 1.7).

The performance trigger criteria for each aquatic fauna monitoring program are presented in Table 27.

A TARP process is undertaken for any exceedance of the performance trigger criteria in Table 27. The TARP process is described in the AMP.

**TABLE 27: AQUATIC FAUNA MONITORING PERFORMANCE TRIGGERS**

Monitoring Type	Monitoring Category	Performance Identification Site	Reference Site	Performance Trigger Criteria <sup>1</sup>	
				Level 2	Level 3
Off-site Performance Identification	Downstream macroinvertebrate impacts	<u>Downstream McArthur River:</u> MR11, MR12	<u>Upstream McArthur River:</u> MR07, MR21, MR27, MR60, MR 61 <u>Regional Sites:</u> GL09, GL67	Statistically significant difference in macroinvertebrate species richness / assemblage at McArthur River impact sites (MR11 and MR12) when compared to reference sites of the same stream order during annual sampling.	Statistically significant difference in macroinvertebrate species richness / assemblage at McArthur River impact sites (MR11 and MR12) when compared to reference sites of the same stream order over two or more consecutive sampling years.
Off-site Performance Confirmation (Downstream)	Downstream aquatic fauna abundance and diversity impacts (early dry season survey only)	<u>Downstream McArthur River:</u> SW12, SW11, Emu Creek Convergence	<u>Upstream McArthur River:</u> Top Crossing, Kilgour Junction, 8 mile, SW27, Cattleyard, SW21 and SW07	During annual monitoring, statistical analysis indicates that species diversity and relative abundance at downstream performance identification sites are significantly different to habitat at reference sites located away from the influence of mining operations.	Over two or more consecutive sampling years, statistical analysis indicates that species diversity and relative abundance at downstream performance identification sites are significantly different to habitat at reference sites located away from the influence of mining operations.
	Metal concentrations in aquatic fauna	<u>McArthur River Diversion Channel:</u> SW16 <u>Downstream McArthur River:</u> SW11, SW32, SW08 <u>Surprise Creek:</u> Rock Hole, SW2 and SW34 <u>Barney Creek:</u> SW03, SW18, SW19 and SW06	<u>Upstream McArthur River:</u> Top Crossing, Kilgour River Junction, 8 Mile Water hole, SW21, SW07 <u>Regional Sites:</u> Limmen River, Wearyan River, Robinson River	Mean tissue concentrations in indicator or commonly consumed species > MPC at performance identification sites on lease and resultant of mine operations.	Mean tissue concentrations in indicator or commonly consumed species > MPC at performance identification sites off lease and resultant of mine operations.
	Targettooth Sawfish is observed navigating or recorded via acoustic receiver station within the McArthur River Diversion Channel or in waters upstream of the Channel	<u>McArthur River Diversion Channel:</u>  <u>Upstream McArthur River:</u> Kilgour Junction, Eight Mile, Cattle Yard, Djirrinmini / Wurrini waterholes.	N/A	Targettooth Sawfish not observed navigating or recorded via acoustic receiver station within the McArthur River Diversion Channel or in waters upstream of the Channel in a consecutive three-year period.	Targettooth Sawfish not observed navigating or recorded via acoustic receiver station within the McArthur River Diversion Channel or in waters upstream of the Channel in a consecutive five-year period.

<sup>1</sup> The TARP process is discussed in detail in Section 5 of the AMP.

## 5 Contingency Measures

This section describes contingency responses/measures that would occur in response to the TARP process outlined in Section 5 of the AMP (MRM, 2021a). Contingency measures will be implemented, as appropriate, to comply with the relevant statutory requirements (Section 1.5.1) and the water management objectives (Section 3.3).

The contingency measures that may be implemented in response to an exceedance of a Level 2 or Level 3 trigger value include:

- waste rock material excavation and re-compaction;
- adjustments and / or maintenance to cover systems and waste rock landforms;
- repair to dam and dam liners;
- removal of mine affected sediments or baseflow;
- increased water treatment capacity;
- alternative water treatment technology;
- increased water storage;
- engineered dust suppression controls;
- expanded water cart fleet / dust suppression capacity;
- construction of interception sumps, drains or bores;
- accelerated rehabilitation;
- construction of additional sediment control structures (e.g. sediment traps);
- in stream sediment traps;
- construction of additional sumps to capture and manage toe seepage;
- construction of an NOEF groundwater interception scheme;
- installation of additional large woody debris within the McArthur River Diversion Channel;
- modified rehabilitation techniques / rehabilitation trials;
- adjustment of mining and processing production rates;
- relocation of operations and/or temporary cessation of operations;
- alternative water disposal techniques to reduce discharge;
- adjustment of water management and discharge volumes; and
- artificial recharge of the Djirrinmini / Wurrini waterholes and other refuge pools.

The most appropriate management measures would be determined based on available information collected and analysed following a Level 2 or Level 3 trigger exceedance. Follow-up inspections will be conducted to assess the effectiveness of implemented management measures and the requirement for any additional management measures. Management measures will be reported in the EMR.

## 6 Review and Update

The WMP will be reviewed, and if necessary revised, on an annual basis. Additionally, the WMP will also be reviewed, and if necessary revised, when an MMP (or amendment) is submitted, following any modification to the conditions of Variation of Authorisation 0059 and following the issue of any WDL renewal or amendment.

The WMP will be updated prior to mine closure to describe the post-mining water management measures.

If necessary, the WMP would be updated in consultation with the appropriate regulatory authorities and stakeholders for any major amendments. Minor changes will be made with version control.

## 7 References

- Australian and New Zealand Governments (2018) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.
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- Indo Pacific Environmental (2018) *Aquatic Fauna Abundance and Diversity Monitoring Program*.
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# Appendix A: 2021/22 McArthur River Mine Site Water Balance

# Appendix B: 2020/21 McArthur River Mine Water Storage TARPs

# Appendix C: McArthur River Mine Waste Discharge Procedure

# Appendix D: 2022/23 Monitoring Schedule

# Appendix E: Macroinvertebrate Monitoring Program

# Appendix F: Aquatic Fauna Abundance and Monitoring Diversity Program

# Appendix G: Freshwater Sawfish Monitoring Program

# Appendix H: Monitoring of Metal Concentrations within Freshwater Fish, Crustaceans and Molluscs of the McArthur River



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