10 Water Resources

10.1 Introduction

This chapter provides a description of the existing surface water and groundwater environments at the McArthur River Mine (MRM), Bing Bong concentrate storage and ship loading facility (Bing Bong) and surrounds. The chapter identifies the potential impacts of the McArthur River Mine Phase 3 Development Project (the Project) on water resources and discusses the water management measures required to appropriately mitigate the potential impacts identified. A description of the Project and its location is provided in Chapter 4.

10.1.1 Legislation and Permits

A brief description of the legislation and permits relevant to the management of water resources at MRM is provided below. Further information on the regulatory framework applicable to the Project and it approvals is provided in Chapter 2.

10.1.1.1 Water Act 2004

The *Water Act 2004* (Water Act) provides for the investigation, allocation, use, control, protection and management of surface water and groundwater resources, as well as the administrative process for licensing these activities. The Water Act also considers the protection and use of water resources for purposes such as recreational, social and cultural uses.

Under the Water Act, mining activities (as defined by the *Mining Management Act 2001*) or another activity for a purpose ancillary to that mining activity, including the use of water as drinking water, are exempt from a number of provisions in the Water Act. This includes, and is not limited to, the use of surface water and groundwater, as well as the construction of works to allow for the use of water.

The current waste discharge licence for the site (WDL 174-1) will be modified to facilitate additional discharge of surface waters from MRM. Waste is defined in the Water Act as any solids, liquids or gas, which, if added to the water, may pollute the water.

10.1.1.2 Water Supply and Sewerage Services Act 2000

The *Water Supply and Sewerage Services Act 2000* provides for the protection of the Northern Territory's water supply system, or any water source from which water is drawn for human consumption. Any abstraction or diversion of water from the Northern Territory's supply system must not be undertaken unless authorised by the appropriate authorities. Penalties are in place for pollution of any water supply or source. This Act applies to the Project's water supply and sewage treatment facilities that will be required on-site.

Water bores with flow rates less than 15 litres per second (Lps) do not require extraction licences. A Project extraction licence may be required for water bores with flow rates above 15 Lps. A Water Extraction Licence under the Water Act to take water from surface waters may be required if the Project activities warrant. An application to the Controller of Water Resources will be required in order to obtain this licence.

A Project Water Management Plan has been developed to guide management activities as a supplement to the MMP which will be updated annually.

The wastewater treatment system for the construction and operations accommodation village may be subject to requirements under the *Public Health Act 1987 and Regulations*.

10.2 Existing Surface Water Environment

This section identifies the surface water resources and values relevant to the Project. The section utilises existing water management monitoring data, studies undertaken for the existing MRM operations and results of technical studies completed for the Project by WRM Water & Environment Pty Ltd (2012) (refer Appendix D3).

10.2.1 Overview

The surface water hydrology and water quality data relevant to existing MRM conditions span a large spatial scale. These include the wider McArthur River catchment as well as local hydraulics of floods and low flows in the McArthur River and its tributaries. The operational management of water at the existing mine site and Bing Bong is also considered.

The description of the existing surface water environment relevant to the Project covers the following aspects:

- Environmental values
- Regional surface water systems and catchment context
- Local surface water systems
- Existing hydrology
- Existing surface water quality
- Existing surface water management.

10.2.2 Environmental Values

The declared Beneficial Uses under the Water Act, 2004, for the McArthur River and its catchment are "Aquatic Ecosystem Protection" and "Environment, Cultural and Riparian". There are no RAMSAR listed wetlands in the catchment. The ecological values of the area are provided Chapter 13. The cultural values of the area are provided Chapter 14.

Surface water resources in the catchment are limited to stream flow during the wet season and ponds during the dry season. There are no constructed storages of any substantial size in the catchment. The main economic uses of surface water are for livestock watering and to support the local fishing and tourism industry. Surface waters in the catchment are not abstracted for utilisation as process water at the MRM mine.

10.2.3 Regional Surface Water Systems and Catchment Context

The McArthur River catchment is located in the wet/dry tropics and experiences a true monsoonal climate regime. The McArthur River is the major surface water feature in the region and is relatively large for the tropical north of Australia, with the catchment covering approximately 18,000 km^2.

The catchment drains from the headwaters in the Barkly Ranges and flows north-east to the Gulf of Carpentaria at the Sir Edward Pellew Group Islands (Figure 10-1). The river falls more than 250 m in elevation over its 330 km length. Major tributaries in the McArthur River Catchment include the Glyde River, Kilgour River, Tooganginie Creek, and Batten Creek.

The MRM is situated adjacent to the McArthur River, in the middle reaches of its catchment, between the confluences of the Kilgour and Glyde Rivers. The mine site is located approximately 120 km upstream of the river mouth, and approximately 5 km upstream of Bukalara Range. The river bed level in the reach near the mine site is between RL 16 and 21 mAHD.

10.2.4 Local Surface Water Systems

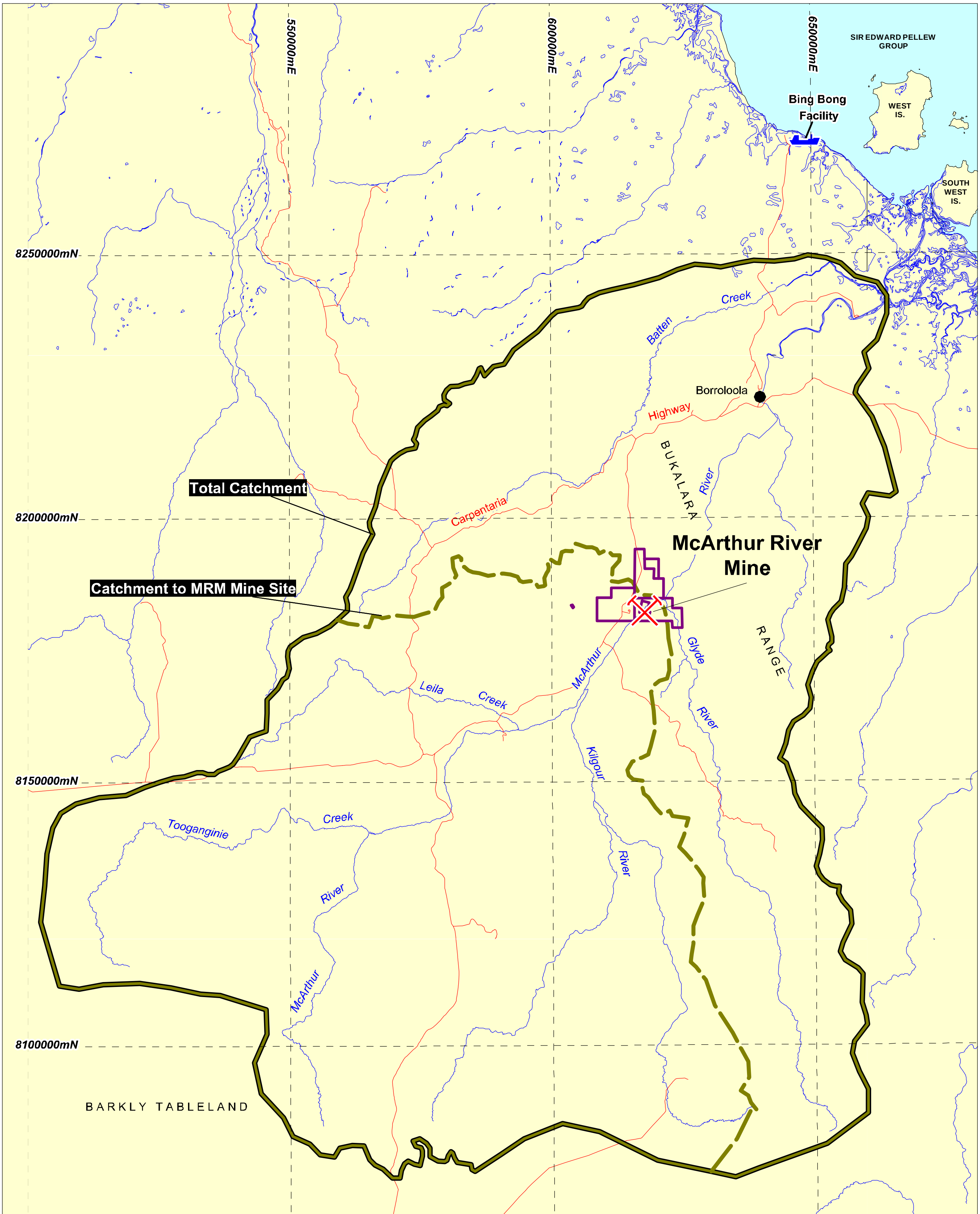
10.2.4.1 Mine Site

The main creek systems that intersect the mine site are Barney and Surprise Creeks. Barney Creek has a total catchment area of approximately 700 km^2. The creeks are dry throughout most of the year. This is particularly the case for Surprise Creek, which has a catchment size of approximately 120 km^2 and normally flows intermittently for three to five months of the year during and after the wet season. Water may be present in the creeks for periods following flow. Local waterways are provided in Figure 10-2.

The Barney Creek catchment is a small tributary of the McArthur River that comprises approximately six percent of the river catchment upstream of the mine. The mine occupies a small portion of the sub-catchments of Surprise and Barney Creek. Sections of the lower reaches of Surprise and Barney Creeks were diverted in 2009 as part of approvals for prior phases of the MRM. The channels are currently monitored regularly by mine staff for siltation and erosion within the channels and reported in the annual Sustainable Development Water Management Plan (SDWMP) (MRM, 2011). No changes are proposed to these existing channels as part of the Project.

Flows in Surprise Creek and Barney Creek are more variable than flow in the larger McArthur River. With smaller catchment areas contributing to these creeks, the magnitude of total annual streamflow is significantly less than in the McArthur River. The creeks also have minimal base flow (sustained flows receding after moderate and large flow events).

Existing mine infrastructure is located on a hill (Barney Hill) between the confluence of Surprise Creek and Barney Creek and the McArthur River.



LEGEND

- Project tenement
- Total Catchment
- MRM Mine Site Catchment
- Principal road
- River
- Town
- McArthur River Mine
- Bing Bong Concentrate Storage and Ship Loading Facility

Data Source: URS 2005 EIS

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McArthur River Mine
Phase 3 Development Project

Regional Catchment Map

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Kilometres

Scale: 1:1,000,000 (A4)

17/01/2012

Datum: GDA94
Projection: MGA53

FIGURE 10-1

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Scale: 1:100,000 (A4)

LEGEND

- River / Creek Channels
- Local Waterways
- Stream Gauge

McArthur River Mine Phase 3 Development Project

Local Waterways Near MRM

16/01/2012

N

Datum: AGD84
Projection: AMG53

FIGURE 10 - 2

10.2.4.2 Bing Bong

Bing Bong is located on dunes and beach ridges adjacent to tidal mud flats along the coastline of the Gulf of Carpentaria (Figure 10-1). The site does not intersect any natural drainage lines. The main drainage lines beyond the site are Mule Creek to the east and Bing Bong Creek to the north. The area is subject to storm surges associated with cyclones. Surges of 3 to 4 m have been observed in the area and current infrastructure at the site has been designed to accommodate these extreme events.

10.2.5 Existing Hydrology

10.2.5.1 General Hydrology

A description of the climatic conditions relevant to the project is provided in Chapter 6. A detailed description of the data sets utilised in the modelling for the Project surface water assessment is provided in Appendix D3.

Stream flow throughout the McArthur River catchment is highly variable as a result of thunderstorm, cyclone or monsoonal rainfall. The greatest flows occur during the 'wet season' which generally extends from November to April. The major wet season flows occur in February and March, however early wet season floods have occurred in December and January and occasionally in November.

The 'dry season' runs from May to October each year. Stream flow typically dries up creating a series of large isolated pools between August and September. No flow periods are typically one to two months however can last up to six months. Some tributary flows are supplemented by natural springs, however this contribution to overall catchment stream flow is small. Further information regarding the stream flows in the McArthur River and its tributaries is provided in Appendix D3.

10.2.5.2 McArthur River Geomorphology and Flooding

The existing geomorphology and flooding hydraulics of the McArthur River near the mine site have been assessed as part of previous environmental assessments regarding the potential stability impacts of the existing McArthur River realignment and associated mitigation strategies.

In general, geomorphology characterises physical features of the broad landscape and processes that form and modify the landscape. Fluvial geomorphology is a specific aspect of river form and behaviour, including the processes that govern changes in the physical shape and form of rivers. Environmental variables such as geology, topography, soils, vegetation, hydrology and land use are relevant to river forming and/or modifying processes. Assessing a river's fluvial geomorphology allows it to be viewed as part of a system rather than operating as a discrete environmental variable.

Stream geomorphology of the McArthur River varies from a single main channel in the upper reaches of the catchment to braided channels and floodplain systems in the lower reaches, from its confluence with Tooganginie Creek to the tidal limit just south of Borroloola.

For most of the year, small and moderate stream flows through the braided parts of the river system are confined to a single channel. During floods, the main channel overflows and spreads across the floodplain into a series of minor channels (known as flood runners) on either side of the main channel.

Tidal influences extend 60 km up the McArthur River to near Borroloola. Tidal influences are less pronounced during the wet season when river levels are high. River flows discharge into the Gulf of Carpentaria near the Sir Edward Pellew Group of islands through a delta containing three main tidal channels and several anabranch channels. The delta and alluvial landforms are geomorphologic evidence of a long history of sustained natural sediment transport from the catchment to the coast.

10.2.6 Existing Surface Water Quality

MRM implement a comprehensive surface water quality monitoring program. The results of the existing program are reported annually in the Sustainable Development Water Management Plan. A summary of the data relevant to the existing surface water management at the mine site is presented below. The data considered has been collected from the following key monitoring sites (see Appendix D3 for locations):

- The McArthur River - SW21 and SW10, located upstream of MRM, and SW11, located downstream of MRM
- Barney Creek - SW4 and SW22, located upstream of MRM
- Surprise Creek - SW23 and SW1, located upstream of the TSF.

The following key points can be extracted from the data collected to date (WRM, 2012):

- Surface water quality in the vicinity of MRM is affected by strong seasonal stream flows and generally high background levels of heavy metals, in particular Cu, Pb and Zn, in the water and stream sediments.
- Background levels of heavy metals in McArthur River flows in the vicinity of MRM are naturally elevated due to the close proximity of mineralised zones to the surface.
- Salinity, pH and SO4 levels are also strongly related to stream flows. Salts tend to accumulate during the dry season as a result of evaporation, and then salt concentrations drop dramatically during the wet season due to dilution and flushing from high flows.
- The metals Cu, Pb and Zn show the opposite trend to salt. Concentrations tend to increase during the wet season when turbidity levels are highest, consistent with strong metal-sediment attachment properties.

Table 10-1 provides the existing surface water quality summary statistics for McArthur River, Barney Creek, Surprise Creek and the Old McArthur River channel (Figure 10-2) for a range of key water quality parameters (i.e. minimum, maximum, median and 90th percentile concentrations) including pH, electrical conductivity (EC), arsenic (As) cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn) and sulphates (SO_4). Table 10.2 shows the water quality summary statistics for Lake Archer and the open pit sump. Lake Archer and the Pit Sump data is considered to best represent the quality of open pit water. The proposed surface water management associated with the Project (Section 10.4.2) is discussed in the context of the existing project Waste Discharge Licence. Therefore the discussion of the existing water quality is also discussed in the context of the WDL requirements (WRM, 2012).

Recorded natural surface water concentrations of water quality parameters are generally within the limits specified in the MRM WDL174-1. The natural surface water is slightly more alkaline than the trigger value for pH and sulphate levels are slightly above the trigger values at the downstream reporting location of the McArthur River (SW11).

For the Old McArthur River channel, the water quality is generally within limits specified in the MRM WDL174-1 except for sulphates, which are approximately 15 times greater than the trigger value.

For Lake Archer and the Pit Sump water, the concentrations for arsenic, cadmium, lead, zinc and sulphates exceed the MRM WDL174-1 trigger values. The Pit Sump has zinc and sulphate concentrations up to 255 and 135 times greater respectively than the trigger values, whilst Lake Archer has values that are 57 and 61 times greater respectively.

Table 10-1 Summary Surface Water Quality Data, McArthur River, Barney Creek, Surprise Creek and MR Channel

Parameter	Units	MRM WDL174-1 Trigger Value	SW11				SW10				SW21				Old McArthur River
			Med-ian	95^{th}%ile	Min	Max	Med-ian	95^{th}%ile	Min	Max	Med-ian	95^{th}%ile	Min	Max	
pH		<6 and >8.5	8.3	8.6	6.6	8.7	8.3	8.56	7.5	8.6	8.4	8.6	7.3	8.6	7.4
EC	µS/cm	n/a	662	751.6	21	783	679	724.2	79	741	662	713	66	735	565
Arsenic (As)	µg/L	13	1.1	2	0.2	2.5	1	1.86	0.3	2.3	1	1.9	0.35	2.3	1.08
Cadmium (Cd)	µg/L	1.79	0	0	0	0.1	0.02	0.02	0.02	0.2	0.02	0.02	0.02	1	0.02
Copper (Cu)	µg/L	11.33	0.5	1	0.2	1.4	0.42	1.33	0.14	2.25	0.49	1.26	0.13	1.35	0.97
Lead (Pb)	µg/L	77.28	0	0.2	0	1	0.01	0.14	0.01	0.79	0.02	0.15	0.01	1	<0.1
Zinc (Zn)	µg/L	64.72	0.5	1.7	0.2	5	0.5	1.36	0.2	24.1	0.5	2.14	0.2	5	33.1
Sulphates (SO)	mg/L	15.8	12.2	19.8	0.6	21	8.2	13.26	0.8	14.5	7.4	12.72	0.9	13.9	248

(WRM, 2012)

Table 10-2 Summary Water Quality Data, Lake Archer and Open Pit Sump

Parameter	Units	MRM WDL174-1 Trigger Value	Lake Archer				Pit Sump			
			Median	95th %ile	Min	Max	Median	95th %ile	Min	Max
pH		<6 and >8.5	8.2	8.2	7.5	8.2	7.7	7.9	6.8	8.0
EC	µS/cm	n/a	1,210	1,594	1,200	1,650	3,320	3,730	2,830	3,760
Arsenic_As	µg/L	13	31.0	40.4	1.5	41.0	1.1	15.9	0.5	16.5
Cadmium_Cd	µg/L	1.79	2.1	18.0	0.2	20.4	8.5	14.7	2.8	15.6
Copper_Cu	µg/L	11.33	0.9	2.1	0.4	2.3	0.7	1.8	0.4	1.9
Lead_Pb	µg/L	77.28	6.0	31.2	0.3	36.6	58.2	77.5	49.9	77.9
Zinc_Zn	µg/L	64.72	488	3,974	48	4,560	13,500	16,610	1,770	16,700
Sulphates (SO_4)	mg/L	15.8	250	895	167	928	2,000	2,140	1,600	2,170

(WRM, 2012)

10.2.7 Existing Water Management Strategy

10.2.7.1 Overview

Since the commencement of the mine, both as an underground and open-cut mining operation, water management has been subject to continuous improvement in terms of overall strategies, operation procedures, water management infrastructure upgrades, corrective actions and safeguards. A major aspect of the existing water management system is ensuring flexibility for extremes of drought and flood.

It recognises that excessive accumulation of mine waters can have undesirable consequences in extreme storm and rainfall events, particularly in tropical climate areas (DME, 1995). The water management system also recognises that sequences of climate (e.g. prolonged or sporadic wet seasons and successive ‘large’ wet seasons) may be just as critical for water management as a single extreme rainfall event.

10.2.8 Existing Mine Water Management System

The existing water management infrastructure consists of the following (WRM, 2012):

10.2.8.1 Contaminated Water Management:

- A Tailings Storage Facility (TSF Cell 2) to store fine rejects (tailings) from the Concentrator Product Plant (Mill), as well as seepage water pumped from the base of the TSF.
- A Water Management Dam (WMD) (future TSF Cell 3) that also collects overflows from TSF Cell 2 during extreme runoff events.
- An out-of-pit mine water dam (Pete's Pond (PP)) to collect water pumped out from the open pit and underground mine void. It is also a distribution point for contaminated water.
- A concentrator runoff dam (Concentrator Runoff Pond (CRP)) to collect overflows from the Mill and Decant Water Tank (DWT).
- A contaminated runoff dam (Anti-Pollution Pond (APP)) to collect runoff from the mine infrastructure area as well as pumped inflows from the CRP and return water from the TSF Cell 2. The APP supplies the Mill process water demands (via the DWT).
- An Overburden Emplacement Facility (OEF) runoff dam (Van-Duncan's Dam (VDD)) to collect Non Acid Forming (NAF) runoff from the West OEF. The VDD supplies the road watering demands.
- An out-of-pit mine water dam (Lake Archer (LA)) to collect runoff from the road part of the West OEF as well as pumped inflows from interception bores along the McArthur River palaeo-channel.
- An open pit (OC) that collects runoff from the open pit, groundwater inflows as well as residual moisture from the pit evaporative fans.
- A decommissioned underground mine void (UG) to collect runoff from the open mine as well as groundwater inflow.
- A temporary out-of-pit mine water dam (Eastern Levee Storage (ELS)) to collect water pumped out from the open pit and underground mine void.
- A clean water dam (Old-McArthur River (OMR) channel to collect runoff from the natural catchment area within the mine levied area).
- Two containment dams at North OEF (Southern PAF Sediment Dam (SPSD) and Southern PAF Run-Off Dam (SPROD)) to collect runoff from Potentially Acid Forming (PAF) runoff from the North OEF as well as water pumped out from PP to maximise evaporation.

- A Raw Water Tank (RWT) to collect production bore water from the MIMEX, Emu and Donkey production bores.
- A Mill supply tank (Decant Water Tank (DWT)) to collect water from the RWT and APP.
- Seepage sumps and borrow pits around the TSF Cell 1 to collect seepage reporting at the base of the TSF Cell 1.
- Evaporative Fans to enhance water losses from TSF Cell 2 and PP.
- Sprinklers and water fountains at storages to enhance evaporation losses.

10.2.8.2 Dirty Water Management:

- Numerous silt traps/sediment ponds located strategically across the mine site to prevent dirty on-site water directly flowing into the natural waterways.

10.2.8.3 Clean Water Management:

- McArthur River channel around the southern boundary of the open pit.
- Bunds, drains and re-contouring within the flood protection levee wall area to direct clean water away from the open pit.
- Barney Creek channel around the northern boundary of the open pit.
- Little Barney Creek channel around the western boundary of the TSF.
- Flood protection levee around the perimeter of the open pit.

10.2.8.4 Waste Discharge Licence Release Points:

- WMD into Little Barney Creek.
- OMR into the McArthur River.

A schematic of the existing surface water management circuit at MRM is provided in Figure 10-3.

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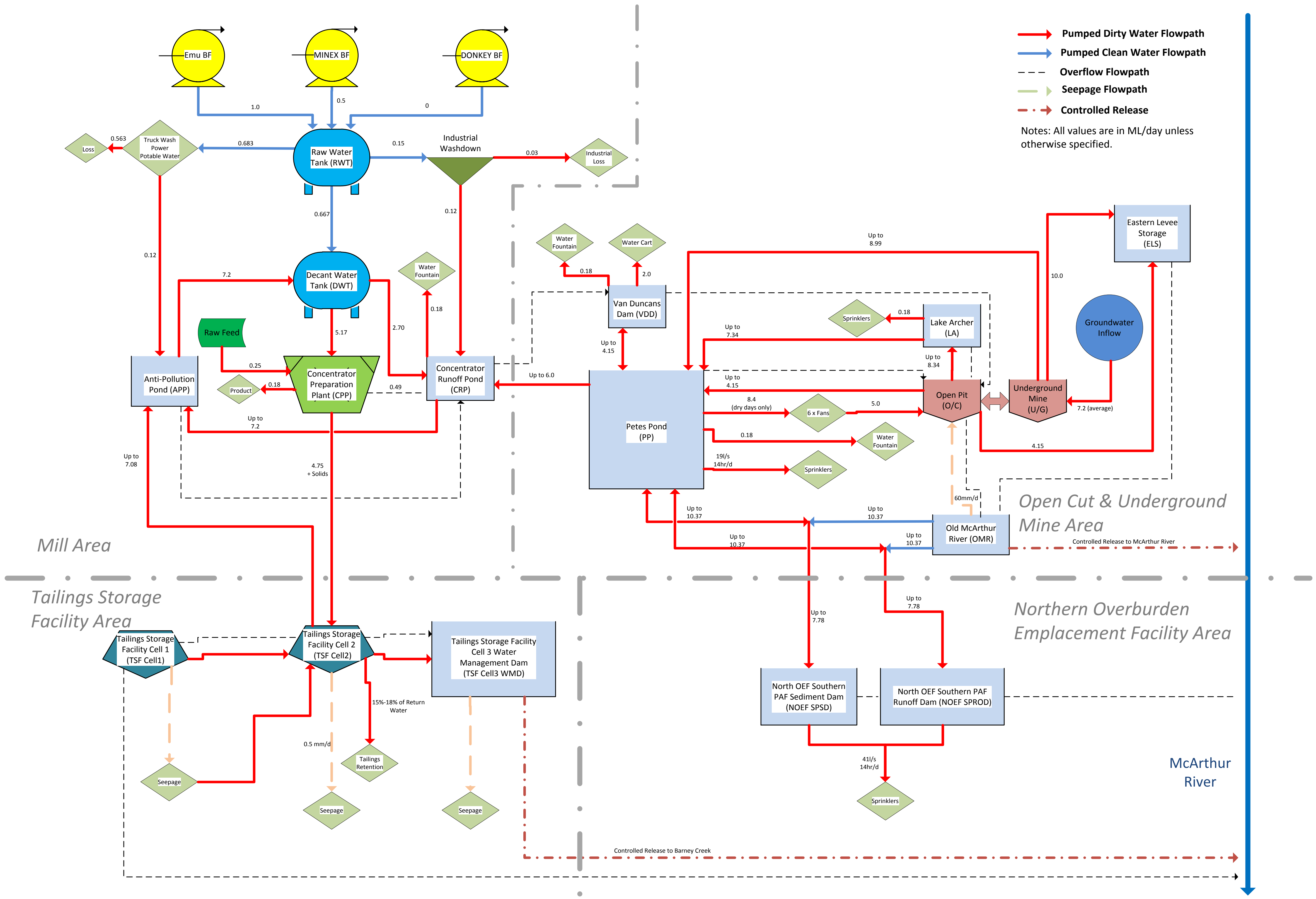

Figure 10–3 Existing Surface Water Management Circuit (WRM, 2012)

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Table 10-3 provides the existing mine water storages and their storage capacities at full supply level (FSL). Further and more detailed information on the existing water management system and infrastructure can be found in Appendix D3.

Table 10-3 Storage Capacities of Existing Dams

Dam Name	Storage Capacity at FSL (ML)
Anti Pollution Pond (APP)	23
Concentrator Runoff Pond (CRP)	30
Van-Duncans Dam (VDD)	25
Pete's Pond (PP)	100
Cell 3 Water Management Dam (Cell 3 WMD)	1,834
Lake Archer (LA)	20
Eastern Levee Storage (ELS)	850
Old McArthur River (OMR) Channel	600
North Overburden Emplacement Facility (NOEF) Southern PAF Sediment Dam (SPSD)	250
Northern Overburden Emplacement Facility (NOEF) Southern PAF Runoff Dam (SPROD)	810

(WRM, 2012)

10.2.8.5 Waste Discharge Licence (No. 174-1)

Controlled releases from the WMD and OMR are permitted in accordance with MRM's waste discharge licence (WDL No. 174-1). Controlled releases from these storages are permitted only when the following water quantity and water quality objectives can be met:

- The river height at the McArthur River upstream gauging station is greater than 2 mGH (which is equivalent to approximately 200 ML/d)
- The water quality at the downstream compliance point (after the controlled release) is within specified water quality trigger levels.
- A dilution ratio of at least 1 part mine water to 160 parts McArthur River water is achieved for the discharge of mine water to the McArthur River (This dilution limit has been set based on MRM eco-toxicity test results).

10.2.8.6 Existing Water Management at Bing Bong

The main components of the water management system at the Bing Bong include the following:

- Raw water system
- Runoff collection system.

Raw water for the Bing Bong is obtained from the Federation Bore and delivered to the Bing Bong via a 25 km pipeline. Raw water is used for the camp utilities and the cleaning of machinery. Water utilised for potable water undergoes treatment and testing to monitor whether it is fit for human consumption. Wastewater is collected and treated in an on-site sewage treatment plant. The Bing Bong has relatively little water use and the major focus of water management is the capture and containment of potentially contaminated stormwater runoff.

The stormwater runoff from the site drains to the main storage area, the Bing Bong Surface Run Off Pond. A secondary pond is utilised for both an emergency overflow pond and an area where excess water can be evaporated throughout the dry season. Additional runoff is collected at sumps on the wharf and adjacent to the wheel wash. Water collected from runoff and cleaning of the Aburri is also collected and pumped to the site runoff pond.

The Project will have little impact on the existing approved surface water management system at Bing Bong, therefore little discussion of the surface water management at Bing Bong is provided.

10.3 Existing Groundwater Environment

This section describes the existing groundwater environment at MRM and provides context to the groundwater modelling investigations that have been completed for the Project.

10.3.1 Geological Setting

10.3.1.1 Topography

The topography of region can be described as the following:

- High rocky sandstone plateaux and ridges mainly associated with the Lower Cambrian Bukalara Sandstone to the east of the study area
- High level valleys and depositional plains with a series of linear ridges of erosion-resistant sedimentary rocks, which trend normal to the direction of drainage and inhibit the normal down cutting of the streams, resulting in a tendency for water impoundment upstream of these transverse linear ridge features
- Broad and narrow fluvial corridors of drainage channels
- River depositional flood plains
- Level to gently undulating plains of unconsolidated, depositional material.

The dominating topographic features of the area include the McArthur River, Barney and Surprise Creek, Barney Hill and the Bukalara Plateau that is approximately 30 to 100 m higher than the surrounding landscape. The sandstone is characterised by its joint pattern, distinctive cross-bedding and slight feldspathic nature.

10.3.1.2 Geology and Lithology

The bedrock of the McArthur Group is overlain associated with the McArthur River and bedrock of the McArthur Group. The McArthur group is comprised of a thick sequence of Proterozoic formations extending from the Queensland border to Arnhem Land. These formations include an interbedded sequence of dolostones, sandstones, siltstone, and shales, with a composite thickness of greater than 4,000 m in the McArthur River Region.

Basement formations in the area include Middle Proterozoic, interbedded cyclic dolostones, dolomitic siltstones, sandstone and shale of the McArthur Group. The McArthur Group is overlain by the Batten Subgroup which consists of shallow marine deposits, dolomitic sandstones, pyritic shale, quartz sandstone and evaporites. Much of the bedrock sequence is weathered at shallow depths (Figure 10-4).

More information on the geology of the site can be found in Chapter 7 – Land Resources and the Groundwater Technical Assessment Report (URS, 2012) provided in Appendix D4.

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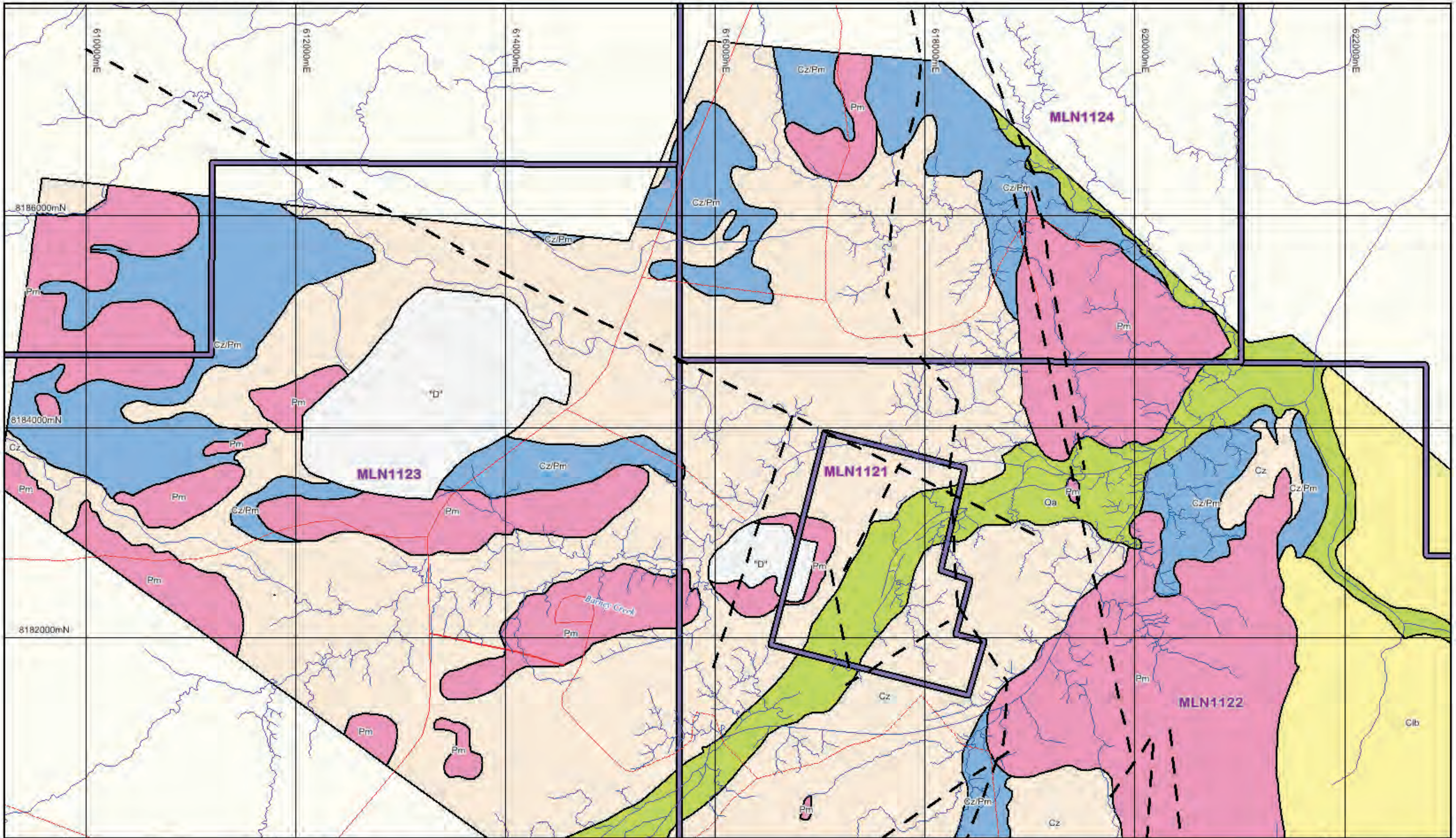

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LEGEND

- Project tenement
- Principal road
- Road (sealed)
- Road (unsealed)
- River
- Faults

Geology Units

- "D"
- Clb
- Cz
- Cz/Pm - Permian
- Pm - Permian
- Qa - Quaternary

McArthur River Mine Phase 3 Development Project

McArthur River Mine Surface Geology

20/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 10 - 4

10.3.2 Groundwater Occurrence

Groundwater in the study area occurs on local scale in both surficial deposits and bedrock. Extensive aquifers with intergranular permeability in the area are rare and are generally limited to the alluvium that occurs along the drainage channels of the rivers and creeks including a paleochannel that extends through the mine site area deposited at one time by the McArthur River channel. Historical inflows into the current open pit indicate that the permeable sections of the weathered bedrock at shallow depths can act as significant aquifers that receive rapid recharge from the ground surface and also serve as a source of recharge to fractured rock aquifers. The underground mine, which lies within the confines of the proposed pit, also has recorded inflows that occur from the mine strata and drainage from the current open pit to the underground.

The following groundwater aquifers can be distinguished in the area:

- local and or perched aquifers in the alluvium
- local and or perched aquifers located at the interface between the soils and/or weathered bedrock and the more solid bedrock
- local fractured rock acquifers (i.e. fractures, joints, vugs, and possible solution channels) of the bedrock.

The aquifers are unconfined to semi-unconfined types with the underground mine forming a sub-surface void.

Presented in Table 10-4 is a generalised stratigraphy, geologic and hydrogeologic characteristics of hydrostratigraphic units found within the study area with a description of the main aquifers in the vicinity of the mine, provided below.

Table 10-4 Generalised stratigraphy, geologic and hydrogeologic characteristics of alluvial deposits and bedrock in the study area

Period	Geologic Formation	Member/Unit Name	Lithological Description	Hydrogeological Description
Quaternary	Alluvium	Alluvium	Unconsolidated sand, silt, clay and other materials with fine texture that may have settled out after floods.	Productive unconfined alluvial aquifer where saturated. Published values of hydraulic conductivity ranges from 4.92E-02 to 3.37 m/d.
		Palaeochannel (buried channel) sediments	Mostly gravel and coarse sand with some boulders deposited in the McArthur River Paleochannel.	High yielding aquifer. Published values of hydraulic conductivity of the palaeochannel ranges from 21.6 to 35.2 m/d.
	Weathered Bedrock	Weathered Bedrock	Weathered bedrock.	Published hydraulic conductivity values for weathered bedrocks ranges from 1.6 to 22.5 m/d.

Table 10-4 Generalised stratigraphy, geologic and hydrogeologic characteristics of alluvial deposits and bedrock in the study area (cont)

Period	Geologic Formation	Member/Unit Name	Lithological Description	Hydrogeological Description
Proterozoic	Barney Creek Formation	HYC Pyritic Shale	Pyritic Shale.	Results from packer tests indicated that the permeability of the shale is approximately 8.65E-05 m/d.
		Main Talus Breccia (Cooley Dolomitic Breccia)	Chaotic breccia, with clasts which range in size from a few millimetres to several tens of meters.	Reported hydraulic conductivity values of the breccia ranges from 2.59E-04 to 5.18E-04 m/d.
		HYC Pb-Zn Ore	Thin-bedded to laminated dolomitic siltstone characterised by a high carbonaceous content.	Can yield groundwater if fractured.
		W-Fold Shale	Green and red, dolomitic siltstone and shale with interbeds of green vitric tuff.	Reported hydraulic conductivity of the W-Fold Shale is 4.0E-04 m/d.
	Teena Dolomite	Coxco	Massive, dark grey and sometimes vaguely bedded dolostone with numerous interbeds orange-weathering, mudstones.	Fractures, joints and other geologic structures in otherwise these solid rocks are conduits through which groundwater flows.
		Lower Teena	Very thin bedded, massive, dark pink and grey dololutite.	
Palaeo-protozoic	Emmer-ugga Dolostone	Mitchell Yard Dolostone	Dark grey weathering, uniform, massive, karstic dololutite which has undergone extensive vadose alteration	Variably saturated karstic/fractured-rock aquifer. Fractures/vuggs dominantly controls groundwater flow in the massive rocks. Reported hydraulic conductivity values obtained from boreholes completed in fractures and vuggs ranges from between 3.37E-02 and 21.17 m/d. Fractures, joints and other geologic structures in this massive rock are conduits through which water flows. Gaven et al (2001) and, Yang et al (2004) assigned hydraulic conductivity value of 2.74E-01 m/d to the faults in their numerical investigation of fluid flow associated with the formation of the HYC deposit in the McArthur River Basin.
		Mara Dolostone	Laminated dololutite. interbedded with thin beds of flake and randomly orientated intraclast breccia, occational recessive interbeds of fine dolomitic sandstone, dolomitic siltstone and silty massive dololutite. The silty units sometimes contain cherts.	

10.3.2.1 Alluvium

The alluvium comprises mainly of a mixture of low to moderate permeability silts, clays, and fine-grained sands. A higher permeability basal section of coarse-grained sands, gravels and cobbles/boulders occur along the deepest portion of the paleaochannel. The base of this palaeochannel is up to 34 m below ground surface (5 m AHD) and this represents the thickest known occurrence of the alluvium in the immediate mine area.

10.3.2.2 Weathered Bedrock

Aquifers occur locally in the weathered and partially weathered bedrock underlying the alluvium in the open pit area. The near-surface geology east of the pit is predominantly weathered dolomite (Cooley Dolomite), and to the west it is dolomitic siltstones, shale and dolomite (Teena Dolomite). The most significant aquifer occurs within the weathered dolomite which appears to have low to high permeability.

Faults that intersect the weathered and partially weathered zones are also considered transmissive and contribute to groundwater flows to the open pit where they intersect the wall.

Generally the base of weathered bedrock ranges between 5 and 22 m AHD (URS, 2006).

10.3.2.3 Bedrock

Groundwater can occur in open vugs or solution channels, fractures, joints and faults within the fresh bedrock. Open vugs and solution channels were observed in the drill cores extending below the zone of weathering to depths in excess of 300 m (-270 m AHD) (URS, 2006). These structures were predominantly in dolomite, located near the Mt Stubbs Fault north of the pit.

Open joints and fractures can also allow the transmission of groundwater and these were observed within the open pit area between depths of 23 m (RL 7 m) and 152 m (RL -122 m), predominantly in dolomite and brecciated units, and occasionally in shales.

Joints and fractures appear to decrease in permeability with depth. From the core viewed, these structures were apparent between depths of 10 m and 240 m (20 and -210 m AHD). Open joints were most predominant above a depth of 100 m (-70 m AHD).

10.3.3 Existing Groundwater Levels

Since 1995, a network of groundwater monitoring bores (Figure 10-5) has been established by MRM to monitor groundwater levels and quality. Groundwater levels fluctuate between wet and dry seasons. Wet season groundwater levels are between 1.3 and 5.9 m higher than dry season levels.

10.3.4 Existing Groundwater Flow

Groundwater level contours in the bedrock across the mining area in 1995/97 are presented in Appendix D4. The 1995/97 groundwater levels in the deep aquifers indicate a general easterly flow of groundwater from the Tailings Storage Facility (TSF) toward the EMU Borefield.

Regional watertable/potentiometric surface elevation contours of the alluvium and weathered bedrock water bearing zones reflect topographic elevation, with groundwater flow from high head to lower head towards the predominately ephemeral tributary streams and the McArthur River.

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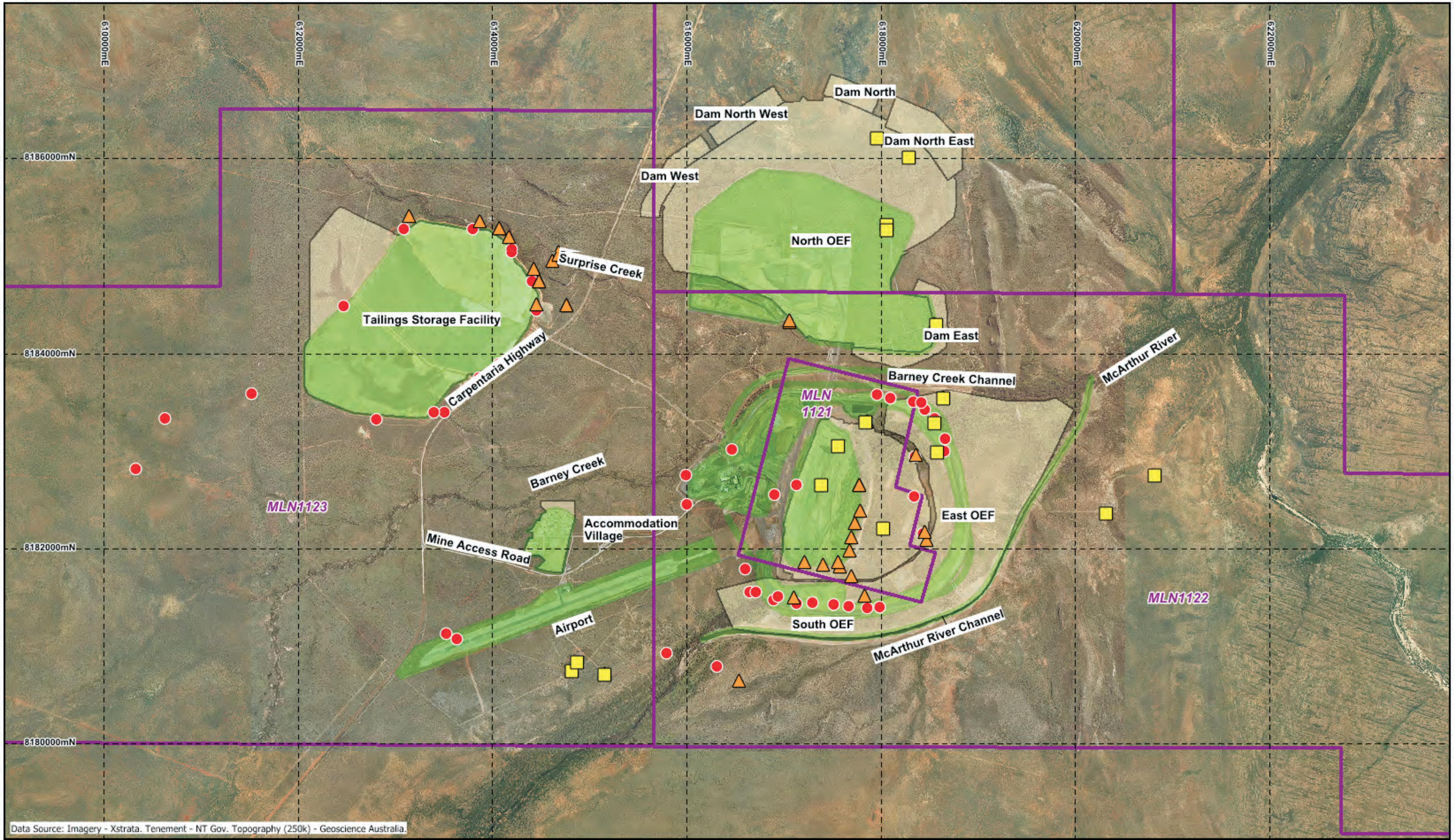

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Kilometres
Scale: 1:80,000 (A4)

LEGEND
- Project tenement
- Proposed Infrastructure
- Existing Infrastructure
- Monitoring Bores
- Observation Bores
- Production Bores

McArthur River Mine
Phase 3 Development Project

Existing Groundwater Bores

20/01/2012

Datum: AGD84
Projection: AMG53

FIGURE 10 - 5

10.3.5 Stream-Aquifer Interaction

Assuming that differences in upstream and downstream flow represent flow into or out of the aquifer system, the annual stream flow values presented in Table 10-5 indicate:

- groundwater discharges into the McArthur River between Glyde River Junction and the MIM pump station and between Emu Creek junction and Glyde River junction
- stream water discharges to the aquifer between Bull Creek junction and Emu Creek junction and between Barney Creek junction and Bull Creek junction.

The observation stations are provided in Appendix D4. Table 10-6 provides the daily average wet season stream flow in the McArthur River.

Table 10-5 McArthur River Catchment Annual Stream Flow (Source: URS 2006)

Station	Mean annual stream flow (ML/year)
Surprise Creek at McArthur River Junction	7,000
Barney Creek at McArthur River Junction	32,000
Bull Creek at McArthur River Junction	3,600
Emu Creek at McArthur River Junction	2,900
Glyde River at McArthur River Junction	102,000
McArthur River at MIM pump station	487,000

Table 10-6 Daily Average Stream Flow (m3/s) in the McArthur River during the Wet Season from 1970 to 2002 at the upstream Gauge Station (Source: URS 2006)

Flow Statistics	Daily Average Streamflow (m^3/s)					
	Nov	Dec	Jan	Feb	Mar	Apr
Median Flow	0.1	0.5	4.5	12	5.4	0.4
80th Percentile Flow	1.2	8.0	37	78	52	3.9
90th Percentile Flow	4.2	25	100	264	183	14
95th Percentile Flow	13	54	324	588	388	25

10.3.6 Existing Groundwater Monitoring and Quality

MRM completes a routine sampling program in the local groundwater monitoring bores around the process area, the North OEF, the Tailings Storage Facility (TSF) and the water Management Dam. Standing water levels are also monitored at bores in the vicinity of Djirrinmini Waterhole and the McArthur River palaeochannel. A summary of the groundwater monitoring locations is provided below. The current groundwater monitoring network will be expanded to meet environmental requirements of the Project.

The objectives of the groundwater monitoring program are as follows:

- monitoring the potential impacts of groundwater abstraction
- assessing the effectiveness of the TSF seepage control systems
- assessing the potential impact of the North OEF
- determining the extent of any contaminants in shallow aquifers.

The groundwater monitoring program is summarised in the Table 10-7 below:

Table 10-7 Groundwater Monitoring Program

Site	Number of sites	Frequency	Parameters
Mine Process Area			
Process area	GW3A, GW5A, GW15, GW16	every 2nd month,	Every two months • standing water level • pH, EC • TDS • filtered metals (As, Cd, Cu, Pb, Zn) • SO4 • hardness Bi- annually • multi-element ICP-MS scan (inc. Hg) • TPH sites: GW3, GW5, GW15.
OEF	GW64S, GW64D, GW65S, GW65D	as above	as above
TSF			
Cell 1 Group C1-	GWTSF01, GWTSF02, GWTSF03, GWTSF04, GWTSF05	as above	as above
Cell 1 Group C1-N	GW42A, GW42B, GW45B, GW48B	as above	as above

Table 10-7 Groundwater Monitoring Program (cont)

Site	Number of sites	Frequency	Parameters
Cell 1 Group C1-NE	GW21, GW22, GW23	as above	as above
Cell 1 Group C1-E	GW43A, GW42B,	as above	as above
Cell 1 Group C1-SE	GW12, GW20A, GW20B	as above	as above
Water management dam perimeter	GW4, GW6, GW7, GW14	as above	as above
Bing Bong			
Bing Bong	GWBB01A, GWBB01B, GWBB002, GWBB03A, GWBB03B, GWBB04A, GWBB04B	as above	as above

Further groundwater quality monitoring will be undertaken as part of the Project. This monitoring will focus on determining water quality at depth, particularly associated with the quality of intercepted water around the pit. Detailed planning work for this monitoring program is anticipated to commence in the dry season of in 2012.

10.3.6.1 Mine Process area

The aquifers in the mining area occur as a result of both intergranular and secondary permeability. These aquifers are unconfined and are in hydraulic connection where large-scale permeable structures are present in the bedrock. This groundwater has high hardness (derived from carbonate bedrock such as dolomite) and is a (Na-Ca-Mg)-Cl type with significant HCO3 AND SO4 (URS, 2005).

The groundwater bores in the Process Area Group (GW15, GW16, GW3A and 5A) are located within the vicinity of the milling area to the west of the pit and are susceptible to contamination from these sources. Results have been displayed since 2007 to coincide with the timeline when the operation converted from underground to open pit.

10.3.6.2 North Overburden Emplacement Facility (NOEF)

Northern Overburden Emplacement Facility (NOEF) Group (GW64D, GW64S, GW65D and GW65S) are located adjacent to the southern boundary of the NOEF dams and in the near vicinity of Surprise Creek and Barney Creek. Pairing of the bores represent shallow and deep drill depths denoted in the bore identification code by the suffix ‘S’ and ‘D’ respectively. Groundwater monitoring is undertaken to measure any potential impacts from any NOEF seepage. Should seepage be detected via monitoring, measures will be implemented to reduce potential seepage impacts. Such measures include pumping seepage back to the NOEF PAF Pond and pumping from there to the TSF on a more regular basis.

10.3.6.3 Tailings Storage Facility (TSF)

Monitoring bores around the Tailings Storage Facility (TSF) have been grouped in relation to their location for ease of analysis. Bores will be discussed in their groups.

10.3.6.4 Water Management Dam Group

The bores in the WMD-1 Group (GW6, GW7, GW14 and GW4) are installed around the perimeter of the Water Management Dam which is located on the southern side of the TSF.

The WMD was constructed over an existing drainage line that ran in a south easterly direction. Bore GW7 is situated in the vicinity of the existing drainage line just before it intersects the northern extent of the WMD. Bores GW14 and GW4 are positioned in the vicinity of the existing drainage line outside the south eastern boundary of the WMD where the drain has been intersected by the WMD. The existing drainage line has been diverted around the southern perimeter of the WMD from near GW7 to rejoin the drainage line near GW14. GW6 is located on the southern boundary of the WMD.

Water within the WMD migrates to the south east due to the natural topography of the pre-existing drainage line. Any seepage from the WMD is therefore likely to express in this region. This is evidenced by several differences in the results of GW14 and GW4, which are located in this area, and the other two bores in the group.

10.3.6.5 TSF Cell 2 – South

The Southern Group (GW18 and GW19) of bores are located east of Cell 2 of the TSF. GW18 is the more southerly of the two bores and is located on the eastern side of the highway, whilst GW19 is located on the western side. This group of bores has maintained concentrations below the guideline levels with the exception of sulphates.

10.3.6.6 TSF Cell 1 – South East

The South Eastern Group (GW12A, GW20A and GW20B), is situated directly east of the TSF near the south eastern corner of Cell 1. This group of bores has maintained concentrations below the guideline levels with the exception of sulphates.

10.3.6.7 TSF Cell 1-East

The Eastern Group (GW43A and GW43B) is situated at one location on the eastern boundary of the TSF. Total bore depth for GW43A and GW43B is 10.35m and 16.5m respectively. Groundwater levels within the group rose at the end of 2008 and have not receded.

10.3.6.8 TSF Cell 1-North East

The North Eastern Group (GW21, GW22 and GW23) is situated near the north eastern boundary of Cell 1. The group forms a transect that spans Surprise Creek. GW21 is situated between the TSF boundary and Surprise Creek, whilst GW22 and GW23 are located on the other side of the creek. GW21 is located in an in-filled tributary of Surprise Creek, which is believed to be a transmissive pathway. Similar to other bore groups in the area, groundwater levels show seasonal fluctuation and a marked increase at the start of 2009.

10.3.6.9 TSF Cell 1 – North

This group borders along the northern boundary of Cell 1.Groundwater levels ranged between 0.38 – 2.9 mBGL in the 2011 late wet season.

10.3.6.10 Bing Bong

MRM made commitments as part of environmental management plans and in accordance with Waste Discharge Licence WDL174-1 to install groundwater monitoring bores and characterise the hydrogeology of the site. The hydrogeological investigation lead by URS Pty Ltd consultants set out to delineate the extent of transmissive aquifers and possible connection with the marine environment.

Seven groundwater monitoring bores were installed at four sites between the 20th November and the 23rd of November 2010. The maximum depths of the bores ranged between 2.25 and 6.6 m below ground level. Initial modelling concluded that the overall direction of groundwater flows towards the coast (URS 2011).

10.4 Surface Water Impact Assessment

This section provides a description of the proposed surface water management system in the context of the modelling and assessments required for its development. The key components and functionality of the strategy are described followed by a discussion of the flood modelling and site water balance modelling that was completed to test the proposed system. Residual impacts associated with the proposed system are also discussed.

The Project will not result in any substantial changes to the existing infrastructure or surface water management systems and procedures at Bing Bong. Therefore no additional potential impacts associated with the Project are anticipated and no further discussion of surface water management at Bing Bong is provided.

10.4.1 Proposed Project Water Management Strategy

The Project will require a change to the existing mine site water management system to accommodate increased areas of runoff such as the new overburden emplacement facility areas. The overall philosophy of mine water management will remain the same as the existing system and will be updated over time in accordance with on-going industry improvements in best practice for mine water management.

The existing operations are managed via a Sustainable Development Water Management Plan (SD WMP). The SD WMP outlines how water will be monitored and managed to facilitate environmental best practice and maximise the environmental sustainability of the site. It is also a planning document outlining objectives for water management moving forward and reporting on water management activities from the previous operational period.

Key aspects of the SD WMP include but are not limited to the following topics:

- Monitoring schedules
- Annual analyses of MRM monitoring
- Annual analyses on consultant reports
- Targets and objectives for water management
- Required infrastructure
- Proposed operations in relation to water.

10.4.1.1 Surface Water Management Objectives and Approach

For surface water management purposes, the surface runoff generated during the Project Site is divided into three types based on water quality:

‘Clean’ – surface runoff from areas of the Project Site where water quality is unaffected by mining operations. Clean water includes runoff from undisturbed areas.

'Dirty' – surface runoff water and seepage from the Project Site areas that are disturbed by mining operations such as NAF waste rock dumps and roads. This runoff may contain silt and sediment, but is unlikely to contain contaminant concentrations in excess of ANZECC (2000) guidelines for a 95% level of protection in freshwater ecosystems for key water quality parameters (adjusted for water hardness). However, this runoff must be of suitable quality if discharge into natural watercourses is required.

'Contaminated' – surface runoff water and seepage from areas affected by mining operations and potentially containing chemicals of various types generated by mining operations. Areas where hazardous waste can potentially be generated include where ore is stockpiled, areas where PAF waste rock is encapsulated on NAF waste rock in a waste rock dump, the open pit and underground mine voids, and process areas. Runoff from these areas must be managed to avoid discharge of potentially contaminated water into the natural watercourses. There are restrictions on the use and release of this water.

The following type of groundwater generated at the Project is also of relevance to the proposed surface water management system based on its water quality:

- 'Intercepted Groundwater' – groundwater that is intercepted by proposed dewatering bores and spears before it enters the open pit void (i.e. before it is contaminated by mixing with water in the open pit and underground mine). Based on available groundwater water quality monitoring data (see MRM, 2011), the intercepted groundwater would have moderately elevated levels of Zn and SO_4, but is unlikely to contain contaminant concentrations in excess of ANZECC (2000) guideline trigger levels for a 95% level of protection in freshwater ecosystems for other key water quality parameters (when adjusted for water hardness).

10.4.1.2 Management Objectives

The general surface water management objectives for the various Project construction and mining phases are as follows:

- Separate 'clean', 'dirty' and 'contaminated' water runoff as much as possible
- Minimise the area of surface disturbance, thus minimising the volume of 'dirty' and/or 'contaminated' runoff
- Treat all 'dirty' water on site via containment storages or sediment ponds, dependant on the toxicity of contaminants likely to be generated.
- Controlled release of 'dirty' water treated in proposed sediment dams, provided water quality is within the MRM Waste Discharge Licence water quality release limits.
- Segregate, collect and contain all 'contaminated' runoff on site via adequately sized containment storages.
- The provision of permanent pumping infrastructure to allow transfer of 'contaminated' runoff between containment storages as required, minimising the potential for overflows.
- Minimise 'raw' water consumption and maximise reuse of 'contaminated' water within the mine site (e.g. for ore processing) without releasing it off-site
- Maximise evaporation of on-site excess 'contaminated' water from available dams in order to minimise the need for off-site releases and/or reliance on external water demands.
- Further excess 'contaminated' water would then be treated to adopted water quality compliance criteria prior to release into the surrounding environment and/or supply for external water use (such as off-site irrigation).

The assessment of the Water Management system includes:

- a site water balance
- modelling and management of potential flood impacts to prevent uncontrolled discharges
- conceptual design of water management infrastructure, including clean and dirty water drains, sediment ponds and process water dams
- a proposed surface water monitoring program.

A numerical water balance model was developed (using the GoldSim modelling software) to design the mine source water management system. The model identifies water supply, demand and off-site release requirements based on the expected mine site catchment runoff behaviour, groundwater inflows into the open pit and underground mine void and projected mine site water demands.

10.4.2 Proposed Mine Water Management System

10.4.2.1 Overview

The Project mining operations require changes to the existing surface water management measures to accommodate the proposed changes to the mine site layout (e.g. increased open pit area, extended overburden emplacement areas, expanded TSF). The proposed Project surface water management strategy will use a number of existing surface water management measures as well as a number of additional surface water management measures that will be implemented during both construction and operational phases.

This section details the proposed water management measures to separate 'clean' runoff from the 'dirty' and 'contaminated' runoff areas and the management measures proposed to manage 'dirty' and 'contaminated' water at the MRM mine site during Project operations.

Figures 10-6 to 10-10 show the locations of the existing and proposed water storages, and contributing catchment areas and land uses during Project operations at five progressive stages of mining (2015, 2020, 2025, 2030 and 2035). Figure 10-11 shows a schematic of the proposed water circuit for the Project. Further information on the water balance is provided in Section 10.4.3.

For the purposes of this EIS, the MRM site surface water drainage system has been divided into 3 separate areas as follows:

- The open pit area (including the South and East OEFs)
- The Tailings Storage Facility (TSF) area
- The North Overburden Emplacement Facility (NOEF) area.

Note that surface water management in the above three areas is integrated and will be managed as a single site-wide water management system. The specific surface water management measures for these areas are provided in Appendix D3.

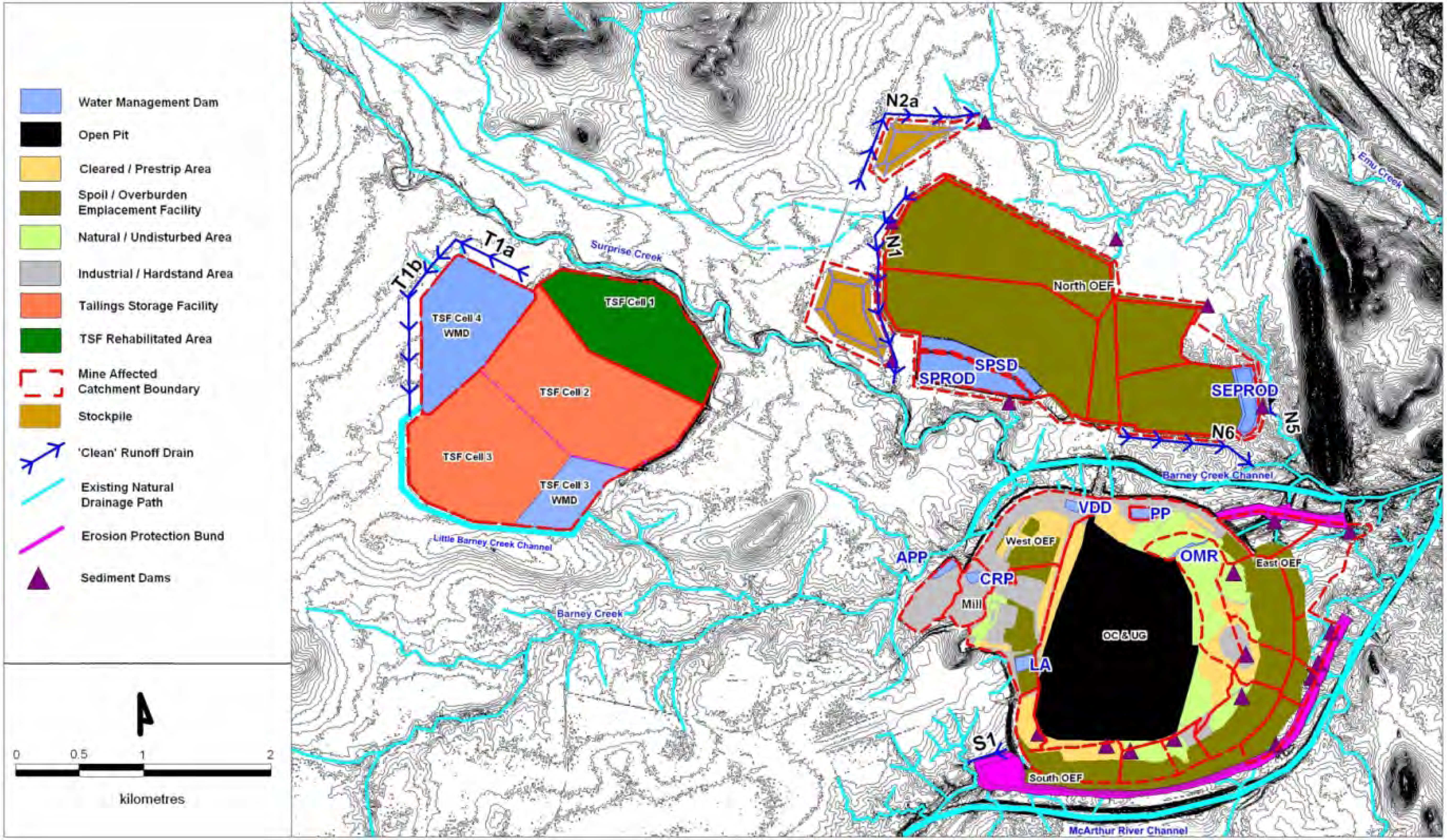

Figure 10-6 Proposed Project Water Management System - Year 2015 (WRM, 2012)

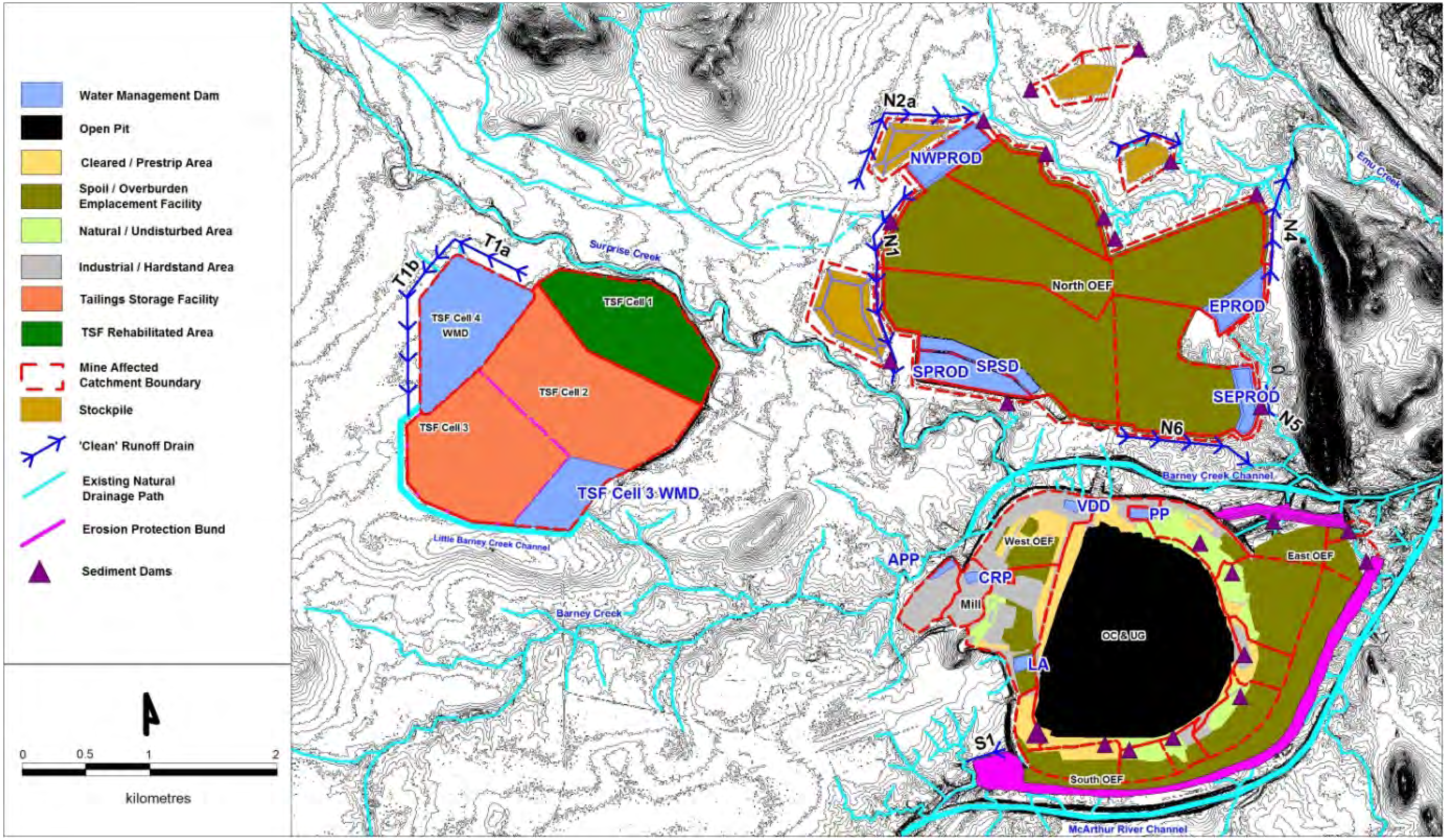

Figure 10-7 Proposed Project Water Management System - Year 2020 (WRM, 2012)

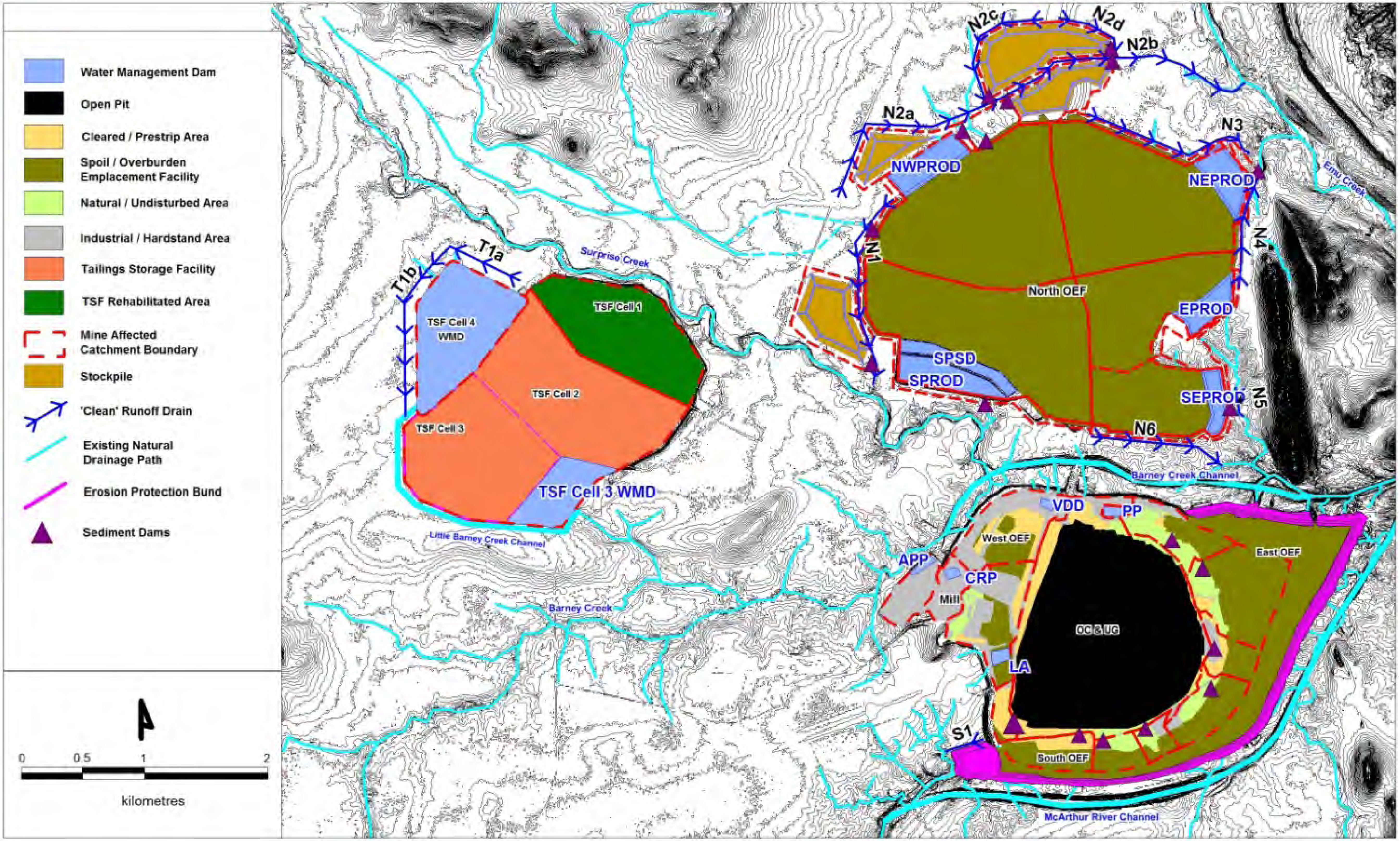

Figure 10-8 Proposed Project Water Management System - Year 2025 (WRM, 2012)

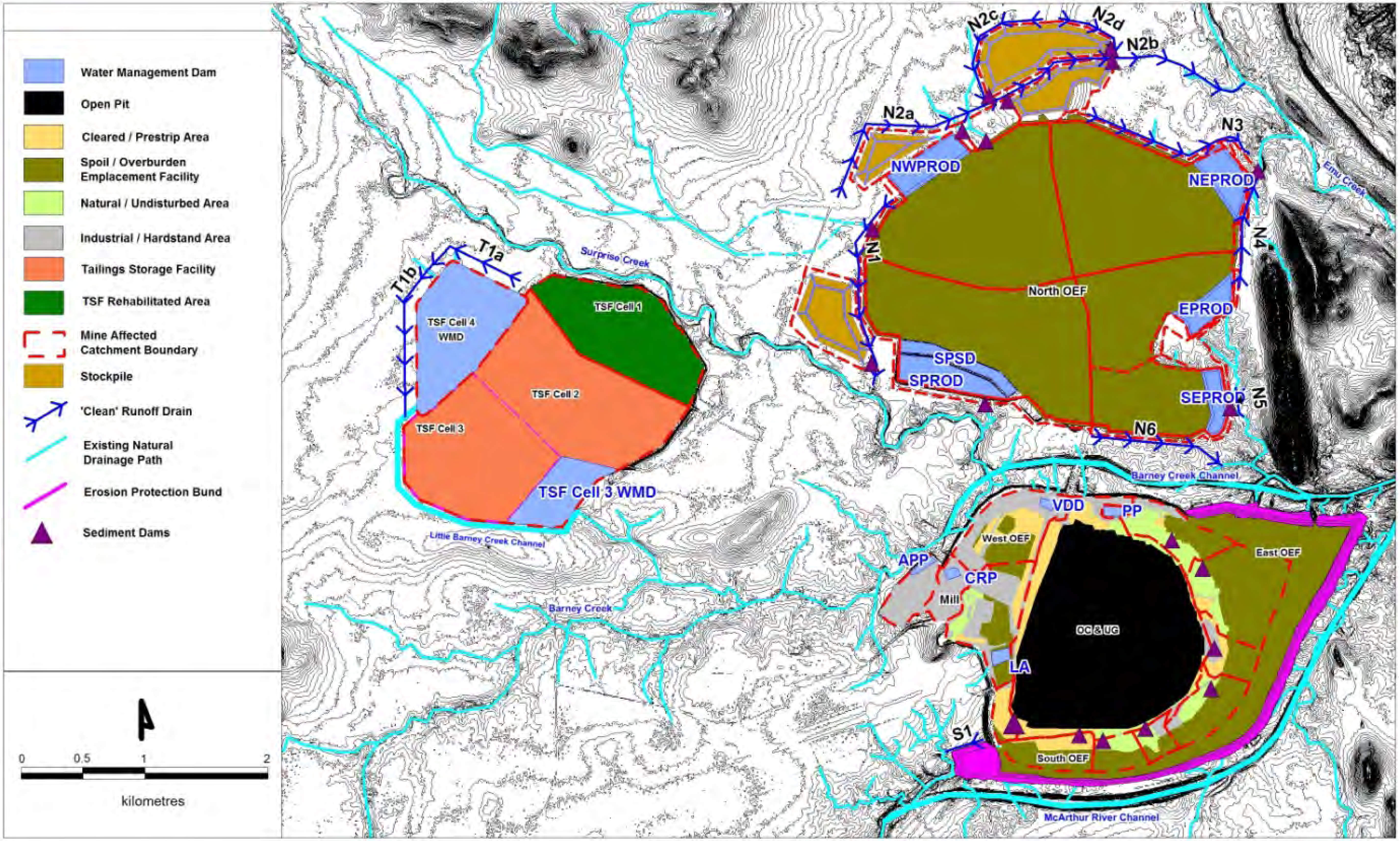

Figure 10-9 Proposed Project Water Management System - Year 2030 (WRM, 2012)

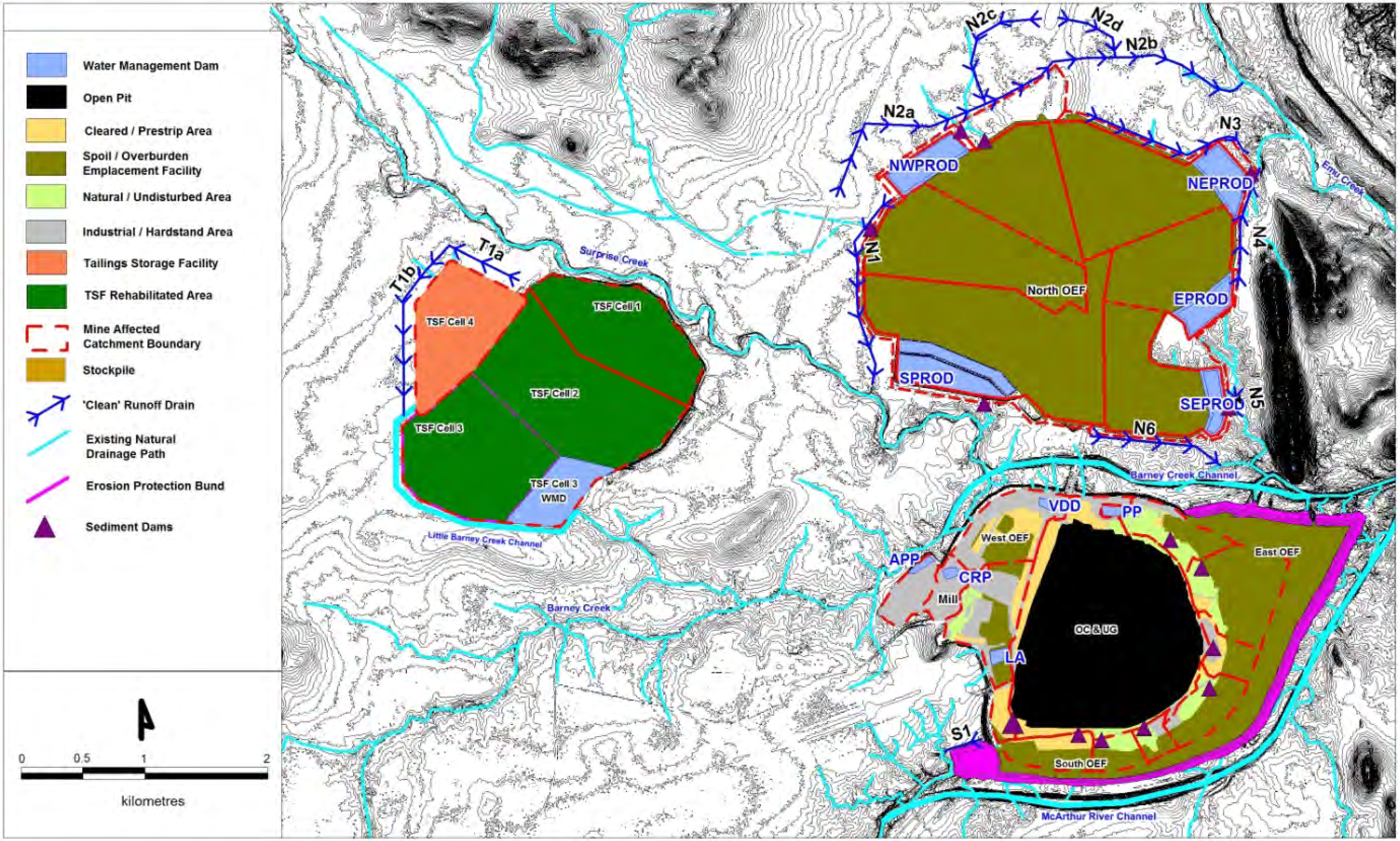

Figure 10-10 Proposed Project Water Management System - Year 2035 (WRM, 2012)

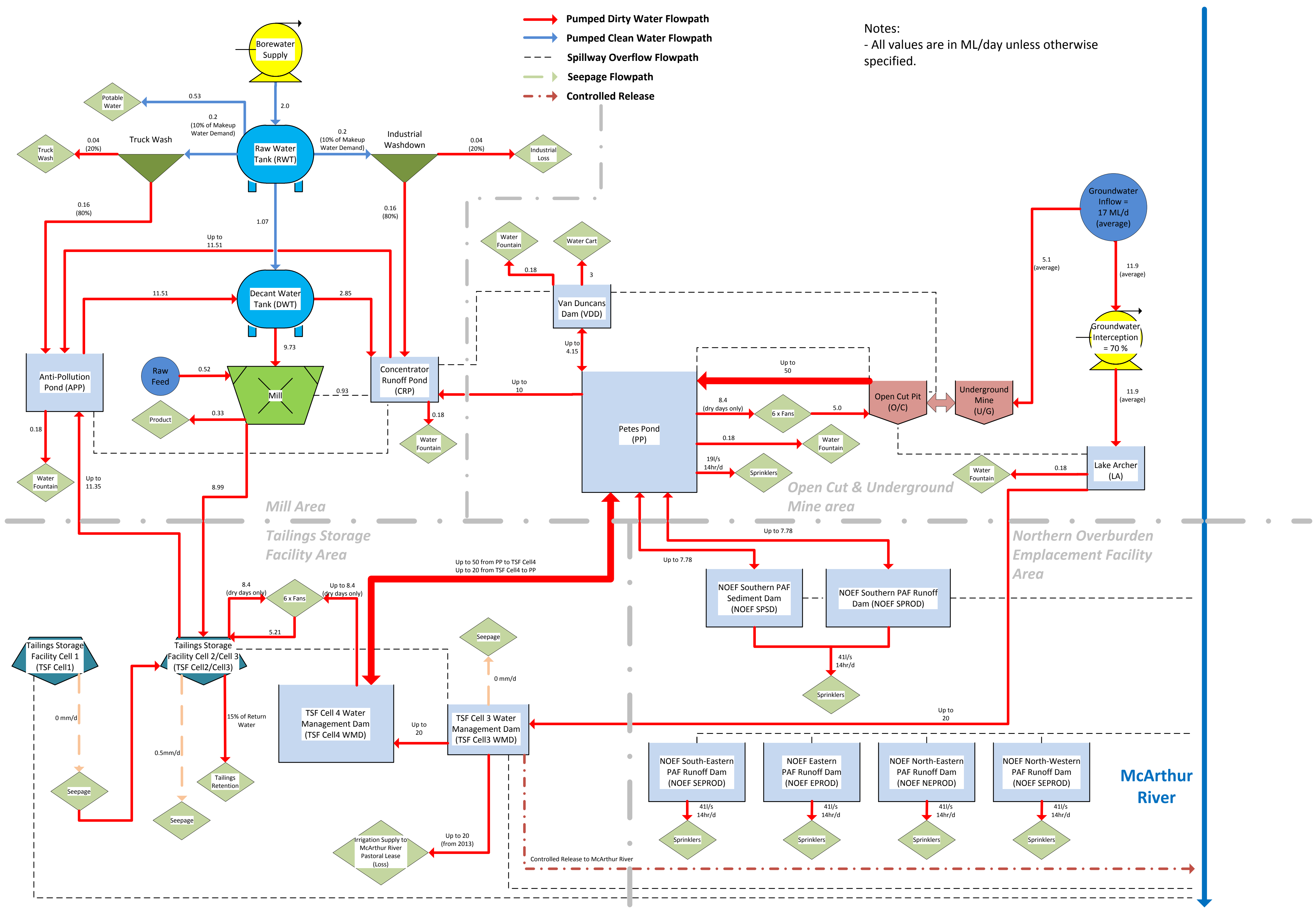

Figure 10-11 Schematic of Proposed Project Water Management System (WRM, 2012)

10.4.2.2 Surface Water Management Strategies

No further diversions of the McArthur River, Barney Creek or Surprise Creek channels are proposed as part of the Project.

The redirection of ‘clean’ runoff away from disturbed areas will reduce erosion and the potential for contamination of 'clean' runoff. A series of bunds and 'clean' runoff drains are proposed to redirect clean water away from disturbed areas of the mine site.

‘Dirty’ runoff at the Project will be managed by constructing several sediment ponds around the perimeter of the North, South and East OEF’s as well as the rehabilitated surface areas of the TSF. 'Dirty' runoff drains will be constructed to capture and direct 'dirty' runoff into the proposed sediment ponds. The sediment pond and drain locations have been selected taking into account the topography of the mine site and to provide the most sustainable locations for such infrastructure for the life of the Project.

‘Contaminated’ water at the expanded mine site will be managed by using the existing containment storages (PP, APP, CRP, VDD, LA, WMD, SPROD and SPSD) as well as TSF Cells 2 and 3. In addition, the following new water storages are proposed:

- Four (4) PAF Runoff dams around the perimeter of NOEF
- The TSF Cell 4 WMD.

The storages, pumped inflows/outflows and catchments draining into water storages containing 'contaminated' runoff will be configured to limit the mixing of ‘dirty’ and ‘contaminated’ water. The following management measures will be implemented (WRM, 2012):

- Within the NOEF, 'contaminated' runoff will be collected in drains in areas where PAF material is exposed and directed into the PAF Runoff dams
- TSF Cell 4, that will collect tailings only towards the end of the mine life (from 2032 to 2036), will be built in 2012 separate to the Project developments, for use as a ‘contaminated’ water storage and evaporation pond for open pit and underground mine void throughout Phase 2 operations
- An additional 'contaminated' water storage may be required to manage water dewatered from the open pit water when TSF Cell 4 is used for tailings deposition after 2032. The additional post-2032 storage requirement will be assessed in the future when more Project operational data becomes available
- Sprinklers and/or sprays will be installed in all ‘contaminated’ water storages to maximise evaporation losses. In addition, six (6) evaporation fans have been installed at the open pit and a further six (6) at the TSF to maximise evaporative losses from Pete’s Pond and the TSF.

The 'intercepted' groundwater at the mine site will be managed using the existing WMD (TSF Cell 3 WMD). Groundwater flowing into the open pit is to be intercepted by constructing dewatering bores and spears around the open pit perimeter. The ‘intercepted’ water will be pumped to the TSF Cell 3 WMD. Excess 'intercepted' water within the MRM water management system will be either disposed to the McArthur River under an appropriate ‘controlled’ release strategy during high flows in the river or pumped off-site for irrigation use at the McArthur River Pastoral Lease (MRPL) (refer Appendix D12). A waste discharge licence would be required from NRETAS to allow controlled releases of 'intercepted' water stored in the TSF Cell 3 WMD to the McArthur River or off-site to MRPL (WRM, 2012).

The following sub-sections describe the various components of the MRM surface water management system proposed for the Project. The behaviour and performance of the proposed water management system (including existing and proposed water storages) over the mine life have been investigated using a long term water balance model, as described in Section 10.4.3.

10.4.2.1.1 Open Pit area Water Management

10.4.2.1.1.1 General

Figures 10-6 to 10-10 provide an overview of the surface water management measures proposed for the open pit area, including the South and East OEF areas. The locations and further detail on the proposed 'clean', 'dirty' and 'contaminated' surface water management measures in the open pit and South and East OEF areas for different stages of mining during the Project (2015, 2020 and 2025-2035 respectively) are provided in Appendix D3. Figure 10-11 shows a schematic of the proposed water circuit in the open pit area. Surface water management measures for the open pit area include the following (WRM, 2012) :

- An existing flood protection levee around the perimeter of the open pit.
- An erosion protection bund around the South and East OEFs
- Two (2) existing 'clean' runoff channels:
- The McArthur River Channel around the southern boundary of the open pit.
- The Barney Creek Channel around the northern boundary of the open pit.
- One new 'clean' runoff drain (S1)
- Several 'dirty' runoff drains
- Several sediment ponds
- Five (5) existing storages (APP, CRP, VDD, PP and LA).

The existing Eastern Levee Storage (ELS) and Old McArthur River (OMR) channel will be decommissioned during the Project because they are located within the proposed expanded open pit and East OEF footprints.

10.4.2.1.1.2 Open Pit Flood Protection levee

The open pit area is located on the floodplain of the McArthur River and is protected from McArthur River floodwaters by a flood protection levee. This levee 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 crest level of the existing flood protection levee is approximately 44 m AHD The proposed Phase 3 mining works will maintain the current level of flood protection (0.2% AEP) to the open pit from McArthur River flooding.

10.4.2.1.1.3 Erosion Protection Bund around South and East OEFs

The alignment of the proposed erosion protection bund around South and East OEFs is provided in Appendix D3. The following design criteria are applicable:

- The proposed bund will be constructed to protect the NAF dump from erosion from McArthur River and Barney Creek floodwaters for floods.
- The average height of the bund wall will vary from approximately 5m to 13m, to place the crest level at least above the 1% AEP (100 year ARI) level. The bund would be constructed with rocks from selected NAF material. The rocks will be sized to withstand erosive forces generated by floodwaters from the McArthur River and Barney Creek.
- The bund will be made out of permeable rock material to prevent NAF seepage water from building up within the South and East OEFs behind the bund wall. Rock will be adequately sized to protect against velocities in the McArthur River and Barney Creek for events greater than the 1% AEP (100 year ARI) flood

- The proposed bund will be set back at least 75 m from the closest top of bank of the McArthur River and Barney Creek diversion channels
- The bund will be constructed in advance of the South and East OEFs dumping schedule during the dry season to protect the dump and 'dirty' runoff drainage system ('dirty' runoff drains and sediment ponds) from potential erosion damage
- It is expected that parts wall of the proposed bund will be affected by McArthur River floodwaters every 2 to 5 years (on average).

10.4.2.1.1.4 The McArthur River and Barney Creek Channels

The McArthur River and Barney Creek were diverted in 2009 to allow for the progression of the existing MRM open pit operations. The channels are currently monitored regularly by mine staff for siltation and erosion within the channels and reported in the annual SDWMP (MRM, 2011). No changes are proposed to these existing channels as part of the Project.

The proposed North, South and East OEFs will constrict the McArthur River and Barney Creek floodplains adjacent to the dumps. The dumps could increase velocities in some sections of the McArthur and Barney Creek channels and floodplain during large flood events. Areas where there is potential for elevated velocities due to the proposed Project will be inspected after major flow events for any evidence of erosion. The key locations where velocities would be elevated and therefore should be monitored are identified as part of the flood impact assessment (Section 10.4.4). If it is found that erosion is taking place along the channels, additional rock protection may be required along the affected reaches. The monitoring schedules for the above channels have been documented in the SDWMP (MRM, 2011).

10.4.2.1.1.5 'Clean' Water Management Measures

A new 'clean' runoff drain approximately 0.3 km long (S1) will be constructed around the western end of the South OEF to collect and redirect 'clean' runoff into an abandoned portion of the McArthur River channel. The catchment area, adopted design standard and configuration of this 'clean' runoff drain are given in Appendix D3.

Temporary 'clean' runoff management measures including bunds, drains and re-contouring within the flood protection levee wall will be constructed as required to prevent 'clean' runoff from flowing into the open pit. Note that some of these 'clean' runoff management measures will be mined through as the open pit progresses to the east.

10.4.2.1.1.6 'Dirty' Water Management Measures

The proposed 'dirty' runoff drains will direct runoff from the South and East OEFs towards sediment ponds. Runoff and seepage from the South and East OEF area is anticipated to be 'dirty' and of a quality that can be released to the receiving waters after treatment in a sediment pond. If runoff and/or seepage from South and East OEF areas is found to be 'contaminated', active management measures and/or additional storage volume would be required to fully contain the contaminated water on site.

It is expected that 'dirty' runoff drains and sediment ponds located within the open pit flood protection levee will be operational (once constructed) for the full duration of the Project. Overflows from sediment ponds within the flood protection levee will be directed into the old McArthur River until it is filled as part of the East OEF, at which time the overflow will be directed into the open pit dewatering system.

'Dirty' runoff drains constructed on the outer perimeter of the dump (which is exposed to McArthur River and Barney Creek floodwaters) will be located on the inside toe of the proposed erosion protection bund. Runoff from the contributing areas will be directed to temporary sediment ponds located at the inside toe of the erosion protection bund. Overflows from the sediment ponds will either seep through the erosion protection bund or flow through a spillway (overflow) pipe through the erosion protection bund. The final design of the sediment pond spillways will depend on the permeability of the erosion protection bund. One-way flap gates may be required on the end of the sediment pond pipe spillway to prevent McArthur River water from back-flowing into the sediment pond during periods of high flow. The proposed drainage system would be protected from the McArthur River and Barney Creek flooding by the erosion protection bund. However, the proposed drainage system would be inundated by McArthur River floodwater seeping through the erosion protection bund on average every 2 to 5 years. Note that the 'dirty' runoff management controls located along the erosion protection bund will be progressively covered over by NAF material as the OEF dumps progress towards the erosion protection bund. Rehabilitating the OEF close behind the advancing face will be important in managing erosion once the ground level sediment controls are buried (WRM, 2012).

10.4.2.1.1.7 Water Storages

The 'dirty' and 'contaminated' water collected in the open pit and the infrastructure area located on the western side of the open pit will be managed using the five existing water storages in the open pit area. The locations of these storages, together with contributing catchment areas and expected land uses within the contributing catchments are provided in Appendix D3.Table 10-8 provides the adopted catchment areas, proposed storage capacity to the full supply level (FSL), maximum operating level (MOL) and optimal operating level (OOL) for each storage. All storages in the open pit area are located within the existing flood protection levee and any spills would eventually flow into the open pit. Hence, the expected environmental harm in the event of spills from these storages would be negligible. It is proposed that all storages within the open pit area have adequate storage capacity during the wet season to contain at least the runoff from a 20% AEP (5 year ARI) 24-hour rainfall event. Spillways of these storages should be sized to convey the peak discharge during a 0.05% AEP (2,000 year ARI) rainfall event. Evaporation from each storage will be enhanced by using sprinklers and sprays within the storage. The characteristics and operating protocols of each storage is discussed below (WRM, 2012).

Table 10-8 Open Pit Area Water Storage Capacities

Storage Name	Contributing Catchment Area (ha)	Stored Volume at FSL (ML)	Stored Volume at MOL (ML) [c]	Stored Volume at OOL (ML)
Pete's Pond (PP)	2.1	100	98	10
Anti Pollution Pond (APP)	14.5	23	12	10
Concentrator Runoff Pond (CRP)	13	27	17	17
Van Duncan's Dam (VDD)	38	35 [a]	6	6
Lake Archer (LA)	36	40 [b]	13	4

[a] It is proposed to increase the FSL of VDD to contain the 20% AEP 24 hour runoff event

[b] The FSL of Lake Archer will be increased to accommodate 'intercepted' groundwater inflows

[c] FSL - 20% AEP (5 year ARI) 24 hour rainfall depth (0.152 m) x the catchment area x volumetric runoff co-efficient of 0.5 (WRM, 2012)

Pete's Pond

Pete's Pond (PP) is a turkey's nest dam with no external catchment area. 'Contaminated' water will be pumped into PP from the open pit and underground mine void at a rate of up to 50 ML/d and from the TSF Cell 4 WMD as required at a rate of up to 20 ML/d. PP will be the distribution point for pit water and will supply water to the following locations in order of priority (from highest to lowest):

- Concentrator Runoff Pond (CRP) for use in the Mill at a rate of up to 10 ML/d
- Van-Duncan's Dam (VDD) for water cart use at a rate up to 4.15 ML/d
- Evaporation Fans at the open pit to enhance evaporation at a rate of up to 8.4 ML/d
- TSF Cell 4 WMD for containment and evaporation at a rate of up to 50 ML/d
- NOEF SPSD and SPROD to enhance evaporation at a rate of up to 7.78 ML/d

The storage capacity of PP to the FSL is approximately 100 ML. This will allow for storage of up to approximately 2 days of continuous pumped inflows during periods of peak pit dewatering. Overflows from PP will be directed into the open pit.

Anti Pollution Pond

The Anti Pollution Pond (APP) has a catchment area that could potentially generate 'contaminated' runoff from the ROM pad and associated lay down areas. 'Contaminated' water will be transferred to APP from CRP at an estimated rate of up to approximately 11.51 ML/d and return water from the TSF at an estimated rate of approximately 11.35 ML/d. The APP will supply process water to the Mill via the decant water tank (DWT) at an estimated rate of approximately 11.51 ML/d. The storage capacity of the APP to the FSL is approximately 23 ML. Overflows from APP will be directed overland via a constructed drain to the CRP.

Concentrator Runoff Pond

The Concentrator Runoff Pond (CRP) has a catchment area that could potentially generate 'contaminated' runoff from the processing area including the Mill. 'Contaminated' water overflowing from the Mill and DWT as well as used water from the industrial and vehicle wheel wash down areas will be directed overland to the CRP. 'Contaminated' water will also be transferred to the CRP from PP as required. The CRP will supply process water to the APP at an estimated rate of up to approximately 11.51 ML/d. The storage capacity of CRP to the FSL is approximately 27 ML. Overflows from CRP will be directed overland via a constructed drain to VDD.

Van Duncan's Dam

Van-Duncan's Dam (VDD) has a catchment area that could potentially generate 'dirty' runoff from NAF material in the West OEF. 'Contaminated' water will be transferred to VDD from PP, as required, at a rate of up to 4.15 ML/d. It is proposed to increase the storage capacity of VDD at FSL from 25 ML to 35 ML to allow for containment of the 20% AEP (5 year ARI) 24-hour rainfall event. VDD will supply water to water carts to be used for dust suppression around the mine site at an estimated rate of 3 ML/d over the life of the mine. Overflows from VDD will be directed into the open pit.

Lake Archer

Lake Archer (LA) has a catchment area that could potentially generate 'dirty' runoff from part of the West OEF and infrastructure area to the north-west of the storage. LA will collect and transfer 'intercepted' groundwater from dewatering bores and spears around the open pit to TSF Cell 3 WMD at a maximum rate of 20 ML/d. Overflows from LA will be directed into the open pit. The capacity of LA will be increased from 20 ML to 40 ML to allow for storage of up to approximately 2 days of 'intercepted' groundwater inflows during the wet season.

Underground Mine Void

Table 10–9 shows the adopted open pit invert (the deepest operating bench level), open pit surface area and the underground mine void storage volume for current, 2015, 2020, 2025, 2030 and 2035 mining stages. The runoff generated by rainfall onto the pit catchment area is potentially 'contaminated' water. Groundwater is also collected in the open pit. The open pit will be dewatered to PP at a maximum rate of 50 ML/d until the water level in the open pit drops below the open pit invert. Some of the 'contaminated' water pumped out of the open pit from PP will be sent back to the open pit via evaporation fans at an estimated rate of 5.0 ML/d (based on a 60% return rate from the evaporation fans).

The underground mine void will collect groundwater that flows into the void as well as 'contaminated' runoff draining from the open pit.

During the Project, the open pit will excavate down into the existing underground mine void. Hence, as the open pit progresses deeper, the available storage volume in the underground mine void will be reduced. The underground mine void dewatering bores are currently located at an elevation of 9730 m Local Mine datum (LMD). The underground mine void dewatering bores will have to be replaced with new deeper bores around year 2018 as the expanding pit will mine out the collar of the shaft. It is understood the lowest level of the underground mine void is at an elevation of 9590 mLMD (WRM, 2012).

Table10-9 Adopted Open Pit Invert and Surface Area and Underground Mine Void Storage Volume for Different Stages of Mining

Mine Year	Open Pit Invert (m Local Mine Datum)	Open Pit Surface Area (ha)	Underground Mine Void Volume (ML)
Current	9920	38	4,575
2015	9885	161	4,425
2020	9790	195	3,075
2025	9740	195	1,950
2030	9705	195	1,275
2035	9630	195	175

(WRM, 2012)

10.4.2.1.2 Tailings Storage Facility Area Water management

10.4.2.1.2.1 General

Figures 10-6 to 10-10 show an overview of the surface water management measures proposed for the TSF area. The locations and further detail on the proposed 'clean', 'dirty' and 'contaminated' surface water management measures in the TSF area for 2015-2030 and 2035 stages respectively are provided in Appendix D3. Figure 10-11 shows a schematic of the proposed water circuit in the TSF area. Surface water management measures for the TSF area include the following:

- One 'clean' runoff drain (T1- a&b)
- Several 'dirty' runoff drains
- Several sediment ponds
- Potential seepage controls
- TSF Cell 2, TSF Cell 3 and TSF Cell 4
- Two (2) TSF water management dams:
    - TSF Cell 3 WMD
    - TSF Cell 4 WMD

10.4.2.1.2.2 'Clean' Water Management Measures

'Clean' runoff drains approximately 0.9 km and 1.3 km long (T1 a&b) will be constructed around the outside wall of the TSF Cell 4 wall to collect and redirect 'clean' runoff from Little Barney Creek around the perimeter of the proposed TSF Cell 4 into the existing Little Barney Creek channel (WRM, 2012) .

10.4.2.1.2.3 'Dirty' Water Management Measures

The proposed 'dirty' runoff management controls will consist of 'dirty' runoff drains that direct runoff from catchment areas that generate 'dirty' runoff (such as rehabilitated TSF cells) to sediment ponds for treatment before releasing the water to the receiving waters including Surprise Creek and Barney Creek Rehabilitated TSF cells will be capped with clay, topped with NAF material and rehabilitated. It is expected that runoff from rehabilitated sections of the TSF will be of a suitable quality to discharge to the receiving environment after appropriate treatment via a sediment pond.

Note that until it can be demonstrated (via appropriate water quality monitoring) that runoff from rehabilitated tailings areas is of acceptable quality to be released to the receiving waters, runoff from rehabilitated areas will be considered 'contaminated' and will be directed or pumped to an active TSF cell for containment (WRM, 2012).

10.4.2.1.2.4 'Contaminated' Water Management Measures

The 'contaminated' water management controls at the TSF area will include two water management dams (TSF Cell 3 WMD and TSF Cell 4 WMD) and active TSF cells (for collection of concentrator tailings slurry from the Mill). The locations of the WMDs and TSF cells, associated catchment areas and expected land uses within the catchment area for different stages of the Project are provided in Appendix D3. Existing seepage trenches and sumps will be maintained around TSF Cell 2 & TSF Cell 3. Additional seepage trenches and sumps will be installed around the perimeter of the TSF as required to collect seepage runoff from the TSF. Seepage water collected in the sumps will be pumped to an active TSF Cell. Table 10-10 shows the adopted catchment areas, storage capacity to the FSL, MOL and OOL for each of the TSF area storages. It is proposed that storages in the TSF area have adequate capacity between the MOL and the FSL to contain runoff from a 1% AEP (100 year ARI)

24-hour rainfall event. WMD spillways will be sized to convey the peak discharge during a 0.05% AEP (2,000 year ARI) rainfall event. The operating strategy for each storage is discussed below (WRM, 2012).

Table 10-10 TSF Area Water Storage Capacities

Storage Name	Contributing Catchment Area (ha)	Stored Volume at FSL (ML)	Stored Volume at MOL (ML)	Stored Volume at OOL (ML)
TSF Cell 3 WMD	25[a]	532	457	457
TSF Cell 4 WMD	65	4,300	4,100	500

[a] After 2015 (WRM, 2012)

10.4.2.1.2.5 TSF Cell 3 WMD

The capacity of the existing TSF Cell 3 WMD will be reduced from approximately 1,830 ML to 532 ML to allow for the construction of the tailings storage component of Cell 3 in 2015. TSF Cell 3 WMD is a turkeys nest dam with a surface area of approximately 129 ha prior to 2015 and 25 ha after 2015. The TSF Cell 2 and Cell 3 spillways report to the TSF Cell 3 WMD. However, these Cells will be designed to contain water up to a 0.5% AEP (200 year ARI) rainfall event before water would spill into the TSF Cell 3 WMD. The TSF Cell 3 WMD will be used to contain 'intercepted' groundwater from the groundwater dewatering bores and spears in the mining area (via Lake Archer). The priority of use for water stored in the TSF Cell 3 WMD is as follows (from highest to lowest priority) (WRM, 2012):

- Mine site process uses such as makeup water to the mill and dust suppression and evaporation
- Controlled releases to the McArthur River, when conditions permit
- Irrigation supply to the McArthur River Pastoral Lease.

The following operational aspects of the TSF Cell 3 WMD are proposed (WRM, 2012):

- Permanent pumping infrastructure with a capacity of approximately 20 ML/d will be provided linking the TSF Cell 3 WMD to the 'intercepted' groundwater dewatering system (via Lake Archer)
- Pumping infrastructure with a capacity of approximately 20 ML/d will be provided to the TSF Cell 4 WMD to maintain the TSF Cell 4 WMD’s OOL storage volume of 500 ML and use within the MRM water management system
- The water storage will be maintained at an optimum volume of 457 ML during the wet season. When flows in the McArthur River allow, controlled releases will be made from the TSF Cell 3 WMD of up to 60 ML/d to the McArthur River via a pipeline. Discharges would be carried out in accordance with a discharge licence to be negotiated with the NRETAS
- Pumping infrastructure with a capacity of approximately 20 ML/d will be provided to link the TSF Cell 3 WMD to the proposed irrigation water supply dam on the McArthur River Pastoral Lease. The design and operation protocols of the irrigation water supply dam are described in Appendix D12.

The quality of 'intercepted' groundwater is assumed to be acceptable for irrigation activities and for controlled release to the McArthur River. If this assumption is incorrect, water in the TSF Cell 3 WMD would have to be evaporated, or treated to an acceptable quality before reuse or discharge off-site. Possible water treatment options will be investigated if water quality monitoring indicates treatment of groundwater will be required.

10.4.2.1.2.6 TSF Cell 4 WMD

The TSF Cell 4 WMD will be a turkey's nest dam approximately 65 ha in surface area with no external catchment area. The TSF Cell 4 wall will be required prior to Project operations commencing and will therefore be constructed during 2012, separate to the Project development and used for 'contaminated' water storage until it is scheduled to collect concentrator tailings from the Mill in 2032. Approval for the TSF Cell 4 WMD has been sought through an alternative approvals mechanism. The TSF Cell 4 WMD will contain potentially 'contaminated' water pumped from the open pit and underground mine void (via PP). The following operational aspects with respect to the TSF Cell 4 WMD are proposed (WRM, 2012):

The storage capacity to FSL is approximately 4,300 ML

- Permanent pumping infrastructure with a capacity of approximately 50 ML/d will be provided to link TSF Cell 4 WMD (via PP) to the open pit
- The stored volume will be maintained at an OOL storage of 500 ML (when possible) to maximise evaporation from the surface of the dam, as well as providing emergency storage during wet periods. This will be achieved by pumping water from the TSF Cell 3 WMD during dry periods to maximise evaporation and reuse for operational purposes such as process water in the Mill and dust suppression
- The MOL is 4,100 ML. If the MOL in the TSF Cell 4 WMD is exceeded, excess pit water will be held in the open pit without pumping to PP
- Evaporation will be enhanced using the existing evaporation fans at the TSF. However, evaporating supernatant water from the active TSF cells will have a higher priority than evaporating water in the TSF Cell 4 WMD
- During dry periods, water will be transferred to PP at a maximum rate of 20 ML/d for process uses on-site including the Mill and dust suppression, as required.

In year 2032, when TSF Cell 4 is expected to begin collecting concentrator tailings from the Mill, an alternate on-site water management storage may be required to draw down the remaining water in the TSF Cell 4 WMD and collect and store pit water for the final four years of mine life. It is possible that some of the proposed PAF Runoff Dams around NOEF may be available at this time. The additional post-2032 storage requirement will be assessed in the future when more Project operational data becomes available.

10.4.2.1.2.7 TSF Cell 2, TSF Cell 3 and TSF Cell 4

TSF Cell 2, Cell 3 and Cell 4 will collect concentrator tailings from the mill throughout the life of mining operations, in addition to direct rainfall onto the surface of the cells. Table 10-11 shows the adopted surface area and years when concentrator tailings are deposited from the Mill. The following operational aspects with respect to the TSF water management system is proposed (WRM, 2012):

- Available water quality monitoring data shows that tailings slurry water contained within the TSF substantially exceeds the ANZECC (2000) water quality guidelines for a 95% level of protection in freshwater ecosystems. This water is considered 'contaminated' and management measures will be implemented to contain and reuse this water within the Project mining water management system. This water will be used for makeup water in the concentrator Mill, dust suppression and disposal using enhanced evaporation measures such as evaporation fans, sprinklers and sprays
- The TSF will be operated with a perimeter spigot arrangement with a central pond so that tailings slurry gravitates towards the centre of the cell to create a dry beach around the edges of the cell. It is intended

that this arrangement will minimise the peizometric head at the walls of the cell and hence minimise the seepage under the walls

- An underdrainage network will be considered beneath the TSF cell 4 that will collect seepage from the TSF to a sump. Any seepage runoff collected in these sumps will be pumped back into the pond within an active TSF cell
- TSF Cell 4 will be appropriately sealed or lined to control seepage through the base and wall of the Cell
- Active TSF cells will be designed to capture and retain rainfall falling directly onto the cell for rainfall events up to the 0.05% AEP (200 year ARI).

Table10-11 TSF Surface Area and Years of Operation for Cell 1, Cell 2, Cell 3 and Cell 4

TSF Cell ID	Adopted Surface Area (ha)	Years of Active Tailings Deposition
Cell 1 (decommissioned)	78	N/A
Cell 2	116	Current - 2030
Cell 3	98	2015 - 2032
Cell 4	65	2032 - 2036

(WRM, 2012)

10.4.2.1.3 North Overburden Emplacement Facility Area Water management

10.4.2.1.3.1 General

Figures 10-6 to 10-10 provide an overview of the surface water management measures proposed for the NOEF area. The locations and further detail on the proposed 'clean', 'dirty' and 'contaminated' surface water management measures in the NOEF area for different stages of mining during the Project (2015, 2020, 2025, 2030 and 2035 respectively) are provided in Appendix D3. Figure 10-11 shows a schematic of the proposed water circuit in the NOEF area. Surface water management measures for the NOEF area include the following (WRM, 2012):

- Six 'Clean' runoff drains (N1 to N6)
- Several 'dirty' runoff drains
- Several sediment ponds
- The existing SPSD and SPROD PAF dams
- Four (4) additional PAF runoff dams including:
- South-East PAF Runoff Dam (SEPROD)
- East PAF Runoff Dam (EPROD)
- North-East PAF Runoff Dam (NEPROD)
- North-West PAF Runoff Dam (NWPROD).

A description of the NOEF NAF/PAF encapsulation and drainage system within the NOEF is described in Appendix E2. In summary, the management of 'dirty' and 'contaminated' runoff from the NOEF will be staged and vary as the material dumped on the NOEF switches from NAF to PAF and back to the final layer of NAF. The type of management measures required for runoff from various sub-catchment areas within the dump will depend on the type of material being placed on the dump at a given point in time. It is expected that areas of the NOEF that contain NAF material will generate 'dirty' runoff and seepage (both before PAF material is placed on the NAF material and after all PAF material in the contributing catchment area is encapsulated by clay capping and topped with NAF material) and will require only a sediment pond for treatment before release to the receiving waters. Areas of the NOEF that contain exposed PAF material could generate 'contaminated' runoff and seepage and has been assumed to require a water storage appropriately sized for containment of all runoff generated from the contributing catchment area .

The years where PAF is exposed in the contributing catchment areas of the proposed PAF runoff storages are provided in Table 10-12. The proposed annual staging of catchments draining to each of the storages around the NOEF over the life of the Project is provided in Appendix D3. The years when NAF material drains to the designated storage is shaded light blue and the years when PAF material drains to the designated storage is shaded in brown. Note that the Western PAF sediment dam (WPSD) has not been sized for containment of PAF runoff because the proposed dump drainage has been designed so that this storage only collects runoff from catchment areas containing NAF material.

Table 10-12 Estimated Storage Volumes Required for 5% Probability of Exceedance When Exposed to PAF Material

Storage Name	Years Exposed to Rainfall Runoff from PAF	Maximum Contributing Catchment Area (ha)		5% Probability of Exceedance of Storage Volume When Exposed to PAF Material (ML)	Adopted Minimum Spillway Elevation (m AHD)
		When Exposed to PAF Material	All Years		
SPROD + SPSD	26 (2011-2037)	166.6	166.5	810	40.2
NWPROD	12 (2022-2027)	85.8	108.5	805	40.2
SEPROD	4 (2013-2016)	51.0	85.0	343	39.3
EPROD	8 (2015-2022)	75.6	75.6	500	39.2
NEPROD	3 (2024-2026)	94.0	121.8	698	38.9

(WRM, 2012)

10.4.2.1.3.2 'Clean' Water Management Measures

Six 'clean' runoff drains are proposed around the NOEF to collect and redirect 'clean' runoff away from areas disturbed by mining. The proposed 'clean' runoff drains include:

- A 1.6 km long drain (N1) located around the western side of the NOEF that will direct 'clean' runoff to Surprise Creek
- Four drains, 1.4 km, 2.5 km, 1.1 km and 0.6 km long (N2–a,b,c&d) located around the north-western side of the NOEF that will direct 'clean' runoff to a tributary of Emu Creek

- A 1.5 km long drain (N3) located around the northern side of the NOEF that will direct 'clean' runoff to a tributary of Emu Creek
- A 1.0 km long drain (N4) located around the north-eastern side of the NOEF that will direct 'clean' runoff to a tributary of Emu Creek
- A 0.3 km long drain (N5) located around the south-eastern side of the NOEF that will direct 'clean' runoff around a proposed PAF Runoff Dam into a tributary of Barney Creek
- A 1.1 km long drain (N6) located around the south side of the NOEF that will direct 'clean' runoff to Barney Creek.

10.4.2.1.3.3 'Dirty' Water Management Measures

The proposed 'dirty' runoff management measures will consist of 'dirty' runoff drains that direct runoff from catchment areas that generate 'dirty' runoff to sediment ponds for treatment before releasing the water to the receiving waters including Surprise Creek, Barney Creek and Emu Creek. The NOEF sediment ponds will collect runoff from catchment areas that may potentially generate 'dirty' runoff including NAF waste dumps and topsoil stockpiles. Sediment ponds around the perimeter of the NOEF will collect runoff both before PAF material is placed on the NAF material and after all PAF material in the contributing catchment area is encapsulated in clay and topped with NAF material. 'Dirty' runoff drains around the base of the NOEF will direct runoff to the sediment ponds. Sizing and design of the NOEF sediment ponds will be undertaken during detailed design of the NOEF.

Permanent sumps will be installed immediately upstream of the connected sediment ponds in locations where seepage runoff from the NOEF report to the 'dirty' runoff drains. During dry days, any seepage reporting to the sumps will be pumped to a PAF Runoff pond. During wet days, seepage together with surface runoff will flow down the 'dirty' runoff drain, fill up the sump storage and overflow into to a sediment pond for treatment. After treatment, water will be pumped out of the sediment pond to the receiving waters, provided the water quality is within the trigger limits specified in the waste discharge licence. Any surface runoff water collected in the seepage sump will be pumped to a PAF runoff pond.

The runoff collected in sediment ponds from NAF material surfaces on top of encapsulated and capped PAF material is assumed to be of acceptable quality for release to the receiving waters. Monitoring of water quality in these sediment ponds would be required to demonstrate that the water quality is within the limits specified in the waste discharge licence prior to release into receiving waters.

10.4.2.1.3.4 PAF Runoff Storages

PAF runoff storages have contributing catchment areas that would potentially generate 'contaminated' runoff such as areas within the NOEF that contain exposed (uncapped) PAF material. Table 10-12 shows the maximum catchment area, storage volume at FSL and years where PAF is exposed in the contributing catchment area for the proposed PAF runoff dams. The PAF runoff dam walls will be built up above the natural ground surface so that the PAF runoff dam spillway levels will be elevated above the McArthur River 1% AEP (100 year ARI) flood level. The required PAF dam spillway elevation is also provided in Table 10-12.

The PAF runoff storages have been sized to fully contain potentially 'contaminated' runoff during periods when PAF material is exposed within the contributing catchment areas. Once all PAF material within the contributing catchment area is capped with clay and NAF material placed on top of the sealed PAF material, the storages will then be allowed to spill. This assumes that runoff from contributing catchment areas after the PAF material has been capped is 'dirty' runoff and can be released to the receiving waters after treatment in a sediment pond. If proposed water quality monitoring shows that this assumption is incorrect, active management measures and/or additional storage volume will be required to fully contain the 'contaminated' water running off the NOEF surfaces until it can be demonstrated that all PAF material within the catchment area has been adequately encapsulated and the surface runoff is of a suitable quality to discharge to the receiving environment (after treatment via sediment ponds).

For the EIS, it was assumed that the new NOEF containment water storages would operate in isolation from the existing mine process water system, except for SPROD and SPSD. Pit water will be pumped at 7.78 ML/d from PP to SPROD and SPSD to a MOL volume of 200 ML and 50 ML, respectively, to maximise evaporation of 'contaminated' water at the mine site.

The PAF Runoff storage volumes at FSL have been determined from the results of the water balance modelling described in Section 10.4.3. The water balance model was run over 26 years (2011-2037) to simulate the performance of the proposed PAF runoff storages during the various mine stages when PAF area runoff is collected. The model was run for 86 separate sequences of rainfall and evaporation generated from 120 years (1900-2011) of synthetic (SILO) data.

Evaporation from the PAF runoff storages will be enhanced using sprinklers and sprays on the storage embankments similar to the sprinkler system currently used at SPSD and SPROD storages. Based on model results described in Appendix D3, the use of evaporation sprinklers and sprays would reduce the required size of the PAF storages by approximately 40%.

The adopted FSL for the PAF runoff storages are based on the 95th percentile volume of water predicted to accumulate in the PAF runoff storage during the period of time that PAF material is expected to be exposed in the contributing catchment area. That is, there is a 5% probability of exceedance that the adopted storage would overflow whilst PAF material is exposed in the contributing catchment area.

10.4.2.2 Infrastructure Design Criteria

The design criteria and concepts for the surface water management infrastructure discussed in the sections above are provided in Appendix D3. This includes:

- ‘Clean’ runoff drains
- ‘Dirty’ runoff drains and sediment ponds
- ‘Contaminated’ Water Storages.

10.4.2.3 Controlled Releases to the McArthur River

It is proposed to dispose 'intercepted’ groundwater under the MRM WDL174-1 conditions outlined in Section 10.2.8. Controlled releases of up to 60 ML/d will be made via a proposed pipeline approximately 4 km long from TSF Cell 3 WMD to the McArthur River, when conditions permit.

The MRM WDL174-1 water quality trigger values for discharges from the mine are based on the quality of mine levee water and the limiting factor for determining the dilution rate appears to be based on the eco-toxicology factors rather than water quality trigger levels. The most recent eco-toxicology testing has found that mine levee water from OMR should be diluted by a factor of 25 with McArthur River water to provide adequate protection of the downstream ecosystem. The eco-toxicology report also found that the concentration of zinc, which was 33 μg/L was adequate to explain the toxicity of the mine water. The relationship between metal concentrations and toxicity to aquatic organisms is complex and it may be non-linear in nature. However, assuming that the relationship is linear and zinc is the limiting parameter, the dilution factor required for the discharge of ‘intercepted’ groundwater at the mine site (based on available palaeochannel groundwater quality data given in SDWMP (MRM, 2011)) would be in the order of 333.

Based on a dilution factor of 333, an analysis of the McArthur River flow record at the MIM Pump station (43 years of data) shows that the potential rate of discharge of 'intercepted’ groundwater to the McArthur River will be in the order of 0.1 GL/yr, 0.9 GL/yr and 4.8 GL/yr for a 90th percentile (dry) year, 50th percentile (median) year and 10th percentile (wet) year respectively.

10.4.2.4 Off-Site Irrigation Supply

It is proposed to reuse 'intercepted' groundwater off-site to MRPL for irrigation activities. An additional water storage will be constructed at the MRPL to store and manage the water transferred from MRM. The MRM water management system has been configured to only send irrigation water to MRPL if there is no capacity within the MRM on-site water management system and controlled releases cannot be made to the McArthur River. Pumping infrastructure with a capacity of approximately 20 ML/d will be provided to link TSF Cell 3 WMD to the proposed irrigation supply dam on MRPL.

Options for the proposed use, storage and management of MRM water supplied to MRPL for irrigation (including the sizing of the proposed irrigation supply dam) are summarised in the sections below and discussed in detail in Appendix D12.

10.4.2.5 Water Quality

The assessment of the suitability of MRM groundwater for irrigation use has been made by comparison of sample data to the ANZECC long term trigger values for irrigation, and stock watering guidelines. Water quality data has been taken from sampling records of nine bores intercepting the paleochannels and weathered rock. Comparisons of the sample data to the guidelines is provided in Table 10-13 (TCT, 2011).

Table 10 –13 Comparison of groundwater quality to ANZECC guidelines

Category	Unit	Value	ANZECC long term trigger value – Irrigation	ANZECC stock watering guidelines
Physico-chemical				
pH		7.35	6 – 8.5	
Electrical Conductivity (EC)	µS/cm	1451		
Salinity (PSS)		0.56		
Total Dissolved Solids (TDS)	mg/L	869		4,000
Turbidity (NTU)		44.3		
Dissolved Oxygen	mg/L	0.76		
Hardness	mg/L	751	<60[1] >350[2]	
Cations				1,000
Calcium	mg/L	109		
Magnesium	mg/L	110		
Sodium	mg/L	48.3	230[3]	
Potassium	mg/L	0.0087		
Sulphate	mg/L	130		1,000

Table 10 –13 Comparison of groundwater quality to ANZECC guidelines (cont)

Category	Unit	Value	ANZECC long term trigger value – Irrigation	ANZECC stock watering guidelines
SAR		0.70		
Anions				
Chloride	mg/L	118	350[4]	
Carbonate/Bicarbonate alkalinity	mg/L	751		
Metals				
Arsenic	mg/L	0.0042	0.1	0.5
Cadmium	mg/L	0.00017	0.01	0
Copper	mg/L	0.00065	0.2	1
Lead	mg/L	0.0014	2	0.1
Zinc	mg/L	0.056	2	20

1 - Hardness <60 with respect to corrosion

2 – Hardness >350 with respect to fouling

3 – With respect to foliar injury to moderately tolerant plants

4 – With respect to increased cadmium uptake by crops (<300mg/L for foliar injury to moderately tolerant plants) (TCT, 2011)

The comparison showed that only hardness is outside the guidelines; however, hardness does not present issues for the environment of plant growth, only potential for scaling and corrosion of irrigation equipment. An analysis of the nature of the minerals causing hardness revealed that they are not corrosive, and would only cause scaling. This problem can be managed by periodic flushing of irrigation systems to dissolve the build-up.

Importantly, salinity is not expected to be a constraint. The salinity level indicated by the EC of 1451 µS/cm is below the 2000 µS/cm threshold for plant health. Careful selection of soils and operation of the irrigation system can adequately manage these levels.

High sodicity, which can lead to degradation of the soil structure, was also assessed and found to be below appropriate limits.

Therefore, the available water quality data indicates that MRM groundwater, if intercepted before the active mining areas, is of a suitable quality to be used for irrigation in suitable soils with appropriate irrigation management without any treatment. Further water quality sampling and analysis, including complete water analyses (covering major anions and cations, pH, conductivity and total alkalinity) will be required for the detailed design phase.

10.4.2.6 Water Quantity

As water for irrigation is the lowest priority destination for excess groundwater, the flows sent to irrigation are predicted to be variable, both from year to year (depending on the annual rainfall) and between months, though most flows to irrigation would occur between the months of April and July (WRM, 2012). Table 10-14 (TCT, 2012) below shows the variability that may be expected.

The size of infrastructure for the irrigation system has been based on the largest flows expected to provide adequate capacity when required.

Table 10-14 – Irrigation supply volumes for a range of scenarios

Scenario	Minimum flow		Average flow		Maximum flow	
	ML/yr	ML/day	ML/yr	ML/day	ML/yr	ML/day
10th percentile (dry)	184	0.5	995	2.7	2,064	5.7
50th percentile (median)	384	1.4	1,113	3.1	2,100	5.8
90th percentile (wet)	260	0.7	1,129	3.2	2,272	6.2

(TCT, 2011)

10.4.2.7 Irrigation Concepts

Based on the water quality and quantities expected, an assessment of the viability of irrigation was made. The concept of this irrigation program is to use excess groundwater to grow pasture suited to cattle grazing, whilst the deep soil zones store residual elements below the root zone. This enables the plants to remain healthy due to sufficient water without being impacted by adverse chemistry. Plant and soil selection, and irrigation management are key elements in a successful irrigation system.

An analysis of various potential systems (including contour bank flood irrigation and tree crops) identified pivot irrigation of pastures as the most suitable system for the MRM area (refer Figure 10-12). The key components of a system at MRM would consist of the following items:

- Groundwater would be extracted from around the pit using submersible pumps in boreholes
- The groundwater would be stored at the Cell 3 WMD out at the TSF area
- Pumps would move the water from here to a holding dam located at the irrigation fields, through suitably sized polyethylene pipes.
- Centre pivot structures with sprinklers would distribute the water over the fields

Figure 10-12 An example of a Pivot Irrigation System

Irrigation would be managed effectively to balance water disposal requirements with plant water demand. Networks of induction probes inserted in the soil would provide real time measures of moisture and relative salinity in the soil, to optimise water allocation without waterlogging. Irrigation would be intermittent, with selected grazing in between irrigation once the pastures have been established.

10.4.2.7.1 Site Selection

Suitable sites for irrigation will be identified in the detailed design phase of the irrigation investigations. The key parameters to be used in this search will include:

- Soil selection
    - Physical properties - soil type, structure, thickness and profile, permeability, particle size
    - Chemical properties – nutrients, salinity
- Terrain – slope is ideally less than 4° so that pivot machinery does not become unstable.
- Proximity to mine site. Closer sites will reduce distribution costs. Fields are preferably on the same side of the river to avoid flooding access issues and possible damage of pipe crossings.
- Groundwater
    - No shallow groundwater flows that could mobilise contaminants

- Surface water
  - Out of flood zones
  - Buffer zones to watercourses

10.4.2.7.2 Prospective Soil Types

TCT (2011) reviewed the available data for soils over the project area and identified that yellow and red earth and dermasol soils would likely be suitable for irrigation. The areas available in close proximity to the mining leases give confidence that extensive areas well in excess of that required would be likely on the neighbouring pastoral leases where cattle operations could benefit from the pastures.

10.4.2.7.3 Pastures for Consideration

The final selection of pastures will depend on the results of detailed soil mapping and analysis, to best match the plants to the conditions. TCT (2011) recommend that legumes are grown in conjunction with grasses to help provide nitrogen for healthy grass growth. Some grasses and legumes were precluded from further consideration due to their high weed potential. Possible species (TCT, 2012) include:

- Grass species
  - Rhodes grass (Chloris gayana cv Callide & Fine cut)
  - Kazungula setaria (Setaria sphacelata (anceps) cv kazungula)
  - Bisset creeping blue grass (Bothriochloa insculpta cv Bisset)
  - Tully humidicola – (Brachiara humidicola cv Tully)
- Lugumes
  - Glenn and Lee joint vetch
  - Centrosema marcrocarpum (brasilianum)
  - Vigna luteola

10.4.2.7.4 Assumptions and Specifications

An analysis of all the inputs resulted in the key parameters presented in Table 10-15.

Table 10-15 Pasture Irrigation Design Parameters (per year)

Parameter	Unit	Value for 90th percentile rainfall year
Total groundwater produced	ML	2,272
Minimum pastrure area required	ha	125
Annual watering rate	mm/ha/yr	1,796
Minimum pond storage required	ML	652
Net pond loss/(gain)	ML	97
Total excess rainfall	mm	342

Table 10-15 Pasture Irrigation Design Parameters (per year) (cont)

Parameter	Unit	Value for 90th percentile rainfall year
Months of excess rainfall	#	4
Irrigation method and rotation type		Sprinkler – pivot
Leaching fraction	%	12%
Proportion of max. irrigation load applied	%	100%

(TCT, 2011)

The area required for irrigation is relatively small in comparison to the size of the pastoral leases.

10.4.2.7.5 Irrigation Management and Monitoring

A sound irrigation operation will identify and manage many aspects to minimise the potential for detrimental environmental impacts.

The pipe between the mine and irrigation fields would have instrumentation to detect any pressure changes associated with a pipe rupture. This would shut down the pumping system, minimising the volume of water spilled. As the chemical composition is not expected to be outside ANZECC guidelines, the potential for environmental harm due to a spill is considered low. Regular pipe inspections and pressure testing should enable preventative maintenance on pipes to reduce the potential for unexpected failure.

Monitoring is an essential part of an irrigation system, both for environmental compliance and effectively managing the water and land resources. The following monitoring would be undertaken:

- Use induction probes to monitor moisture levels in the soil profile, as well as changes in salinity. These probes can be wired into a 'real time' monitoring system to alert operators of any out-of-specification soil characteristics
- Groundwater monitoring including: water levels, conductivity, and periodic full chemical analysis
- Surface water monitoring
- Monitor biomass for optimal nutrient management
- Periodic soil sampling of structure and chemistry.

10.4.3 Water Balance Modelling

Water balance modelling was undertaken to develop and assess the proposed water management system. This section provides a summary of the water balance methodology and results. Details of the model inputs, configuration and calibration are provided in Appendix D3.

10.4.3.1 Approach

AWBM rainfall runoff models (Boughton, 2003) were developed to estimate runoff volumes from different land use types (hardstand, pit, stockpile and natural areas) as well as flows in the McArthur River at the MRM site. The Goldsim model (Goldsim Technology Group, 2011) was then used to simulate the long-term behaviour of the water management system at MRM and determine the mine site water balance for existing and proposed Project mining operations.

The Goldsim model was used to assess the performance of the MRM water management system and included the determination of:

- The long-term behaviour of the various on-site storages
- The ability and reliability of the various on-site storages to supply the mine site water requirements
- The sizes of proposed new storages at the MRM site
- The frequency and volume of potentially 'dirty' and/or 'contaminated' water overflows from various on-site storages
- The ability to dewater the open pit within acceptable time frames
- The frequency and volume of 'intercepted' groundwater disposed to the McArthur River and MRPL for irrigation supply
- The overall site water balance.

The Project mine site GoldSim model was run on a daily time step over 26 years to simulate the performance of the proposed water management system during the various mine stages. The model was configured for 6 stages of mining operations to represent the open pit progression over the mine life:

1. Stage 2011 - applies for the 2011-2013 period (2 years)
2. Stage 2015 - applies for the 2013-2017 period (4 years)
3. Stage 2020 – applies for the 2017-2022 period (5 years)
4. Stage 2025 - applies for the 2022-2027 period (5 years)
5. Stage 2030 - applies for the 2027-2032 period (5 years
6. Stage 2035 - applies for the 2032-2036 period (4 years).

The water management system performance was assessed for the dry (10th percentile), median (50th percentile) and wet (90th percentile) 26-year simulations based on historical rainfall records.

A second GoldSim model was used to better simulate the performance of the proposed North OEF PAF Runoff dams as configuration of the North OEF areas draining to the PAF runoff dams change over the 26 years of mine life.

Both models were run for 86 separate sequences of rainfall and evaporation generated from 121 years (1889-2011) of SILO data. The use of such a long period of continual data would provide a good indication of the behaviour of the various on-site storages at MRM over extended dry and wet periods.

10.4.3.2 Model Results

Table 10-16, Table 10-17 and Table 10-18 present representative long-term mine site water balance results for different stages of mining based on simulation results for the dry (90th percentile), median (50th percentile) and wet (10th percentile) 26-year rainfall sequences. It should be recognised that rainfall, runoff, evaporation and controlled release components of the water balance would be highly variable from year to year because they are subject to climatic variability.

The MRM site is a net producer of water due to the substantial amounts of groundwater inflows to the open pit and underground mine void and high rainfall and runoff during the wet season. Almost all of the direct rainfall and surface runoff inflows to the MRM water management system are generated during the wet season between October and April. During the dry season, the only significant inflows to the MRM water management system are generated from groundwater sources. A major component of the proposed water management system is enhancement of evaporation losses via the use of evaporation fans, sprinklers and water fountains.

Table 10-16 Summary Annual Average Water Balance, Dry Rainfall Sequence (1940 to 1966)

Component	Process	Average Volume (ML/y)						
		2012 (2 years)	2015 (4 years)	2020 (5 years)	2025 (5 years)	2030 (5 years)	2035 (5 years)	Total (26 years)
Inflows	Direct Rainfall	857	823	680	505	645	471	635
	Surface Runoff	1,329	2,434	1,885	1,533	1,894	1,213	1,732
	Groundwater	4,660	4,750	5,293	5,922	6,015	6,112	5,578
	Borefields	731	731	730	730	731	730	731
	Raw Feed Moisture	191	191	191	191	191	191	191
	Total	**7,769**	**8,928**	**8,779**	**8,882**	**9,476**	**8,717**	**8,866**
Outflows	Evaporation	2,896	1,922	1,907	1,751	1,980	1,507	1,892
	Spray Fans	2,171	2,101	2,131	2,203	2,179	2,148	2,156
	Sprinklers/Water Fountain	1,361	1,355	1,360	1,360	1,361	1,360	1,359
	Irrigation	5	387	699	1,184	1,377	1,007	881
	Water Cart Usage	1,096	1,096	1,096	1,096	1,096	1,096	1,096
	Truck Wash	15	15	15	15	15	15	15
	Potable Use	194	194	194	194	194	194	194
	Industrial Use	15	15	15	15	15	15	15
	Product Moisture	120	120	120	120	120	120	120
	TSF Moisture Retention	493	493	492	492	493	492	493
	Seepage losses	64	63	48	33	46	9	41
	Off-site Releases	1,144	1,198	1,001	579	889	719	885
	Total	**9,573**	**8,956**	**9,077**	**9,041**	**9,764**	**8,679**	**9,145**
Change in Site Water Inventory		-1,799	-28	-298	-159	-288	38	-279

(WRM, 2012)

Table 10-17 Summary Annual Average Water Balance, Median Rainfall Sequence (1934 to 1960)

Component	Process	Average Volume (ML/y)						
		2012 (2 years)	**2015 (4 years)**	**2020 (5 years)**	**2025 (5 years)**	**2030 (5 years)**	**2035 (5 years)**	**Total (26 years)**
Inflows	Direct Rainfall	876	1071	792	693	585	570	740
	Surface Runoff	1,715	3,289	2,017	1,951	1,710	1,648	2,047
	Groundwater	4,660	4,750	5,293	5,922	6,015	6,112	5,578
	Borefields	731	731	730	730	731	730	731
	Raw Feed Moisture	191	191	191	191	191	191	191
	Total	**8,173**	**10,031**	**9,023**	**9,488**	**9,232**	**9,251**	**9,286**
Outflows	Evaporation	3,142	2,117	2,224	1,952	1,839	1,590	2,030
	Spray Fans	2,250	2,123	2,139	2,139	2,187	2,162	2,159
	Sprinklers/Water Fountain	1,361	1,360	1,360	1,360	1,361	1,360	1,360
	Irrigation Supply	5	421	1,245	1,008	1,366	1,166	985
	Water Cart Usage	1,096	1,096	1,096	1,096	1,096	1,096	1,096
	Truck Wash	15	15	15	15	15	15	15
	Potable Use	194	194	194	194	194	194	194
	Industrial Use	15	15	15	15	15	15	15
	Product Moisture	120	120	120	120	120	120	120
	TSF Moisture Retention	493	493	492	492	493	492	493
	Seepage losses	63	64	69	49	40	13	48
	Off-site Releases	942	1237	1040	1181	818	950	1030
	Total	**9,694**	**9,253**	**1,0007**	**9,620**	**9,543**	**9,172**	**9,543**
Change in Site Water Inventory		-1,516	778	-984	-132	-311	78	-256

(WRM, 2012)

Table 10-18 Summary Annual Average Water Balance, Wet Rainfall Sequence (1928 to 1954)

Component	Process	Average Volume (ML/y)						
		2012 (2 years)	2015 (4 years)	2020 (5 years)	2025 (5 years)	2030 (5 years)	2035 (5 years)	Total (26 years)
Inflows	Direct Rainfall	1,289	895	728	1,037	682	518	807
	Surface Runoff	2,859	2,347	2,257	2,691	1,950	1,468	2,190
	Groundwater	4,660	4,750	5,293	5,922	6,015	6,112	5,578
	Borefields	731	731	730	730	731	730	731
	Raw Feed Moisture	191	191	191	191	191	191	191
	Total	**9,730**	**8,913**	**9,199**	**10,571**	**9,69**	**9,019**	**9,496**
Outflows	Evaporation	2,821	2,247	2,023	2,345	1,986	1,541	2,081
	Spray Fans	2,171	2,129	2,187	2,125	2,153	2,168	2,155
	Sprinklers/Water Fountain	1,361	1,360	1,360	1,360	1,361	1,360	1,360
	Irrigation	5	1,210	870	1,444	1,410	952	1,086
	Water Cart Usage	1,096	1,096	1,096	1,096	1,096	1,096	1,096
	Truck Wash	15	15	15	15	15	15	15
	Potable Use	194	194	194	194	194	194	194
	Industrial Use	15	15	15	15	15	15	15
	Product Moisture	120	120	120	120	120	120	120
	TSF Moisture Retention	493	493	492	492	493	492	493
	Seepage losses	63	71	53	70	53	12	52
	Off-site Releases	1,833	857	936	1,263	1,099	1,086	1,116
	Total	**10,187**	**9,805**	**9,360**	**10,538**	**9,994**	**9,050**	**9,781**
Change in Site Water Inventory		-452	-892	-162	34	-425	-32	-284

(WRM, 2012)

Figure 10-13 provides a schematic of the Project site water balance.

10.4.3.2.1 TSF Cell 4 WMD Storage Behaviour

As discussed in Section 10.4.2, the TSF Cell 4 WMD will be constructed in 2012 to store pit water until 2032. The results show that a groundwater interception rate of 70% enables the open pit to be fully drained to TSF Cell 4 WMD at an uninterrupted dewatering rate of up to 50 ML/d, and with minimum disruption to mining in the open pit. It is noted that should the capacity of the TSF Cell 4 WMD be reached, excess water would have to be held in the pit until spare storage becomes available in TSF Cell 4 and this would disrupt mining in the open pit. It is also noted that for wetter rainfall sequences a higher dewatering rate and/or additional storage capacity may be required to maintain the open pit fully drained to minimise disruption to mining.

10.4.3.2.2 Open Pit Storage Behaviour

The model results show that the stored volume in the open pit would exceed 200 ML for approximately 0.4%, 0.7% and 1.7% of the time respectively during the dry, median and wet rainfall sequences. Based on the results for the wet rainfall sequence, the pit could be pumped ‘dry’ within 1 week for a median period of pit inundation, 4 weeks for a 90th percentile (wet) period of pit inundation and within a maximum of 10 weeks after a major rainfall event.

Further detail is provided in Appendix D3.

10.4.3.2.3 Off-Site Releases to the McArthur River and the McArthur River Pastoral Lease

Releases to the McArthur River would generally occur only between the months of January and April during high flows in the river. Most releases to the river would occur in February and March. The results show that over the 26-year life of the mine approximately 22,910ML, 25,630ML and 28,230ML could potentially be released in dry, median and wet rainfall sequences, respectively. These values indicate that approximately 1,000 ML/year can be released, on average, to the McArthur River.

Release of 'intercepted' groundwater to MRPL for irrigation use would generally occur between the months of April and July. During other months of the year, MRM can generally manage on-site water either within the water management system or by releasing to the McArthur River. The results show that over the 26 year life of the mine approximately 22,460ML, 26,070ML and 27,830ML could potentially be pumped to MRPL in dry, median and wet rainfall sequences, respectively. These values indicate that approximately 1,000 ML/year can be pumped, on average, to MRPL.

Between July and December the mine site water management system is generally able to manage water stored on-site without off-site releases.

Further detail is provided in Appendix D3.

10.4.3.2.4 North OEF PAF Runoff Dam Storage Behaviour

The model results indicate that the use of evaporation sprinklers could significantly reduce the required size of the storages, with reductions of the order of 40%. The estimated storage volumes required for 5% probability of exceedance if evaporation sprinklers are installed at each of the storages are provided in Appendix D3. Note that SPSD overflows into SPROD once it reaches its FSL of 250 ML. Hence the required volume (810 ML) includes the calculated SPROD volume requirement of 560 ML + 250 ML.

Further detail is provided in Appendix D3.

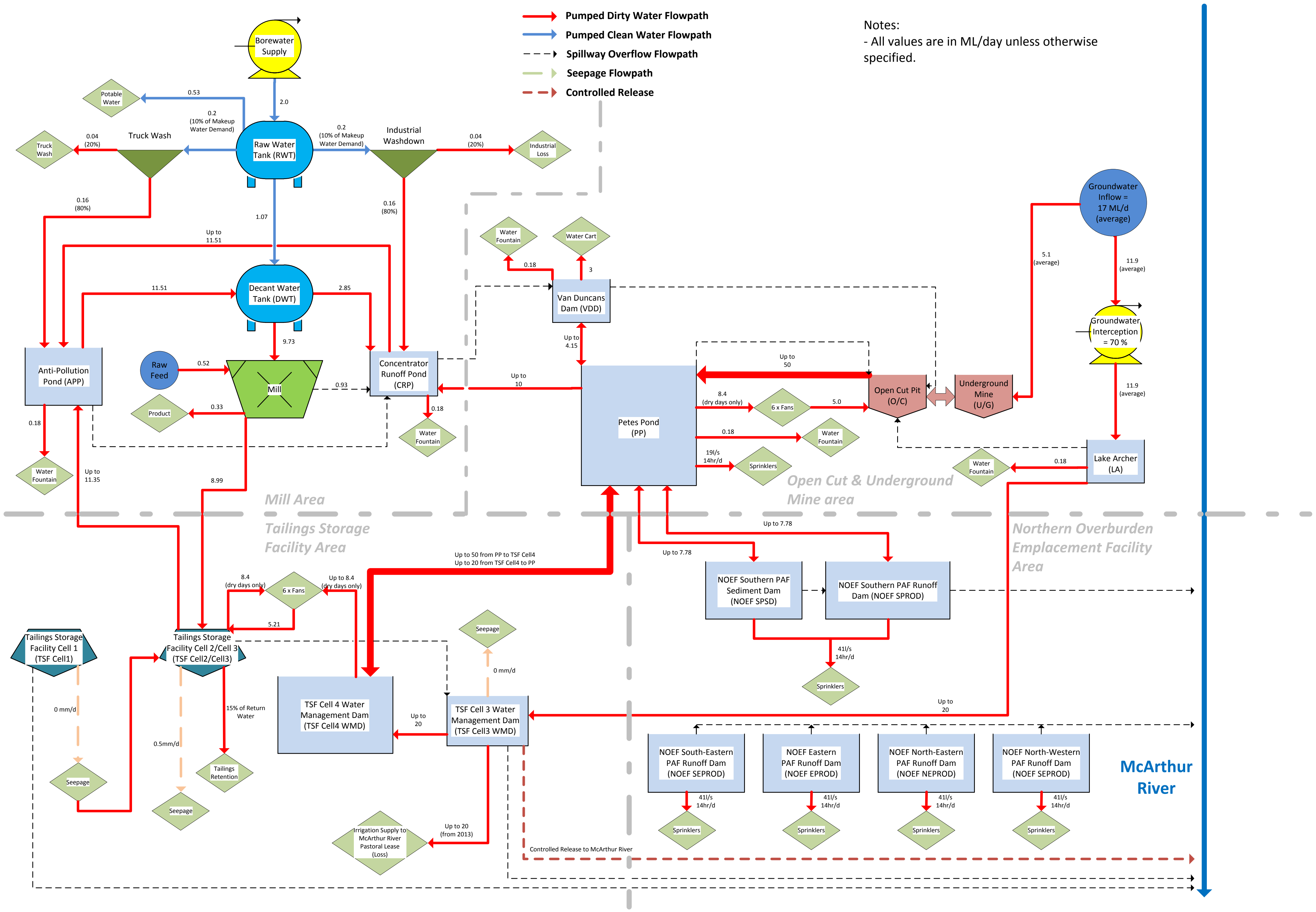

Figure 10-13 Project Water Balance Schematic (WRM, 2012)

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10.4.4 Flood Modelling

10.4.4.1 Approach

The URBS runoff-routing model (Carroll, 2004) was used to estimate design flood discharges in the McArthur River and its tributaries in the vicinity of MRM. This model was developed by WRM for the Northern Territory Department of Natural Resources, Environment, The Arts and Sport (NRETAS) in November 2011 for use in the Borroloola Floodplain Mapping Study. The URBS model was calibrated to recorded flood discharges at three stream gauging stations at Bailey's Grave (No G9070142), MIM Pump (No G9070132) and Borroloola Crossing (No G9070121) for 9 historical flood events, including the four recent events in January 2009, January 2010, February 2011 and March 2011.

Due to the flat topography of the McArthur River floodplain in the vicinity of MRM, a two-dimensional hydraulic model (TUFLOW) was used to predict the movement of floodwater across the floodplain. The TUFLOW model was developed and calibrated to recorded data for the 2001, 2003, 2009 and 2010 flood events.

The calibrated URBS and TUFLOW models were used to estimate design discharges, flood levels, velocities and extents in the McArthur River and its tributaries at MRM for the 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) design flood events for current and proposed Project conditions. The design discharges estimated by the URBS model were reconciled with discharges estimated from flood frequency analysis (FFA) of recorded peak annual flood discharges at the MIM Pump stream gauging station. Design flood hydrographs predicted by the URBS model were used as inflows into the TUFLOW model. The model results were used to assess the potential impacts of the proposed Project on flood levels, depths, velocities and extents of the McArthur River and its tributaries.

A discussion of the model inputs, extent and calibration is provided in Appendix D3.

10.4.4.2 Model Results

The TUFLOW model was used to determine potential impacts of the proposed Project on flood levels, velocities and extents for the 1% AEP (100 year ARI), and 0.2% (500 year ARI) flood events. In addition to flood level, flood velocity and extent maps, flood modelling and flood impact results are reported for a number of representative locations identified in Table 10- 19. These representative reporting locations are provided in Figure 10-14.

The flood model shows that during major flood events substantial breakouts occur from the main McArthur River channel upstream of the mine site and flow into Barney Creek. The largest potential impacts on flood levels occur at four locations:

The impacts on flood levels on the floodplain on the western side (upstream) of the open pit. are due to the obstruction of flow across the floodplain caused by the proposed North, South and East OEFs.

Along the McArthur River channel adjacent to the proposed South and East OEFs upstream of Emu Creek and the Glyde River confluences. The impacts on flood levels and velocities along this reach are due to the constriction of flow along the McArthur River corridor caused by the obstruction of the floodplain by the South and East OEFs.

The obstruction of the floodplain adjacent to the McArthur River along the Barney Creek channel forces more water around the western (upstream) side of the pit into Barney Creek. This would lead to increased flood levels and velocities along the Barney Creek channel.

Along the sections of the Carpentaria Highway in the vicinity of MRM within the McArthur River floodplain.

Table 10-19 Model Results Reporting Locations

Reporting Location ID	Surface Level (m AHD)	Location and Description
A	38.87	McArthur River downstream of the Barney Creek channel junction
B	39.00	McArthur River adjacent to the proposed East OEF
C	39.63	McArthur River adjacent to the proposed South OEF (east)
D	40.12	McArthur River adjacent to the proposed South OEF (mid)
E	40.31	McArthur River upstream of the proposed South OEF
F	40.28	Overbank area upstream of the western end of the flood protection levee
G	38.98	Barney Creek adjacent to the East OEF (mid)
H	39.01	Barney Creek adjacent to the East OEF (west)
I	39.45	Barney Creek adjacent to the western end of the flood protection levee
J	39.69	Barney Creek upstream of the flood protection levee
K	38.99	Overbank area adjacent to the eastern side of the North OEF
L	38.89	Overbank area adjacent to the north-eastern side of the North OEF
M	38.93	Overbank area adjacent to the northern side of the North OEF
N	38.96	Overbank area adjacent to the north-western side of the North OEF
O	39.35	Overbank area adjacent to the western side of the North OEF
P	39.75	Overbank area adjacent to TSF Cell 3 WMD spillway

(WRM, 2012)

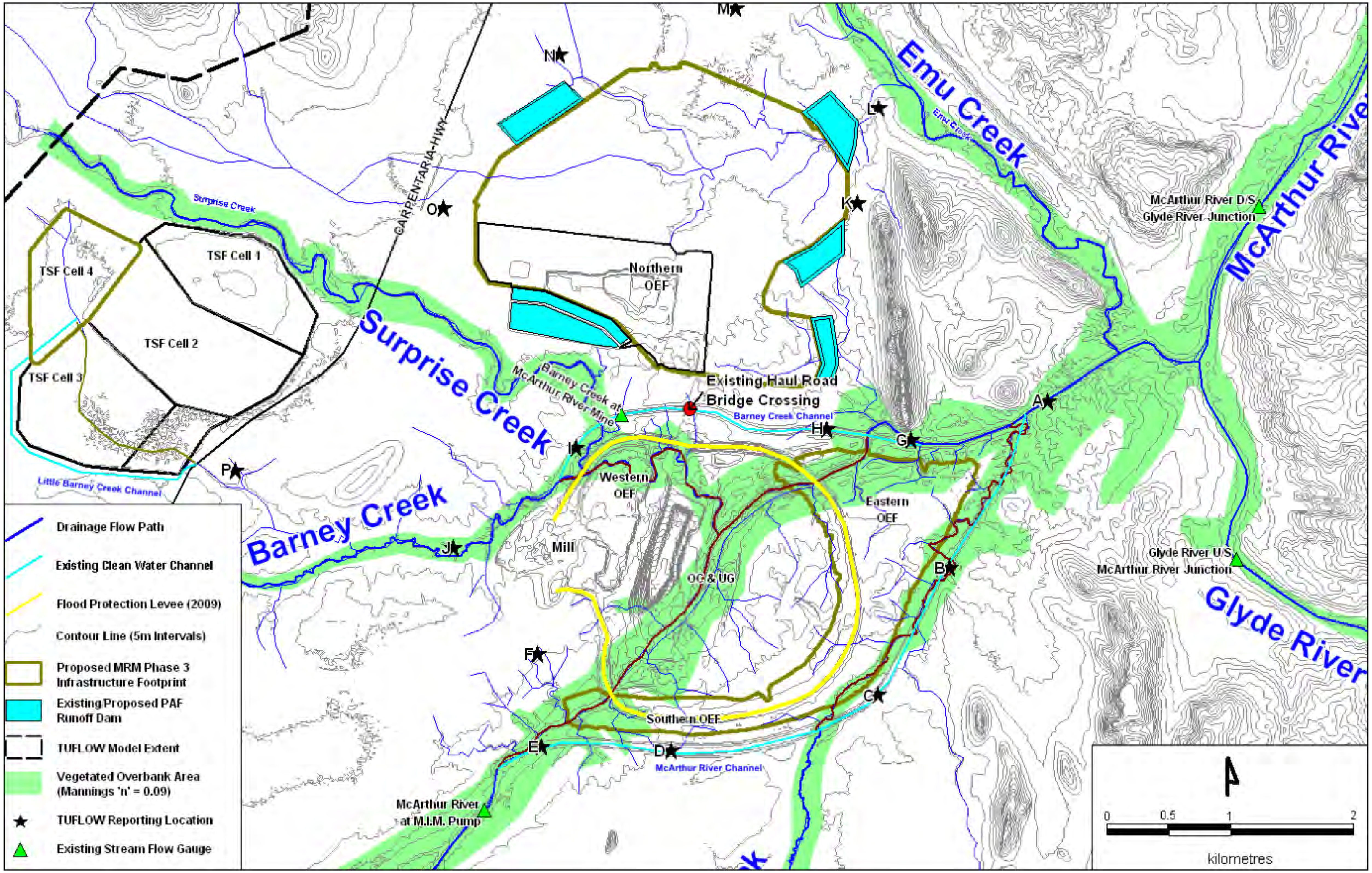

Figure 10-14 Flood Modelling Reporting Locations (WRM, 2012)

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10.4.4.2.1 Flood Levels

Figure 10-15 and Figure 10-16 show the predicted potential flood level impacts in the vicinity of the mine for the 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) flood events. Table 10-20 shows the potential impact of the proposed mine infrastructure on peak flood levels at the 16 reporting locations for the 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) events. For the proposed Project conditions, the following results have been determined:

- The 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) flood levels along the McArthur River channel range from 38.9 mAHD at location A to 40.8 mAHD at location F and from 41.7 mAHD at location A to 42.9 mAHD at location F respectively.
- The 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) flood levels along the Barney Creek channel range from 39.0 mAHD at location G to 40.3 mAHD at location J and from 41.8 mAHD at location G to 42.8 mAHD at location J respectively.
- The 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) flood levels around the perimeter of the Northern OEF range from 37.2 mAHD at location N to 40.2 mAHD at location O and from 41.5 mAHD at location M to 42.7 mAHD at location O respectively.
- The 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) flood level in the vicinity of the Water Management Dam spillway (location P) is 40.4 mAHD and 42.9 mAHD respectively.
- The estimated 0.2% AEP (500 year ARI) flood levels around the existing open pit flood protection levee are between 41.7 mAHD (location A) on the eastern side of the pit and 42.9 mAHD (location F) on the western side of the pit. The potential flood level impact due to the proposed OEFs around the pit levee is up to 0.7 m. The flood protection levee around the open pit is designed to withstand flooding from the McArthur River up to a level of approximately 44 mAHD. Therefore, the protection of the open pit from a 500 year ARI event is not compromised by the proposed Project.
- The potential 1% AEP (100 year ARI) flood level impact around the perimeter of the North OEF is up to 0.8 m on the western side of the dump. Note that the existing PAF cells and the PAF dam spillways remain above the new modelled 100 year ARI level.
- The potential 1% AEP (100 year ARI) flood level impact at the Carpentaria Highway in the vicinity of the TSF Cell 3 spillway is up to 0.6 m. It is understood that the Carpentaria Highway would be inundated for flood events greater than 5 year ARI (KBR, 2005). The proposed phase 3 mining works would result in a small increase in the duration of inundation of the highway during the modelled events.
- The spillway level of the TSF Cell3 WMD is approximately 42.7 mAHD. The predicted 0.2% AEP (500 year ARI) flood level is 42.9 mAHD. It is noted that the TSF Cell3 WMD spillway is above the 1% AEP (100 year ARI) flood level of 40.5 mAHD but 0.2 m lower than the predicted 0.2% AEP (500 year ARI) flood level. The adopted 1% AEP (100 year ARI) flood immunity level requirement for 'contaminated' water storages would be maintained during the Project.
- The model results indicate that the existing haul road crossing of Barney Creek has very little impact on flood levels because it is drowned out during the modelled flood events.

Table 10-20 Peak Flood Levels and Flood Level Impacts for the 1% and 0.2% AEP (100 & 500 year ARI) Events, Existing and Proposed Mine Conditions

Reporting Location	Peak Flood Level (mAHD)				Peak Flood Level Impact (m)	
	Existing		Phase 3 EIS			
	1% AEP	0.2% AEP	1% AEP	0.2% AEP	1% AEP	0.2% AEP
McArthur River Channel						
A	38.87	41.61	38.92	41.66	0.05	0.05
B	39.00	41.72	39.16	41.85	0.16	0.13
C	39.63	42.03	39.86	42.29	0.23	0.25
D	40.12	42.26	40.63	42.79	0.51	0.53
E	40.31	42.34	40.77	42.87	0.47	0.53
F	40.28	42.33	40.76	42.87	0.47	0.54
Barney Creek Channel						
G	38.98	41.70	39.05	41.76	0.07	0.06
H	39.01	41.75	39.21	41.92	0.20	0.17
I	39.45	42.03	40.10	42.65	0.65	0.62
J	39.69	42.21	40.32	42.80	0.63	0.59
North OEF						
K	38.99	41.74	38.98	41.68	-0.01	-0.06
L	38.89	41.69	38.71	41.52	-0.18	-0.16
M	38.93	41.72	38.71	41.53	-0.21	-0.19
N	38.96	41.75	37.21	41.84	-1.75	0.08
O	39.35	41.95	40.17	42.65	0.82	0.70
Water Management Dam Spillway						
P	39.75	42.29	40.39	42.85	0.63	0.57

(WRM, 2012)

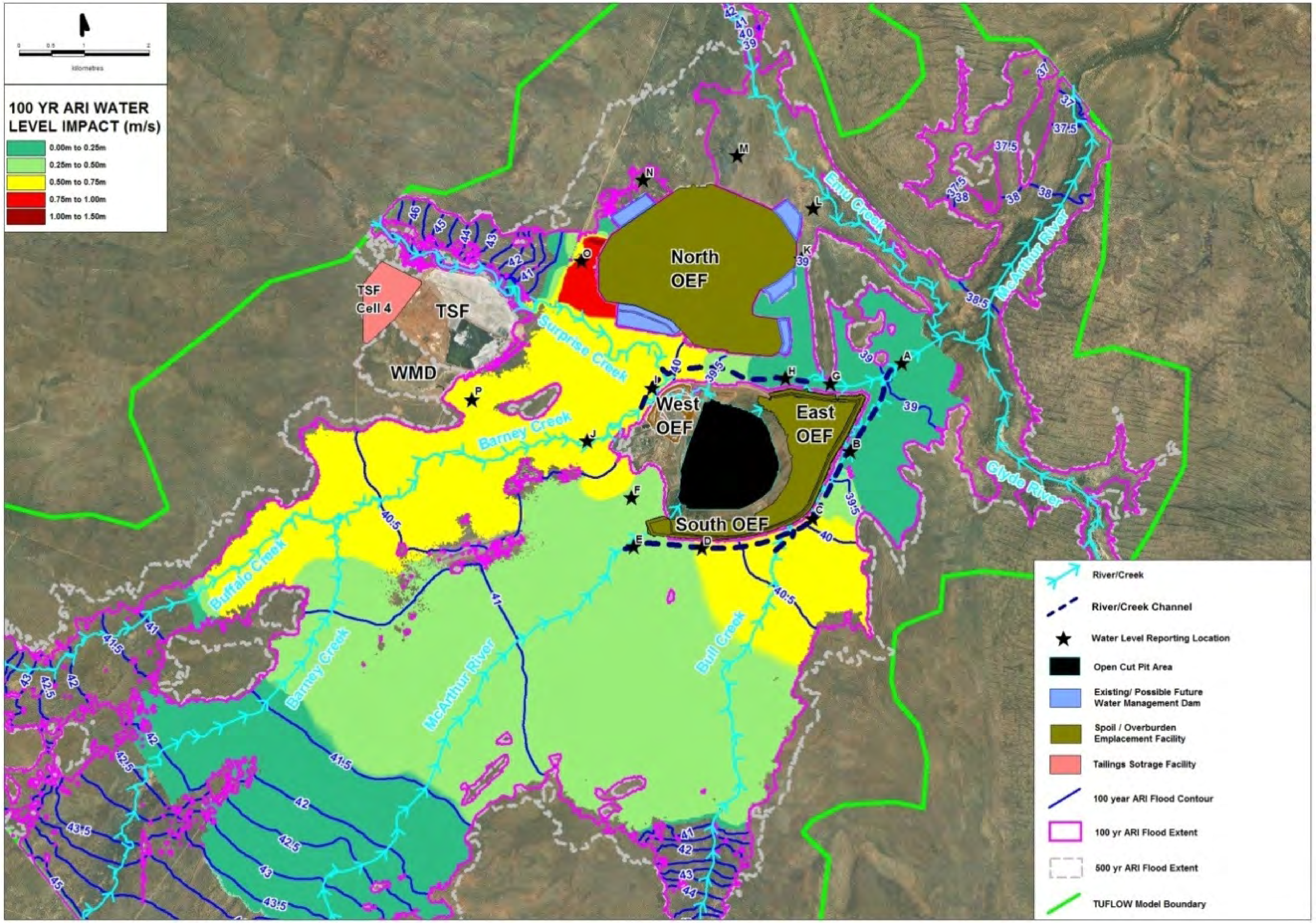

Figure 10-15 Project Peak Flood Levels, Extents and Impacts, 1% AEP (100 year ARI) Event (WRM, 2012)

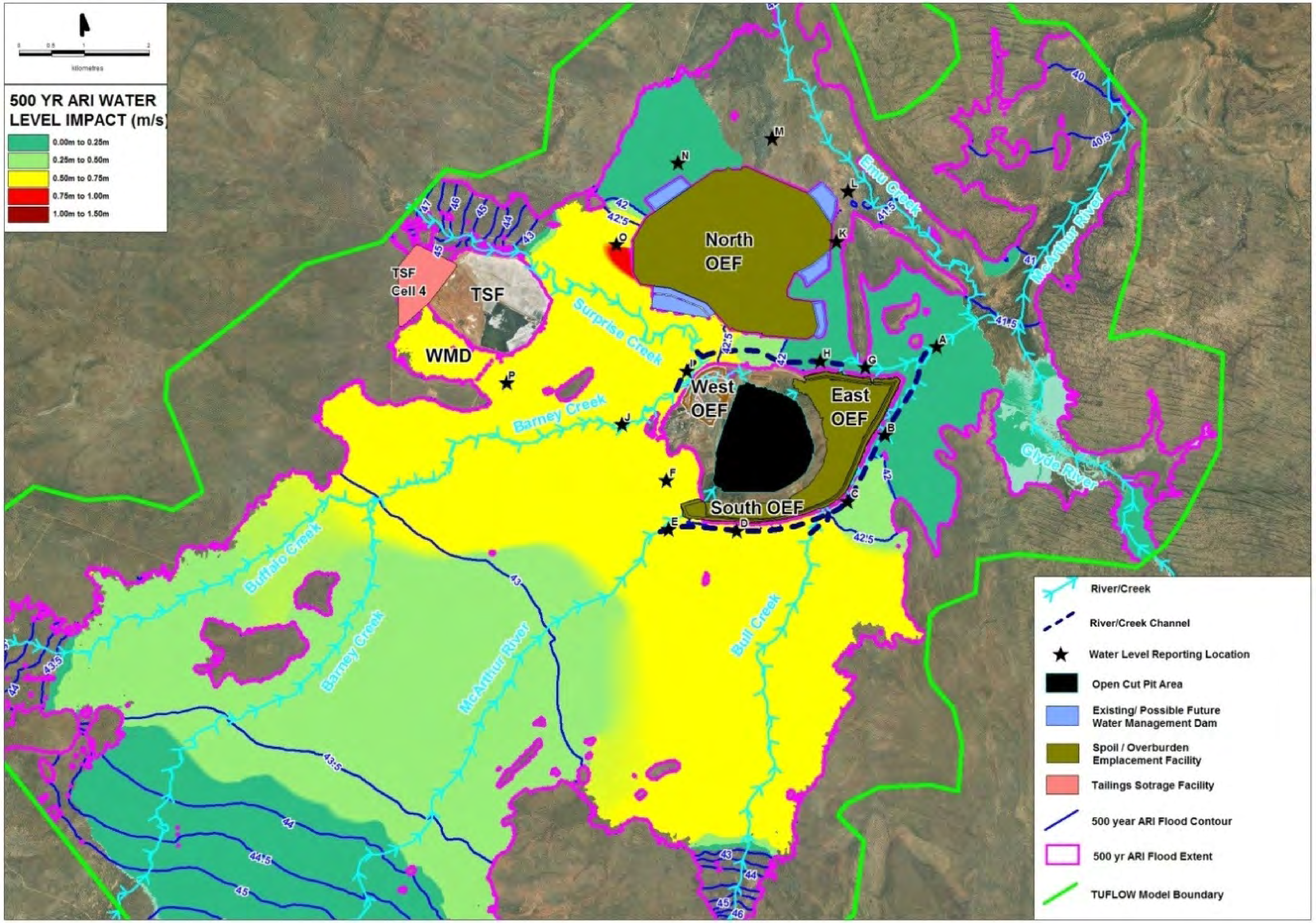

Figure 10-16 Project Peak Flood Levels, Extents and Impacts, 0.2% AEP (500 year ARI) Event (WRM, 2012)

10.4.4.2.2 Flood Velocities

Figure 10-17 and Figure 10-18 show the predicted Project mine peak flood velocities for the 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) flood events respectively. Table 10-21 shows the potential impact of the proposed Project on peak flood velocities at the 16 reporting locations for 1% AEP (100 year ARI) and 0.2% AEP (500 year ARI) flood events. For the proposed Project mining conditions, the following potential impacts are of note:

- The velocities along the McArthur River channel could potentially be increased by up to 1.0 m/s at location B and up to 0.7 m/s at location C.
- The velocities along the Barney Creek channel could potentially be increased by up to 0.2 m/s at location G.
- The velocities along the Barney Creek channel overbank area along the northern side of the pit flood protection levee and southern side of the North OEF could potentially be increased by up to 1 m/s.
- The velocities around the North OEF could potentially be increased by up to 1.1 m/s at location K and up to 0.5 m/s at location O.
- Two areas with potential to experience significant flood velocities between 4 m/s and 7 m/s along the Barney Creek channel between reporting locations H and I in the vicinity of the Haul Road and velocities between 3 m/s and 4 m/s along the McArthur River channel between reporting locations B and D.
- The predicted flood velocities may have an impact on in-stream erosion for flood events greater than approximately 18% AEP (20 year ARI) once significant flood breakouts from the McArthur River channel start to occur. The proposed works are unlikely to impact on stream erosion for more frequent events less than 18% AEP (20 year ARI).

Table 10-21 Maximum Flood Velocities and Velocity Impacts for the 1% and 0.2% AEP (100 & 500 year ARI) Events, Existing and Proposed Mine Conditions

Reporting Location	Maximum Flood Velocity (m/s)				Velocity Impacts (m/s)	
	Existing		Phase 3 EIS			
	1% AEP	0.2% AEP	1% AEP	0.2% AEP	1% AEP	0.2% AEP
McArthur River Channel						
A	1.3	1.1	1.4	1.3	0.1	0.2
B	1.9	1.8	2.9	2.8	1.0	1.0
C	3.1	3.0	3.8	3.6	0.7	0.6
D	2.8	2.8	2.6	2.5	-0.2	-0.3
E	1.5	1.7	1.5	1.7	0.0	0.0
F	0.5	0.5	0.5	0.5	0.0	0.0
Barney Creek Channel						
G	1.6	1.6	1.8	1.8	0.2	0.2
H	2.0	2.0	2.0	2.0	0.0	0.0
I	0.9	0.9	0.9	0.9	0.0	0.0
J	0.6	0.6	0.6	0.5	0.0	-0.1
North OEF						
K	0.3	0.3	1.2	1.4	0.9	1.1
L	0.7	0.7	0.3	0.5	-0.4	-0.2
M	0.1	0.1	0.1	0.2	0.0	0.1
N	0.0	0.1	0.0	0.2	0.0	0.1
O	0.1	0.4	0.6	0.6	0.5	0.2
Water Management Dam Spillway						
P	0.0	0.2	0.0	0.2	0.0	0.0

(WRM, 2012)

The proposed flood mitigation infrastructure is discussed below in Section 10.6.2

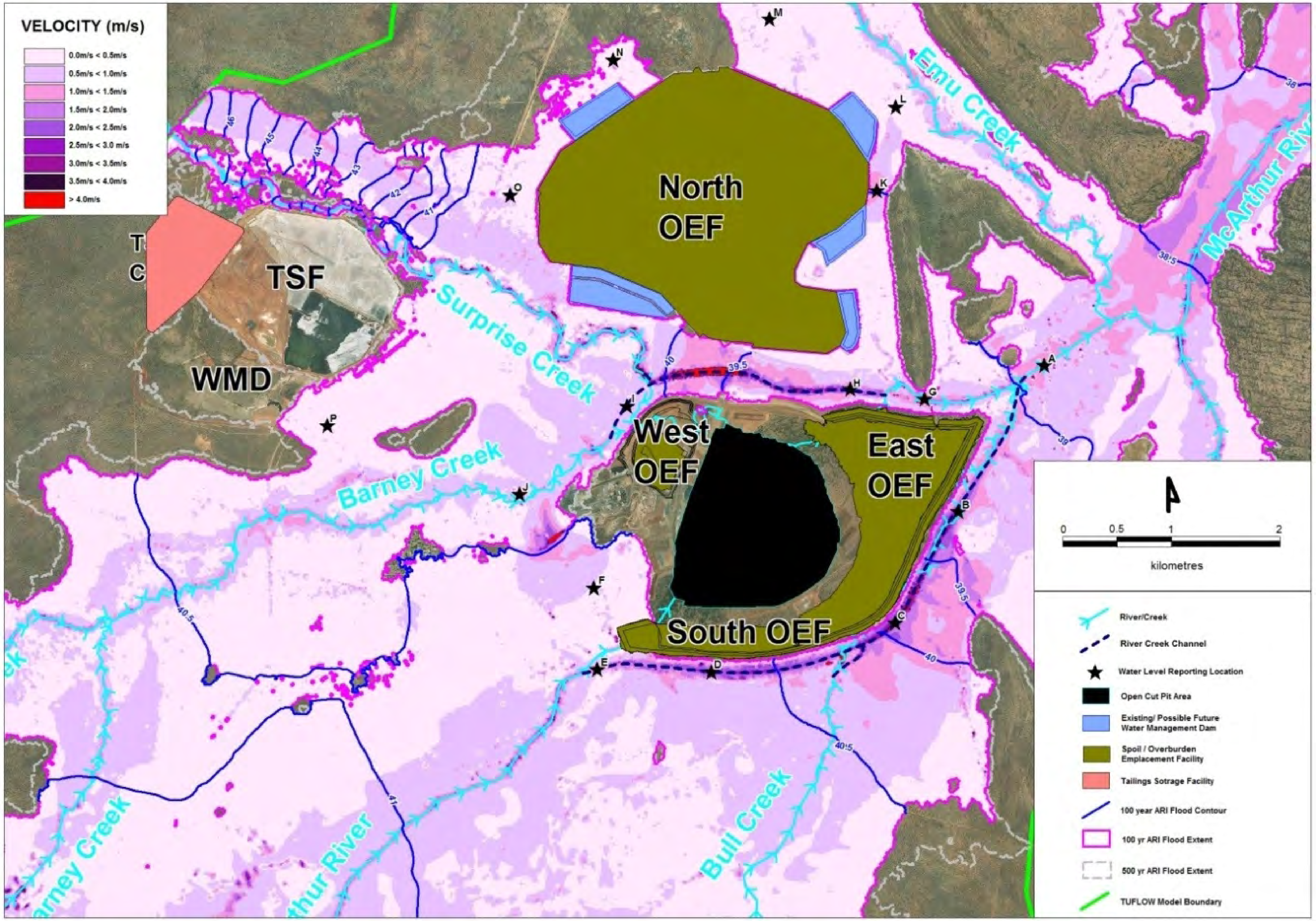

Figure 10-17 Project Maximum Flood Velocities and Velocity Impacts, 1% AEP (100 year ARI) Event (WRM, 2012)

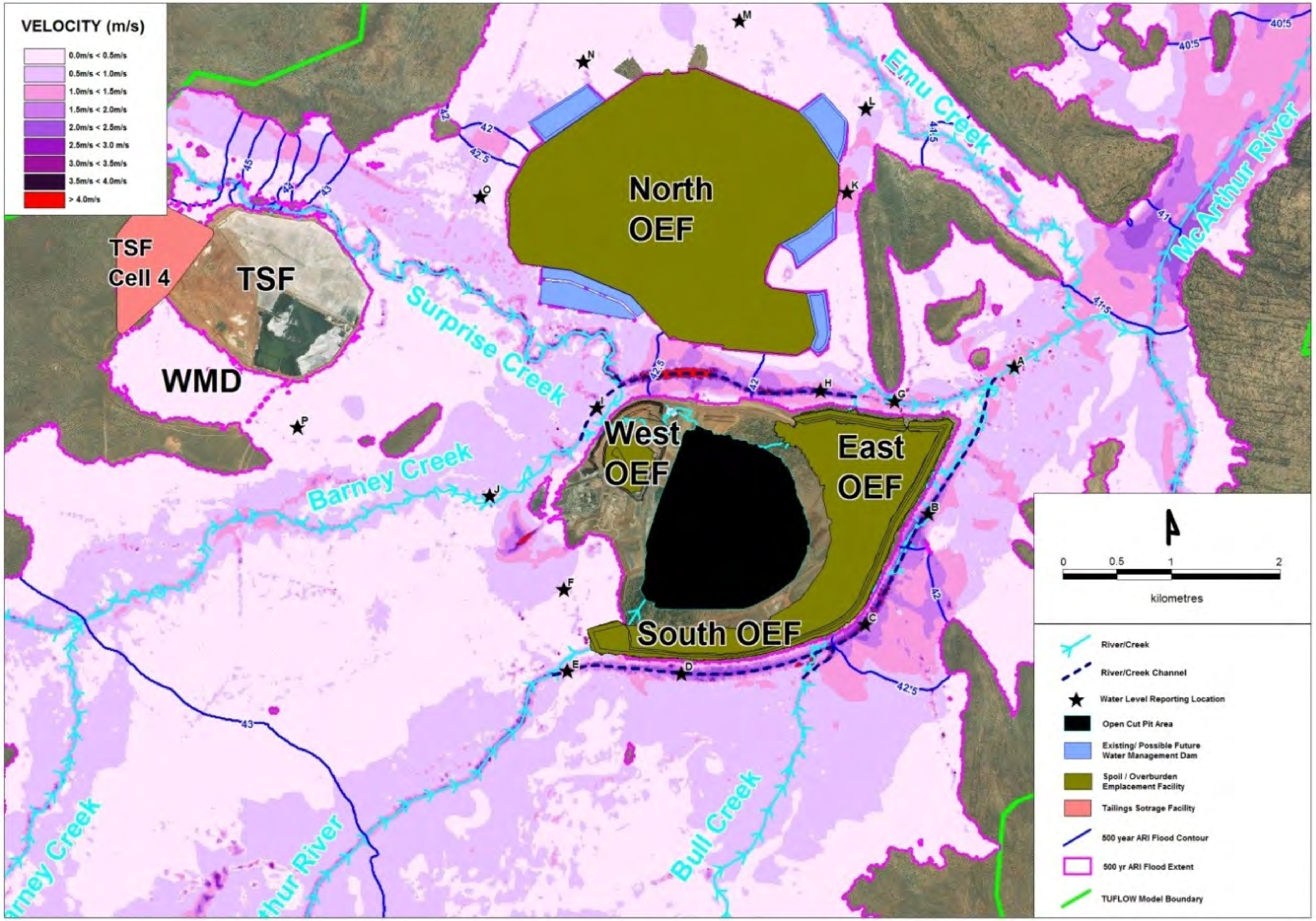

Figure 10-18 Projects Maximum Flood Velocities and Velocity Impacts, 0.2% AEP (500 year ARI) Event (WRM, 2012)

10.5 Groundwater Impact Assessment

10.5.1 Overview

A groundwater impact assessment (Appendix D4) was undertaken to predict the potential groundwater inflows into the pit throughout the mine life and to determine the potential groundwater draw down that would result from mining activities.

URS was commissioned to undertake an investigation of the groundwater impacts of the Project. The investigation included analysing the data from previous investigations and modelling exercises for MRM. Data from the network of groundwater production and monitoring bores, were used to develop a conceptual and numerical groundwater model for the site. This model has been used to describe the behaviour of groundwater aquifers at the site and to predict the potential groundwater impacts due to the proposed Project.

10.5.2 Groundwater Modelling

A conceptual model of the local hydrogeology was constructed to facilitate the simulation of the interaction between the Project and the groundwater systems. The model was vertically divided into 11 layers. A summary of field determined properties for the model layers is presented in Table 10-22. The model layers are described below.

10.5.2.1 Model Layer 1: Alluvial Sediments

This layer represents the alluvium which includes:

- Quaternary recent alluvium consisting of silt, sand and gravel. This deposit occurs on the flood plains, levees, flood terraces and channel floors of the McArthur River and the Glyde River
- Cainozoic Tertiary to Quaternary sediments consisting of colluvial and outwash fan deposits, older alluvial and lacustrine deposits of clay, silt and sand and gravelly residual soils (underlain by bedrock).

The alluvial aquifer is directly connected to the McArthur River and contains good quality fresh water. The alluvial sediments may locally have high permeability due to the presence of sand and gravel deposits. The majority of the upper sediments of the alluvium are mixture of clay, silt, sand and gravel with moderate permeability. Only the basal few meters of the alluvium contain permeable coarse-grained sand, gravel and cobble/boulder deposits.

The main channel of the McArthur River contains up to 30 m of saturated alluvial sediments.

The top of model Layer 1 is defined by land-surface elevations.

10.5.2.2 Model Layer 2: The McArthur River Palaeochannel

The McArthur River Paleochannel was simulated as a separate layer and it is represented as model Layer 2. The McArthur River paleochannel is approximately 800 m wide and on average 8 m thick. The base is up to 34 metres below ground level (5 m AHD).

10.5.2.3 Model Layer 3: Weathered and Partially Weathered Bedrock

The locally occurring aquifers in completely and partially weathered bedrock are presented as model Layer 3. This layer lies beneath the alluvium. Faults that run through the weathered and partially weathered bedrock can act as conduits. Generally the base of the weathered horizon is between 5 m AHD and 22 m AHD.

10.5.2.4 Model Layer 4 and Layer 5: Eastern Dolomite

The dolomite to the east of the mine is presented in the model as Layer 4 and Layer 5. These layers extend from the Mt Stubbs and Woyzbun fault lines to the Bukalara Sandstone interface.

Drilling activities in the area indicates that groundwater occurs also in geological structures (faults, joins, fractures, vugs and possibly solution channels) and within fresh bedrock, as evident in bore holes EMU 5 and MAC1P. Analysis of drill logs indicate the presence of open vugs and solution channels in dolomites located near the Mt Stubbs Fault at depths in excess of 300 m (-270 m AHD). At borehole EMU 5 vuggy dolomite was intercepted at depth of 65 m depth (-35 m AHD). Open joints and fractures have been intercepted in the open pit at depths of 23 m (7 m AHD) and 152 m (-122 m AHD), predominantly in dolomite and brecciated units and occasionally in shale.

Model Layer 4 extends vertically from the bottom of the weathered zone to a depth of -92 m AHD.

Model Layer 5 extends vertically from the bottom of Layer 4 to a depth of -400 m AHD. This depth represents the floor elevation of the final open pit.

To the west of the mine where Layers 4 and 5 lithological zones around the mining zone are absent, they are represented by a thin layer of 0.1 m thickness.

10.5.2.5 Model Layer 6: HYC Pyritic Shale

This is thin-bedded to finely laminated dolomitic, carbonaceous and pyritic shale and siltstone, coarse sedimentary breccias and tuffaceous horizons.

10.5.2.6 Model Layer 7: Cooley Dolomite Breccia

This is a chaotic breccia, with clasts which range in size from a few millimetres to several tens of metres.

10.5.2.7 Model Layer 8: Ore Zone (HYC Deposit)

This layer is shallow-dipping and it is approximately 1.5 km long and 1.0 km wide and up to 70 m thick (McGoldric and Large, 1998). The average thickness of the ore zone is estimated at 55 m. This layer has been eroded along its western margin, where it is covered with approximately 30 m of alluvium and soil. On the eastern margin, layer 8 thickens and is folded to form the fault zone which has a strike length of at least 600 m. The south eastern corner is down faulted by approximately 110 m along the northeastely trending Woyzburn Fault. Lying on the western margin of this layer is the Hinge zone, a sub-vertical zone with a strike length of 1.0 m and a vertical height of 200 m. The northern margin inter-finger with the breccias (Model Layer 7) and the southern margin grades into pyritic siltstone.

10.5.2.8 Model Layer 9: W-Fold Shale

This consists of dolomitic siltstone and shale with interbeds of tuff. The top and bottom elevation of this layer has been identified in drilling logs up to 1,600 metres depth.

10.5.2.9 Model Layer 10 and Layer 11

These layers represent the dolomite west of the mine. The bottom elevation of Layer 10 varies between -92 m AHD and -400 m AHD. The top of Layer 10 is the bottom of the weathered zone. Layer 11 extends vertically from the bottom of Layer 10 to a depth of -600 m AHD.

As groundwater flow in the vicinity of an open pit or underground mine is three dimensional, the model was vertically extended to -600 m AHD (175 m below the final bottom of the pit configuration) to reasonably simulate vertical inflow to the bottom of the mine.

Table10-22 Summary of Model Layers

Model Layer	Description	
	Geologic Unit	Top and Bottom of Layers
Layer 1	Alluvium	Top at land surface from land surface contours. Bottom at bottom of alluvial deposits
Layer 2	Palaeochannel	Top at bottom of Layer 1. Bottom at the bottom of palaeochannel
Layer 3	Weathered Rock	Top at the bottom of Layer 2. Bottom at bottom of weathered rock or top of bedrock
Layer 4	Eastern Dolomite	Top at bottom of weathered zone (Layer 3). Bottom up to -92 m AHD
Layer 5	Eastern Dolomite	Top at bottom of Layer 4 and bottom up to -400 m AHD
Layer 6	HYC Pyritic Shale	Top at bottom of Layer 5 and bottom at bottom of HYC Pyritic Shale
Layer 7	Breccia	Top at bottom of HYC Pyritic Shale. Bottom at top of orebody
Layer 8	Ore Horizon	Top ranges between 32 m AHD and -466 m AHD. Bottom at the top of W Fold Shale
Layer 9	W Fold Shale	Top at top of W Fold Shale and Bottom at bottom of W Shale Fold
Layer 10	Western Dolomite	Top at bottom of W Shale Fold.
Layer 11	Western Dolomite	Top at bottom of Layer 10. Bottom at -600 m AHD

(URS, 2012)

Further information on the conceptual and numerical model construction, inputs, assumptions, calibration and functionality is provided in Appendix D4.

10.5.3 Model Results

The calibrated numerical model was utilised to predict the hydrologic regime during mining operations from April 2011 through to December 2036 using the open pit plan provided by MRM. The dimensions of the proposed staged expansion of the mine are presented in Appendix D4.

The open pit mining dimensions were input into the model using the mining sequence information provided by MRM and simulated using the model drain seepage face package. Seepage face drains representing each stage of mining were turned on (i.e. became active) at each in accordance with the mining sequence provided.

For the predictive simulation, recharge was calculated as 10% of rainfall and evaporation was calculated as 65% of the published evaporation rate.

The model simulated changes to the groundwater flow system during mining operations using the end of the calibration-period simulation (2011) as an initial condition. The following outputs were generated by the model:

- Average mine inflow rates
- Mine influenced water levels
- Model mass balance.

10.5.3.1 Predicted Mine Inflow Rates

The model calculated groundwater inflows into the underground and open pit mines are presented in Figure 10-19. These inflows are predicted to increase from an average value of 13 ML/d in the first year to an average value of 17 ML/d in the final year when the pit reaches its deepest depth with a range between 10 to 13 ML/day during the dry season and 20 to 24 ML/day during the wet season. Due to the geology of the area there is potential for peak short term higher inflows depending on whether any localised vuggy/fractures zones are encountered, which are not represented in the model.

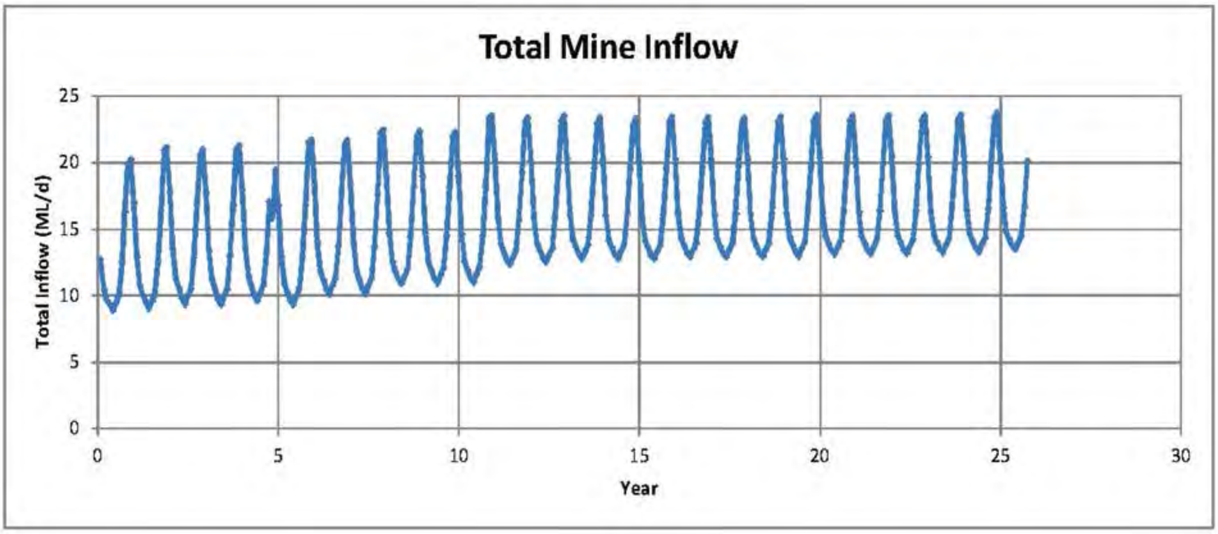

Figure 10-19 Predicted Total Mine Inflow (URS, 2012)

10.5.3.2 Predicted Drawdown

Simulated drawdown for 2016, 2026 and 2036 resulting from mine expansion simulations are provided in Appendix D4 (palaeochannel). Within the open pit area, the water table has been lowered to a maximum amount of approximately 414 m below ground surface (approximately-382 m AHD) within bedrock and faults.

The Djirrinmini Waterhole is located in the McArthur River. The downstream end of Djirrinmini Waterhole is located on low permeability weathered bedrock, but the banks at the upstream end of this pool are in alluvium, underlain partially by a palaeochannel. The groundwater model predicts drawdown in 2036 of approximately 0.7 m that may result in a decrease in the depth and extent of the pool at the end of the dry season, prior to being replenished in the following wet season. This reduction will not occur until after 25 years of mining and prior to this, the drawdown will be significantly less. The existing groundwater monitoring network will allow for the confirmation of the predicted effects and provide an early warning of potential environmental impacts allowing management of such impacts.

10.5.3.3 Potential Impacts on Other Groundwater Users

Where groundwater stock wells, private domestic supply bores and industrial supply bores are located within the cone of depression, potential impacts associated with the lowering of groundwater levels through mine dewatering can occur. Such drawdown can increase pumping heads, reduce available drawdown, and reduce pumping rates from bores. It is understood that there are no other groundwater bores in the area other than those owned by MRM. Therefore the predicted cone of depression will not impact on any other groundwater users.

10.5.3.4 Potential Impacts on Surrounding Vegetation

Drawdown caused by dewatering has the potential to lower groundwater levels in the superficial sediments around the pit and in the alluvium associated with both the current McArthur River channel and the palaeochannel sediments. Groundwater levels in the superficial sediments over most of the area (away from the major drainages) are reasonably deep (10 to 15 m below ground surface) and in some areas, these sediments are largely unsaturated. Lowering of groundwater levels in these sediments, therefore, cannot have a significant environmental impact as most flora in the area are likely to rely on soil moisture (rather than the water table) for survival.

There is potential for drawdown to affect the remaining riparian vegetation within the old McArthur River channel, inside the bund. However, these areas will be disturbed as part of the eastern and southern OEF developments associated with the Project. Therefore if impacts on vegetation associated with drawdown occur in this area, they will be of short duration prior to vegetation removal for overburden emplacement activities.

10.5.3.5 Post-Mining Groundwater Rebound

10.5.3.5.1 Groundwater Levels

A post mining simulation was undertaken to predict the time taken for groundwater levels to rebound after the cessation of mine dewatering.

Recharge and evapotranspiration rates applied were 10% of rainfall and 0.005 m/d, respectively. Surface run-off into the pit was not simulated.

Figure 10-20 presents the simulated rebound groundwater level at GW37 (T5_3) which is located at the centre of the pit. The results of the simulation indicate that the groundwater levels will reach a dynamic equilibrium (fluctuating between approximately 18.2 m AHD in the dry season and approximately 21.2 m AHD in the wet season), 1.5 years after the cessation of mine dewatering. Ground level is typically at 35 m AHD.

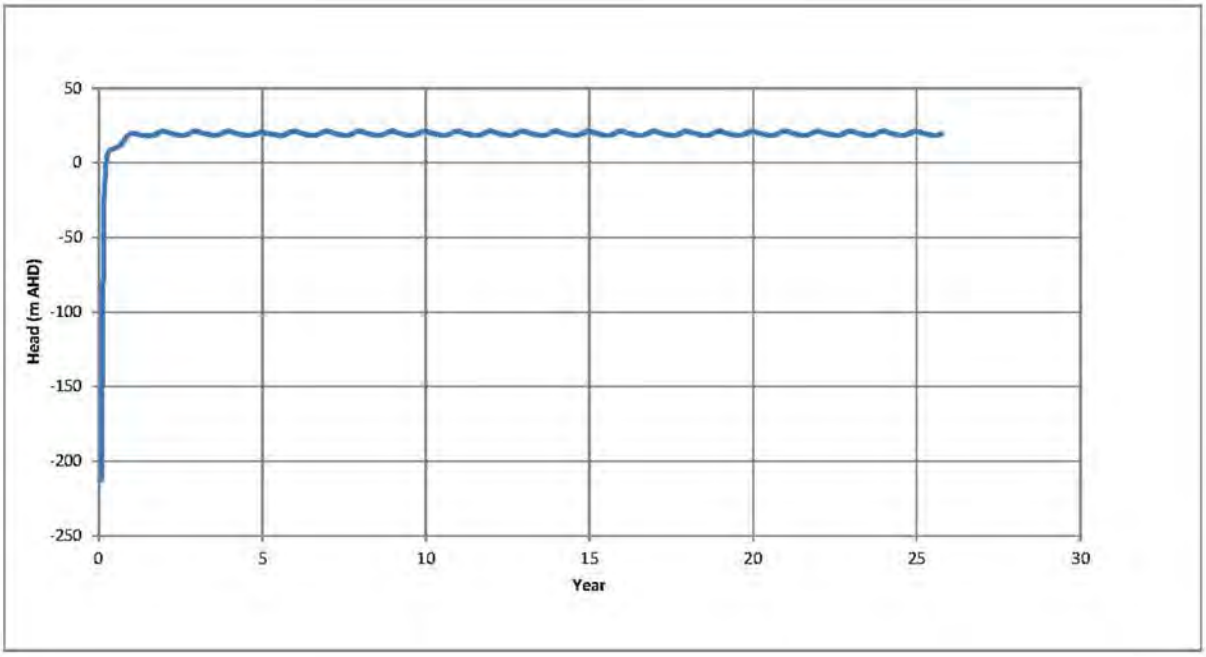

Figure 10-20 Predicted Post-mining Groundwater Level Rebound (URS, 2012)

10.5.3.5.2 Pit Void Infill

A post mining simulation was undertaken to determine the time taken for the final pit void to fill after the cessation of mine dewatering and mine closure.

WRM (2012) provided run-off and lake evaporation for a 111 year period. Run-off volumes were calculated using the AWBM rainfall-runoff model for a rehabilitated catchment area of 252 ha, and 195 ha final pit void. It was assumed all rainfall applied to the pit void was converted to runoff. Lake evaporation coefficients between 50% and 80% were simulated to account for reduced wind, shading effects from the walls of the pit and higher relative humidity.

The results of the simulation are presented in Figure 10-21. For the 70% lake evaporation scenario, the pit void will fill and stabilise at approximately -15 m AHD (approximately 50 m below ground level), which is below the rim of the pit as the rate of groundwater seepage into the pit slows as the pit water level rises. The water level stabilises at the point evaporation matches groundwater seepage and rainfall run-off.

Results indicate it is likely to take some 300 to 400 years for water levels to stabilise.

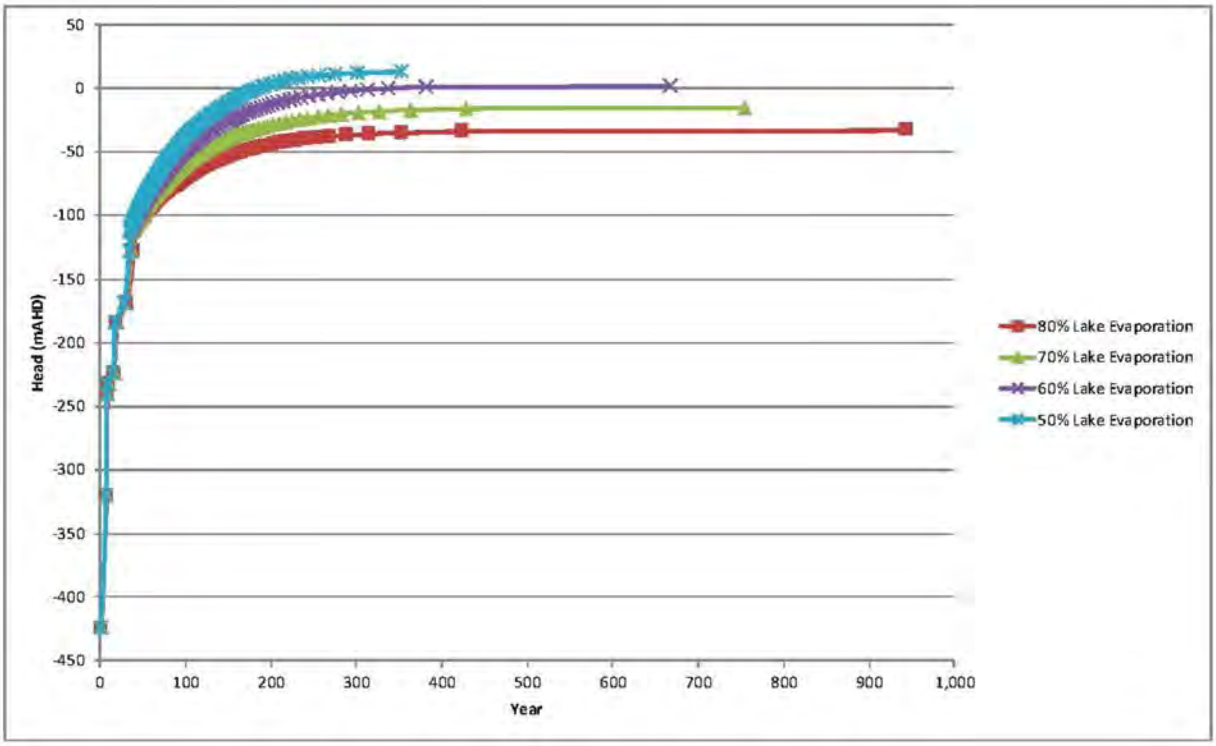

Figure 10-21 Predicted Post-mining Pit Void Level Rebound (URS, 2012)

10.5.3.6 Final Void Water Quality

The walls of the final void will contain exposed PAF material which could influence the pit water quality. A scheduled drilling program has been completed to improve the geochemistry knowledge of PAF predictions in the open-pit walls to determine the influence on pit water. Pit water quality modelling was undertaken as part of the open-pit project EIS in 2005. The closure scenario of having the pit fill naturally from groundwater inflows and direct rainfall was modelled – that is, no surface water inflows to the pit from the McArthur River will occur. This is the current closure scenario proposed in the Mine Closure Plan (Appendix E4).

An advantage of this scenario is that the pit will not overflow as a result of seepage inflow and rainfall alone. A disadvantage is that water quality in the pit will decline over time as a result of concentration by evaporation, with sulphate concentrations (and concentrations of other ions and metals) gradually increasing with time. The 2005 modelling showed that sulphate concentrations would increase to approximately 2,800 mg/L after 33 years, and be in the order of 4,900 mg/L after 99 years. Pit water quality is expected to be similar for the Project. As mentioned previously, further scheduled geochemical investigations will verify the final void wall geochemistry.

10.6 Surface Water Management and Mitigation

Implementation of the water management system for the Project operations has been designed to limit potential adverse impacts on receiving waters by minimising the probability of uncontrolled discharges from key containment storages to an acceptable level. The system has also been designed to minimise the impacts of flooding on Project operations. In consideration of the proposed management and mitigation measures, the potential impacts associated with the Project are considered to be minor.

10.6.1 Site Water Management

Water balance modelling will be used to determine, plan, and upgrade system performance on adaptive management basis. This provides maximum flexibility to accommodate actual groundwater inflow rates into the Project pit, continually reassess the potential for discharge to the environment, and minimise reliance on external raw water supplies.

The following mitigation strategies will be implemented to optimise the effectiveness of mine water management strategies, systems, works, and procedures in avoiding potential adverse impacts on receiving surface waters:

Water balance modelling will be updated regularly to provide reliable representation of:

- the structure and operating rules of the water management system
- actual storage and transfer capacity of system components (confirmed by surveys)
- mine production rates and associated concentrator process water balance
- rates of groundwater inflows into the mine and total pit dewatering requirements (confirmed by flow monitoring)
- varying catchment areas and 'type' over the mine life (e.g. staged construction of OEFs and runoff contributions to the OEF ponds)
- varying water reuse demands and improved knowledge of demand influencing factors (e.g. seasonal variation, relationship to production rates, etc.)
- improved knowledge of catchment runoff characteristics (confirmed by flow monitoring as required)
- variation of modelled climatic data with monitoring data (to confirm system performance in response to climate variation)
- on-going seepage management of new and existing storage ponds including review, assessment and implementation of interception strategies and mitigation works where necessary
- regular engineering safety/audit assessments of the integrity of water storages where there is potential for spill to receiving waters in the event of a storage breach
- review of the potential consequences from containment storage overflows as site water monitoring data are obtained, and where necessary, revise the target overflow probability used to size containment storages
- upgrading water management infrastructure (pond storage capacity, pumps and pipeline capacity) as required to maintain acceptable overflow criteria (spill potential) as determined from the water balance modelling
- updating water balance modelling/analysis technology, or upgrading modelling approach, as required to reflect on-going improvements in best practice water management for the mining industry.

10.6.2 Flood Mitigation Infrastructure

10.6.2.1 South and East OEF Erosion Protection Bund

It is proposed to construct the South and East OEF erosion protection bund to provide flood protection up to the 1% AEP (100 year ARI) flood level. The location of the proposed bund as well as 11 reporting locations, labelled A to K, used to specify design levels along the bund are provided in Appendix D3. It is recommended that this erosion protection bund be designed and constructed to appropriate engineering standards.

10.6.2.2 North OEF PAF Material

It is proposed that the placement of North OEF PAF material and the North OEF PAF Runoff Dam spillway levels will be above the 1% AEP (100 year ARI) flood level at the specific locations. This indicates a design level of between 38.7 mAHD (locations L and M) and 40.3 mAHD (location J). The minimum levels of PAF material placement required to achieve the flood immunity requirements around the North OEF would be determined at the detailed design phase of the North OEF. All existing PAF cells and dams will remain above the 1% AEP (100 year ARI) flood level throughout the Project.

10.6.2.3 Existing Flood Protection Levee

The proposed mine infrastructure would potentially increase peak flood levels adjacent to the flood protection levee by up to 0.7 m to 42.9 mAHD. This level is lower than the minimum crest level (44 mAHD) of the flood protection levee. Although a significant increase in the peak flood levels along the McArthur River is predicted due to the proposed mine infrastructure, the downward revision of the design discharge for the 0.2% AEP (500 year ARI) flood event when compared with previous estimates has resulted in up to 0.5 m lower predicted peak levels along the levee for existing conditions (see Appendix D3). On this basis, no additional open pit flood protection works are required because the existing flood protection levee would be adequate to protect the open pit up to a 0.2% AEP (500 year ARI) during the Project.

10.6.2.4 Erosion Protection along the diverted McArthur River and Barney Creek Channels

During large flood events, velocities between 4 m/s and 7m/s would potentially occur along the Barney Creek channel between reporting locations H and I in the vicinity of the Haul Road and velocities between 3 m/s to 4 m/s would potentially occur along the McArthur River channel between reporting locations B & D (see Figure 10-14 for locations). It is recommended that a regular erosion monitoring program be undertaken along these high velocity reaches. Additional erosion protection works should be undertaken in areas where visible erosion is evident.

10.6.2.5 Erosion Protection at North, South and East OEFs

The proposed North, South and East OEFs will constrict the McArthur River and Barney Creek floodplains adjacent to the OEFs. The flood modelling results indicate that the OEFs could increase flood velocities in some sections of the McArthur and Barney Creek channels and floodplain during large flood events. It is recommended that areas where there is a risk of elevated velocities due to the proposed Project works be inspected after major flow events for any evidence of erosion. If it is found that erosion is taking place along the channels or OEFs, additional rock protection may be required along the affected reaches.

10.6.2.6 Greenhouse Climate Change Influences on the Water Management System

Research literature reports that Greenhouse effects on climate change are generally expected to cause an increase in wet season rainfall in tropical Australia. It is not possible at this time to estimate the potential changes in the intensity of rainfall events, effects on rainfall event sequences (both inter-seasonal and inter-annual), typical wet season rainfall, evaporation, and the combined effects of these factors on runoff and floods. All of these factors (particularly rainfall event sequences), together with the capacities of the water management infrastructure are critical to the performance of the proposed Project water management system.

The proposed water management system has been developed on the basis of system modelling with a long period of historical rainfall record which accounts for a wide range of rainfall events and event sequences. This approach is consistent with international best practice as applied to diverse water management applications. In particular, the use of historical rainfall data enables the system to be planned to handle a wide range of possible rainfall events and event sequences that are credibly known to be possible from past observations.

The key strategy for water management at the Project is to continually update and re-assess the water balance model of the water management system, to guide the requirement to upgrade infrastructure (pipes, pumps, and storages) to maintain an acceptable low potential for overflow from containment storages to receiving waters. This adaptive management approach is consistent with a philosophy of continuous improvement. It will allow the water management system to be optimised with improving knowledge of water sources (particularly groundwater inflow into the expanded pit), and can include planning for Greenhouse climate change effects on rainfall when reliable predictions become available in the future.

10.6.3 Monitoring

The aims and objectives of the surface water monitoring program during Project mining operations will remain the same as under current MRM operations. Therefore, the current surface water monitoring network will remain largely unchanged. A number of minor changes to improve and expand the current surface water monitoring program are proposed to account for the proposed changes in site layout.

10.6.3.1 Natural Surface Water

The stream gauging records at the current Barney Creek monitoring station (SW19) are unreliable and water levels at this station are affected by backwater from the McArthur River levels during high flow events. It is proposed to remove SW19 from the surface water monitoring network and replace this station with two new stations - one on Barney Creek approximately 5 km upstream of the removed station at the Capricorn Highway crossing (SW4) and the other on Surprise Creek at the at the Capricorn Highway Crossing (SW2). The two new stations are expected to provide more accurate streamflow data for both Barney Creek and Surprise Creek. The proposed locations of the above two stations are provided in Appendix D3.

Three new surface water quality monitoring stations are proposed to monitor the potential impact of the NOEF runoff on Emu Creek receiving waters. These stations will monitor the background (upstream) water quality in Emu Creek, the quality of surface runoff entering Emu Creek from the NOEF area and the potential impact of the NOEF on Emu Creek receiving water quality. The proposed locations of the above three stations are provided in Appendix D3. No changes to the existing suite of parameters monitored or the monitoring frequency are proposed.

Table 10-23 shows the easting and northing of the proposed natural surface water monitoring sites discussed above.

Table 10-23 Proposed Natural Surface Water Monitoring Locations

Location	Easting in AMG84 Zone 53 (m)	Northing in AMG84 Zone 53 (m)	Station Type
Emu_Ck_1	618,645	8,187,253	Water Quality
Emu_Ck_2	618,996	8,186,438	Water Quality
Emu_Ck_3	619,946	8,185,846	Water Quality
SW2	615,040	8,184,770	Water Quality/ Stream Gauge
SW4	613,267	8,182,523	Water Quality/ Stream Gauge

(WRM, 2012)

10.6.3.2 Artificial Surface Water

It is proposed to expand the artificial surface water monitoring network to include the monitoring of the six (6) new 'contaminated' storages proposed for the site. These are the two new storages in the TSF area (TSF Cell 3 WMD and TSF Cell 4 WMD) and the four new storages in the NOEF area, namely South-East PAF Runoff Dam (SEPROD), East PAF Runoff Dam (EPROD), North-East PAF Runoff Dam (NEPROD) and North-West PAF Runoff Dam (NWPROD). Table 10-24 shows the easting and northing of the proposed artificial surface water monitoring sites discussed above. The locations of these storages are provided in Appendix D3. No changes to the existing suite of parameters monitored or the monitoring frequency are proposed.

Table 10-24 Proposed Artificial Surface Water Monitoring Locations

Location	Easting in AMG84 Zone 53 (m)	Northing in AMG84 Zone 53 (m)	Station Type
North OEF Area			
NWPROD	616,084	8,185,970	Water Quality/ Water Level
SEPROD	618,518	8,184,086	Water Quality/ Water Level
EPROD	618,247	8,185,033	Water Quality/ Water Level
NEPROD	618,777	8,185,759	Water Quality/ Water Level
TSF Area			
TSF Cell 3	613,440	8,183,470	Water Quality/ Water Level
TSF Cell 4	612,159	8,184,234	Water Quality/ Water Level

(WRM, 2012)

During the Project, it is proposed to direct runoff from NAF areas in the South and East OEFs towards sediment ponds. This is based on the assumption that runoff and seepage from the North, South and East OEF areas can be considered 'dirty' and can be released to the receiving waters after treatment in a sediment pond. Monitoring of water quality in these sediment ponds would be required to demonstrate that the water quality is within the limits specified in MRM's WDL prior to release into receiving waters. If runoff and/or seepage from North, South and East OEF areas is found to be 'contaminated', active management measures and/or additional storage volume would be required to fully contain the contaminated water on site (WRM, 2012).

10.7 Groundwater Management and Mitigation

With the proposed management of groundwater inflows to the pit and the monitoring of drawdown and seepage around the site, the potential impacts associated with Project are anticipated to be localised and minor.

10.7.1 Pit Inflows

The projected open pit groundwater inflows identified in Section 10.5.3, will be managed as part of surface water management system (Section 10.4.2). A detailed description of the surface water management system, including the management of pit inflows is provided in Section 10.4.2 and Appendix D3.

10.7.2 Monitoring

MRM currently operates a comprehensive groundwater monitoring program as discussed in Section 10.3.6.The current program will be continued throughout the Project including monitoring of drawdown on Djirrinmini Waterhole. Additional monitoring will be undertaken as part of the Project. Particular focus will be on monitoring of groundwater quality at depth and drawdown associated with the proposed interception bores that will surround the open pit. Detailed planning work for this monitoring program is anticipated to commence later in 2012.

Monitoring of potential seepage associated with TSF and NOEF is discussed in the Tailings Storage Management Plan (Appendix E1) and the Overburden Emplacement Management Plan (Appendix E2).

10.7.3 Residual Void Management

Following cessation of mining at the Project, dewatering will cease and groundwater will continue to seep into the final void. As the final void fills with groundwater and direct rainfall, surrounding groundwater levels will begin to recover. Groundwater simulation results suggest that regional groundwater levels will recover progressively, reaching equilibrium conditions after approximately 300 - 400 years. While this recovery time is quite lengthy from an operational timeframe, given the existing limited use of groundwater in the area it is not predicted that this recovery time will necessitate any additional management controls. Further information on the post-mining management of the final void is provided in Chapter 5.

10.7.4 Post-Closure Monitoring

Following cessation of mining, once decommissioning and rehabilitation works are complete, the Proponent will seek to relinquish the MRM Mineral Leases. Prior to relinquishment, the Proponent will discuss the nature, scope and resourcing of an on-going groundwater monitoring program with the Northern Territory Government and other interested parties. This program may be a continuation of that outlined for operational mining, or an agreed variation, depending on the circumstances at the time. Post-mining groundwater monitoring will be undertaken within monitoring bores that were installed during the operational phase of the Project.