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**McArthur River Mine
Overburden Management Project**

Water Resources

Draft Environmental Impact Statement

8 Water Resources

8.1 Introduction

Management of water is crucial for successful operations and closure at McArthur River Mine (MRM). MRM requires water for various site activities including industrial uses, environmental uses, and potable water. Water associated environmental, social and cultural values exist downstream of the mine.

As part of the Overburden Management Project (the Project) environmental impact statement (EIS), McArthur River Mining has established a set of closure objectives that have and will guide both operations and closure planning and activities (**Appendix S – Conceptual Mine Closure Plan**). Additionally, McArthur River Mining operate under waste discharge license 174-08 (WDL) administered by the Northern Territory Environment Protection Authority (NT EPA) that places conditions on water quality at a compliance point just downstream of the MRM leases. The WDL conditions aim to protect downstream environmental values. Successful site water management is based on achieving the objectives and complying with the conditions of the WDL.

McArthur River Mining, informed by a suite of interconnected water assessment and management models, has designed a water management system (WMS) that will enable the site to achieve the objectives and protect downstream values during the operations and closure phases. A monitoring system will be used to validate and refine models and track the performance of the WMS. Monitoring will also enable McArthur River Mining to determine if adaptation of the WMS is required to continue to meet the objectives into the future.

This chapter describes the WMS for the Project, including physical infrastructure, operating practices, and strategies; and presents the impact assessments undertaken to conclude that residual risks associated with water management are acceptable.

8.1.1 Project Description and Context

This EIS recognises that some aspects of the Project represent significant alterations from the Phase 3 Development Project (Phase 3), and require reconsideration to acceptably manage newly understood risks. The assessment process has taken a holistic site-wide approach and has aimed to address long-term potential risks associated with the Project through revised designs, and operational and closure practices. Therefore, project alterations are not limited to overburden management, but rather focus on achieving the Project closure objectives through revision of a number of aspects of the site. A detailed description of the Project is provided in **Chapter 3 – Project Description and Justification**, and includes a breakdown of existing activities that will continue through the life of the Project and those that represent alterations from previous proposals. In summary, these alterations include:

- an improved design and construction methodology for the development of the North Overburden Emplacement Facility (NOEF);
- removal of the South and East Overburden Emplacement Facilities (SOEF and EOEF) between the mine levee wall and the McArthur River Channel;
- revised NOEF cover, closure and management approach;
- altered final void geometry in the south through the addition of a benign material quarry;
- placement and permanent storage of overburden mined during the final approximate six years of mining operations within the open cut;

- rehandling of overburden stored within the temporary EOEF and SOEF during the open cut operations into the final open cut void upon cessation of mining;
- revised final void closure and management strategy incorporating connection with the McArthur River;
- revised seepage management infrastructure; and
- a revised approach to Tailings Storage Facility (TSF) closure, involving reprocessing of the TSF and placement of tailings within the open cut final void upon cessation of mining.

These Project alterations have necessitated an update of the WMS at MRM. This chapter describes how the system will manage the potential impacts of the Project to protect downstream environmental, social and cultural values.

8.1.2 Regulatory Framework

8.1.2.1 Water Act 2004

The *Water Act* provides for the investigation, allocation, use, control, protection and management of surface water and groundwater resources, as well as processes for licensing these activities. The *Water Act* also provides for the protection and use of water resources for specified purposes such as recreational, social, agricultural, environmental and cultural uses.

Under the *Water Act*, mining activities 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, although 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 *Water Act* also regulates the disposal of waste into water. Waste is defined as any solids, liquids or gas, which, if added to the water, may pollute the water. MRM currently holds a WDL, which provides for the discharge of waters from the mine WMS.

8.1.3 Assessment Approach

The following presents key information that has influenced the approach to the assessment of potential impacts on water resources and has guided the development of appropriate mitigation and management measures.

8.1.3.1 TOR Requirements

The Final Terms of Reference (TOR) (refer **Appendix A – Final Terms of Reference**) governing the assessment requirements of the Project EIS were provided to McArthur River Mining in September 2014. The TOR broadly defines the scope of the EIS as needing to address those aspects of the Project that have significantly changed since the assessment of the Phase 3 EIS in 2012 and the Phase 3 authorisation in 2013.

The water resources section of the TOR requires a detailed risk assessment approach to the identification and management of potential impacts to water resources and downstream values. These key risks are detailed in **Chapter 7 – Project Risk Assessment**, which also explains the risk assessment process undertaken. The Project definition and risk assessment process has been informed by comprehensive groundwater and surface water impact assessments. These technical assessments are documented in the **Appendix T – Groundwater Impact Assessment Report** and **Appendix U – Surface Water Impact Assessment Report**. The TOR required site-wide surface water and groundwater models to be completed. Due to the connectivity between the surface water and groundwater systems in the MRM region, these assessments are highly integrated. The technical assessment reports have been summarised in this chapter and the complete technical reports should be referred to for further information.

8.1.3.2 Waste Discharge Licence Reference Point for Assessment

MRM currently operates in accordance with a WDL which facilitates release of water from the Project to the McArthur River in certain river hydraulic conditions. It presents a series of water quality trigger levels that must be maintained at all times at a downstream water quality monitoring point called SW11, including during releases of water from the mine site. SW11 is located in the McArthur River immediately downstream of the Project mineral lease boundary (refer to **Figure 8-13**). The WDL trigger levels and other compliance conditions are designed to allow for the safe release of water while maintaining protection of environmental values. Further information on the development of the WDL trigger values and their specific objectives is provided in **Appendix U – Surface Water Impact Assessment Report**.

The strategy for preserving environmental values of receptors centres on an alignment with the environmental protection philosophy of the WDL. That is, protect the downstream environment from MRM impacts at all times. This is done so in recognition that mining activities inherently have a localised impact on the environment and that this impact is authorised as part of McArthur River Mining's mining authority. Authorised mixing zones are part of the WDL philosophy and acknowledge that in the immediate vicinity of the mining operations, impacts are likely to occur, however through dilution, off-lease impacts can be managed. Therefore, the receptors for the purposes of the EIS water resources impact assessment are those that exist downstream of the mineral leases. The potential impacts on these receptors are conservatively measured at the SW11 monitoring location just beyond the lease boundary and are measured in accordance with the WDL trigger levels.

McArthur River Mining has undertaken significant fieldwork and groundwater model calibration to gain a robust understanding of the levels and movement of groundwater, and its interaction with surface water systems and Project related structures (including the NOEF and TSF). The work has demonstrated that beyond the influence of the open cut dewatering drawdown zone, groundwater flows regionally west to east towards the McArthur River, and locally towards creeks, where discharge occurs. Thus, groundwater makes its way into surface water on the lease, or into the dewatered open cut/underground WMS. Therefore, compliance with the WDL trigger levels at SW11 is considered to maintain protection of downstream environmental values potentially influenced by water quality, to an acceptable level. This understanding has been adopted by the EIS for the assessment of potential Project impacts on water quality.

This assessment approach was presented to the NT EPA and the Department of Primary Industry and Resources (DPIR) throughout the consultation process. The WDL trigger levels at SW11, as a reference point for the assessment, have directed a significant amount of the technical work completed as part of this EIS. It has guided the revision of the overburden classification system, provided a reference point for closure objectives and most importantly, has been used as a water quality target for the development of the mine WMS and the management of potential impacts from the Project.

8.1.3.3 Environmental Values and Objectives

Environmental values are the qualities of waterways to be protected from activities in the catchment. Protecting environmental values aims to maintain healthy aquatic ecosystems and waterways that are safe and suitable for community use. Environmental values reflect the ecological, social and economic values and uses of the waterway (such as stock water, cultural uses, maintaining biodiversity, fishing and agriculture).

The processes to identify environmental values and determine water quality objectives (WQOs) are based on the National Water Quality Management Strategy: Implementation Guidelines (NWQMS, 1998). They are further outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000).

In consideration of the above guidelines, McArthur River Mining has identified a number of values for the receiving waters downstream of MRM. These include:

- aquatic and terrestrial ecosystems;
- primary industries including stock drinking water, irrigation and general water uses;
- recreation and aesthetics; and
- cultural and spiritual values.

The above guidelines define the condition of the McArthur River in the vicinity of MRM as Level 2: slightly to moderately disturbed ecosystems. The adopted surface water quality indicators relevant to meeting the above environmental values for aquatic ecosystems are those documented in MRM's WDL (refer to **Section 8.1.3.2**). The aquatic ecosystems values are considered to be the most conservative of those listed above and have therefore been adopted as the key surface water management values of focus. The WDL trigger levels therefore provide the suite of indicators utilised to measure protection of all environmental values downstream of MRM.

From a groundwater perspective, the *Water Act* allows for focussed water resource management through the development of Water Allocation Plans. The Project area is not situated within a declared water allocation planning area.

There are no privately owned bores within a 5 kilometre (km) radius of the Project area. All of the bores within this 5 km buffer are owned by the mine site. In terms of environmental values for groundwater, the project site does not contain any non-project related values for aquaculture, public water supply, agricultural supply, domestic use or industrial use. There is stock watering that occurs on and adjacent to the Project site, however, there are no registered bores which are used for stock watering purposes.

Djirrinmini waterhole is a culturally-significant section of the McArthur River that is groundwater-fed and relies on sufficient hydraulic head within shallow and deep groundwater systems to maintain water levels. McArthur River Mining commits to managing the water level at this site, as required to maintain the cultural and ecological values present at this waterhole. Refer to **Chapter 9 – Biodiversity** for further information on ecological values.

Further information on the values associated with downstream water quality is provided in the following EIS Chapters:

- aquatic and terrestrial ecosystems values: **Chapter 9 – Biodiversity**
- primary industries values: **Chapter 1 – Introduction**
- recreation and aesthetic values: **Chapter 12 – Socio-Economic Environment**
- cultural and spiritual values: **Chapter 11 – Cultural Heritage**

The protection of environmental values is governed by the overarching Project closure objectives. As part of the Project EIS, McArthur River Mining has established a set of closure objectives that have and will guide both operations and closure planning and activities (**Appendix S – Conceptual Mine Closure Plan**). The objectives specifically related to water management are:

- Landform stability:
 - Geotechnical stability will be maintained at these standards:
 - NOEF: Long-term static drained Factor of Safety (FoS) of 1.5; Maximum Design Earthquake (MDE) – 1 in 1,000 year event;
 - open cut walls: Probability of Failure (Pf) for inter-ramp slopes of <5%; and
 - TSF: as per ANCOLD (2012) guidelines.
 - Erosional stability; maintainable for these aspects:
 - cover system and landform to maintain functionality;
 - sediment release from erosion does not adversely impact on water quality;
 - erosion does not affect functionality of the landform; and
 - resulting suspended solids can be mitigated.
 - Geochemical stability will be defined, managed and monitored:
 - seepage water quality at toe/base of landforms; and
 - water quality within the mine pit lake.
- Manage surface water and groundwater such that environmental values and ecosystems are maintained downstream of the lease boundary in the short term (0-100 years), and within the McArthur River in the long term (100-1,000 years).
- Landform will host suitable vegetation for post-mining land use.

The manner in which the WMS achieves these objectives will be referred to throughout this chapter, often using the concept of the source-pathway-receptor model. Groundwater and surface water can act as pathways between the sources (including the overburden emplacement facilities (OEFs), open cut, TSF and water management dams) and receptors. The pathways are primarily related to the thin alluvial units, the McArthur River palaeochannel, the weathered bedrock and the shallow fractured bedrock.

8.1.3.4 Water Quality Contaminants of Concern

This EIS incorporates complex water quality modelling of both surface and groundwater systems and includes the output of unsaturated flow modelling of the OEFs and the TSF. The modelling has involved integrating data from a number of modelling packages and methods. Given this, it was important to establish an acceptable suite of water quality contaminants of concern (CoCs) to be modelled through the process early on in the assessment. These CoCs were required to provide a representative suite of indicators to facilitate the assessment of the potential impacts specific to the Project and its downstream environment, including potential salinity, acid drainage and neutral drainage.

The EIS technical specialists and MRM environmental personnel identified an appropriate suite of potential contaminants to be modelled. To manage model complexity, five chemical species listed in the WDL that are considered representative proxies for a broader suite of potential contaminants based on their chemical behaviour were selected. The selected suite represents key indicators for salinity, acid drainage and neutral metalliferous drainage at MRM.

The selected modelling contaminants include:

- sulphates: the primary indicator of sulphide oxidation processes and salinity;
- lead and zinc: present in high concentrations in Here's Your Chance (HYC) mineralisation and pH sensitive (i.e., significantly more soluble and mobile as acidification occurs); and

- cadmium and arsenic: potentially enriched in overburden rocks and may be mobile in neutral pH conditions.

Turbidity was identified as a relevant parameter for the assessment of potential impacts on aquatic ecological values. This was relevant to surface water modelling only.

The selected potential contaminants were presented to and discussed with the NT EPA prior to the commencement of modelling activities. The NT EPA determined that the selection covered the prediction of the known Project risks and potential impacts to water that would need to be addressed by the EIS.

8.1.3.5 Assessment Timeframe

Through consultation with the relevant regulatory agencies, McArthur River Mining was advised to complete an assessment within this EIS of the potential environmental impacts associated with the Project over a 1,000 year period. This requirement extends beyond industry standard practice for environmental impact assessment and contains potential inherent uncertainties associated with predicting Project outcomes for extended periods into the future.

The focus of the EIS has remained on the Project operational period and the shorter term closure period (the next 100 years or so); however, where practicable and meaningful to do so, this EIS has made an assessment of potential impacts for up to a 1,000 year period. It should be noted however that this approach has necessitated different modelling approaches between short-term and long-term assessments, with differing levels of confidence in the predictions presented by those approaches. Further detail on the limitations and validity of long-term impact assessment modelling is provided later in this chapter along with the outcomes of the long-term modelling activities.

8.1.3.6 Climate Change Assessment Methodology

At a global level, Glencore acknowledges the importance of climate change policy and the identification of opportunities and challenges in relation to managing the effects of climate change.

The assessment of potential impacts on water resources has incorporated an assessment of climate change based on the relevant variables including rainfall, temperature and relative humidity. A detailed description of the approach used in assessing the impacts of climate change is provided in **Appendix D – Climate Change Assessment Methodology**.

8.2 Modelling Approach

The following section provides a brief overview of the models used in the water resources impact assessment and how they integrate. The assessment incorporated the following models:

- NOEF geochemistry and unsaturated flow;
- groundwater;
- mine pit lake limnology and quality;
- water balance;
- waterways; and
- flooding.

The ground and surface water models included all three Project domains (NOEF, TSF, and open cut).

Climate data used for all of the predictive models included climate variability as summarised in Section 11 of **Appendix U – Surface Water Impact Assessment Report**. This describes the development of a 125 year baseline climate dataset from the Queensland Climate Change Centre of Excellence (QCCCE) SILO (Scientific Information for Land Owners) Data Drill Service (1889 – 2014). This was looped to cover a 1,000 year assessment period. A sensitivity analysis was then completed to generate ‘worst’ case, ‘best’ case and ‘maximum consensus’ climate future for the representative concentration pathway (RCP)4.5 climate change scenario. These ranges were obtained using the projection builder tool provided in the Climate Change Australia website. Further information on the climate change assessment is provided in **Appendix D – Approach for Assessing Climate Change Impacts**.

A whole of site water balance model was created using the GoldSim modelling package. Details of this model can be found in Section 8 of **Appendix U – Surface Water Impact Assessment Report**. The model was developed to simulate the behaviour of the site-wide WMS at MRM during the life of mine (LOM) (2018 to 2047) and determines the mine site water balance for existing and proposed operations. This model is linked to the waterways model for the assessment of off-site water release opportunities, potential mixing zones and impacts due to uncontrolled flow from water storages. It includes all areas of the operation, including the open cut, NOEF and TSF domains.

The Project waterways model is described in Section 9 of **Appendix U – Surface Water Impact Assessment Report**. This model was constructed in the GoldSim modelling package and was developed to assess potential impacts of the Project on surface water quantity and quality on receiving waterways during the operational period (2018 to 2047) and closure (2048 to 3018). The waterways model, which simulates the waterway water quantity and quality behaviour, was used to simulate the natural and mine derived surface water flow volumes, dissolved concentrations of CoCs and sediment loads along the McArthur River, Barney Creek, Little Barney Creek, Surprise Creek, Emu Creek and Bull Creek through the project area to the downstream mine lease boundary at SW11. The waterways model incorporated baseflow contributions to the creeks and rivers based on outputs from the groundwater model. This facilitated the cumulative assessment of mine affected groundwater and its influence on the surface waters of the McArthur River area and in particular at the downstream water quality compliance point SW11.

Surface water flood modelling was completed for the Project and is presented in Section 10 of **Appendix U – Surface Water Impact Assessment Report**. This was completed in the TUFLOW modelling package using a previous flood model constructed in 2012. The model has a 10 metre (m) grid which extended approximately 20 kilometres (km) downstream of MRM. The model was used to estimate design flood levels, velocities and extents in the McArthur River and its tributaries at MRM for the 5% (1 in 20) Annual Exceedance Probability (AEP), 2% (1 in 50) AEP, 1% (1 in 100) AEP, 0.2% (1 in 500) AEP and 0.1% (1 in 1,000) AEP design flood events for 2018 conditions and the proposed future mine development stages (eleven in total). The model results were used to assess the potential impacts on flood levels, velocities and extents along the McArthur River and its tributaries for the various stages of the mining operations at MRM. It incorporates the climate data discussed above and is a standalone model.

A mine pit lake limnology model was developed using ELCOM (Estuary, Lake and Coastal Ocean Model) to simulate the long-term stability of mine pit lake water during the closure period after the in-pit tailings placement phase. This is presented in **Appendix V – Final Void Limnology Assessment**. The final open cut was modelled to include 16 million tonnes (Mt) of metalliferous saline non-acid forming (MS-NAF) and potentially acid forming (PAF) material in an in-pit dump and 95 Mt of tailings material. The open cut will then be filled rapidly with water from the McArthur River. The ELCOM model has been used to assess relevant hydrodynamic processes that would affect the long-term mine pit lake water quality such as stratification, vertical mixing and turbulence. It simulated a 20-year period starting in 2050 using the SILO data.

A mine pit lake water balance and water quality model was then generated using Goldsim and PHREEQC and incorporated in the limnology assessment results. This looked at the reactions in the mine pit lake considering the in-pit material, mine wall geochemistry, water cover and water balance. When water levels are high enough, surface water, and to a lesser degree groundwater, flow out of the mine pit lake. These flows are considered as groundwater recharge (input into the groundwater model), and surface water contributions to both the water balance and waterways models.

An NOEF seepage model was created using the O’Kane Consultants (OKC) DumpSim assessment tool, a proprietary modelling tool specifically designed for the unsaturated modelling of waste rock dumps. The model incorporates the NOEF’s current and future internal structure including cover systems, gas fluxes and oxidation rates to estimate seepage and potential acid and metalliferous drainage (AMD) load.

The DumpSim seepage output was used as input into an unsaturated model of the foundation (built using TOUGH2) to determine the proportion that reports to the shallow groundwater as basal seepage, and the proportion that reports to surface water as toe seepage.

The Groundwater Impact Assessment model was generated using MODFLOW. This model investigated the Project groundwater regime across all three domains. A separate and detailed TSF groundwater model was also completed and incorporated into the final site-wide groundwater model. Further information on this model are located in **Appendix T – Groundwater Impact Assessment Report**. The model simulates the groundwater response from rainfall, storage of groundwater, and the water quality changes and pathways over time. Periods when baseflow is sufficient for groundwater discharge to creeks and rivers are incorporated as inputs to both the waterways and water balance models.

The groundwater model simulated contributions from sources which are both MRM derived (NOEF, open cut and TSF) and natural (shallow mineralisation). The naturally mineralised sources were derived from a correlation of known site geology (Williams, 1978) and MRM water quality datasets. This was validated using pre-mining soil metal concentrations where high soil concentrations, known mineralisation zones and groundwater quality data correlated with the earlier work completed by Williams.

As part of the groundwater model, standard validation methods were used such as modelled versus measured hydrographs and modelled concentrations versus measured concentrations. Calculated dry season sulphate loads from MRM monitoring records were utilised to confirm that the models adequately replicated observed measurements before long-term simulations were undertaken.

8.3 Overview of Water Resources and Site Features

This section provides an overview of the water resources of the Project area and within the broader region. It discusses the general surface water and groundwater environmental features and the environmental values downstream of MRM. The existing mine infrastructure, WMS and water balance are also described.

8.3.1 Climate

The McArthur River catchment experiences a monsoonal climate regime, which is strongly seasonal with distinct wet and dry seasons. The average daily minimum and maximum temperatures at MRM range between 12°C (in July) and 39°C (in November). A detailed discussion of the MRM climate is provided in **Chapter 1 – Introduction**. This section explains how the available climatic data has been extrapolated for the purposes of the EIS.

Long-term historical climate data required for this Project was obtained from the Queensland Climate Change Centre of Excellence (QCCCE) Scientific Information for Land Owners (SILO) Data Drill Service. The MRM Data Drill data was derived by interpolation of recorded climate data between regional weather stations. The Data Drill provides a continuous daily data set between 1889 and 2015. Previous assessments have shown that the recorded mean monthly and annual climate data (including rainfall and evaporation) at MRM correlate well with the Data Drill data.

The mean monthly rainfalls at MRM exhibit distinct wet (November to April) and dry (May to October) seasons during the year. The wet season mean monthly rainfalls (32 millimetres (mm) to 188 mm) are significantly higher than the equivalent dry season monthly rainfalls (0.4 mm to 14 mm). The mean SILO annual rainfall at the MRM site over the period 1889 to 2015 is approximately 713 mm (refer **Figure 8-1**).

The mean annual pan evaporation at the MRM site is estimated to be approximately 2,739 mm, which is approximately 3.8 times the average mean rainfall. The evaporation rate is high throughout the year, with peak evaporation rates occurring in the months between August and January. Evaporation is generally much higher than rainfall in all months of the year, which creates a water deficit, except for January and February, where rainfall dominates.

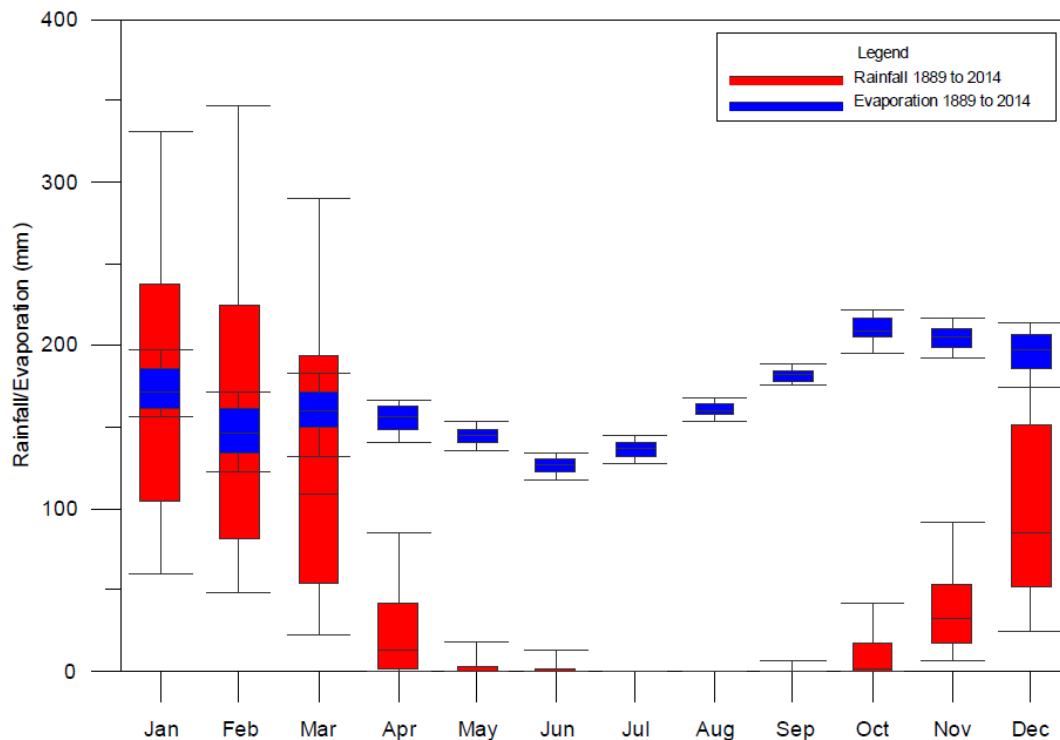


Figure 8-1 SILO Rainfall and Evaporation at MRM (1889 to 2015)

Further information on the SILO Data Drill dataset utilised in this assessment is provided in **Appendix U – Surface Water Impact Assessment Report**.

8.3.2 Topography

The topography of the Project area predominantly comprises of flat floodplain areas bordered by low hilly land. The low hills generally slope from the northwest and the southeast towards the McArthur River, which is reflective of geological bedding and is a relevant influence on surface and groundwater flow regimes. Immediately east of MRM, the Bukalara Plateau, which is the major feature of the local area, stands approximately 30 m to 100 m above the surrounding countryside. This area is dominated by rocky outcrop and would be an area for groundwater recharge as well as being a topographic driver for local surface water flow. A digital terrain map is presented in **Chapter 3 – Project Description and Justification**. In general, the terrain units (topography and geology) across the mineral leases are consistent with, and typical of, the Gulf Region.

8.3.3 Geology and Structural Features

This section provides an overview of the geology of the MRM region. It discusses general geology and the geological features that have an influence on groundwater and its management.

The project area is underlain by bedrock of the Umbolooga Subgroup, which is part of the Proterozoic McArthur Group. The McArthur Group consists of a sequence of Proterozoic formations, primarily dolomitic, and extends from the Queensland border to Arnhem Land in the Northern Territory. These formations include an interbedded sequence of dolostones, siltstones, shales, and sandstones, with a composite thickness of greater than 4,000 m in the McArthur River region.

The Umbolooga Subgroup is comprised of interbedded dolomite, dolomitic siltstone, sandstone and shale (**Figure 8-2**). The Reward Dolomite outcrops to the west of the mine area and the Masterton Sandstone outcrops to the north-east (Smith, 1972) (**Figure 8-2**).

A zone of weathering occurs typically 10 to 30 m within the upper profile. This occurs in dolomite and dolomitic siltstone that have undergone substantial weathering, leading to the development of enhanced secondary permeability in areas of subcrop and outcrop. The extent of weathering will vary due to depth to surface, host rock mineralogy and the structure which facilitates the movement of air and water through that material. Further information is provided in **Appendix T – Groundwater Impact Assessment Report**.

The relevance of the site geology to the local hydrogeological interpretation is significant. From west to east the system transitions from a relatively tight rock mass with variable faulting effects and a consistent weathered upper aquifer sequence, into the brecciated and permeable Western Fault Block, which is located between the Western Fault and Emu Fault. This corridor comprises of steep easterly dipping beds of the Barney Creek Formation. Drilling in this fault block corridor has intersected some areas of open, yet not continuous, voids and cavities. It has also provided substantial airlift and pumping yields to greater depths than the unconsolidated system. Hydraulic testing indicates that permeability in this corridor is highest just north and south of the Barney Creek Channel. This highly permeable trend has not been fully delineated southwards of the Barney Creek Channel and is an area for further drilling, testing and investigations.

An increase in water table levels is observed on the eastern side of the corridor. As this zone is removed by mining, it could lead to a period of increased groundwater seepage into the mine and hence open cut water balance. The mine void will also provide preferential flow conditions for seepage affected groundwater from the north and west (refer **Appendix T – Groundwater Impact Assessment Report**)

The positions of the Western Fault, Woyzbun Fault and Whelan Fault are based on the MRM detailed geology model in the vicinity of the mining area. The remaining regional faults are based on fewer drill holes, airborne geophysics, geological mapping and other datasets. Fractures within weathered and fresh bedrock present either preferential seepage pathways or barriers to seepage. Evidence of fracturing is present in the upper sequences of rock, although these tend to tighten with depth, with the exception of the Western Fault Zone which is a corridor of brecciated and in places karstic units with the capacity to store and transmit large groundwater volumes.

The McArthur River and the associated creeks and tributaries receive both localised and regional discharge from shallow groundwater. This creates a boundary effect in the groundwater model and represents a point where groundwater is lost to the surface water system. Other than pumping and the open cut, this discharge is a critical driver within the Projects hydrogeological system.

Zones of shallow mineralisation are also located within the Project area (Williams, 1978). Of note, are the mineralised Cooley I & II deposits and their proximity to the McArthur River Channel (refer to **Figure 8-3**).

8.3.4 Groundwater

This section provides a general description of the groundwater environment in the MRM area. It identifies the major groundwater bearing rock units, discusses general groundwater flow patterns across the site and the quality of groundwater within the system.

8.3.4.1 Major Groundwater Bearing Units

There are three main groundwater bearing units across the project areas: alluvial (referred to as 'overburden' in **Appendix T – Groundwater Impact Assessment Report**), weathered bedrock and bedrock (fractured and intact). The alluvial unit is further subdivided into a general alluvial cover and a deeper buried palaeochannel within the McArthur River floodplain. These units are typically semi-confined (meaning not directly connected to rainfall recharge).

8.3.4.1.1 Alluvium

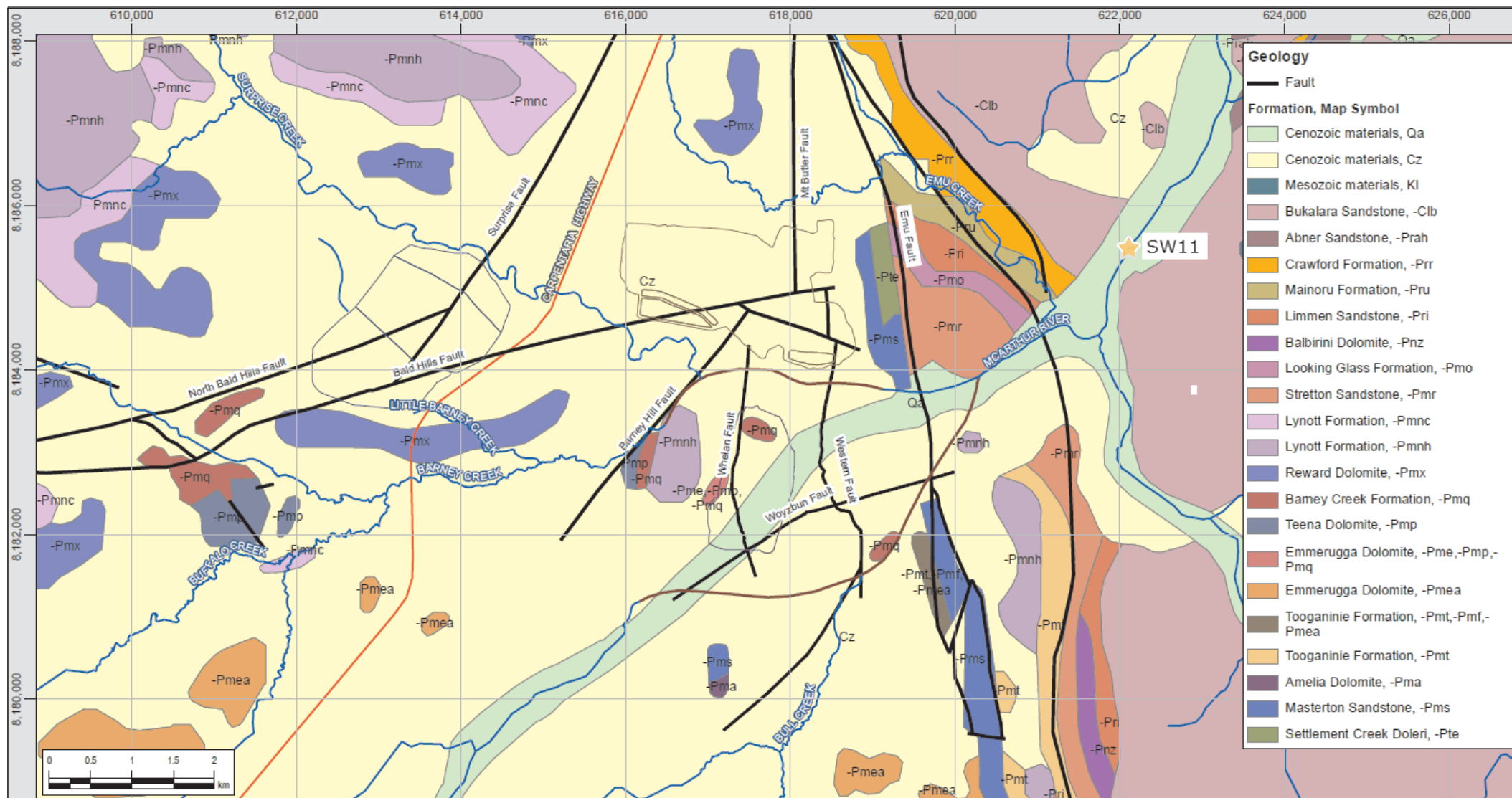
Unconsolidated sediments overlie the bedrock and consist of recent alluvial silt, sand and clay deposited on the floodplains, flood terraces, levees and channel floors of the McArthur River. Drilling at MRM has revealed thin alluvial deposits have formed along the channels of the ephemeral streams and rivers including Surprise Creek, Barney Creek and Emu Creek. Away from these streams and rivers there are mainly finer-grained sediments and residual soils occurring at or near ground surface.

The alluvial unit thickness is greatest (20-30 meters (m)) along the McArthur River, Surprise and Barney Creeks and the area north of Barney Creek Channel between the NOEF and the Emu Fault.

Table 8-1 provides a summary of the units' hydraulic conductivity. Hydraulic conductivity describes the ease with which water can move through pore spaces or fractures. Further information is provided in **Appendix T – Groundwater Impact Assessment Report**. The alluvial hydrogeological unit is made up of the coarse and fine alluvium parameters. The table illustrates the variability of hydraulic conductivity ranges and the amount of testing completed.

Table 8-1 Hydrological Unit Hydraulic Conductivity

	Number	Max (m/day)	Min (m/day)	Median (m/day)
Alluvial Coarse	23	34.7	0.1	3.3
Alluvial Fine	10	10.1	0.05	0.6
Weathered Bedrock	34	53.3	0.01	0.4
Bedrock	49	56.6	2 x 10 ⁻⁴	0.07



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LEGEND

PROJECTION

- Horizontal Datum: GDA94
- Grid Zone: 53
- Vertical Datum: Mean Sea Level

Data Source: KCB, 2017

Notes:

- Geology: Bauhinia Downs 1: 250,000 published geology map.
- Faults supplied by MRM geology.
- Surface Water and Road features are based on published 1: 250,000 data that has been adapted to the background image.

McArthur River Mine

Overburden Management Project EIS

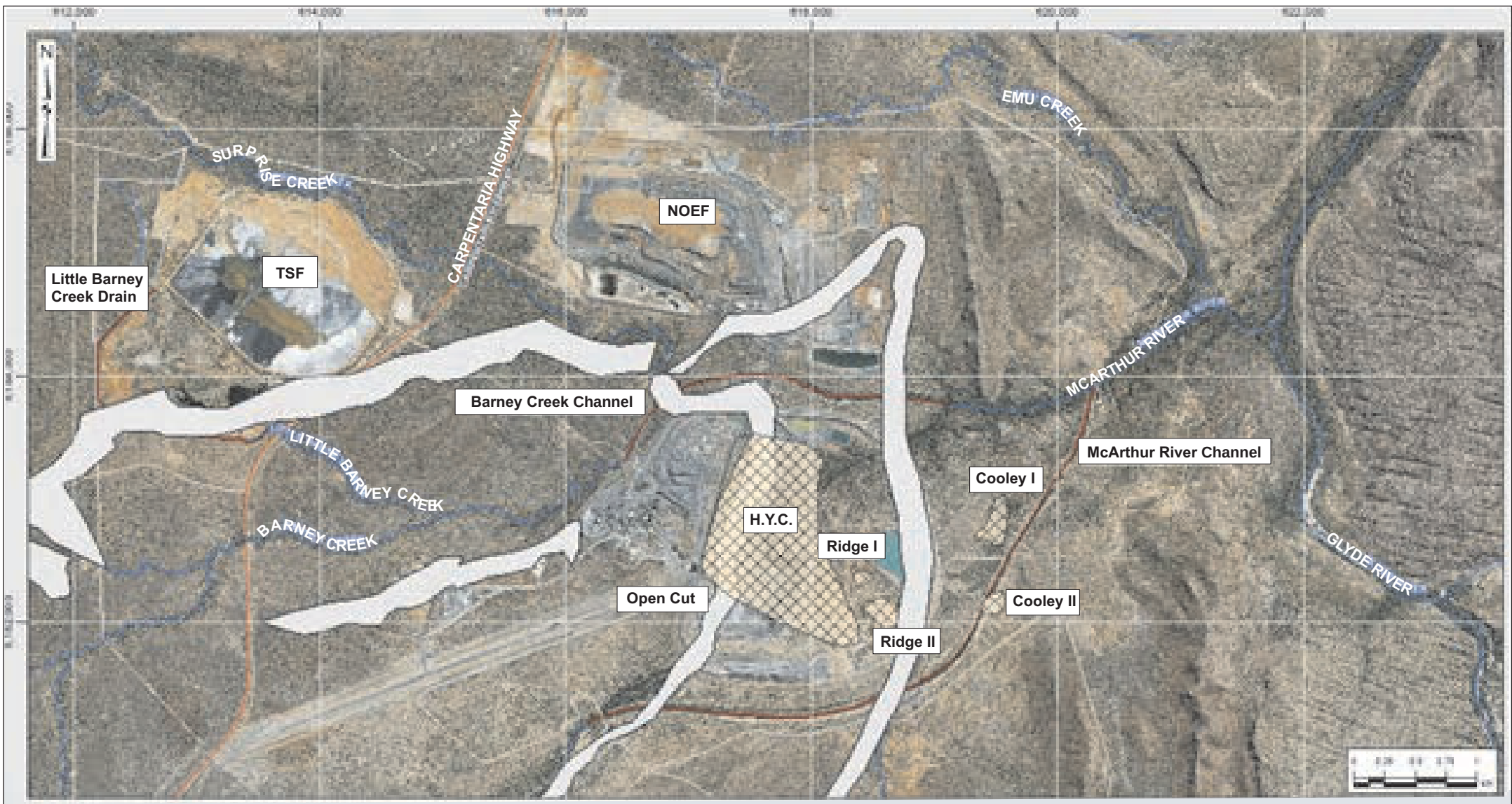
Local Geology and Interpreted Structural Features

0 0.5 1 1.5 2 km

01/03/2017

Datum: GDA 94
Projection: MGA 53

FIGURE 8-2





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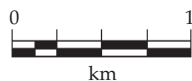
LEGEND

PROJECTION

- Horizontal Datum: GDA94
- Grid Zone: 53
- Vertical Datum: Mean Sea Level

River/Creek	— Main Road
Diversion	— Track
Principal Road	 H.Y.C. Ore Body
	 Pyritic Shale Extent

McArthur River Mine
Overburden Management Project EIS
**MRM Satellite
Deposits**



0 1
km

01/03/2017

Datum: GDA 94
Projection: MGA 53

FIGURE 8-3

The following core images (from a well drilled east of the Southeast Perimeter Runoff Dam (SEPROD)) illustrate the different units and the transitions between them (refer to **Figure 8-4** to **Figure 8-9**).



Figure 8-4 Tray 1 (3-8.2 m) Alluvial Clay, Sands and Some Rock Fragments



Figure 8-5 Tray 2 (8.2-12.6 m) Unconsolidated Alluvial Clays, Sands and Some Rock Fragments with Small Conglomerate Dolomitic Fragment of Core



Figure 8-6 Tray 3 (12.6-17.6 m) Transition into Weathered Bedrock with Silt and Sand Lenses.

The McArthur River palaeochannel lies south of the original river and is oriented southwest to northeast. It is exposed in the eastern and southern open cut walls (refer **Figure 8-7** below). This illustrates well sorted and defined layers. Site drilling programs which have intersected this feature suggest a mixture of sand and gravel underlain by clay and a permeable basal unit, and would typically be located at the edges of the channel. Defining the orientation, zones of recharge, and geometry of this structure are important to determine its impact on the open cut and other receptors.

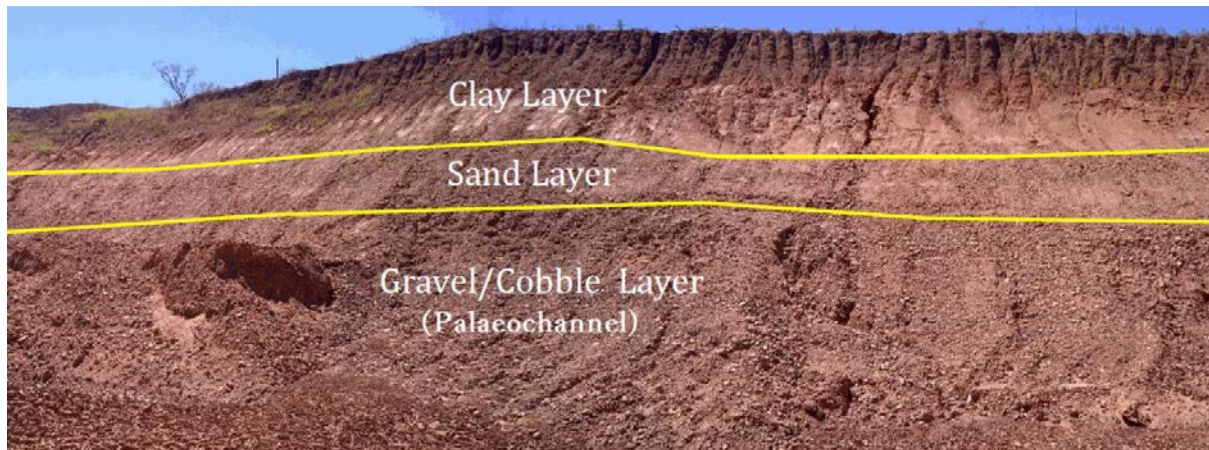


Figure 8-7 McArthur River Palaeochannel

8.3.4.1.2 Weathered Bedrock

Subcropping and outcropping dolomite and dolomitic siltstones have undergone significant weathering to form secondary permeability features such as vugs and solution cavities. These features form localised unconfined to semi-confined aquifers, of varying lateral extent. The permeability of the weathered dolomite is highly variable with a range of over three and a half orders of magnitude. This is most likely a result of differential weathering, variable host rock type and other secondary processes such as fractures and faulting. **Figure 8-8** illustrates the weathered bedrock to bedrock transition.



Figure 8-8 Tray 4 (12.6-17.6 m) Transition to Weathered Bleached HYC Shale Bedrock with Lenses of Silts and Sands



Figure 8-9 Tray 5 (17.6-22.5 m) Highly Weathered Black Carbonaceous Shales

8.3.4.1.3 Bedrock

Bedrock is defined as material with limited to no weathered minerals or features. This boundary is more a transition as weathering from surface diminishes. The depth of weathering will vary due to depth to surface, host rock mineralogy and the structure which facilitates the movement of air and water through that material.

Bedrock units within the Project area are generally very hard dolomitic and competent in nature, they will have some degree of fracturing which is related to fault and structural zones proximity and regional tectonic stresses.

Figure 8-10 illustrates the variability in fracturing within the bedrock. In this example from MRM, between 35.2 and 35.6 m shows high degree of fracturing, while for section 37.8 to 41.1 m shows more competent and less fractured rock. The degree of connectivity between these fractures is important to understanding pathways for groundwater movement. The aperture of these fractures and the amount of mineral infilling both influence fracture permeability.



Photograph II.98 **MRM2014-04, 35.2 m to 37.8 m (Dry and Wet)**



Photograph II.99 **MRM2014-04, 37.8 m to 41.1 m (Dry and Wet)**

Figure 8-10 Bedrock Fracturing

8.3.4.2 Groundwater Flows

This section provides a brief discussion of groundwater flows within the major hydrogeological units in the MRM area. Given MRM's proximity to the McArthur River, the groundwater and surface water systems are highly connected, with one system often influencing the other. McArthur River Mining has undertaken significant fieldwork and groundwater model calibration to develop a robust understanding of the levels and movement of groundwater, and its interaction with surface water systems and Project infrastructure. The work has demonstrated that beyond the influence of the open cut dewatering drawdown zone, groundwater flows regionally towards the McArthur River, and locally towards the ephemeral creek systems, where discharge occurs. Thus, groundwater migrates into the surface water drainage system, or into the dewatered open cut/underground groundwater system.

Appendix T – Groundwater Impact Assessment Report presents groundwater level contours generated from bores screened in alluvial unit, weathered bedrock and fresh bedrock at the end of the 2015 dry season, and at the end of the 2015/2016 wet season. There exists a high level of hydraulic connectivity between these units, however bedrock material becomes much less permeable at depth. These contours support the following observations:

- Across the MRM site, the alluvial unit trends broadly from higher topographic elevations in the west to lower elevations in the east. There are no major changes in flow direction between the end of the dry season in 2015 and the end of the wet season in 2015/2016. The effect of local drainage is not represented in the data but is likely to be an influence on a local scale.
- Weathered bedrock trends are similar to the alluvial levels and also conform to regional trends flowing broadly from west to east. There are no major changes in flow direction between the end of the dry season in 2015 and the end of the wet season in 2015/2016. There are localised areas within the project which have a strong hydraulic link between the alluvial and weathered bedrock.
- Bedrock trends are broadly from west to east with some localised abrupt variations which are probably reflective of structural influences. The trends are not starkly different to other units, indicating that any structural controls are more an influence to regional trends rather than the sole controller of deeper groundwater movement. These potential structural controls on groundwater movement are currently being investigated by McArthur River Mining.

Appendix T – Groundwater Impact Assessment Report presents hydrographs for the major groundwater units and discusses these in detail for each of the key Project areas. It also presents the key characteristics (parameters) of each of the groundwater bearing units.

8.3.4.3 Groundwater Quality

8.3.4.3.1 Groundwater Chemistry

This section summarises the general water types and qualities which are found on site. A more detailed description of water chemistry is presented in **Appendix T – Groundwater Impact Assessment Report**, including data and plots for bores screened exclusively in each of the water bearing units. Groundwater is classed in three principal types based on water chemistry. The classification is based on the dominant cations and anions present in the waters and include:

- Magnesium, calcium– bicarbonate type waters (Mg, Ca-HCO₃);
- Magnesium, calcium– sulphate type waters (Mg, Ca-SO₄); and
- Sodium, magnesium – chloride, sulphate type waters (Na, Mg-Cl, SO₄).

In the magnesium, calcium-bicarbonate type waters (Mg, Ca-HCO₃), calcium and magnesium are the dominant cations, while bicarbonate is the dominant anion. This is interpreted as representing a water type unaffected by mineralisation or mining activities. Dolomite is the dominant rock type in the area, and the overlying alluvium and residual soils are likely derived from it. The chemical composition of dolomite is CaMg(CO₃)₂, therefore natural water-rock interactions would be expected to yield Mg, Ca-HCO₃ type water or Ca, Mg - HCO₃ type water. This chemistry is typical of groundwater in the area west, north and northeast of the NOEF, northwest of the TSF, and in the vicinity of Djirrinmini waterhole. Bores at the open cut area also have a distinct Mg-HCO₃ type signature, with the exception of one which has a Mg-SO₄,Cl type water.

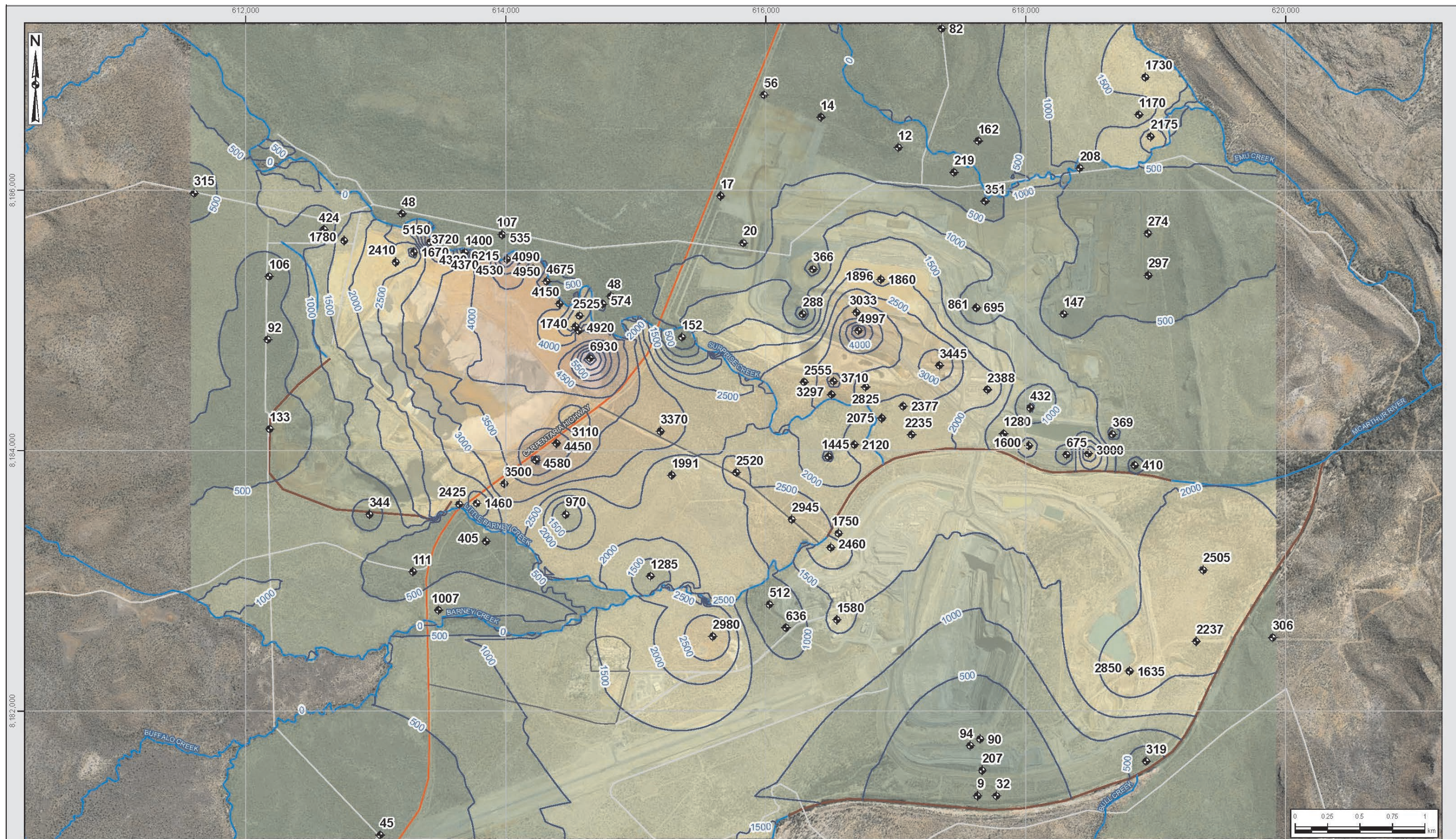
In magnesium, calcium-sulphate type waters (Mg, Ca-SO₄), magnesium and calcium are the dominant cations, while sulphate is the dominant anion. This is interpreted as representing a water type affected by mineralisation or mining activities. The primary source of sulphate in the area is the oxidation of pyrite (FeS₂), which is found in elevated quantities in the regional Barney Creek Formation. Alluvial and residual soils in the MRM area are therefore naturally enriched in sulphates, primarily in the form of gypsum (CaSO₄·2H₂O). This results in naturally elevated sulphate waters. Seepage from mine contaminated water facilities will also result in elevated sulphate waters. This chemistry is typical of groundwater in the area north of the TSF, suggesting impacts from tailings water seepage. Other areas include southeast of the NOEF, and the southwest of the NOEF where bores show a general trend towards increased sulphate.

In sodium, magnesium-chloride, sulphate type waters (Na, Mg-Cl, SO₄), sodium and magnesium are the dominant cations, while chloride and sulphates are the dominant anions. This water type is uncommon in the area and appears associated with the location of regional scale faults. Upwelling of older Na-Cl type water along the fault zone may be a potential source for this distinct chemistry. Given that the current conceptual model indicates that the faults are very low permeability features at depth, this would imply that migration of deeper NaCl rich water has occurred over a significant period of time. This chemistry is found in bores northeast of the NOEF alongside the Emu Fault, and southeast of the TSF. Bores in the north of the open cut area have a mix of water types, including Mg-SO₄ type, Mg-Cl, SO₄ type and Mg, Na-SO₄, Cl type. The chemistry of the bores to the southwest of the TSF seem to be controlled by their position relative to the outcropping Reward Dolomite, with Mg, Ca-HCO₃ type waters south of the outcrop and Na,Mg-SO₄,Cl type water on the northern TSF side of the outcrop.

8.3.4.3.2 Current Sulphate Concentrations

Figure 8-11 presents a contour map of sulphate concentrations across the MRM site. The map was generated using the average 2016 concentrations for the shallow monitoring bores (predominantly screened in alluvial and weathered bedrock units). To provide an adequate coverage of data across the site, where no monitoring bore was installed in the weathered bedrock, the groundwater quality from the appropriate alluvial unit bore was reported.

The contour map shows elevated sulphate concentrations in the vicinity of a number of key MRM infrastructure areas, including the TSF, NOEF and NOEF PRODs. Concentrations of sulphate in these areas range from ~ 2,000 to ~ 5,000 milligrams per litre (mg/L). Levels are significantly reduced in areas further away from the mine facilities (e.g., south of the open cut, north of the NOEF etc.).



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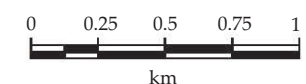
PROJECTION

1. Horizontal Datum: GDA94
2. Grid Zone: 53
3. Vertical Datum: Mean Sea Level

- | | | |
|--|--|--|
| — River/Creek | — Minor Road | — Diversion |
| — Principal Road | — Track | — Concentration Contour (mg/L) |

Data Source: KCB, 2017

McArthur River Mine Overburden Management Project EIS Average Sulphate Concentration Contours at MRM (2016)



01/03/2017

Datum: GDA 94
Projection: MGA 53

FIGURE 8-11

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8.3.5 Surface Waters

8.3.5.1 Regional Catchments

The McArthur River is the major surface water feature in the region. The McArthur River originates in the Barkly Ranges and flows in a northeast direction before discharging into the Gulf of Carpentaria near the Sir Edward Pellew Group Islands (refer to **Figure 8-12**). The river falls more than 250 m over its 330 km length. The total catchment area of the McArthur River is approximately 18,000 square kilometres (km²). The MRM site is located adjacent to the McArthur River between its confluences with the Glyde and Kilgour Rivers in the middle reaches of the catchment. The Glyde River, which has a catchment area of approximately 2,440 km², originates 95 km southeast of MRM and joins the McArthur River approximately 6.9 km downstream of the mine site. The Kilgour River, which originates approximately 112 km south of MRM, has a catchment area of approximately 3,100 km² and joins the McArthur River approximately 20.7 km upstream of the mine site (WRM, 2017).

8.3.5.2 Local Catchments and Waterways

Most of the mine site is within the McArthur River floodplain. The Glyde River joins the McArthur River to the northeast (and downstream) of the mine (refer to **Figure 8-13**). Bull Creek and Emu Creek join the McArthur River from the east and northwest respectively in the vicinity of the mine upstream of the Glyde River confluence. Surprise Creek flows into Barney Creek which joins the McArthur River from the western side through the mine site.

The mine occupies a small portion of the catchments of Barney, Surprise and Emu creeks. Most of the existing mine infrastructure is located on a low hill (Barney Hill) between the confluences of Barney Creek, Surprise Creek and McArthur River.

The McArthur River, Barney Creek and Little Barney Creek within the mine site, were realigned approximately ten years ago, to facilitate open cut mining activities. In addition, a flood protection levee (the mine levee wall) has been constructed to protect the open cut and mine infrastructure from McArthur River flooding. Bull Creek is intercepted by the McArthur River Channel. Surprise Creek is intercepted by the Barney Creek Channel. The above stream realignments are presented in **Figure 8-13**.

8.3.5.3 Surface Water Flows

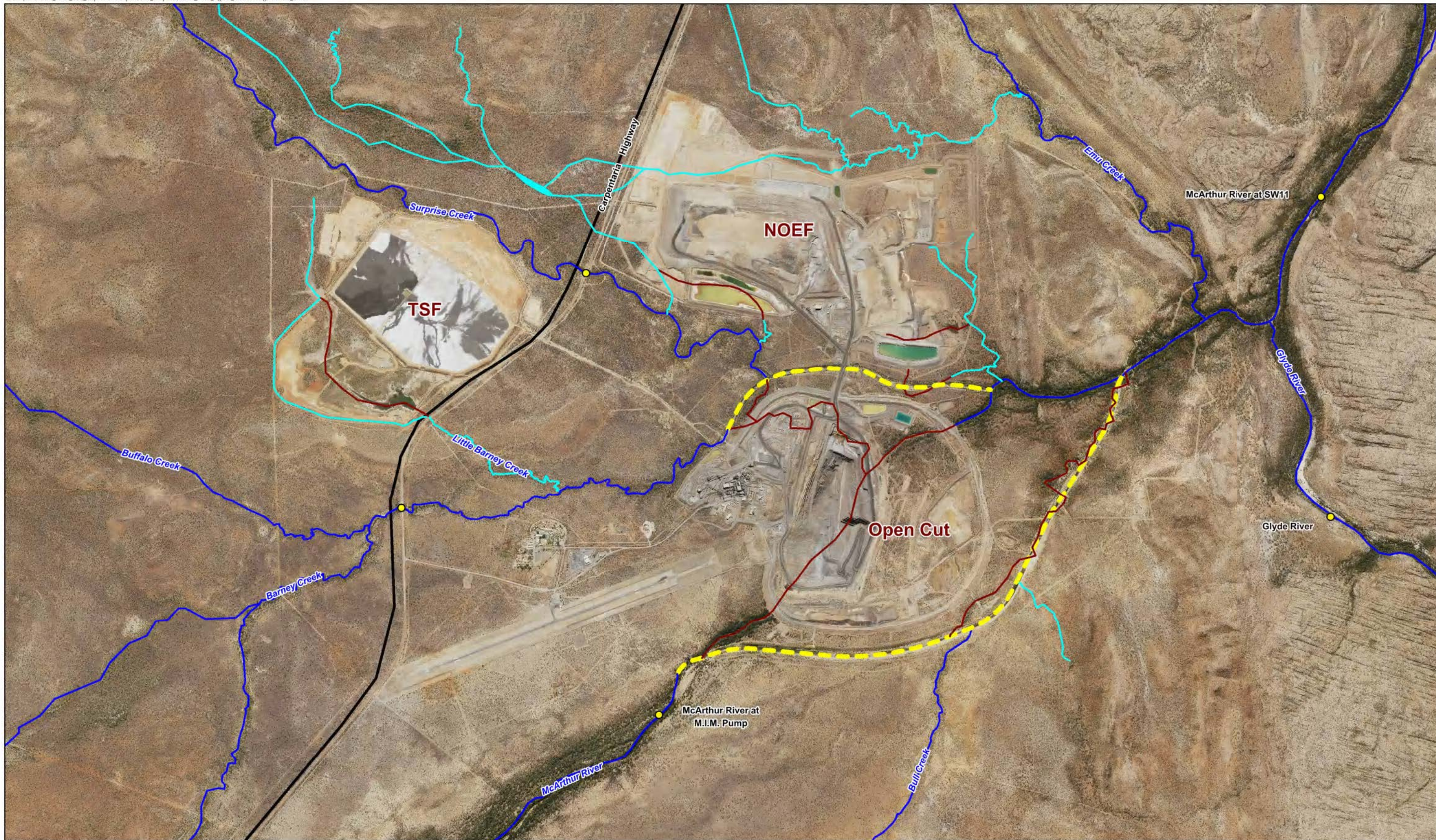
McArthur River flows at MRM are highly variable. High levels of streamflow are recorded during the 'wet season' which typically occurs from November to April. During the dry season, stream flows are much lower and long periods of little to no flow can occur. During major floods, the main channel of the McArthur River overflows and spreads floodwater laterally across the floodplain for several kilometres. The 'M.I.M Pump' monitoring location represents upstream McArthur River Flows. The 'SW11' monitoring location represents downstream McArthur River Flows (refer to **Figure 8-13**).

Glyde River flows are highly variable. High levels of streamflow are generally recorded during the wet season which typically occurs from November to April. During the dry season, streamflow is much lower and long periods of little to no flow can occur. Barney Creek flows only for short periods and high flows are generally recorded only during the wet season. During the dry season there is little or no flow in Barney Creek. Following 2011/12 and 2013/14 wet seasons, prolonged baseflow was recorded into the dry season, possibly due to localised elevated groundwater levels. Surprise Creek at MRM flows only for short periods and high flows are generally recorded only during the wet season. During the dry season there is little or no flow in Surprise Creek. Data on flow variation and volumes and daily flow frequency curves are provided in **Appendix U – Surface Water Impact Assessment Report**.

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	 A GLENORE COMPANY	LEGEND	
		 Key Location	
		 Major Watercourse	
		 McArthur River Catchment	
Data Source: Location, Catchments, Watercourse, Landsat 7 Mosaic - WRM (Feb 2017)			
		McArthur River Mine Overburden Management Project EIS McArthur River Catchment and Major Water Courses	
		 Scale: 1:900,000 (A3)	
		02/03/2017  Datum: GDA94 Projection: MGA53	
		FIGURE 8-12	



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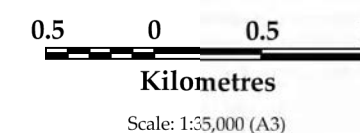


LEGEND

- Stream Gauging Station
- Highway
- Pre-Diversion Drainage Path
- - - Existing Diversion
- Tributary
- Major Drainage Path

Data Source: Gauging Station, Tributary, Major Drainage, Diversion/Pre-Diversion - WRM (Feb 2017); Highway - NT Gov. (2012); Aerial - McArthur River Mining Pty Ltd (Jul 2016)

**McArthur River Mine
Overburden Management Project EIS
Local Drainage Network and
Surface Water Features**



02/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-13

8.3.5.4 Surface Water Quality Monitoring

A comprehensive surface water and groundwater quality monitoring program within and in the vicinity of the mine site has been underway for over 20 years. This program aims to assess background water quality and measure the impact of mining activities on water quality. Currently water quality is monitored at 32 natural surface water sampling sites and 55 artificial (associated with MRM water management infrastructure) surface water sampling sites i.e., PRODs, dams, sumps and seepage collection locations. **Figure 8-14** presents the location of the natural surface water monitoring sites in and around the MRM site.

8.3.6 Surface Water and Groundwater Interaction Mechanisms

This section briefly describes the key mechanisms that facilitate interaction between groundwater and surface water at MRM. A schematic of these mechanisms is provided in **Figure 8-15**.

8.3.6.1 Rainfall Runoff

During and following rainfall, water that lands on the surface within the MRM area will either infiltrate into the soil or rock as recharge (see **Section 8.3.6.2** below) or flow towards drainage lines as runoff. Surface water runoff is diverted and managed depending on the material that the water interacts with and derived suspended solids.

8.3.6.2 Recharge/Infiltration

During and following rainfall, some of the water that lands on or flows onto the surface (including in creeks and rivers) can soak into the soil or rock. The water that infiltrates the surface and does not evaporate or transpire through plants back into the atmosphere is known as groundwater recharge. Groundwater recharge is the mechanism by which the groundwater levels within the hydrogeological units at MRM are fed additional water. Infiltration also occurs into constructed features such as an OEF or the TSF.

8.3.6.3 Toe and Basal Seepage

Seepage is a general term used to describe the water that has infiltrated a body of material and under the influence of gravity, is moving. This can be in the form of basal seepage (bottom of a facility) or toe seepage (at the edge of a facility). Seepage that results from infiltration into non-benign material at MRM is likely to not meet WDL targets. Seepage through benign material may only require sediment management into the groundwater. Basal seepage may report to surface water systems distant from the source (refer to **Section 8.3.6.4**). Toe seepage mainly reports to the surface WMS and can be collected in drains and sumps as required.

8.3.6.4 Baseflow

Baseflow describes the discharge of groundwater into the surface water system. At MRM this results when site groundwater levels in an area around a creek or river are higher than those within the creek or river, resulting in a flow gradient towards the surface water feature. All the active groundwater below MRM reports to, and discharges as baseflow locally to, creeks and regionally to the McArthur River.

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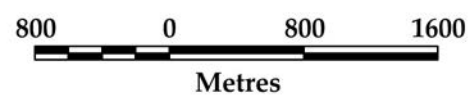


LEGEND

- Stream Gauging Station
- Surface Water Monitoring Locations
- Watercourse

Data Source: Gauging Station, Monitoring Location, Watercourse - WRM (Feb 2017); Aerial - McArthur River Mining Pty Ltd (Jul 2016)

**McArthur River Mine
Overburden Management Project EIS
Natural Surface Water
Monitoring Locations**



Scale: 1:45,000 (A3)

02/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-14

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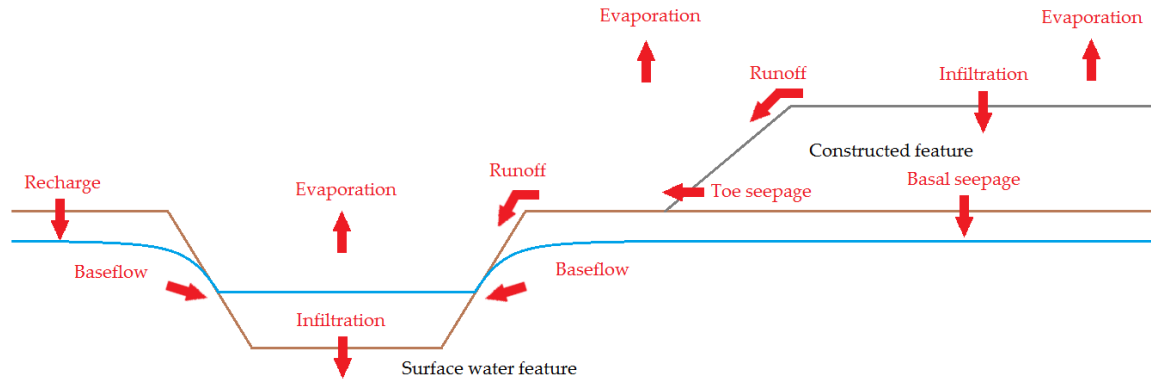


Figure 8-15 Surface Water and Groundwater Interaction Mechanisms

8.3.6.5 Evaporation

Evaporation is the loss of water from the surface (land or water) to the atmosphere. For simplicity, this section will use the term evaporation only. At MRM, the average evaporation rate is much greater than the rate of rainfall, with the exception of January and February. Evaporation also has an effect on groundwater levels. Given the high evaporation rates, evaporation also represents an effective mechanism for removal of excess water from the surface WMS.

When evaporation is assisted by vegetation (either natural or revegetated surfaces on mine affected areas), it is termed evapotranspiration. This term is mainly used when describing water loss from the shallow soil via vegetation, rather than from an open water body.

8.4 Existing Mine Infrastructure

This section briefly describes the current location of key mine infrastructure and WMS components over the LOM and their interaction with the natural site features described above. Further information is provided in **Section 8.3** and **Chapter 3 – Project Description and Justification**. The interactions between mine infrastructure and the surface water and groundwater systems are discussed in detail in **Section 8.5**.

8.4.1 Site Domains

Water management on site is based on managing water qualities in the various operational areas to meet the WDL trigger values at the compliance point SW11. McArthur River Mining has an understanding of the quality and quantity of water produced from the various areas of the site. To effectively manage water with different water qualities, McArthur River Mining have developed a system of classifying waters according to some key properties (refer to **Section 8.4.2.1**). The site water management infrastructure and management strategies are planned to manage the quantities of various water classes to meet the water quality objectives.

The overall site is divided into three spatial domains, with the boundaries and key facilities in each show in **Figure 8-16**. Surface water and groundwater link between all three domains. These interactions are discussed throughout the chapter. An overview of the domains is provided in the sections below.

8.4.1.1 Open Cut Domain

The open cut domain encompasses the open cut mining operation. The mine levee wall extends around the open cut area to protect the mine and associated facilities from McArthur River flooding up to a 1,000 year event. The McArthur River Channel connects the original McArthur River to the southwest and northeast of the mine levee wall, bypassing the operations area. The Barney Creek Channel is located around the northern edge of the mine levee wall and directs flow from the northwest around to the northeast where it joins the old McArthur River.

The open cut is where the ore is mined. To access the ore, overburden is removed and hauled away to OEFs. The open cut is underlain by redundant MRM underground mine workings. Groundwater and surface runoff flow into the open cut and underground workings, and must be removed to enable operations to continue in dry conditions (dewatered). The open cut is a net generator of water of a variety of qualities that require management.

The WOEF (West Overburden Emplacement Facility) is the original overburden emplacement facility, developed when the open cut was first constructed. It is now used for offices and workshops, and a ROM pad for mined ore. The EOEF and SOEF are temporary stockpiles and will contain a number of different material types throughout the life of the project. These OEFs are all located inside the mine levee wall, with their runoff contained in various WMSs within the domain using drains, dams, ponds, pipes and pumps.

The processing plant and power station are located to the west of the open cut, inside the mine levee wall on top of Barney Hill. The processing plant is where the ore is crushed, ground and separated into the useful product (concentrates) and waste (tailings). The processing operations consume large quantities of water of various classes, and also pump out large volumes of water with the tailings slurry. Runoff from all of these facilities are contained in the WMS.

The domain also includes infrastructure to support the operations including the airport, accommodation village, stores, workshops and connecting roads. The Mount Isa Mines Exploration (MIMEX) borefield plus Emu bores EMU37 and PU38 located in the domain are the main source of raw water for use in the processing plant and for making potable water. The Donkey borefield is used to intercept minor amounts of groundwater before it migrates to the open cut.

A 6 megalitre per day (ML/d) reverse-osmosis water treatment plant (WTP) is currently being constructed inside the mine levee wall to treat excess mine affected waters.

The McArthur River, Barney Creek, Donkey borefield and southern Emu bores are receptors in this domain.

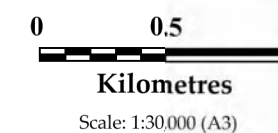


LEGEND

- Emu Borefield
- Mimex Borefield
- Donkey Borefield
- Watercourse
- Project Domains

Data Source: Watercourse - Geoscience Australia (2006); Highway - NT Gov. (2012); Aerial - McArthur River Mining Pty Ltd (Jul 2016); Borefield - KCB (Feb 2017); Project Domains - MetServe (Feb 2017)

McArthur River Mine Overburden Management Project EIS Project Domains and Existing Infrastructure



10/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-16

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River
Mining**
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8.4.1.2 NOEF Domain

The NOEF domain is located to the north of the open cut, on the northern side of the Barney Creek Channel. The NOEF has been the primary OEF since 2009, and will continue that role throughout the Project. A number of benign material stockpiles and alluvial borrow areas are located around the NOEF. The NOEF is serviced by PRODs, which store runoff water from disturbed areas of the facility, and toe seepage recovered from drains and sumps around the active stages. There are currently three operational PRODs: South PROD (SPROD) and SouthEast (SEPROD) on the southern side and West PROD (WPROD) to the west of the NOEF. A network of drains and pumps connect the PRODs together to enable transfer of waters between facilities to manage water levels, types and overflow risk. A network of levees around the base provides protection from floodwaters and separation of external and mine-affected waters. Sediment basins service cleared areas that are in early stages of development.

Surprise Creek and Barney Creek to the south of the NOEF are receptors in this domain. The Emu borefield and Emu Creek are also possible receptors.

8.4.1.3 TSF Domain

The TSF domain is located west of the NOEF and open cut, on the western side of the Carpentaria Highway. It is comprised of two areas which receive tailings (Cells 1 and 2) in slurry form. Cells 1 and 2 will integrate into a single cell as the facility develops through 2017-2018, and remain combined for the rest of the LOM. Tailings are deposited around the perimeter of the cells, with excess water recovered from a central decant pond, where it is recycled back to the processing facilities. Tailings and return water are transported through pipes in a bunded corridor between the process area and the TSF.

A third cell to the southwest of Cell 1 and Cell 2, named Cell 3, is currently used to store water from the TSF and mining area. In the near term, Cell 3 will be divided into two lined water management structures; the 2 gegalitres (GL) Water Management Dam (WMD) and the 4 GL Process Water Dam (PWD). The WMD will be used to store selected waters in preparation for release under permitted conditions. The PWD will be used to store excess water from the open cut/underground and TSF, for evaporation and/or future treatment.

A clean water drain conveys clean water from the western side of the TSF around the southern side of Cell 3 to Little Barney Creek. A TSF groundwater interception trench (refer to **Section 8.3.1**) will be constructed along the northern edge of the TSF, between Cell 1 and Surprise Creek, in 2017. A series of benign material borrow areas and stockpiles are located in the areas around the TSF.

8.4.2 Background to the Existing Water Management System

This section provides a brief overview of the existing WMS. **Section 8.4.3** presents general water management methods employed at MRM. **Section 8.4.4 to Section 8.4.6** presents further detail on the existing WMS in each domain. **Section 8.4.7** presents an overview of the existing site water balance. The WMS modifications proposed for the Project are presented in **Section 8.5**.

8.4.2.1 Water Classes

The existing MRM WMS has adopted a new water classification system, expected to be implemented in 2017. The system is based on the range of water qualities on site and their potential impacts on the receiving environment. Wherever possible, water at MRM is to be managed in a way that separates different water classes to limit the volume of poor quality water and process water produced and maximise the end use opportunities for cleaner water classes.

The six water classes proposed for MRM are:

- Class 1 – diverted water. This water class is typically sourced from upstream catchments that are unaffected by mining. Wherever practicable, controls are put in place to divert this water away from mining activities without impacting its quality.
- Class 2 – surface water. This water class is typically sourced from cleared areas and benign stockpile areas. Runoff from these areas is required to go through a sediment management structure to capture and settle sediment prior to passive release through the structure or active dewatering once the sediment particles have settled out.
- Class 3 – treated water. This water class is permeate from a reverse osmosis water treatment plant.
- Class 4 – managed release water. This water class is typically sourced from surface runoff from cleared areas with some exposed and/or capped non-benign material. This water typically has sulphate and/or metal concentrations that are higher than downstream compliance point trigger values specified in the WDL conditions. This water can be used for many end uses on site. This water can also be released to the McArthur River in accordance with the WDL conditions, which uses high river flows for dilution.
- Class 5 – poor quality water. This water class is typically affected by seepage from the TSF and NOEF, runoff from areas with exposed non-benign material and/or underground void water.
- Class 6 – process water. This water class is typically water that has been used by the Mill and TSF as well as other process streams including brine from a water treatment plant.

Further information, including typical limiting water quality parameters and the typical range of release rates and minimum McArthur River flow triggers for each class, is provided in section 4.3 of **Appendix U – Surface Water Impact Assessment Report**. The report also provides operational objectives in relation to each water class.

These water classes will continue to be used as the Project progresses and have been utilised in the development of the proposed WMS (refer **Section 8.5**).

8.4.2.2 Waste Discharge Licence

As discussed above, the MRM WDL trigger values provide indicators for the protection of environmental values and therefore a measure of performance against the Project closure objectives. The water quality at the SW11 monitoring location referenced to the WDL trigger values provides a reference point for the monitoring and evaluation of system performance. The Site Specific Trigger Values (SSTVs) for MRM can be found in Section 4.2 of **Appendix U – Surface Water Impact Assessment Report**. In effect, the WDL enables mine affected waters to mix, in a mixing zone, with other surface waters (including flows from the Barney Creek, Emu Creek, McArthur River and Glyde River), diluting the water quality to below the trigger levels and hence by definition, maintaining environmental protection. Discharge of mine waters for mixing is termed “managed release”.

8.4.3 General Water Management Methods

There are some general strategies and physical infrastructure items that are used on site at MRM to achieve the water quality objectives and maintain compliance with the WDL triggers at SW11. These are described generally below.

Levee walls are physical barriers typically constructed from compacted clay, alluvial or topsoil to separate catchments and/or to contain waters in an area. These are often used in conjunction with drains to enable a positive flow of water to downstream areas (refer to **Figure 8-17**). The dimensions of the drains and levee will vary depending on the materials used, planned life, location and specific purpose. The design requirements of these structures are provided in Section 7.5.2 and Section 7.6.2 of **Appendix U – Surface Water Impact Assessment Report**. At MRM, these structures are typically used to divert Class 1 water away from operational areas, and separate catchments of different water classes. Levees are also used for flood protection.

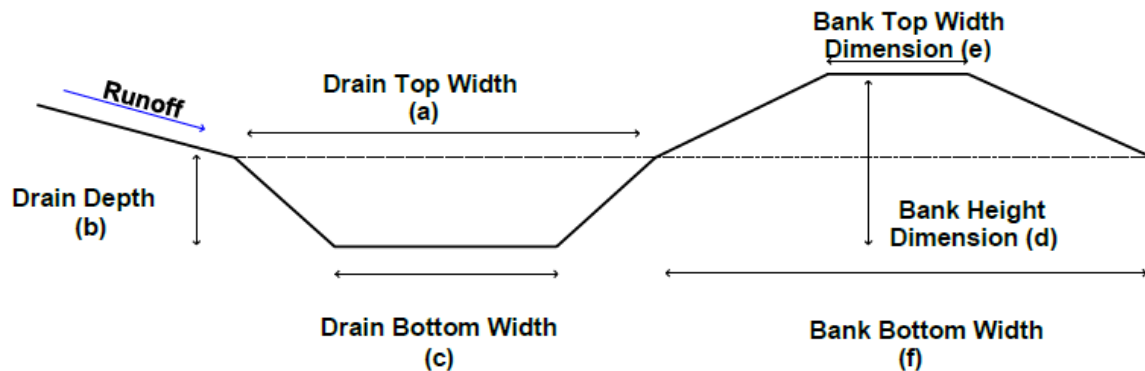


Figure 8-17 Conceptual Drain and Levee Configuration

Sediment management is required for Class 2 waters. These typically take the form of sediment basins, which are elongated ponds with an inlet at one end and an outlet at the other. Water flows into the basin and slows down, allowing sediment to drop to the bottom (**Figure 8-18**). The clearer water then flows out or is pumped out to the receiving environment. Periodic removal of the sediment from the bottom of the pond maintains the capacity. The standards for these structures can be found in section 7.6.3 of **Appendix U – Surface Water Impact Assessment Report**.

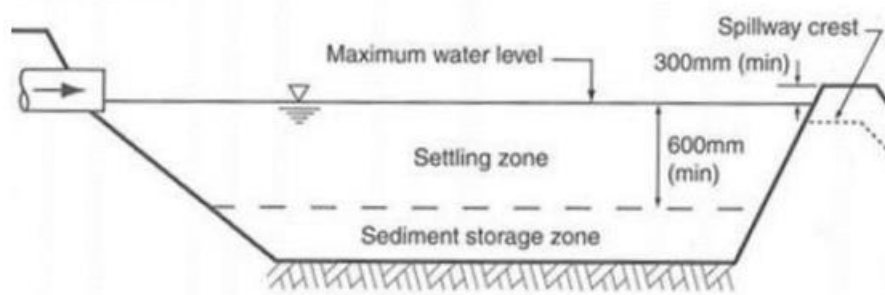


Figure 8-18 Conceptual Section through a Sediment Basin

Toe drains are often used around OEFs and in the open cut to direct water to a sump, where it can be collected and pumped away. The drains and sumps may be lined with clay or a geomembrane (such as high-density polyethylene (HDPE)) to reduce the risk of leaks. Pumps and pipes are sized to suit the required pumping rates.

Subsoil drains are drains that are to be buried at the base of a facility (such as an OEF) to assist in draining away water that has infiltrated through the facility. Subsoil drains will be lined with a low permeability barrier (typically compacted clay or a geomembrane) and have coarser rock in the drain to promote flow to extraction sumps.

Perimeter Run-Off Dams (PRODs) are constructed around the NOEF to collect and store runoff and pumped inflows from areas around the operational areas, typically catering to water of classes 4, 5 and 6. These are built with crests above the 100 year flood level, with engineered spillways in case of overflow. Liners used in these dams include compacted clay and geomembranes (HDPE). They often feature sprinklers around the inner perimeter to evaporate additional water. **Figure 8-19** shows SEPROD as an example. The design standards for PRODs are presented in Section 7.4.3 and Section 7.7 of **Appendix U – Surface Water Impact Assessment Report**. PRODs have operating rules to balance operational requirements (such as storage capacity and evaporation) whilst limiting the risk of overflow due to large rain events. Water levels are aimed to be maintained at the Optimum Operating Level (OOL) but can fill up to the Maximum Operating Level (MOL), if required (refer **Figure 8-20**). At the MOL, no further pumping into the dam would occur. At the Full Storage Level (FSL), any additional water added to the dam from runoff or direct rainfall would result in an overflow from the spillway.



Figure 8-19 Aerial View of SEPROD

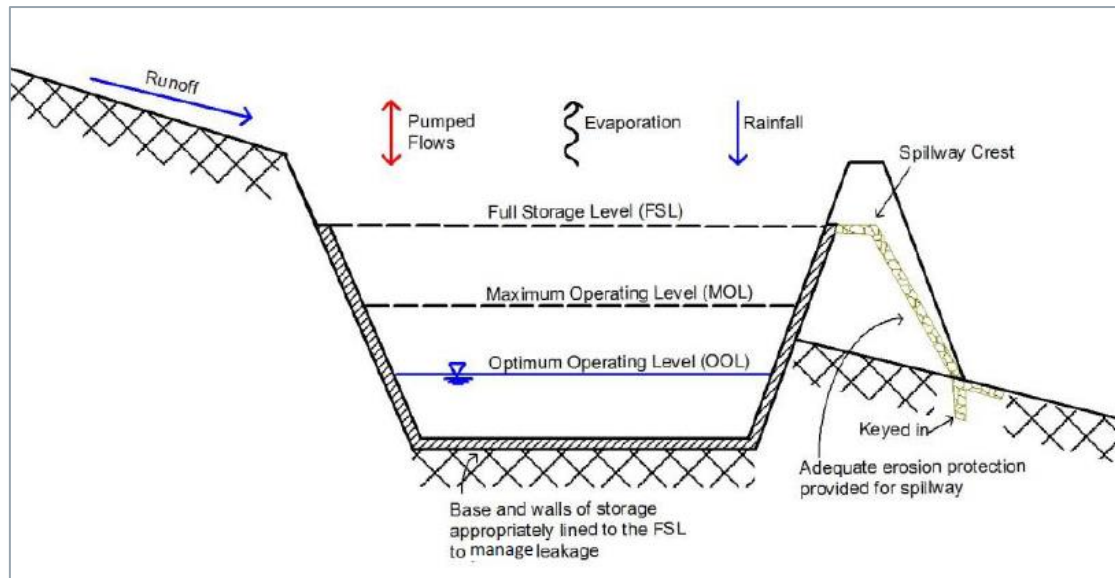


Figure 8-20 Cross-section showing the Key Aspects of a PROD

Water dams constructed away from the NOEF have various site specific names. Their crest elevations, liners, sizes, and operating rules vary depending on the classes of water in them, catchment area reporting to the dam, and consequences of overflow. Waters can generally be transferred between various dams using the pumping infrastructure and pipe networks. Water transfers are tracked by flowmeters and computerised sensors to detect parameters such as levels and temperature. Having multiple dams and pipe systems enables MRM to keep different classes of water separate, increasing the opportunity to discharge the better quality water classes in accordance with the WDL.

In addition to operating sprinklers to evaporate water, MRM uses purpose built evaporation fans to reduce water quantities in the site inventory. These are similar to snowmakers used on ski fields. Water is sprayed into the air in a mist, with approximately 39% of the water being evaporated. The remainder returns to ground level and is collected and managed.

Groundwater will be managed utilising various systems. The method used depends on many factors, including the space available, depth and variability in depth, ground conditions, and recovery efficiency required.

Interception trenches are typically continuous, narrow excavations cut below the water table across the groundwater flow direction, down-gradient of the source (refer to **Figure 8-21**). The lower part of the trench is backfilled with porous fill to promote flow to sumps enabling extraction of groundwater by pumping. The upper part of the trench is typically backfilled with low permeability materials to limit surface water entry.

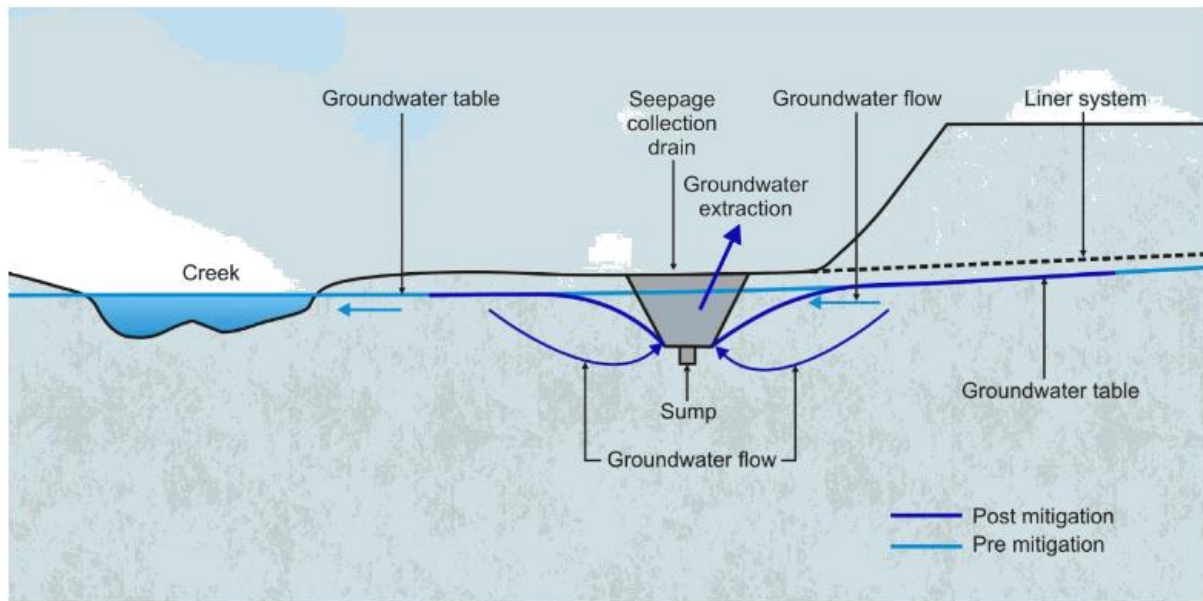


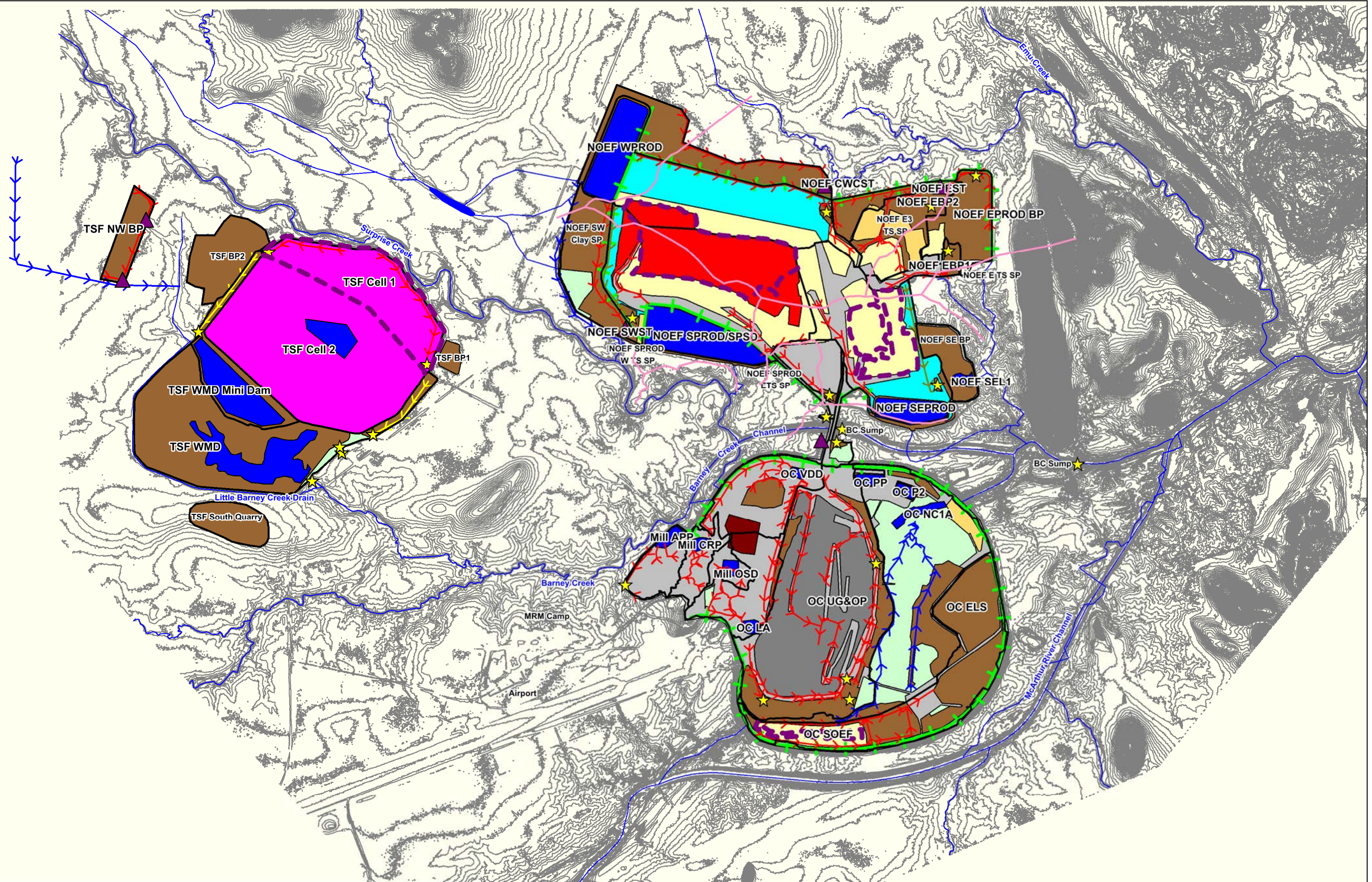
Figure 8-21 Schematic of a Groundwater Interception Trench

An alternative to a trench is to use vertical or horizontal bore holes drilled through the ground and equipped with pumps to draw groundwater water out. The spacing between the holes and the nature of the groundwater flow through the earth, affects the efficiency of groundwater recovery utilising these systems.

Barriers to groundwater flow can also be constructed, by either backfilling a trench with low permeability material or drilling and injecting grouts or polymers into the ground to block off water pathways. However, groundwater may build up behind the barrier and migrate beneath, over or around it.

A key piece of water management infrastructure being introduced at MRM from 2017 is the WTP. The initial plant will treat 6.0 ML/d of Class 5 and 6 waters utilising the reverse osmosis process. The brine (waste) will be consumed by the processing plant while the permeate (treated water) will either be released to the McArthur River (initially via P2) under the conditions of the WDL, or will be stored within the Class 4 water storages, primarily at the upgraded TSF WMD. The minimum flow requirement in the McArthur River prevents direct release from the WTP to the receiving environment all year round. Minor amounts of the clean permeate may also be used in on-site processes where clean water is required.

Figure 8-22 presents the existing WMS configuration, including many items described generically above. **Figure 8-23** presents a schematic of the existing WMS circuit. The key features of the WMS, by domain, are discussed in the following sections.



LEGEND

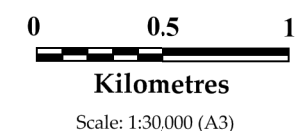
- Sediment Management Structure
- Outlet Collection Pit / Sump
- Surface Runoff Drain
- Diverted Runoff Drain
- Seepage Trench
- Primary Subsoil Drain
- Pre-NOEF (2006) Catchment Boundary

- Natural drainage path
- Flood Protection Bund / Mine Levee Wall
- Surface Catchment Boundary
- Water Surface
- LS-NAF(HC) (In-situ Rocks)
- LS-NAF(HC)
- PAF(HW)

- MS-NAF(HC)
- PAF(HC)
- PAF(RE)
- MS-NAF(LC)
- Final Cover Alluvium Plateau
- Natural (Undisturbed)
- Open Cut (In-situ Rocks)

- Alluvium/Clay Stockpile
- Hardstand / Industrial
- Cleared (Disturbed)
- Ore Stockpile
- Tailings
- Rehabilitated
- Interim Clay/Alluvial Caps

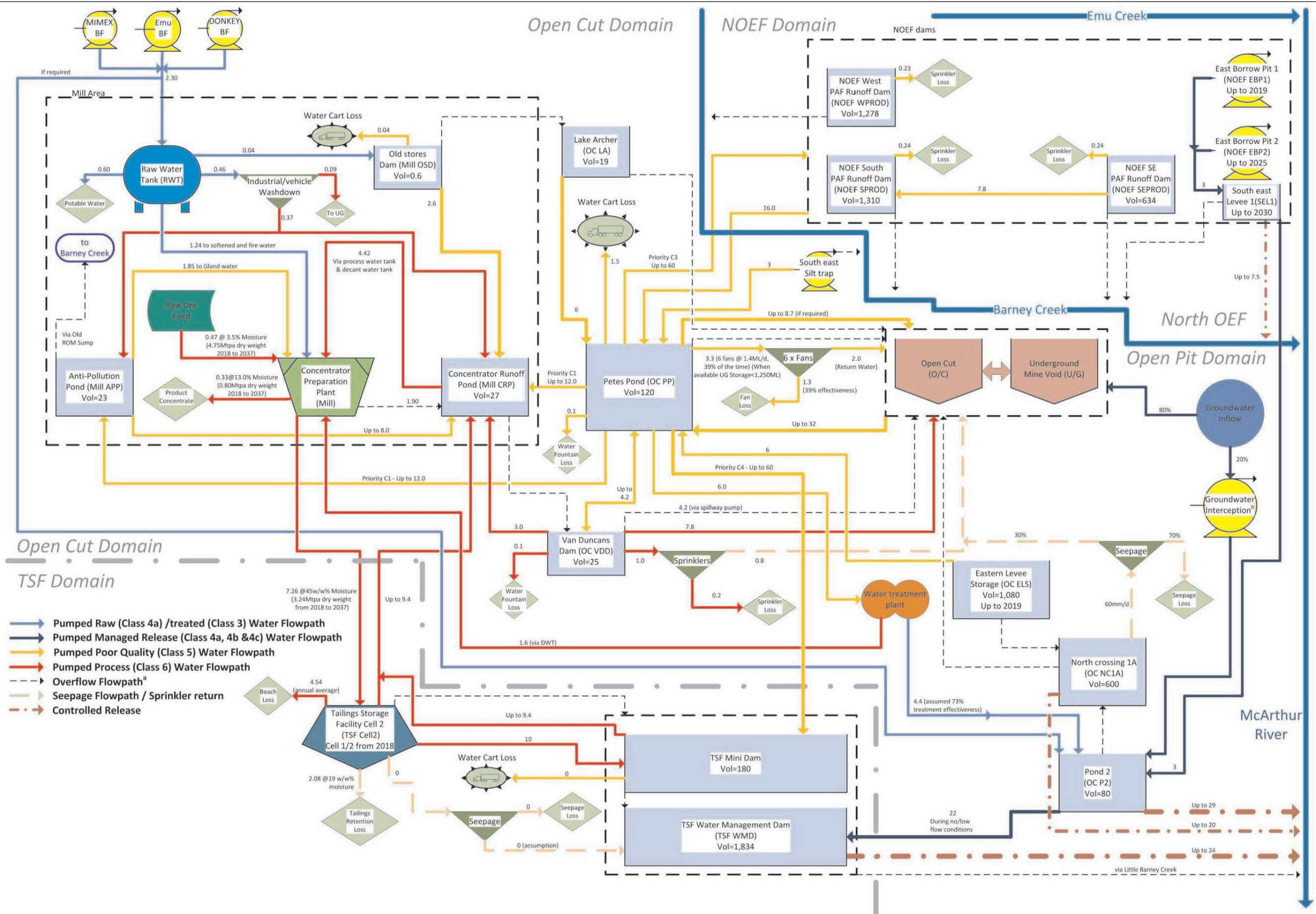
**McArthur River Mine
Overburden Management Project EIS
Existing Water Management System**



08/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-22



Notes:

All values are in ML/day unless otherwise specified.
 Metered data provided between July 2012 and June 2015
 Vol – Water storage capacity below spillway (in ML)
 In addition to inflows and outflows shown in this schematic, all dams and open pits account for direct rainfall and surface runoff inflows as well as evaporation and seepage outflows
^a Overflows/releases to natural watercourses from mine water dams are not predicted under normal operating conditions
^b Groundwater interception sumps include Subaru Sump, South Ramp Sump, South East Pit Sump, & I Pit Sump

Data Source: WRM, 2011

McArthur River Mine
 Overburden Management Project EIS
 Existing Water Management
 System Circuit Schematic

01/03/2017

FIGURE 8-23

8.4.4 Existing Open Cut Domain Water Management

The open cut domain WMS layout at the start of the Project EIS (2018) is presented in **Figure 8-24**. The colour shading represents the exposed surface (and hence informs the water runoff versus infiltration factors, and the likely runoff quality) whilst the coloured lines and symbols represent water related infrastructure. Water management in this domain is focussed on three main objectives, including:

- maintaining a dry open cut operations area (inflows to the pit are approximately 10 ML/d);
- maintaining a supply of water to the processing operations (approximately 9-10 ML/d is required at the full processing rate); and
- containing CoCs within the WMS to meet the surface water objectives at SW11.

The mine levee wall that protects the operating areas from flooding is visible around the low lying areas and butts into Barney Hill in the west. To the east of the open cut, a Class 1 clean WMS is operated, utilising the old McArthur River bed (North Crossing 1A (OC NC1A)) as a sump to enable pumping for either managed release or storage. Clean water is kept separate where possible.

The rest of the area inside the mine levee wall is disturbed to varying degrees, and hence reports to various dams and ponds via drains. **Figure 8-23** can be used to trace where water is directed and at what rates. The dam Open Cut Pond 2 (OC P2) is the main dam used for distributing Class 4 waters around site, and can also be utilised in the management of Class 1 water if required. Class 4 waters are sourced from the sumps on the upper benches of the open cut.

The dam Open Cut Pete's Pond (OC PP) is the major dam utilised to distribute Class 5 water around the various mine water storage facilities. OC PP receives the majority of its water from pumping of the open cut and underground mine, and pumping collected runoff from the WOEF and SOEF. These waters may be sent to other dams within the network, to the evaporation fans on the north wall of the open cut for evaporation, or to the WTP for treatment.

The industrial areas of the processing plant are serviced by dams, with the water recycled back into the process.

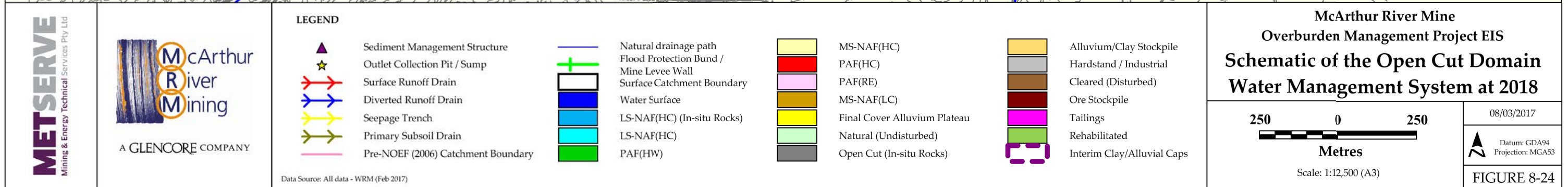
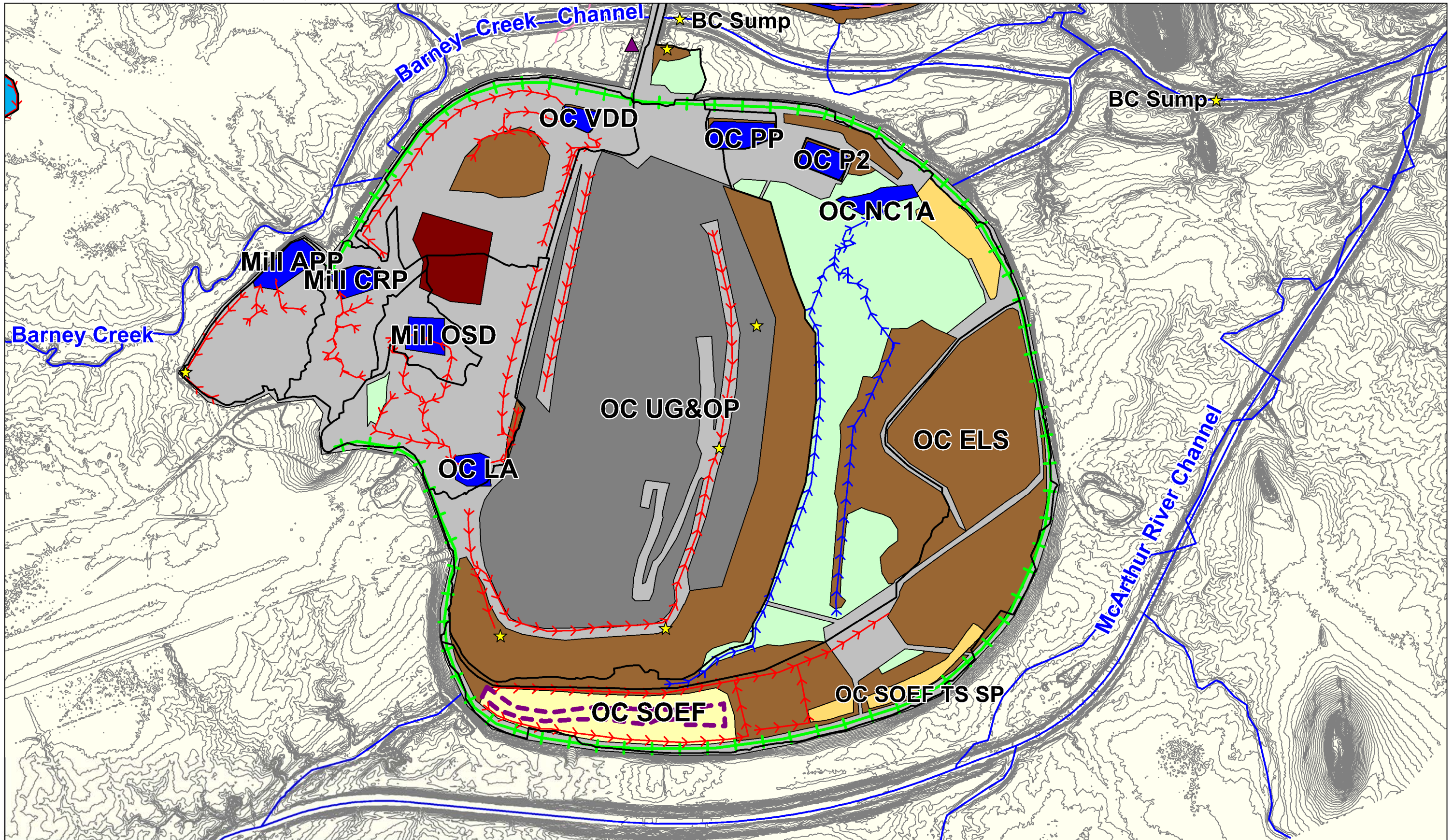
Figure 8-24 shows two sumps and a sediment trap where the haul bridges cross Barney Creek. These facilities enable collection of runoff and sediment on the haul roads, reducing loads into Barney Creek. The figure also shows a sump in Barney Creek, called "BC Sump". This sump is utilised to recover baseflow in Barney Creek and is operated as required in the dry season to maintain water quality at SW11.

The MIMEX borefield and Emu bores in the domain (**Figure 8-16**) will continue to be the main supply of raw water for use on site, with usage of around 1.5 to 3.0 ML/d. The Donkey bores only supply minor amounts of groundwater to the Class 4 system.

Information on dam capacities, pumping rates, OOL, MOL, FSL, and overflow risks is provided in **Appendix U – Surface Water Impact Assessment Report**.

Appendix T – Groundwater Impact Assessment Report presents borefield abstraction rates and periods of operation.

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8.4.5 Existing NOEF Domain Water Management

The NOEF is constructed from a range of materials (from benign to varying grades of non-benign overburden) in variable settings. The WMS aims to protect the environmental values around the NOEF and maintain the landform geotechnical stability, both during the construction and closure phases. Thus there are multiple layers of design features, infrastructure and management strategies to achieve these objectives. This section explains the key means by which the existing NOEF manages this.

Figure 8-25 presents the NOEF with a range of land uses and material types and water management infrastructure. As the NOEF is in its early development phase, there are no major rehabilitated areas (excluding two minor topsoil stockpiles).

The western side of the NOEF is where the PAF cells are located. The West stage (refer to **Chapter 3 – Project Description and Justification** for stage names) has a capped PAF cell that drains in a southerly direction into SPROD/south perimeter sediment dam (SPSD). SPROD is a HDPE-clay composite lined PROD, connected to a network of runoff drains and culverts built onto the landform. The clay core embankment of SPROD forms flood protection for the NOEF West stage to the 100 year flood level, in conjunction with a standalone levee up the western side that joins into the WPROD embankment.

The Central West stage is shaped to drain in a westerly direction into WPROD, which is another HDPE-clay composite lined PROD. As the topography falls slightly to the east, Central West is also serviced by a sump and pump on the eastern end of the stage, with collected waters pumped back to WPROD. The northern side of the stage is protected by a levee wall built to the 20 year ARI flood level, as this face is only temporary and is planned to be further developed in less than two years. The base of Central West is constructed from low salinity non-acid forming (high capacity) (LS-NAF(HC)) material with a basal compacted clay liner (CCL) and subsoil drains, so floodwaters overtopping this levee would have a lower risk of impacts on the receiving environment.

The overburden portions of the eastern side of the NOEF consist of varying grades of NAF. This overburden is sloped to the south so that runoff drains into SEPROD. SEPROD is a compacted clay lined PROD. Where possible, the exposed NAF materials have been capped with interim alluvial capping to increase runoff factors and improve the quality of runoff reporting to SEPROD. The eastern areas of the current footprint are occupied by topsoils and alluvial stockpiles and borrow pits where clay has been sourced to use in capping layers.

The southeast corner of the NOEF is a topographic low, with a thick natural clay base. This represents conditions that promote toe seepage. A toe drain along the eastern side of the NOEF delivers seepage to the south, behind a levee. A series of two levees have been constructed across the original drainage line to collect seepage, from where it is pumped into SEPROD. The southeast levee (SEL) acts as a back-up levee and sediment trap until the NOEF footprint expands out to it in the future. The Southeast and East stage has flood protection to a 20 year ARI flood level provided by low levees.

The benign stockpiles that are not rehabilitated are contained inside levees with sediment traps. The southwest clay stockpile is protected by a topsoil levee, which also operates as a Class 1 diversion drain, and has a passive sediment trap installed in the southern end, whilst the Eastern sediment trap (EST) requires pumping. Central West C Sediment Trap (CWCST) also services the cleared land in the north of the Central West stage.

The Emu bores in the southeast area of the NOEF were used to supply the processing plant with most of its top up water through the 1990s up until 2013, when the encroaching NOEF development required operation of the bores to cease.

A network of groundwater and internal water monitoring bores is sampled periodically to track groundwater levels and qualities. As discussed in **Section 8.4.4.**, the operation of Barney Creek sumps during the dry season, as required, is a key NOEF seepage mitigation strategy.

8.4.6 Existing TSF Domain Water Management

The WMS for the TSF aims to manage runoff, seepage, and sediment to enable the site to meet the surface water objectives at SW11. The means by which this is achieved is described briefly here, with further information available in **Appendix U – Surface Water Impact Assessment Report, Appendix T – Groundwater Impact Assessment Report** and **Appendix R – Tailings Storage Facility Design Development – LOM Plan.**

The tailings are deposited in slurry form around the perimeter of the combined TSF Cells 1 and 2 (**Figure 8-26**). The central decant pond enables released water to be reclaimed and recycled back into the processing water circuit. The tailings slurry and return water are transported in pipes between the processing and deposition facilities, in a corridor equipped with emergency bunds, sumps and pumps. The size and depth of the decant pond are maintained at low levels to reduce seepage, and provide adequate storage capacity for operational requirements and emergency storm storage. If the TSF FSL is exceeded, the spillway will discharge excess water into the PWD rather than the external environment.

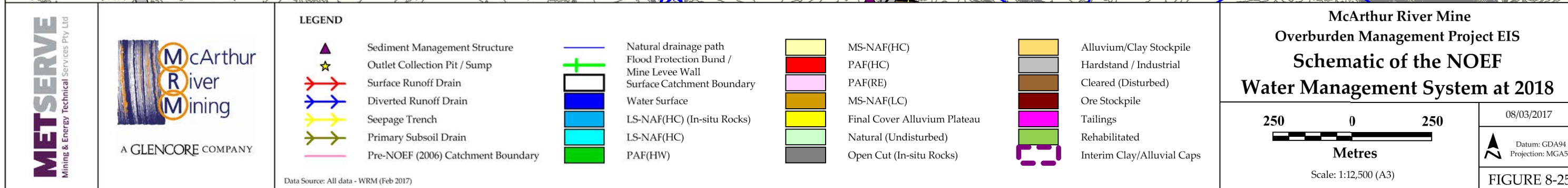
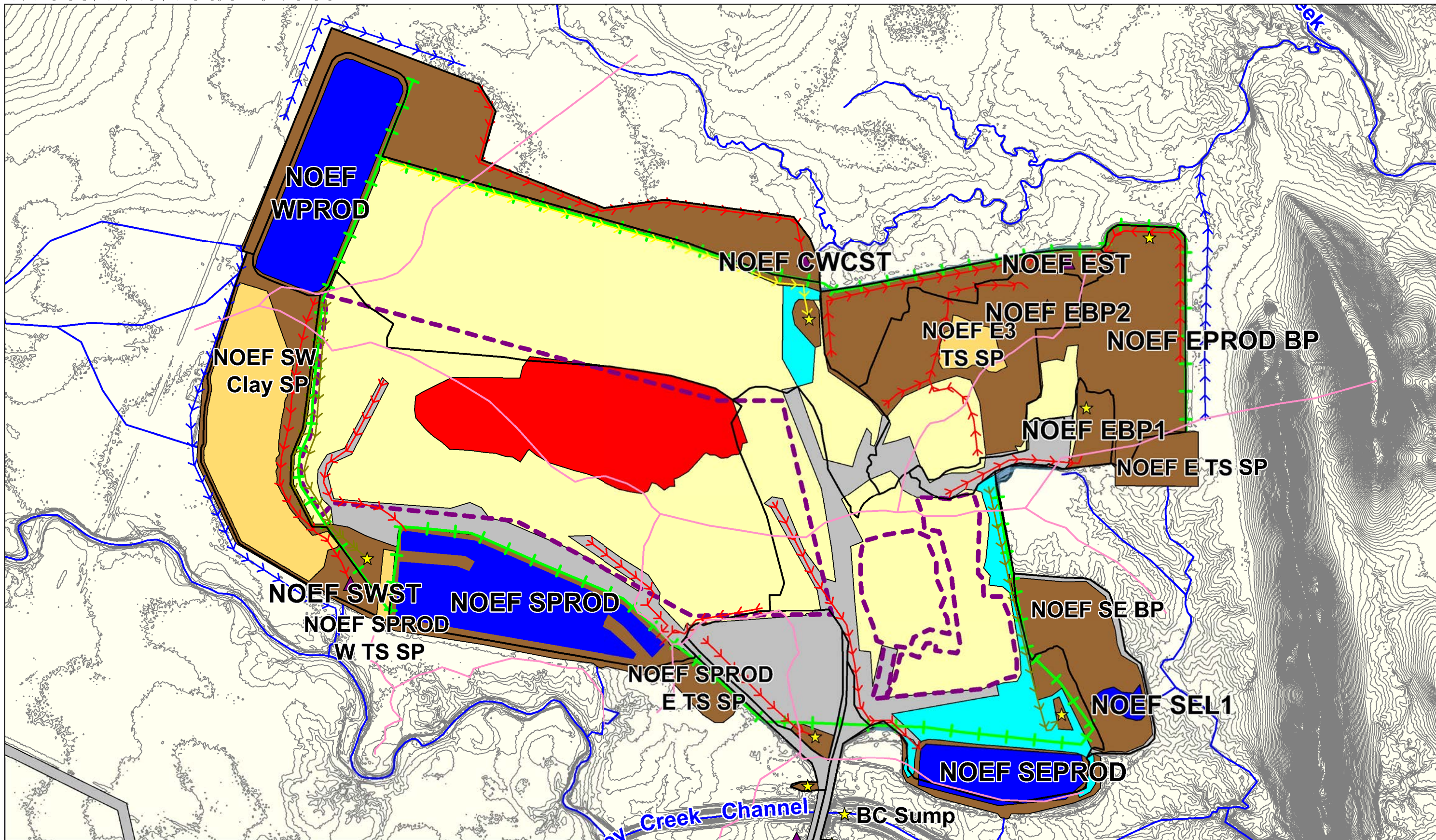
The TSF embankments are constructed with a low permeability compact clay portion to limit seepage through the walls, whilst the tailings themselves are fine-grained and have a low permeability. Shallow seepage interception trenches target seepage in the shallow groundwater bearing zones on the southeast and northwest walls. On the northeast side, seepage is collected by a larger and deeper trench called the Surprise Creek Groundwater Interception Trench. Waters collected in these trenches is pumped to the PWD. Grout and polymer barriers around the toe of the TSF embankments were installed some time ago to constrain seepage, in combination with vertical seepage recovery bores, however due to inadequate installation they are of limited effectiveness.

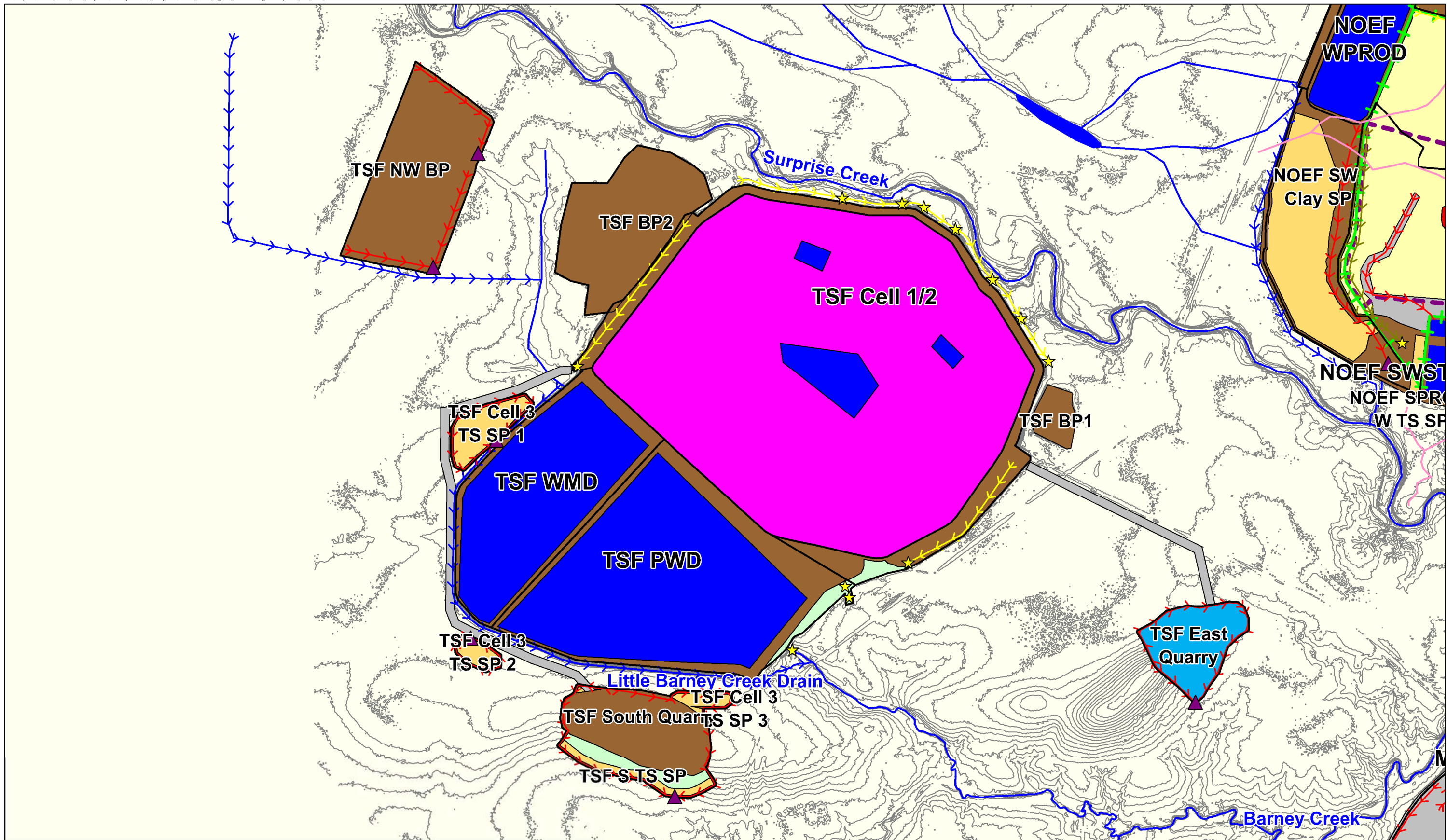
Seepage water that is not captured by mitigation measures at the TSF itself will report as baseflow in Surprise, Little Barney and Barney Creeks. Where required to meet the water quality commitments, pumping from the Barney Creek sumps will recover affected waters for management in the Class 5 and 6 WMSs.

The Cell 3 footprint will be split into two new large water management dams planned for development in 2017-18. The WMD will be used to store selected waters (typically Class 4 waters collected from around the open cut domain, and Class 3 WTP permeate) in preparation for release under permitted conditions. The PWD will be used to store excess water from the open cut/underground and TSF, for evaporation and/or future treatment.

A Class 1 clean water drain reroutes water from the western extent of Little Barney Creek around the southern wall of Cell 3 and back into its original channel to the east.

The benign material quarries around the TSF are all serviced by perimeter drains and levees directing runoff into sediment management structures prior to release to local watercourses.





LEGEND

- Sediment Management Structure
- Outlet Collection Pit / Sump
- Surface Runoff Drain
- Diverted Runoff Drain
- Seepage Trench
- Primary Subsoil Drain
- Pre-NOEF (2006) Catchment Boundary

- Natural drainage path
- Flood Protection Bund / Mine Levee Wall
- Surface Catchment Boundary
- Water Surface
- LS-NAF(HC) (In-situ Rocks)
- LS-NAF(HC)
- PAF(HW)

- MS-NAF(HC)
- PAF(HC)
- PAF(RE)
- MS-NAF(LC)
- Final Cover Alluvium Plateau
- Natural (Undisturbed)
- Open Cut (In-situ Rocks)

- Alluvium/Clay Stockpile
- Hardstand / Industrial
- Cleared (Disturbed)
- Ore Stockpile
- Tailings
- Rehabilitated
- Interim Clay/Alluvial Caps

McArthur River Mine
Overburden Management Project EIS
**Schematic of the TSF
Water Management System at 2018**

300 0 300
Metres
Scale: 1:15,000 (A3)

08/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-26

8.4.7 Existing Site Water Balance

MRM maintains an existing water balance model which incorporates the flows and storages of the various water classes. It is utilised to manage the various water classes around site and maintain sufficient capacity in storages and sufficient supply to water consuming facilities of the site. It incorporates groundwater inputs and losses and is reviewed and updated annually. Detailed information on the forecasted water balance associated with the Project is provided in Section 8 of **Appendix U – Surface Water Impact Assessment Report**.

The water balance prior to the Project is based on the layout shown in **Figure 8-22** and **Figure 8-23**. The main water movements include:

- inflows to the open cut and underground are approximately 10 ML/d;
- processing plant consumption of approximately 10 ML/d; and
- approximately 7.8 ML/d of water is pumped to the TSF with the tailings slurry, with approximately half of that returned to the process via the decant pond.

Depending on the wet season rainfalls, the existing site water balance can range from a net loss of water of about 2 gigalitres per year (GL/yr) to a net gain of 3 GL/yr. The response of the site water balance to rainfall is not obvious – ‘dry’ years do not necessarily result in a net loss of water, as the opportunities for managed release (discharge) of Class 4 and higher waters in these years can be limited, due to limited flows in the receiving system.

8.5 Project Water Management

The Project has several phases over its life. The open cut mining operations phase runs from 2018 to 2037, defined by mining from the open cut and ore processing. The Tailings Reprocessing Operations Phase extends the life of mine to 2047, during which time the TSF is reprocessed and the spent tailings are deposited in the open cut void. Next is the Closure Phase from 2048 to approximately 2100 when the open cut is rapidly filled to become a mine pit lake and the site is transitioned from operational status to closure status, with rehabilitation and adaptive management. Further information can be found in **Chapter 3 – Project Description and Justification**. This section explains the function of the WMS in each domain through these phases using conceptual site models along with plans of site development and water management infrastructure. The section presents water management information for each domain, within the major time phase, and discusses the interaction between waters of each domain.

WMS layouts for the site for the following years: 2018, 2019, 2022, 2027, 2032, 2037, 2042, 2047, and 2052 have been prepared. Selected periods representative of the three major phases defined above are presented in the following sections. All layouts are provided in **Appendix U – Surface Water Impact Assessment Report**.

Further information on the designs of particular facilities are presented in **Chapter 3 – Project Description**.

8.5.1 Operations Phase – Open Cut Mining

8.5.1.1 Open Cut Domain

8.5.1.1.1 Water Management System

The strategy for managing water in the domain is the same as that employed currently. That is to intercept surface waters and groundwaters as soon as possible to reduce potential contamination, with the intent to retain them as Class 4 or better waters, increasing their ability to be released under the WDL conditions. Poorer quality waters are to be stored in dedicated storages for use in processing, site dust suppression in operational areas, evaporation or treatment. The open cut domain layout throughout the operations phase is represented by **Figure 8-27**.

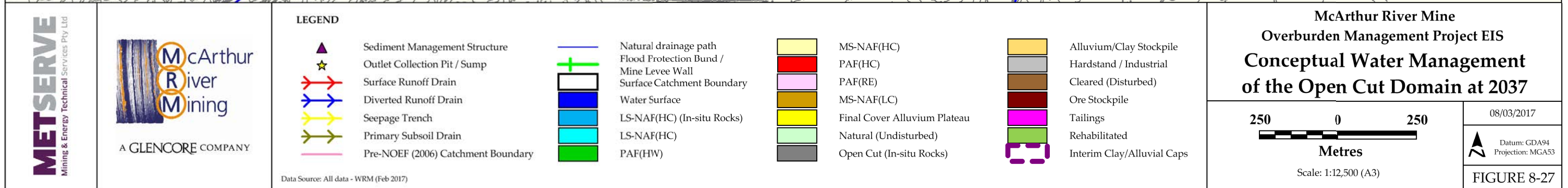
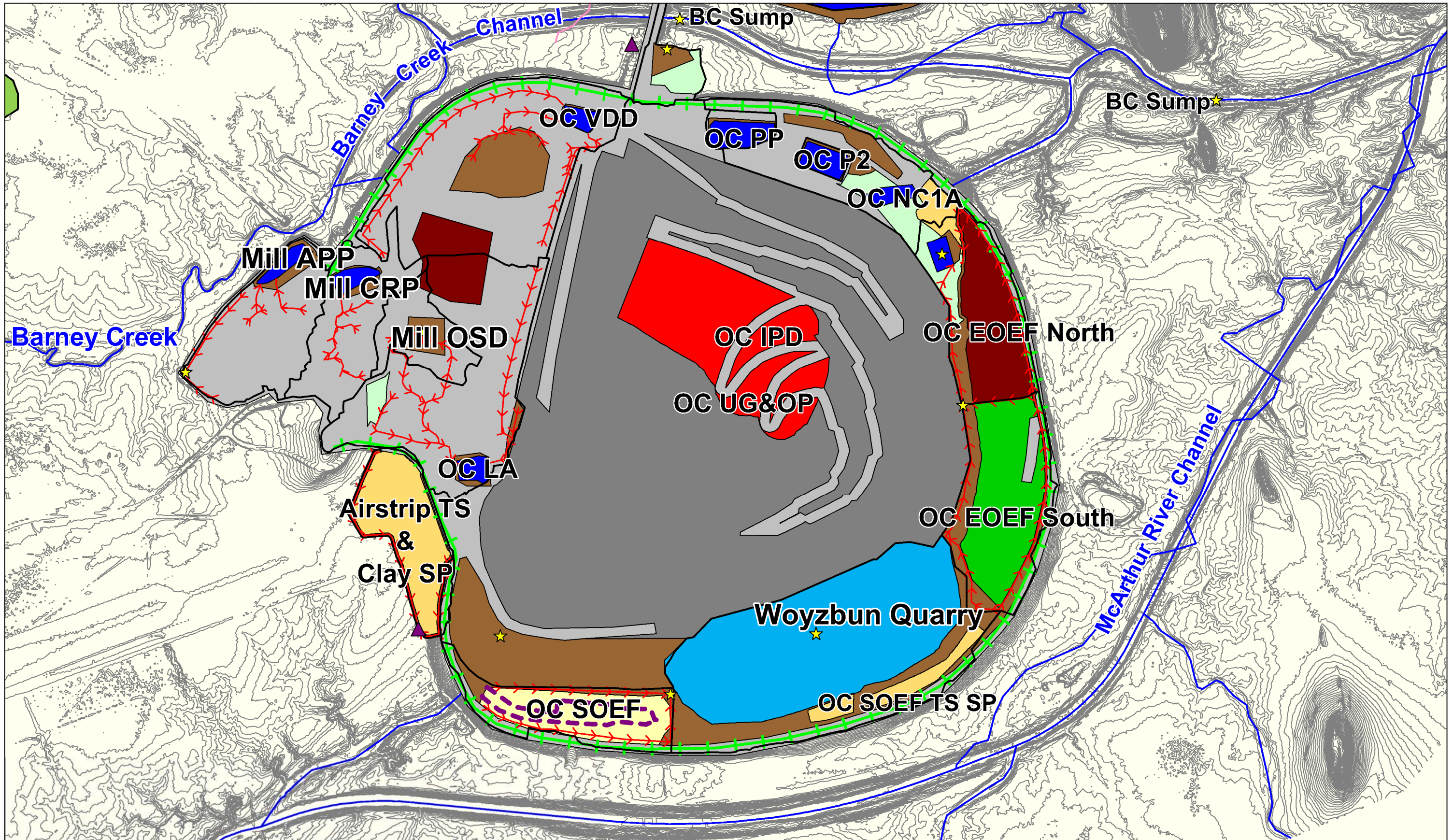
Through the operations phase, the open cut mine and Woyzbun Quarry will expand in both footprint and depth. The larger open cut will collect more rain, and have higher palaeochannel and groundwater inflows (**Figure 8-28**). As in the current system, drains and sumps built into the upper benches at the base of the alluvial zone will collect and remove the shallow groundwater inflows (including into the benign Woyzbun Quarry) to the OC P2 dam/Cell 3 WMD WMS. The deeper inflows and rain reporting to the open cut rock surfaces will be collected in sumps and the remnant underground workings, where the water will be pumped to the contaminated water system (OC PP) for use in the processing plant and disposal through evaporation (from dams with sprinklers and evaporation fans) or water treatment. The groundwater drawdown due to this dewatering activity extends radially around the open cut excavation, as far as the McArthur River and Barney Creek Channels.

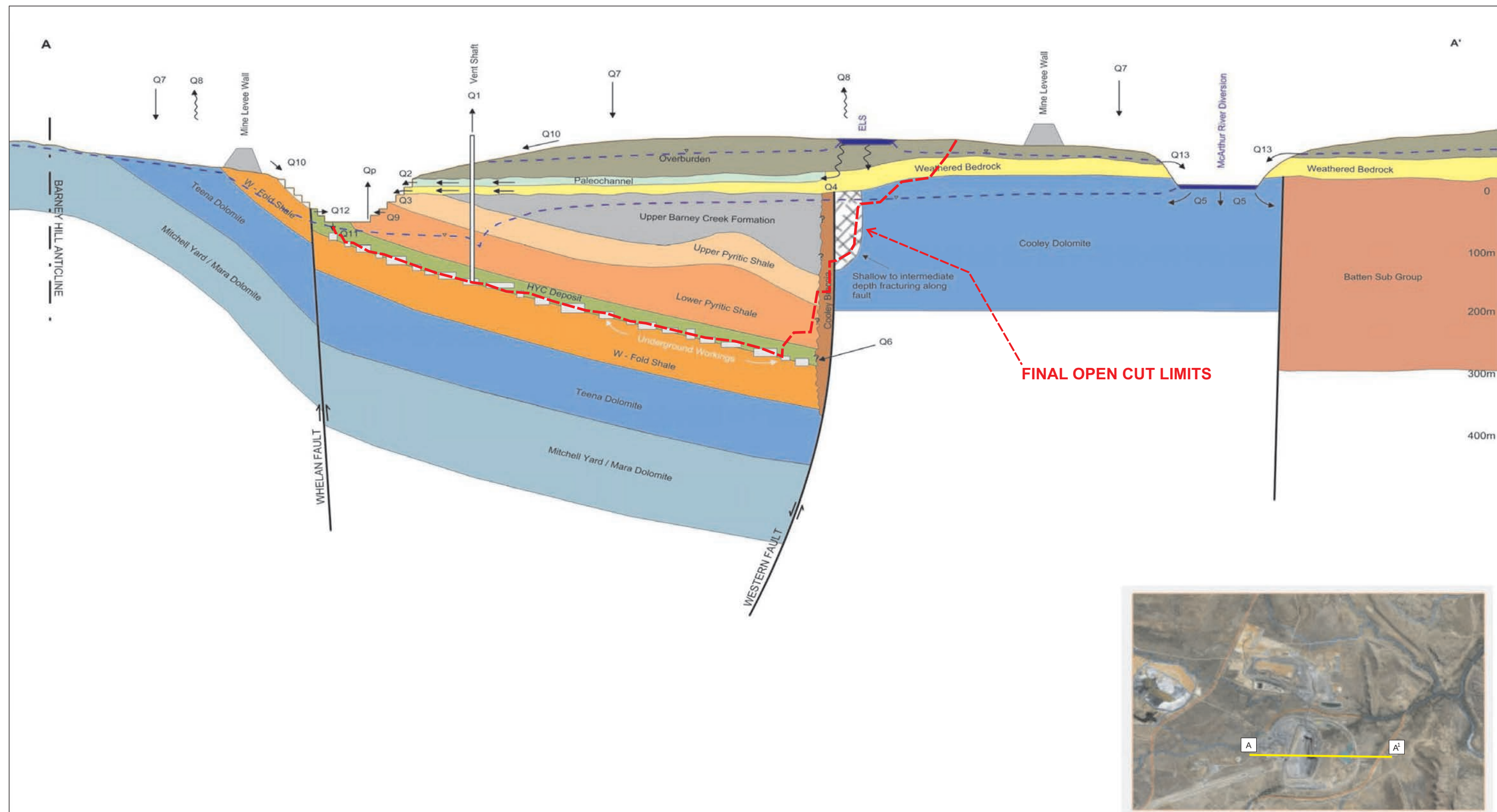
The deeper groundwater inflows are predicted to increase in particular when the mine intersects the Western Fault, exposing the open cut workings to the faulted and more permeable northern Cooley Dolomite that extends under the Barney Creek Channel and the eastern side of the NOEF. Groundwater inflows are expected over a broad zone of sheared and faulted ground with karstic features, and over a range of elevations in the open cut wall. Thus, it was considered more practical and conservative at this stage of planning to assume these inflows would be collected in the open cut and underground mine rather than through dewatering bores, resulting in the waters being categorised as Class 5 rather than potentially Class 4. Further investigations into the viability of dewatering bores will be completed prior to open cut mining intersecting the fault from 2023.

During the operations phase, an in-pit dump (IPD) will be constructed in the lower 250 m of the void using non-benign materials. As the IPD is wholly within the open cut, there is no change to the WMSs. Water quality in the open cut/underground system will be unaffected.

To manage the larger open cut inflows, which are expected to increase to around 14-16 ML/d (but with the potential for short-term spikes in rates when the Western Fault is intersected), additional capacity to remove water from the system is required. An expansion of the new water treatment plant with an additional capacity in the order of 9 ML/d is proposed for use throughout the operating phase. Permeate from the plant would continue to be managed through the Class 4 system, with storage in OC P2 and Cell 3 WMD until external conditions allow managed release under the WDL conditions. Brine from the plant (assuming a similar reverse osmosis system is used) would be pumped to the Cell 3 PWD for evaporation and use in the processing plant.

The processing plant would continue to consume approximately 9-10 ML/d, with similar movements of water to the TSF and back in the reclaim system.





Losses

Q1 = Groundwater extraction from underground working via vent shaft
 Q2 = Palaeochannel seepage to pit walls
 Q3 = Weathered bedrock seepage to pit walls
 Q8 = Evapotranspiration
 Q9 = Bedrock flow to pit
 Q10 = Surface Runoff
 Q12 = Fault and fracture flow to pit
 Q13 = Baseflow to McArthur River Diversion
 Qp = (Q1+Q2+Q3+Q9+Q12) Extraction from pit sumps

Data Source: KCB, 2017

Gains

Q4 = Recharge from ELS and other water dams
 Q5 = Leakage from McArthur River
 Q6 = Recharge to underground workings from McArthur River via unknown conduit
 Q7 = Rainfall recharge during wet season
 Q11 = Pit seepage to underground void

Note

1. Bedrock K moderate to 100m, largely due to fractures and conduits.
2. Bedrock K low to very low below 100m.
3. Conceptual section is a schematic and not to scale

McArthur River Mine Overburden Management Project EIS Open Cut Domain Hydrogeological Conceptual Site Model

01/03/2017

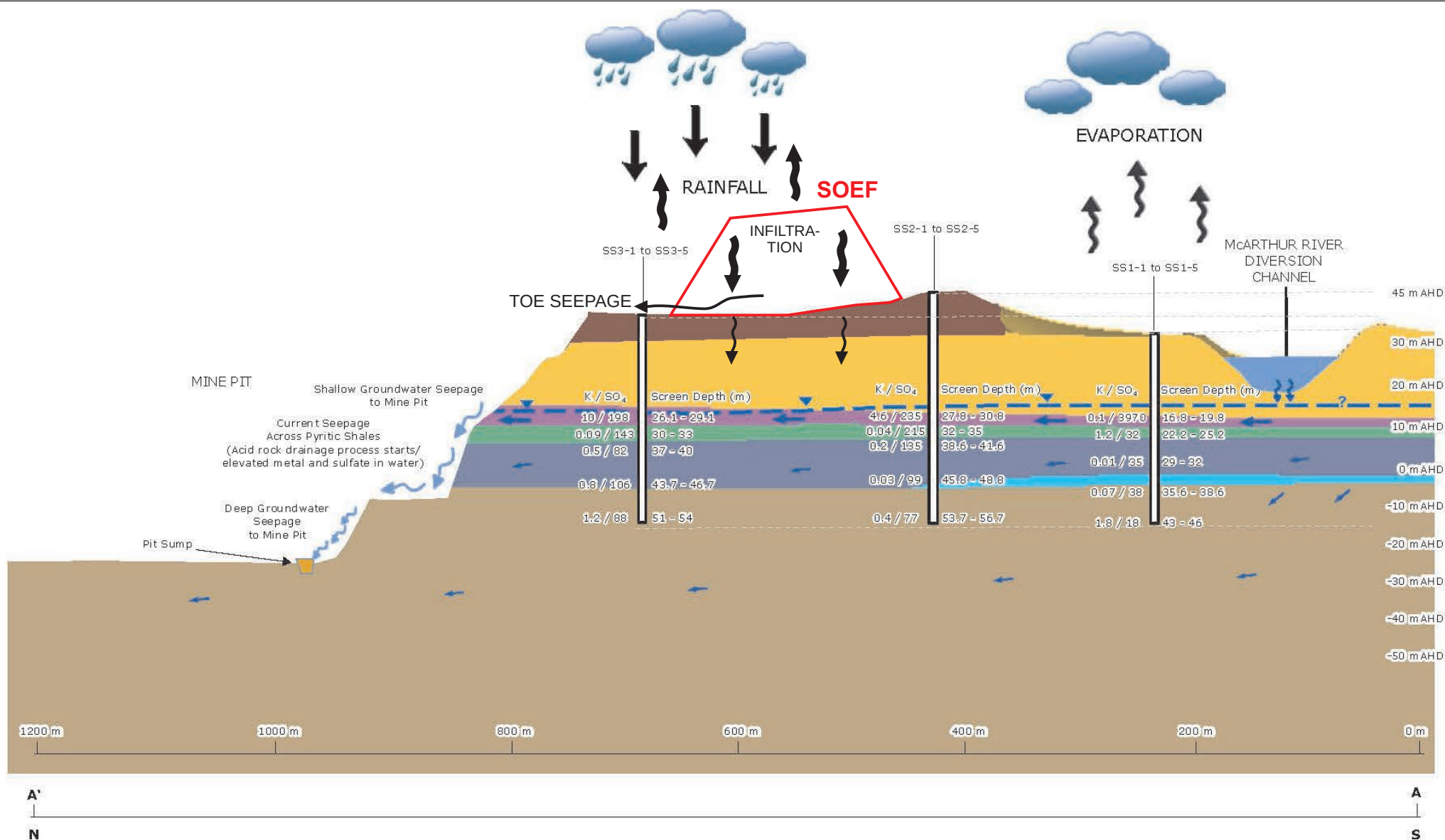
FIGURE 8-28

Surface water management from the processing area, WOEF and SOEF will be largely unchanged from the current arrangements, with runoff reporting to local sumps and ponds. The SOEF will require a new sump to be excavated on its eastern end once the Woyzbun Quarry mines through the existing drain system. The conceptual model for the SOEF (**Figure 8-29**), based on a transect of groundwater bores through the facility foundation, shows the influence of the open cut drawdown on this facility. There is a steep hydraulic gradient into the open cut, resulting in SOEF seepage reporting to shallow groundwater inflows in the open cut.

As occurs currently, infiltration through the WOEF will continue to migrate east into the dewatered open cut. The northern footprint of the facility drains on the clay foundation to the original Barney Creek alignment (within the mine levee wall). The central and southern parts are conveyed in the alluvial and shallow weathered bedrock groundwater units.

The EOEF is a new facility to be constructed inside the mine levee wall to temporarily store various overburden materials mined from the open cut area, including alluvial, LS-NAF(HC), low grade ore (LGO) and high pyrite, hanging wall PAF (PAF(HC)). The hydrogeological conceptual model (**Figure 8-30**) presents the setting for the EOEF. The base beneath the EOEF will be prepared with a basal CCL sloping to the open cut to promote runoff and seepage to lined toe drains constructed around the perimeter. The rock placement above the foundation will also be sloped to retain water inside the EOEF drains. Sumps on the western and northern sides will collect the waters for transfer into the appropriate WMS, which will change as the materials stored on the stockpiles vary (therefore varying the water quality and class collected by the system). The proximity of the EOEF to the open cut will result in basal seepage reporting to the deep open cut WMS.

The Airstrip topsoil and clay stockpile (Airstrip TS & Clay SP, **Figure 8-27**) outside the mine levee wall has a perimeter drain and bund directing runoff through a sediment basin at its southern end.



LEGEND

Data Source: RPS, 2015

Geology

- Fill
- Alluvium
- Paleochannel Gravel
- Extremely Weathered Rock
- Moderately Weathered Rock
- Slightly Weathered Rock
- Fresh Rock

Groundwater Movement

- Shallow Groundwater Flow
 - Deep Groundwater Flow
 - Infiltration
 - Groundwater Seepage to Pit
 - Water Level
- SO₄ = Sulphate (mg/L)
K = Hydraulic Conductivity (m/day)

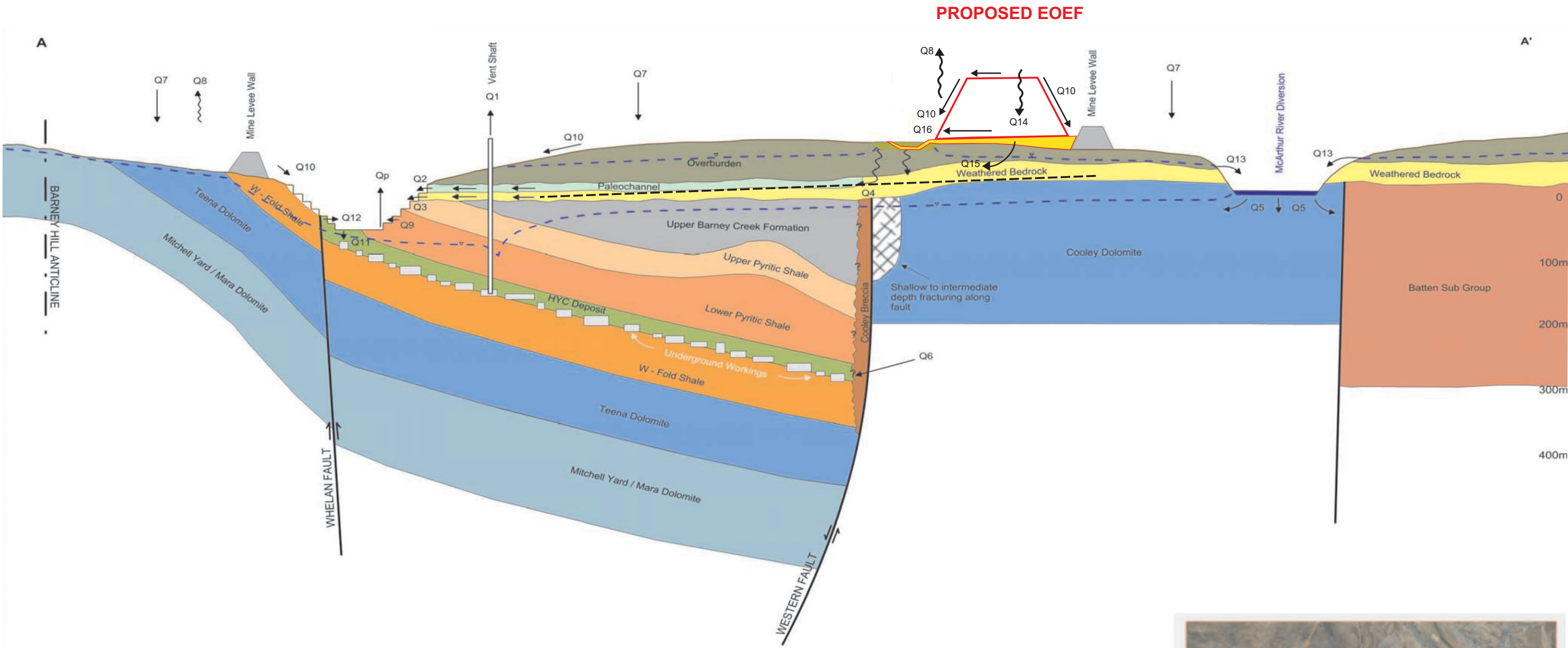


A254_001 Rev: A Produced: Loader Reviewed
: Loader Date: 14/11/2012

McArthur River Mine Overburden Management Project EIS Conceptual Hydrogeological Model of the SOEF

01/03/2017

FIGURE 8-29



Losses

Q1 = Groundwater extraction from underground working via vent shaft
Q2 = Palaeochannel seepage to pit walls
Q3 = Weathered bedrock seepage to pit walls
Q8 = Evapotranspiration
Q9 = Bedrock flow to pit
Q10 = Surface Runoff
Q12 = Fault and fracture flow to pit
Q13 = Baseflow to McArthur River Diversion
Qp = (Q1+Q2+Q3+Q9+Q12) Extraction from pit sumps
Q16 = Toe seepage
Data Source: KCB, 2017

Gains

Q4 = Recharge from ELS and other water dams
Q5 = Leakage from McArthur River
Q6 = Recharge to underground workings from McArthur River via unknown conduit
Q7 = Rainfall recharge during wet season
Q11 = Pit seepage to underground void
Q14 = Net percolation into EOEF
Q15 = Foundation seepage from EOEF

Note

- 1. Bedrock K moderate to 100m, largely due to fractures and conduits.
- 2. Bedrock K low to very low below 100m.
- 3. Conceptual section is a schematic and not to scale

**McArthur River Mine
Overburden Management Project EIS
Hydrogeological Conceptual
Model with the EOEF**

01/03/2017

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The sumps and ponds inside the mine levee wall area pose no risk to the environment as potential overflows report to the open cut. The minor seepage from most of the storages will also be drawn into the open cut/underground dewatering system by the effects of drawdown.

Groundwater management during the operations phase is focused on two objectives. These are identifying sources of groundwater inflows into the open cut/underground to enable extraction before waters enter operational areas and degrade in quality; and managing potential drawdown impacts on Djirrinmini waterhole.

Further groundwater investigations are planned in the short term to better identify targets for groundwater interception, particularly associated with the Cooley Dolomite and Western Fault. Monitoring bores around the Djirrinmini waterhole will inform the requirement to undertake any further investigations or mitigation to maintain water levels.

8.5.1.1.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the operations (open cut mining) period is contained in **Table 8-2** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

Table 8-2 Source-pathway-receptors for the Open Cut during Operations

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Contaminated water in WMS	Surface water runoff or baseflow seepage	Surface waters at SW11	E.g. pipe burst, storage facility seeps or overflows	- Engineered storage structures with low permeability bases - Continued open cut dewatering to maintain groundwater drawdown - WMS monitoring - Water treatment
Soluble oxidation products	EOEF overburden or Low Grade Ore (LGO)	Surface water runoff or baseflow seepage	Surface waters at SW11		- Continued open cut dewatering to maintain groundwater drawdown - Perimeter drains - Water treatment
Soluble oxidation products	WOEF overburden, stockpiled ore	Shallow groundwater	Surface waters at SW11	via Barney Creek	- Pumping from Barney Creek sumps - Continued open cut dewatering to maintain groundwater drawdown - Water treatment
Soluble oxidation products	WOEF overburden, stockpiled ore	Surface runoff	Surface waters at SW11		- Surface drainage system, e.g., drains, sumps, pumps etc. - Pumping from Barney Creek sumps - Water treatment

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	SOEF overburden	Shallow groundwater	Surface waters at SW11		- Continued open cut dewatering to maintain groundwater drawdown - Water treatment

8.5.1.2 North Overburden Emplacement Facility Domain

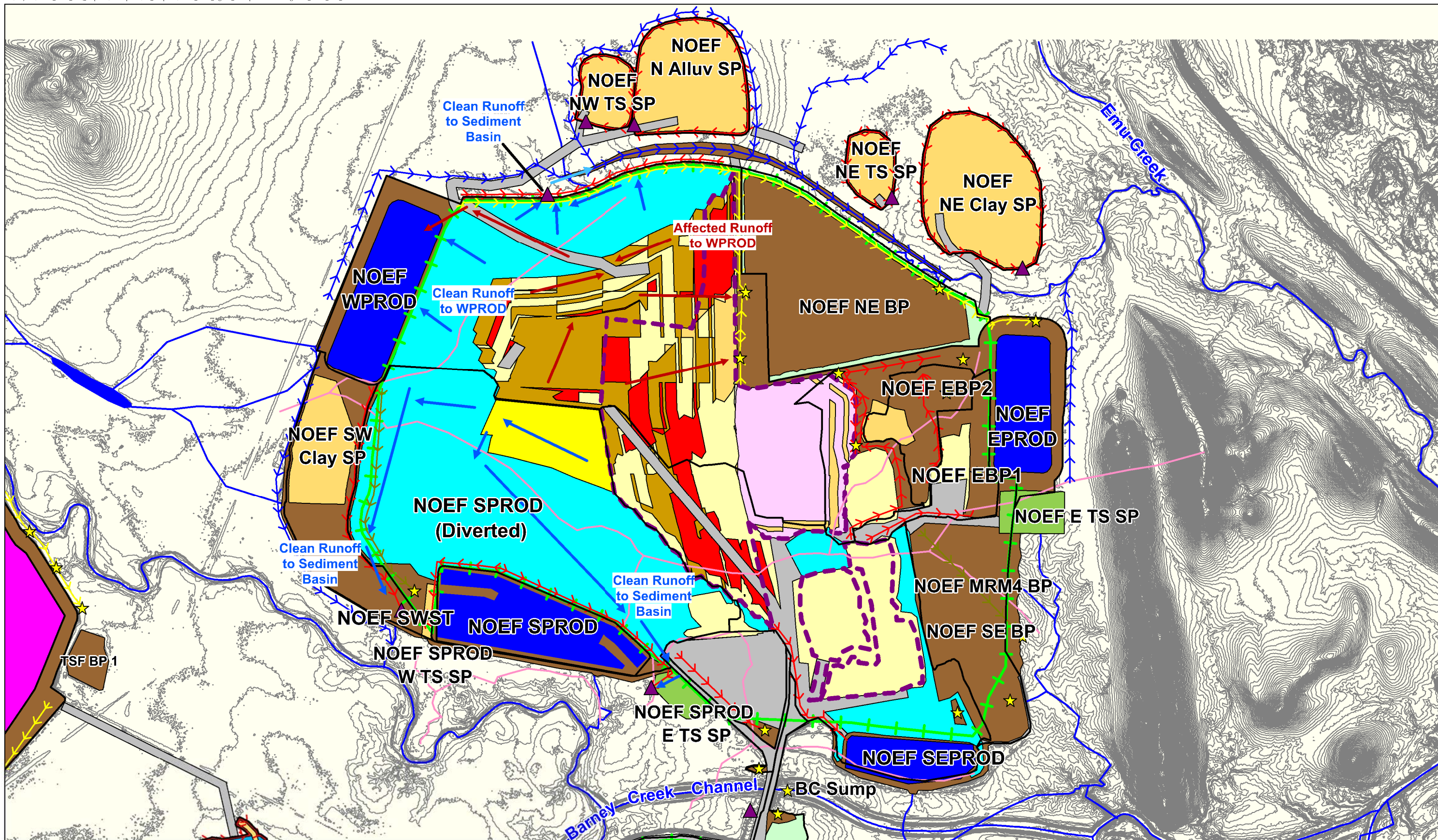
8.5.1.2.1 Water Management System

The NOEF is the primary overburden storage facility from 2018 to 2032, after which the in-pit dump is utilised. The NOEF requires a WMS capable of containing contact water from and infiltration through non-benign surfaces. As progressive rehabilitation encapsulates the non-benign zones in the interior of the facility, infiltration will reduce and runoff will increase. The increased amounts of Class 2 runoff from the cover system will require segregation, where possible, to enable release to the environment through a sediment management system. Therefore, the NOEF WMS will be dynamic through the operational phase. This section provides a brief explanation of the system attributes and function. **Chapter 3 – Project Definition and Justification** provides further information on the NOEF layers and construction methods.

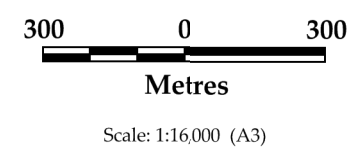
Two snapshots of the NOEF WMS (2022 and 2027) are presented on **Figure 8-31** and **Figure 8-32**, respectively. Arrows have been added to provide an example of how surface runoff from an active stage will be managed, with blue arrows indicating Class 2 runoff (requiring sediment management only), and red arrows indicating Class 4 or higher runoff (requiring evaporation or treatment). In **Figure 8-31**, the West stage reporting to SPROD has been completed, and is encapsulated with a benign cover system. However, the northwest stage in the WPROD catchment is still under construction, with MS-NAFs and PAF materials exposed. The active tip areas are sloped towards the main haul ramp to facilitate drainage down to the PROD level (indicated by the red arrows), where it is directed into WPROD. The lower batters have had benign cover systems installed, generating Class 2 runoff however, the western face still drains WPROD until water quality testing of the cover interflow and runoff is verified as being Class 2. In **Figure 8-31**, runoff quality from the northern face has been verified so it discharged to the receiving environment through a sediment basin. Internal runoff from the eastern exposed face is collected by toe drains and sumps for transfer to WPROD or EPROD.

Figure 8-32 presents the NOEF WMS five years later in 2027, when the northwest stage has been completed. With the runoff water quality verified, the main ramp drain configuration is changed at the base of the NOEF to direct runoff through the sediment basin rather than WPROD. The western base is also reshaped to shed runoff to the north and south around WPROD. This results in most of the contact water reporting to the receiving environment via sediment management facilities. Therefore WPROD is primarily utilised to manage pumped inflows. This achieves the objective of segregating water classes to reduce the amount of impacted waters to be managed.

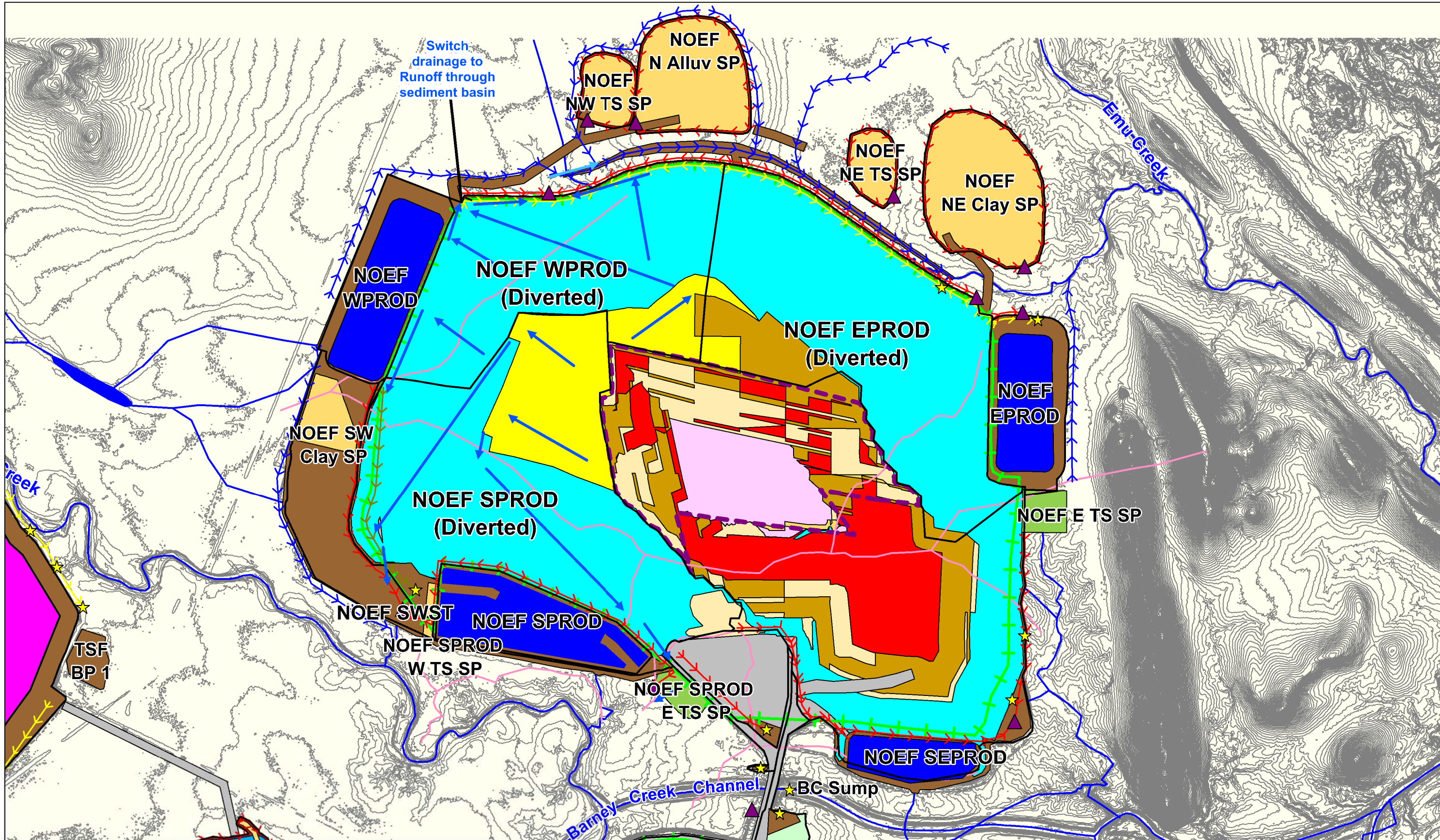
Erosion of the cover system will be managed by providing adequate drainage, materials selection, and revegetation. Appropriately sized and armoured drains will be constructed to convey the larger flow rates and velocities. The non-benign growth media layers on the batters of the NOEF will be LS-NAF(HC) rock to better resist the higher erosive forces present. Alluvial materials may only be used on the flatter slopes planned for the plateau area, grading to rock in the drains.



METSERVE Mining & Energy Technical Services Pty Ltd	McArthur River Mining A GLENORE COMPANY	LEGEND ▲ Sediment Management Structure ★ Outlet Collection Pit / Sump → Surface Runoff Drain → Diverted Runoff Drain → Seepage Trench → Primary Subsoil Drain → Pre-NOEF (2006) Catchment Boundary	— Natural drainage path + Flood Protection Bund / Mine Levee Wall — Surface Catchment Boundary — Water Surface — LS-NAF(HC) (In-situ Rocks) — LS-NAF(HC) — PAF(HW)	- MS-NAF(HC) - PAF(HC) - PAF(RE) - MS-NAF(LC) - Final Cover Alluvium Plateau - Natural (Undisturbed) - Open Cut (In-situ Rocks)	- Alluvium/Clay Stockpile - Hardstand / Industrial - Cleared (Disturbed) - Ore Stockpile - Tailings - Rehabilitated - Interim Clay/Alluvial Caps	McArthur River Mine Overburden Management Project EIS Conceptual Water Management for the NOEF in 2022 08/03/2017 Datum: GDA94 Projection: MGA53 FIGURE 8-31
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Data Source: All data - WRM (Feb 2017)



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LEGEND

- ▲ Sediment Management Structure
- ★ Outlet Collection Pit / Sump
- Surface Runoff Drain
- Diverted Runoff Drain
- Seepage Trench
- Primary Subsoil Drain
- Pre-NOEF (2006) Catchment Boundary

- Natural drainage path
- + Flood Protection Bund / Mine Levee Wall
- Surface Catchment Boundary
- Water Surface
- LS-NAF(HC) (In-situ Rocks)
- LS-NAF(HC)
- PAF(HW)

- MS-NAF(HC)
- PAF(HC)
- PAF(RE)
- MS-NAF(LC)
- Final Cover Alluvium Plateau
- Natural (Undisturbed)
- Open Cut (In-situ Rocks)

- Alluvium/Clay Stockpile
- Hardstand / Industrial
- Cleared (Disturbed)
- Ore Stockpile
- Tailings
- Rehabilitated
- Interim Clay/Alluvial Caps

McArthur River Mine
Overburden Management Project EIS
**Conceptual Water Management
for the NOEF in 2027**

300 0 300
Metres
Scale: 1:16,000 (A3)

08/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-32

Data Source: All data - WRM (Feb 2017)

Figure 8-31 and **Figure 8-32** identify that EPROD has been constructed (scheduled to be constructed in 2019). EPROD will provide more storage and evaporation capacity to the water balance, thereby reducing the pressure on the expanded WTP. The flood protection bund is incorporated into the EPROD wall and is extended around the full perimeter of the NOEF, providing flood protection to the 100 year ARI flood level. This is achieved by constructing the cover system (including the barrier layer CCL) and a portion of the Halo zone early, to provide a flood barrier. Flood levels are presented in **Section 8.6**. Note that there will be internal levees and drains as required to segregate operational areas from undisturbed areas, in accordance with the strategy to limit the mixing of waters of different classes. An example of this is the trench and sump separating the northwest stage from the northeast borrow pit (NE BP).

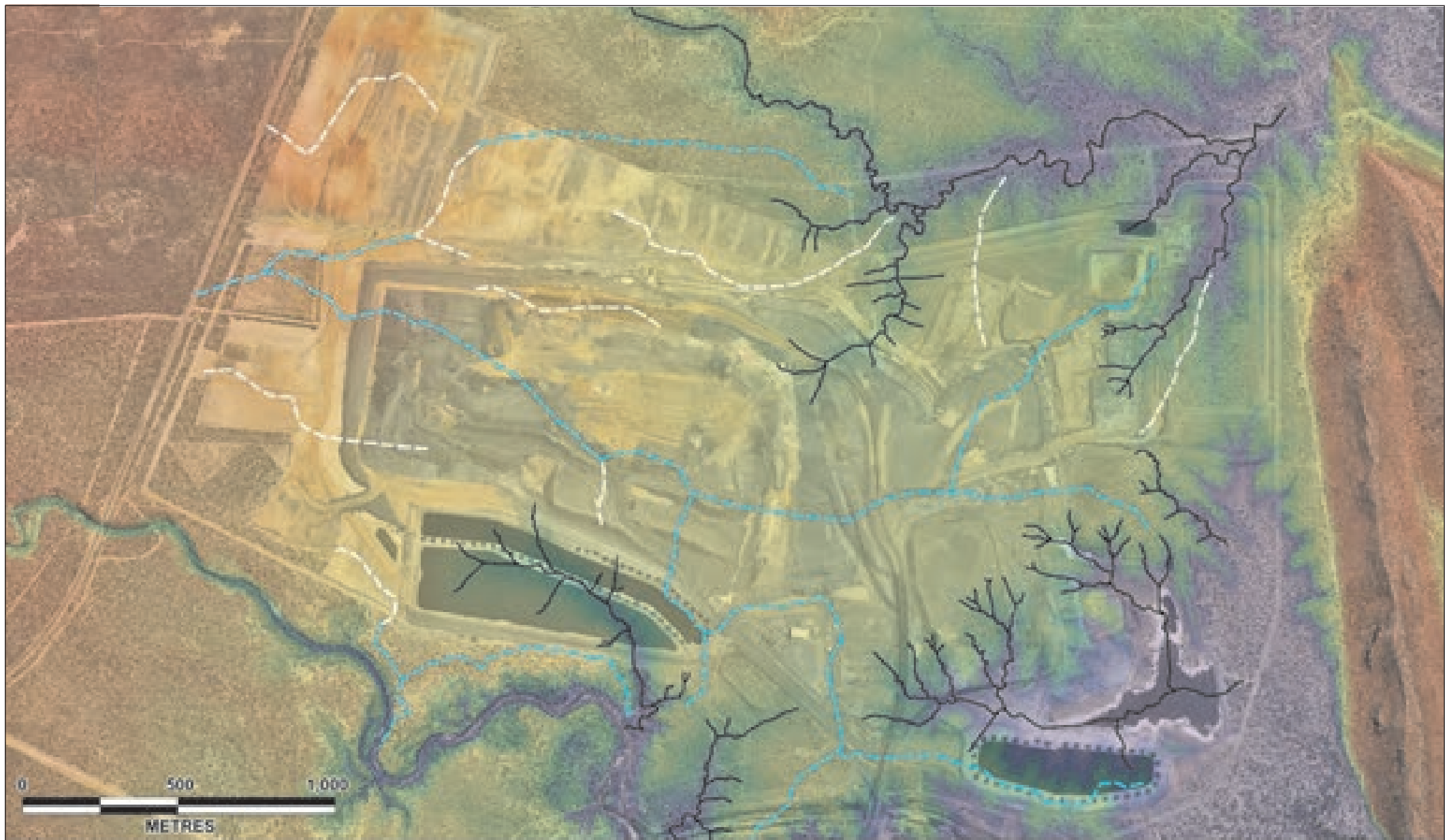
The area north of the NOEF shows several additional new facilities. The expansion of the footprint to the north has filled over an unnamed tributary of Emu Creek, which conveyed water from a catchment to the west and northwest of the NOEF into Emu Creek. To replace this function, a Class 1 clean water drain has been designed, offset from the toe of the NOEF. It will be excavated through the benign alluvial and weathered bedrock, armoured where required, and revegetated.

A series of benign stockpiles has been planned to the north of the new drain, for managing alluvial, clays and topsoil required for NOEF internal and cover layers. Each stockpile has clean water drains and levees to direct clean water around them. The disturbed footprints are then serviced by internal drains directing the runoff to a sediment management structure before discharge.

The management of water infiltrating into the NOEF is also considered in the design and operation of the NOEF. The behaviour of seepage is influenced by both natural and engineered factors. Seepage through the NOEF could be expected to be Class 5 water. Whilst migration of metals are expected to be attenuated by physico-chemical processes in the groundwater zones, the transport of sulphates is not. Therefore, collection and management of these waters will be required to meet the surface water objectives.

The original topography under the NOEF is presented in **Figure 8-33**. The original land surface generally graded west to east, and is quite flat (1V:300H to 1V:500H) with poorly developed surface drainage features under the western half of the existing NOEF. The southeast corner features steeper incised gullies and surface water drains into the Barney Creek Channel. The unnamed tributary on the northern side of the existing NOEF joins with Emu Creek to the northeast of the NOEF. Due to the flat gradients and thinner alluvium, it is conceptualised that infiltration into shallow alluvial and weathered bedrock groundwater zones is higher in the western side of the NOEF than the east, where the topography promotes runoff. The eastern side of the NOEF has thick deposits of low permeability clays which also resist infiltration. Further information is presented in **Appendix T – Groundwater Impact Assessment Report**.

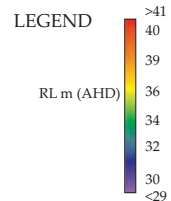
On the eastern side where the existing NOEF has been built, the thick in-situ low permeability clays result in most seepage following the original surface contours and reporting as toe seepage in drainage lines along the eastern side and southeastern corner. These waters are retained by the NOEF flood barrier and the existing SEL structure, enabling the toe seepage to be collected and pumped to into SEPROD for management. Where the NOEF foundation has not yet been constructed, the Project specifies a low permeability basal CCL in the foundation sloping to specific drainage lines, using either in-situ natural or imported engineered materials. The subsoil drains in **Figure 8-34** show the network of existing and planned foundation drains which will convey collected seepage to extraction points around the perimeter of the NOEF. Further detailed drawings are provided in **Appendix AD – Borrow Pit and NOEF Subsoil Drainage Designs**. Toe seepage will then be pumped into the nearest PROD.



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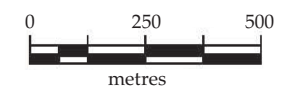


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Data Source: MRM , 2017

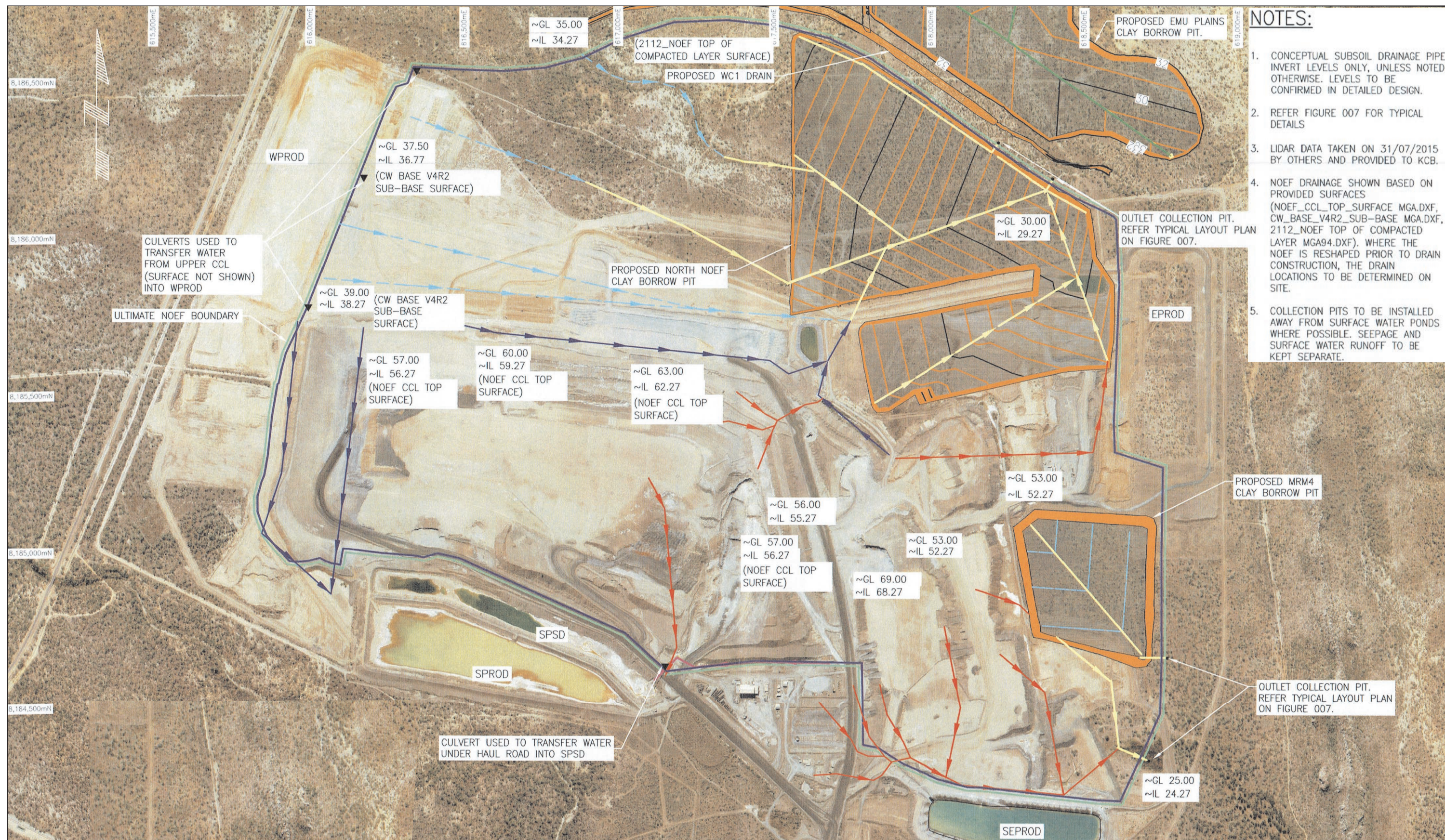
McArthur River Mine
Overburden Management Project EIS
Original Topography(coloured) and
Watercourses over the 2014 Aerial Photo



01/03/2017



FIGURE 8-33

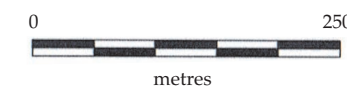


LEGEND

- PRIMARY SUBSOIL DRAIN
- SECONDARY SUBSOIL DRAIN
- EXISTING SUBSOIL DRAINAGE LINES
- NATURAL SUBSOIL DRAINAGE LINES
- EXISTING DRAINAGE UNDER PAF CELL
- VEGETATED DRAINAGE SWALE

Data Source: KCB, 2017

**McArthur River Mine
Overburden Management Project EIS
NOEF Subsoil Drainage**



01/03/2017

Datum: GDA 94
Projection: MGA 53

FIGURE 8-34

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Seepage infiltrating through the foundation moves into the alluvial and weathered bedrock zones. Particle tracking using the site-wide groundwater model shows how the travel path and destination for groundwater under the NOEF varies throughout the operational phase. **Figure 8-35** is applicable for the period from 2018 to 2023. During this time, the open cut is mining in the Barney Creek Formation shales and siltstones, with the open cut dewatering drawdown zone not extending very far north beyond the Barney Creek Channel. The green lines originating in the NOEF area are mainly moving to the south and southeast in shallow zones to Barney Creek. Therefore, the major control for potentially affected groundwater from the NOEF area is to recover groundwater expressing in the Barney Creek Channel downstream of the predicted inflows. A sump (shown as a yellow star) can be seen in **Figure 8-31** in Barney Creek just to the east of the predicted inflows. This would be operated on an as-required basis to achieve the surface water objectives at SW11, which would be predominantly in the late dry season when stream baseflows are reduced. In the order to 1-3 ML/d in anticipated to be removed from the sump.

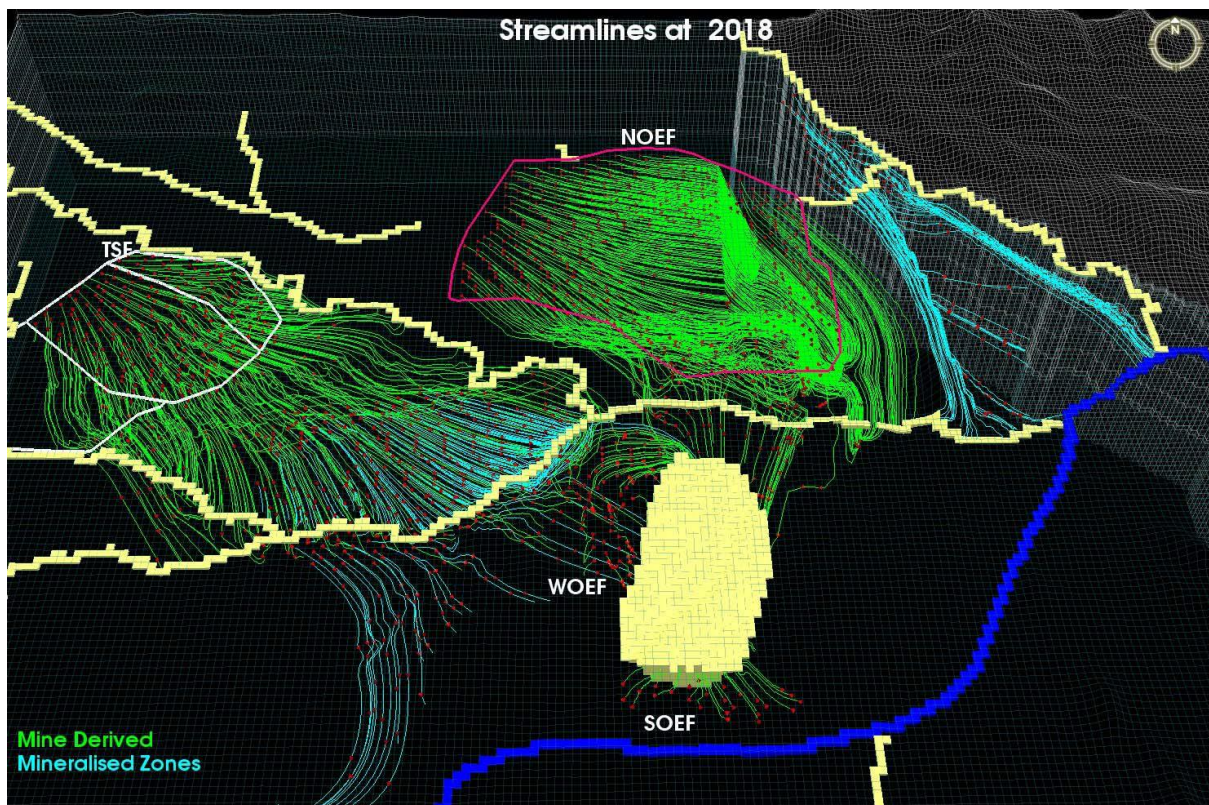


Figure 8-35 Particle Tracking at the End of 2018

A series of sulphate particle tracking videos for the first 150 years of the groundwater simulation is available via the following links:

2019-2022 EIS Particle Tracking Model: <https://goo.gl/T3Tlnm>

2023-2027 EIS Particle Tracking Model: <https://goo.gl/y0lmDZ>

2028-2032 EIS Particle Tracking Model: <https://goo.gl/G9VTpr>

2033-2037 EIS Particle Tracking Model: <https://goo.gl/ASbdPb>

2038-2047 EIS Particle Tracking Model: <https://goo.gl/KPNFyL>

2048-2057 EIS Particle Tracking Model: <https://goo.gl/ICikbs>

2058-2067 EIS Particle Tracking Model: <https://goo.gl/HRXw19>

2068-2087 EIS Particle Tracking Model: <https://goo.gl/9AsCd>

2088-2107 EIS Particle Tracking Model: <https://goo.gl/rwIatA>

2108-2167 EIS Particle Tracking Model: <https://goo.gl/wv31Xc>

During 2023, mining in the open cut will intersect the Western Fault and the Cooley Dolomite rock unit. In the north end of the open cut, this rock unit has a higher permeability due to fractures and karstic features. With the open cut dewatering now connected to this zone of higher permeability, the groundwater from the faulted rock unit will flow to the open cut. The effect this has on groundwater under the eastern side of the NOEF, and for waters within and beneath Barney Creek is presented in **Figure 8-36**. Most particle tracks now extend down deeper with the dip of the Western Fault/fractured karstic Cooley Dolomite, drawn by open cut dewatering. This reduces the reliance on the eastern Barney Creek sump for groundwater recovery in the dry season.

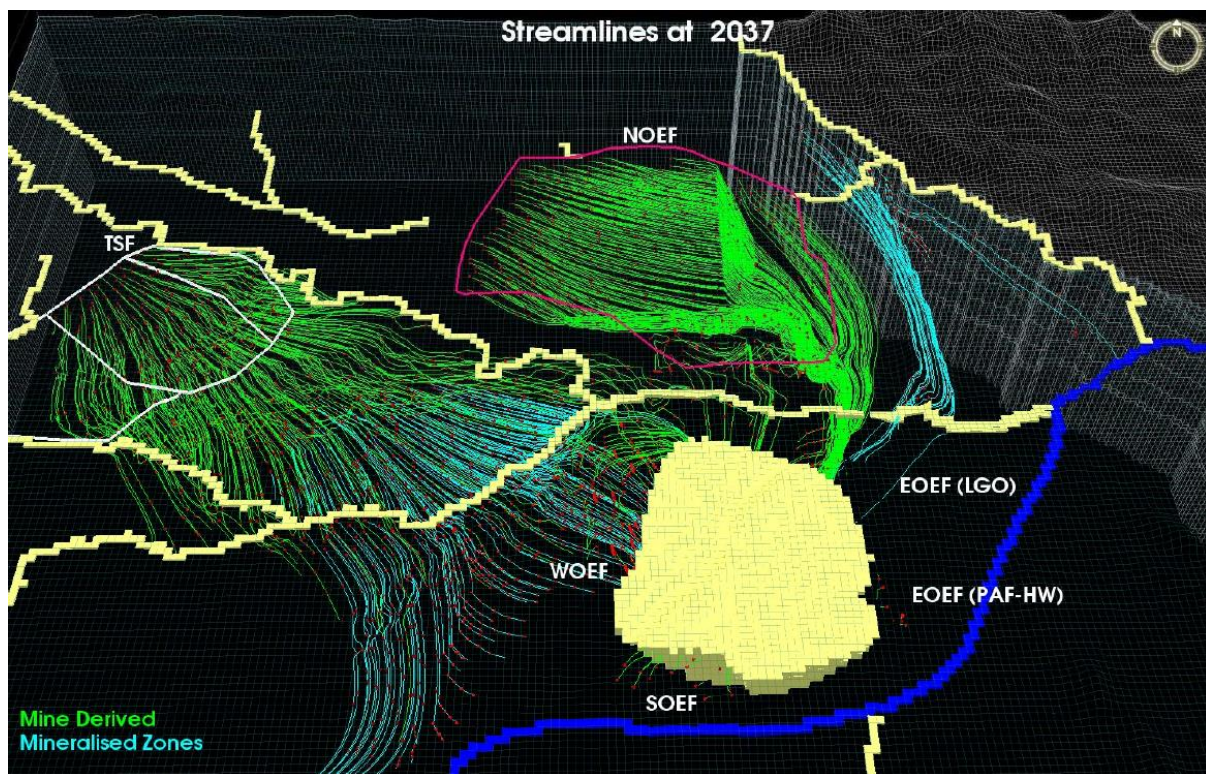


Figure 8-36 Particle Tracking at 2037

Note that the particle tracking shows no traces into Emu Creek. The conceptual model indicates that if heads in the NOEF area remain low (by avoiding leaks from water storages such as EPROD and sumps), then the groundwater table will remain below Emu Creek with flows to the south and southeast. For this reason storages in the Emu Creek area are designed with low permeability liners.

There are no plans to regularly operate the Emu bores in the southeast NOEF area during the operations period. These bores are typically over 50 m deep and not expected to influence the fate of NOEF seepage. There is no requirement for them to supply raw water for the plant or potable water. The bores may be used intermittently to supply water for clay conditioning.

The water balance through the operations phase assessed the likelihood of overflows of water from the NOEF PRODs, (modelled as holding Class 5 water). The water balance identified that for a range of climatic inputs, the overflow risk of the dams met the design criteria of less than 5%. The waterways modelling assessed these overflow events and found that, during overflows, the surface water quality measured at SW11 was below the WDL trigger levels due to the large amounts of diluting floodwaters present between the source and the SW11 site.

8.5.1.2.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the operations (open cut mining) period is contained in **Table 8-3** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

Table 8-3 Source-pathway-receptors for the Open Cut during Operations

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Existing NOEF	Groundwater, shallow and Western Fault block	Surface waters at SW11	Via Barney or Surprise Creeks	- Cover system barrier - NOEF subsoil drainage system - Continued open cut dewatering to maintain groundwater drawdown - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	New NOEF	Groundwater, shallow and Western Fault block	Surface waters at SW11	Via Barney or Surprise Creeks	- Cover system barrier - NOEF subsoil drainage system - Continued open cut dewatering to maintain groundwater drawdown - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	Existing NOEF	Toe seepage via old creek beds (NE, SE, S)	Surface waters at SW11		- NOEF surface WMS - NOEF subsoil drainage system - Water treatment
Soluble oxidation products	New NOEF	Toe seepage via foundation	Surface waters at SW11		- NOEF surface WMS - NOEF subsoil drainage system - Water treatment
Soluble oxidation products	PRODs, drains, sumps	Seepage into groundwater	Surface waters at SW11		- Engineered structures constructed with low permeability bases - Pumping from Barney Creek sumps - Water treatment

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	PRODs, drains, sumps	Overtopping into surface water	Surface waters at SW11		- Water management structures sized to limit probability of overtopping - Ability to transfer to interconnected water management facilities - Annual Water Balance updates - Water treatment
Sediment, turbidity	NOEF	Surface water	Surface waters at SW11		- Landform design - Energy dissipation basins - Sediment management
Soluble oxidation products	NOEF overburden	Floodwater	Surface waters at SW11		- Cover system barrier layer - Internal temporary flood levees - Water treatment

8.5.1.3 Tailings Storage Facility Domain

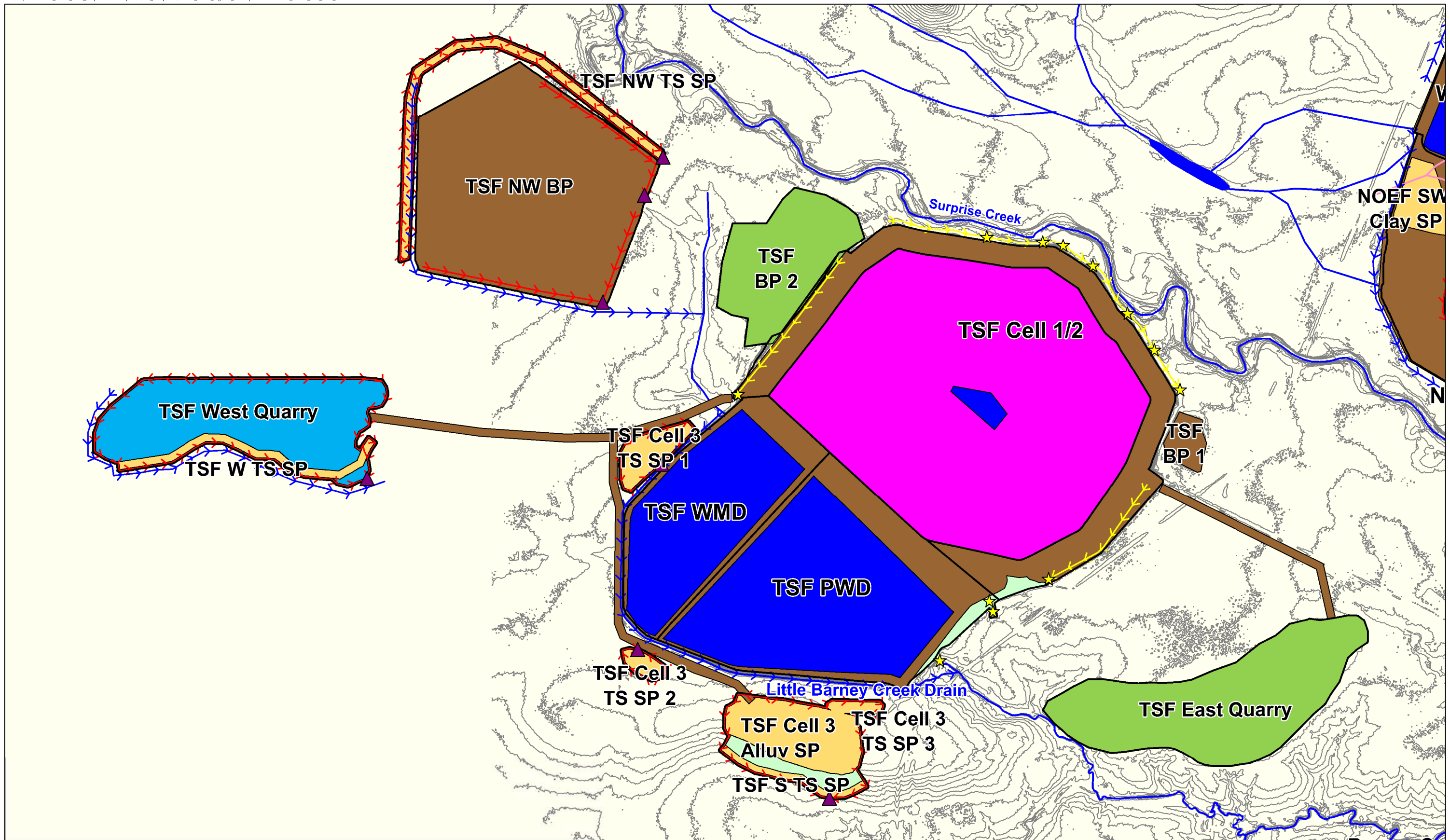
8.5.1.3.1 Water Management System

Water management in the TSF domain focuses on managing process water associated with tailings delivery and deposition, in close proximity to surface water features. The domain is also planned to hold up to 6 GL of mine affected waters in engineered dams, and have benign material quarries and borrow pits for construction materials. The management of these functions and facilities to meet the surface water objectives, at SW11, is presented below.

Figure 8-37 presents a representative depiction of the TSF WMS during the operations phase.

Cell 1/2 will continue to be used for tailings deposition over the life of the Project, increasing in height as it progresses. The current operating practice of maintaining a small decant pond will continue. For extreme events, the cells have an engineered spillway planned for the western wall that will spill into the PWD, limiting the risks to the receiving environment. Details on OOL, MOL and FSL are provided in **Appendix R – TSF Design Development – Life of Mine Plan**.

The TSF will continue using the upstream raising method with a low permeability compacted clay liner in the embankment. This, in combination with the limited decant pond, will limit seepage generation.



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LEGEND

- Sediment Management Structure
- Outlet Collection Pit / Sump
- Surface Runoff Drain
- Diverted Runoff Drain
- Seepage Trench
- Primary Subsoil Drain
- Pre-NOEF (2006) Catchment Boundary

- Natural drainage path
- Flood Protection Bund / Mine Levee Wall
- Surface Catchment Boundary
- Water Surface
- LS-NAF(HC) (In-situ Rocks)
- LS-NAF(HC)
- PAF(HW)

- MS-NAF(HC)
- PAF(HC)
- PAF(RE)
- MS-NAF(LC)
- Final Cover Alluvium Plateau
- Natural (Undisturbed)
- Open Cut (In-situ Rocks)

- Alluvium/Clay Stockpile
- Hardstand / Industrial
- Cleared (Disturbed)
- Ore Stockpile
- Tailings
- Rehabilitated
- Interim Clay/Alluvial Caps

McArthur River Mine
Overburden Management Project EIS
Conceptual TSF Domain
Water Management for 2032

300 0 300
Metres

Scale: 1:16,000 (A3)

08/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-37

Data Source: All data - WRM (Feb 2017)

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A hydrogeological conceptual site model for the TSF area during operations has been developed (**Figure 8-38**) and assists in understanding the fate of seepage from the facility. Infiltration through the tailings, and pore water released from the tailings during consolidation, will migrate through the tailings to the dam foundation. The foundation consists of alluvium with varying permeability, and fractured weathered bedrock. These materials provide pathways for basal seepage into the shallow groundwater zones. The groundwater under and around the TSF is generally moving from the northwest to southeast toward the original McArthur River, with local distortion to Surprise and Barney creeks as shallow flows contribute to baseflow in these surface water systems. Therefore, seepage from Cell 1/2 will migrate with groundwater and reach surface water features between the TSF and the open cut.

As discussed in **Section 8.4.1.3**, the Surprise Creek Groundwater Interception Trench (the “trench”) will be operated throughout this phase of the TSF life to recover TSF affected groundwater migrating north towards Surprise Creek. The water collected in this system will continue to be pumped into the PWD for evaporation, re-use in the process, or treatment. Affected groundwater reporting to Surprise or Barney Creeks beyond this control will be able to be intercepted and removed from surface waters as required by the Barney Creek Sumps, located to the south and southeast of the NOEF.

As the north wall of Cell 1 is close to Surprise Creek, it may be exposed to elevated velocities in some flood circumstances. This wall will be armoured with suitable durable LS-NAF(HC) rock to limit erosion. Note that the crest of the tailings dams is above the 1,000 year ARI flood level, so inundation of tailings is a negligible risk.

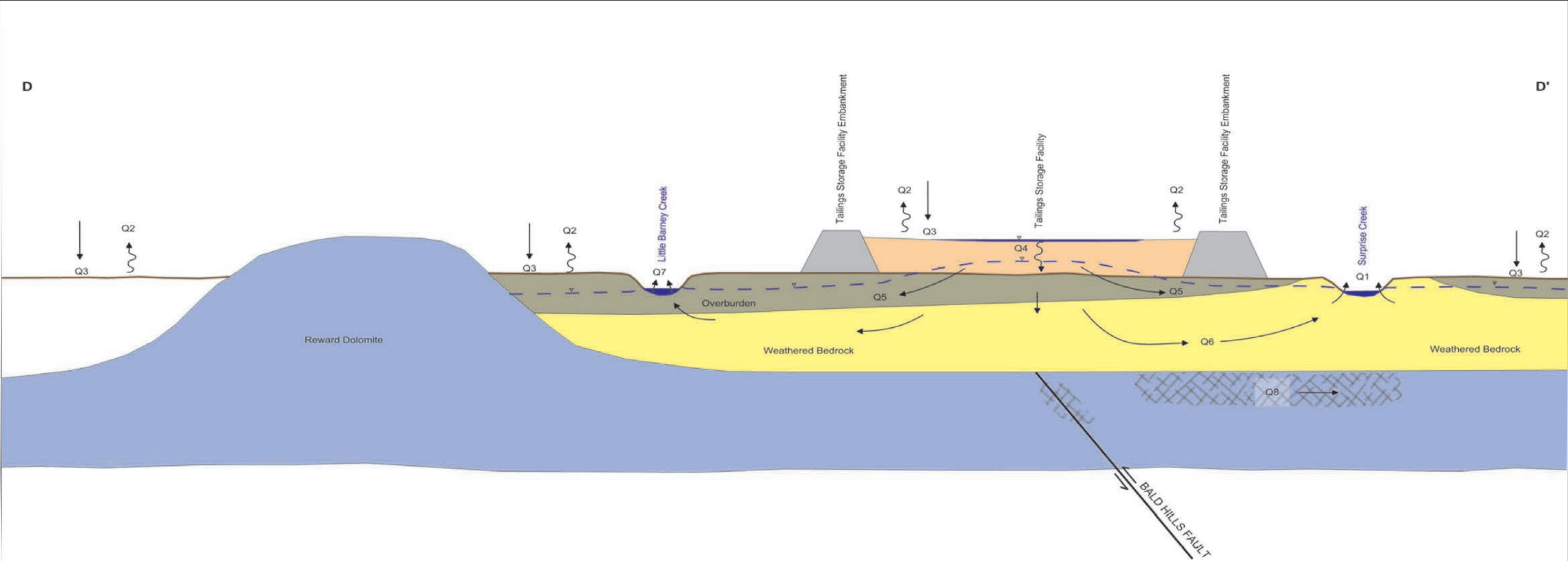
The Cell 3 water dams will continue to be operated as per the pre-Project phase. The WMD will be used to store Class 4 and Class 3 waters awaiting opportunities for discharge during elevated McArthur River flows. Managed releases at rates of up to 200 ML/d will be possible into Little Barney Creek, in accordance with the conditions of the WDL. Note that this is not a large release in the context of annual flood flows through this system, so they present no additional risk of erosion.

The PWD will continue to be used to manage Class 5 and 6 waters, for evaporation, re-use in the process, or treatment. The composite liner construction will limit seepage out of the dam. Seepage collection sumps are present on the eastern toe of the dam to intercept shallow toe seepage. Collected seepage will be pumped back into the PWD.

The overflow risk of the Cell 3 dams was modelled, and found to be less than a 1% probability over the life of the Project. If an overflow did occur, modelling shows the considerable volume of surrounding floodwaters would dilute the overflow waters such that the water quality at SW11 was predicted to be below the WDL trigger values.

The conceptual plan also shows various borrow pits, quarries and stockpiles associated with benign materials required for embankment construction and rehabilitation. The plans show the clean water drains and levees, surface runoff drains, and sediment management constructions to separate clean and impacted waters, and settle out sediment before release to the receiving environment. The NW BP will be excavated below ground level, and hence will not be free-draining. Surface waters will be pumped out of the borrow sediment traps. The quarries incorporate targeted elevated ridges such that they are free-draining.

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METSERVE Mining & Energy Technical Services Pty Ltd	McArthur River Mining A GLENORE COMPANY	Losses Q1 = Baseflow to Barney Creek Q2 = Evapotranspiration Q7 = Baseflow to Little Barney Creek Gains Q3 = Rainfall recharge during wet season Q4 = TSF seepage through tailings Q5 = TSF seepage enters shallow groundwater flow system Q6 = Rapid migration through weathered and fractured rock Q8 = Regional groundwater flow system Data Source: KCB, 2017	McArthur River Mine Overburden Management Project EIS TSF Domain Hydrogeological Conceptual Site Model (looking west)	
		Note - conceptual section is schematic and not to scale	01/03/2017	
			FIGURE 8-38	

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8.5.1.3.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the operations (open cut mining) period is contained in **Table 8-4** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

Table 8-4 Source-pathway-receptors for the TSF during Construction

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Tailings	Shallow groundwater	Surface waters at SW11		- Surprise Creek Groundwater Interception Trench - Groundwater interception bores - TSF operational water management practices - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	Pumped waters and tailings	Seepage from trenches, drains or pipes into shallow groundwater	Surface waters at SW11		- Bunded pipe corridors - Surface drainage system, e.g., drains, sumps, pumps. - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	Tailings	Surface Water	Surface waters at SW11	TSF failure, e.g., due to poor water management, poor wall construction, larger than Maximum Design Earthquake	- QA/QC and design processes - TSF operational water management practices - Pumping from Barney Creek sumps - Water treatment

8.5.1.4 Site-wide Water Management

Whilst the above sections have discussed each domain during the operations period, it is important to discuss the interactions of surface water and groundwater between the domains.

McArthur River Mining has undertaken significant fieldwork and groundwater model calibration to gain a robust understanding of the levels and movement of groundwater, and its interaction with surface water. The information presented in this EIS demonstrates that beyond the influence of the open cut dewatering drawdown zone, groundwater flows regionally towards the McArthur River, and locally towards creeks, where discharge occurs. Thus, groundwater makes its way into surface water on the lease, or into the dewatered open cut/underground WMS. Potential contaminants transported by groundwater that do not report to the open cut/underground will therefore eventually report to the SW11 compliance point.

Calibrated site-wide groundwater and surface water models have been developed to facilitate predictions of these effects and to develop and test mitigation strategies in a number of climatic and operational scenarios. The model processes and results are summarised in **Section 8.6**.

MRM has numerous systems, instruments and hardware used to monitor and manage the surface water system, including:

- operations manuals for major dams, including Trigger Action Response Plans (TARPs);
- instrumentation including flowmeters, level probes and weather stations fitted to major infrastructure, linked into a networked computer system that can be used to monitor water management activities and status of infrastructure; and
- competent management and operators.

8.5.2 Operations Phase – Tailings Mining

This phase of operations (2038 to 2047) is focussed on reclaiming and reprocessing tailings from the TSF, with final emplacement of spent tailings into the completed open cut void. Temporary overburden stockpiles, as well as potentially contaminated materials reclaimed from landform rehabilitation works, will also be placed into the IPD in this period. The NOEF will have limited works being undertaken during this phase as its operation will have ceased in 2032. Further details on operations in this phase are provided in **Chapter 3 – Project Description and Justification**.

The objective of the WMS during this period is to maintain safe operations for the deposition works; maintain a water supply for processing and tailings re-mining; and to manage site-wide water inventories.

8.5.2.1 Open Cut Domain

8.5.2.1.1 Water Management System

With the completion of open cut mining, activities in the domain centre on the reprocessing of tailings with in-pit deposition of spent tailings and rehandled overburden from the temporary stockpiles. A set of tailings pipelines will be installed down the western haul ramp into the mine void, and then down the undulating footwall toward the lower elevations of the mine void. It is likely that the tailings deposition will be subaqueous (underwater), as there is limited capacity in the bottom of the open cut with a large surface water catchment and groundwater inflows. As the tailings level rises, the pipes will be periodically retracted back up the wall. Over the 10 year reprocessing period, the tailings will fill up the bottom 235 m of the final void, with a finished surface at approximately 185 m below the crest of the open cut.

The slurry water that transports the tailings will largely be released by consolidation of the tailings, with the majority of water being released relatively quickly, and continuing at reduced rates over time. The modelling of this is detailed in **Appendix AC – Tailings Deposition into Open Pit Consolidation Modelling**. As water is required for tailings mining and reprocessing during this period, some water will be reclaimed from the open cut and recycled into these processes.

Appendix U – Surface Water Impact Assessment Report details the water balance for this phase of the Project. The net water balance on average is expected to be a gain of approximately 11.6 ML/d. This is driven by the assumption that groundwater inflows to the open cut total 14.1 ML/d, and that these inflows are impractical to intercept prior to reaching the open cut workings.

The excess water will be managed using the same Class 5/6 WMS as that used during the mining operations phase. The water will either be evaporated from Class 5/6 dams, or treated by the WTP at rates of up to 15 ML/day. This is a conservative assumption. If the groundwater quality is better than Class 5 and could be intercepted, the water would be available for managed release. At this stage of planning, all of the site water dams will be retained for the commencement of the tailings reprocessing phase to provide flexibility and capacity to manage a range of excess water classes.

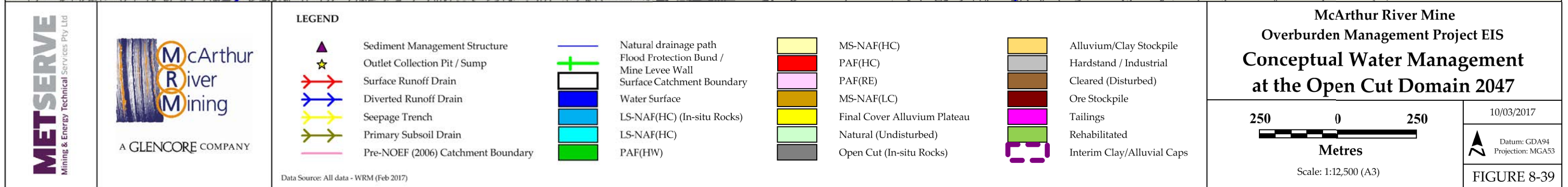
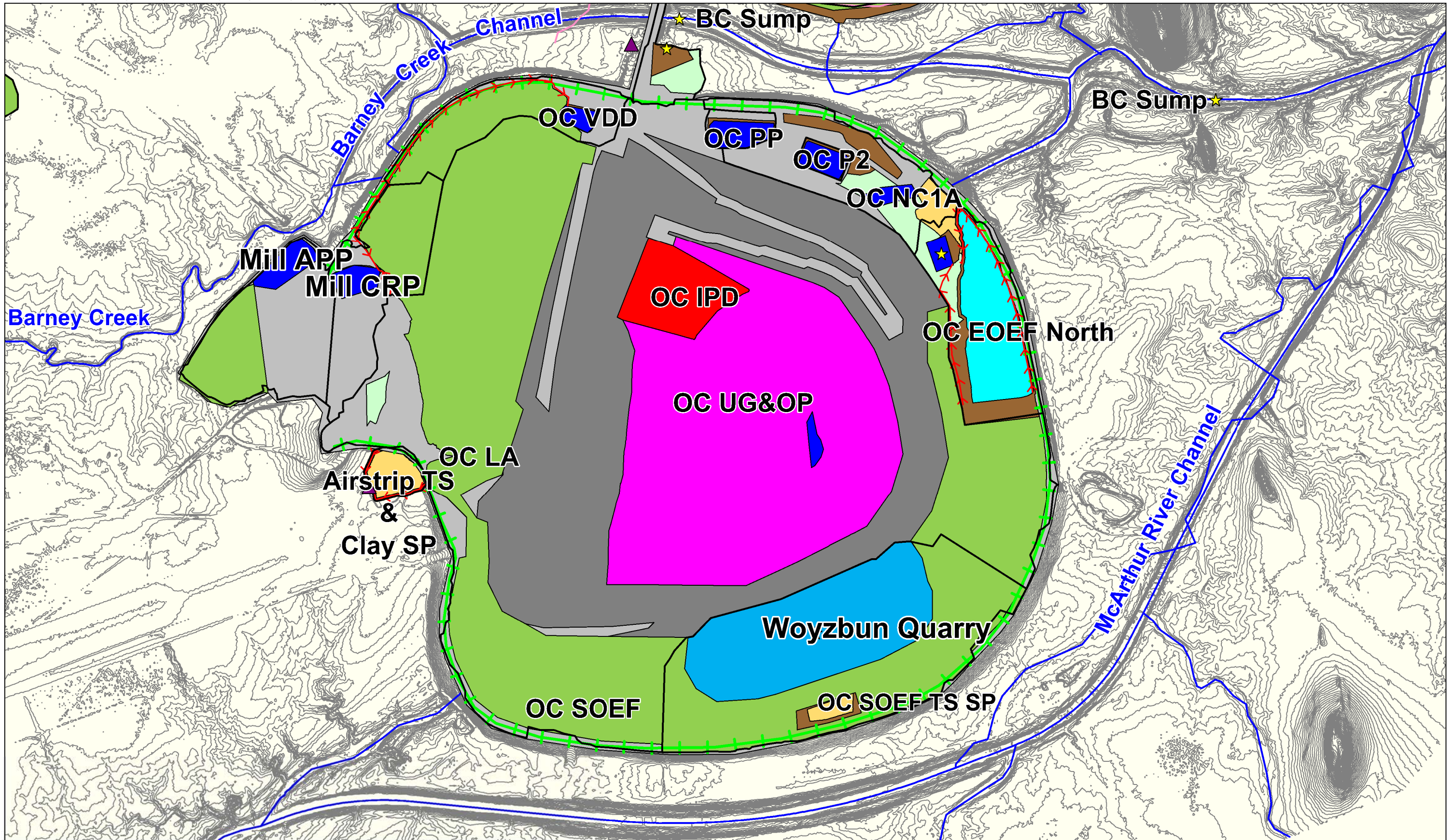
The rehandling of the EOEF and SOEF into the open cut void will occur in the five year period from 2038-2042. The materials will be hauled from surface into the open cut, for inundation by the rising tailings and water. Until the tailings submerge the materials, they will release stored oxidation products into the tailings reclaim water. This water will be managed with the other waters in the final void, with water treatment and evaporation.

The Woyzbun Quarry will have benign materials in the walls, and will continue to receive inflows of Class 4 or better waters from the palaeochannels. A sump and pump will be maintained in the base to capture and remove this water for management in the Class 4 WMS. This is consistent with the objective of not mixing water with a poorer quality class where possible.

The rehabilitated footprints of the EOEF and SOEF will be contoured to be free-draining, and direct runoff through sediment management structures for the deposition of sediments. During this phase of operations, this water will be pumped into the Class 4 WMS and not discharged into the open cut. Vegetation growth will assist in the control of erosion.

With the cessation of ore mining, the WOEF will be rehabilitated during this phase. The low permeability cover will enhance water runoff and evapotranspiration, and reduce infiltration and subsequent seepage. The cover system will feature engineered drains to control erosion, assisted by vegetation. The drains will direct runoff through Open Cut Van-Duncan's Dam (OC VDD) and Open Cut Lake Archer (OC LA) (refer **Figure 8-39**), which will be configured as sediment basins until erosion rates are acceptable.

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8.5.2.1.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the operations (tailings mining) period is contained in **Table 8-5** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks. Only chains different to the open cut mining operations phase are shown.

Table 8-5 Source-pathway-receptors for the open cut during the Tailings Mining phase

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Contaminated water in WMS	Surface water runoff or baseflow seepage	Surface waters at SW11	E.g. pipe burst, storage facility seeps or overflows	- Engineered storage structures with low permeability bases - Continued open cut dewatering to maintain groundwater drawdown - WMS monitoring - Water treatment
Soluble oxidation products	EOEF overburden or Low Grade Ore (LGO)	Surface water runoff or baseflow seepage	Surface waters at SW11		- Stockpiles removed at start of phase - Continued open cut dewatering to maintain groundwater drawdown - Perimeter drains - Water treatment
Soluble oxidation products	WOEF overburden, stockpiled ore	Shallow groundwater	Surface waters at SW11	via Barney Creek	- Pumping from Barney Creek sumps - Continued open cut dewatering to maintain groundwater drawdown - Water treatment
Soluble oxidation products	WOEF overburden, stockpiled ore	Surface runoff	Surface waters at SW11		- Surface drainage system, e.g., drains, sumps, pumps etc. - Pumping from Barney Creek sumps - WOEf cover system - Water treatment
Soluble oxidation products	SOEF overburden	Shallow groundwater	Surface waters at SW11		- SOEF removed at start of phase - Continued open cut dewatering to maintain groundwater drawdown - Water treatment

8.5.2.2 North Overburden Emplacement Facility

8.5.2.2.1 Water Management System

NOEF construction and development has ceased by this stage (the NOEF was completed in 2032). Only infrastructure on and around the NOEF is used in this period. **Figure 8-40** presents the WMS halfway through the phase.

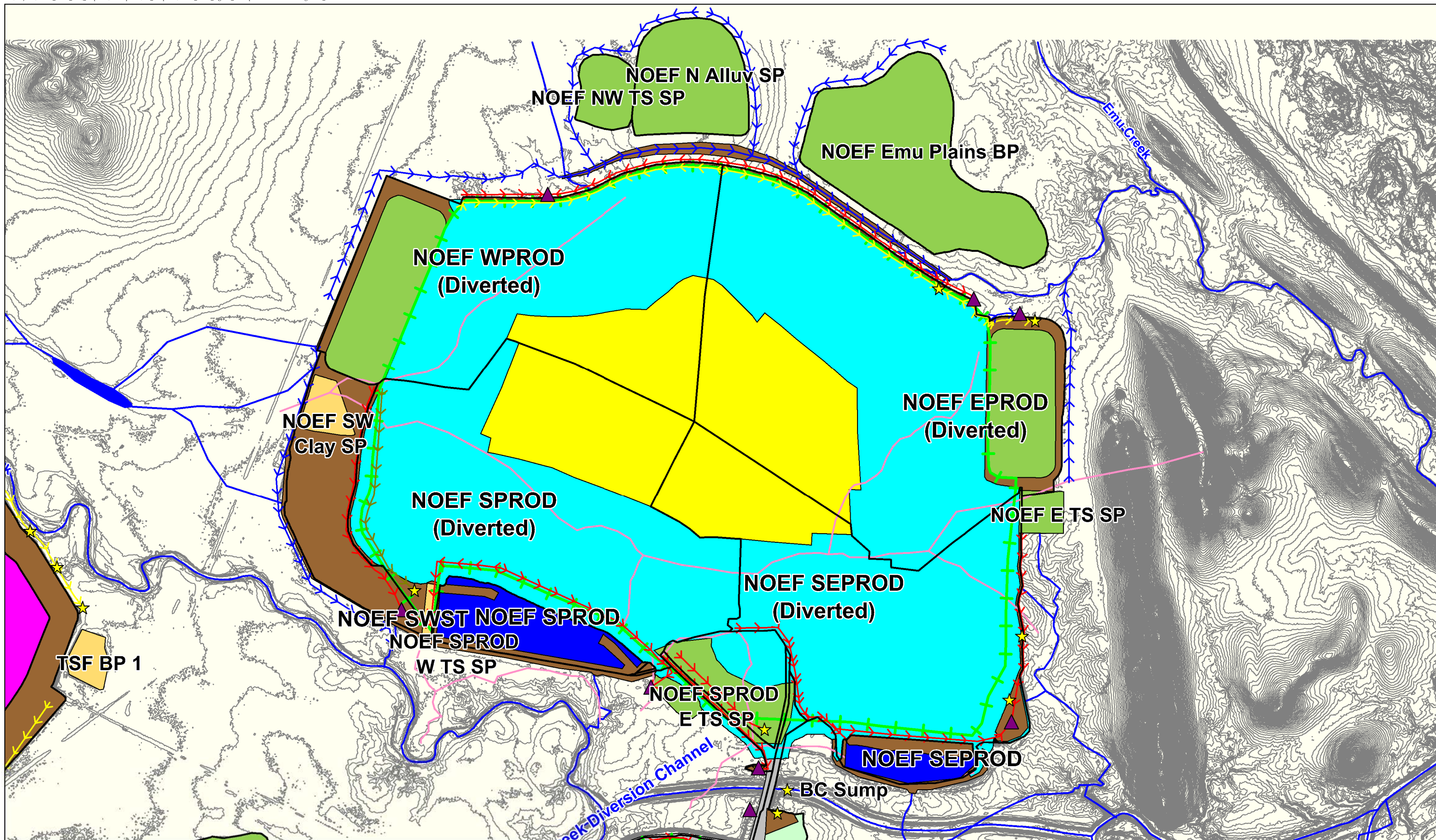
Surface water management of the facility is simplified by the ongoing performance of the NOEF benign cover system. A portion of the rainfall will be captured by the store-and-release layers of the cover system, with evapotranspiration removing excess water. Larger events would also generate runoff, conveyed by the drains and drainage layers incorporated into the cover. Where erosion has not yet attained target low rates, sediment management facilities will be operated to manage runoff before discharge to the receiving environment. Where vegetation and Adaptive Management corrections have stabilised erosion rates, direct runoff to the environment will be facilitated.

Figure 8-40 presents two PRODs in a decommissioned and rehabilitated state. PRODs will be retained beyond the end of the open cut mining operations phase until the tailings reprocessing phase water balance is understood in further detail. If the water balance identifies that the PRODs are surplus to site water storage and evaporation requirements, they will be decommissioned and rehabilitated. The order of decommissioning will depend on dam performance and interconnecting infrastructure.

Figure 8-40 also presents that the mine infrastructure area (MIA) (workshops and hardstand) has been removed and rehabilitated, with an LS-NAF(HC) stockpile remaining for ongoing maintenance works. The MIA sump will be converted into a sediment basin until soil erosion rates meet targets.

The management of the rehabilitated borrow pits will not have changed from the previous phase. The southwest clay stockpile is shown as remaining – this is for use in long-term maintenance. As such, the topsoil levee bank that diverts Class 1 runoff around the southwest of the NOEF is still in place, as is the sediment trap at the southeast end of the stockpile area.

The groundwater monitoring system will continue to provide the levels and qualities of the various groundwater zones around the facility. With the continued management of water levels in the open cut well below the original water table level, groundwater from under the NOEF area is predicted to travel via the fractured zones in the Cooley Dolomite near the Western Fault into the open cut. Dry season baseflows in the Barney Creek Channel are also predicted to continue reporting to the open cut. This is reflected in the predicted groundwater quantities recovered from the Barney Creek sumps through this phase: BC1 (close to the Barney Creek bridges) is shown as recovering from 31-24 megalitres per year (ML/yr) (down from a peak of 40 ML/yr during the mining operations phase), whilst BC2 (to the southeast of the NOEF) is predicted to only remove 0-0.1 ML/yr.



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LEGEND

- Sediment Management Structure
- Outlet Collection Pit / Sump
- Surface Runoff Drain
- Diverted Runoff Drain
- Seepage Trench
- Primary Subsoil Drain
- Pre-NOEF (2006) Catchment Boundary

- Natural drainage path
- Flood Protection Bund / Mine Levee Wall
- Surface Catchment Boundary
- Water Surface
- LS-NAF(HC) (In-situ Rocks)
- LS-NAF(HC)
- PAF(HW)

- MS-NAF(HC)
- PAF(HC)
- PAF(RE)
- MS-NAF(LC)
- Final Cover Alluvium Plateau
- Natural (Undisturbed)
- Open Cut (In-situ Rocks)

- Alluvium/Clay Stockpile
- Hardstand / Industrial
- Cleared (Disturbed)
- Ore Stockpile
- Tailings
- Rehabilitated
- Interim Clay/Alluvial Caps

**McArthur River Mine
Overburden Management Project EIS
Conceptual NOEF Water Management System
During the Tailings Reprocessing Phase**

Scale: 1:16,000 (A3)

08/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-40

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8.5.2.2.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the operations (tailings mining) period is contained in **Table 8-6** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

Table 8-6 Source-pathway-receptors for the NOEF during the Tailings Mining phase

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Existing NOEF	Groundwater – shallow and Western Fault block	Surface waters at SW11	Via Barney or Surprise Creeks	- Cover system barrier - NOEF subsoil drainage system - Continued open cut dewatering to maintain groundwater drawdown - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	New NOEF	Groundwater, shallow and Western Fault block	Surface waters at SW11	Via Barney or Surprise Creeks	- Cover system barrier - NOEF subsoil drainage system - Continued open cut dewatering to maintain groundwater drawdown - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	Existing NOEF	Toe seepage via old creek beds (NE, SE, S)	Surface waters at SW11		- NOEF surface WMS - NOEF subsoil drainage system - Water treatment
Soluble oxidation products	New NOEF	Toe seepage via foundation	Surface waters at SW11		- NOEF surface WMS - NOEF subsoil drainage system - Water treatment
Soluble oxidation products	PRODs, drains, sumps	Seepage into groundwater	Surface waters at SW11		- Engineered structures constructed with low permeability bases - Pumping from Barney Creek sumps - PRODs decommissioned when no longer required - Water treatment
Soluble oxidation products	PRODs, drains, sumps	Overtopping into surface water	Surface waters at SW11		- Water management structures sized to limit probability of overtopping - Ability to transfer to interconnected water management facilities - Annual water balance updates - Water treatment

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Sediment, turbidity	NOEF	Surface water	Surface waters at SW11		- Landform design - Energy dissipation basins - Sediment management
Soluble oxidation products	NOEF overburden	Floodwater	Surface waters at SW11		- Cover system barrier layer - Water treatment

8.5.2.3 Tailings Storage Facility

8.5.2.3.1 Water Management System

The WMS for the TSF during this phase has the primary objective of supporting tailings mining operations whilst continuing to contain mine-affected waters within the WMS.

The TSF WMS is shown conceptually for the 2042 and 2047 periods in **Figure 8-41** and **Figure 8-42** respectively. The tailings are proposed to be mined from the TSF using hydraulic mining methods. High pressure hydraulic monitors will be used to move the tailings towards recovery sumps, where the tailings will be slurried back to the processing plant. This process is estimated to require around 46 ML/day of water, which will be supplied from recycled open cut and/or process plant water. A new pipeline between the mine and TSF will be required and will be placed in the existing banded pipeline corridor. The tailings mining operation will excavate tailings on benches of approximately 10 m high. As the tailings are removed, the walls will be deconstructed using conventional surface mining equipment. Therefore no hydraulic process would be used for wall deconstruction. The wall crest elevation will be maintained at all times with suitable freeboard to manage the risk of overflow. Sprinklers would likely be run around the inactive areas of the tailings to control dust and maintain moisture, thereby limiting oxidation and the risk of spontaneous combustion.

Further details on mining methods and rehabilitation of the TSF are provided in **Appendix R – Tailings Storage Facility Design Development – Life of Mine Plan**.

The benign materials from the deconstructed walls will be required to reshape and rehabilitate the TSF footprint, and so must be stockpiled during the reprocessing phase. The TSF BP1 and BP2 areas will be used for stockpiles. Suitable sediment control structures will be required to manage runoff from these piles.

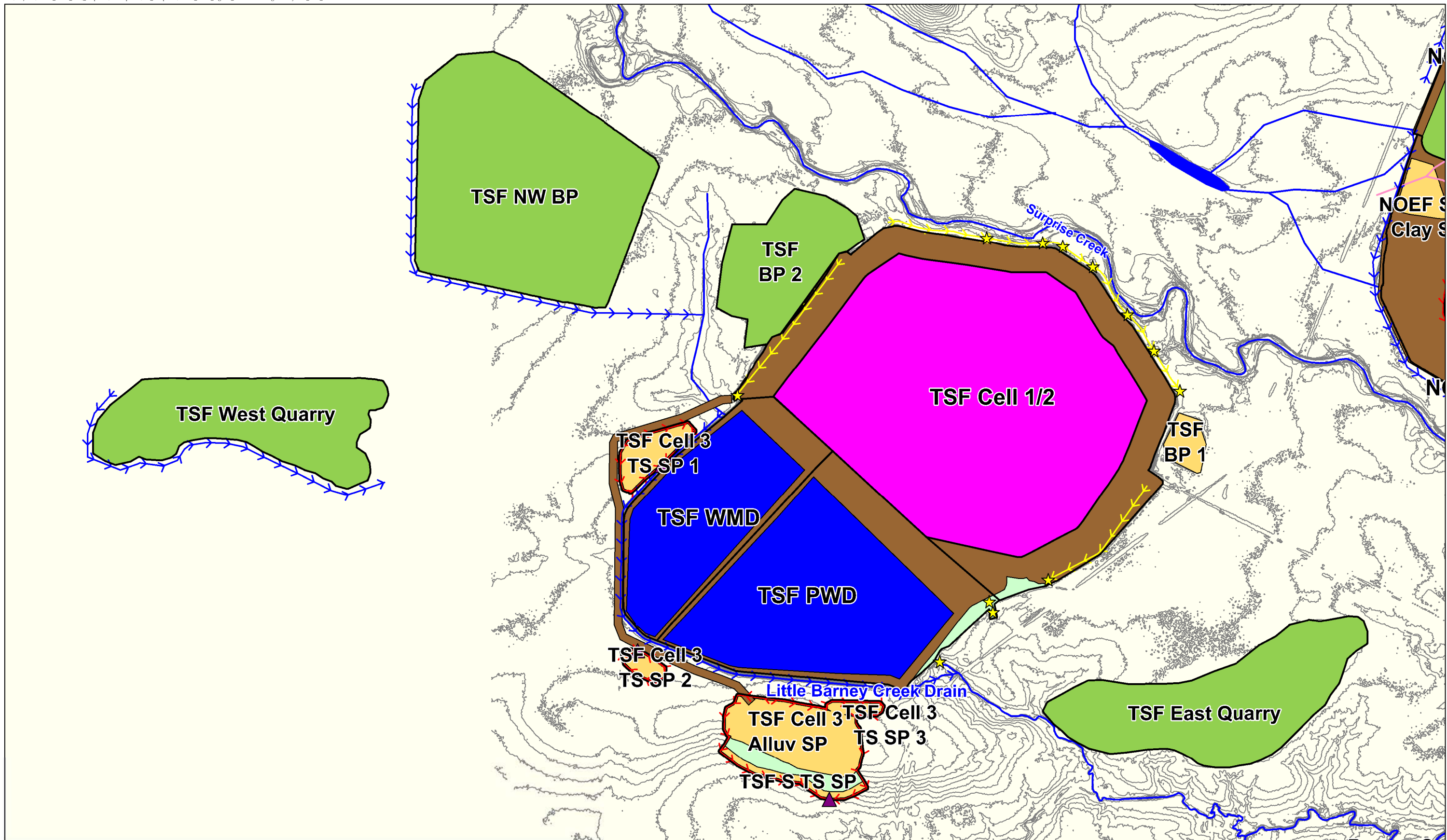
The quarries and borrows that were closed and rehabilitated late in the open cut operations phase have unchanged water management practices. Surface diversion drains are maintained as required, erosion controls are maintained, and vegetation growth is promoted. These activities will continue to manage the Class 1 and 2 waters associated with the facilities.

At the end of the reprocessing phase, the Cell 1/2 embankments will still exist as low walls, and the Cell 3 water dams will still be operational. Therefore, the Little Barney Creek drain will remain. The Cell 3 WMD will continue to be an integral part of the Class 3/4 managed release water system, whilst the PWD would continue to service the Class 5/6 system requirements.

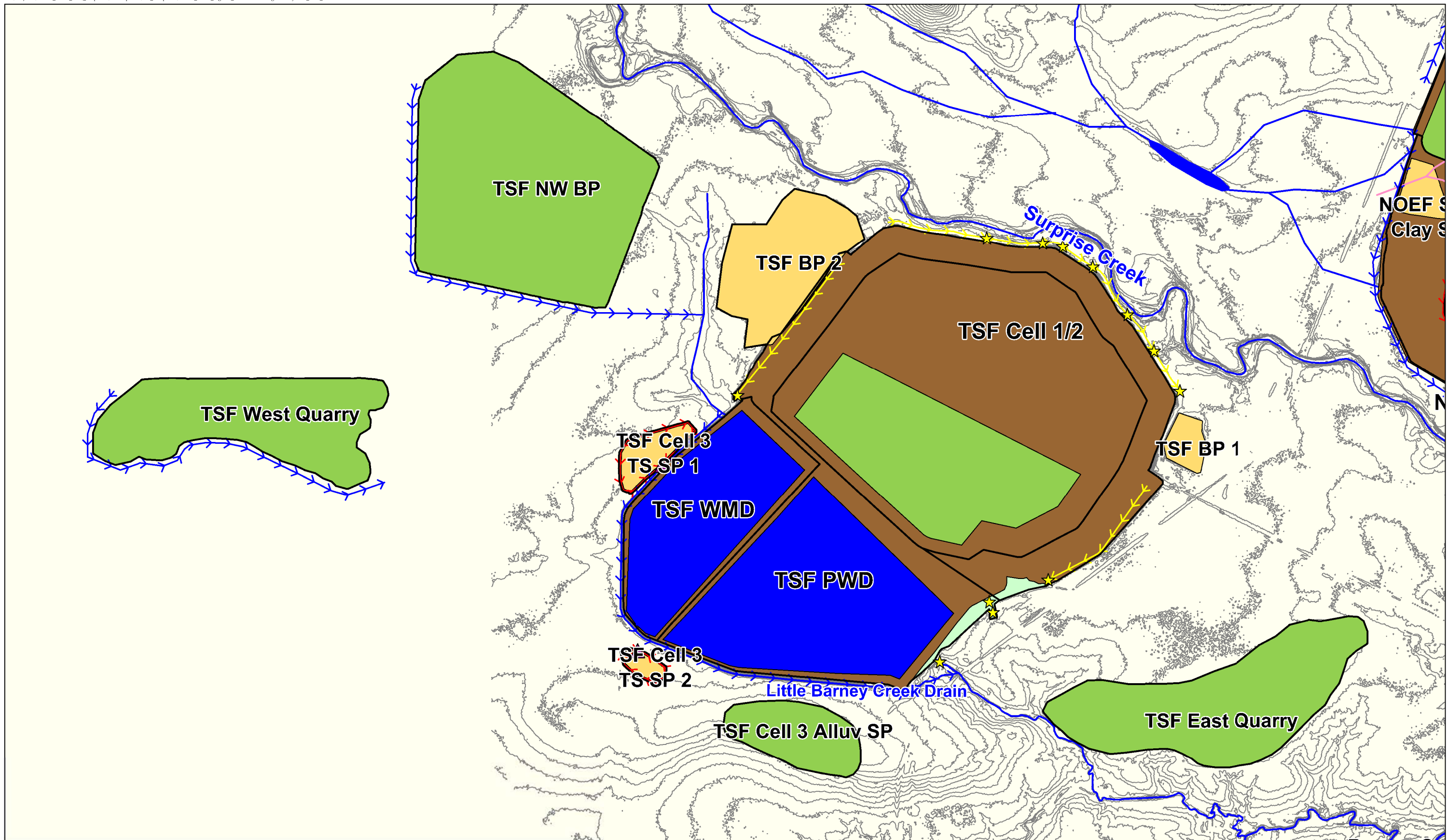
Groundwater management requirements should reduce as the tailings are removed through the ten year period. Reduced water application to the footprint will result in lower seepage rates. The Surprise Creek trench system at the TSF will remain to recover seepage migrating to the north. The shallow toe seepage drains on the west and east will also remain and be operated as required. Deeper seepage-effected groundwater migrating to the east will report to Surprise and/or Barney Creek to the east of the TSF. The Barney Creek sumps will recover this water as required dependent of quality and flow.

Ongoing groundwater and surface water monitoring will track performance of the controls put in place during this phase of the TSF life.

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	 A GLENORE COMPANY	LEGEND				McArthur River Mine Overburden Management Project EIS TSF Domain Water Management System 2042			
		Sediment Management Structure Outlet Collection Pit / Sump Surface Runoff Drain Diverted Runoff Drain Seepage Trench Primary Subsoil Drain Pre-NOEF (2006) Catchment Boundary		Natural drainage path Flood Protection Bund / Mine Levee Wall Surface Catchment Boundary Water Surface LS-NAF(HC) (In-situ Rocks) LS-NAF(HC) PAF(HW)		MS-NAF(HC) PAF(HC) PAF(RE) MS-NAF(LC) Final Cover Alluvium Plateau Natural (Undisturbed) Open Cut (In-situ Rocks)		Alluvium/Clay Stockpile Hardstand / Industrial Cleared (Disturbed) Ore Stockpile Tailings Rehabilitated Interim Clay/Alluvial Caps	
		Data Source: All data - WRM (Feb 2017)				Scale: 1:16,000 (A3)			
				08/03/2017 Datum: GDA94 Projection: MGA53		FIGURE 8-41			



 A GLENORE COMPANY	LEGEND ▲ Sediment Management Structure ★ Outlet Collection Pit / Sump → Surface Runoff Drain → Diverted Runoff Drain → Seepage Trench → Primary Subsoil Drain — Pre-NOEF (2006) Catchment Boundary	— Natural drainage path + Flood Protection Bund / Mine Levee Wall — Surface Catchment Boundary — Water Surface — LS-NAF(HC) (In-situ Rocks) — LS-NAF(HC) — PAF(HW)	- MS-NAF(HC) - PAF(HC) - PAF(RE) - MS-NAF(LC) - Final Cover Alluvium Plateau - Natural (Undisturbed) - Open Cut (In-situ Rocks)	- Alluvium/Clay Stockpile - Hardstand / Industrial - Cleared (Disturbed) - Ore Stockpile - Tailings - Rehabilitated - Interim Clay/Alluvial Caps	McArthur River Mine Overburden Management Project EIS TSF Domain Water Management System 2047	
					 Scale: 1:16,000 (A3)	
					08/03/2017 Datum: GDA94 Projection: MGA53 FIGURE 8-42	

8.5.2.3.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the operations (tailings mining) period is contained in **Table 8-7** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

Table 8-7 Source-pathway-receptors for the TSF during the Tailings Mining Phase

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Tailings	Shallow groundwater	Surface waters at SW11		- Surprise Creek Groundwater Interception Trench - Groundwater interception bores - TSF operational water management practices - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	Pumped waters and tailings	Seepage from trenches, drains or pipes into shallow groundwater	Surface waters at SW11		- Bunded pipe corridors - Surface drainage system, e.g., drains, sumps, pumps. - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	Tailings	Surface Water	Surface waters at SW11	TSF failure, e.g., due to poor water management, poor wall construction, larger than Maximum Design Earthquake	- QA/QC and design processes - TSF operational water management practices - Pumping from Barney Creek sumps - Water treatment
Soluble oxidation products	Tailings	Surface Water	Surface waters at SW11	TSF Failure due to hydraulic mining undercutting embankment	- TSF mining operational practices - Pumping from Barney Creek sumps - Water treatment

8.5.2.4 Site-wide Water Management

The site-wide water balance modelling for a range of conditions indicates the annual water balance would vary in the range of a 500 ML loss to no net loss or gain. This is achieved through use of the WTP.

The PWD level is maintained less than 25% full through this phase. This is because it is assumed that tailings can be deposited sub-aqueously in the open cut void, so the final void has up to 3.5 GL stored in it at times (equating to a depth of up to 5-10 m deep, depending on the bench area).

The WMD is most full late in the dry season of each year; however its utilisation of capacity ranges from approximately 25% full up to 95% full throughout the period.

The sumps in Barney Creek Channel are operated to recover low flows of poor quality water as required in the dry season. BCS1 recovered water quantities drop to 24-31 ML/yr, down from a peak of up to 40 ML/yr during the mining operations phase. BCS2 ranges from 0.1 ML/yr to nil, down from peak of 106 ML/yr during the mining operations phase. The drop in BCS2 pump rates is directly related to the effect of groundwater drawdown from when the open cut intersects the Western Fault in 2023. This mechanism will remain in force until the mine pit lake is formed and regional groundwater levels recover in the Closure phase (refer **Section 8.5.3**).

The integrated waterways modelling, incorporating the proposed Project operations and infrastructure, predicts that the WMS would meet the objective of having no exceedances of the WDL trigger levels at SW11. Generally better performance was predicted during the tailings mining phase than during the open cut mining phase as the open cut drawdown is in effect for the whole period and the NOEF has been closed for over 5 years.

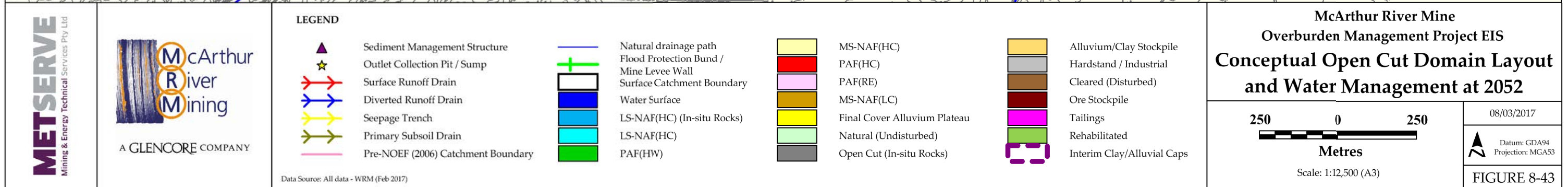
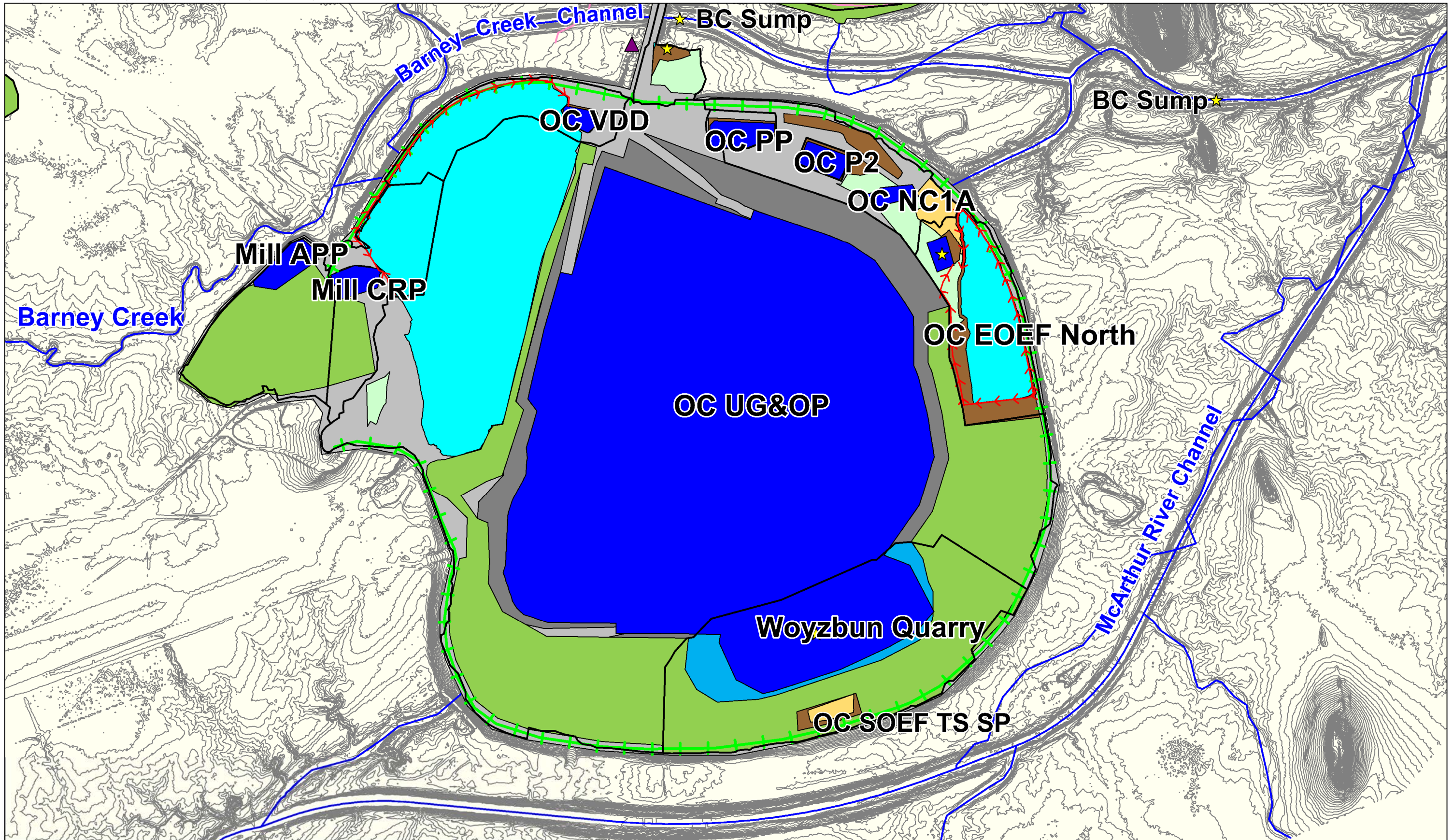
8.5.3 Closure Phase

The closure phase of the Project runs from 2048 (after the cessation of tailings reprocessing). During this time, the remaining disturbed areas that are not either required for long-term maintenance or signed over to other users, will be rehabilitated. The closure phase covers decommissioning, Adaptive Management and Reactive Management. To clarify what key activities are undertaken during this phase, refer to **Chapter 3 – Project Description and Justification**, whilst **Chapter 4 – Decommissioning, Rehabilitation and Closure** provides further information on the Project rehabilitation activities. Sections 9.8 and 9.9 of **Appendix U – Surface Water Impact Assessment Report**, present modelling data identifying that the closure phase strategy meets the water quality objectives at SW11.

8.5.3.1 Open Cut Domain

8.5.3.1.1 Water Management System

This phase of the project will see extensive changes to the facilities in the domain, as well as the hydrogeological and hydrologic conditions. The objective is to convert the domain into a mine pit lake with a stable water quality that can be opened to the receiving environment for periodic mixing with external high flow floodwaters whilst still maintaining compliance with the WDL trigger levels at SW11. To enable this to occur, the mine pit lake water quality must be suitable after all inflows from surrounding landforms and groundwater sources are added. **Figure 8-43** shows the WMS through the closure phase.



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After the tailings relocation to the open cut is complete, water from McArthur River will be harvested during high flow periods using siphons and/or pumps. Water will be harvested at a rate of approximately 60 GL per year over approximately five wet seasons, and discharged into the open cut void. Abstraction during high flows only is proposed to maintain the downstream river system hydrology.

The water abstraction will fill the void rapidly to a steady state mine pit lake water level, which is estimated to be approximately 15 m below ground level, near the base of the alluvial zone. The tailings and IPD overburden would be buried beneath a water cover of approximately 150 m. Operation of the WTP will be required during this period to manage oxidation products from the mine walls and buried materials. The storages of OC PP, OC P2, SPROD, SEPROD, Cell 3 PWD and Cell 3 WMD will be retained for management of waters associated with the WTP.

During this initial period of creating the mine pit lake, the mine levee wall will be maintained intact to protect the operational areas from flooding, and from unplanned discharge of potentially affected waters. The power station is located at the natural ground level and would be exposed to flooding if the mine levee wall were breached; therefore, a flood barrier will be constructed between the southern end of the WOEF and the existing mine levee wall to protect this asset.

Once processing operations are complete, the processing plant and associated infrastructure not required for ongoing monitoring and maintenance will be decommissioned and deconstructed. With Barney Hill cleared of steel, concrete and contaminated materials, it will be rehabilitated with LS-NAF(HC) rock, topsoil and vegetation. Surface drainage will be directed through the re-purposed anti-pollution pond (APP) and concentrator runoff pond (CRP), which will act as sediment basins before discharging the treated waters through rocky chutes into Barney Creek.

Before the Woyzbun Quarry is inundated, a stockpile of LS-NAF(HC) for long-term maintenance requirements will be mined and stockpiled in the previous EOEF footprint. The EOEF drains and sump will act as sediment management infrastructure for this facility.

As the mine pit lake level rises, the groundwater regime will slowly recover. The drawdown cone will diminish, with the drawing in of groundwater from first the eastern NOEF and then Barney Creek subsiding. Once established, the conceptual model for the mine pit lake has the following inputs and outputs:

- Inputs:
 - direct rainfall and surface runoff from rehabilitated landforms inside the mine levee wall;
 - shallow groundwater through the palaeochannel system; and
 - shallow groundwater from under the WOEF containing infiltration through the WOEF cover.
- Outputs:
 - evaporation from the mine pit lake, and evapotranspiration from the lake foreshore and landforms within the domain;
 - surface runoff from the processing plant area and parts of the WOEF over the mine levee wall and into Barney Creek;
 - shallow groundwater through the palaeochannel system in limited times when the mine pit lake level is high from retained rainfall but external floodwaters are gone; and
 - water extraction and treatment by the WTP.

Extraction of small quantities of water for long-term potable water and industrial uses will continue from the MIMEX borefield.

Once the isolated mine pit lake water quality has been confirmed, the domain will transition to a backwater mine pit lake. A portion of the downstream mine levee wall will be removed and an engineered inlet constructed such that high McArthur River flows are allowed to flow, via the inlet, into the mine pit lake. This will enable the exchange of an average of approximately 25 GL of water between the mine pit lake and the river each wet season. Due to this, the operation of the WTP will cease, and collected dry season groundwater from the Barney Creek sumps will be directed into the mine pit lake. Modelling of the waterways shows that the water quality objectives measured at SW11 are met during these exchanges. Once performance has been confirmed for a range of conditions, the WTP and associated dams and infrastructure will be removed.

After an indicative period of ten years, allowed for monitoring the performance of the backwater system, and subject to satisfactory performance of the system, the backwater system will be transitioned to a flow-through system. A section of the upstream mine levee wall will be removed and another engineered high flow inlet created, converting the mine pit lake into a secondary flow path for McArthur River floodwaters. Annual average water exchanges increase to around 46 GL, equivalent to approximately 5% of the McArthur River flow.

8.5.3.1.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the closure phase is contained in **Table 8-8** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

Table 8-8 Source-pathway-receptors for the Open Cut Domain during Closure

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Open cut walls	Shallow groundwater & surface water.	Surface waters at SW11 and McArthur River Channel.	Limited to the shallow parts of mine pit lake and above.	- Open cut geometry. - Rapid open cut filling. - Water treatment as required.
Soluble oxidation products	Ongoing consolidation of tailings	Shallow groundwater & surface water.	Surface waters at SW11 and McArthur River Channel.	Requires mixing of mine pit lake waters.	- Rapid open cut filling. - Water treatment as required. - Transition to flow through mine pit lake scenario.
Soluble oxidation products	NOEF	Shallow groundwater & surface water.	Surface waters at SW11 and McArthur River Channel.	Recovered seepage pumped into the mine pit lake.	- Water treatment as required. - Transition to flow through mine pit lake scenario.
Soluble oxidation products	Open cut walls	Shallow groundwater or surface water.	Surface waters at SW11 and McArthur River Channel.	If wall failure undercuts the mine levee wall (MLW).	- Stability analysis of open cut – FoS > 1.5. - Open cut crest offset from MLW toe. - Transition to flow through mine pit lake scenario.

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	WOEF	Shallow groundwater	Surface waters at SW11 and McArthur River Channel		- Water treatment as required - Transition to flow through mine pit lake scenario

8.5.3.2 North Overburden Emplacement Facility

8.5.3.2.1 Water Management System

Decommissioning and rehabilitation of the NOEF will be undertaken to achieve the site closure objectives as described in detail in **Chapter 4 – Decommissioning, Rehabilitation and Closure**. Due to progressive rehabilitation, the use of in-pit dumping and tailings reprocessing, the NOEF landform will be completed in 2032, with only minor infrastructure items remaining. This section will cover from 2032 to comprehensively address the water management through this transitional time period.

Figure 8-44 presents the facility in the steady-state closure configuration. The NOEF will have a full cover system installed by 2032, with functional drains conveying excess water from the landform to sediment management infrastructure at the toe, with the managed water allowed to discharge to the receiving environment. If water qualities are found to be unsuitable for discharge, water can be transferred from the sediment basins to the PRODs as required. Once vegetation coverage and Adaptive Management adjustments have resulted in stable and low erosion rates, the sediment management facilities will either be decommissioned or converted to passively operating structures, reducing the requirement for intervention.

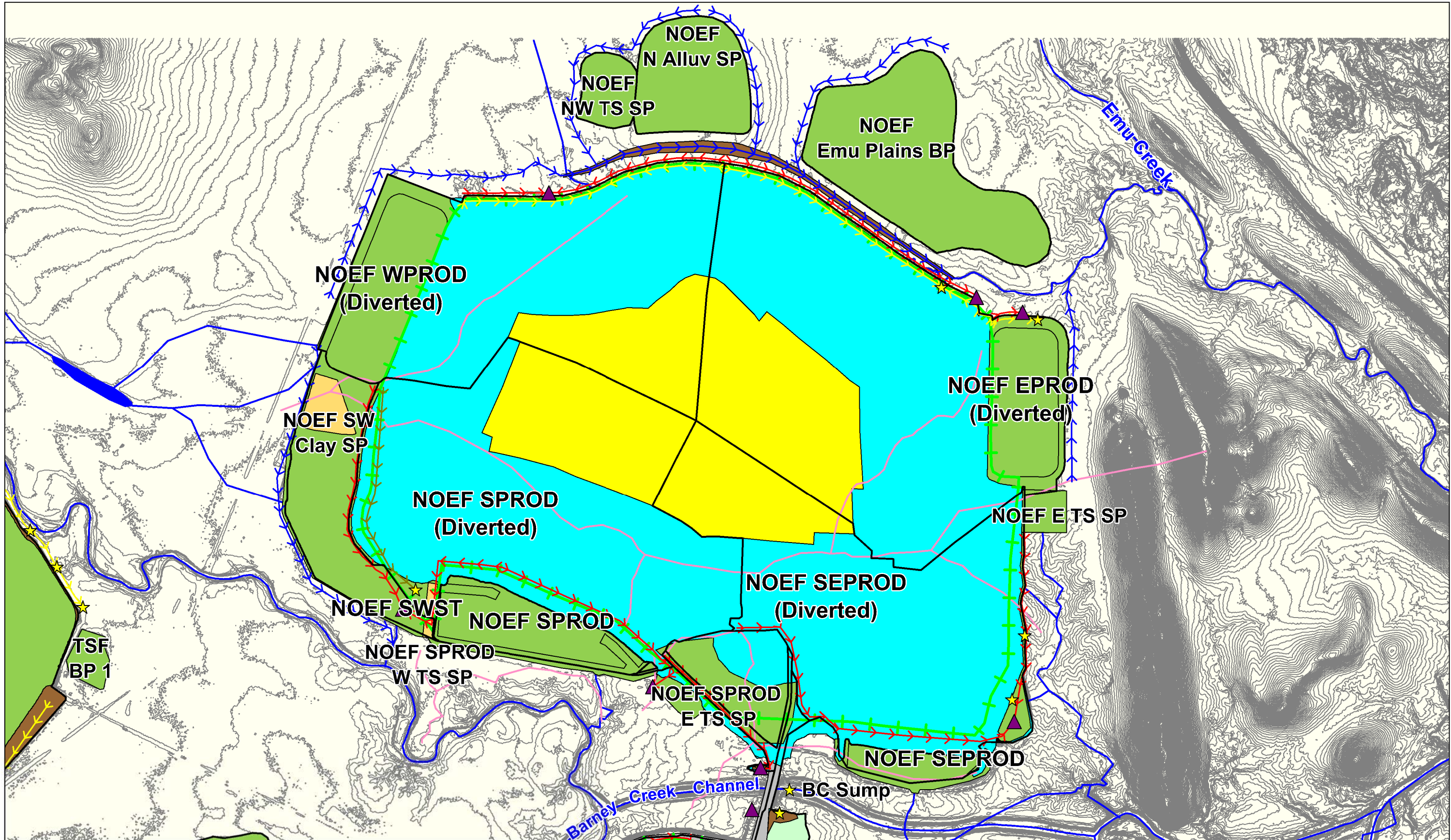
The exhausted borrow pits and stockpiles will be rehabilitated by 2037 and will retain the clean water drains.

Based on water balance requirements, WPROD will be removed by 2037, followed by EPROD by 2042. Note that the order and timing of PRODs removal may be altered in the future based on performance monitoring.

By 2047, the MIA infrastructure will be removed and a cover constructed over this area using stockpiled clays, LS-NAF(HC) and topsoil. SPROD and SEPROD remain for management of mine pit lake water.

Groundwater management through this period will vary. Once the cover system has been installed and vegetation established, Net Percolation (infiltration) is modelled to be in the 5 to 10% range, depending on the rainfall patterns and intensities. This is lower than when parts of the facility were under construction. Therefore, there will be a period after the cover is installed where the higher infiltration associated with construction phase, drains down and exits the facility as toe or basal seepage. Based on modelling, this period is expected to take approximately 15 years.

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LEGEND

- Sediment Management Structure
- Outlet Collection Pit / Sump
- Surface Runoff Drain
- Diverted Runoff Drain
- Seepage Trench
- Primary Subsoil Drain
- Pre-NOEF (2006) Catchment Boundary

- Natural drainage path
- Flood Protection Bund / Mine Levee Wall
- Surface Catchment Boundary
- Water Surface
- LS-NAF(HC) (In-situ Rocks)
- LS-NAF(HC)
- PAF(HW)

- MS-NAF(HC)
- PAF(HC)
- PAF(RE)
- MS-NAF(LC)
- Final Cover Alluvium Plateau
- Natural (Undisturbed)
- Open Cut (In-situ Rocks)

- Alluvium/Clay Stockpile
- Hardstand / Industrial
- Cleared (Disturbed)
- Ore Stockpile
- Tailings
- Rehabilitated
- Interim Clay/Alluvial Caps

McArthur River Mine
Overburden Management Project EIS
**Conceptual NOEF Domain Layout
and Water Management at 2052**

Scale: 1:16,000 (A3)

08/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-44

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Modelling provides the split of seepage between basal and toe seepage during the closure phase (from 2048 in **Figure 8-45**). The groundwater table is not expected to mound significantly inside the NOEF or rise up from below during this period, thus the driving forces of the split between basal and toe seepage will remain to be driven by the foundation and the efficacy of the basal drainage system. Due to the engineered construction of the system, it is expected the internal drains will continue to be functional, enabling toe seepage to be extracted by pumping well into the closure period.

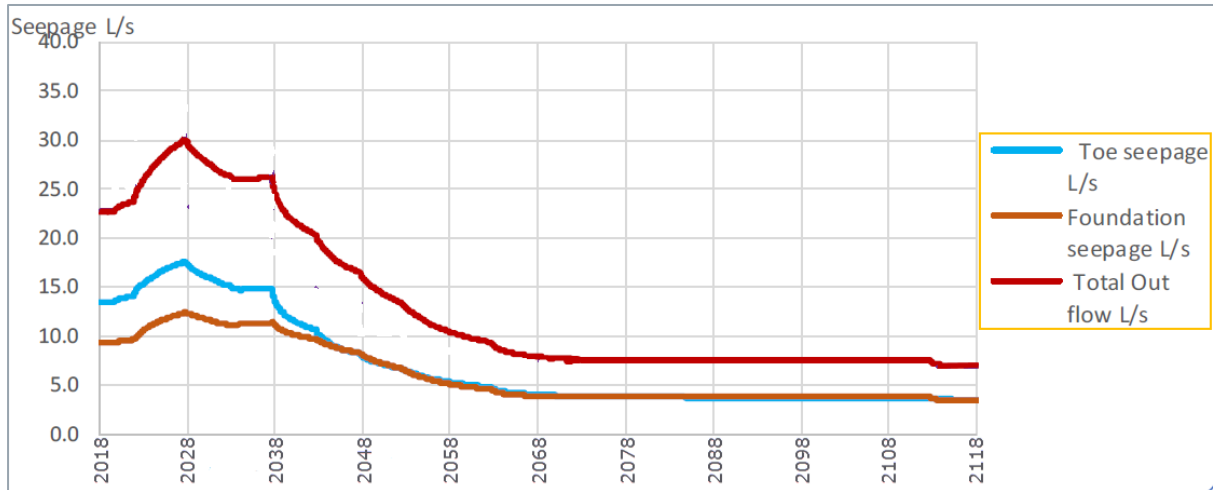


Figure 8-45 Prediction of NOEF Long-term Seepage

Once the mine pit lake has established to the full level and the local groundwater zones have recharged, the groundwater levels will be similar to pre-mine conditions. **Figure 8-46** presents groundwater particle tracking under the NOEF, with a baseflow connection re-established with Barney Creek. The long-term NOEF seepage will require intermittent collection and management in the Barney Creek sumps, typically in the dry season, to meet surface water quality objectives at SW11.

Collected NOEF toe seepage and intercepted waters from the Barney Creek sumps will require management. As described in the open cut domain, the WTP and associated management dams are expected to be operational until around 2060, and will be used to manage the poor quality NOEF waters. Once the backwater mine pit lake has been established and the WTP system decommissioned, the NOEF waters will be directed to the mine pit lake for dilution. Due to the small quantities of water to be transferred from the NOEF and Barney Creek sumps, mine pit lake and waterway modelling indicates that the water quality objectives at SW11 continue to be met.

8.5.3.2.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the closure phase is contained in **Table 8-9** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

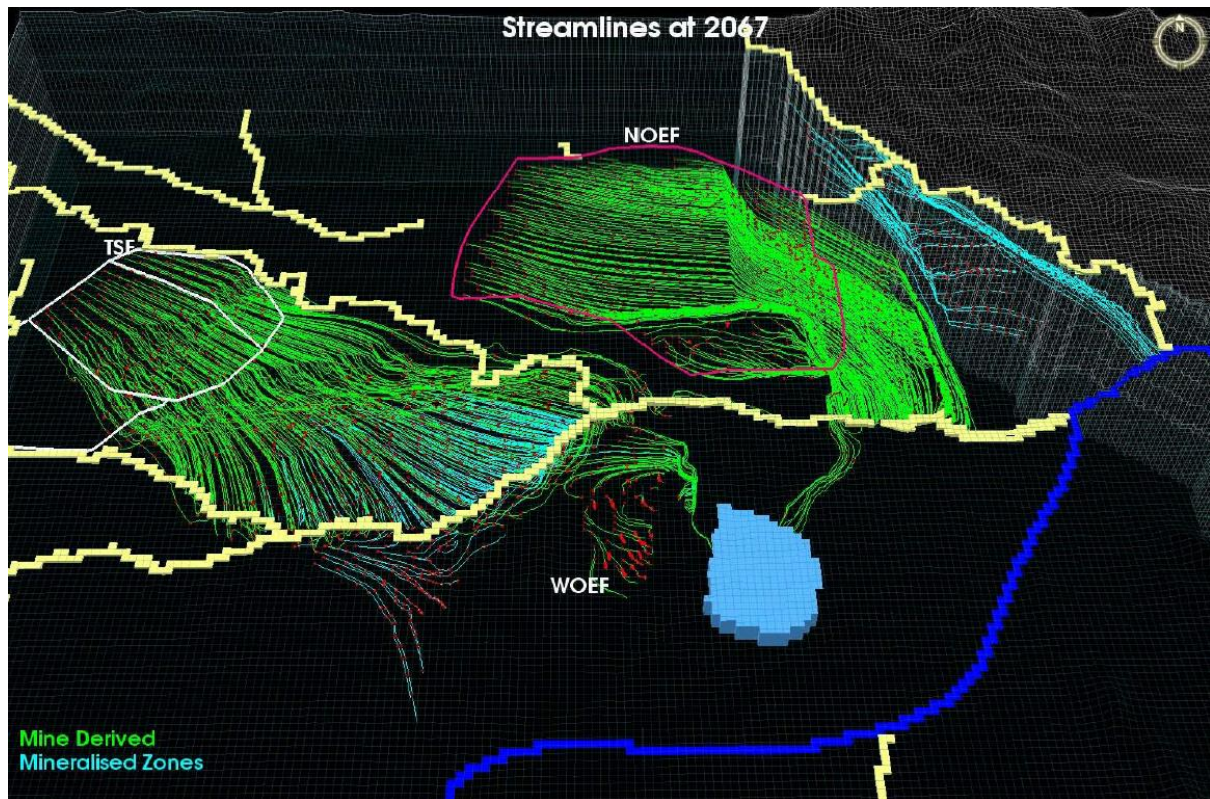


Figure 8-46 Particle Tracking of Groundwater Contaminants at 2067

Table 8-9 Source-pathway-receptors for the NOEF during Closure

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Existing NOEF	Groundwater – shallow and Western Fault block	Surface waters at SW11 and McArthur River Channel	Via Barney or Surprise Creeks	- Cover system barrier - NOEF subsoil drainage system - Pumping from Barney Creek sumps - Water treatment as required
Soluble oxidation products	New NOEF	Groundwater, shallow and Western Fault block	Surface waters at SW11 and McArthur River Channel	Via Barney or Surprise Creeks	- Cover system barrier - NOEF subsoil drainage system - Pumping from Barney Creek sumps - Water treatment as required
Soluble oxidation products	Existing NOEF	Toe seepage via old creek beds (NE, SE, S)	Surface waters at SW11 and McArthur River Channel		- NOEF surface WMS - NOEF subsoil drainage system - Water treatment as required
Soluble oxidation products	New NOEF	Toe seepage via foundation	Surface waters at SW11 and McArthur River Channel		- NOEF surface WMS - NOEF subsoil drainage system - Water treatment as required

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	PRODs, drains, sumps	Seepage into groundwater	Surface waters at SW11 and McArthur River Channel		- Engineered structures constructed with low permeability bases - Pumping from Barney Creek sumps - PRODs decommissioned when no longer required - Water treatment as required
Soluble oxidation products	PRODs, drains, sumps	Overtopping into surface water	Surface waters at SW11 and McArthur River Channel		- Water management structures sized to limit probability of overtopping - Ability to transfer to interconnected water management facilities - PRODs decommissioned when no longer required - Water treatment as required
Sediment, turbidity	NOEF	Surface water	Surface waters at SW11 and McArthur River Channel		- Landform design - Energy dissipation basins - Revegetation
Soluble oxidation products	NOEF overburden	Floodwater	Surface waters at SW11 and McArthur River Channel		- Cover system barrier layer - Water treatment as required

8.5.3.3 Tailings Storage Facility

8.5.3.3.1 Water Management Systems

Following tailings mining, reprocessing and pumping into the open cut final void, rehabilitation of the TSF area will take place as described in **Chapter 4 – Closure, Decommissioning and Rehabilitation**.

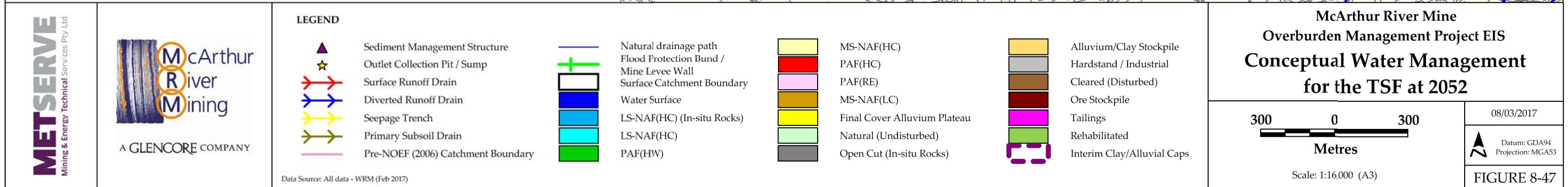
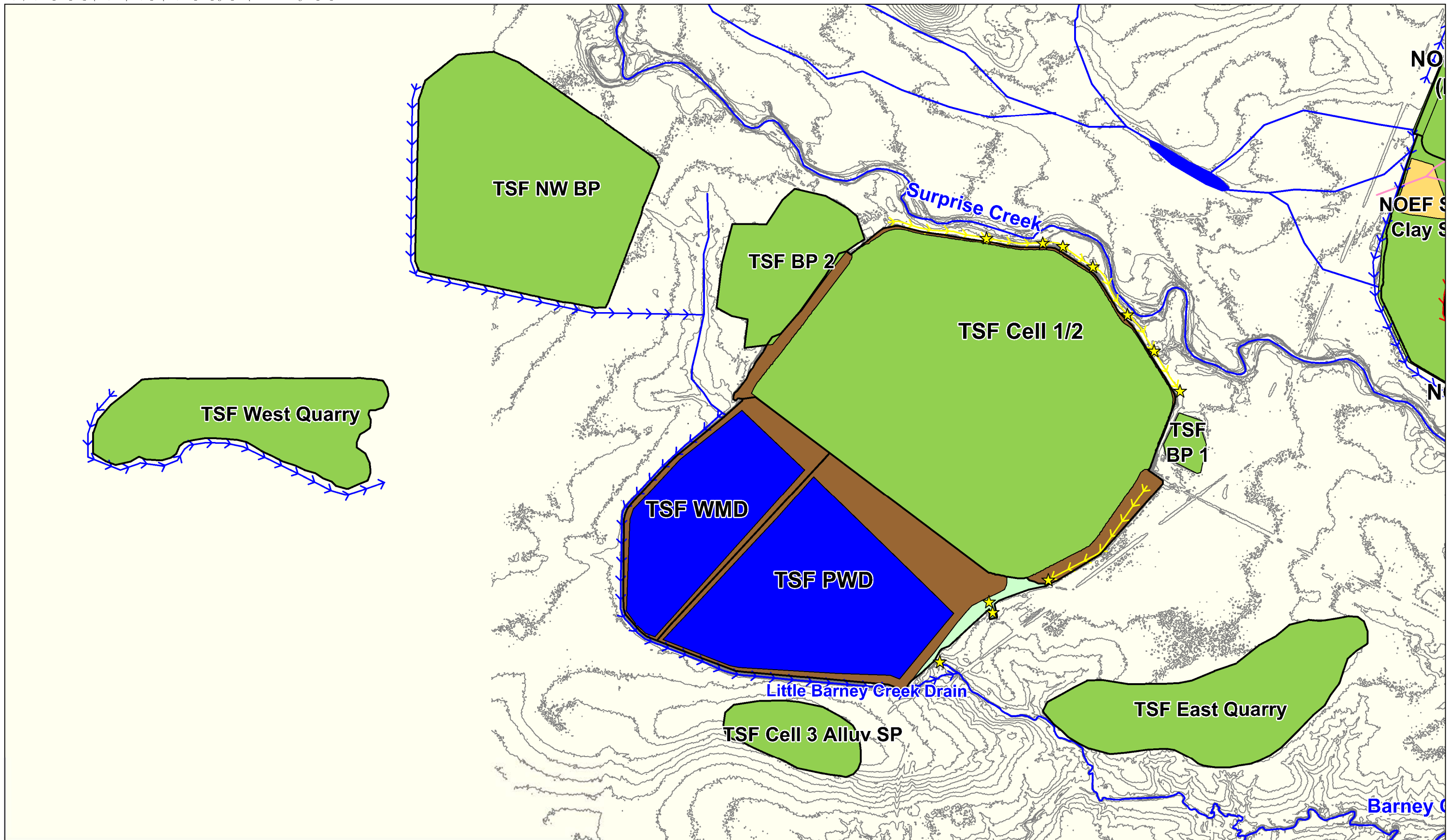
These works involve rehabilitation with benign materials and remediated areas, thus water management is simplified. **Figure 8-47** presents the TSF domain WMS at 2052. The Cell 3 dams will still be in place to service water treatment activities.

Disturbed areas will be reshaped using the benign materials remaining from the deconstruction of the TSF embankments. The surface will be free-draining to Surprise and Little Barney Creeks where possible. Alluvial material and topsoil will be placed over the higher ground before revegetation with suitable species (source control for dust and erosion). The drain areas will have suitable rocky LS-NAF(HC) lining the main flow paths to reduce erosion (source control). Sediment management systems will be installed and maintained downstream of the rehabilitated areas until erosion rates meet the closure objectives (pathway control). Remaining borrow pit depressions will be revegetated with suitable species for the altered conditions. Any remnant infrastructure not required for ongoing activities during the Adaptive Management phase, such as some roads, powerlines, and pipelines, would be removed.

From a conceptual model perspective, the TSF site itself will be returned to a similar state to pre-mining conditions. Rainfall will land on the former footprint, where it will either be retained in the soils and evaporated back to the atmosphere, run off the surface to surface waterways, or infiltrate to shallow groundwater zones. Early in the revegetation stage, and in the depressions of borrow pits, there may be a higher level of groundwater recharge than the original land. However, as vegetation coverage increases, evapotranspiration will increase and reduce infiltration closer to pre-mine levels.

Infiltration would proceed to the alluvial and weathered bedrock groundwater zones and generally migrate to the east, with local deviation towards Surprise and Barney Creeks in their proximity. With the lack of mine dewatering, regional groundwaters will have recovered, so shallow groundwater could be expected to contribute to baseflow in creeks to a greater extent. The recovered groundwater table will also rise around the natural sources of sulphates between the TSF and open cut area, reducing their oxidation rate and contribution to loads in the system.

The management of affected groundwater, regardless of its origins (mine derived or natural), will be based on monitoring around the TSF and downstream. It is expected that the Surprise Creek Groundwater Interception Trench will be able to be decommissioned within one wet season of the tailings having been removed and rehabilitation completed. Groundwater migrating to the east will be managed via the Barney Creek sumps, along with NOEF affected groundwater. The management of this system is as described in **Section 8.5.3.2** above.



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8.5.3.3.2 Summary of Management Features

A summary of the key water-related source-pathway-receptors for each of the facilities in the domain through the closure phase is contained in **Table 8-10** below. This summarises the mechanisms employed by the design and operation of the facilities to manage the water resources risks.

Table 8-10 Source-pathway-receptors for the TSF during Closure

Potential contaminant	Source	Pathway	Receptor	Comment	Controls
Soluble oxidation products	Previous tailings	Shallow ground water	Surface waters at SW11 and McArthur River Channel	For the period it takes the contaminated load to dissipate	- Source is removed, i.e., tailings relocated to open cut void - Surprise Creek Groundwater Interception Trench until concentrations diminish - Groundwater interception bores - Pumping from Barney Creek sumps - Water treatment as required
Sediment	Rehabilitated TSF area footprints	Surface water	Surface waters at SW11 and McArthur River Channel	From benign surfaces	- Revegetation - Sediment management

8.5.3.4 Site-wide Water Management

The closure phase sees a transition of the WMS from an active system to a passive system. Once rehabilitation is established and the mine pit lake flow-through system is functioning, active management of mine site waters will be limited. In the initial period, monitoring will be completed extensively and frequently with passive system modifications and maintenance completed through adaptive management as required. Monitoring will become less intensive as data indicates acceptable system stability and performance.

The integrated waterways modelling, incorporating rehabilitated areas and the flow-through mine pit lake, predicts that the WMS will meet the objective of having no exceedances of the WDL trigger levels at SW11.

8.6 Modelling and System Performance

As discussed in **Section 8.5**, the management of water resources at MRM is focussed on meeting the mine closure objectives. The primary measure of this is to operate in accordance with the WDL conditions as specified and measured at the downstream monitoring compliance point (site SW11). This section provides a brief discussion of the key modelling results and predicted WMS performance outcomes.

Chapter 7 – Project Risk Assessment provides a consolidation of the key risks associated with water resources. It presents inherent risks and associated current mitigation and management measures and compares that with residual risk associated with the proposed WMS and mitigation measures.

8.6.1 Modelling Overview

The forecasted performance of the WMS (refer **Section 8.5**) has been predicted utilising a suite of integrated surface water and groundwater models. The assessment incorporated the following models;

- NOEF geochemistry and unsaturated flow;
- groundwater;
- mine pit lake limnology and quality;
- water balance;
- waterways; and
- flood.

An overview of each of the models and their purpose is provided in **Section 8.2**.

As discussed in **Section 8.2**, modelling of surface WMS performance was completed with a complex sequential process linking a number of different models together. Based on the conceptual understanding presented in the **Section 8.5**, the modelling sequence aimed to replicate the relationships and interactions between the surface water and groundwater systems, proposed Project infrastructure and the WMS, as they change over time. A simplified representation of the model interactions is presented in **Figure 8-48** below.

The NOEF geochemistry and unsaturated flow model was utilised to determine seepage output from the NOEF. This was split into toe seepage and basal seepage. Toe seepage outputs were utilised as inputs to the water balance model and basal seepage outputs as inputs to the groundwater model. The groundwater and waterways models were highly integrated and facilitated the modelling of seepage and natural mineralisation influences (as baseflow) on surface water flows and quality.

The water balance model informed the infrastructure and operational requirements of the WMS in consideration of the different water classes managed on site.

Incorporating the influence of the groundwater system, the waterways model captured the surface water interactions with the Project infrastructure and WMS. This facilitated a cumulative assessment of WMS performance throughout the site, and most importantly, at the SW11 downstream monitoring location.

The flood model was an independent model and was utilised to predict the influence of mine infrastructure on flooding and to assess the effectiveness of flood mitigation measures in the protection of the mining operation.

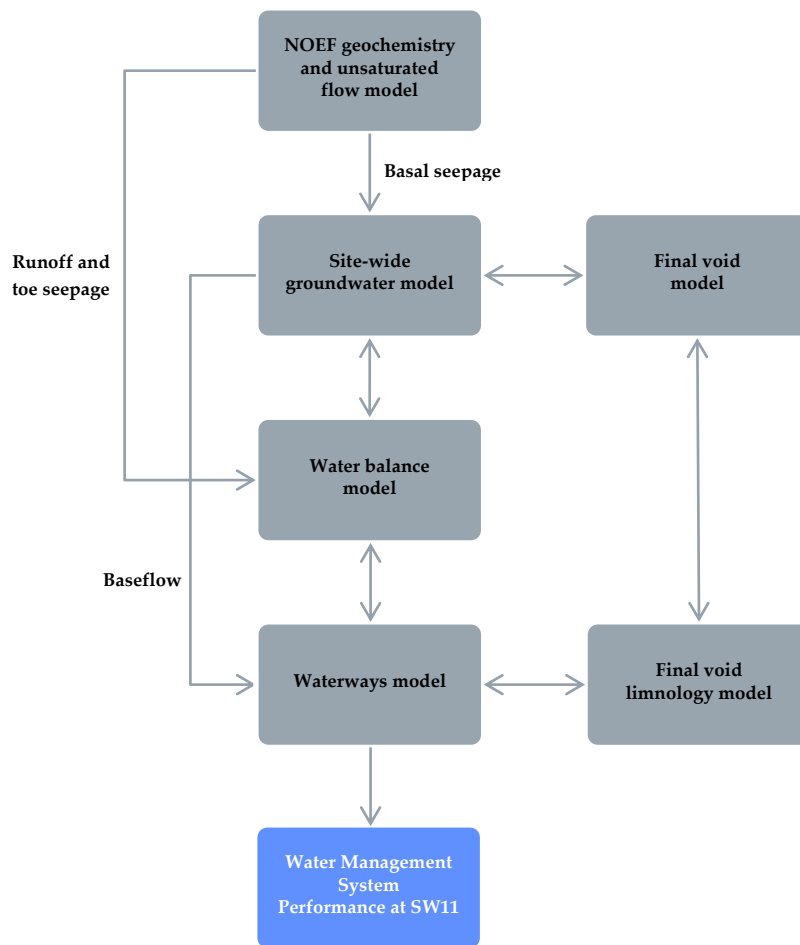


Figure 8-48 Water Resources Model Interactions

The models utilised are discussed in detail in the following appendices:

- **Appendix P – NOEF Assessment for Waste Placement, Footprint Seepage and Water Quality;**
- **Appendix T – Groundwater Impact Assessment Report;**
- **Appendix U – Surface Water Impact Assessment Report; and**
- **Appendix V – Final Void Limnology assessment Report.**

Uncertainties associated with model outcomes will be monitored through the life of the Project (refer **Section 8.7**) with management revisions and maintenance applied as required through an adaptive management framework. Areas of further investigation are identified in **Section 8.7** to resolve gaps in the available data and conceptualisation of modelled site processes. Further management contingencies are also presented in **Section 8.7** should monitoring of performance indicate that additional or alternative controls are required.

This section also discusses the potential implications of climate change on water management at MRM.

8.6.2 Water Management System Performance

This section provides a summary of the modelling outputs and predicted WMS performance. Detailed presentations of the modelling outputs are provided in the technical assessment reports incorporated as EIS appendices. References to these are provided in **Section 8.6.1**.

The assessments considered the influences of potential CoC sources, contributions from the surface and groundwater system and the effectiveness of the proposed surface WMS. With appropriate mitigation measures in place, the potential impacts of the proposed mining operations on surface flows and water quality in receiving waters downstream of MRM are considered to be insignificant at SW11.

The assessment has been thorough and has been based on a significant amount of monitoring data from MRM. The key uncertainties associated with this assessment are known and have been tested through sensitivity analysis, rigorous model calibration and validation. Model outcomes will be monitored throughout the life of the Project to evaluate performance and if necessary, refine the proposed WMS. **Section 8.7** provides information on existing and proposed monitoring, further investigations and management contingencies.

8.6.2.1 Water Balance

The site-wide water balance model (refer **Appendix U – Surface Water Impact Assessment**) represents the movement of water within the MRM surface WMS over time based on inputs and specified operating rules. It includes all inflows (e.g., rainfall, surface runoff, pumped inflows, groundwater inflows) and outflows (e.g., evaporation, seepage, storage overflows, pumped outflows, site water usage, off-site releases) affecting the on-site storages and waterways.

The water balance model was established to determine the:

- long-term behaviour of the various on-site storages;
- ability and reliability of the various on-site storages to supply the mine site water requirements;
- sizes of proposed new storages at MRM;
- CoC loads transported around the site;
- risk of Class 4, 5 or 6 water overflows from various on-site storages;
- ability to dewater the open cut within acceptable time frames;
- potential frequency and volume of managed water releases to the McArthur River (and their qualities); and
- overall site water balance.

Major components of the proposed WMS are the expansion of the water treatment plant and enhancement of evaporation via the use of evaporation fans and target operating levels in containment storages. These measures are required as MRM will be a net producer of water due to the predicted groundwater inflows to the open cut 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 WMS are generated during the wet season between November and April. During the dry season between May and October, the majority of inflows to the MRM WMS are generated from groundwater sources.

Water balance modelling has identified additional surface water management infrastructure that will be required during the proposed Project operations. These are presented in **Section 8.5**. The Project water balance model components and interactions are presented in **Figure 8-49** below.

The water balance results for the open cut domain identify the following:

- inundation of the open cut is based more on individual wet season variation rather than cumulative wet years;
- prior to the construction of the TSF PWD (2018/19 wet season), a considerable volume of water (up to 4,200 ML) is stored in the open cut for the wetter climatic sequences;
- following construction of the TSF PWD (and up until the tailings mining phase starting in Year 2038), the maximum volume stored in the open cut is around 1,000 ML; and
- during the tailings mining phase, the peak open cut inventory reaches around 3,500 ML which is a deliberate strategy to maintain sub-aqueous storage of tailings to limit oxidation.

In the context of the second dot point above, storage of water in the open cut was required in early 2017 following above average rainfall. This was required because the capacity of the WMS storages was exceeded and as per site operating procedures, excess water was stored in the open cut to maintain downstream environmental protection.

The approved NOEF PRODs were sized to achieve a 5% AEP risk of overflow during operations. That is, while the dams capture runoff from active NOEF areas, there will only be a 5% risk that an overflow from the PRODs will occur in any year during operations. This design criterion has been maintained and will apply to the proposed EPROD. The PRODs are managed as a linked storage network to assist in the management of overflow risk. Modelling identifies that compliance with the SW11 WDL trigger limits are maintained during these overflows due to the volume of water in the receiving surface water system when PRODs are predicted to overflow.

The water balance results for the TSF domain identify the following:

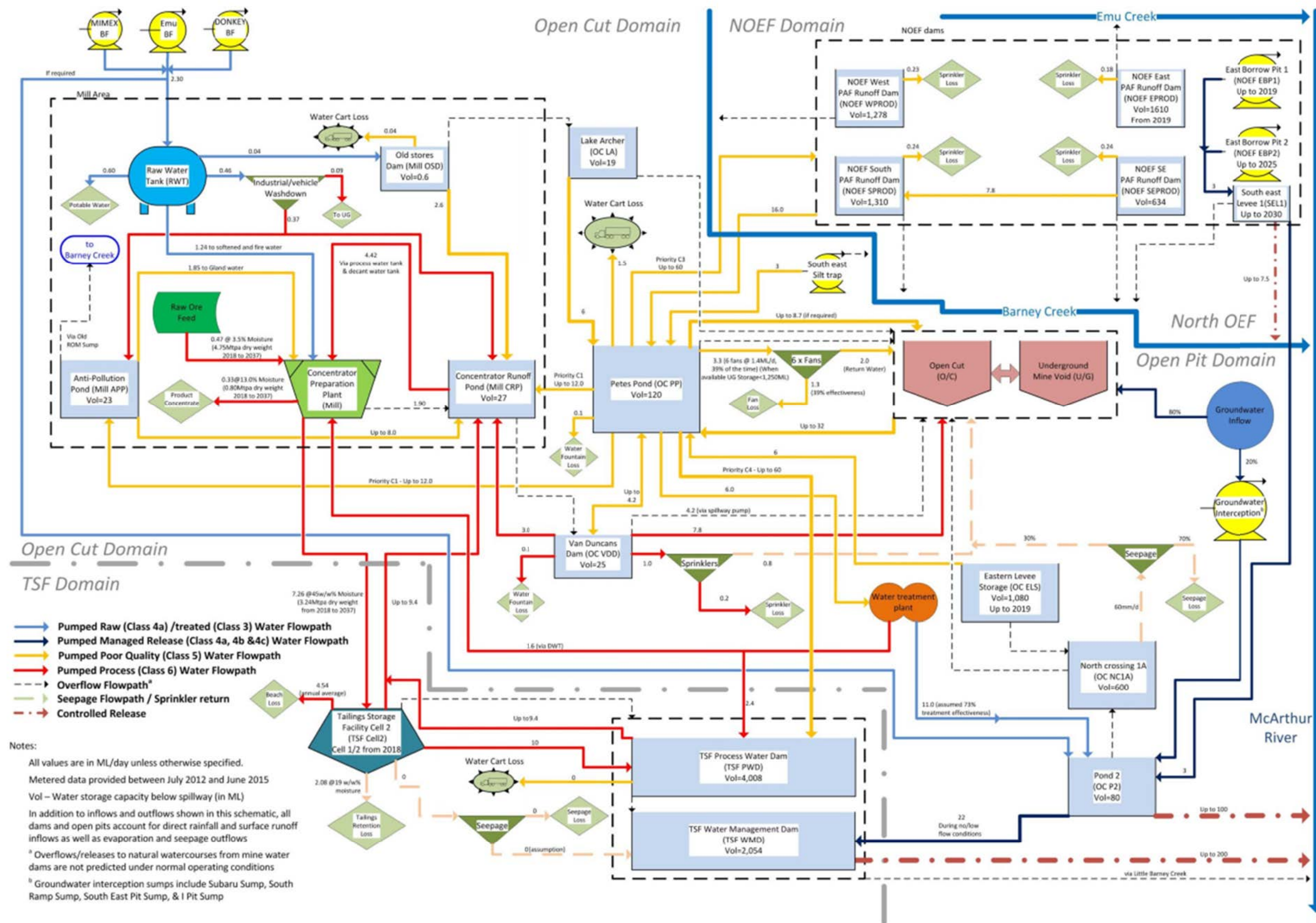
- for the maximum, very wet and wet sequences, the TSF PWD is maintained close to its MOL for substantial periods of time, as it was designed to do (the modelling was used to establish the MOL as part of the design phase);
- for the median sequence, the peak TSF PWD inventory is around 2,300 ML, or 57% of its full supply capacity; and
- for the drier sequences, the peak TSF PWD inventory is generally less than around 1,500 ML, or 37% of its full supply volume.

A detailed presentation of the water balance model results are provided in **Appendix U – Surface Water Impact Assessment Report**.

The MRM WMS will continue to include the capability to release mine water to the receiving environment under regulated conditions. The waterways model (refer to **Section 8.6.2.2**) indicates that during releases, compliance with WDL trigger limits at SW11 will be maintained.

The water balance modelling results indicate that, with the proposed additional water management measures in place, the proposed WMS will be robust and will have adequate storage capacity to manage surface water runoff generated at MRM for a wide range of possible climatic conditions, including extended wet and dry periods.

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8.6.2.2 Waterways Assessment

The waterways model, which simulates water quantity and quality behaviour on a daily basis, was used to simulate the natural and mine derived surface water flow volumes, dissolved CoC concentrations and sediment loads along the McArthur River and relevant tributaries through the project area to the downstream mineral lease boundary at SW11 (refer **Appendix U – Surface Water Impact Assessment**).

Specifically, the waterways model was developed to estimate:

- the long-term background surface water flow volumes, dissolved CoC concentrations and sediment loads generated upstream of MRM;
- the potential surface water quantity and quality impacts from MRM along the waterways within the study area during the operational and closure periods;
- the potential surface water quality impacts of predicted overflows from mine water storages during the mine operational period on CoC concentrations on the receiving waterways;
- the potential surface water quantity and quality impacts of the mine pit lake connection with the McArthur River (including “isolated”, “backwater” and “flowthrough” scenarios) on the McArthur River flow concentrations, CoC loads and sediment loads at SW11; and
- the “mixing zones” incorporated in the waterways model and its influences at SW11.

A schematic representation of the waterways model is presented in **Figure 8-50**.

8.6.2.2.1 Operational Period Performance

The results indicate that, with the proposed mine site WMS, predicted CoC concentrations passing SW11 will remain below the WDL trigger values during the operational period of mining.

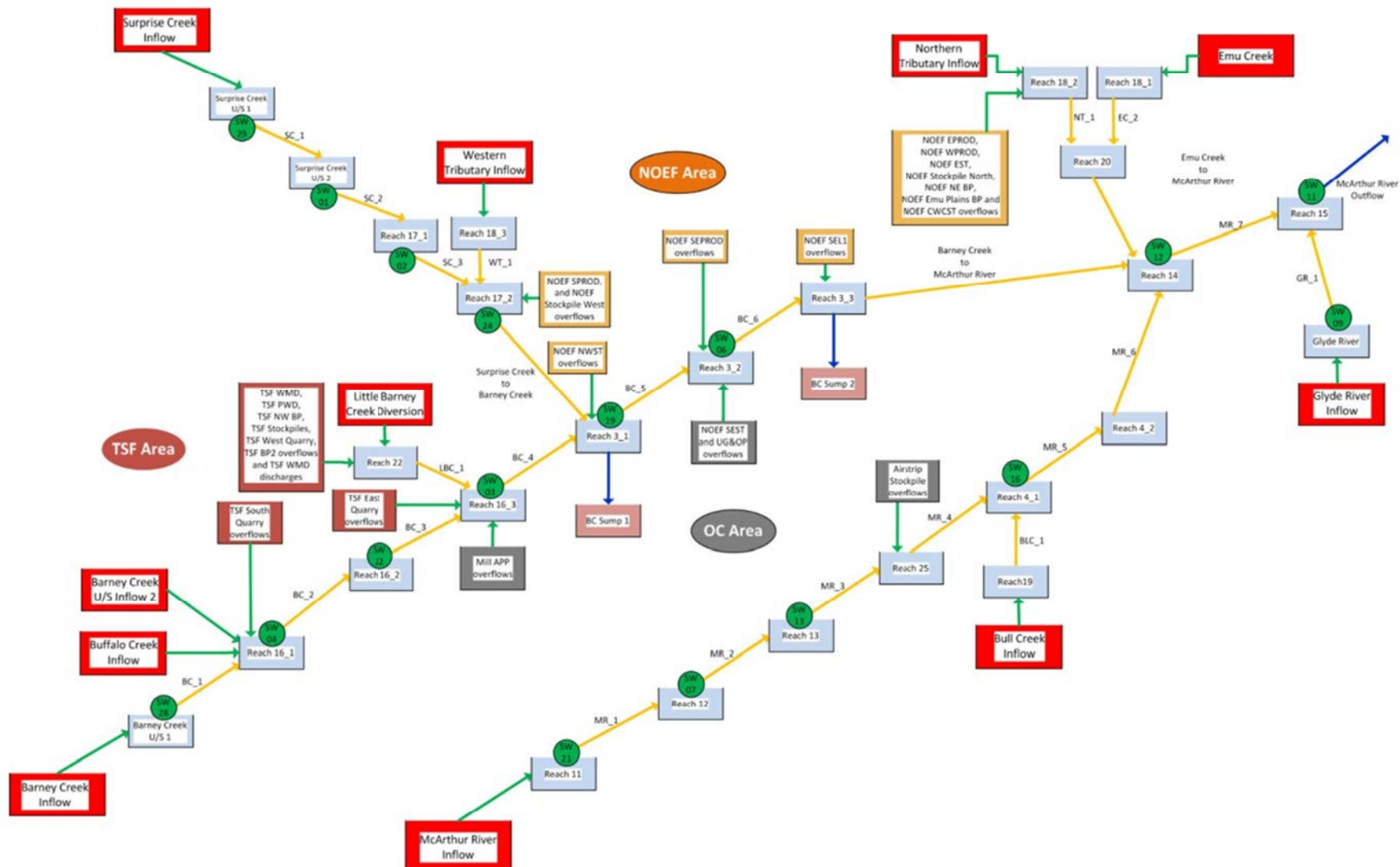
After 2027 the regional groundwater table drawdown caused by the dewatering of the open cut and underground voids results in a noticeable reduction in concentrations at SW11 during the dry season when compared with earlier stages of the Project.

Predicted mine water releases (including managed, passive and uncontrolled) do not result in CoC concentrations exceeding the adopted CoC trigger values at SW11. This is mainly due to the significant dilution with waterway flows between the point of mine water release and SW11.

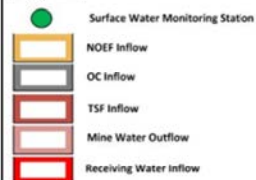
8.6.2.2.2 Closure Period Performance

The results indicate that, with the adopted mine pit lake flow-through configuration and Barney Creek collection sumps, predicted CoC concentrations passing SW11 will remain below the WDL trigger values during the closure assessment period.

The predicted interaction between the McArthur River and the mine pit lake does not result in CoC concentrations at SW11 exceeding the WDL trigger values for SW11. The waterways model was used to determine the inflows to the mine pit lake (post 2047). Freshwater recharge via the McArthur River will occur for approximately 10 days per year (on average) through both the upstream and downstream mine levee wall openings, with the number of days varying depending how long the river levels exceed the height of the lake levee openings. Outflows from the mine pit lake to the McArthur River last for 35 to 40 days per year (on average) and are governed by the McArthur River receding water levels and the mine pit lake flood storage level above the downstream levee opening.



Legend:



Data Source: WRM (Feb 2017)

Notes:

Each GoldSim reach accounts for the following:

- Inflows
 - Catchment inflow load
 - Groundwater inflow and load
- Outflows
 - Bank evaporation
 - Stream evaporation
 - Groundwater outflow and load
- Change in the bank storage

**McArthur River Mine
Overburden Management Project EIS
Waterways Model Schematic**

(not to scale)

06/03/2017

FIGURE 8-50

The assessment has not incorporated the potential influence of thermal stratification in the mine pit lake. The adopted mine pit lake water quality assumes a fully mixed water column and does not consider the potential benefits of lake stratification. Based on the assessment of mine pit lake limnology (refer to **Appendix V – Final Void Limnology Assessment Report**), the water quality near the surface of the lake will likely be orders of magnitude better than what has been modelled due to thermal stratification of the mine pit lake. Hence, the limnologic assessment results suggest that the predicted loads exiting the mine pit lake are expected to be similar to normal river flow. Despite this conservative assumption, predicted water qualities at SW11 are maintained within the WDL trigger values.

The predicted annual average suspended sediment load in the McArthur River is approximately 173,000 tonnes per year (t/yr). Of this, approximately 20,000 t/yr of sediment is predicted to flow from the McArthur River into the mine pit lake. Assuming (conservatively) that no suspended sediment load flows back from the mine pit lake into the McArthur River, the mine pit lake will collect approximately 12% of the upstream McArthur River suspended sediment load per year. This is anticipated to develop a layer of sediment over the tailings at the bottom of the mine pit lake, providing further encapsulation of tailings material.

The mine pit lake is modelled to lose approximately 1,650 ML/yr mainly to due evaporation. This loss is made up with McArthur River inflows through the mine levee wall openings. This loss represents approximately 0.2% of the modelled annual average McArthur River flows passing SW11.

Modelling has determined that with the proposed surface WMS in place, McArthur River surface water quality will be maintained below the WDL trigger values at the downstream compliance point during the operational and closure assessment periods.

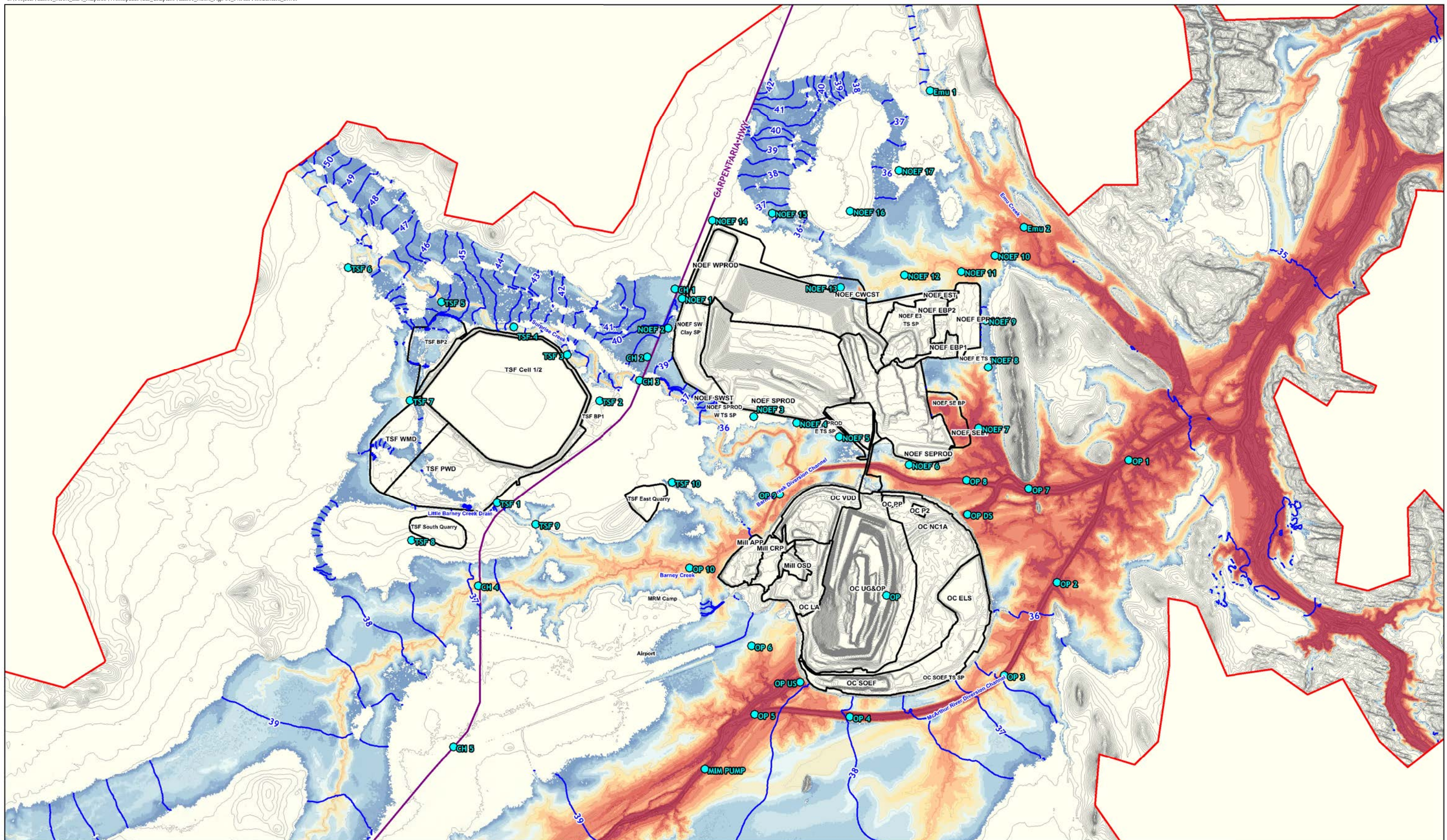
8.6.3 Flood Mitigation Performance

The proposed mine infrastructure has insignificant flood level impacts (up to 0.05 m) upstream and downstream of the mine site compared to the current conditions for all design flood events modelled up to and including the 0.1% (1 in 1,000) AEP. Modelled flood levels associated with the Project are also similar to the modelled flood levels for the Phase 3 project. Modelled flood maps (for the Project) for the 5% (1 in 20) and 1% (1 in 100) flood events are provided in **Figure 8-51** and **Figure 8-52**. Maps for all modelled scenarios (for the Project) up to and including the 0.1% (1 in 1,000) AEP are presented in **Appendix U – Surface Water Impact Assessment Report**.

The proposed mine infrastructure would increase the peak flood level around the mine levee wall by less than 0.09 m. Such an increase in peak flood levels has no material impact on the open cut flood immunity which is up to approximately 0.1% (1 in 1,000) AEP. The existing SPROD and WPROD have a flood immunity better than 1% (1 in 100) AEP under existing and future proposed mine plan conditions. The flood immunity of the existing SEPROD spillway is slightly less than the 1% (1 in 100) AEP due to design flood levels increasing slightly. The original SEPROD spillway was designed to 1% AEP flood immunity without freeboard.

The proposed mine infrastructure would increase peak flood levels at the Carpentaria Highway by less than 0.07 m. The increase in the duration of submergence of the highway for flood depths greater than 0.3 m is insignificant for all flood events up to and including the 0.1% (1 in 1,000) AEP.

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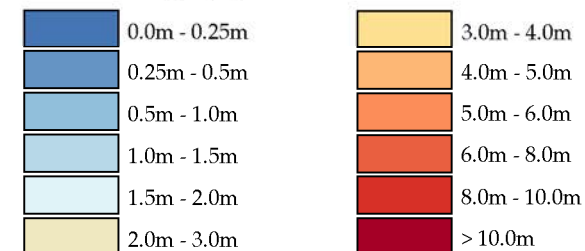


LEGEND

- Reporting Location
- Existing Ground Contour (2m Interval)
- Peak Flood Level Contour (0.5m Interval)
- Highway
- Catchment Boundary
- TUFLOW Model Boundary

Data Source: All data - WRM (Feb 2016)

Peak Flood Depth (m)



**McArthur River Mine
Overburden Management Project EIS
5% AEP Peak Flood Extent,
Depths and Level Contours, Base Case**

0.75 0 0.75 1.5

Kilometres

Scale: 1:40,000 (A3)

03/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-51

The proposed mine infrastructure has no adverse impacts on flood velocities upstream and downstream of MRM during the operational and closure assessment periods. The peak flood velocities in the vicinity of the NOEF and TSF are generally less than 1.5 metres per second (m/s) for the 1% AEP flood event. Higher flood velocities are predicted in the proposed 20 m wide mine levee wall openings (upstream and downstream openings for the flow-through mine pit lake). Erosion protection measures will be considered for these channels during the detailed design stage.

Appendix U – Surface Water Impact Assessment Report provides a detail discussion of the model results in relation to site infrastructure, model sensitivity and uncertainties.

8.6.4 Climate Change Assessment

8.6.4.1 Methodology

The climate change impact assessment for the Project EIS was undertaken adopting the projections and methodologies given in the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Commonwealth Bureau of Meteorology (BoM) report entitled “Climate Change in Australia Technical Report” (CSIRO, 2015). This report provides guidance on the possible projections of future climate for the Monsoonal North based on a current understanding of the climate system, historical trends and model simulations of the climate response to changing greenhouse gas and decreasing aerosol emissions.

Further detail on a climate change literature review, historical climate data and adopted climate change methodology for the Project EIS is provided in **Appendix D – Approach for assessing Climate Change Impacts**.

Appendix U – Surface Water Impact Assessment Report discusses sensitivity parameters and provides additional detail on assessment data and results. A summary is provided below.

8.6.4.2 Potential Short-term Impacts

Short-term climate change impacts to the water balance were assessed for the operational period (2018-2047). The MRM water balance model developed for the Project EIS was used to simulate the short-term ‘best’ case, ‘worst’ case and ‘maximum consensus’ case.

8.6.4.2.1 Open Cut Inundation Risk

The results show that for the ‘consensus’ and ‘worst’ cases, the potential impacts due to climate change slightly increase the AEP risk of open cut inundation for greater than 6 months by up to approximately 3% and 7% respectively when compared to the ‘base’ case. The ‘best’ case AEP risk of open cut inundation for greater than 6 months would be similar to the base case.

8.6.4.2.2 Class 5/6 Water Storage Risk of Overflows

The results show that for the ‘consensus’ and ‘worst’ cases, the potential impacts due to climate change slightly increase the AEP risk of overflows for NOEF dams by up to approximately 2% and 4% respectively when compared to the ‘base’ case. The ‘best’ case AEP risk of overflows for NOEF dams would be similar to the base case. Whilst the overflow risk may increase slightly (‘consensus’ and ‘worst’ cases), there would also be more water in the receiving environment in these scenarios. Therefore the net effect on water quality at SW11 is anticipated to be immaterial.

8.6.4.3 Potential Long-term Impacts

Long-term climate change impacts to the waterways were assessed for the closure assessment period (2047-3018). The MRM waterways model developed for the Project EIS was used to simulate the long-term 'best' case, 'worst' case and 'maximum consensus' case.

In the long-term, most water management infrastructure will have been decommissioned and removed from site. Where infrastructure is to remain in the long-term (for example the runoff drains off the NOEF final landform), conceptual designs have been prepared in consideration of potential climate change.

8.6.4.3.1 Overall Waterways Water Balance

The results show the following potential impacts due to climate change:

- For the 'best' and 'consensus' cases, McArthur River flow volumes at SW11 significantly increase by approximately 41% and 27% respectively when compared to the 'base' case, whereas the 'worst' case McArthur River flow volume changes are small (3%). This suggests that future increases in annual average rainfall volumes may result in significantly greater runoff volumes in the McArthur River.
- Bank and stream evaporation along the waterways increase slightly but are not sensitive to the three climate change cases modelled.
- Mine pit lake evaporation losses are predicted to increase slightly but are not sensitive to the three climate change cases modelled.

8.6.4.3.2 Mine Pit Lake Interaction with the McArthur River

The results show the following potential impacts due to climate change:

- Total annual flow volumes through the mine pit lake are predicted to increase for all three climate change scenarios when compared to the 'base' case. However, the inflow to the mine pit lake from the river is predicted to reduce as a proportion of total flow in the McArthur River because of the significant increase in McArthur River runoff volumes.
- The total number of days of outflows from the mine pit lake to the McArthur River is predicted to increase under all three climate change cases investigated.

8.6.4.3.3 McArthur River Flows and Concentration at SW11

The McArthur River flows are potentially sensitive to the influences of climate change with McArthur River flows at SW11 increasing by 9%, 18% and 15% for the 'best' case, 'worst' case and 'consensus' cases respectively. Predicted CoC concentrations at SW11 remain further below the WDL trigger values for all climate change cases assessed.

8.6.4.4 Potential Impacts on Flooding

An assessment of potential flooding impacts was undertaken by determining the potential increase in flood event AEPs based on the potential increase in design rainfall AEPs using the procedures given in Book 1 of ARR (2016). The ARR (2016) procedure for determining potential long-term climate change impacts are based on the long-term temperature predictions by the CSIRO (2015) GCMs. ARR (2016) suggest that climate change will have negligible impact on design rainfalls characteristics in the short-term planning horizon (up to 20 years from 2015). Hence, only the potential long-term (2090+) climate change flooding impacts have been considered for this assessment.

Appendix U – Surface Water Impact Assessment Report presents the 5% to 0.1% AEP current and long-term climate change design rainfall depths for the 48 hour storm duration (the critical storm duration for McArthur River flooding) at MRM. It also provides the current rainfall depth AEP adjusted based on the projected increased long-term climate change rainfall depths. The following is of note:

- The design rainfall depth AEPs under current climate conditions are predicted to increase under the long-term climate change conditions considered. That is, design rainfall events of a certain magnitude are predicted to become more frequent under the long-term climate change conditions.
- The 5% (1 in 20), 1% (1 in 100) and 0.1% (1 in 1,000) AEP design rainfall depths under current climate conditions are equivalent to a 9.1% (1 in 11), 2.1% (1 in 48) and 0.24% (1 in 420) AEP for the projected climate change conditions.
- The change in design flood levels with changing rainfall depths is non-linear due to a number of factors including rainfall losses, runoff routing and hydraulic factors. Notwithstanding this, this assessment gives an indication of the potential increase in AEP of flood events under the long-term climate change impact scenario considered for this study.
- The mine levee wall currently provides open cut flood protection up to the 0.1% (1 in 1,000) AEP plus 0.4 m freeboard. This assessment suggests that it is likely the mine levee wall would provide 0.2% (1 in 500) AEP protection (with a reduced freeboard) under long-term climate change conditions.

8.7 Monitoring, Investigations and Further Mitigation Alternatives

This section provides a description of the existing surface water and groundwater monitoring programs conducted at MRM. It also identifies additional monitoring programs that will be implemented to evaluate the future performance of MRM infrastructure and operations and discusses proposed future investigations to improve understanding and confidence in modelling outcomes and to provide guidance for adaptive management.

The section also identifies a number of mitigation contingencies that were either identified through the Project alternatives assessment process (refer to **Chapter 5 – Project Alternatives**) or have been developed concurrently with the EIS. These are not proposed as part of the Project however are discussed as possible alternatives to the water management measures proposed in this EIS (refer **Section 8.4** and **Chapter 3 – Project Description and Justification**). These would be investigated further should monitoring, or other factors, determine that alternative mitigation measures are warranted.

8.7.1 Existing Monitoring Programs

The existing monitoring programs relevant to the management of water resources at MRM are provided below. Proposed additional monitoring programs are presented in **Section 8.6.3**.

8.7.1.1 Groundwater

A groundwater monitoring network was first established in 1995 and has since been expanded to monitor groundwater levels and groundwater quality across the site. MRM monitors the following groundwater quality parameters:

- lab pH;

- lab electrical conductivity (EC);
- total dissolved solids (TDS);
- major cations calcium, magnesium, sodium, potassium and hardness;
- major anions, chloride, sulphate, fluoride and alkalinity (including speciation);
- ionic balance, total anions, total cations;
- filtered metals, aluminium, antimony arsenic, , barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, thallium, uranium, vanadium, zinc;
- filtered mercury;
- nitrate as nitrogen, ammonia as nitrogen;
- filtered ferrous iron (Fe²⁺); and
- filtered ferric iron (Fe³⁺).

A summary of the monitoring networks within each of the site areas is provided in **Table 8-11** and **Table 8-12**. **Figure 8-53** presents the monitoring bore locations within the Project area.

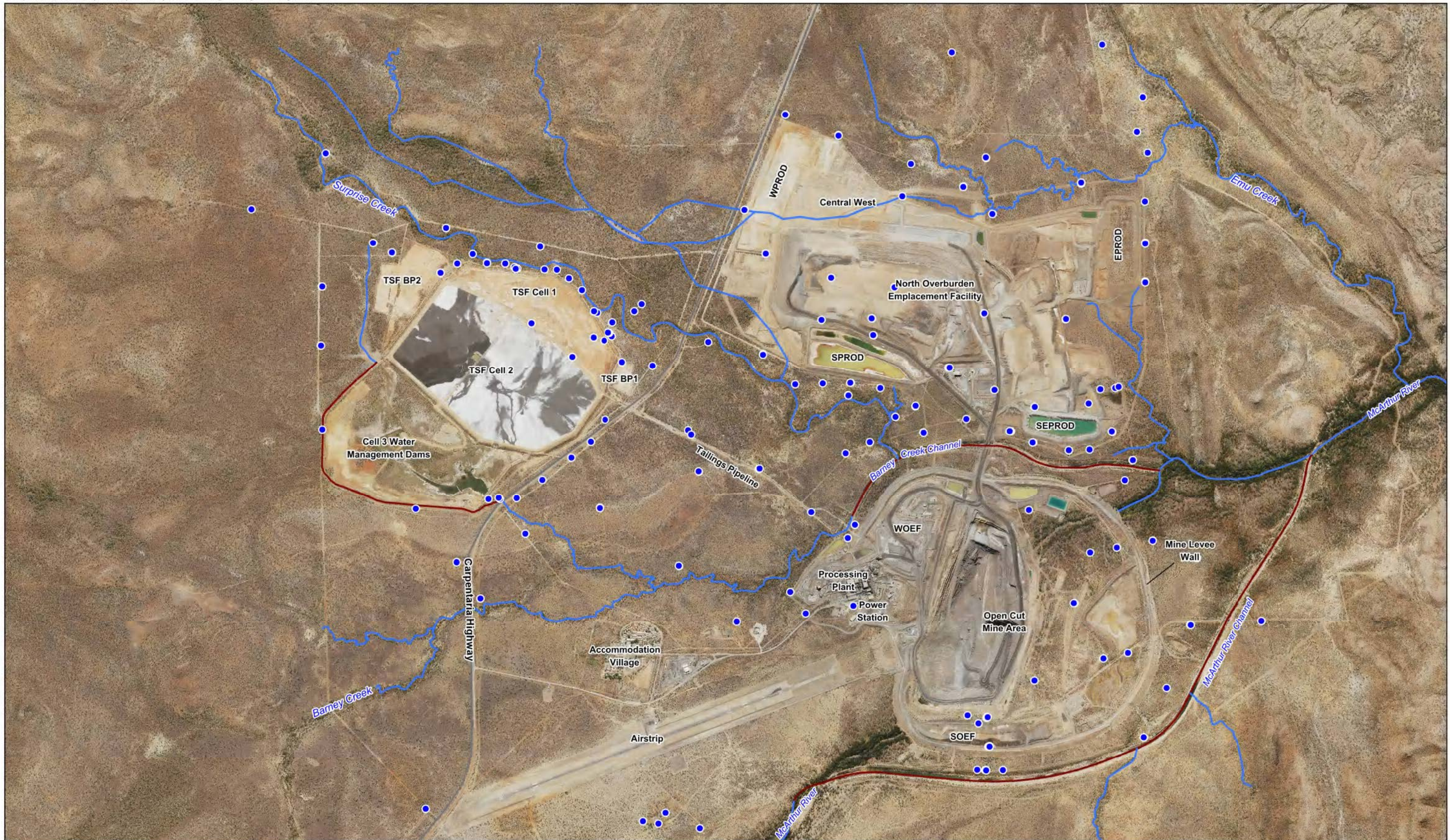
Table 8-11 Groundwater Monitoring Network Summary by Mine Site Area

Site Area	Total Bores	Monitoring Period			
		Monthly	Quarterly	Bi-Annually	Annually
TSF	91	1	34	43	13
Open cut	35	14	10	11	
NOEF	84		80	4	
Processing Plant	6		6		

Table 8-12 Groundwater Monitoring Network Summary by Hydrogeology Unit

Screen Geology	Number of Bores	Minimum Screen Depth (mbgl*)	Maximum Screen Depth (mbgl)	Average Screen Depth (mbgl)	Upper Quartile Screen Depth (mbgl)	Lower Quartile Screen Depth (mbgl)
Alluvial	46	2.8	30.8	14.8	20.3	7.3
Weathered Bedrock	51	3.9	48.8	18.8	26.7	9
Fresh Bedrock	65	6	256	42.7	31	15.8
Mixed	26	6	102	15.4	15.4	9.9
Mine infrastructure	19	4.2	14.7	8.5	10.9	4.6
Not defined	4	19	40	26.3		

*metres below ground level

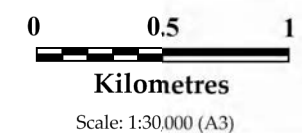


LEGEND

- Groundwater Monitoring Site
- Highway
- Channel
- Watercourse

Data Source: Highway - NT Gov. (2012); Aerial - McArthur River Mining Pty Ltd (Jul 2016); Watercourse, Channel - WRM (Feb 2017); Groundwater Monitoring Site - KCB (Feb 2017)

**McArthur River Mine
Overburden Management Project EIS
Existing Groundwater
Monitoring Network**



10/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-53

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8.7.1.2 Surface Water

MRM currently has a comprehensive surface water monitoring network and data collection program within and in the vicinity of the mine site to collect:

- water level (flow) data in the McArthur River, Barney Creek and Surprise Creek;
- water quality data in the natural streams upstream and downstream of the mine site, and throughout the mine site; and
- water quality data in the WMS.

Currently, surface water is monitored at 32 stream locations within and in the vicinity of the mine site and 55 artificial surface water sites (including 48 storages and sumps). **Figure 8-54** and **Figure 8-55** show the location of the 'natural' and 'artificial' surface water monitoring sites in and around MRM.

Data from the water quantity and quality monitoring stations are used to assess the impact of mining activities on water quantity and quality in receiving waters and to demonstrate compliance with WDL conditions. Details of MRM's surface water monitoring network and its objectives are presented in annual natural and artificial surface water monitoring reports. The reports include the parameters monitored at each station, together with the monitoring procedure and frequency for each of the parameters tested.

8.7.1.2.1 Current Monitoring Locations

8.7.1.2.1.1 *Natural Surface Water*

The 32 natural surface water monitoring sites are shown in **Figure 8-54**. The monitoring sites cover the catchments of the McArthur River (12 sites), Barney Creek (8 sites), Surprise Creek (7 sites), Emu Creek (3 sites), Bull Creek (1 site) and the Glyde River (1 site). There is an additional station labelled Early Warning Flood System (EWFS) Station on the McArthur River approximately 21 km upstream of the mine (just downstream of the confluence with the Kilgour River) that records river levels for early flood warning for the mine.

Water quality is monitored at all stations. Stream gauging is undertaken in the McArthur River at EWFS, M.I.M. Pump Station, and SW11; in Barney Creek at SW04; and in Surprise Creek at SW02. Monitoring location SW11 is the compliance point for receiving environment water quality conditions specified in the current WDL.

8.7.1.2.1.2 *Artificial Surface Water*

Water stored in mine water storages and sumps at MRM is referred to as 'artificial' water. These storages are designed to contain water generated within the mine site. Artificial water is not released to the natural receiving waters unless it is blended to comply with WDL conditions. The 55 current artificial surface water monitoring sites are shown in **Figure 8-55**. Water quality is monitored at all stations to track water classes and manage them in accordance with the site water balance and WMS operating rules. This is undertaken to meet the site objectives and maintain protection of downstream environmental values.

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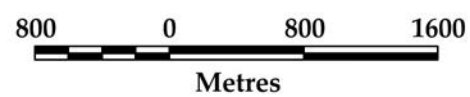


LEGEND

- Stream Gauging Station
- Surface Water Monitoring Locations
- Watercourse

Data Source: Gauging Station, Monitoring Location, Watercourse - WRM (Feb 2017); Aerial - McArthur River Mining Pty Ltd (Jul 2016)

**McArthur River Mine
Overburden Management Project EIS
Natural Surface Water
Monitoring Locations, MRM Site**

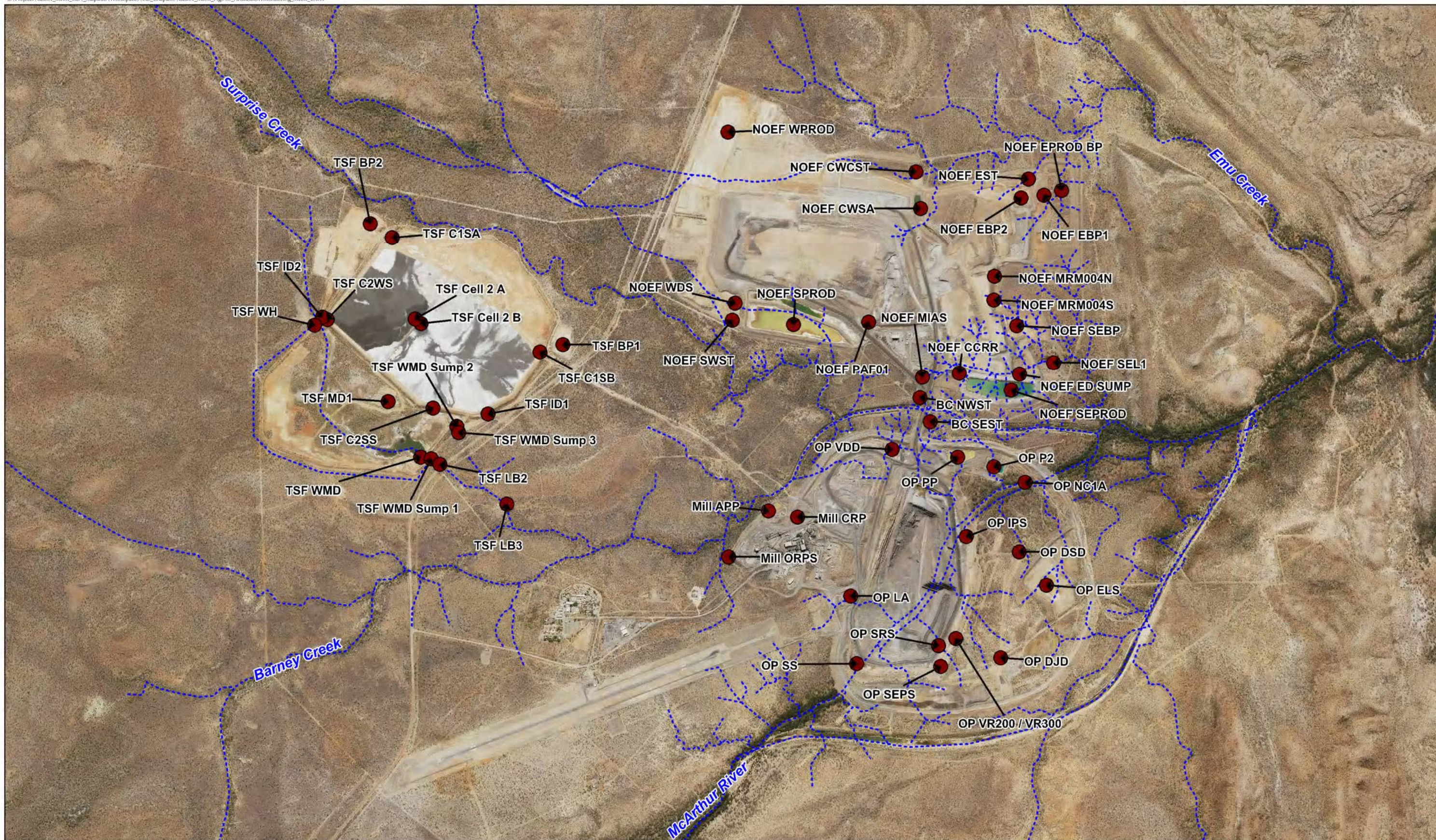


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Datum: GDA94
Projection: MGA53

FIGURE 8-54

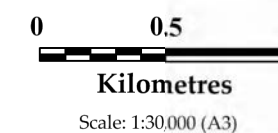


LEGEND

- Artificial Surface Water Monitoring Location
- Natural Drainage (Pre-Mine)

Data Source: Natural Drainage, Monitoring Location - WRM (Feb 2017); Aerial - McArthur River Mining Pty Ltd (Jul 2016)

**McArthur River Mine
Overburden Management Project EIS
Artificial Surface Water
Monitoring Locations, MRM Site**



06/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-55

8.7.1.2.1.3 Water Quality Monitoring Parameters

The suite of standard field parameters measured and the laboratory analysis conducted on surface water samples (both 'natural' and 'artificial') are listed below in **Table 8-13**. Additional analyses for total metals and total petroleum hydrocarbons (TPH) are also undertaken at select sites in accordance with the WDL conditions. Results are analysed and reported where non-compliances at WDL compliance points are identified.

Table 8-13 Suite of Water Quality Parameters Monitored at MRM

Laboratory Parameters	Field Readings
pH	pH
EC	EC
Total suspended solids (TSS)	Dissolved oxygen saturation (DO)
TDS	Oxidation/reduction potential (ORP)
Major cations, calcium, magnesium, sodium, potassium and total hardness	Water temperature
Major anions, chloride, sulphate, fluoride and total alkalinity	General field observations
Ionic balance, total anions and total cations	
Filtered metals aluminium, arsenic, cadmium, copper, iron, manganese, nickel, lead and zinc	

8.7.1.3 Existing NOEF Performance Monitoring

As part of the existing NOEF remediation program, a total of 29 monitoring bores were drilled into the NOEF in 2015 and 2016. Of these, 15 are used for groundwater monitoring beneath the facility and 12 are used for temperature and gas monitoring. Management of oxidation is fundamental to controlling the potential impacts of MRM overburden material, particularly in relation to water resources.

The bores that extend through the full thickness of 40 m in the PAF cells are equipped with thermocouples and gas ports at different depths and enable gas sampling and the ongoing monitoring of internal temperatures within the NOEF (refer **Appendix H – NOEF Historical Construction and Drilling Report**). These are indicators of oxidation reactions and provide MRM with an indication of current NOEF performance. McArthur River Mining also monitor a number of NOEF erosion and geochemical field barrel investigations to provide information on slope stability and geochemical behaviour of overburden. These in-field programs support the extensive test work completed to inform this EIS and assist in the prediction of NOEF performance and evaluation of potential impacts on the groundwater system. Further information is provided in **Chapter 6 – Materials Characterisation**.

8.7.2 Proposed Monitoring and Investigations

This section discusses proposed additions to the surface water and groundwater monitoring programs and identifies key areas for further investigation and characterisation. These will be used to build further confidence in the predictive modelling and the effectiveness of the proposed management system.

8.7.2.1 Proposed Groundwater Monitoring

The existing MRM groundwater level and quality monitoring bore network will be maintained, reviewed and expanded throughout the Project where necessary. Redundant bores may be removed as site circumstances change. The monitoring network will be designed to identify any significant departures from current model simulations and conceptualisations of the source-pathway-receptor relationships that may result in MRM not meeting its environmental objectives.

The key areas of focus for additional monitoring include:

- Groundwater directly down-gradient of the NOEF in the alluvial, weathered bedrock and shallow bedrock. This monitoring will include groundwater discharge as baseflow to the Barney Creek Channel and to identify any mine affected baseflow to Emu Creek (not anticipated). Groundwater monitoring bores positioned between the NOEF and the Barney Creek Channel will enable early detection of migrating CoCs from the NOEF.
- Groundwater to the immediate north, east and south of the TSF in the alluvial, weathered bedrock and shallow bedrock. This monitoring will include groundwater discharge as baseflow to Surprise Creek, Little Barney Creek and Barney Creek.
- Groundwater within and down-gradient of natural mineralised zones.
- Groundwater to the north, east and south of the open cut area in alluvium, weathered bedrock and shallow bedrock. This monitoring will include groundwater discharge as baseflow to Barney Creek Channel and McArthur River Channel. As the open cut breaches the Western Fault and begins to mine out the Cooley Dolomite, additional monitoring of pressure response in this water-bearing formation will be conducted to better understand the dynamic pathways between the NOEF, the Cooley Dolomite, and the Barney Creek Channel.
- Groundwater recharge mechanisms associated with the underground void.
- Groundwater in the water-bearing formations that influence recharge and discharge at the Djirrinmini waterhole.

8.7.2.2 Proposed Surface Water Monitoring

The aims and objectives of the surface water monitoring program at MRM during the proposed mining operations will remain the same as under current 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, improved understanding of mine site water behaviour and better mine site water quality management.

8.7.2.2.1 Natural Surface Water Monitoring

It is proposed to install low flow monitoring stations along the McArthur River, Barney Creek and Surprise Creek to better estimate baseflow rates and CoC loads along streams through the mine site. Indicative low flow monitoring stations are presented on **Figure 8-56**. Three control sites are proposed in the McArthur River, Barney Creek and Surprise Creek, upstream of the mine influence. Seven other sites throughout and downstream of the mine site are proposed to measure the influence of mine operations.



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LEGEND

- Stream Gauging Station
- Surface Water Monitoring Locations
- Indicative Low-Flow Gauge Site
- Watercourse

Data Source: Low Flow/Gauging Station, Monitoring Location, Watercourse - WRM (Feb 2017);
Aerial - McArthur River Mining Pty Ltd (Jul 2016)

McArthur River Mine
Overburden Management Project EIS
Indicative Surface Water
Low Flow Monitoring Stations

800 0 800 1600
Metres
Scale: 1:45,000 (A3)

08/03/2017

Datum: GDA94
Projection: MGA53

FIGURE 8-56

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Note that these locations are indicatively based on modelling outputs. Final locations will be dependent on suitable hydraulic controls for low flow monitoring structures and will be located and installed by a suitably experienced hydrographer. Also note that a number of the groundwater/surface water interaction investigations discussed above in the groundwater section (**Section 8.6.2.1**) incorporate surface water flow and quality components.

It is also proposed to install a water level gauge on the Glyde River to measure stream flows (subject to access constraints). This stream gauge will be located upstream of McArthur River backwater effects and located at a suitable hydraulic control for low flow and high flow monitoring.

No new natural surface water quality monitoring sites are proposed and no changes to the existing suite of parameters monitored or the monitoring frequency are proposed.

8.7.2.2.2 Artificial Surface Water Monitoring

It is proposed to expand the artificial surface water monitoring network to include the monitoring of the new mine water storages proposed for the site. The proposed (via MMP amendment) TSF Storages (WMD and PWD) will be included once constructed (2017-2019). The new storage in the NOEF area, namely East Perimeter Runoff Dam (EPROD), as well as future sumps and sediment ponds around the NOEF, stockpiles and borrow pits will also be incorporated into the monitoring program. **Table 8-14** provides indicative eastings and northings of the proposed new artificial surface water monitoring sites, together with the type of monitoring proposed at each site. In addition, it is proposed that all future NOEF seepage collection sumps include flow meters to estimate the rate of seepage expressing at the toe. WTP inflows and outflows will also be included in the surface water monitoring program. No changes to the existing suite of parameters monitored or the monitoring frequency are proposed.

8.7.2.2.3 Mine Pit Lake Monitoring

The mine pit lake will be included as a surface water quality and water level monitoring site during closure (after 2047). Monitoring sites will be established to measure water quality, flows and temperature and will monitor a range of depths to assess mine pit lake stratification and the effects of interactions with the McArthur River.

Table 8-14 Artificial Surface Water Monitoring Locations

Location	Easting (m)*	Northing (m)*	Station Type
NOEF Area			
EPROD	618,653	8,185,958	Water Quality/Water Level
Future NOEF seepage sumps	TBC	TBC	Water Quality/Flow meter
TSF Area			
WMD	612,317	8,183,757	Water Quality/Water Level
PWD	613,404	8,183,573	Water Quality/Water Level

Location	Easting (m)*	Northing (m)*	Station Type
Open cut area			
Mine pit lake	TBC	TBC	Water Quality, Water Level and Flow, Temperature, Density
WTP inflows/outflows	TBC	TBC	Water Quality
EOEF sump	TBC	TBC	Water Quality/Flow meter
Future dewatering sumps	TBC	TBC	Water Quality/Flow meter
All areas			
Future sediment dams	TBC	TBC	Water Quality/Managed releases

* MGA94

8.7.2.3 NOEF Performance Monitoring

McArthur River Mining will continue to monitor gas and temperature in the existing NOEF while access to do so is maintained. Managing the geochemical and hydrological processes within the NOEF is critical to its performance and resultant influence on groundwater and surface water systems. To monitor the effectiveness of proposed overburden management strategies and overall NOEF performance, a closure performance monitoring program has been developed which will assess the overall effectiveness of the proposed NOEF cover system and landform design in managing AMD and erosion risks. The proposed monitoring system is designed to evaluate performance of the full-scale cover system and landform of the NOEF, thereby capturing the inherent spatial and temporal variability of water dynamics, temperature, and gas fluxes within the facility; and verifying key design assumptions.

Appendix O – NOEF Closure Monitoring System Report presents detailed proposals for the long-term monitoring of the NOEF. In general, the monitoring program has been designed to gather information on various components of the water balance such that multiple lines of evidence can be developed to inform cover system performance. Internal NOEF monitoring will provide validation of the impacts of material placement practice, and an understanding of the internal controls of AMD production and release. Net percolation will be monitored directly below the cover system and also estimated utilising measured components of the water balance and analytical techniques to scale-up the measured net percolation to a landform performance. A watershed scale runoff and interflow monitoring system at the outlet channel of the southwestern section of the NOEF will provide essential data for the facility's overall water balance.

8.7.2.4 Further Investigations

To further support the conceptual models and understanding of water environment at MRM, McArthur River Mining propose to undertake a number of additional site investigations. The following investigations are being developed to reduce conceptual and hence model source-pathway-receptor uncertainty:

- McArthur River Mining will consider the development of groundwater level and quality performance indicators for representative monitoring bores (where appropriate utilising existing monitoring bores) (Refer to **Appendix T – Groundwater Impact Assessment Report** for the approximate location and depths of these).
- Groundwater monitoring data will be utilised to validate water levels and concentrations predicted by the groundwater modelling. Monitoring will provide early indication of deviation from modelled performance and will facilitate review and where required, revision of water management practices.
- A number of mineralised zones have been identified across the site which conceptualised to contribute a background load to the shallow and deep aquifers. The current groundwater monitoring network in the vicinity of these areas will continue to collect water quality data to develop a dataset that will provide more understanding and appreciation of how these areas influence the water quality in down-gradient aquifer systems.
- McArthur River Mining has undertaken a thorough investigation to better delineate the geology across the site. This has included undertaking new geophysical investigation and reprocessing of previous surveys, consolidation and reinterpretation of the extensive exploration drilling database, drilling of additional core holes and further aquifer testing. The updated geological model for the site is currently in preparation and will be compared to the conceptual site groundwater model. Future groundwater assessments will incorporate any refinements within the conceptual and numerical models in areas where updated information is available.
- The TSF area will change over the operations, decommissioning and closure phases. Further monitoring of piezometric levels, moisture profiles and hydraulic response to increasing elevations of the TSF will be put in place. This will allow improved confidence in the predicted fluxes and loads from the TSF. This monitoring may include further refinement of the hydraulic parameters, particularly if future monitoring can provide evidence that consolidation effects in the deeper-lying portions of the tailings result in decreased vertical permeability. Travel times and differentiation between pore water contributions, pond water impacts and natural salinity in the aquifers may be obtained from proposed isotope investigations for this area.
- Extensive geochemical materials characterisation studies have been completed, with ongoing field and laboratory testing. Further hydrogeochemical modelling using these results may provide greater certainty in the source terms used for the groundwater CoC transport simulations. Further discussion of NOEF monitoring and investigations is provided in subsequent sections.
- The open cut conceptual model incorporates a linkage between the McArthur River Channel and the underground voids. McArthur River Mining will investigate the recharge flow mechanisms of the underground void water balance and investigations will be undertaken to better understand hydraulic relationship between the Western Fault Corridor, other fault structures, open cut, underground voids and the Cooley Dolomite. McArthur River Mining will continue to investigate the source of these inflows, and opportunities to intercept the flows before they reach the operating areas.

8.7.3 Adaptive Management

The monitoring phases for the Project were developed during the design Failure Modes and Effects Analysis (FMEA), which was based on a proposed staged approach to operations and closure management (refer to **Figure 8-57** below). The approach included the development of a number of stages within separate “short-term” and “long-term” timeframes.

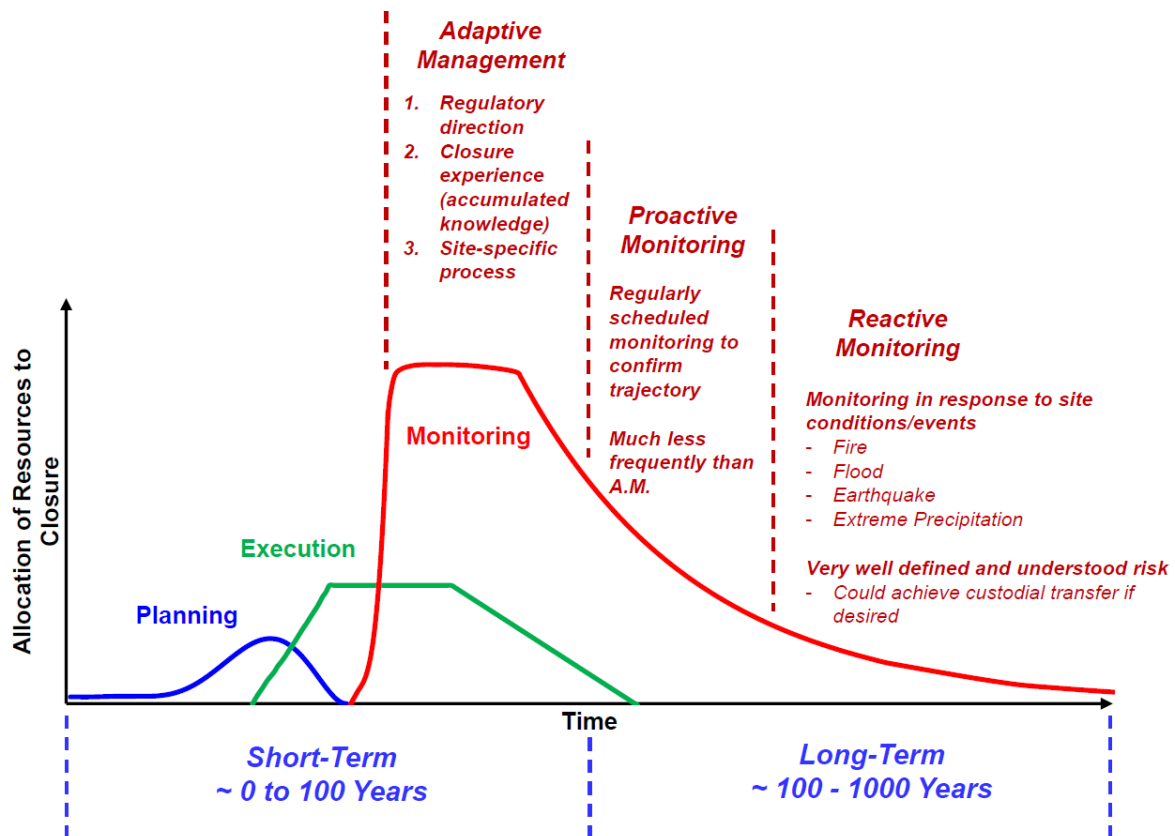


Figure 8-57 MRM Management and Monitoring Timeframes

Short term is regarded as the first 100 years and includes:

- planning and execution (operation) ~20-30 years; where:
 - plans will be developed to assist with the implementation of “true adaptive management”, rather than simply “monitoring and reacting”; and
 - further modelling and evaluation as part of the Project, as well as consultation with NT regulatory agencies, will be used to better define the appropriate adaptive management timeframe;
- adaptive management nominally ~ 70-80 years; where:
 - a site presence will be maintained to monitor and mitigate potential impacts;
 - a flexible management approach will be adopted, whereby management modifications will be implemented in response to closure and rehabilitation monitoring results and/or regulatory requirements; and
 - a performance trajectory will be established through monitoring and assessed in the context of predictive modelling conducted as part of the Project EIS.

Long term is regarded as the period from 100 years from commencement to 1,000 years and includes:

- Proactive monitoring:
 - to continue illustrating that performance is on the appropriate trajectory;
 - but with a reduced frequency as compared to the adaptive management phase; and
 - the timeframe to be determined through numerical modelling.

- Reactive monitoring:
 - monitoring will be undertaken in response to particular events (cyclones, floods) to evaluate mitigation requirements; and
 - where relinquishment or custodial transfer can be achieved because there is well defined risk that can be managed and costed.

Should monitoring identify that additional or alternative management intervention is required, McArthur River Mining has developed a suite of management contingencies that can be drawn upon. These contingencies have been developed through a number of processes and are briefly described below.

The Project definition process has incorporated the evaluation of a substantial number of alternative approaches to infrastructure design, environmental management and mine closure (refer to **Chapter 5 – Project Alternatives**). Whilst preferred options have been identified and brought forward in the process as part of the Project Description (refer to **Chapter 3 – Project Description and Justification**), a number of feasible alternatives were identified in the process. In the event that monitoring identifies a material deviation from predicted environmental performance, these alternatives may present an effective alternative that could be developed and implemented.

Appendix Q – NOEF Mitigation Options Report presents a range of potential additional NOEF mitigation measures that could be implemented to assist with seepage management if required. It provides a summary of the key sources, pathways and receptors relevant to the NOEF and the protection of downstream values.

The report also provides discussion and concept drawings for the likely most effective mitigation measures, which were groundwater interception trenches and interception borehole configurations.

The groundwater interception trench and borehole concepts identified above are also applicable to other areas of the site and could be implemented in the surrounds of the TSF to complement the groundwater interception trench to be constructed between the TSF and Surprise Creek for 2017.

Further to the management contingencies identified above, the proposed surface WMS (refer **Section 8.4**) incorporates a number of components that also present opportunities for additional water management, should monitoring or operational circumstances identify a requirement. The capacities and operation of the WMS are governed and optimised by the site water balance which determines the optimal use and sizing of each of the water management infrastructure components. Where required, and where practicable, the capacity or number of the following management system components could be increased:

- WTP;
- water reuse;
- water storages; and
- water discharges.

Following the adaptive management phase, by approximately 2100, it is anticipated that modifications to the site WMS would not be required with management focussing on monitoring and maintenance. Ongoing monitoring would transition through a period of routine monitoring (Proactive Monitoring) to confirm performance trajectories into event based monitoring (Reactive Monitoring) in response to a particular event (e.g., fire, flood, cyclone).