Independent Monitor ENVIRONMENTAL PERFORMANCE ANNUAL REPORT 2015

McARTHUR RIVER MINE

AUGUST 2016
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ERIAS GROUP

ERIAS Group Pty Ltd
ACN 155 087 362

Report to the Minister for Mines and Energy
Department of Mines and Energy

McArthur River Mine

Independent Monitor
Environmental Performance Annual Report
2015

August 2016
(Report No. 01164C_1_v2)

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Executive Summary

This is the third environmental performance report prepared by ERIAS Group since being appointed as the Independent Monitor (IM) in December 2013. The IM has prepared this report following review of monitoring data and various environmental assessments and similar documents, and a site inspection. The period covered by this report is October 2014 to September 2015. Information obtained as a result of the IM site visit in April 2016 and information provided by both McArthur River Mining (MRM) and the Northern Territory Department of Mines and Energy (DME) which is applicable to matters outside the reporting period has also been reviewed and incorporated into the report where relevant.

McArthur River Mining has expended considerable effort and progress in the current IM reporting period towards better defining the geochemical properties of, and risks associated with, mine materials, and has made a number of improvements in operational management to better control currently identified geochemical issues and impacts. However, the highly pyritic and reactive nature of the mine materials means that potential generation of acid, metalliferous and/or saline drainage, and the associated potential adverse impacts both on site and downstream, remains the most significant environmental risk at McArthur River Mine. The northern overburden emplacement facility (NOEF), tailings storage facility (TSF) and open pit are the key potential long-term sources of contaminated drainage. The main geochemical issues for the site therefore relate to the need to:

- Improve operational controls to manage rapid oxidation and seepage.
- Better define the distribution of geochemical rock types and their geochemical properties.
- Develop closure management strategies that ensure the successful long-term mitigation of potential impacts.

Strategies for the closure of the overburden emplacement facilities (OEFs), TSF and open pit, as well as other mine components, are currently being prepared and will be released as part of the Overburden Management Project environmental impact statement (EIS). The development of these strategies is fundamental to understanding the risks and impacts (if any) that will extend beyond the operation of the mine, and the mechanisms that will need to be implemented to ensure that these strategies perform as designed. The timeframe over which management of the site will be required after the operation has closed (which is currently scheduled for 2038) is yet to be determined. At the time of preparing this report, technical investigations were continuing and final strategies for the closure of the OEFs, TSF and open pit were being developed. Finalisation of these strategies will be critical in determining post-closure monitoring and maintenance requirements and the duration of these activities.

As with the 2014 IM report, this document focuses considerable attention on actions to complete recommendations contained in the 2012-2013 IM report. These recommendations have been modified as more information is obtained to ensure that they remain appropriate and reflect the increase in knowledge about the various issues. The collection of field data by MRM to not only improve the understanding of a particular issue but also to enable site data to be incorporated into models is commended. While the IM appreciates that site data in some areas remains limited, MRM's commitment to initiate the collection of this data is a positive step towards increasing confidence in model results.

Some of the improvements noted by the IM in its review are:

- Effective TSF pond management with evidence that a subaerial tailings beach of at least 50 m is being maintained, that pond water is being efficiently reclaimed, and that safe operating levels have been established.
- Completion of a number of studies and assessments to address information gaps, including infill waste rock geochemical characterisation, drilling of the NOEF to better understand geochemical and hydrological processes, cover design modelling and assessment, preliminary pit lake water quality modelling, and investigations into spontaneous combustion.
- Improved understanding of geochemical properties of key waste rock types, based on static and kinetic testing, which supports the current classification criteria.
- Definition of a low salinity non–acid-forming (LS-NAF) resource outside the existing pit (i.e., Woyzbun Quarry) that can be quarried to make up shortfalls in cover design requirements.
- Continued placement of newly mined high capacity potentially acid-forming (PAF-HC) and reactive potentially acid-forming (PAF-RE) material in paddock-dumped and roller-compacted (2 m) lifts to minimise oxidation and limit infiltration.
- Use of protective layers to limit desiccation and cracking of compacted clay liners (CCL) and compacting CCLs wet of optimum.
- Compaction testing frequencies generally meeting or exceeding MRM’s specification.
- Placement of clay and re-compaction of existing clay to minimise seepage from the southern PAF runoff dam (SPROD), which is a known source of contaminated water.
- Retention of extensive amounts of large woody debris installed at the downstream end of the McArthur River diversion channel in recent years, with fish communities in the area being comparable to those in the natural channel.
- Significantly increased vegetation along the McArthur River diversion channel, particularly near the lookout and along the waterline where establishment of vegetation is difficult (and this has been a focus of MRM in recent years). This is a result of high density planting by MRM staff and drier than normal wet seasons in 2014-2015 and 2015-2016.
- Expansion of a number of monitoring programs, e.g., marine and aquatic ecology, to include additional sites.
- Installation of nine piezometers and survey marks around the perimeter of the Bing Bong Loading Facility dredge spoil ponds embankment and the commencement of annual inspections to monitor and manage embankment performance.

- Installation of additional monitoring equipment (flow meters and pond water level sensors). The data from the new and existing sensors is now transferred in real time to a water balance database. Software has been developed to manipulate and display the data in an easy-to-understand format.
- Inclusion in the water balance modelling of sensitivity analyses in relation to multiple years, changes in water chemistry, and increases in runoff.
- Inclusion of TSF Cell 1 and Cell 2 in the water balance model.

Issues that the IM has identified during the review of the 2015 operating year include the following:

- Test frequency for the central west phase of the northern overburden emplacement facility (CWNOEF) is generally in accordance with version 2.0 of the relevant design, construction and operations manual. However, the IM recommends that consideration be given to reinstating the testing requirements adopted for version 1.2 of the manual, i.e., a minimum of two permeability tests per lot.
- In the 2012-2013 IM report, a recommendation was made that 'Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river'. While this has been a high priority recommendation in the last two IM reports, only limited progress has been made. The IM's view is that, until load estimates (and load balances) are available, possible downstream impacts associated with the mine potentially remain unknown to some degree, and quantification and targeting of mine-associated sources remains poorly defined.
- Twenty environmental incident reports were provided to the IM. Further to these reports and additional review of monitoring data and relevant documents, the IM believes that additional events that related primarily to exceedances of various guidelines should also have been reported as incidents.

  The reporting of environmental incidents is an important component of any continuous improvement system. Failure to report incidents has resulted in a lack of investigation as to why the guidelines against which MRM is monitoring and reporting were exceeded. Reasons for the exceedances may be due to the natural mineralisation of the area or procedural errors when collecting the sample, or may reflect direct impacts from the operation. Without reporting these exceedances as incidents and undertaking a subsequent investigation, the reasons remain unknown and changes to management measures will not be implemented.
- While progress has been made to rehabilitate the McArthur River diversion channel, much work remains to be done. As recommended in previous IM reports, a revegetation plan which includes a reasonable completion date for the diversion channel to be self-sustaining and a series of milestones against which performance can be assessed is needed. This will allow MRM to determine the effort required on a yearly basis to meet this goal and determine if rehabilitation is on track at an early stage.

The IM has also reviewed the Northern Territory Department of Mines and Energy's (DME) performance in regulating the McArthur River Mine. During the 2015 operational period, the DME initiated a series of field inspections that were aimed at:

- Informing the assessment by DME mining officers of the 2013-2015 MMP.
- Providing an update to management on the status of operations and assessing compliance with DME conditional approvals.

The IM commends the DME on undertaking these site visits and notes that such visits should be used to facilitate the exchange of technical information and minimise misunderstandings between the two parties.

During the operational period (October 2014 to September 2015), the DME issued a series of instructions to MRM. A number of these related to requesting additional information to assist in the assessment of the revised 2013-2015 MMP or MRM's monitoring data. The IM commends the DME on the level of detail provided in various comments and responses attached to the instructions, and notes the application of considerable technical knowledge to the challenges posed by the McArthur River Mine. However, the requests would benefit from some type of ranking so that MRM personnel could prioritise their responses.

The DME also requested that MRM appoint an independent certifying engineer (ICE) and an independent tailings review board (ITRB). The IM supports the engagement of external specialist advice and recommends that the DME should promote clarity between the roles of the ICE and ITRB to optimise synergies and to ensure that the maximum benefit is obtained from the engagement of these specialists.

1. Introduction

1.1 Role of the Independent Monitor

ERIAS Group Pty Ltd (ERIAS Group) commenced the role of Independent Monitor (IM) in 2014 following appointment by the Department of Mines and Energy (DME) in December 2013. ERIAS Group's scope of work is to provide an independent monitoring assessment of the environmental performance of the McArthur River Mine (Figure 1.1). The scope of the project includes the mine (Figure 1.2) and Bing Bong Loading Facility (Figure 1.3). The main role of the IM is to assess the environmental performance of the McArthur River Mine by reviewing and reporting on environmental assessments and monitoring activities undertaken by McArthur River Mining Pty Ltd (MRM), and environmental assessments and audits undertaken by DME, with respect to the environmental performance of the mine and Bing Bong Loading Facility.

The imperative for the IM is outlined in the MRM mining authorisation (0059-02), where Schedule 2 (independent monitoring assessment conditions) states that:

> 3.1 The purpose of these conditions is to establish and set out the operational requirements for an independent monitoring assessment of the environmental performance of the mine.
>
> 3.2 The Department will engage an Independent Monitor to undertake the independent monitoring assessment.

1.2 Scope of the Assessment

Clause 4.1(a) of the independent monitoring assessment conditions states that the IM is required to monitor the environmental performance of the mine[1] by reviewing:

> (i) environmental assessments and monitoring activities undertaken by the Operator; and
>
> (ii) environmental assessments and audits undertaken by the Department.

Issues relating to mine safety, social issues, personnel matters, administration matters or governance arrangements resulting from the operation of the mine in the McArthur River region will not be included in the assessment.

This assessment of environmental performance addresses the period from October 2014 to September 2015[2] and is referred to as the 2015 operational period[3].

The scope of the assessment included the following:

- An inception meeting with the operator (MRM) and department, i.e., the regulator (DME) in Darwin to discuss the process undertaken during the 2015 review, areas for improvement and the schedule for the 2016 review.

[1] Includes Bing Bong Loading Facility.
[2] Note that monitoring data has been assessed for the period of July to June, i.e., July 2014 to June 2015. Monitoring data from July 2015 to December 2015 has also been reviewed and discussed, where relevant to the findings from the July to June monitoring period.
[3] The term operational period is interchanged with operational year, reporting period and review period throughout this report.

PROJECT LOCATION

McArthur River Mine Project

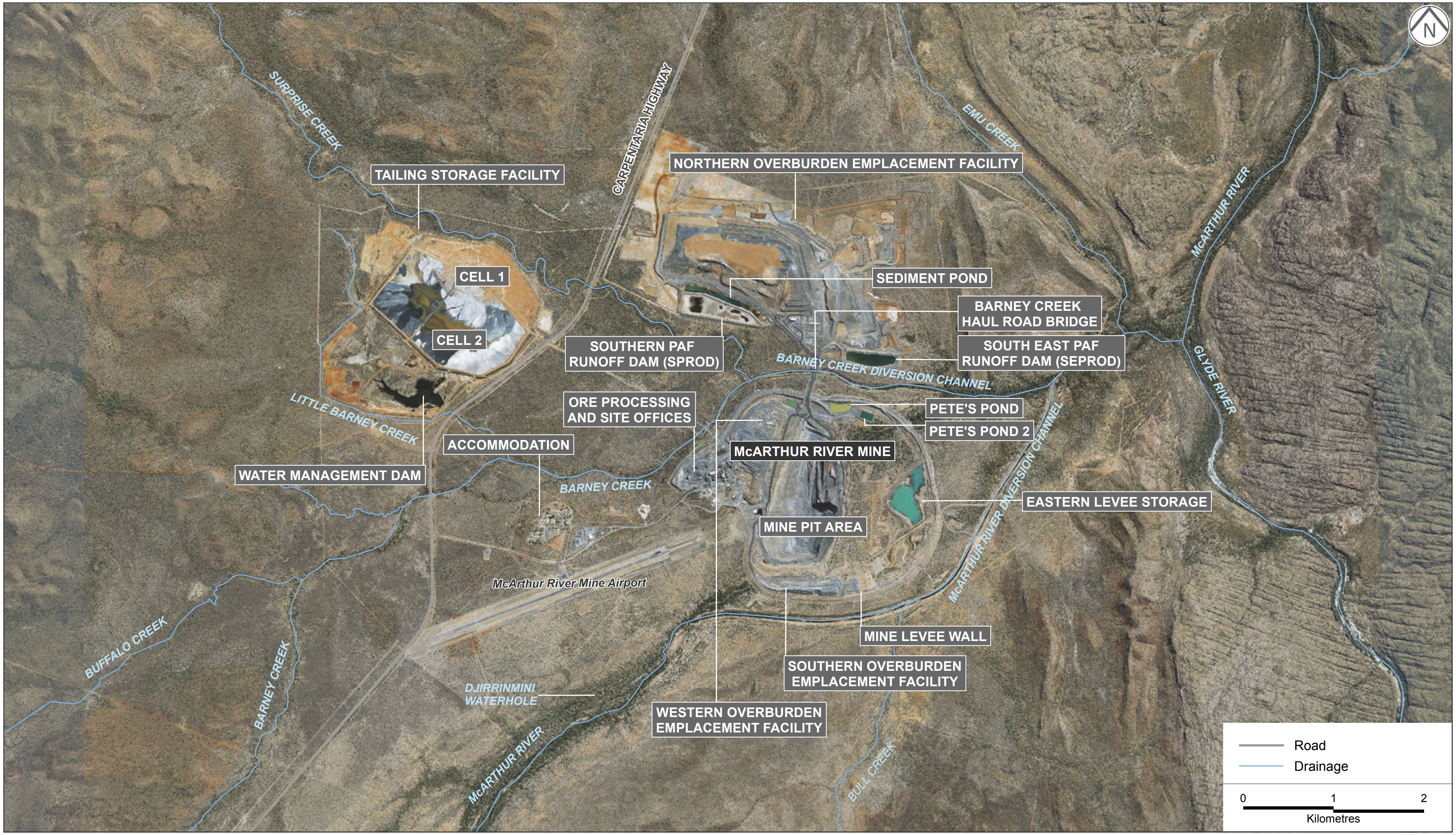
FIGURE 1.1

ERIAS GROUP

McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 1.2



BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 1.3

- Reviewing environmental assessments, monitoring activities and reviews undertaken by both MRM and DME.
- Reviewing relevant research required to inform monitoring activities.
- Discussions with DME personnel regarding progress on completion of recommendations from the last IM report.
- Updating the risk assessment and gap analysis (for the 2015 operational period).
- Undertaking a site visit and discussions with MRM personnel and MRM consultants.
- Preparing a report for the Minister for Mines and Energy concerning the environmental performance of the MRM operation (by both the operator and regulator).
- Preparing and distributing a report to the Borroloola community and other key stakeholders concerning the environmental performance of the MRM operation. This includes a community presentation.
- Developing and maintaining a website for the display of the report, the response reports from the operator and regulator, community report and other relevant information.

The scope of subsequent assessments will be similar to that described above and defined in the associated environmental performance annual report.

1.3 Objectives of the Assessment

The objectives of the IM assessment are to:

- Document the review of environmental performance.
- Report on progress from the previous IM assessment.
- Identify any urgent issues that require investigation and reporting.
- Identify areas of MRM's and DME's environmental performance that require improvement and recommend actions to address these deficiencies.
- Acknowledge areas of MRM and DME environmental performance that are done well.

1.4 Report Structure

This report comprises nine chapters:

- Executive Summary – provides a summary of how the assessment was undertaken and the key findings.
- Chapter 1 Introduction (this chapter) – provides definition around the scope of the assessment.
- Chapter 2 Background – provides general context for the assessment.

- Chapter 3 Method – outlines the approach to the review of environmental performance.
- Chapter 4 Results – presents results by technical discipline, e.g., terrestrial ecology, and highlights key risks, controls, incidents and non-compliance, progress since the previous IM assessment, successes and new recommendations. Assessment of MRM and DME performance is described separately.
- Chapter 5 Summary of Recommendations – provides a summary of new and ongoing recommendations.
- Chapter 6 Conclusions – presents an overview of the environmental performance of the McArthur River Mine since the previous assessment and highlights the main areas of concern.
- Chapter 7 Limitations – identifies the limitations of the assessment.
- Chapter 8 Definitions – provides definitions for less commonly used terms.

The details of the bibliographic references used in the report are provided at the end of each chapter, as applicable.

Supporting information such as the updated risk assessment and gap analysis are appended to the report.

2. Background

2.1 Statutory Requirements

The need for the IM environmental assessment is set out in the mining authorisation (see Section 1.1) that is issued by the Mining Environmental Compliance Group of DME under the Northern Territory *Mining Management Act* (MM Act).

The MM Act is the main piece of legislation that governs mining operations in the NT. Pursuant to the act, a mining management plan (MMP) must be prepared that details the particulars of the management systems to address environmental issues. Operators are obliged to comply, and manage their operations in accordance, with the approved MMP. The currently approved MMP is the revised interim 2013-2015 MMP (see Section 3.2) that was approved by the DME in December 2015.

During the review period, two waste discharge licences[4] (WDL 174-06 and WDL 174-07) issued under the *Water Act* applied to the discharge of wastewater into the McArthur River and Bing Bong Loading Facility. It is an offence under the *Water Act* if the holder of the waste discharge licence contravenes, or fails to comply with, the conditions of the licence.

The McArthur River Mine is also operated with reference to other legislation, agreements, standards and codes of practice, some of which are:

- *Aboriginal Sacred Sites Act* (NT) and *Aboriginal and Torres Strait Islander Act 2005* (Cwlth).
- *Environmental Assessment Act* (NT).
- *Heritage Act* (NT).
- *Mineral Titles Act* (NT).
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
- *Waste Management and Pollution Control Act* (NT).
- Licences and agreements.
- Other relevant codes and standards (e.g., National Water Quality Management Strategy, National Health and Medical Research Council, Enduring Value Framework (Minerals Council of Australia), national environment performance measures).

2.2 Project Status

Mining at McArthur River commenced in 1995 with underground operations and converted to open pit mining in 2007. In 2012, MRM submitted an environmental impact statement for the Phase 3 Development Project which involved expanding the operation to increase throughput of

[4] Note that WDL 174-06 applied until 16 January 2016 when WDL 174-07 became effective.

the processing plant from 2.5 million tonnes per annum (Mtpa), producing 360,000 dry metric tonnes per annum (dmtpa) of zinc-lead concentrate, to 5.5 Mtpa to produce approximately 800,000 dmtpa of zinc-lead concentrate. The Phase 3 Development Project also increased the mine life by an additional nine years to 2036. Construction and commissioning of the Phase 3 Development Project was completed in 2014.

In December 2013, MRM staff advised that following further testwork of waste rock the geochemical classification of the waste rock had changed. New categories for classification of the waste rock were introduced and in particular categories for waste rock which have the potential to generate saline/neutral metalliferous drainage. A notice of intent was submitted to the EPA in June 2014 by MRM. The EPA, in its statement of reasons issued in July 2014, determined that an environmental impact statement was required to assess the environmental impacts associated with the change in geochemical classification of waste rock. The terms of reference for the Overburden Management Project EIS were finalised in September 2014 and MRM is currently undertaking investigations to address the terms of reference. The IM understands that the EIS will be released for pubic comment towards the end of 2016.

Ore from the zinc/lead/silver deposit is extracted and processed to produce a high-grade bulk zinc/lead/silver concentrate. Waste associated with mining and processing is stored in the northern overburden emplacement facility (NOEF), western overburden emplacement facility (WOEF), southern overburden emplacement facility (SOEF) and tailings storage facility (TSF) (which comprises two cells and an adjacent water management dam). Three watercourse diversions have been required to facilitate the operation resulting in the construction of three diversion channels: McArthur River diversion channel, Barney Creek diversion channel and Little Barney Creek diversion channel. Surprise Creek is the other catchment within the mine development area (see Figure 1.2).

The concentrate is transported from the mine to Bing Bong Loading Facility by road along the Carpentaria Highway. The concentrate is stored at the loading facility in a concentrate storage shed from where it is loaded onto the MV Aburri bulk carrier and barged to waiting ships in a transfer (trans-shipment) zone in the Gulf of Carpentaria. Concentrate is offloaded via a boom that feeds the material onto conveyor belts that discharge into the hold of the ship. A swing basin and channel allow the MV Aburri to move between Bing Bong Loading Facility and waiting ships; these facilities require regular maintenance dredging with the spoil stored in onshore dredge spoil ponds (see Figure 1.3).

Surface water at the mine site is managed via a series of ponds and dams that manage process water, pit water (including dewatering) and runoff. Similarly, surface runoff from the facilities at Bing Bong Loading Facility is managed via three ponds and a pond drain. The main features of these systems are described in Table 2.1 and shown in Figures 1.2 and 1.3.

Table 2.1 – Surface Water Management Ponds/Dams

Pond/Dam	Description of Water Stored
Mine Site	
Anti-pollution pond (APP)	Contaminated water[1] from the old run of mine (ROM) area, laydown areas, process water, and water from the concentrator runoff pond (CRP) and TSF
Concentrator runoff pond (CRP)	Contaminated water from the processing area, process water
Van Duncan's dam (VDD)	Mine water, runoff from the new ROM area and overflow from the process water circuit (CRP overflow)
Pete's pond (PP)	Mine water from underground workings and pit
Pete’s pond 2 (P2)	Clean intercepted groundwater
Old McArthur River Channel	Water storage prior to discharge to McArthur River
Eastern levee storage (ELS)	Mine water from underground workings and pit (the ELS was removed as a water storage during the 2015 operating year)
Lake Archer (LA)	Not currently part of the water circuit and contains lead concentrate
Subaru sump	Intercepts water before it enters the pit
NOEF southern potentially acid-forming (PAF) sediment dam (SPSD)	Runoff from OEF (waste rock) (contaminated)
NOEF southern PAF runoff dam (SPROD)	Runoff from OEF and SPD overflow (contaminated)
NOEF southeast PAF runoff dam (SEPROD)	Runoff from southeast area of NOEF (contaminated)
NOEF western PAF runoff dam (WPROD) - under construction	Runoff from western area of NOEF (contaminated)
NOEF eastern PAF runoff dam (EPROD) - proposed	Runoff from eastern area of NOEF (contaminated)
Central west A sump	Runoff from northern NOEF (contaminated)
Central west C sediment trap (CWCST)	Surface runoff (and sediment) from north of the NOEF
East sediment trap (EST)	Surface runoff (and sediment) from northeast of the NOEF
South west sediment trap (SWST)	Surface runoff (and sediment) from southwest of the NOEF
Tailings Storage Facility	
TSF Cell 1 sump A	Runoff from TSF Cell 1 (potentially contaminated)
TSF Cell 1 sump B	Runoff from TSF Cell 1 (potentially contaminated)
TSF Mini Dam (located within the WMD)	Water from TSF Cell 1 sump A and B
Water management dam (WMD)	Contingency storage with ability to receive water from Pond 2
Bing Bong Loading Facility	
Bing Bong surface runoff pond 1	Contaminated runoff from sumps, washdown and infrastructure areas
Bing Bong surface runoff pond 2	Water from Bing Bong surface runoff pond 1
Bing Bong surface runoff pond 3	Water from Bing Bong surface runoff pond 1
Dredge spoil pond drain	Water from dredge spoil

1. May contain contaminants such as heavy metals, hydrocarbons, and mill reagents.
2. Contains sediment.

2.3 Previous Independent Monitor Reviews

The first IM review of MRM's environmental performance was for the period October 2006 to September 2007 or also known as the 2007 operational period. Subsequent reviews have been completed for the operational periods of 2008, 2009, 2010, 2011, a combined report was prepared in 2014 (which reviewed the 2012 and 2013 operational periods, i.e., October 2011 to September 2013) and 2014. The key findings of each review are provided in Table 2.2.

Table 2.2 – Overview of Previous IM Reviews

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2007	♦ Improved monitoring, technical review and interpretation of all water monitoring data around the mine, in particular the assessment of seepage from the TSF into Surprise Creek ♦ Improved management and subsequent reduction of fugitive dust emissions at the Bing Bong Loading Facility ♦ Improved dust management practices, particularly at the TSF ♦ Improved management and rehabilitation of the Bing Bong Loading Facility dredge spoil ponds ♦ Adjustments to analytical suites for the surface water and groundwater monitoring programs	♦ High level of procedural conformance with statutory commitments and conditions
2008	Significant issues: ♦ Tailings leachate migration from TSF Cell 1 into Surprise Creek ♦ Saline leachate from the Bing Bong Loading Facility dredge spoil ponds affecting vegetation surrounding the spoil ponds Less urgent, but still significant issues: ♦ Fugitive dust emissions at the Bing Bong Loading Facility ♦ Weed management along the river diversion channels and around the mine site	♦ Some improvements since the 2007 review
2009	♦ Excess water storage in TSF Cell 2, which poses a significant risk of overtopping and embankment failure due to the TSF spillways being under-designed for a flood event ♦ Seepage migration from the TSF to Surprise Creek and the hazard classification of tailings in Cell 1 and Cell 2 ♦ Fugitive dust emissions from the mine site ROM (run of mine) pad/ore crushing area at the mine site ♦ Fugitive dust emissions from the Bing Bong Loading Facility concentrate storage shed ♦ Detail of reporting and quality of data analysis for the dust, soil and sediments monitoring program and inclusion of long-term trends and base studies ♦ Weed management along the river diversion channels and the mine site ♦ Structural integrity of the Bing Bong Loading Facility dredge spoil ponds ♦ Testing of the TSF Cell 1 clay cap to ensure it meets design specifications	♦ A number of issues identified in the previous reviews addressed; however, there were a number of ongoing, and additional, issues

Table 2.2 – Overview of Previous IM Reviews (cont'd)

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2010	♦ Adverse impacts of seepage from the TSF detected in Surprise Creek ♦ Dust from operations at the ROM pad and crushing plant, and also historically from the TSF expressed in stream sediments in both Barney and Surprise creeks ♦ Volume of water stored in Cell 2 of the TSF remains a concern as there is an extreme risk of embankment failure or overtopping of the spillway ♦ Visual method for classification of non–acid-forming (NAF)/PAF waste rock of concern as there is the potential for misclassification ♦ Progress of acidification of the tailings and delineation of the treatment options ♦ Generation of fugitive dust emissions from the ROM pad and crushing plant, and, to a lesser extent, the Bing Bong Loading Facility concentrate storage shed ♦ Structural integrity of the Bing Bong Loading Facility dredge spoil ponds ♦ Slow progress of revegetation on the McArthur River diversion channel ♦ Inadequacy of reporting for many routine monitoring programs	♦ Many improvements were noted through the review and the following monitoring programs were considered to be generally adequate: – Flora and fauna monitoring both at the mine site and at Bing Bong Loading Facility – Surface water monitoring – Fluvial sediment monitoring – Structural monitoring of the river diversion channels
2011	♦ The volume of water stored in Cell 2 of the TSF ♦ Delineation of seepage at the TSF, and its effect on Surprise Creek ♦ Progress of acidification of the tailings and delineation of the treatment options ♦ Identification and management of PAF rock waste at the NOEF ♦ Progress of revegetation on the McArthur River diversion channel, particularly along downstream sections	♦ Environmental performance had improved over the past five years of monitoring, most notably around: – The level and detail of reporting presented within the 2011-2012 MMP and water management plan – Dust mitigation and monitoring at the mine site – Ongoing rehabilitation of the McArthur River diversion channel
2012 & 2013	♦ Significant changes to the classification of overburden advised by MRM following additional testing of waste rock resulting in revisions to the proposed closure concepts and implications for the management of water ♦ Concentration of lead in fish at SW19 (monitoring point adjacent to Barney Creek haul road bridge located on the mine site) identified lead concentrations above the maximum permitted in Food Standards Australia and New Zealand (2009) ♦ Volume of water stored on the surface of TSF Cell 2 identified as a concern ♦ Quality control during the construction of TSF Cell 2, Stage 2, found to be inadequate	♦ McArthur River Mining has undertaken significant work to improve its understanding of the geochemical properties of the waste rock. This key issue requires extensive work to understand the implications of the changes in geochemical classification of waste rock. Other improvements include: – Continued addition of large woody debris in the McArthur River diversion channel

Table 2.2 – Overview of Previous IM Reviews (cont'd)

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2012 & 2013 (cont'd)	♦ Quality control for construction of compacted clay liners at the NOEF may not be in accordance with design specifications with potential impacts on assumed performance ♦ Erosion of up to 2 m has occurred in the past four years along sections of the McArthur River diversion channel ♦ DME to improve the timeliness of issuing audit reports ♦ DME to implement a system for tracking MRM's progress to complete IM review recommendations ♦ Commitments made by MRM in MMPs to be specific and measureable	– Construction of interim clay cover over PAF material on the NOEF – Development of interim cover design for TSF Cell 1 – Extension of geopolymer cut-off wall along entire length of eastern embankment of the TSF – Ongoing improvements to minimise fugitive dust emissions
2014	♦ Current estimates are that 9% of all waste rock is benign and therefore suitable for use as the outer layer of the cover. The actual material balance is unknown pending the outcome of the current cover design investigations ♦ Procedures for the quality testing of compacted clay liners, and the response by MRM when quality testing fails, is not being consistently applied, and the procedures were found to be unclear in some circumstances ♦ Examination and assessment of incidents relating to the TSF has raised some new concerns with the IM, specifically with regard to: – Efficacy of inspections – Accuracy of monthly operating and infrastructure reports – Efficacy of annual reviews – Flood capacity of TSF Cell 1 ♦ Contaminated water runoff, sediment and/or dust are entering the environment surrounding the Barney Creek haul road bridge ♦ Review of the 2013-2018 MMP and 2013-2015 MMP (interim and revised interim) evolved in a very complex and protracted way as a result of the MMPs being referred to the EPA and a number of requests for additional information, and submission by MRM of MMP amendments to ensure that the mine could continue to operate while MMPs were being assessed	♦ The operation of the TSF had been significantly improved ♦ Improvements bring TSF operation largely into line with the Phase 3 EIS commitments ♦ Modifications to the design and operation of TSF Cell 2 to reduce seepage impacts and geotechnical risks ♦ Development of a successful system to control material that had spontaneously combusted ♦ Finalisation of the waste rock classification criteria ♦ Installation of additional groundwater monitoring bores around the NOEF ♦ Placement of significant quantities of large woody debris in the McArthur River diversion channel ♦ Expansion of the aquatic biota monitoring program ♦ Installing and upgrading sediment traps at the Barney Creek haul road bridge ♦ Instrumentation of ponds and pipelines and development of a computer program which provides real time information on volume of water stored on site

2.4 Stakeholders

The assessment of the environmental performance of the MRM operation is of interest to the following audience (Table 2.3). These people and groups are the McArthur River Mine's stakeholders.

Some of these stakeholders, e.g., DME and MRM employees, were involved in the assessment (Chapter 3), while others are interested in the outcomes (e.g., other government agencies, environment groups, other interested parties).

Table 2.3 – Stakeholders

Government	Non-government
Minister for Mines and Energy	McArthur River Mining (MRM)
Department of Mines and Energy (DME)	Traditional owners of the Borroloola region
Minister for Lands, Planning and the Environment	Local indigenous organisations
Department of Lands, Planning and the Environment (DLPE)	Wider community of Borroloola and surrounds
Northern Territory Environment Protection Authority	Land councils
Department of Primary Industry and Fisheries	Environment groups
Department of Health	Other interested parties
Other Northern Territory Government agencies	
Commonwealth Government agencies, e.g., Department of the Environment	

The IM is maintaining a website that provides:

- An overview of the role and activities of the IM.
- Access to current and previous annual IM reports, operator and regulator response reports, community reports and other relevant information prepared, or used, by the IM in assessing environmental performance.
- Links to other relevant websites.

This website allows stakeholders to access information associated with the annual assessment of performance. Information will also be disseminated to local community stakeholders via a separate community report and presentation.

The website can be accessed at: www.mrmindependentmonitor.com.au.

3. Method

3.1 Review Team

The IM is led by ERIAS Group and supported by a team that brings together the experience and skills required to fulfil the role (see Sections 1.1 and 1.2). The roles of the IM team members are outlined in Table 3.1.

Table 3.1 – IM Team

Name	Company	Technical Expertise for the Assessment
David Browne	ERIAS Group	Team leader; environmental risk and management; closure planning
Michael Jones	ERIAS Group	Natural surface water, artificial surface water and marine water quality
Michelle Clark	ERIAS Group	Dust, soils, fluvial and marine sediment quality
Luci David	ERIAS Group	Peer review
Mick Cheetham	Water Technology	Diversion channel hydraulics
Richard Walton	Water Technology	Site water balance and management; surface hydrology
Gareth Swarbrick	Pells Sullivan Meynink	Geotechnical; TSF, OEF and Bing Bong Loading Facility dredge spoil ponds
Rob Garnham	Groundwater Resource Management	Groundwater modelling and monitoring
Stuart Miller	Environmental Geochemistry International	Geochemistry; TSF and NOEF cover design strategies
Warwick Stewart	Environmental Geochemistry International	Geochemistry; TSF and NOEF cover design strategies
Bill Low	Low Ecological Services	Terrestrial flora and fauna; aquatic ecology; marine ecology
Nicola Hanrahan	Low Ecological Services	Terrestrial flora and fauna
Matt Le Feuvre	Low Ecological Services	Aquatic ecology; marine ecology (including the annual marine monitoring program, seagrass and *Vibrio* assessment)
Derek Mascarenhas	Integrated Design Solutions	Website design and maintenance; graphic and report/ presentation production support

3.2 Assessment Framework

The IM team adopted the same assessment framework as that used last year and reviewed environmental performance within MRM's mining lease numbers 1121, 1122, 1123, 1124, 1125 and 1126, and downstream along the McArthur River to the coast and beyond within the Sir Edward Pellew Group of Islands (see Figure 1.1) in terms of:

- Key risks (Section 3.5).
- Controls:

- Previously reported controls.
- New controls – implemented and planned.

- Review of environmental performance:
  - Incidents.
  - Non-compliances.
  - Progress and new issues.
- Successes.

With the exception of key risks, each of these is discussed below. Deficiencies in any of the above translate to either an ongoing or new recommendation.

In general, performance has been assessed in terms of the:

- Mining management plan, which is the principal document required under the MM Act that informs how the mine will be operated and describes the controls that will be implemented to manage and monitor environmental risks (see Section 2.1). The currently approved MMP is the revised interim 2013-2015 MMP (MRM, 2015a), which was approved by the DME in December 2015. Three documents form the revised interim MMP assessed by DME, their relevance being as follows:
  - Sustainable Development Mining Management Plan 2013-2015. Volume 1 (March 2015). This document addresses proposed management and monitoring for the period October 2013 to September 2015 (MRM, 2015a).
  - Interim Mining Management Plan 2013-2015. Volume 2: Environmental Monitoring Report (January 2015). The report reviews environmental monitoring data collected over the period July 2013 to June 2014 (MRM, 2015b).
  - Supplementary Environmental Monitoring Report 2014 (February 2015). The report was requested by DME and covers monitoring activities over the period July to November 2014 (MRM, 2015c).

  In addition, MRM submitted a number of MMP amendments to DME for approval. The amendments related to actions contained in the MMP that needed to commence. Hence, MRM requested that DME review and approve the amendments while review and assessment of the main MMP continued.
- Relevant criteria, guidelines and standards, e.g., Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ, 2000), Australian National Committee on Large Dams guidelines (ANCOLD, 2012).
- Leading practice, in the context of the key risks identified in the risk assessment (Section 3.5).

3.2.1 Controls

The IM team has identified the existing controls that MRM has implemented to manage and monitor environmental risks. New controls that have been included during the operating year or are planned to be implemented have also been identified. These are summarised for each technical area and assessed for adequacy.

3.2.2 Review of Environmental Performance

Review of environmental performance was assessed in three areas.

1. Incidents and non-compliance.

Incidents are defined by MRM as (MRM, 2011):

> An unplanned or unwanted event with the potential to harm personnel, the environment, equipment or the community.

Incidents are managed according to the MRM Incident Management Procedure (GEN-SD-PRO-6040-0015) and ranked based on severity (actual or potential in the case of a near miss) as per Table 3.2.

Table 3.2 – Incident Severity Ranking

Ranking	Environmental Impact
1	No or very low environmental impact. Impact confined to small area. Site impact only
2	Low environmental impact. Rapid clean up by site staff and/or contractors. Impact controlled to area currently impacted by operations
3	Moderate environmental impact. Clean up by site staff and/or contractors. Impact confined within lease boundaries. Or, minor impact off site; however, no irreversible damage
4	Major environmental impact. Considerable clean up effort using site and external resources. Impact may extend beyond lease boundaries
5	Severe environmental impact. Local species destruction and likely long recovery period. Extensive clean up involving external resources. Impact on regional scale

There were 20 incident reports provided to the IM in the reporting period and these will be discussed within each technical area of the report.

There were a number of instances during the operational period where the IM considered an event to be an incident, even though MRM did not report these in accordance with their incident management procedure. These events have been identified within the relevant technical area of the report.

Compliance was assessed in two areas:

- Compliance with the waste discharge licence (WDL 174-06 and WDL 174-07) that specifies trigger values that must not be exceeded for two authorised discharge points (SW11 and BBDDP – dredge spoil drain).
- Compliance with relevant criteria, standards and guidelines.

Issues of compliance are discussed is each discipline section. Note, in 2014 the IM reported on compliance with commitments listed in the main body of the 2012-2013 MMP. The revised interim 2013-2015 MMP does not contain an equivalent list of commitments. Instead, three appendices in different formats comprise over 70 pages of MMP commitments. The format of these appendices was inappropriate for the IM to review compliance (Section 4.3.2.4).

2. Progress and new issues

The recommendations from the previous (2015) IM review were reviewed and progress assessed. Those recommendations that have not been closed out are discussed in each of the technical areas and documented in the review of the previous IM recommendations.

New issues are those in addition to an incident or non-compliance (Section 3.2.4), or an ongoing issue from a previous IM review. They may relate to an information gap (Section 3.6) or be risks (Section 3.5) that are not addressed in existing controls (Section 3.2.1).

3. Successes

The assessment of environmental performance identifies areas of improvement, e.g., closing out an ongoing IM recommendation, and where it can be demonstrated that an environmental value, e.g., environment protection objective or beneficial use declaration (as defined in the waste discharge licence (see Section 2.1)) has been protected by meeting, where relevant, a criterion, guideline or standard.

3.3 Document Review

The IM was provided with a number of documents and other files and commenced its document review prior to the site inspection. Following the site inspection, additional documents were requested as a result of discussions with MRM and DME personnel and during the process of preparing this report. A full list of files used in the assessment is provided in Appendix 1.

3.4 Site Inspection

A smaller IM team than in previous years consisting of David Browne, Michael Jones, Rob Garnham, Richard Walton, Warwick Stewart, Gareth Swarbrick and Matthew Le Feuvre visited the McArthur River Mine (including Bing Bong Loading Facility) on 27 and 28 April 2016. The purpose of the site visit (inspection) was to:

- Visit the mine site and project infrastructure, including the TSF, NOEF, SOEF, water storage ponds, river diversion channels, concentrate storage and handling facility at Bing Bong Loading Facility (including dredge spoil ponds) and monitoring sites located upstream and downstream of the mine.
- Gather information from discussions with MRM personnel and in particular progress with completion of recommendations from the 2015 IM report and work that is either in progress or is being planned.
- Present preliminary outcomes of the review at a close out meeting with MRM at the end of the site visit.

On 26 April 2016, the IM team members attending the site visit met with the Department of Mines and Energy (DME) to discuss with DME personnel the following:

- Progress with completion of 2015 IM recommendations.
- Status of the approved 2013-2015 MMP.

On 29 April 2016, members of the IM team presented preliminary observations following the site visit to DME personnel.

3.5 Risk Assessment

3.5.1 Objective

Each year the IM is required to undertake a risk assessment to assess environmental risks associated with the MRM operation. The objectives of the risk assessment are to:

- Identify environmental risks.
- Evaluate whether environmental monitoring and assessment practices undertaken by MRM are adequate and appropriate to mitigate the risk of potential environmental impacts.
- Determine if MRM is addressing the risks identified by the IM and if actions are appropriate.

3.5.2 Method

Following review of documentation (and in particular the update provided by MRM on actions to address issues in the risk assessment) and the site visit, IM team members reviewed the previous risk assessment and completed the following:

- Updated information regarding the description of the risk where additional information is known.
- Reviewed the consequence and likelihood rating.
- Updated the existing controls.
- Provided comment on whether additional controls are required.

This updated the previous risk assessment (completed in 2015) and therefore used the same method. This method is in accordance with ISO 31000:2009 – Risk Management Principals and Guidelines (SA/SNZ, 2009), is described in EES (2012) and is based on the following definitions and matrices (Tables 3.3 to 3.6).

Table 3.3 – Consequence Definitions

Consequence		Definition
1	Catastrophic	Severe environmental impact. Local species destruction and likely long recovery period. Extensive clean up involving external resources. Impact on regional scale
2	Major	Major environmental impact. Considerable clean up effort using site and external resources. Impact may extend beyond lease boundaries
3	Moderate	Moderate environmental impact. Clean up by site staff and/or contractors. Impact confined within lease boundaries. Or, minor impact off site; however, no irreversible damage
4	Minor	Low environmental impact. Rapid clean up by site staff and/or contractors. Impact controlled to area currently impacted by operations
5	Insignificant	No or very low environmental impact. Impact confined to small area. Site impact only

Table 3.4 – Likelihood Definitions

Likelihood		Definition
1	Certain	Expected to occur frequently at this operation
2	Likely	Expected to occur occasionally at this operation
3	Possible	Has occurred, or could occur, for this or a comparable operation
4	Unlikely	Known to occur in the global industry, but unlikely
5	Improbable	Not known to occur in the global industry, but plausible

Table 3.5 – Risk Matrix

Consequence		Likelihood				
		1	2	3	4	5
		Certain	Likely	Possible	Unlikely	Improbable
1	Catastrophic					
2	Major					
3	Moderate					
4	Minor					
5	Insignificant					

Table 3.6 – Risk Rating Definitions

Risk Rating	Definition
E	Extreme. Immediate intervention required to eliminate or reduce risk at a senior management/government level
H	High. It is essential to eliminate or reduce risk to a lower level by the introduction of monitoring and assessment measures implemented by senior management
M	Moderate. Corrective action required, and monitoring and assessment responsibilities must be delegated
L	Low. Corrective action should be implemented where practicable, and risk should be managed by routine monitoring and assessment procedures

3.5.3 Outcomes

The updated risk register is provided in Appendix 2. A total of 75 risks were assessed. A comparison of the risk assessment results with the previous three assessments is provided in Table 3.7.

Table 3.7 – Comparison of Risk Assessment Results

Risk Rating	2011 IM Risk Assessment	2014 IM Risk Assessment	2015 IM Risk Assessment	2016 IM Risk Assessment
Extreme	2	1	2	2
High	13	31	25	24
Moderate	36	29	38	40
Low	19	7	12	9
Total	**70**	**68**	**78***	**75**

* It was not possible to subscribe a risk rating to the remaining 1 risk, as this item relates to closure.

Key risks are discussed in each technical area of the report, with all risks detailed in Appendix 2.

3.6 Gap Analysis

In the 2012-2013 and 2014 IM reports, ERIAS Group adopted the gap analysis used in previous IM reviews, where a gap was defined as (EES, 2012):

> a discrepancy between the monitoring program that is taking place, and the monitoring program that should be taking place if MRM's environmental performance is to be maintained at industry best practice standards.

In undertaking the 2015 review, it has been recognised that gaps in modelling can be equally important as those relating to monitoring programs. The gap analysis register was reviewed and each team member identified monitoring, modelling and/or assessment gaps in their field of expertise based on three questions:

1. Is monitoring and/or modelling undertaken in accordance with associated potential risk?
2. Is monitoring sufficient in design (frequency, type, location), and/or is modelling supported by sufficiently validated inputs/assumptions, in order to address and mitigate potential risk?
3. Is monitoring and/or modelling data/output information assessed, interpreted and managed to track risk alteration and evaluate the need for improved risk mitigation?

Gaps were categorised into three groups (Table 3.8).

Table 3.8 – Gap Categories

Category	Description
1	Monitoring and/or modelling to mitigate potential associated environmental risk is not undertaken
2	Monitoring and/or modelling is undertaken, but monitoring is not sufficient in design (that is, frequency, location, type and so on), or the inputs to/assumptions of modelling are not validated, such that results are insufficient to identify or quantify potential environmental risks
3	Monitoring and/or modelling is undertaken and is appropriate, however data/output information is not adequately assessed, interpreted or managed to appropriately mitigate potential environmental risks

A total of 84 gaps were identified, 22 more than in the 2015 IM review:

- 20 Category 1 gaps.
- 43 Category 2 gaps.
- 21 Category 3 gaps.

These gaps will be discussed within each technical area of the report and in the most relevant section, i.e., existing controls, new issues or non-compliance.

3.7 Review of DME’s Monitoring

The IM conducted a review of DME in regulating the environmental performance of MRM under the MM Act and regulations. This included review of:

- The DME's assessment of the MMP.
- Instructions and investigations initiated by DME.
- Independent Monitor recommendations tracking.
- Previous IM recommendations regarding DME performance.

It should also be noted that no DME audits were undertaken in 2015, nor were any DME check monitoring reports available for the same period. The only check monitoring data that was available for IM review related to surface water and groundwater samples taken in November 2015, which is after the IM reporting period.

3.8 References

ANCOLD. 2012. Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure. May. Australian National Committee on Large Dams Incorporated. Hobart, Tasmania.

ANZECC/ARMCANZ. 2000. Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.

EES. 2012. Independent Monitor Audit of the McArthur River Mine for the 2011 Operational Period. Report to the Minister for Mines and Energy. 1 October 2012. Version 1. Prepared by Environmental Earth Sciences for the Department of Mines and Energy, Darwin, NT.

MRM. 2011. Incident Management Procedure. GEN-SD-PRO-6040-0015. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015a. Sustainable Development Mining Management Plan 2013-2015, Volume 1. 3rd March 2015. Reference Number GEN-HSE-PLN-6040-0003, Issue Number: 7, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015b. Interim Mining Management Plan 2013-2015, Volume 2: Environmental Monitoring Report. January 2015. Reference Number GEN-HSE-PLN-6040-003, Issue Number: 7, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015c. Supplementary Environmental Monitoring Report 2014. February 2015. Reference Number GEN-HSE-RPT-6040-002, Issue Number: 1, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

SA/SNZ. 2009. AS/NZS ISO 31000:2009. Risk Management – Principles and Guidelines. Originated as AS/NZS 4360:1995. Third edition. Revised and redesignated as AS/NZS ISO 31000:2009. Standards Australia/Standards New Zealand, Canberra, ACT.

4. Results

4.1 Approach and Key Risks

The IM has reviewed and updated the risk register presented in the 2015 IM report (for the 2014 operational period). The updated risk register is based on the following actions:

- All risks were reviewed to determine if they remain current; those that were no longer pertinent were deleted.
- Where relevant, risks that remain current have been updated to reflect changes since the register was last compiled.
- New risks as a result of the IM's document review and site inspection have been included.

Review of the risk register has resulted in the number of risks identified by the IM decreasing from 78 to 75. Table 4.1 provides a summary of the risks from the 2012, 2014, 2015 and 2016 risk assessments undertaken by the IM.

Table 4.1 – Summary of Risks Identified by the IM in 2012, 2014, 2015 and 2016

Report Year	2012	2014	2015	2016
Operational Year/s	2011	2012-2013	2014	2015
Extreme risk	2	1	2	2
High risk	13	31	25	24
Moderate risk	36	29	38	40
Low risk	19	7	12	9
TOTAL	70	68	78*	75

* In 2015, there was one risk for which it was not possible to assign a risk rating, as this item related to closure.

Risks identified in the 2016 review of the risk register that are considered by the IM to be key risks include (those marked with an asterisk are new for the reporting period):

- Potential failure of the NOEF final cover as a result of erosion, slumping, differential movement, and cracking/heaving due to convective oxidation, leading to exposure of highly pyritic waste rock to oxidation and infiltration. The consequence of this event is acid, metalliferous and/or saline drainage impacts on groundwater quality, and terrestrial and aquatic ecosystems.
- Potential failure of the TSF cover as a result of erosion, slumping or embankment failure, leading to the exposure of highly pyritic tailings to oxidation and infiltration. The consequence of this event is acid, metalliferous and/or saline drainage impacts on groundwater quality, and terrestrial and aquatic ecosystems.
- Oxidation of exposed PAF and NAF materials in the pit walls leading to development of poor pit water quality and potential impacts on surface water quality through overtopping and/or

groundwater movement, with consequent impacts on groundwater quality, and terrestrial and aquatic ecosystems.

- Seepage of tailings water impacting on groundwater quality, and aquatic and terrestrial ecosystems where groundwater is discharged to creeks or the surface.
- Seepage from the NOEF impacting on groundwater quality, and aquatic and terrestrial ecosystems where groundwater is discharged to creeks or the surface.
- Deterioration in mine site seepage and/or runoff water quality beyond current estimates resulting in changed conditions and the requirement to manage larger volumes of contaminated water.
- Fugitive dust emissions and seepage as a result of operations result in a reduction in water quality, thereby reducing the diversity and abundance of aquatic fauna. Metals may bioaccumulate in aquatic fauna.
- Revegetation of the McArthur River diversion channel is insufficient in preventing erosion of areas of the diversion channel, and lack of suitable habitat for terrestrial and aquatic flora and fauna.
- Existing mine closure costs are based on a strategy that is currently being revised. It is likely that any revised strategy will involve additional costs both in terms of construction and post closure monitoring and maintenance. These additional costs are currently unknown and therefore are not included in the existing security bond.
- Erosion along the mine levee wall leading to failure of the levee wall during a flood event resulting in flooding of the open pit and potential downstream impacts to terrestrial and aquatic ecosystems.
- Dust emissions associated with operation of the processing plant, TSF, NOEF and haul roads leading to heavy metal contamination of receiving waterways and diversion channels.

As a result of the technical investigations currently being completed as part of the Overburden Management Project EIS, the IM expects that the risks will become more detailed in subsequent IM reports due to increased levels of understanding. Further discussion on risks identified by the IM is outlined in Sections 4.2 to 4.13.

4.2 Mine Site Water Balance

4.2.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of mine site water balance, and is based upon:

- Observations and discussions with MRM personnel during the site inspection.
- Review of various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's mining management plan (MRM, 2015a) and the site water balances for the McArthur River Mine and Bing Bong Loading Facility, for 2014-2015 (WRM, 2014) and 2015-2016 (WRM, 2015a).
- Review of various MRM forms and similar documents such as incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the mine site provided by MRM.
- Review of ALS (topographic) data of the mine site provided by MRM.
- Review of other documents such as DME field inspection reports.

4.2.2 Key Risks

The risk of the site water balance not performing as predicted is the delivery of a greater volume of water to one or more storages than estimated. It may not be possible to transfer this additional water to other ponds in a timely manner and this, in turn, may lead to uncontrolled off-site releases of contaminated water. The key risks to the mine site water balance as described in the risk assessment (Appendix 2) are:

- Errors in the water balance model parameter estimation. There is considerable interaction between water balance model parameters, that is, it is possible to obtain a match between modelled and observed water levels in ponds with a range of different parameter sets. The potential issue is that while the model may appear to provide a reasonable estimate of the water balance under the current mine site conditions, it may be a poor predictor of the water balance under changed mine site conditions (e.g., increased catchment areas, changes in runoff parameters, clay capping of NOEF). These errors may result in the delivery of a greater volume of water to one or more storages than estimated by the modelling.
- Changes in mine site runoff/seepage water quantity. This is most likely due to changes in land use (e.g., increasing surface runoff as a result of the new NOEF operational procedure of flattening the batters and placing a clay cap to reduce water infiltration). A greater volume of water may be delivered to one or more storages than estimated by the modelling.
- Changes in mine site runoff/seepage water quality. There is a chance that the mine site runoff and seepage water quality (collected in ponds on site) may become substantially worse than currently estimated. This is because the large volumes of PAF waste rock may result in a reduction in runoff/seepage pH with a concomitant increase in dissolved metal concentrations. Poorer quality site water would require (without the addition of a water

treatment plant) greater dilution for controlled off-site releases. This may reduce the volume of water that can be released off site, which in turn may lead to greater volumes of water in one or more on-site storages than estimated by the modelling. This may lead to an increase in uncontrolled off-site releases.

- Changes in climate. The water balance modelling assumes that the historical climate record from 1889 to the present is representative of the current and future climate (during the mine life). If the current and future climate are wetter than the historical climate, there may be a greater volume of runoff and/or less evaporation than that estimated by the modelling. This may lead to greater volumes of water in one or more on-site storages than estimated by the modelling, which may lead to an increase in uncontrolled off-site releases.

- Failure of pumps or pipes during periods of heavy rain. The current site water balance modelling assumes that the water transfer network will not fail. However, it is possible for a pump or pipe to fail during a period of high rainfall (e.g., 100 mm over three days). In this case, it could be difficult to repair the failure in a timely manner (e.g., due to reduced site access during wet weather or absence of spare parts) and an uncontrolled off-site release may occur.

- Use of the underground void/open pit for water storage. The current site water balance is based upon infrastructure (pumps, pipes, storages and their interconnections) that is configured and sized so that excess mine site water is stored in the underground void/open pit (the underground void and open pit are treated as one storage). This strategy is likely to have an impact upon mining operations because there is a reasonable chance the underground void will become full of water, with further inflows to the underground void/open pit resulting in water ponding in the open pit.

  With the exception of some short-term wet season changes to mine operation (implemented annually), there are no medium- to long-term plans to reduce the risk of water ponding in the open pit. During the site inspection, MRM personnel advised that they intend to address the medium- to long-term risk of water ponding in the open pit as part of the current EIS. The IM will review this information in next year's report.

- The open pit expansion is continually advancing into the underground void, which will eventually be engulfed by the open pit. This poses two problems: the loss of the underground void storage from the water balance and the need to remove the existing water in the underground void to allow for the mine expansion. The lead time to modify the site water balance to account for these changes (e.g., design and build more storages and/or design and build a water treatment plant, change the site water balance configuration to allow for increased controlled releases) will be a number of years. There are currently no strategies to manage the loss of the underground void/open pit as a water storage and to remove the existing water from the underground void. Inadequate lead time to adapt to the loss of the underground void as a storage may result in one or more on-site storages being too small to hold the available water. This could lead to uncontrolled off-site releases of contaminated water.

4.2.3 Controls

4.2.3.1 Previously Reported Controls

The existing controls employed by MRM to reduce risk in the mine site water balance management are:

- Annual revision of the water balance model to incorporate changes in the site layout and additional monitoring data. Additional modelling is also undertaken between the annual revisions, as required.
- Continual investment in equipment used to monitor the water balance (e.g., pond levels and pump rates). This greatly assists in the parameterisation of the water balance model which, in turn, reduces model prediction uncertainty.
- Modelling the mine site water balance prior to the wet season (using current water levels at that time) to assess the probability of controlled and uncontrolled releases, and water ponding in the pit. The results of this assessment are used in risk management.
- Collating monitored pond water levels and pumping rates in a database, in real time, with a user-friendly interface. This allows for easy and rapid assessment of the current status of the site water balance, as well as the analysis of historical data to identify trends and ongoing problems.

4.2.3.2 New Controls – Implemented and Planned

The following controls have been implemented during the reporting period:

- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds (ongoing).
- Pond evaporation and seepage investigations (ongoing).
- Improved water balance modelling reporting (ongoing).
- Runoff investigations of the NOEF and SOEF (ongoing).

The following controls are planned for the next 12 months:

- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds. This is an ongoing commitment by MRM.
- Incorporating manual valve change logs (in the pipe network) into the digital records.
- Setting up weather stations (i.e., to measure rainfall and evaporation) on selected ponds.
- Pond evaporation and seepage investigations.
- Lining of the SPROD to reduce seepage.
- Improved water balance modelling reporting.

- Lining of the eastern levee storage (ELS) to reduce seepage.
- Runoff investigations of the NOEF and SOEF.
- Evaporation measurements/investigations of the NOEF PAF dams and TSF Cell 2 (although it is currently unclear which NOEF PAF dams will be measured).
- Revision of the waste discharge licence to include additional discharge locations. This will allow a greater rate of controlled release from the site (while still complying with the water quality criteria for McArthur River).

4.2.4 Review of Environmental Performance

4.2.4.1 Incidents and Non-compliances

Incidents

McArthur River Mining did not report any incidents impacting upon the site water balance during the 2015 operational period.

Non-compliances

The revised interim 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances.

4.2.4.2 Progress and New Issues

Documentation and Reporting

Reporting in the Main Body of the MMP

The 2014 operational period IM report listed a number of reporting limitations in the surface water management section of the revised interim 2013-2015 MMP (MRM, 2015a). The overarching limitations are:

- It does not accurately reflect current surface water management on site. This is because the adaptive nature of site water management makes the MMP surface water management section out of date almost as soon as it is finalised.
- It does not provide a process to allow for the adaptive management of surface water on site.

Of note, the 2015-2016 site water balance for the McArthur River Mine and Bing Bong Loading Facility references the revised interim 2013-2015 MMP for full details of the development and configuration of the current site water management systems (WRM, 2015a). The revised interim 2013-2015 MMP does not contain this information.

It is acknowledged that the site water balance configuration is continually evolving and operational decisions change (at least) annually. This makes it difficult to provide specific detail regarding the site water management in a multi-year MMP. Notwithstanding this, the current surface water section of the MMP is of limited use for either management (by MRM) or compliance/auditing (by DME or the IM).

The relevance and usefulness of the surface water section of the MMP would be substantially improved if the following recommendations were adopted:

- The water management gap analysis (Section 6.2.1 of the MMP) is reconfigured to provide:
  - Specific and measureable actions.
  - Estimated commencement and completion times.
  - An 'effectiveness ranking' (e.g., 1 to 5) of the impact the task will have on the site water balance.
  - A 'priority ranking' (e.g., 1 to 5) for completing the task. This will most likely be based upon the results of a cost/benefit analysis.
- The gap analysis is updated regularly (e.g., every 6 or 12 months) and produced as a separate document, outside of the MMP.
- Each gap analysis update tabulates the progress on the tasks identified in the previous gap analysis.

It is of note that failure to meet a target does not necessarily constitute a problem. What is important is that performance is monitored. This is a fundamental risk management principle.

Water Balance Modelling and Reporting

The quality of reporting in the most recent water balance modelling report (WRM, 2015a) has improved compared with previous reports (e.g., WRM, 2014; 2013). In particular, the tabulation of key monitoring and modelling data/results provides clarity to the document. This has allowed for easier identification of data and modelling gaps/errors, e.g., clearer reporting has allowed identification of which ponds and pumps are monitored and the probability of uncontrolled releases from different ponds.

Given the improvements in clarity, understanding and error checking that tabulation of data and results provides, additional changes are recommended for reporting. In general, it is recommended that more tables be used. Table 4.2 lists specific comments on the 2015-2016 annual water balance report (WRM, 2015a) to assist in the preparation of future water balance reports.

Table 4.2 – Specific Recommendations to Improve Water Balance Reporting

WRM (2015a) Reference	Recommendation
Table 4.2 Pond storage capacities	Include columns to show: ♦ The pond lining (e.g., none, CCL, geofabric) ♦ The class of water stored in the pond ♦ Whether the pond water level is monitored ♦ This table shows data for the previous (2014-2015) modelling period. There is no table for the current (2015-2016) modelling period. This is confusing ♦ Include a similar table for the current modelling period

Table 4.2 – Specific Recommendations to Improve Water Balance Reporting (cont'd)

WRM (2015a) Reference	Recommendation
Tables 4.3, 4.4 and 4.5 2014-2015 water transfer details	♦ These tables show data for the current (2015-2016) modelling period. There is no set of similar tables for the previous (2014-2015) modelling period. This is confusing as the section on the 2014-2015 model checking refers to this information ♦ Include similar tables for the previous modelling period
Table 7.4 MRM 2015-2016 site water balance	♦ The table shows that off-site uncontrolled releases are expected. The table does not define the quality of the water in these releases and one tends to assume that the water is contaminated. McArthur River Mining has clarified that the uncontrolled releases are from sediment dams ♦ It is recommended that an additional row be included in the table to separate uncontrolled releases of contaminated and clean water ♦ It is recommended that the 'off-site uncontrolled releases' row be split into the following three rows: – Off-site uncontrolled releases – clean water – Off-site uncontrolled releases – sediment dam water – Off-site uncontrolled releases – contaminated water
Table 7.7 Probability of spill from selected ponds	It is recommended that additional columns be added to identify: ♦ Where the ponds spill to (in particular, if it is off site) ♦ The quality of water in the ponds (i.e., class 1 to 6)
Section 7.9 Limitations and associated uncertainties	This section needs to be summarised in a table. Additional information required in the table includes: ♦ An assessment of how the assumption impacts the water balance modelling ♦ What is being done to remove each assumption/reduce each uncertainty ♦ A priority/ranking for the removal/reduction of each assumption/ uncertainty and a due date for completion
Section 9 Recommendations for additional monitoring	This section needs to be summarised in a table. Additional information required in the table includes: ♦ An assessment of how the assumption impacts the water balance modelling ♦ What is being done to remove each assumption/reduce each uncertainty ♦ A priority/ranking for the removal/reduction of each assumption/ uncertainty

Water Balance Sensitivity Testing

A key concern of the IM is the resilience of the water management system. That is, while the current site water balance modelling shows that the probability of uncontrolled off-site releases is within the design criterion (less than 5% probability of uncontrolled release), the key modelling assumption is that model inputs (e.g., rainfall probabilities, site water quality) are correct and the system performs as modelled (e.g., pumps and pipes do not fail). It is unclear whether the system has enough spare design capacity to maintain the release criterion should any of the modelling assumptions fail. As previously reported, the assumptions need testing through sensitivity testing in the following areas:

- Climate change impacts.
- Changes to mine site water quality.

- Modelling of multiple years.

Progress in these areas is reported in Table 4.3. The IM has identified that assumptions in relation to the following matters also require testing:

- Pump or pipe failure.
- Runoff.

It is further recommended that:

- For clarity, the results of all sensitivity analyses are consolidated in one section of the water balance modelling report. The exception is where, for clarity, the sensitivity analysis needs to be with the 'standard conditions' modelling, in which case the sensitivity analysis section of the report should have a subheading for the missing item and a reference to where details are provided in another section of the report.
- The sensitivity analyses are undertaken for all subsequent annual water balance modelling reports.

Pump or Pipe Failure

The site water balance modelling does not assess the risk of pump of pipe failure. That is, the current modelling shows that the probability of uncontrolled off-site releases is within the design criterion (less than 5% probability of release). This is achieved by having the pumps, pipes, storages and their interconnections sized so that excess mine site water can be transferred between storages or released off site in a timely manner before ponds spill. During discussions with MRM (as part of the IM site visit), it was agreed that it is possible for a pump or pipe to fail during a period of high rainfall (say 100 mm over three days). In this case, it could be difficult to repair the failure in a timely manner (e.g., due to reduced site access during wet weather or absence of spare parts) and an uncontrolled off-site release may occur.

The assessment of all ponds and pipes may be onerous. Therefore, the analysis of pump or pipe failure should include an assessment of which ponds represent a risk of uncontrolled off-site discharges, if a pump or pipe should fail. Understanding the impact of failure of the pumps and pipes transferring water to and from these ponds should be undertaken as a priority.

Runoff

The 2015-2016 water balance modelling report (WRM, 2015a) included an assessment of the impact on the site water balance from increased runoff due to capping of the NOEF. The site water balance modelling showed a low sensitivity to NOEF cap runoff estimates. This and similar analyses need to be undertaken for all future annual water balance modelling.

Risk Management of the Site Water Balance

Use of the Underground Void/Open Pit for Water Storage

The current site water balance configuration (pumps, pipes, storages and their interconnections) is sized so that excess mine site water is stored in the underground void/open pit. That is, the probability of uncontrolled off-site releases is kept within the design criterion (less than 5%

probability of uncontrolled off-site release of contaminated water) by using the underground void/open pit as a system buffer. The modelling indicates that this is effective in preventing uncontrolled off-site releases of contaminated water as the system can compensate for losses in storage capacity (e.g., removal of TSF Cell 2 for water storage, removal of the SPROD and the ELS from the network). However, this comes at the expense of increased water volumes in the underground void/open pit.

There is a reasonable chance that the underground void will become full of water, with further inflows to the underground void/open pit resulting in water ponding in the open pit. With the exception of some short-term wet season changes to mine operation (implemented annually), there are no medium- to long-term plans to reduce the risk of water ponding in the open pit. The IM understands that mining cannot continue with more than a small volume of ponded water in the open pit.

Supporting evidence to show that there is a reasonable chance of water accumulating in the open pit is as follows:

- Water ponded in the open pit in 2011.
- The 2015-2016 water balance modelling shows that if, over a two-year period, the two-year average rainfall (or greater) occurs, water will pond in the base of the open pit (WRM, 2015a).
- Water was transferred from TSF Cell 2 to the underground void/open pit for the first time in 2015-2016. This was despite 2015-2016 being a well-below average wet season (about a 16% annual rainfall probability).
- The current storage volume on site is less than previous years with the permanent loss of TSF Cell 2 as a water storage and temporary removal of the SPROD and the ELS from the network.
- There is an increased surface water storage requirement with the lining of SPROD reducing seepage and the expansion and capping of the NOEF increasing runoff.
- The open pit expansion is continually advancing into the underground void, which will eventually be engulfed by the open pit. This poses two problems: the loss of the underground void storage from the water balance and the need to remove the existing water in the underground void for mine expansion.

  Discussions with MRM during the 2012 and 2013, 2014, and 2015 operational period IM site inspections revealed that MRM is concerned about the impact upon mining of ponding in the open pit, e.g., measures were undertaken in late 2014 to stockpile ore in case in-pit ponding reduced mining operations.

During the site inspection, MRM staff advised that they intend to address the medium- to long-term risk of water ponding in the open pit as part of the current EIS. The IM will review this information in next year's report.

Water Storage Ponds and Tailings Storage Facilities

Surface water management issues with the TSF are as follows:

- Tailings storage facility Cell 1 surface runoff is collected in sumps and then pumped to the TSF Mini Dam. The TSF Mini Dam spills to the WMD, with a probability of spill of approximately once every two years (WRM, 2015b). Therefore, any spills from the TSF Mini Dam may render the WMD water unsuitable for release. This is likely to have a substantial adverse impact upon the site water management.

- Tailings storage facility Cell 1 currently has a temporary capping. During the site inspection MRM staff advised the following:

  - The cap is damaged in some places and surface runoff water comes into contact with tailings. This contaminates the surface runoff.

  - There is an ongoing program of temporary, localised repair of the cap.

  - McArthur River Mining intends to improve TSF Cell 1 runoff quality, rather than reduce the chance of spill from the TSF Mini Dam.

The aim of the site water management strategy is to separate water of different quality to minimise the volume of poor quality water and maximise the 'end use opportunities' of the cleaner water classes (WRM, 2015a) (e.g., off-site release). Therefore, the environmental performance of the mine site could be improved by ensuring that the runoff water quality from TSF Cell 1 is such that it can be directed to the WMD without adverse impact on water quality.

The current management of the TSF Cell 1 clay cap does not provide confidence that the surface runoff water quality will improve, which conflicts with MRM's stated management intent. This conflict needs to be resolved.

Accurate Quantification of Water Balance Processes

Simultaneous Calibration of Multiple Parameters

The limitation in the water balance modelling was identified in both the 2012 and 2013, and 2014, operational period IM reports. The best (if not only) way to remove the correlation between parameter estimates is to measure parameters independently. Then, over time, the uncertainty in parameter estimation is reduced. McArthur River Mining is gradually isolating individual elements of the water balance as follows:

- A continual increase in the amount of surface water monitoring undertaken at the mine site.

- Targeted short-term runoff, evaporation and seepage trials.

The 2015 operational period reporting period shows some successes with this approach (e.g., identifying the high level of seepage from SPROD). The IM acknowledges MRM's commitment and this year's successes. Notwithstanding this, there remains substantial uncertainty in the water balance modelling and the isolation of key elements will be a multi-year task. Simultaneous calibration of multiple parameters is a fundamental limitation to surface water management on site and warrants continual attention.

Evaporation Fan/Sprinkler/Fountain Performance

Additional equipment installed by MRM (i.e., water level sensors and flow meters) will assist in improving the fan/sprinkler and fountain evaporation estimates. Notwithstanding this, there has been no reduction in the evaporation estimate uncertainty for these devices in the current operational period.

Previous field trials to quantify evaporation from the mine site ponds (including fans, sprinklers and fountains) have relied upon SILO Data Drill daily evaporation estimates (Queensland Government, 2016). This is gridded, interpolated data based upon historical evaporation measurements across Australia. Evaporation is a complex, site-specific process, and this is particularly true for small ponds in an (otherwise) arid environment (e.g., the McArthur River Mine ponds). The IM considers the use of SILO Data Drill evaporation data inappropriate for the pond evaporation trials. Site specific evaporation measurements are required.

Problems with using the SILO Data Drill evaporation in field trials are acknowledged by MRM (2015b; 2015c). During the IM site inspection, MRM staff advised that there were plans to directly monitor evaporation from selected ponds. The IM acknowledges and commends this.

Groundwater Inflow Rates

The water balance modelling reports acknowledge that there is substantial uncertainty in the groundwater inflow estimation. This limitation in the estimation of groundwater inflow rates was identified in previous operational period IM reports. It is noted that MRM has commissioned studies (in progress) aiming to reduce this uncertainty, although the uncertainty in the groundwater inflow rate remains.

Seepage

Seepage is difficult to measure directly and is usually calculated by difference from known, or more easily estimated, processes. This means that seepage can end up as an error term, where it is used to compensate for uncertainty in the estimation of other water balance components, i.e., it suffers from the problem of 'simultaneous calibration of multiple parameters', described previously in this section.

The 2015-2016 water balance model report highlights a number of problems with the seepage estimates (WRM, 2015a):

- The recorded NOEF seepage is substantially higher than that predicted by the water balance model (Section 5.4.6 in WRM (2015a)).
- There is substantial uncertainty in the seepage from TSF Cell 2:
  - The water balance model estimate for TSF Cell 2 seepage is approximately 2.3 ML/day (Figure 6.8 in WRM, 2015a), whereas the TSF Cell 2 raise 3 design report adopts a seepage rate of 0.2 ML/day (Table 24 in GHD, 2015).
  - The water balance model includes an arbitrary 'additional tailings beach loss' which accounts for the uncertainty in evaporation from, and seepage through, the beach surface. This additional 'beach loss' varies between 3 times (a 'dry' year) and 0.6 times (the 'wettest' year) the seepage loss from the entire site.

This uncertainty in seepage estimates need to be resolved, as recommended in both the 2012 and 2013, and 2014, operational period IM reports. With the exception of SPROD, there has been no reduction in this uncertainty for the current IM review. Notwithstanding this, uncertainty in other pond inflows/outflows is incrementally reducing (through additional monitoring). It is likely that seepage may be the last parameter to show improved accuracy, i.e., since it is calculated by difference, it requires all other inflows/outflows for a pond to be defined first. Of note, during the IM site inspection, MRM staff advised that there is currently considerable focus on better quantification of the TSF Cell 2 evaporation and seepage, particularly from the beach areas. The IM acknowledges and commends this.

McArthur River Mining has undertaken field trials to measure the seepage from the SPROD and SEPROD (MRM, 2015b; 2015c). These trials adopted long-term average evaporation estimates to calculate pond evaporation (see Section 'Evaporation Fan/Sprinkler/Fountain Performance)'. The source of this data is unclear in the reports, and the IM considers the use of long-term average evaporation data inappropriate for the pond seepage trials. Site-specific evaporation measurements are required.

The MRM trial reports also conclude that the use of long-term average evaporation data was inappropriate for the trials. During the IM site inspection, MRM staff advised that there were plans in place to directly monitor evaporation from selected ponds. The IM acknowledges and commends this.

Runoff

During the IM site inspection, MRM staff advised that runoff trials were in place (with more planned) for the NOEF and the SOEF (e.g., SMI, 2016). The IM commends MRM for undertaking such trials. However, accurate measurement of surface runoff is notoriously more difficult than it appears. In particular, surface runoff measurements do not necessarily scale between small and large catchments. This is because:

- Small-scale trials do not accommodate the hydraulic heterogeneity across a larger catchment.
- Different physical processes dominate at different scales, e.g., generally speaking, the relative impact of preferential flowpaths on hydraulic behaviour tends to increase with catchment area.

The application of the trial results to the site water balance modelling requires caution. If not done well, the monitoring could introduce more errors into the water balance model than currently exist.

Reduction in Predictive Uncertainty

The water balance modelling reports shows limited consideration of reducing model predictive uncertainty over time. That is, while predictive uncertainty appears to be reducing, there is no evidence in the water balance modelling report that this reduction is the outcome of any broad plan. A strategy needs to be developed to reduce model parameter and calibration uncertainty. Steps to be considered should include: list the model uncertainties, prioritise their impact on model estimation, identify tasks to reduce this impact, and prioritise the tasks (based upon cost-benefit and practicality). This is a multi-year strategy that needs to be explicitly quantified in the water balance modelling report.

No assessment of the change in predictive uncertainty from year to year is undertaken. For example, the water balance modelling report does not undertake an assessment of the accuracy of the previous year's water balance predictions (made 12 months earlier in the previous annual water balance) against performance (using the updated model). This would be a simple task and provide insight into model performance and changes in predictive uncertainty. The current model 'validation', while worth undertaking, does not assess the accuracy of the previous year's water balance predictions and is of limited use in assessing model predictive uncertainty. Further, the main inputs to the underground void/open pit water balance are the pumped outflows and underground void/open pit stage storage curves (both directly measured) and the groundwater inflows (calculated by difference). Therefore, unsurprisingly, there is a good correlation between recorded and modelled underground void/open pit storage volumes. The water balance modelling report itself confirms this limitation (WRM, 2015a).

Of note, during the IM site inspection, MRM staff showed awareness of this model predictive uncertainty and evidence of explicitly addressing it as a high priority. This on-site behaviour is generally not reflected in the water balance modelling report.

Surface Water Monitoring at Bing Bong Loading Facility

No monitoring of pond water levels and transfers was undertaken at the Bing Bong Loading Facility during the 2015 operational period. It is recommended that the water monitoring program at the facility be reinstated.

McArthur River Mining's performance against previous IM review recommendations relating to mine site water balance is outlined in Table 4.3.

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
Documentation and reporting	The following improvements in reporting are required: ♦ The MMP should provide the broad goals and objectives for mine water management (i.e., MRM's vision). For example: – A list of mine site water management commitments – A statement of intent to continually improve water balance monitoring and reporting – A statement of intent to manage the risk of water in the base of the pit – A list of the current limitations in the mine site water balance, ranked by impact on the water balance	♦ The current MMP is the same as that reviewed last year. Therefore no change

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Documentation and reporting (cont'd)	– An outline of the proposed mine expansion during the MMP and the site water management changes that may be required (e.g., additional levees, ponds and/or pumps) – A prioritised list of options that may be considered to improve mine site water management. This should include commentary on each option (e.g., ease of implementation) and a feasibility-level cost/benefit analysis ♦ There needs to be consistency between on-site water management practice, the MMP and water balance modelling reporting. The water balance modelling reporting needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty	
Water balance scenario testing	Changes in climate: ♦ The possible impact of climate change on the site water balance needs to be addressed Changes in water chemistry: ♦ The water balance needs to assess the risks posed by possible deterioration in site runoff and seepage water quality Modelling of multiple years: ♦ Assessment of multiple years with the same site configuration should be considered to manage the risk of high starting pond water levels (following two or more consecutive wet years)	♦ Climate change recommendations not adopted. During discussions with MRM during the 2016 IM site inspection, it was agreed that climate change will be incorporated, as a sensitivity analysis, into future water balance modelling ♦ Water chemistry recommendations adopted. The 2015-2016 water balance modelling report (WRM, 2015a) undertook this analysis by changing the controlled release dilution rate from 1 part mine water to 15 parts McArthur River water (1:15) to 1:50. It was found the changes had negligible impact upon the overall site water balance. It is unknown why a 1:50 dilution ratio was chosen. The adopted change in site water quality needs to be justified with: – Current water quality monitoring data and/or predictions (e.g., pond water quality estimates, TSF/NOEF seepage estimates) – Input from professionals with expertise in geochemistry ♦ Multiple year modelling recommendations adopted with modelling of two consecutive years in a number of reports (e.g., WRM, 2015a; 2015b; 2015c; 2015d). The results in all four of these reports shows a higher risk of water ponding in the open pit than that when only one year is modelled

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Water balance scenario testing (cont'd)		♦ Water balance modelling should cover a period at least as long as that required for MRM to reduce any risk of excess mine site water; predicted by the modelling (e.g., allowing time to design and build a new storage) ♦ During discussions with MRM staff during the 2016 IM site inspection, it was agreed to model to the start of the EIS project (April 2018)
Water storage ponds and tailings storage facilities	♦ More comprehensive reporting of TSF Cell 1 water management design and operation is required	♦ Complete. TSF Cell 1 included in water balance model
	♦ The risk and impact of TSF Cell 2 spills contaminating water stored in the WMD, and thereby making it unsuitable for off-site release, needs to be assessed	♦ The risk of spill from the TSF Cell 2 to the WMD has been modelled. However, the impact of the spill on the site water balance (by contamination of WMD water) has not been undertaken. WRM (2016) confirms this is a risk. This IM recommendation has not been adopted
Risk management of the site water balance	Variation in rainfall: ♦ McArthur River Mining needs to develop the surface water management system to the point where there is sufficient capacity that variation in rainfall between years (and sequences of consecutive wet/dry years) is treated as business as usual and not something abnormal	♦ Not addressed
Accurate quantification of water balance processes	The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: ♦ The amount of simultaneous calibration of multiple parameters needs to be reduced ♦ Evaporation fan/sprinkler/fountain performance needs to be accurately quantified ♦ Groundwater inflow rates need more accurate estimation ♦ Seepage rates and runoff rates need more accurate estimation ♦ A strategy needs to be developed to reduce predictive uncertainty over time	♦ Incremental improvement has been made in most areas ♦ The reduction in uncertainty has identified: – Specific actions that could be undertaken to improve water management (e.g., lining of SPROD) – Specific areas that warrant targeted investigation (e.g., seepage and evaporation estimates for the TSF Cell 2) ♦ McArthur River Mining has responded positively to identified actions ♦ Given the large degree of uncertainty and the fact that improvement can only be made incrementally each year, this recommendation is ongoing
NOEF expansion flood study	McArthur River Mining needs to review the most recent flood study and flood and compare impacts to those provided in the Phase 3 EIS to: ♦ Determine if the off-site flood impacts have increased	Removed from ongoing recommendations as this should be undertaken as part of the new EIS for the NOEF expansion

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
NOEF expansion flood study (cont'd)	♦ Demonstrate that the current flood level estimates against the NOEF batters do not compromise the MRM commitment to place all PAF material above the 1% annual exceedance probability (AEP) flood level	
Runoff modelling of the new clay capping on the NOEF	The method of incorporating the new clay capping into the 2014-2015 water balance modelling (WRM, 2014) does not provide confidence that the impact of the clay capping on the water balance has been adequately accounted for. The method of modelling the clay capping needs revision	Completed. A sensitivity analysis showed that the site water balance had low sensitivity to changes in the volume of clay capping runoff
2012 and 2013 Operational Periods		
Documentation and reporting	Increased detail is required in the reporting of the following items: ♦ The rainfall-runoff model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted ♦ The water balance model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted ♦ The monitoring of water balance components, in particular what is monitored, the frequency of monitoring and the accuracy of the measurement ♦ How the monitoring data is used in the water balance modelling ♦ A summary table of water balance storages, inflows and outflows needs to be included in the water balance modelling reports ♦ How the tailings storage facilities are included in the site water balance ♦ How the TSF Cell 1 surface runoff is treated in the water balance model	♦ In the 2015-2016 water balance modelling report: – Substantial improvements in the reporting/tabulating of system and monitoring data – Little improvement in documentation of calibration procedures ♦ Further improvement required
Changes in climate	The possible impact of climate change on the site water balance needs to be addressed	♦ Recommendation not adopted
Changes in water chemistry	The water balance needs to assess the risks posed by possible deterioration in site runoff and seepage water quality	♦ Undertaken in 2015-2016 water balance modelling ♦ Needs to be included in all future annual water balance modelling

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
Monitoring	Studies need to be undertaken to quantify the performance of evaporation fans, sprinklers and fountains. Targeted monitoring of selected ponds needs to be undertaken to reduce the number of processes that need to be estimated by difference in the water balance model	♦ In progress ♦ McArthur River Mining has undertaken two separate trials (MRM, 2015b; 2015c). The study results were inconclusive ♦ Further studies are required
Mine site water balance model calibration	The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: ♦ The groundwater inflow rate ♦ Seepage estimates ♦ Additional sensitivity analysis (which needs to be undertaken in the water balance modelling) While the reduction in uncertainty is implicit in most of the recommendations, the key requirement here is that the reporting quantifies how the uncertainty is reduced in each successive year	♦ No improvement in the quantification of the reduction in model uncertainty in the water balance reporting
Evaporation data	The evaporation data adopted in the water balance model uses long-term evaporation averages prior to 1970. The effect of this on the water balance model results needs checking	Not completed. Use of long-term evaporation data is not believed to be an important consideration in the overall water balance results. This recommendation will not be reported on in subsequent IM reports
Modelling of multiple years	Assessment of multiple years with the same site configuration should be considered to manage the risk of high starting pond water levels (following two or more consecutive wet years)	Multiple year recommendations adopted in the 2015-2016 water balance modelling. During discussions with MRM staff as part of the 2016 IM site inspection, it was agreed to model three consecutive years in future studies
2011 Operational Period		
TSF	A review of available capacity to store tailings, process water and rainfall runoff while maintaining sufficient freeboard, also taking into account the initiative to increase evaporation by using a larger part of the WMD. A review of the water balance including detailed water balance modelling should be carried out	Completed
TSF Cell 2	Following a water balance review, excess water to be removed from the facility	Completed

4.2.4.3 Successes

The successes of MRM's site water management over the reporting period and up to the time of the IM site visit (27 to 28 April 2016) include the following:

- There is a continuing overall awareness and appreciation by MRM of the importance of mine site water management on mine operation and on environmental management. There is also an appreciation of the complex interaction between different areas of mine operation and water management, and the need to manage risks associated with this.
- Additional monitoring equipment has been installed since the last IM review (flow meters and pond water level sensors). The data from the new and existing sensors is now transferred in real time to a database. Software has been developed to manipulate and display the data in in an easy-to-understand format.
- Seepage at SPROD is being addressed through the installation of a synthetic pond liner.
- A large difference in estimates for TSF Cell 2 seepage between the water balance modelling and the TSF Cell 2 raise 3 design report has been identified and is being investigated.
- McArthur River Mining has committed to complete a cost/benefit analysis of lining the ELS.
- The water balance modelling has included sensitivity analysis of multiple years, changes in water chemistry, and increases in runoff.
- There has been improvement in the water balance modelling reporting.
- Field trials have been undertaken to better quantify seepage from the SPROD and SEPROD.
- Tailings storage facility Cell 1 and 2 are now included in the water balance model.

4.2.5 Conclusion

The reporting period has seen continual improvement in the site water balance in the following two areas:

- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds.
- Water balance model reporting and scenario testing.

Both the 2012-2013 and 2014 operational periods IM reports considered the mine site water balance to be somewhat of a ‘black box’. That is, the site water always ‘balanced’ (without uncontrolled off-site releases of contaminated water). However, there was uncertainty as to how this was achieved. The 2015 operational period has seen reduction in this uncertainty. This reflects the monitoring and modelling reaching a stage of development where the behaviour of individual elements of the system is better understood. This improved understanding has highlighted areas of concern that warrant further investigation and consideration, and MRM has/is either rectifying or undertaking further investigations. The IM acknowledges and commends this. New issues that have come to light in the 2015 operational period are:

- Reliance upon the underground void/open pit as a balancing storage.
- Reduction in water storage capacity:
  - Permanent loss of TSF Cell 2.
  - Temporary loss of the ELS while investigations continue into the source of TDS to the McArthur River diversion channel. There will also be a temporary loss of the ELS if MRM decides to line the storage.
- Substantially reduced seepage from SPROD once it is lined (resulting in more water to manage).
- The need to test the resilience of the water balance network (e.g., with respect to pump or pipe failures).
- Difference between the site water balance and engineering design seepage estimates for TSF Cell 2.
- Difference between site water balance estimates and recorded totals for NOEF seepage.

It is important to note that the identification/isolation of elements of the water balance that are of concern is a positive outcome because it indicates a detailed level of system understanding that allows for problems to be accurately identified. This, in turn, should lead to targeted responses, which reflects a commitment by MRM for continual improvement of site water management. It is anticipated that the ongoing improvement of the water balance monitoring and modelling will continue to reveal areas of water management that require improvement.

Ongoing and new IM recommendations related to mine site water balance issues are provided in Table 4.4.

Table 4.4 – New and Ongoing Mine Site Water Balance Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Documentation and reporting	The following improvements in reporting are required: ♦ The MMP should provide the broad goals and objectives for mine water management (i.e., MRM's vision). For example: – A list of mine site water management commitments – A statement of intent to continually improve water balance monitoring and reporting – A statement of intent to manage the risk of water in the base of the pit – A list of the current limitations in the mine site water balance, ranked by impact on the water balance – An outline of the proposed mine expansion during the MMP and the site water management changes that may be required (e.g., additional levees, ponds and/or pumps) – A prioritised list of options that may be considered to improve mine site water management. This should include commentary on each option (e.g., ease of implementation) and a feasibility-level cost/benefit analysis	Medium

Table 4.4 – New and Ongoing Mine Site Water Balance Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Documentation and reporting (cont'd)	♦ The water balance modelling reporting needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty Increased detail is required in the reporting of the following items: ♦ The rainfall-runoff model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted ♦ The water balance model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted ♦ The monitoring of water balance components, in particular what is monitored, the frequency of monitoring and the accuracy of the measurement ♦ How the monitoring data is used in the water balance modelling	
Water balance scenario testing	Changes in climate: ♦ The possible impact of climate change on the site water balance needs to be addressed Changes in water chemistry: ♦ The water balance needs to assess the risks posed by possible deterioration in site runoff and seepage water quality ♦ The adopted change in site water quality needs to be justified with: – Current water quality monitoring data and/or predictions (e.g., pond water quality estimates, TSF/NOEF seepage estimates) – Input from professionals with expertise in geochemistry Modelling of multiple years: ♦ An assessment should be undertaken that involves modelling to the start of the EIS project (April 2018)	Medium
Water storage ponds and tailings storage facilities	♦ While the risk of TSF Cell 2 spills to the WMD has been modelled, the impact (on the site water balance) of contaminating water stored in the WMD, thereby making it unsuitable for off-site release, needs to be assessed	Medium
Risk management of the site water balance	Variation in rainfall: ♦ McArthur River Mining needs to develop the surface water management system to the point where there is sufficient capacity that variation in rainfall between years (and sequences of consecutive wet/dry years) is treated as business as usual and not something abnormal	Medium
Accurate quantification of water balance processes	The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: ♦ The amount of simultaneous calibration of multiple parameters needs to be reduced ♦ Evaporation fan/sprinkler/fountain performance needs to be accurately quantified ♦ Groundwater inflow rates need more accurate estimation ♦ Seepage rates and runoff rates need more accurate estimation ♦ A strategy needs to be developed to reduce predictive uncertainty over time While the reduction in uncertainty is implicit in most of the recommendations, the key requirement here is that the reporting quantifies how the uncertainty is reduced in each successive year	Medium

Table 4.4 – New and Ongoing Mine Site Water Balance Recommendations (cont'd)

Subject	Recommendation	Priority
New Items		
Documentation and reporting	Reporting in the main body of the MMP: ♦ The water management gap analysis should be reconfigured to provide: – Specific and measureable actions – Estimated commencement and completion times – An 'effectiveness ranking' (say 1 to 5) of the impact the task will have on the site water balance – A 'priority ranking' (say 1 to 5) for completing the task. This will most likely be based upon the results of a cost/benefit analysis ♦ The gap analysis should be updated regularly (say every 6 or 12 months) and produced as a separate document, outside of the MMP Water balance model reporting: ♦ It is recommended that more tables are used to improve clarity, understanding and error checking ♦ Sensitivity analysis results should be consolidated in one section of the water balance modelling report	Medium
Water balance sensitivity testing	Pump or pipe failure: ♦ An assessment of the impact of pump or pipe failure should be undertaken Sensitivity analysis: ♦ Needs to be undertaken for all subsequent annual water balance modelling reports	Medium
Water storage ponds and tailings storage facilities	♦ The risk of spills from the TSF Mini Dam to the WMD, thereby making it unsuitable for off-site release, needs to be assessed ♦ The MRM intent of improving TSF Cell 1 runoff quality is not reflected in current management of the cell's clay capping. This needs to be resolved	Medium
Risk management of the site water balance	Use of the underground void/open pit for water storage ♦ MRM needs to provide a medium- to long-term plan which resolves the conflict between mine operations and using the underground void/open pit as a water storage	Medium
Accurate quantification of water balance processes	♦ Surface water monitoring at Bing Bong Loading Facility needs to be resumed	Medium

4.2.6 References

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WRM. 2015d. Tailings Storage Facility Water Storage Volume Behaviour Assessment. Report No 0790-18-B2. Dated 9 June 2015. Prepared by WRM Water and Environment for McArthur River Mining Pty Ltd, Winnellie, NT.

WRM. 2016. Response to Independent Monitor's Report Comments on MRM Site Water Balance Modelling. Report No 0790-21-C. Dated 7 March 2016. Prepared by WRM Water and Environment for McArthur River Mining Pty Ltd, Winnellie, NT.

4.3 Surface Water Quality Management

4.3.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of surface water quality, and is based on review of:

- Observations and discussions with MRM personnel during the site inspection.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's environmental monitoring report (MRM, 2015a), supplementary monitoring report (MRM, 2015b), mining management plan (MRM, 2015c), surface water monitoring report (MRM, 2015d) and WDL monitoring report (MRM, 2015e).
- The Excel workbook provided by MRM that contains collated laboratory and in situ water quality data for 2014 and 2015.
- Laboratory documents including sample receipt notification, certificates of analysis (analysis results) and quality control reports.
- Various MRM forms and similar documents such as chain of custody forms, survey results, incident notification letters, and correspondence between MRM and other parties.
- Aerial and other photographs of the MRM mine site provided by MRM.
- Other documents such as MRM's waste discharge licence (WDL) and DME compliance audit reports.

4.3.2 Key Risks

The key risks to surface water quality, as described in the risk assessment (Appendix 2), are summarised below for each of the mine site (and surrounds) and Bing Bong Loading Facility (and surrounds).

Mine Site and Surrounds

As noted in previous IM reports, the nature of the mine and processing plant at the McArthur River Mine is such that a number of risks are inherently associated with the operation. While some of these are relatively minor, the following key risks have been recognised:

- Poor quality seepage and surface runoff, primarily from areas such as the TSF and NOEF (which contain tailings and waste rock respectively), may result in poor water quality in McArthur River tributaries such as Surprise Creek and Barney Creek, as well as McArthur River itself. The water quality variables of most concern are pH, salts (e.g., sulfates) and trace metals (e.g., Pb, Zn, As, Cd and Cu). Poor water quality can result in loss of aquatic flora/fauna (including benthic biota) and bioaccumulation of metals with consequent human health or animal health implications should this biota be consumed. This type of risk also includes impacts such as those that might be associated with:
    - Tailings storage facility embankment failure (in which case the tailings solids themselves would also present a significant hazard) and/or the TSF overtopping.

  – Neutral or saline leachates from waste rock[5].

  – Saline seepage from areas such as the ELS potentially reporting directly to McArthur River.

  – Poor quality surface runoff from waste rock that has been used for construction around the site but, given the revised geochemical classification, should not have been used for such purposes.

  Changes in the conductivity (EC) in McArthur River, which may be due to the influence of the Cooley deposits and oxidising pyritic shale that is intercepted by the McArthur River diversion channel (as suggested by MRM) and/or the ELS and SOEF (as suggested by the DME), also requires consideration.

- Poor quality surface runoff due to soil contamination from depositional dust generated by mining and processing operations, primarily from the TSF, ROM pad, crushing circuit and external concentrate storage area, and direct dust deposition itself, may cause poor water quality (pH, salts, trace metals) in Surprise Creek, Barney Creek and, again, McArthur River. As noted above, this can have adverse impacts on aquatic flora/fauna and, potentially, human health or animal health via bioaccumulation.

It has also been noted by MRM that process water itself if not properly contained poses an environmental hazard due primarily to elevated concentrations of sulfate, other major ions, trace metals (e.g., Pb and Zn), and process additives (MRM, 2015c).

A key closure-related risk concerns the final pit lake water quality and the potential for poor quality water to reach nearby watercourses, with adverse impacts as noted above. This is discussed further in Section 4.8. A related long-term concern is the potential for poor quality drainage from OEFs and the TSF due to factors such as failure of the cover(s) and/or mistaken classification (and hence management) of waste rock, with adverse effects on surface water quality.

Bing Bong Loading Facility and Surrounds

With respect to surface (including marine) water quality, risks associated with the Bing Bong Loading Facility were fewer than those found at the mine site. However, a number of risks were identified that warrant discussion, including:

- Poor quality surface runoff due to contamination from depositional dust generated by loading operations (and other material management procedures) causing poor water quality with respect to trace metals (e.g., Pb and Zn) in onshore drainages and the nearshore environment. This can have adverse impacts on aquatic and marine flora/fauna and, potentially, human health or animal health via bioaccumulation.

- Concentrate spillages or direct dust deposition during MV Aburri barge loading or trans-shipment, directly affecting coastal or marine water quality, with consequent adverse impacts as described above.

[5] As noted elsewhere in this report, the waste rock classification was amended in 2013 to include rock that potentially produces a metalliferous and saline runoff.

As was the case in the previous reporting period, the risk associated with the release of dredge spoil due to embankment failure, with consequent adverse impacts on aquatic and marine flora/ fauna and, potentially, human health or animal health via bioaccumulation, was minimised during the reporting period due to the lack of dredging activities.

4.3.3 Controls

4.3.3.1 Previously Reported Controls

Mine Site and Surrounds

In terms of the main sources of contaminants that can affect surface water quality on the mine site and surrounds, existing controls are discussed in the relevant sections that address:

- Geochemical classification of mine materials, materials management and monitoring, and design, construction and operation of the TSF and NOEF, all of which act as controls in relation to seepage and surface runoff from these facilities.
- Materials management and generation of contaminated dust.

Within the surface water management system itself, existing controls are best summarised in the operation's revised interim 2013-2015 MMP (MRM, 2015c), where key elements include:

- Classifying mine water into various categories. This is further discussed below given the new water classification system that has recently been adopted for the mine (WRM, 2015a).
- Establishing the following objectives (which remain unchanged from those described previously) with a view to minimising the discharge of mine affected (or 'contaminated') surface water to the surrounding environment:
  - Minimise raw water consumption by maximising the reuse of process water.
  - Evaporate excess contaminated water.
  - Maintain a non-release system for 'contaminated' mine waters, except under extreme conditions, as approved.
  - Provide adequate storage in the surface water management system.
  - Minimise the generation and release of contaminants, with an emphasis on source control.
  - Minimise the retention of 'clean' water.
- Achieving these objectives by implementing measures (which remain unchanged from those described previously) such as:
  - Separating clean, dirty and contaminated waters.
  - Intercepting as much surface water and groundwater from around the pit before it contacts the waste rock.

- Storing dirty or high-sulfate waters in dedicated storages in the dry season until they can be discharged in the wet season under the conditions of the WDL.
- Ensuring that the TSF has a tailings beach around the perimeter of the dam against the walls in all but above average rainfall events.
- Minimising raw water use in the mill, using reclaimed TSF water and mine dewatering water as much as possible.
- Operating contaminated dams at their maximum operating levels to maximise evaporation.
- Using sprinklers and evaporation fans as much as possible.
- Where possible (i.e., in all but extreme rainfall events), using the open pit/underground voids as the ultimate fall-back position for water storage to avoid unplanned discharges into the receiving environment (and noting that this may impede production).

For the purposes of this report, performance of the surface water management system is assessed largely in terms of adherence to the WDL conditions and the revised interim 2013-2015 MMP (MRM, 2015c), although additional levels of assessment are discussed herein where relevant. The effectiveness of the management and mitigation strategies has been determined by the monitoring program results presented in MRM's surface water monitoring report (MRM, 2015d) for the period 1 July 2014 to 30 June 2015 and MRM's WDL monitoring report (MRM, 2015e) for the same period, supplemented by review of the data provided by MRM in separate spreadsheets for the period 1 January 2014 to 31 December 2015. During the IM reporting period (i.e., 1 October 2014 to 30 September 2015), MRM operated under two WDLs, with the conditions of WDL 174-06 remaining applicable until WDL 174-07 became effective on 16 January 2015. The expiry date for WDL 174-07 was notionally 30 September 2016, although WDL 174-08 didn't become effective until 17 March 2016, i.e., well after the current IM reporting period.

Surface water management incidents, e.g., discharges in contravention of the site’s WDL, are discussed in Section 4.3.4.1. Other areas where MRM could fail to comply with surface water management requirements, as defined by MRM, include the following (MRM, 2015c):

- Breach in integrity of ponds, pipes or drains.
- Overflow from contaminated water management system.

Should an incident occur, specific corrective actions range from cleaning out sedimentation ponds through to modifying the operating strategies for the surface water management system, and providing other rectification measures as appropriate.

An important feature of MRM's controls at the mine site with respect to water discharges is undertaking a mixing and dilution calculation prior to all discharges using a release (dilution) calculator, where this is based on measured water quality and flow rates. This allows MRM to calculate theoretical concentrations at the McArthur River point of compliance, i.e., SW11, which can then be compared with the trigger values specified in the WDL. Review of the spreadsheet shows that it is a mass balance calculation that takes no account of changes in metal speciation after discharge, assumes complete mixing, and includes a 25% safety factor. While a simple approach, this is likely to be an effective management tool but would benefit from verification by actual measurements at SW11 during the discharge event.

A key aspect of MRM's management plan, as referred to above, is an environmental monitoring system. The stated aims and objectives of the surface water monitoring program (MRM, 2015d) are to:

- Measure the water quality in McArthur River, Barney Creek, Surprise Creek, Emu Creek and Glyde River.
- Compare the measured water quality in McArthur River with site-specific trigger values (SSTVs).
- Compare water quality from downstream monitoring sites with upstream control sites to help identify possible contamination of surface water.
- Identify the potential sources of any contamination measured in McArthur River or the local tributaries.
- Determine the efficacy of the controls implemented by MRM to prevent contamination of surface waters.

This monitoring program includes sampling sites located upstream and downstream of the mine and monitoring at site water storage points, with both in situ and laboratory (NATA-accredited or similar) analyses being undertaken.

As has been noted in previous IM reports, MRM devotes considerable effort to this monitoring program. Key elements of the program include:

- Natural surface waters – sampling sites are shown in Figure 4.1, including SW11 that is used to determine compliance with MRM's WDL. The McArthur River monitoring sites are sampled weekly unless insufficient water exists to take a representative sample. Surprise Creek, Barney Creek and Emu Creek are intermittent streams with varying flow regimes that reflect seasonal rainfall patterns. Sites on these creeks are therefore sampled weekly as part of the surface water program when flow is observed at the sampling site. Site SW08 on the downstream McArthur River is located at the Burketown Crossing in Borroloola (about 60 km downstream from the mine site) and is sampled on a monthly basis.

  Both in situ (e.g., pH, temperature, dissolved oxygen (DO), EC, turbidity, oxidation-reduction potential (ORP)) and laboratory (e.g., pH, EC, total dissolved solids (TDS), total suspended solids (TSS), major ions and filtered (<0.45 μm) trace metals) analysis is undertaken.

NATURAL SURFACE WATER MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.1

Additional laboratory analysis (e.g., total metals) is undertaken for samples that are taken as part of the WDL monitoring program, with organics (total petroleum hydrocarbons (TPH) and benzene/toluene/ethylbenzene/xylenes/naphthalene (BTEXN)) also being determined at selected sites. However, elemental scans for more than 50 elements that were previously undertaken on total and filtered samples from each site on an annual basis no longer occurs, reportedly due to cost constraints.

It is worth noting that if the upstream control site is not flowing on the same day as corresponding downstream sites are sampled, then those sites have in the past been referred to as 'artificial surface waters' (ASWs). If the control sites are flowing, then the corresponding downstream sites were referred to as 'surface waters' (SWs). This has recently been revised by MRM such that the criterion is now flowing water at the actual sampling site rather than the control site. However, even with this updated criterion, the potential remains for confusion with the artificial surface water sampling program (described below) that includes sites such as the TSF and waste dump drainage. For example, MRM (2015d) contains a section called 'Artificial Water Quality' that refers to sites labelled ASW18, ASW19 and ASW06, all of which apparently correspond to sites SW18, SW19 and SW06 as shown in Figure 4.1 but reflect different hydrological conditions. While the IM accepts the benefits of differentiating between these results, use of the term artificial surface waters sites to describe sites within both streams/rivers and dams/ponds/sumps, where the latter are artificial waterbodies that are part of MRM's water management system (see following bullet point), remains ambiguous.

- Artificial surface water – all sampling sites are shown in Figure 4.2, which includes both 'committed' and 'non-committed' sites. The latter have been used by MRM for internal purposes where data was not necessarily reported to the regulator. However, following an instruction from DME, all data from both committed and non-committed sites is now provided to the regulators. These sites are generally located around the processing facility, TSF, open pit and NOEF. Sampling is generally on a monthly basis, subject to factors such as access to high-risk sites or the lack of water at the sampling site. However, some sites (e.g., NOEF SEL1, NOEF SPROD, OP P2) are sampled on a weekly basis, some (e.g., BC NWST, OP DSD) have event-based sampling, and a third group (e.g., NOEF SPROD SEEP1) are sampled on a monthly basis but only during the dry season. Both in situ (e.g., pH, temperature, DO, EC, turbidity, ORP) and laboratory (pH, EC, TDS, TSS, major ions and filtered (<0.45 μm) trace metals analysis is undertaken. Hydrocarbons are also determined on a biannual (twice per year) basis.

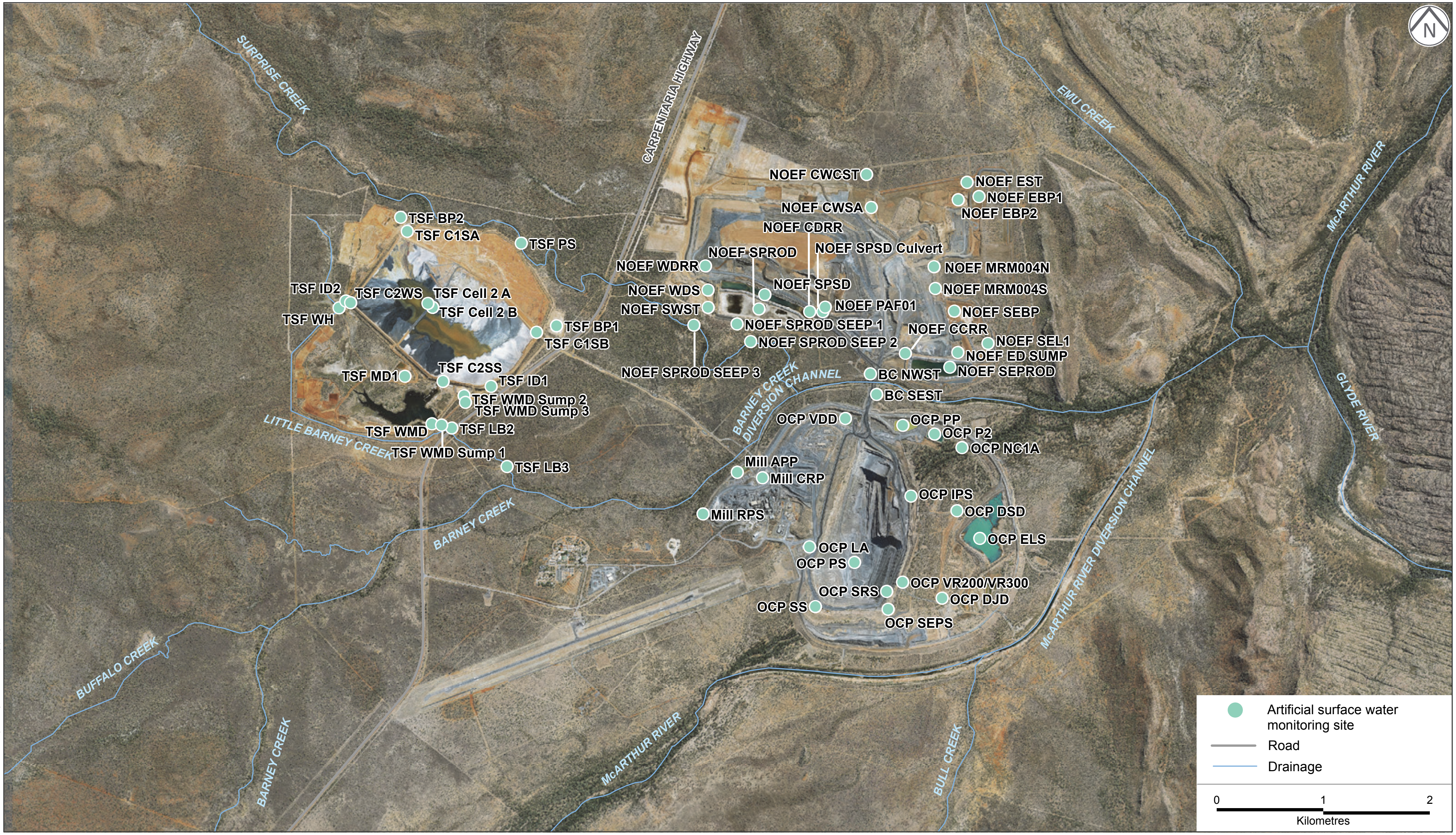
Bing Bong Loading Facility and Surrounds

In terms of sources of contaminants that can affect surface water quality at Bing Bong Loading Facility and surrounds, existing controls relating to generation of contaminated dust (primarily when concentrate is loaded onto the MV Aburri transport barge and when trans-shipment occurs) are discussed in Section 4.13.

ARTIFICIAL SURFACE WATER MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.2



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Advice from MRM (MRM, 2016) is that the general surface water management objectives that apply to Bing Bong Loading Facility are compliance with the WDL and protection of the receiving environment. Surface water management at Bing Bong Loading Facility involves primarily (Figure 4.3):

- A surface runoff pond (SRP1) that collects runoff from the industrial area around the Bing Bong Loading Facility and return water from the truck wash.
- Two overflow ponds (SRP2 and SRP3) that collect water pumped from SRP1.
- Two water collection sumps (that collect surface runoff and pump it back to SRP1), two 1137-L tanks located on the MV Aburri that are pumped to SRP1 via the dock sump, and collection of runoff from the roof of the concentrator shed so that it reports to SRP1.

A dredge spoil emplacement area (DSEA) (also referred to as 'dredge spoil ponds') is located immediately next to the Bing Bong Loading Facility. This area consists of five ponds, where decant from settled dredge spoil passes sequentially through the ponds to allow solids to settle and is then discharged via the dredge spoil drain to the tidal mud flats east of the Bing Bong Loading Facility area (see Figure 4.3). No dredging was undertaken in the swing basin or navigation channel over the 2014-2015 reporting period and hence no active releases occurred from the dredge spoil settlement ponds to the receiving environment during this period.

Measures to minimise impacts on water and sediment quality at the Bing Bong Loading Facility remain as described in last year's IM report and include:

- Ensuring that all runoff from the concentrate shed and the hardstand areas around the loading facility is captured within SRP1 and disposed of primarily via sprinkler and pond evaporation.
- Intercepting seepage in a perimeter drain around dredge spoil ponds and directing this water away from vegetated areas and towards the discharge point (BBDDP) in the marine environment.
- Loading the concentrate onto the MV Aburri via a covered conveyor system.

As with the mine site, MRM devotes considerable effort to surface water monitoring at Bing Bong Loading Facility and in the surrounding marine environment. The routine marine monitoring program is to assess whether MRM activities in the area have a significant impact on the local marine ecosystem. The specific objectives of the program are to (MRM, 2015e):

- Monitor the quality of the water, sediments and biota in the receiving environment adjacent to the Bing Bong Loading Facility.
- Determine the impact on the receiving environment from the Bing Bong Loading Facility operations.
- Determine mitigation options for any impacts deemed unacceptable.

LOCAL DRAINAGE FEATURES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.3

Artificial surface water monitoring is undertaken to determine (MRM, 2015a):

- The level of contamination and therefore management options.
- The risk to the receiving environment (with respect to the dredge spoil drain).

The objectives of the marine monitoring program were met through a series of specialist projects that addressed seawater quality (using DGTs[6]), nearshore sediment quality, seagrass surveys and sediment quality (including lead isotope ratios). Marine water samples were also collected from 20 sites in the vicinity of the Bing Bong Loading Facility and both east and west of that facility, as well as throughout the Sir Edward Pellew Group of Islands (SEPI), in December 2014 as part of the annual marine monitoring program (which also included sediment and biota samples). Apart from DGTs, which are discussed below, these various components of the monitoring program are addressed elsewhere in this report.

From a surface water perspective, key elements of the monitoring program include:

- Marine waters – DGTs were deployed at six sites (Figure 4.4) for the 2014-2015 monitoring period (10 July 2014 to 8 July 2015). Subsequent analysis was for trace metals and Pb isotope ratios. Deployments were undertaken on a monthly basis, with each deployment being for either four or five days. DGT-labile Zn, Pb, Cd, Co, Cu, Ni, Mn and Fe were determined. The results were assessed in terms of ANZECC/ARMCANZ (2000) guideline values for marine waters (95% level of protection and 99% level of protection).
- Artificial surface waters – sampling sites are shown in Figure 4.5 (three runoff ponds and three sites along the dredge spoil perimeter drain[7] (DSD)). Sampling is generally on a monthly basis, subject to dry season conditions, although hydrocarbons are determined on a biannual (twice per year) basis. Both in situ (e.g., pH, temperature, DO, EC, turbidity) and laboratory (e.g., TDS, TSS, filtered (<0.45 μm) trace metals) analysis is undertaken. Figure 4.3 shows the location of site BBDDP, which is the authorised discharge point specified in the WDL.

4.3.3.2 New Controls – Implemented and Planned

The classification system for mine water at the McArthur River Mine has been revised to include six water classes based primarily on quality, as follows (WRM, 2015a):

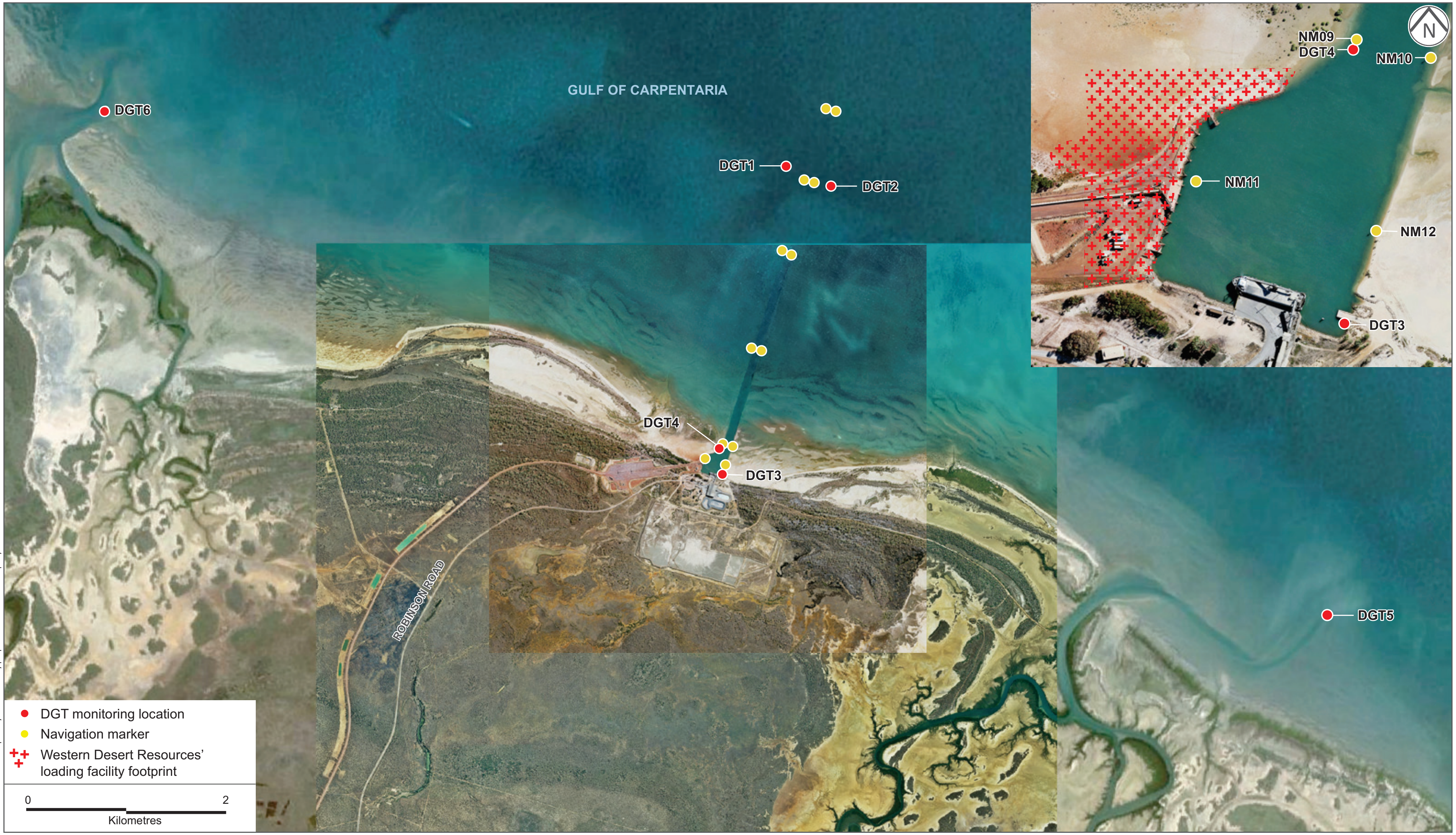
- Class 1 – diverted water. This is typically sourced from upstream catchments that are unaffected by mining. Wherever possible, this water is diverted away from mining activities.
- Class 2 – surface water. This is typically sourced from cleared areas and clay/stockpile areas. This runoff requires treatment through a sediment trap prior to release.
- Class 3 – treated water. This is permeate from the water treatment plant (and is discussed further below).

[6] The ‘diffusive gradients in thin films’ (DGT) technique provides in situ determination of thermodynamically and kinetically labile metal species in aquatic systems (Tsang, 2015).
[7] The fourth site did not contain enough water to allow representative sampling.

DGT MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.4



Source: Tsang, 2015.

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ARTIFICIAL SURFACE WATER MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.5

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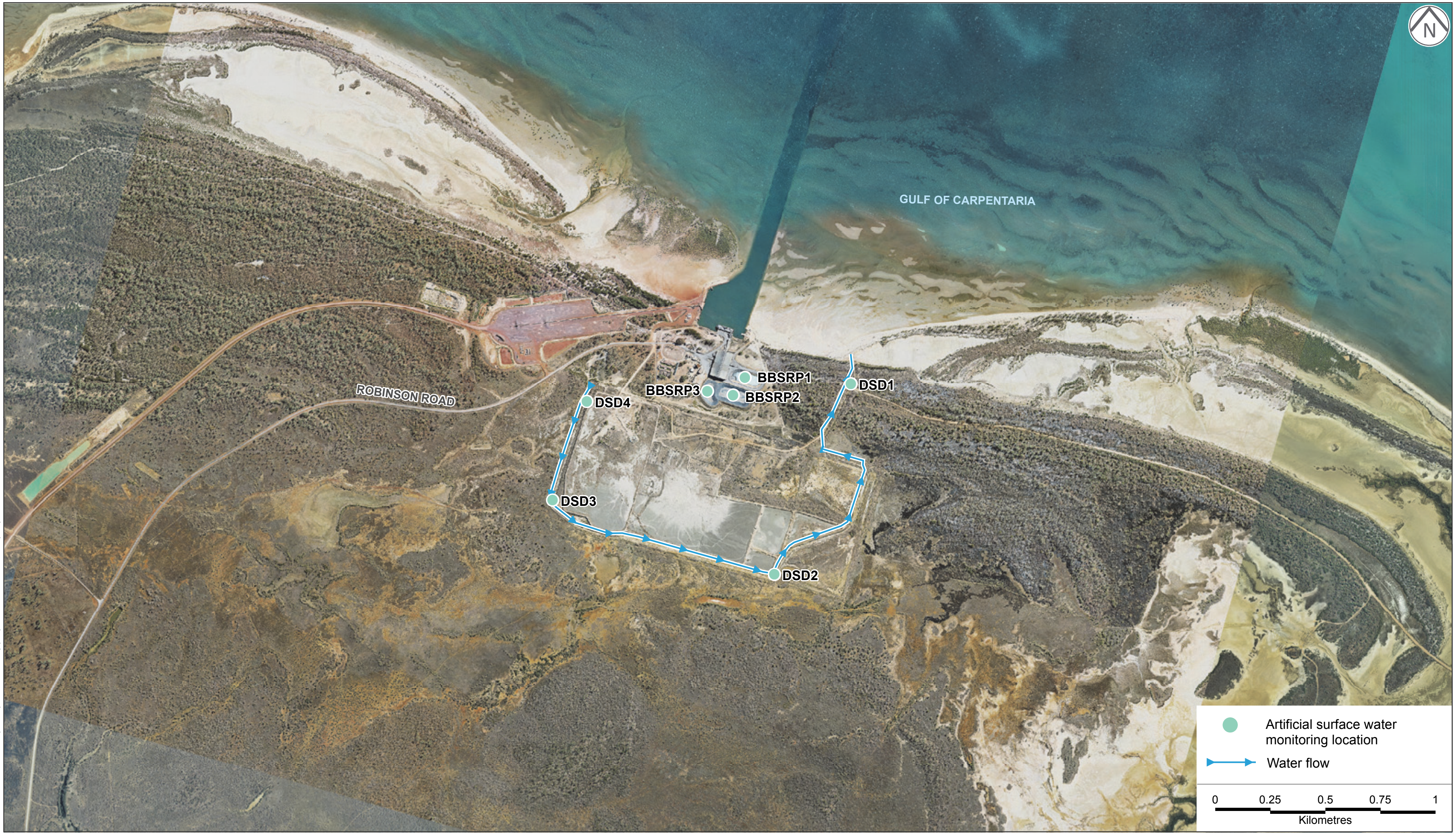


- Class 4a/b/c – managed release water. This is typically sourced from surface runoff from cleared areas with some exposed/capped non–acid-forming (NAF) material. This water typically has sulfate and/or metal concentrations that are elevated relative to trigger values specified in the WDL. End uses of this water include managed releases to McArthur River from authorised discharge points in accordance with the WDL.

- Class 5 – poor quality water. This is typically seepage from the TSF and NOEF, runoff from areas with exposed potentially acid-forming (PAF) material, and underground void water. This water class is contained within the mine water management system and is not released off site.

- Class 6 – process water. This is typically used within the mill and TSF as well as other process streams. This water class is contained within the mine water management system and is not released off site.

The adoption of this classification scheme should assist MRM with their surface water management, given that it represents a move towards increasing focus on water quality rather than water source.

A major item of infrastructure that is planned for the mine site but has yet to be constructed is a water treatment plant that is proposed to treat poorer quality mine water (Class 5 and/or 6) to help manage the volume of stored process water. The plant will involve precipitation and filtration pre-treatment prior to reverse osmosis (RO) and pH correction. End uses for the permeate are proposed to include (WRM, 2015a):

- Managed releases to McArthur River.

- Storage within the managed release water circuit.

- Mine water demands (such as raw water make supply to the mill and dust suppression).

Waste streams will include filter backwash and brine from the RO process, where these waste streams will be either used in the mill (Class 6 water) or contained in the poor quality water circuit (Class 5).

Other new controls that have been implemented or planned in relation to matters such as the TSF, OEFs and open pit (including closure scenarios) and which can influence the extent of adverse impacts on McArthur River are discussed in the relevant sections. These include measures to address the high sulfate concentrations in Barney Creek (see discussion below) such as:

- Repairing the clay liner in the SPROD.

- Implementing new operating conditions for TSF Cell 2 that have resulted in significantly lower stored water volumes and reduced the hydraulic head within the cell.

- Patching sections of the interim clay cover on Cell 1 to minimise infiltration over the wet season and hence reduce seepage migrating towards Surprise Creek.

A further point to note is MRM's development of an environmental laboratory on site, with NATA accreditation reportedly occurring in the near future. This should facilitate sample turn around times and generate analytical results more promptly than is currently the case, and also provides an opportunity to undertake investigations into specific aspects of potential impacts associated with the operation, e.g., metal speciation and partitioning between dissolved and particulate phases should these be considered useful in the future. However, day-to-day operation of such a laboratory at the mine site presents a number of challenges, especially with respect to potential contamination. Continuous vigilance will be required by MRM personnel, as will the ongoing application of a high quality QA/QC program.

The IM considers that the existing surface water controls at the McArthur River Mine and Bing Bong Loading Facility are generally adequate. However, some deficiencies are still evident in some aspects of the monitoring program, e.g., determination of mine-derived metal loads, as noted in previous IM reports and discussed further in Section 4.3.4.2.

4.3.4 Review of Environmental Performance

4.3.4.1 Incidents and Non-compliances

Mine Site and Surrounds

McArthur River Mining's WDLs applicable to the reporting period (WDL 174-06 and WDL 174-07) specify values for a range of water quality triggers (SSTVs) for SW11 that are largely based on, or derived from, the ANZECC/ARMCANZ (2000) guidelines for 95% protection of species in freshwater systems. Some water quality results at this site exceeded the SSTVs in the 2014-2015 monitoring period (1 July 2014 to 30 June 2015), with these exceedances primarily involving (MRM, 2015e):

- Elevated concentrations of filterable Al in the wet season (nine occurrences in December 2014 and January 2015), and, to a lesser degree, filterable Fe (twice in December 2014 and once in March 2015). As in previous years, MRM attributed these values to naturally-occurring leaching from clays in the upper catchment (McArthur River, Glyde River, Surprise Creek, Barney Creek) soils, rather than water that was actively pumped from the mine under the authorisation of the WDL. Elevated filterable Al concentrations were also reported in December 2015 on two occasions, consistent with previous years. The IM agrees that these elevated levels of filterable Al and Fe at SW11 are likely to be due to factors other than mine-related activities.

- Dissolved oxygen levels that were both lower than, and greater than, the WDL trigger levels in both the wet and dry seasons, although MRM noted that DO values for all sites along McArthur River including the upstream control sites routinely fall outside of this trigger range, and that no trends in DO values were found to be related to mine activities. The IM supports this conclusion based on visual assessment of the plotted data. Non-compliance in terms of values that were both lower than, and greater than, the trigger levels continued to be reported in the second half of 2015.

- Elevated EC values, primarily at the end of the dry season. The EC trigger value was exceeded eight times over the 1 July 2014 to 30 June 2015 period – six times in 2014

(September to November) and twice in 2015 (June) – and this was attributed by MRM to inputs from either Barney Creek or a source along the McArthur River diversion channel. Detailed investigation into the latter by MRM resulted in identification of two zones of mineralisation – the Cooley deposits and pyritic shale – that MRM believes is responsible for an observed step change in EC between SW15 and SW16, with the influence of these features becoming apparent at low flows in the river. However, the IM notes MRM's reference to undertaking investigations to ensure that the ELS is not contributing to these changes, and encourages the rapid reporting of the investigation outcomes and inclusion of the ELS in source load calculations.

Further review of the data for the months beyond those reported in MRM (2015e) shows that the elevated conductivity values that occurred in June 2015 continued to trend upwards over the months of July to September 2015, reaching a maximum of 2,240 μS/cm on 22 September before substantially decreasing (presumably due to the onset of the wet season). This maximum value is more than twice the SSTV of 1,000 μS/cm. As noted in Joll (2015) in relation to the non-compliant values recorded in July, August and early September 2015, no active discharges occurred from the mine when the exceedances were recorded, and MRM's investigation indicated that the sources of the salts were the mineralisation known to occur along the McArthur River diversion channel (described in the preceding paragraph) that caused downstream sulfate increases, and groundwater that had interacted with dolomitic limestone and migrated along the southern extension of the western fault, expressing as base flow in the constructed diversion.

- The in situ pH at SW11 on 29 December 2014 was 5.93, which is marginally outside the SSTV range of 6.0 to 8.5. Investigations by MRM indicated that this was largely due to inputs from Glyde River (pH 6.06 on the same day). A pH value of 8.52 was also reported for 14 October at SW11 and 8.53 on 3 August 2015 (MRM, 2015e), although the IM notes that both of these values are the same as the upper SSTV value when two significant places are used (as in the WDL).

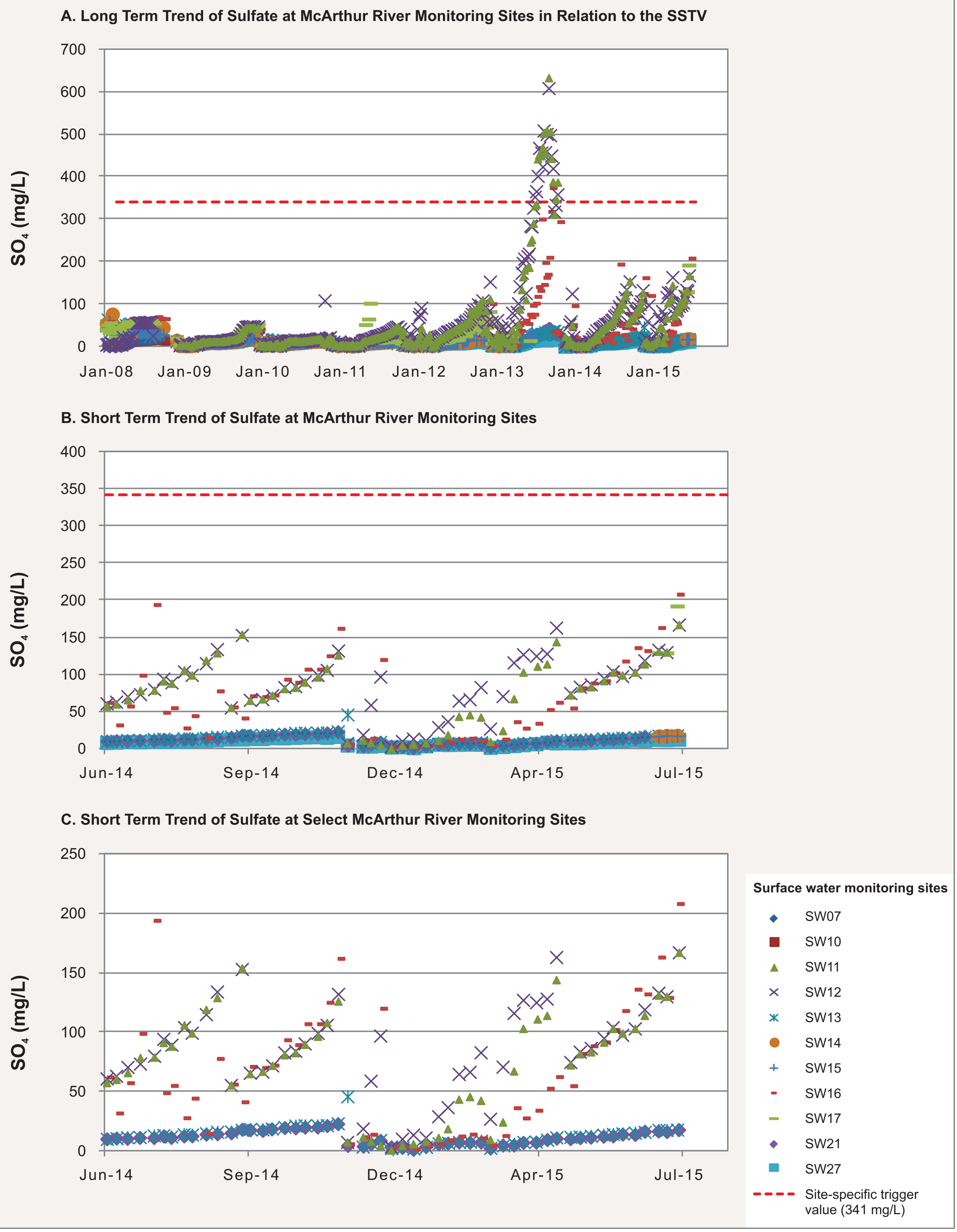
During the 1 July 2014 to 30 June 2015 period, the SSTV for sulfate at SW11 of 341 mg/L was not exceeded, which reflects MRM's use of a pump in Barney Creek at the haul road bridge to remove creek water that was high in sulfate and TDS (MRM, 2015d). This action was initiated in the 2014 dry season in an effort to avoid a repeat of elevated sulfate levels at SW11 that were observed in the 2013 dry season (and was the focus of previous IM reports). Once pumping operations began at the haul road bridge, the sulfate concentrations at SW12 and SW11 reduced abruptly, although sulfate from the McArthur River diversion channel continued to be an influence for the remainder of the dry season (Figure 4.6). The sulfate concentrations were then rapidly diluted by the onset of the wet season and increased flow in the river.

This trend was repeated in the 2015 dry season with sulfate concentrations at SW12 and SW11 rising independently of SW16 until pumping operations were initiated. After pumping began, the sulfate levels at SW12 and SW11 reduced suddenly and then continued to rise in line with the concentration at SW16. This increase continued into the late 2015 dry season such that the WDL SSTV (341 mg/L) at SW11 was exceeded throughout August and September (five occasions), with the maximum value being 593 mg/L on 22 September 2015 before substantially decreasing (Figure 4.7) (with the onset of the wet season).

PHYSICO-CHEMICAL DATA FOR McARTHUR RIVER NATURAL SURFACE WATER MONITORING SITES (2008 - 2015)

McArthur River Mine Project

FIGURE 4.6

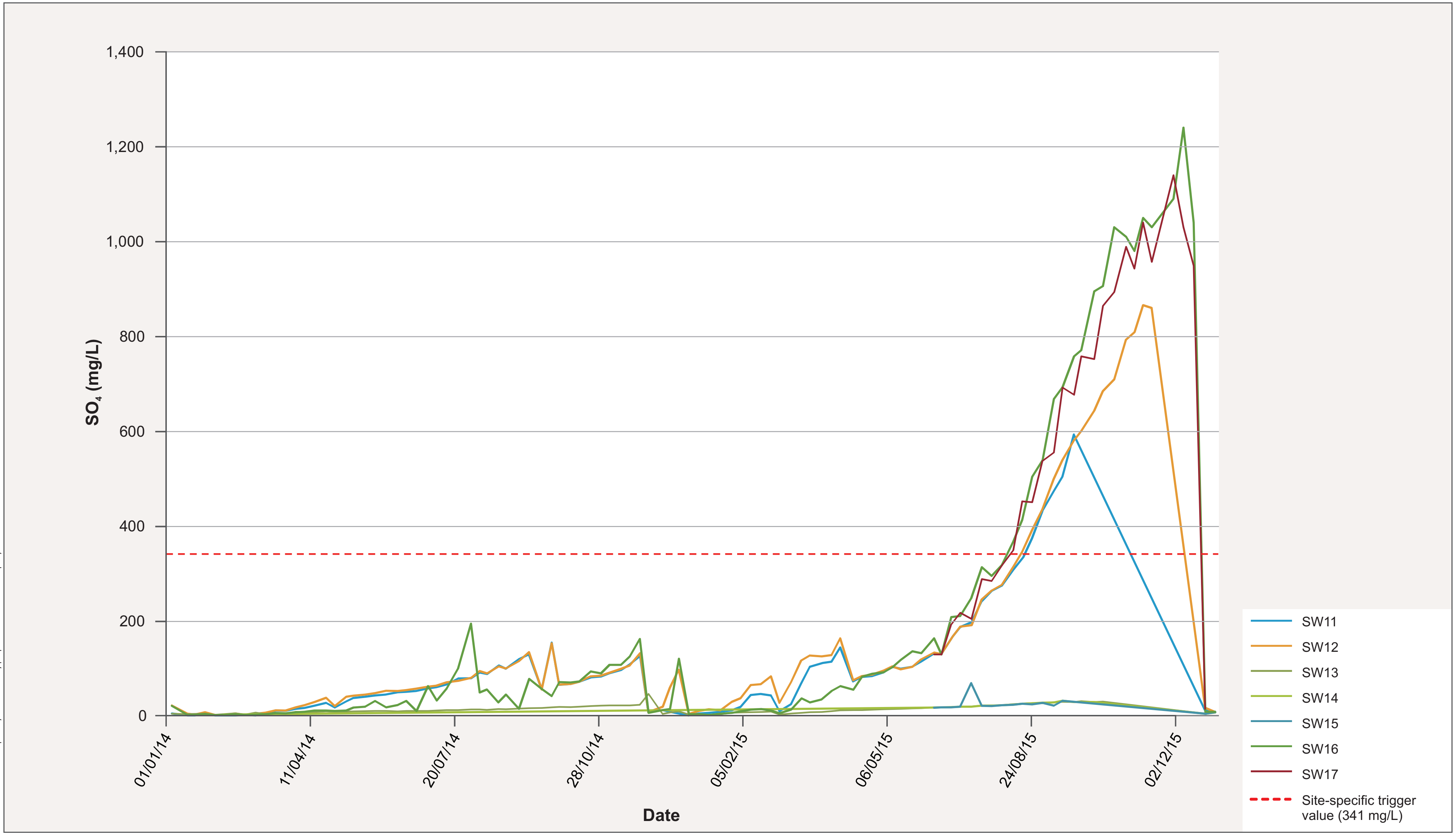


Source: MRM, 2015.

SO_4 CONCENTRATIONS ALONG THE McARTHUR RIVER

McArthur River Mine Project

FIGURE 4.7



As further noted in MRM (2015e), the sulfate data indicates that both the McArthur River diversion channel and Barney Creek were contributors of this major ion (which is closely correlated with EC) to McArthur River over the reporting period. Without the use of the Barney Creek pump in both 2014 and 2015, the total sulfate load entering the river from mine-impacted catchments would have been considerably higher.

One other non-compliance with the WDL that is worth noting concerns nitrate at SW11 on 22 December 2015, where the recorded value was twice the WDL trigger value (1,439 μg/L compared with 700 μg/L). This was attributed by Strohmayr (2016) to a combination of sources including Emu Creek (upstream of mine influences), Glyde River (removed from mine influences) and Barney Creek, with the latter including potentially mine-affected areas. A possible explanation is that this resulted from the first flush in Little Barney Creek given that heavy rains occurred on site in the period 19 December 2015 to 22 December 2015 (Strohmayr, 2016). Although water was released from Pond 2 to McArthur River over the period 20 to 22 December 2015, the nitrate concentrations in this released water were relatively low (66 μg/L) and hence this was not responsible for the observed non-compliance.

From the perspective of additional incidents that could have direct adverse impacts on surface water quality at the mine site and surrounds, a split suction hose on a pump at the anti-pollution pond (APP) near the mine site's crushing plant occurred on 17 November 2015. This resulted in about 1,000 L of runoff water leaking from the pipe, although there was no evidence of the water reaching nearby Barney Creek or associated drainage lines. McArthur River Mining concluded that there was minimal and reversible impact on the environment and assigned a severity classification of 1, and the IM has no reason to disagree with this finding or the recommended corrective and preventive actions.

As addressed in recent IM reports, the potential for hydrocarbons originating from the May 2011 diesel leak (approximately 28,000 L) to contaminate local drainage lines and affect downstream water quality warrants some discussion. The leak resulted from an open valve discharging diesel to the ground in the vicinity of the mine’s power plant and MRM subsequently implemented a product recovery and groundwater monitoring program. The results of the risk assessment presented in MRM (2015a) suggests that there is no risk to Barney Creek or McArthur River since groundwater from the impacted area is inferred to discharge into the underground workings during both wet and dry seasons. This contaminated groundwater will then undergo further attenuation and dilution before possibly emerging in the pit or being pumped to the mine's water management circuit. This is further discussed in the groundwater section.

A further point is that the IM notes the following in MRM (2015d):

> Given that site specific trigger values were exceeded at the McArthur River authorised monitoring point and that a number of these exceedances were found to be related to mine activities, it can be concluded that the controls implemented over the 2014/15 period to prevent surface water contamination at MRM were insufficient.

The IM encourages MRM to adopt the recommendations contained in that report, particularly in relation to:

- Mitigation of elevated concentrations of metals and major ions in Surprise and Barney Creek, with a view to preventing the need for dry season dewatering of Barney Creek.

- Further investigation of the causes of deteriorating dry season water quality in the McArthur River diversion drain.
- Calculating total and filtered contaminant loads that report to Surprise and Barney creeks via installation of small rated channel, v-notch weirs or similar.
- Further investigation to determine if the source of filtered manganese (and nitrate) measured in the downstream section of Barney Creek is mine derived.

A final point to note is that MRM proposed a number of amendments to WDL 174-07 to reflect planned operational changes for the 2015 dry season, as described in MRM (2015f). These planned changes include:

- Separate discharge of managed release water from NC1A, P2 and the WMD.
- Using a pipeline for water release from SEL1 to Barney Creek rather than a spillway.
- Adding three sediment traps and the water treatment plant as authorised discharge points.

Relevant changes to the WDL, as determined by the NT EPA, will be taken into account in next year's IM report.

Bing Bong Loading Facility and Surrounds

The WDL for the first part of the reporting period (WDL 174-06) specifies values for a range of water quality triggers for BBDDP that are largely based directly on the ANZECC/ARMCANZ (2000) guidelines for 95% protection of species in marine waters[8]. In contrast, WDL 174-07 contains specific values from ANZECC/ARMCANZ (2000), where these include both high reliability 95% protection values and values that, while still sourced from that document, are of lesser reliability and should be regarded as 'indicative interim working level(s)' (ANZECC/ ARMCANZ (2000)).

No dredging was carried out in the swing basin or navigation channel during the reporting period, hence no dredge spoil was deposited into the emplacement facility and no active releases occurred from the dredge spoil settlement ponds to the receiving environment. All runoff from the concentrate shed and the hardstand areas around the loading facility was captured within the three runoff ponds and disposed of via sprinkler and pond evaporation. At the authorised discharge point (BBDDP), passive released water flows across the intertidal flats to the Gulf of Carpentaria via the Bing Bong navigation channel. However, dry conditions during the reporting period meant that the perimeter drain and BBDDP were either dry or contained small stagnant pools of water with no flow or indication of downstream connection observed. As a result, representative analytical data was not reported for either BBDDP or the perimeter drains (MRM, 2015e).

From the perspective of incidents that could have direct adverse impacts on surface water quality at Bing Bong Loading Facility and surrounds, the following was reported by MRM:

[8] WDL 174-06 refers directly to '95% marine ecosystem protection' for field measurements, metals and metalloids, and 'other' (sulfate and nitrate), with specific values of 700 μg/L and 600 μg/L specified for benzene and TPH, respectively.

- Oil leak (less than two litres) from the MV Aburri into the swing basin on 6 November 2014 (and this was noted in last year's IM report). McArthur River Mining reported nil impact to flora and fauna, with the severity classification being 1, and the IM has no reason to disagree with this conclusion.

No complaints directly concerning surface water quality were reported by MRM.

As also noted in last year's IM report, MRM has previously requested that the EPA review the WDL on a number of grounds, including relevance of some of the water quality variables and the lack of 95% marine ecosystem protection trigger values under the ANZECC/ARMCANZ (2000) guidelines for water quality variables such as DO and pH. Although review of the WDL does not lie within the IM's scope of services, the IM notes that the WDL now addresses this issue. The IM also notes MRM's suggestion that the authorised monitoring point should be located in the swing basin or navigation channel and agrees that this is worthy of consideration, as is the addition of As to the DGT program.

4.3.4.2 Progress and New Issues

Water quality monitoring data has been discussed in other sections in terms of successes and non-compliances.

McArthur River Mining's performance against previous IM review recommendations relating to surface water quality management is outlined in Table 4.5. While additional comment to that provided in the table is not required for most matters, an exception concerns the recommendation that 'Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river'. While this has been a high priority recommendation in the last two IM reports, only limited progress has been made. The need to determine loads is based largely on two considerations:

- Reliance on filterable metal concentrations does not take into account downstream effects that might be associated with the long-term biogeochemical cycling of metals, including metals associated with suspended particulates, and hence total (unfiltered) metals also need to be considered. This includes establishing background and mine-derived loads of key metals such that the increments due to the mine can be placed into the appropriate context, taking into account downstream depositional (including coastal) environments.

- Determination of loads from various sources within the mine site and subsequent prioritisation of current and potential inputs will allow appropriate focus to be placed on management and mitigation measures such that the downstream environmental values can be maintained both now and in the future.

Given that significant loads of both soluble and particulate material are transported during flood events, and taking into account the relationships between water quality and river flow reported in WRM (2016), sampling over individual flood events should be considered to ensure that the resulting load estimates are robust and to complement the data from the current weekly sampling program. This could include sampling during managed releases, thereby also serving as a validation exercise with respect to the release calculator.

Such a focus on determining contaminant loads is consistent with both RGC (2015), where it is noted that the absence of information concerning contaminant loads to or from the local groundwater system or to McArthur River or its tributaries is a significant data gap, and MRM's own surface water monitoring report (MRM, 2015d), as noted above, that recommends determining total and filtered contaminant loads in Surprise and Barney creeks at base flow.

The IM's view is that, until load estimates (and load balances) are available, possible downstream impacts associated with the mine potentially remain unknown to some degree, and quantification and targeting of mine-associated sources remains poorly defined. The IM also notes that daily averaged flows have been estimated for sites SW06, SW18, SW28 and SW29 (see Figure 4.1 for site locations) for the 2014-2015 financial year (WRM, 2015b) and encourages MRM to further develop flow estimates for relevant locations and, thence, loads. This would also then provide a basis for predicting loads corresponding to various management and mitigation scenarios, including post-closure considerations. These load estimates should reflect relevant natural and mine-associated sources reporting to Surprise Creek, Barney Creek (and diversion channel), Emu Creek and McArthur River (and diversion channel), and take into account both background, current mine-derived and predicted mine-derived loads, and seasonal variation. Loads from Glyde River should also be estimated (although this is a lower priority).

One further area that requires comment relates to suspended sediment from MRM's operations. McArthur River Mining has advised that mine-derived TSS impacts on McArthur River downstream are viewed as lower risk and are generally not included in water quality assessments due to the elevated TSS concentrations that occur in McArthur River, particularly during flood events. However, mineralised suspended material reporting to McArthur River during flood events remains a possible pathway for downstream impacts to occur (as noted above), and downstream impacts might therefore be attributable to the suspended solids themselves or their mineralised nature (or both). An assessment that validates (or otherwise) MRM's view concerning the low risk associated with this issue would therefore provide a level of comfort that is currently absent in the material reviewed by the IM. This assessment should also include TSS from the operations at the Bing Bong Loading Facility reporting to surface (including coastal) waters.

Table 4.5 – Surface Water Quality Management Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
NOEF and TSF/ surface water monitoring program	Given the ongoing issues associated with the NOEF and TSF, the surface water monitoring program should be reviewed on an ongoing basis to ensure that sufficient early warning is provided concerning potential impacts on surface water quality from NOEF and TSF leachates and runoff (or other potential failures of these project infrastructure components). This should include implementing a formal procedure whereby the review process, outcomes and required actions are documented and available for IM review	There has been no progress in terms of developing a formal procedure that addresses this issue. However, the IM has been advised that MRM has a process which involves weekly review of the surface water data during the wet season and subsequent preparation of a weekly memo for MRM's management team highlighting trigger weekly exceedances

Table 4.5 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
McArthur River/SW11	If sulfate concentrations at SW11 reach 80% of the WDL trigger value (i.e., 273 mg/L), and sulfate concentrations show an increasing trend prior to this value being reported, a risk assessment should be undertaken concerning (i) possible implications (if this trend were to continue in the dry season), (ii) likely causes, and, if MRM operations are found to be a major contributing factor, (iii) mitigation measures commensurate with the level of risk	There has been some progress. Comparison of diversity and abundance near SW16 between the early and late dry season 2015 shows no measureable adverse impact due to elevated EC or sulfate levels, where the latter ranged from 210 to 771 mg/L at SW16 in Q3 2015. However, a more integrated assessment that draws together these findings and other factors such as additional relevant monitoring data (including duration of elevated sulfate levels) and the science underlying the derivation of the 341 mg/L SSTV, and takes into account confounding factors such as fauna concentration due to receding water levels, is required to address the broader risk posed by sulfate (and conductivity) levels
Monitoring	Elevated trip blank Zn and Al levels, implementing an inter-laboratory program, using only NATA-accredited laboratories, and occasional poor precision for DGT analyses should be investigated	There has been some progress in this area but Zn blank levels and poor precision for the DGTs remains an issue that requires further attention
	Alternative labeling of natural surface water sampling sites when the corresponding control sites are not flowing should be investigated; these sites are not artificial and should not be labeled as such	There has been some progress, with MRM's criterion being revised to reflect flow at the site being sampled rather than at upstream control sites. However, the potential for confusion still remains
Water management system	Descriptions of water types within MRM's water management system at the mine should be rationalised	Completed. A new classification involves six classes of water
	Specific surface water quality management objectives should be formalised for Bing Bong Loading Facility	Although these have been informally conveyed to the IM, there has been no progress with the formalisation of these objectives

Table 4.5 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Water management system (cont'd)	Additional information about the use of water quality monitoring data from the ASW program should be provided for IM review	There has been no progress; it remains unclear how the ASW monitoring data assists water management on a day-to-day basis
General data interpretation and reporting	Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river. If additional stream gauging data is required, a plan for obtaining such data should be developed and implemented as a priority	There has been limited progress on this item. See accompanying text in Section 4.3.4.2
	All relevant water quality data (in situ and laboratory) should be collated on a yearly basis in a format that is readily accessible and able to be interrogated (e.g., a single Excel spreadsheet or similar); this should include a reconciliation of all actual versus proposed/committed sampling events	There has been significant progress; however, MRM should still ensure that the data for all variables is presented to the IM in the single spreadsheet, and reconciliation is yet to be demonstrated
	Copies of completed chain of custody forms should be obtained from the laboratory after sample receipt	Completed
2012 and 2013 Operational Periods		
NOEF and TSF	The relevant monitoring programs (groundwater and surface water monitoring, and geochemical characterisation) should be reviewed to ensure that sufficient early warning is provided concerning potential impacts on surface water quality from NOEF and TSF leachates and runoff (or other potential failures of these project infrastructure components)	This has been superseded by a subsequent recommendation
McArthur River/SW11	Particular attention should be paid to increasing sulfate concentrations (and EC values) at SW11 as dry season progresses. If concentrations equal or exceed the trigger value (341 mg/L), a risk assessment should be undertaken concerning (i) possible implications (should this trend continue in future dry seasons), (ii) likely causes and, if found to be due to MRM operations, (iii) mitigation measures commensurate with the level of risk	This has been superseded by a subsequent recommendation
Monitoring	The feasibility of real-time in situ monitoring at the stream gauging stations on McArthur River, Surprise Creek, Barney Creek and Glyde River should be determined and, if found to be feasible, this capability should be installed so as to be consistent with leading industry practice. The parameters for which the feasibility of real-time in situ monitoring should be investigated include pH, temperature, DO, EC (first priority) and turbidity (second priority)	Multi-probes for real-time monitoring have been installed at a number of sites. The probe at SW11 was buried by sand during the recent (2015-2016) wet season and further effort is required to implement an effective system at this site
General data interpretation and reporting	Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river	This has been superseded by a subsequent recommendation

Table 4.5 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods		
General data interpretation and reporting (cont'd)	Further interpretation and analysis of data should be presented in the MMPs, including further detail about water quality changes with river/stream flow and mine-derived influences	Additional discussion about water quality changes in relation to flow and mine-derived influences is evident; however, the discussion would further benefit from analysis such as presented in WRM (2016)
	All data should be collated on a yearly basis in a format that is readily accessible and able to be interrogated; this should include a reconciliation of all actual versus proposed/committed sampling events	This has been superseded by a subsequent recommendation
	Comparison of metal and metalloid results with ANZECC/ ARMCANZ (2000) values should include the 95th percentile value as well as median values	No material was reviewed that indicated that this has occurred
	Evaluation of marine water quality data should reflect ANZECC/ARMCANZ (2000) requirements for Cd and Ni to consider 99% protection levels for slightly to moderately disturbed ecosystem	Completed for DGT results
	Reporting surface water management measures and monitoring data should focus on reducing technical and editorial errors	The frequency of errors in the documents reviewed for this report has reduced compared to earlier reports
	Figures in the MMP that show sampling sites should show ALL sampling sites, including control sites	Both committed and non-committed sampling sites should be shown (although referring to the site at the Burketown Crossing in Borroloola as a footnote on a figure is acceptable)

4.3.4.3 Successes

Mine Site and Surrounds

From a broader water quality perspective, and consistent with the approach described in Section 4.3.3.1 and used in previous IM reports, evaluation of success from a surface water quality perspective is based primarily on the following rationale:

- The beneficial uses that have been declared for the McArthur River Area are aquatic ecosystem protection, recreational water quality and aesthetics (as referred to in the WDL), while those for the McArthur River Catchment Area are environment, cultural and riparian (also referred to in the WDL).
- Notwithstanding other factors such as habitat and stream flow, the water quality required to be achieved at SW11 (see Figure 4.1) by the WDL will ensure the protection of these beneficial uses downstream of this site.

- Where considered useful, further analysis of the data is undertaken in relation to trigger values from ANZECC/ARMCANZ (2000) where the latter differ from the WDL trigger values.

As described in previous IM reports, this approach acknowledges that some deterioration of water quality upstream of the compliance point at SW11, both in McArthur River and tributaries such as Surprise Creek and the Barney Creek diversion channel, is expected due to the proximity of the watercourses to the mine. As noted in MRM (2015d), the relatively low rainfall that occurred in the 2014-2015 wet season meant that only limited samples were taken from Surprise and Barney creeks. However, the available data showed that mine affected areas had a negative influence on the surface water quality of these two creeks. The data indicated that metals and major cations (including sulfate) and anions were found in elevated concentrations in comparison to the upstream control sites. The data also indicated a long-term increase in the concentration of major cations and anions including sulfate, calcium and magnesium, particularly in dry season base flows. This has been discussed previously in Section 4.3.4.1.

It should also be noted that both versions of the WDL that applied during the monitoring period state that water quality at SW11 and BBDDP 'must not exceed the trigger values specified' in the licence, i.e., the WDL specifies a maximum value (or, in the case of pH and DO, both maximum and minimum values). This is conservative compared with the approach described in ANZECC/ ARMCANZ (2000), whereby for physical and chemical stressors such as pH, DO or nutrients, the median concentration of samples from a test site (i.e., not the maximum value) should be compared with the 80th percentile value from a reference site or, if reference site data do not exist, the relevant guideline value published in ANZECC/ARMCANZ (2000). Similarly, the recommended approach for toxicants is to compare the 95th percentile value (i.e., again, not the maximum value) with the default guideline values. Use of ANZECC/ARMCANZ (2000) guidelines as regulatory requirements is therefore a conservative implementation of these values. ANZECC/ ARMCANZ (2000) also notes that 'these Guidelines should not be used as mandatory standards', and that exceedance of a trigger value (using the statistical approach described above) should result in further action such as:

- Incorporating additional information or undertaking further site-specific investigation to determine if the chemical poses a real risk to the environment.
- Initiating management action or remediation (on the basis that the trigger value can be applied directly to the site in question).

Notwithstanding the shortcomings described above, the results from the monitoring program demonstrate a relatively high level of success in terms of compliance with WDL discharge requirements, as summarised in Table 4.6. Three controlled discharges were undertaken during the reporting period, with one of these originating from sump NC1A and two from Pond 2. Discharge dates and volumes are shown in Table 4.7.

Table 4.6 – Comparison of MRM Monitoring Data for SW11 with WDL Requirements

WDL 174-07 (for the 2015 Reporting Period)[1]			MRM Monitoring Data (SW11)[2]
Parameter	**Units**	**Site-specific Trigger Value (SSTV) for SW11**	**Oct 2014 – Sept 2015[3] (Minimum – Maximum)**
pH (in situ)	pH units	6.0 – 8.5	**5.9** – 8.5
EC (in situ)	μS/cm	1,000	22 – **2,240**
DO (in situ)	% saturation	85 – 120	**51** – **195**
Al (filtered 0.45 μm[4])	μg/L	55	1.4 – **205**
As (filtered 0.45 μm)	μg/L	24	0.3 – 2.4
Cd (filtered 0.45 μm)	μg/L	1.73	<0.02 – <0.1
Cu (filtered 0.45 μm)	μg/L	10.97	0.43 – 1.68
Fe (filtered 0.45 μm)	μg/L	300	16 – **488**
Pb (filtered 0.45 μm)	μg/L	16.6	<0.01 – 0.94
Mn (filtered 0.45 μm)	μg/L	1,900	2.13 – 119
Hg (filtered 0.45 μm)	μg/L	0.6	<0.02 – 0.14
Ni (filtered 0.45 μm)	μg/L	11	0.34 – 0.74
Zn (filtered 0.45 μm)	μg/L	62.68	0.5 – 5.7
TPH fraction C6-C9 (filtered 0.45 μm)	μg/L	N/A	N/A
Benzene (filtered 0.45 μm)	μg/L	950	All values <2
TPH fraction C10-C14 (filtered 0.45 μm)	μg/L	600	<50 – 130
C15-C28 (filtered 0.45 μm)			
C29-C36 (filtered 0.45 μm)			
SO_4 (filtered 0.45 μm)	mg/L	341	0.8 – **593**
NO_3 (filtered 0.45 μm)	μg/L	700	<22 – 509

1. The trigger values for WDL174-07 include Ni; this metal was not included in previous versions of the WDL.
2. Ranges of values were extracted from spreadsheets provided by MRM.
3. Values in **bold** lie outside the relevant SSTV.
4. The licence actually refers to 'Total and filtered (0.45 μg/l)' for metals and metalloids.

Table 4.7 – Discharges During the 2014-2015 Reporting Period

Date	Location	Discharge Volume (ML)[1]
16 to 19 January 2015	NC1A	53
16 to 19 January 2015	Pond 2	41
22 to 24 January 2015	Pond 2	27
TOTAL		121

1. MRM (2015e).

McArthur River Mining (MRM, 2015e) reported the following in relation to filterable metal concentrations at SW11 for the 2014-2015 monitoring period (with additional comment being provided as required by the IM to take into account the IM's reporting period):

- Most of the results showed water quality at SW11 that complied with the WDL SSTVs. For example, all pH (in situ) values at SW11 were within the WDL trigger limits of 6.0 and 8.5, apart from a single value of 5.9 in late December 2014. Almost all benzene and TPH results were less than the respective detection limits and SSTVs, the exceptions being some samples taken in January and December 2015 where TPH values were above the detection limits but still well below the trigger value. Nitrate values were similarly generally less than the WDL SSTV of 700 μg/L, with one exception being reported (as discussed previously).
- Most EC results at SW11 were less than the 1,000 μS/cm SSTV, with the average value being 872 μS/cm. However, most EC results from this site towards the end of the 2014 dry season were above the trigger value, and this trend was repeated in the 2015 dry season. This has been further discussed in terms of non-compliance (Section 4.3.4.1).
- Individual dissolved oxygen values at SW11 ranged from 50 to 195% saturation compared with the trigger values of 85 to 120%, with the average value over the reporting period being 98%. According to MRM (2015d), DO at all sites along McArthur River, including the upstream control sites, routinely fall outside the range of trigger values, with no trends found to be related to any mine activities (as previously discussed).
- In relation to metals and metalloids:
  - All results for filtered metals and metalloids other than Al, Fe and Cu (i.e., As, Cd, Pb, Mn, Ni (which was not included in versions of the WDL prior to WDL 174-07), Hg, Zn) were below both the WDL SSTVs and the ANZECC/ARMCANZ (2000) 95% level of protection guideline values.
  - The SSTV for Al of 55 μg/L (which is also the ANZECC/ARMCANZ (2000) 95% level of protection guidelines value) was exceeded at SW11 a number of times over the reporting period. However, MRM (2015d) reported that, in all cases, these were not mine-related and were typically influenced by the catchments of McArthur River, Glyde River and Barney Creek upstream from mine operations. The elevated concentrations at these upstream reference sites were attributed by MRM to leaching of clays that are naturally high in Al by heavy rains (see 'Incidents and Non-compliances'), and the IM notes that this is supported by the elevated results obtained for upstream sites. The trend associated with elevated filtered Al and upper catchment rainfall has been discussed by MRM with government regulators in the past.
  - The concentration of total filtered (soluble) Fe at SW11 exceeded the trigger value of 300 μg/L a total of three times over the reporting period. As was the case with Al, MRM (2015d) reported that these results were generally influenced by the upper catchments of McArthur River and its tributaries, with leaching of soils high in iron oxides causing high Fe concentrations throughout the system. This is also consistent with data from previous years.
  - The results for filtered Cu were all less than the WDL SSTV (10.97 μg/L) and generally less than the ANZECC/ARMCANZ (2000) 95% level of protection guidelines value (1.4 μg/L), the exceptions being three values that marginally exceeded the latter (with the range being 1.51 to 1.68 μg/L).

- When evaluated against hardness modified trigger values (HMTVs) calculated using the hardness of each sample from SW11, MRM (2015e) reported only one exceedance, this being for Zn where the measured value of 3.1 μg/L exceeded the HMTV of 2.52 μg/L. This was attributed by MRM (2015e) to the very low hardness of 7.7 mg/L (as $CaCO_3$). The toxicological implications of this single low-level exceedance are unlikely to be significant. Further assessment of the data for the period 1 July to 30 September 2015 shows that no exceedances were evident, with the three Cu values that exceeded the unmodified ANZECC/ ARMCANZ (2000) trigger value being less than the corresponding HMTVs (by an order of magnitude in two of the three samples).

A final parameter that warrants discussion is sulfate. As noted in previous IM reports, elevated sulfate concentrations at SW11 in the latter part of the dry season have been a potential concern. These elevated sulfate concentrations are discussed further in terms of non-compliance. From a 'success' perspective, MRM installed a dewatering pump in the downstream section of Barney Creek diversion channel late in the 2014 dry season and again in the 2015 dry season (MRM, 2015e). This was used to remove water from the creek to help reduce sulfate and TDS loads entering McArthur River and resulted in an immediate drop in sulfate concentrations at SW11 in both years. The sulfate concentrations at SW11 then closely resembled those at SW16 (see Figure 4.1 for the location of this site) as the McArthur River diversion channel became the primary source of sulfates to the downstream McArthur River.

With respect to the artificial surface water monitoring program, and as noted above, the objective of the program is to determine the level of contamination and hence management options, including off-site discharge and storage options, and provide an early indicator of potential environmental issues (MRM, 2015a). The program consists of both committed and non-committed sites.

The monitoring data reported by MRM indicates that the artificial surface water monitoring program provides a suitable basis for this objective to be achieved, and can also flag potential issues of concern, e.g., as noted in last year's IM report, a number of high concentrations of Cd and Cu at TSFC1SA (see Figure 4.2) over the monitoring period that exceeded the TSF Cell 2 concentrations (with limited data from the current reporting period showing some improvement in Cu concentrations at TSFC1SA). However, as also noted previously, the extent to which this data is actively used to assist water management on site is not clear.

Reporting of the QA/QC data for surface water monitoring continues to show improvement, although continued effort is required to address Zn and, to a lesser extent, Al trip blank values. The data presented in MRM (2015e) shows that blank values for Zn are routinely reported to be between 1 and 3 μg/L, which are similar to the actual values reported for samples (where the range at SW11 is 0.5 to 5.7 μg/L). Continued effort is also needed to address the sometimes poor precision obtained from analysing duplicate samples.

Also worth noting is MRM's modification of the system whereby samples where the corresponding upstream control sites were not flowing on the day of sampling are differentiated from those where flows at the upstream sites were evident. This modification requires the focus to be on the sampling site itself rather than the upstream control site such that sampling requires flow to be evident at the site itself. This should further facilitate analysis and interpretation of data depending on the status of surface flow (although labelling of these sites remains ambiguous and should be revisited to minimise potential confusion with sites in the artificial surface water monitoring program).

The overall conclusion is that the mining and processing operation has had relatively low impacts on downstream surface waters during the reporting period as determined by assessment of contaminant concentrations and general water quality variables (primarily at SW11), although areas for improvement remain. However, a potentially significant risk continues to be posed to future surface water quality due to the issues associated with acid, saline and/or metalliferous drainage from the NOEF and TSF, particularly after closure (although this risk would be reduced by placing the tailings in the final pit void for subaqueous storage). Downstream impacts associated with the pit lake after closure may also pose a major risk. The impact of the mine in terms of loads of contaminants (as opposed to concentrations) is yet to be determined by MRM.

Bing Bong Loading Facility and Surrounds

Analogous to the approach described above for the mine site and surrounds, evaluation of success at Bing Bong Loading Facility is based on the following rationale:

- The beneficial uses that are applicable to the coastal waters of, and surrounding, the Bing Bong Loading Facility are aquatic (marine) ecosystem protection, recreational water quality and aesthetics.
- The water quality required to be achieved in these waters is as defined by ANZECC/ ARMCANZ (2000) toxicant trigger values for 95% level of protection of marine species or otherwise sourced from ANZECC/ARMCANZ (2000) (and the IM notes the change in WDL 174-07 whereby previous blanket references to 'ANZECC (2000)' have been replaced by specific values).

Although the WDL specifies application of ANZECC/ARMCANZ (2000) trigger values to BBDDP (see Figure 4.3) as a statutory compliance point, this effectively means that ambient water quality guideline values are applied to the discharge from the dredge settling ponds. Evaluation of data from the swing basin and navigation channel is more likely to provide an indication of environmental performance in terms of the protection of these beneficial uses. This approach has therefore been adopted in this report (which is consistent with the approach adopted by MRM and previous IM reports, and MRM's suggested change to the WDL conditions).

It should also be noted that no dredging in the Bing Bong Loading Facility area or entrance channel occurred in the reporting period and the dredge spoil ponds were not operated (MRM, 2015e).

The results from the monitoring program that employed DGTs around the Bing Bong Loading Facility demonstrate a relatively high level of success in terms of being less than the SSTVs specified in the WDL, as summarised in Table 4.8.

Table 4.8 – Comparison of MRM DGT Monitoring Data for Bing Bong Loading Facility with WDL Requirements

WDL 174-07				MRM Monitoring Data[1]
Parameter	Units	Site-specific Trigger Value (SSTV) for BBDDP[2]	ANZECC/ARMCANZ (2000) 95% (99%)[3]	Oct 2014 – Sept 2015[4]
Mn	µg/L	80	Insufficient data	0.67 – **288**
Fe	µg/L	N/A	Insufficient data	0.25 – 976
Cd	µg/L	5.5	5.5 (<u>0.7</u>)	0.004 – 0.035
Cu	µg/L	1.3	<u>1.3</u> (0.3)	0.09 – 0.74
Co	µg/L	N/A	<u>1.0</u> (0.005)	<0.01 – 0.361
Ni	µg/L	70	70 (<u>7</u>)	0.08 – 2.38
Pb	µg/L	4.4	<u>4.4</u> (2.2)	0.008 – **5.09**
Zn	µg/L	15	<u>15</u> (7)	<0.10 – **16.6**

1. Values for ranges were extracted from Tsang (2015) and monthly reports generated by Charles Darwin University for AIMS.
2. The licence actually refers to ‘Total and filtered (0.45 µg/l)’ for metals and metalloids.
3. Underlined values are recommended by ANZECC/ARMCANZ (2000) for slightly to moderately disturbed systems; values in brackets are aimed at 99% level of protection rather than 95%.
4. Values in **bold** lie outside the relevant SSTV.

Tsang (2015) reports that, during the 2014-2015 monitoring period, the concentrations of DGT-labile Co, Ni, Cu, Zn, Cd and Pb at all six marine monitoring sites, i.e., both inside and outside the swing basin, were typically less than their respective ANZECC/ARMCANZ (2000) 95% protection level. Examination of Table 4.8 shows that this means the values were also typically below the SSTVs. With respect to the values that exceed the SSTV/ANZECC/ARMCANZ (2000) 95% protection level values in the reporting period:

- Two individual Mn results exceeded the SSTV of 80 µg/L, with these being replicates for one sampling event (February 2015) at one site (DGT Site 5) with values of 142 and 288 µg/L. The next highest value that was recorded was 21.1 µg/L, which is well less that the SSTV.
- One Pb result (5.09 µg/L, June 2015, DGT Site 2) exceeded the SSTV/ANZECC/ARMCANZ (2000) 95% protection level, with its duplicate being similar (4.45 µg/L). Tsang (2015) suggested that these values might be due to Pb mobilisation from resuspended sediment (given high turbidity measured at the start of the DGT deployment), but also did not discount contamination. The next highest value that was recorded was 3.77 µg/L (June 2015, DGT Site 1), which is slightly less than the SSTV and guideline value.
- One Zn result (16.6 µg/L, December 2014, DGT Site 6) exceeded the SSTV/ANZECC/ ARMCANZ (2000) 95% protection level, with its duplicate being significantly lower (0.93 µg/L) and well less than the SSTV and guideline value. The high value was attributed to contamination.

When assessing the DGT data, Tsang (2015) also noted that the swing basin is a slightly–moderately disturbed marine system, hence the concentrations of DGT-labile Zn, Pb, Co and Cu should be less than their respective ANZECC/ARMCANZ (2000) 95% protection level, whereas DGT-labile Cd and Ni concentrations should be less than their respective ANZECC/ARMCANZ

(2000) 99% protection level. The DGT-labile (average) concentrations of all of these metals in the swing basin generally complied with the ANZECC/ARMCANZ (2000) water quality objectives for a slightly–moderately disturbed marine system, the exceptions being the individual Pb and Zn results referred to above.

Determination of Pb isotope ratios indicated that concentrate-derived Pb (and possibly other metals) had dispersed from the Bing Bong Loading Facility into the surrounding marine environment (Tsang, 2015). However, the DGT-labile Pb concentrations at all monitoring sites were typically below relevant ANZECC/ARMCANZ (2000) protection levels (other than the exceptions described above) and therefore are not expected to adversely impact the marine environment.

In addition to the low levels of metals obtained at all sites, a related success is the continued implementation of the DGT method instead of grab water samples for marine monitoring. The IM endorses this approach but notes that the poor reproducibility of some results, as shown by imprecise duplicate concentrations on some occasions (which was also noted in last year's IM report), requires further investigation and resolution. Tsang (2015) notes that 'The overall quality of the monitoring dataset was good, but there were some issues identified that may have affected data quality. Duplicate DGT data were sometimes poor with substantial differences…' and lists the following possible causes:

- Improper handling of the DGT units.
- Contact between the DGT units and bed sediments.
- Contamination from the stainless steel DGT holders.
- Biofouling of the DGT units.

The IM encourages further development of the use of DGTs to improve the precision of the data.

As with monitoring at the mine, the objective of the artificial surface water monitoring program at Bing Bong Loading Facility is primarily to assess the level of contamination and consequent management options, as well as risk to the receiving environment in relation to the dredge spoil drain. Given that there was no dredging, no active discharge occurred the ponds and hence the compliance point BBDDP was not monitored. Monitoring data for the dredge spoil drain corresponding to the IM reporting period was highly limited and was consistent with that from the previous year in that the water was saline and slightly alkaline. The concentrations of filterable metals in the SRP were relatively high and generally consistent with those in the previous year, being (understandably) dominated by Zn and, to a lesser extent Pb. As in previous years, EC increased over the dry season, as did the concentrations of filterable metals such as Zn.

A further point to note is that MRM has acted on recommendations from previous IM reports concerning the need to upgrade DGT monitoring QA/QC procedures, although additional effort to further address occasional poor precision is still required.

The overall conclusion is that the mining and processing operation had relatively low impacts on adjacent coastal waters during the reporting period, although areas for improvement remain.

4.3.5 Conclusion

McArthur River Mining continues to devote considerable effort to water management at both the mine site and Bing Bong Loading Facility. Surface water quality monitoring data up to October 2015 indicates that adverse impacts on downstream surface waters due to the mine are currently limited, although some effects are noticeable in watercourses within the mine lease boundaries (and this is not unexpected) and some non-compliance with waste discharge SSTVs due to mine activities has occurred. Adverse impacts on coastal waters near Bing Bong similarly remain limited. However, assessment to date has focused largely on water quality as described by reference to the concentrations of various parameters. The effects of the operation in terms of mine-derived loads reporting to McArthur River and the various sources that contribute to these loads, which currently remain largely unquantified, should be investigated. It is also timely for further rigorous consideration to be given to closure scenarios and their potential impacts on downstream water quality (including contaminant loads), given the potential issues associated with the NOEF, TSF and pit lake in terms of acid, saline and/or metalliferous drainage after closure.

Ongoing (including those recommendations that have been modified on the basis of additional information) and new IM recommendations related to surface water issues are provided in Table 4.9.

Table 4.9 – New and Ongoing Surface Water Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
NOEF and TSF/ surface water monitoring program	Given the ongoing issues associated with the NOEF and TSF: ♦ The surface water monitoring program should be reviewed on an ongoing basis to ensure that sufficient early warning is provided concerning potential impacts on surface water quality from NOEF and TSF leachates and runoff (or other potential failures of these project infrastructure components) ♦ This should include implementing a formal procedure whereby the review process, outcomes and required actions are documented and available for IM review	High
McArthur River/ SW11/other surface water sites	A risk assessment should be undertaken concerning: ♦ Possible implications associated with elevated sulfate concentrations and conductivity levels at SW11 (and sites within the ML that are next to or downstream of MRM facilities) exceeding the respective SSTVs ♦ Likely causes ♦ If MRM operations are found to be a major contributing factor, mitigation measures commensurate with the level of risk	High
Monitoring	Real-time in situ monitoring at SW11 should be implemented with the issues observed during the 2015-2016 wet season (i.e., burial of the probe) being appropriately addressed	High
	Continued focus should be placed on QA/QC as part of the water sampling program, including: ♦ Elevated trip blank Zn and Al levels ♦ Occasional poor precision for DGT analyses ♦ Potential contamination issues associated with operating an environmental laboratory on a mine site	Medium

Table 4.9 – New and Ongoing Surface Water Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Monitoring (cont'd)	Alternative labeling of natural surface water sampling sites when no flow is evident at the sites should be further investigated; these sites are not artificial and should preferably not be labeled as such	Low
	Additional effort should be devoted to the following in relation to mine-derived loads of contaminants*: ♦ Contaminant load estimates should be determined, where these reflect both natural and mine-associated sources (including but not limited to the TSF, OEFs, ELS, run-off dams and open pit) reporting to Surprise Creek, Barney Creek (and diversion channel), Emu Creek, and McArthur River (and diversion channel). Glyde River should also be included in these estimates (although this is a lower priority) ♦ Load calculations (and load balances) should take into account current and predicted natural and mine-derived loads, and seasonal variation ♦ The need to sample over specific flood events in McArthur River, Barney Creek, Surprise Creek and Emu Creek (and Glyde River) to complement the weekly sampling program and obtain robust load estimates should be considered ♦ Using the results from the above, mine-associated sources should be ranked in terms of contributions of contaminants to McArthur River at SW11 and further downstream, and used to prioritise management and mitigation actions	High
Water management system	Specific surface water quality management objectives should be formalised for Bing Bong Loading Facility and incorporated into relevant MRM documents	Low
	Additional information about the use of water quality monitoring data from the ASW program should be provided for IM review, i.e., this additional information should describe how the ASW data is used on a day-to-day or week-to-week basis	Low
General data interpretation and reporting	All relevant water quality data (in situ and laboratory) should be collated on a yearly basis in a format that is readily accessible and able to be interrogated (e.g., a single Excel spreadsheet or similar); this should include a reconciliation of all actual versus proposed/committed sampling events	High
	Comparison of metal and metalloid results with ANZECC/ARMCANZ (2000) values should include the 95th percentile values as well as median values	Medium
New Items		
TSS loads	An assessment that validates (or otherwise) MRM's assertion about the low risk associated with mine-derived TSS is required. This assessment should also address TSS from the operations at the Bing Bong Loading Facility	Medium
Monitoring	Results of the release calculator should be validated by concurrent water quality measurements at SW11	Low
	Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows)	Low
	The feasibility of deploying DGTs to monitor seawater quality in the trans-shipment area during transfer of the concentrate should be determined	Medium

• This recommendation has been relocated from 'General data interpretation and reporting'.

4.3.6 References

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4.4 Diversion Channel Hydraulics Management

4.4.1 Introduction

This section addresses MRM's performance during the operational period with regards to management of diversion channel hydraulics, and is based on review of:

- Aerial and other photographs of the mine site provided by MRM.
- Other documents such as DME field inspection reports.
- Email discussions with MRM staff.
- Proposal for works 'Geomorphological Assessment of the McArthur River and Barney Creek Diversions' (Hydrobiology, 2015).

4.4.2 Key Risks

The key risks to diversion channel hydraulics as described in the risk assessment (Appendix 2) are:

- Flooding within the open pit in a rarer than 0.2% AEP[9] flood event, resulting in cessation of mining activities and generation of large quantities of poor quality water (mine wall built to protect the mine site from 0.2% AEP flood event).
- Flooding of the McArthur River causing erosion at the toe of the mine levee wall, potentially leading to failure of the mine levee wall.
- Erosion along an unplanned overland flow path from the old McArthur River channel into the diversion channel, potentially leading to severe erosion and substantial sediment input into the diversion.
- Ponding of water between the diversion channel and mine bund leading to increased seepage through the shallow soil zone and mobilisation of salts from the underlying sediments (EES, 2012).
- Ongoing erosion in the McArthur River diversion channel, with potentially detrimental effects on rehabilitation efforts and on water quality (higher sediment loads), with subsequent impacts on aquatic ecology.
- Erosion at several sites along the mine levee wall, potentially leading to failure and flooding of the open pit.
- Rock for erosion protection and large woody debris (LWD) additions to the diversion channels are in short supply. Sourcing of appropriate materials for armouring (erosion protection) and LWD installation is required.

[9] 1 in 500 year event – 0.2% chance of occurring in any one year.

4.4.3 Controls

4.4.3.1 Previously Reported Controls

McArthur River Mining has a range of existing control measures to address the key risks listed in Section 4.4.2. These are provided in Table 4.10.

Table 4.10 – Existing Control Measures in Place for Risks Associated with Diversion Channel Hydraulics

Risk	Current Control
Flooding within the mine pit	♦ Early Flood Warning System Procedure
Erosion at toe of mine levee wall	♦ No current control ♦ To be assessed as part of the geomorphological assessment of the McArthur River and Barney Creek diversion channels
Erosion along an unplanned flow path between the old McArthur River channel and the diversion channel	♦ After erosion experienced in the 2009-2010 wet season, rock armouring works were conducted in 2010 ♦ No evidence that inspections are still being carried out. Whereas the flow path armouring appears to be stable, it should be inspected after each wet season
Ponding of water between channel diversion and mine bund	♦ Small diameter pipes (<100 mm) to allow drainage installed (according to Risk Register (EES, 2012)). These pipes were not found during the 2014-2015 site inspection
Ongoing erosion in McArthur River diversion channel	♦ Rock armouring in parts (some failed due to inappropriate rock sizing and high energy hydraulic forces) ♦ The post-wet season photograph monitoring along diversion channel banks has not been actioned in the 2014 or 2015 reporting period and is therefore no longer considered a control ♦ There is no evidence of informal assessment of aerial laser survey (ALS) topography and aerial photographs being actioned in the 2015 reporting period. This is therefore no longer considered a control
Integrity of mine level wall.	♦ Inspections being carried out but with no reporting ♦ To be assessed as part of the geomorphological assessment of the McArthur River and Barney Creek diversion channels
Sourcing of appropriate materials (rock and wood)	♦ Appropriate materials for rock armouring (erosion protection) and LWD installation are in short supply ♦ There are no plans as to how rock or wood will be sourced

4.4.3.2 New Controls – Implemented and Planned

No new controls have been identified during the 2015 operational period. However, MRM has commissioned a geomorphological assessment of the McArthur River and Barney Creek diversion channels. This investigation will inform several key risks identified in previous IM reports, including some information on the integrity of the mine levee wall. The report should also provide potential controls associated with the integrity of the mine levee wall and ongoing erosion along the diversion channel.

4.4.4 Review of Environmental Performance

4.4.4.1 Incidents and Non-compliances

Incidents

The IM has not identified any incidents in the 2015 operational period relating to diversion channel hydraulics.

Non-compliances

The IM has not identified any non-compliances in the 2015 operational period relating to diversion channel hydraulics.

4.4.4.2 Progress and New Issues

McArthur River Mining has commissioned a geomorphological assessment of the McArthur River and Barney Creek diversion channels. The investigation is currently being undertaken by Hydrobiology with the full report expected in June 2016. This investigation will inform several key risks identified in previous IM reports as described in Table 4.11. No new issues have been identified in this reporting period; however, no information was provided by MRM relating to the ongoing monitoring of diversion channel and bank erosion, which limits the IM's assessment of performance during the reporting period.

McArthur River Mining's performance against previous IM review recommendations relating to diversion channel hydraulics is outlined in Table 4.11.

Table 4.11 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
Integrity of the mine levee wall	It is recommended that the mine levee wall be assessed by a qualified geotechnical engineer, particularly at the sites identified in Figure 4.8. While runoff is predicted to be minor, it is recommended that these sites be repaired to ensure stability. It is also recommended that MRM produces a plan for revegetation, stabilisation and monitoring to ensure that the levee remains intact after mine closure	♦ The IM was informed that 'minor' areas of erosion have been assessed and are to be addressed, but that no formal reporting is planned. It is recommended that the stabilisation of these areas be reported ♦ The more severely eroded section of the levee wall upstream from the old McArthur River adjacent to the start of the diversion channel is being assessed as part of the geomorphological assessment of the McArthur River and Barney Creek diversion channels. Full report expected in June 2016
Sourcing materials	Given the need for additional LWD in the diversion channels and the potential requirement for additional rock armouring (both on the diversions and the levee wall), it is recommended that future sources for these materials be investigated	♦ Required quantities to be investigated based on the outcomes of the geomorphological assessment of the McArthur River and Barney Creek diversions channels ♦ Sources are yet to be investigated ♦ No LWD added in the 2015 operational period

Table 4.11 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Erosion at toe of mine levee wall	Erosion at the toe of the mine levee wall appears to be due to local runoff rather than fluvial erosion from flood events; however, it may pose a threat to long-term stability. It is recommended that the erosion be assessed by a qualified geomorphologist (included in the scope of the planned assessment)	This will be informed by the outcomes of the geomorphological assessment of the McArthur River and Barney Creek diversion channels
Overland flow path	The rock protection of the overland flow path appears to be adequate at present; however, it is recommended that the rock protection be inspected after each wet season to ensure its stability. This site should be included in the detailed geomorphic assessment	This will be informed by the outcomes of the geomorphological assessment of the McArthur River and Barney Creek diversion channels
Ponding of water	The site referred to in the 2011 IM Report (EES, 2012) as 'ponding of water between the diversion channel and mine bund' has yet to be inspected. The 2011 IM Report (EES, 2012) recommended re-contouring the section to provide adequate drainage. It is recommended that the location of this site be identified and that the status of the recommended actions be reported	This will be informed by the outcomes of the geomorphological assessment of the McArthur River and Barney Creek diversion channels. The area will also be inspected during the 2017 IM field inspection
2012 and 2013 Operational Periods		
Geomorphology	A full geomorphic condition assessment and erosion mitigation study of both diversions is recommended as follows: ♦ The study should utilise on ground inspection in addition to recent and future ALS ♦ The study should be carried out for both the Barney Creek and McArthur River diversion channels with priority on McArthur River diversion channel ♦ The study should include the watercourses for at least 1 km upstream and downstream of the diversion channels ♦ The study should aim to identify areas of erosion and deposition, and the current geomorphic processes causing erosion, and to quantify the degree and rate of erosion along the entire reach ♦ The study should draw upon the results of the Phase 3 Development Project Surface Water Assessment (WRM, 2012a) and the Review of the 'As-Designed' and 'As-Constructed' McArthur River and Barney Creek Diversions (WRM, 2012b) ♦ Locations of channel constriction and/or high flow velocities should be prioritised, along with areas that have undergone erosion	The IM has reviewed the Hydrobiology (2015) proposal and confirms that the scope identified, along with comments received from MRM, is appropriate for a geomorphic condition assessment. The assessment is currently being undertaken

Table 4.11 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Period (cont'd)		
Geomorphology (cont'd)	♦ The study should consider previous attempts at erosion control, including revegetation attempts ♦ This study should then be used to assess the methods of erosion control that can be used and prioritise areas for corrective works	
Erosion	Ongoing monitoring of diversion channel and bank erosion should continue utilising ALS complemented by photograph monitoring, and visual inspection. It is recommended that an annual report on observed erosion should then be completed. These reports should detail: ♦ The observed erosion ♦ The existing mitigation measure (if any) ♦ The planned mitigation measure ♦ The status of implementation of the planned mitigation measure	No progress identified from documents provided

4.4.4.3 Successes

No particular successes have been identified for the 2015 operational period. However, the geomorphological assessment currently being undertaken will represent a significant step towards addressing key issues identified in previous IM reports.

4.4.5 Conclusion

From the documents provided as part of this year's assessment, the IM is not able to identify progress on any issues previously raised.

The DME field inspection reports show additional information on both the erosion of the mine levee wall and the continued degradation of the McArthur River diversion channel. Additionally, the aerial imagery provided by MRM shows that erosion is continuing, both on the inside and outside of the mine levee wall (Figure 4.8). Whereas MRM has informally stated that inspections of the mine levee wall have been conducted, and that works to stabilise the sites will be undertaken during the next dry season, more information on these issues would be beneficial. The levee wall is only nine years old and rilling along the wall is widespread, with some areas of major erosion. No information could be found on the expected design life of the mine levee wall; however, assuming that the levee wall is expected to last in perpetuity, some plan for ensuring stability after mine closure or ongoing monitoring and maintenance is seen as vital. It is expected that once the geomorphological assessment is complete, the findings in terms of implications for monitoring and maintenance post closure will be incorporated into the mine closure plan that is currently being prepared as part of the Overburden Management Project EIS. This issue, and the issue of ongoing erosion along the diversion channel, were flagged with high risk ratings.

OBSERVED AREAS OF EROSION ALONG THE MINE LEVEE WALL IN 2015

McArthur River Mine Project

FIGURE 4.8

Photo monitoring of the diversion channel was not reported on in this or the 2014 reporting period, such that two years of monitoring data is now absent from the record.

Ongoing and new IM recommendations related to diversion channel hydraulics issues are provided in Table 4.12. Due to the dependence of some high priority issues on the outcomes of the geomorphic assessment, the assessment has now been flagged with a high priority.

Table 4.12 – New and Ongoing Diversion Channel Hydraulics Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Geomorphology	A full geomorphic condition assessment and erosion mitigation study of both diversions is recommended as follows: ♦ The study should utilise on ground inspection in addition to recent and future ALS ♦ The study should be carried out for both the Barney Creek and McArthur River diversion channels with priority on McArthur River diversion channel ♦ The study should include the watercourses for at least 1 km upstream and downstream of the diversion channels ♦ The study should aim to identify areas of erosion and deposition, and the current geomorphic processes causing erosion, and to quantify the degree and rate of erosion along the entire reach ♦ The study should draw upon the results of the Phase 3 Development Project Surface Water Assessment (WRM, 2012a) and the Review of the 'As-Designed' and 'As-Constructed' McArthur River and Barney Creek Diversions (WRM, 2012b) ♦ Locations of channel constriction and/or high flow velocities should be prioritised, along with areas that have undergone erosion ♦ The study should consider previous attempts at erosion control, including revegetation attempts ♦ This study should then be used to assess the methods of erosion control that can be used and prioritise areas for corrective works	High
Erosion	Ongoing monitoring of diversion channel and bank erosion should continue utilising ALS complemented by photograph monitoring, and visual inspection. It is recommended that an annual report on observed erosion should then be completed. These reports should detail: ♦ The observed erosion ♦ The existing mitigation measure (if any) ♦ The planned mitigation measure ♦ The status of implementation of the planned mitigation measure	Medium
Integrity of the mine levee wall	It is recommended that the mine levee wall be assessed by a qualified geotechnical engineer, particularly at the sites identified in Figure 4.8. While runoff is predicted to be minor, it is recommended that these sites be repaired to ensure stability. It is also recommended that MRM produces a plan for revegetation, stabilisation and monitoring to ensure that the levee remains intact after mine closure	High
Sourcing materials	Given the need for additional LWD in the diversion channels and the potential requirement for additional rock armouring (both on the diversions and the levee wall), it is recommended that future sources for these materials be investigated	Low

Table 4.12 – New and Ongoing Diversion Channel Hydraulics Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Erosion at toe of mine levee wall	Erosion at the toe of the mine levee wall appears to be due to local runoff rather than fluvial erosion from flood events; however, it may pose a threat to long-term stability. It is recommended that the erosion be assessed by a qualified geomorphologist (included in the scope of the planned assessment)	High
Overland flow path	The rock protection of the overland flow path appears to be adequate at present; however, it is recommended that the rock protection be inspected after each wet season to ensure its stability. This site should be included in the detailed geomorphic assessment	Low
Ponding of water	The site referred to in the 2011 IM Report (EES, 2012) as 'ponding of water between the diversion channel and mine bund' has yet to be inspected. The 2011 IM Report (EES, 2012) recommended re-contouring the section to provide adequate drainage. It is recommended that the location of this site be identified and that the status of the recommended actions be reported on	Low
New Items		
Diversion channel erosion monitoring	Photo monitoring of the diversion channel was not reported on in the 2014 or 2015 reporting periods. It is recommended that this be undertaken every year to ensure an accurate record of erosion along the diversion	Low

4.4.6 References

EES. 2012. Independent Monitor Audit of the McArthur River Mine for the 2011 Operational Period, Report No 212010 dated 1 October 2012. Prepared by Environmental Earth Sciences for the Northern Territory Minister for Mines and Energy, Darwin, NT.

Hydrobiology. 2015. Geomorphological Assessment of the McArthur River and Barney Creek Diversions. Proposal of Services. Prepared by Hydrobiology for McArthur River Mining Pty Ltd, Winnellie, NT.

WRM. 2012a. Phase 3 Development Project Surface Water Assessment, Report No 0790-01-D dated 23 January 2012. Prepared by WRM Water and Environment for McArthur River Mining Pty Ltd, Winnellie, NT.

WRM. 2012b. Review of the 'As-Designed' and 'As-Constructed' McArthur River and Barney Creek Diversions. August 2012. Prepared by WRM Water and Environment for McArthur River Mining Pty Ltd, Winnellie, NT.

4.5 Groundwater Management

4.5.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of groundwater and is based on review of:

- Observations and discussions with MRM personnel during the site inspection.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1), which includes the approved current mining management plan (MRM, 2015a), 2014-2015 groundwater monitoring report (MRM, 2015b), quarterly reports relating to the remediation of the 2011 diesel spill (MRM, 2015c; 2015d; 2015e; 2015f), and various reports relating to the TSF, NOEF, PAF runoff dams and mine area.
- The Excel workbook provided by MRM that contains collated water quality data for 2014 and 2015 (MRM, 2015g).
- Various MRM forms and similar documents such as survey results, incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the mine site provided by MRM.

4.5.2 Key Risks

The key risks to groundwater management, as described in the risk assessment (Appendix 2), are associated with both the operation phase of mining and the post-mining closure phase, and remain essentially the same as described in last year's IM report.

From an operation phase perspective, key risks are as follows:

- Oxidation of ore, mine waste and concentrate, resulting in acid, saline and/or metalliferous drainage which, if released to the groundwater system, will impact on groundwater quality and aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Poor quality seepage from the TSF impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Poor quality seepage from water storages, including the PAF runoff dams and the dams and ponds used to manage dirty and contaminated water, impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Spills/leaks from stored hydrocarbons resulting in seepage of hydrocarbons to groundwater, impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Drawdown from mine dewatering and water supply activities impacting the groundwater resource in terms of both water supply and quality (due to mixing of different quality groundwater), lowering of groundwater levels in heritage areas (Djirrinmini Waterhole) or in

areas associated with groundwater-dependant ecosystems (GDEs), and interactions between groundwater and surface water.

- Poor quality seepage from the dredge spoil ponds at Bing Bong Loading Facility impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.

In terms of the post-mining closure phase, the key risks are:

- Poor quality seepage from the pit lake reporting to the groundwater system after mine closure, impacting groundwater quality and aquatic and terrestrial ecosystems where pit lake water discharges to creeks/rivers.

- Failure of the cover on the OEFs resulting in acid, saline and/or metalliferous drainage which, if released to the groundwater system, will impact on groundwater quality and aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.

- Failure of the cover on the TSF resulting in poor quality seepage which, if released to the groundwater system, will impact on groundwater quality and aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface[10].

4.5.3 Controls

4.5.3.1 Previously Reported Controls

McArthur River Mining has developed a variety of control measures to assist in managing groundwater-related risks, including:

- Measures to identify and assess existing and future impacts (e.g., groundwater monitoring and review of monitoring data, adoption of groundwater quality trigger values, geophysical surveys, groundwater modelling, EC profiling of rivers and creeks, and pit lake modelling).

- Measures designed to mitigate current or predicted impacts (e.g., installation of seepage recovery systems, installation of low permeability barriers to restrict groundwater flows, lining of storages used to manage contaminated water, minimisation of the TSF decant pond, and the ongoing remediation of a diesel spill near the mine's power station).

The majority of the controls were adopted prior to the current reporting period and are summarised in this section. New control measures and the results of recently completed studies are discussed in Section 4.5.3.2.

Groundwater Monitoring

Groundwater monitoring data is collected by MRM at both the McArthur River Mine and Bing Bong Loading Facility. Monitoring bores at the mine site are divided into two groups:

[10] The IM has been advised by MRM of its preferred strategy to relocate tailings to the final pit void at closure, and notes that if this proceeded, the risk associated with the TSF would be reduced.

- Committed monitoring bores, which MRM is required to monitor under the water management plan.
- Non-committed monitoring bores at the mine site, which are used intermittently by MRM for internal assessments.

All of the monitoring bores at the Bing Bong Loading Facility are classified as committed monitoring bores. The locations of the committed monitoring bores are shown in Figure 4.9 (mine site) and Figure 4.10 (Bing Bong Loading Facility).

The committed monitoring bores are positioned around the facilities associated with potential impacts to the groundwater environment. A summary of the committed monitoring bores is provided in Table 4.13.

Table 4.13 – Summary of Committed Monitoring Bores

Facility	Number of Committed Monitoring Bores
TSF Cell 1	13
TSF Cell 2	2
WMD	3
NOEF	16
SPROD	8
SEPROD	10
Plant area	4
Proposed EPROD	1
Bing Bong Loading Facility	18
Diesel spill area	28

Groundwater monitoring data is assessed annually either as part of the MMP or for the operation's groundwater review. The assessment comprises both groundwater levels and quality for the committed monitoring bores.

McArthur River Mining also has reporting commitments relating to the 2011 diesel spill near the old power plant. These include quarterly progress reports on the site remediation effort, and an annual report reviewing the results from the previous 12 months and recommending further development of the site remediation plan.

McArthur River Mining's groundwater monitoring schedule is summarised in Table 4.14.

PRE-EXISTING COMMITTED GROUNDWATER MONITORING BORES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.9

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COMMITTED GROUNDWATER MONITORING BORES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.10

Table 4.14 – Groundwater Monitoring Schedule Summary

Location	Frequency	Parameters
TSF, WMD, NOEF and SEPROD	Quarterly	Laboratory Suite 4 (pH, EC, TSS, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, NO_3, alkalinity, ionic balance; filtered Al, As, Bi, Cd, Cu, Fe, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, Zn and Hg)
	Quarterly	Field Suite (pH, Temp, DO, EC, Turbidity, ORP)
SPROD	Monthly	Laboratory Suite 4 (pH, EC, TSS, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, NO_3, alkalinity, ionic balance; filtered Al, As, Bi, Cd, Cu, Fe, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, Zn and Hg)
	Monthly	Field Suite (pH, Temp, DO, EC, Turbidity, ORP)
Plant and bores GW004, 03A, 05A, 06, 14-16, 18; and GWBB06A	Quarterly	Laboratory Suite 4 (pH, EC, TSS, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, NO_3, alkalinity, ionic balance; filtered Al, As, Bi, Cd, Cu, Fe, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, Zn and Hg)
	Quarterly	Field Suite (pH, Temp, DO, EC, Turbidity, ORP)
	6-monthly	Laboratory Water Suite Organics (TPH and BTEXN)
Proposed EPROD	6-monthly	Laboratory Suite 4 (pH, EC, TSS, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, NO_3, alkalinity, ionic balance; filtered Al, As, Bi, Cd, Cu, Fe, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, Zn and Hg)
	6-monthly	Field Suite (pH, Temp, DO, EC, Turbidity, ORP)
Bing Bong Loading Facility	Quarterly and monthly for 3 months prior to and during dredging, and 3 months after dredging	Laboratory Suite 4 (pH, EC, TSS, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, NO_3, alkalinity, ionic balance; filtered Al, As, Bi, Cd, Cu, Fe, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, Zn and Hg)
	Quarterly and monthly for 3 months prior to, during and 3 months after dredging	Field Suite (pH, Temp, DO, EC, Turbidity, ORP)
Diesel spill area	Quarterly	Laboratory Suite 5 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, ionic balance, filtered Fe^{2+} and Mn, TPH, TPH (silica gel clean up) and sulfide)
	Quarterly	Field Suite (pH, Temp, DO, EC, Turbidity, ORP)
	Fortnightly	Groundwater and diesel interface depth

Groundwater trigger values are used at the mine site and at the Bing Bong Loading Facility to help identify impacts to groundwater quality, as stated in the 2013-2015 revised interim MMP. The trigger values are based upon the limits for livestock in NEPC (Agricultural Livestock Purposes, 1999[11]).

Surface Geophysical Surveys

Surface geophysical surveys have been conducted on a number of occasions since 2003 to help identify areas affected by seepage. The areas surveyed comprised the TSF, TSF Cell 3 WMD, previously proposed TSF Cell 4, SPROD, SEPROD and the proposed EPROD. The most recent

[11] As referenced in the revised interim MMP; no bibliographic information provided.

surveys were completed during the 2014 IM reporting period around SPROD, SEPROD and the proposed EPROD.

The surveys around the TSF show both shallow and deep areas of higher electrical conductivity (EC) at two locations on the northern side of TSF Cell 1, at the southeast corner of TSF Cell 2, and on the eastern side of TSF Cell 3 WMD coincidental with the old Little Barney Creek channel. The results for the SPROD show a broad front of higher EC extending south and west of the dam towards Surprise Creek.

A review of the program by MRM indicated that the results were strongly influenced by the groundwater depth. However, the surveys do appear to highlight areas of relatively high conductivity (i.e., compared to the background level), which may be linked to elevated salinity and contaminated groundwater as a result of the operations.

As suggested by MRM staff during the IM site visit, it would be advantageous to conduct surveys over areas that may be vulnerable from future activities to characterise the background response (i.e., prior to any contamination). This would facilitate identification of future impacts and assessment of environmental performance.

Groundwater Flow Modelling

A number of groundwater flow models have previously been developed for the mine site. These include the following:

- A two-dimensional (2-D) model of pit developed by Golder Associates (Golder) to estimate inflows via the McArthur River channel alluvium (Golder, 2004).
- A three-dimensional (3-D) MODFLOW-SURFACT model developed by URS to investigate seepage from the TSF (URS, 2006).
- A 2-D model of TSF Cell 1 (Golder, 2011).
- A preliminary site-wide 3-D model developed by URS for the Phase 3 EIS to estimate both dewatering rates from the pit and underground, and drawdown impacts from pumping (URS, 2012).
- Refinement of the URS Phase 3 EIS model by RPS on two occasions to investigate seepage impacts from the proposed EPROD and SEPROD (RPS, 2013; 2012).
- Various 2-D models of the NOEF and proposed WPROD developed by KCB during the previous reporting period (KCB, 2014; 2015a; 2015b; 2015c).

Further modelling has been undertaken during the current reporting period by GHD, as discussed in Section 4.5.3.2.

EC Profiling of Rivers and Creeks

An EC survey was carried out during the previous reporting period to identify reaches along rivers and creeks that may be impacted by high salinity seepage from the TSF, NOEF and mine area. The drainages surveyed comprised:

- Surprise Creek from immediately upstream of TSF Cell 1 to its confluence with Barney Creek diversion channel.
- The lower reaches of Barney Creek diversion channel to McArthur River.
- McArthur River along and downstream of the diversion channel.

The results identified contamination adjacent to TSF Cell 1 and SPROD along Surprise Creek, contamination adjacent to NOEF and SEPROD along Barney Creek, and contamination south and east of the ELS along the McArthur River diversion channel. The high values along Surprise and Barney Creeks are almost certainly influenced by seepage. The high readings for the diversion channel may relate to natural mineralisation exposed during the channel construction and coincide with interpreted faults (as discussed elsewhere in this report).

The EC survey results are presented in Figure 4.11.

Pit Lake Modelling

Numerical modelling has been undertaken to assess the condition of the pit lake after mine closure. Initial modelling was conducted by URS as part of the Stage 3 EIS (URS, 2012), using outputs from their 3-D groundwater model. During the current reporting period, KCB has completed a high level assessment of the pit lake recovery and water quality using a water and solute balance (KCB, 2016a). At the time of the IM review, results were preliminary and further work is being undertaken as part of the Overburden Management Project EIS.

Seepage Recovery

A combination of recovery bores, sumps and trenches have been used to help mitigate seepage from the TSF and TSF Cell 3 WMD. Operation of these controls commenced in early 2009. However, the recovery bores have not been operational since late 2012 when surface infrastructure was damaged by fire. The locations of the seepage recovery bores, sumps and trenches are shown in Figure 4.12.

However, the effectiveness of these existing controls is uncertain, based upon recent investigations carried out at TSF Cell 1 (KCB, 2015d). These identified a broad seepage front extending northwards from Cell 1 towards Surprise Creek and groundwater flows within the near-surface overburden, weathered bedrock and fractured bedrock aquifers. This interpretation is supported by the available monitoring data which indicates that the recovery system that operated between 2009 and 2012 had no appreciable impact on the contaminant loads entering Surprise Creek.

McArthur River Mining has stated that recovery bores, sumps and trenches will (where required) be used to manage seepage from the NOEF and the associated runoff dams.

Low Permeability Barriers

Geopolymer barriers have been used at the mine site to provide a low permeability wall within the superficial deposits and weathered bedrock. Barriers have been installed around TSF Cell 1 and along the southern boundary of TSF Cell 2 and TSF Cell 3 WMD to reduce groundwater flows away from these facilities. Attempts were also made to limit inflows of uncontaminated

GROUNDWATER AND SURFACE WATER SURVEY EC RESULTS

McArthur River Mine Project

FIGURE 4.11

TAILINGS STORAGE FACILITY GEOPOLYMER BARRIER AND TRENCH LOCATION PLAN

McArthur River Mine Project

FIGURE 4.12

groundwater into the pit by installing barriers across the southern limb of a palaeochannel and at discrete groundwater inflow points along the southern edge of the pit. The palaeochannel is thought to trend through the pit and provide a conduit to the McArthur River.

As for the seepage recovery systems (discussed above), there is some uncertainty regarding the effectiveness of the existing geopolymer barriers. Assessments reported in KCB (2015d) identified a broad seepage front north of Cell 1 and groundwater flows in the deeper fractured bedrock that may pass underneath the existing barrier network. This interpretation is supported by the groundwater levels measured upstream and downstream of the TSF Cell 1 barrier, which show negligible head differences across the barrier.

Locations of the geopolymer barriers are shown in Figure 4.12.

Lining of Water Storages

A number of storages are operated by MRM to manage potential release water, poor quality water and process water (Classes 4, 5 and 6 (WRM, 2015)). These storages are lined to limit seepage losses. The design and construction method for storage liners has improved over recent years resulting in a significant reduction in seepage rates, as discussed further in Section 4.5.3.2.

Appropriate lining of storages is considered to be one of the most effective controls for limiting impacts on the groundwater environment from mining and processing activities.

Diesel Spill Remediation

Hydrocarbon spills have been recorded at the McArthur River Mine operations on three occasions, the most recent being in 2011 when 28,000 L of diesel was released from the fuel storage near the old power station. The largest spill occurred in 1997 when 155,800 L of diesel was released in the same area.

Since the 2011 spill, MRM has been engaged in remediation of the affected area. This work has included installation of 25 monitoring bores and a product recovery system, implementation of a comprehensive monitoring program, and assessment and reporting of results both quarterly and annually.

4.5.3.2 New Controls – Implemented and Planned

A number of studies were completed during the review period, some of which identified possible controls that could be used to manage impacts upon the groundwater environment. These studies included:

- A site-wide hydrogeological assessment (review of existing information, site investigations and revision of the site-wide conceptual hydrogeological model).
- A hydrogeological assessment of the TSF area (review of existing information, site investigations, installation of new monitoring bores, revision of the conceptual hydrogeological model and groundwater flow modelling of the TSF area).
- A hydrogeological and geochemical assessment of the NOEF (drilling and installation of new monitoring bores into the facility and a preliminary assessment of the hydrogeological conditions within and immediately below the deposited waste).

- Assessments of the PAF Runoff Dams (further design of the WPROD which is under construction, site investigations at the SPROD, upgrading of the existing SPROD clay liner, and simple water balance calculations to estimate seepage rates from the SPROD and SEPROD).
- Water and solute modelling of the pit void lake post-closure.
- Diesel spill remediation (ongoing assessment).

These studies are described in more detail in the following sections.

Site Wide Hydrogeological Assessment

McArthur River Mining, as part of the NOEF EIS, engaged KCB to provide an estimate of the impacts on the groundwater environment from historic and planned mining operations. This work included a review of existing information, site investigations to reduce gaps in the site-wide hydrogeological understanding, and revision of the conceptual hydrogeological model for the operation (KCB, 2015e). The outcomes from KCB's work included:

- Re-classification of aquifer types into:
  - Overburden/alluvial aquifers (sands and gravels along the main drainages, including the McArthur River palaeochannel).
  - Weathered bedrock aquifers (secondary permeability associated with dissolution features and broken zones, enhanced locally by faulting).
  - Bedrock aquifers (secondary permeability associated with dissolution features and broken zones, commonly associated with faults or joints, likely to be more apparent near surface).
- Identification of groundwater recharge processes associated with rainfall, interaction with rivers and creeks (mainly in the wet season), and artificial recharge via seepage from water storages and the TSF.
- Identification of groundwater discharge processes through evapo-transpiration, interaction with rivers and creeks (mainly in the dry season), and artificially through pumping.
- Inferred presence of a feature recharging the underground workings from either rainfall and/or the McArthur River diversion channel and/or the McArthur River palaeochannel, resulting in the need for high dewatering rates at the mine.
- Characterisation of the natural groundwater as Mg-Ca-HCO_3 type, except near fractured rock aquifers where groundwater is enriched in Na-Cl reflecting the hydrochemistry of deeper groundwater.
- Identification of contaminated groundwater enriched with SO_4 in areas north of TSF Cell 1 and the SPROD.

- Downward vertical hydraulic gradients over most of the site, reflecting recharge processes, apart from the area west of the TSF where upward gradients have been identified in response to seepage from the TSF.

Although useful, the IM considers that the results from KCB's work are general in nature and do not resolve some specific gaps in the understanding of the groundwater system. These include the need for:

- A better understanding of the background hydrogeological conditions away from the TSF, OEFs, pit and borefields, i.e., beyond areas where past investigations have been concentrated.
- Confirmation of the presence of deep aquifers that may provide preferential pathways at the pit and OEFs, and estimation of their hydraulic properties (hydraulic conductivity and aquifer storage).
- Better estimates of the hydraulic properties of the deep fractured bedrock aquifer(s) that may provide preferential pathways at the TSF.
- Confirmation of the presence, location and geometry of the McArthur River palaeochannel aquifer.
- Confirmation and location of naturally mineralised zones that may impact on groundwater quality, particularly if these exist in areas thought to be affected by contamination.

Field investigations including groundwater exploration drilling, installation of test bores and hydraulic testing at a representative scale are required to resolve these gaps. This will enable the development of a comprehensive conceptual model facilitating the construct of more representative groundwater flow models. These can then be used to more reliably assess future impacts upon the groundwater environment and assist in the design of effective controls, both during operations and (more importantly) after closure.

Given that groundwater is common to most of the issues affecting the operation, it is strongly recommended that the revised conceptual model is further developed in consultation with other disciplines to help ensure that a consensus is reached. This will promote the use of a single conceptual model when assessing impacts and mitigation options. A list of new recommendations is provided in Section 4.5.5.

TSF Area Hydrogeological Assessment

Hydrogeological assessments have been carried out in the vicinity of the TSF by KCB (2015d) and GHD (2015a; 2016a; 2016b).

The work by KCB has built on the site-wide assessment completed for the NOEF EIS (discussed above). The results include the following:

- Identification of a deep, high-permeability fault zone passing underneath the northern embankment of TSF Cell 1, which is thought to be associated with the Surprise Fault. The estimated hydraulic conductivity of the feature at one location is about 100 m/d. This feature appears to be associated with deeper Na-Cl type groundwater.

- Estimation of hydraulic conductivity values for the overburden aquifer (1 to 20 m/d), the weathered bedrock aquifer (0.2 to 20 m/d) and bedrock aquifer (0.3 to 100 m/d) using historic test results.
- Identification of radial groundwater flow away from the TSF.
- Identification of equivalent groundwater heads across the geopolymer barrier located north of TSF Cell 1, indicating that the barrier is ineffective in reducing groundwater flows away from the facility.
- Estimation of significant potential metals attenuation in the groundwater host medium, indicating higher than expected retardation properties. This is consistent with the high sulfate and low metal concentrations in contaminated groundwater emanating from the TSF.
- The conclusion that seepage from TSF Cell 1 towards Surprise Creek is likely to be an ongoing issue because of the proximity of the creek, the high hydraulic gradient driven by the decant pond, and the presence of higher permeability zones. Presently these impacts appear to be confined to elevated concentrations of conservative contaminants (e.g., sulfate), but there is potential for mobilisation of metals if groundwater acidification occurs.
- The conclusion that the majority of the engineered seepage mitigation design options (e.g., hydraulic barriers, recovery bores and drains) are unlikely to effectively contain TSF seepage, because of deeper groundwater flow regimes and the broad seepage contamination front extending away from the facility. Other options that could be considered include changing the tailings deposition strategy to eliminate stored water on the TSF, reducing the decant pond size, and changing the current environmental strategy to manage Surprise Creek and other creeks and rivers. The latter option would likely require the diversion of Surprise Creek and use of the natural channel to capture contaminated groundwater which would be managed within the site's water management system.

These results suggest that the conceptual model for the TSF is more advanced than the site-wide model discussed above. However, a number of the gaps still remain, as discussed in the preceding section, and further investigations are required to develop a more comprehensive model.

The work completed by GHD included groundwater flow modelling of the TSF and surrounding area, based on a modified version of the original MODFLOW-SURFACT model constructed by URS. The model was roughly calibrated to groundwater levels and used to investigate various engineered seepage mitigation design options. The model outcomes are summarised in Table 4.15.

Table 4.15 – TSF Groundwater Modelling Summary

Scenario*	Outcome
Scenario 1: No new seepage mitigation	**TSF Seepage Outflow**. Rates initially rise from about 1,400 to 2,400 m^3/d when TSF Cells 1 and 2 are combined in 2017. From 2017 to 2019, seepage rates fall dramatically to about 600 m^3/d when the decant pond in the combined cells is reduced and the long-term beach is established. The seepage rate after 2019 slowly rises to around 750 m^3/d at the end of processing in 2037
	Seepage to Surprise Creek. Rates initially rise from about 400 to 490 m^3/d when TSF Cells 1 and 2 are combined, then reduces to about 300 m^3/d between 2018 and 2030 before stabilising. The reductions are seen in both the shallow and deep groundwater systems, with the largest reduction occurring in the fresh rock aquifer
Scenario 2: Shallow interception trench between Cell 1 and Surprise Creek	**TSF Seepage Outflow.** Almost identical response to Scenario 1
	Seepage to Surprise Creek. A similar trend to Scenario 1, although rates are lower initially rising from about 370 to 390 m^3/d when TSF Cells 1 and 2 are combined, then reducing to about 220 m^3/d between 2018 and 2030 before stabilising. The shallow trench is predicted to capture all flows in the overburden and weathered bedrock aquifers, but seepage via the fresh rock aquifer is estimated to continue
Scenario 3: Deep interception trench between Cell 1 and Surprise Creek	**TSF Seepage Outflow**. Almost identical response to Scenario 1
	Seepage to Surprise Creek. Rates are predicted to fall slightly from 220 to 250 m^3/d in 2018. After 2018, the rate of seepage reduction increases before stabilising at about 110 m^3/d in 2030. However, the flows in the overburden and weathered bedrock aquifers are predicted to reverse (i.e., flows will be from the creek to the TSF), while flows into the creek via the fresh rock aquifer continue.
Scenario 4: Deep interception trench and pressure release bores between Cell 1 and Surprise Creek	**TSF Seepage Outflow**. Similar trend to Scenario 1, but with slightly higher (approximately 100 m^3/d) seepage rates
	Seepage to Surprise Creek. Rates are predicted to fall from 180 to 10 m^3/d in 2023 before stabilising. As for Scenario 3, the flows in the overburden and weathered bedrock aquifers are predicted to reverse (i.e., flows will be from the creek to the TSF), while flows into the creek via the fresh rock aquifer continue but at a low rate (about 90 m^3/d)

* All scenarios assumed a reduction in the TSF decant pond size.

The modelling results suggest that significant reductions in TSF seepage can be achieved using an interception trench, particularly when combined with pressure release bores. The IM considers that these outcomes have limited value because of the gaps in the conceptual model. The IM also notes that interception trenches have had minimal impact on seepage along the northern side of Cell 1 and the eastern side of Cells 1 and 2 and the WMD. These outcomes are also at odds with the findings by KCB (discussed above) that engineered seepage mitigation design options are unlikely to effectively contain TSF seepage. These diverging views support a more coordinated approach in developing a suitable conceptual model.

A list of the IM's new recommendations for the TSF is provided in Section 4.5.5.

NOEF Hydrogeological Assessment

A hydrogeological and geochemical investigation of the NOEF was completed by MRM to identify groundwater conditions within and below the facility, determine the geotechnical properties of the deposited waste, and collect geochemical information of the waste rock (MRM, 2016a). The investigation comprised the drilling and instrumentation of eight monitoring bores, which were installed through the NOEF into the underlying overburden, and analysis of waste rock samples. The results from the program are summarised as follows:

- No saturated zones were identified in the waste rock, although high moisture contents were measured in gas samples.
- No water was intercepted above the compacted clay liner (CCL) and little water was encountered on top of the former natural ground surface; groundwater levels were between 4 and 6 m below the base of the NOEF, which is consistent with the groundwater depths in the monitoring bores at the SPROD.
- The CCL above the NOEF base was classified as moist (not saturated).
- A gravel unit was intersected at one location below the NOEF.
- The background temperatures in the NAF and PAF were 50˚C and 60 to 65˚C respectively, which may account in part for the absence of saturated conditions in the waste rock and the low moisture content of the CCL.

McArthur River Mining plans to develop an integrated conceptual model of the NOEF during the 2017 IM reporting period.

The results from the MRM program were further assessed in the context of the site-wide conceptual hydrogeological model by KCB (2016b). The assessment outcomes are as follows:

- The hydrogeological condition of the NOEF will be controlled by the rainfall infiltration rate through the CCL and the subsequent seepage outflows (either vertically through the base of the facility or via lateral seepage).
- Site-wide investigations have not identified any potential groundwater flow preferential pathways. The overburden aquifer is therefore considered to be a single heterogeneous hydraulic unit. Similarly, there is no evidence of a high permeability zone in the weathered bedrock and fresh rock aquifers beneath the NOEF.
- Groundwater flow directions are likely to be primarily controlled by the regional eastward hydraulic gradient towards McArthur River, with more localised influences from pit dewatering and elevated groundwater heads in the NOEF. Groundwater flow modelling by KCB (report in preparation) indicates that the drawdown cone around the pit will capture all seepage from the current NOEF while pit dewatering is active.
- Various seepage mitigation design options were listed by KCB with their respective generic advantages and disadvantages.
- In determining unacceptable impacts and seepage mitigation options, consideration should be given to the maximum contaminant loads in the groundwater seepage and the likely impacts upon surface water receptors.

Key uncertainties identified by KCB (2016b) include:

- Background hydrogeological conditions away from the NOEF and the potential for preferential pathways.
- The presence of possible preferential pathways in the weathered bedrock and fresh rock aquifers.
- The effects of seepage from PRODs, which are not adequately modelled.
- The effectiveness of the various seepage mitigation designs, which are yet to be modelled.
- Possible future groundwater level mounding in the NOEF, which may promote deeper groundwater flows.

The IM concurs with these key uncertainties and recommends that the emphasis be placed on field investigations to ground-truth the assumptions adopted in the groundwater modelling studies. Determining contaminant loads in the groundwater seepage is considered a key issue which would assist with determining loads in surface water as discussed in Section 4.3.4.1. Recommendations are discussed further in Section 4.5.5.

PAF Runoff Dam Assessments

Site investigations at the SPROD and upgrading of the existing clay liner were completed during the reporting period. In addition, simple water balances were developed by MRM for the SPROD and SEPROD to estimate seepage losses from the dams.

A geotechnical investigation of the SPROD was carried out by GHD (2015b), which included the excavation of 18 test pits. The pits were logged and samples of the clay liner and underlying overburden collected for laboratory analysis. The investigation concluded that the:

- Thickness of the clay liner ranged from 0.5 to 1.5 m.
- Liner material was generally suitable for use as a low permeability liner, apart from three sites on the western side of the dam where the material was silty sand.
- Liner material was poorly compacted.
- Natural alluvium beneath the liner appeared more permeable than expected.

It was also recommended by GHD (2015b) that the liner be upgraded by re-working the existing liner material (as a short-term measure to reduce seepage) and that synthetic liner be installed (as a longer-term seepage mitigation option). The short-term remediation of the existing liner was subsequently completed in November 2015, with installation of the synthetic liner planned for completion prior to the 2016-2017 wet season.

Two simple steady state water balances were developed to estimate seepage rates from the SPROD and SEPROD (MRM, 2015h; 2015i). The estimated seepage rate for the SPROD was about 4,000 m^3/d, while that for the SEPROD was about 300 m^3/d (where the SEPROD was constructed using a properly engineered compacted clay liner). These results support the option of adequately lining all PAF runoff dams. The high seepage rate from the SPROD is consistent with groundwater quality impacts observed in nearby monitoring bores, particularly bores GW064S and D (see Figure 4.9).

The improvement to the liner at the SPROD is considered a significant achievement during the reporting period. The results also highlight the potential seepage impacts on the groundwater environment from the PAF runoff dams and other storages used to manage poor quality water and the requirement for adequate passive controls.

Pit Lake Modelling

A water and solute balance model was developed by KCB (2016a) to investigate the pit lake development post-closure, based on options to complete mining in 2018 or 2037. The model incorporated inflows and outflows related to groundwater interaction, rainfall runoff and evaporation. The option to manage water treatment waste brines through pit disposal and the influence of the indirect river inflows to the underground mine were also assessed. The results of KCB's pit lake modelling are summarised in Table 4.16.

Table 4.16 – Pit Void Lake Modelling Summary

Scenario	Base Case Outcomes
Closure in 2018, with wastewater discharge and river inflows to underground	Pit void lake levels - recovery to 180 mAHD in about 40 years
	Water quality - long-term rises in concentrations of SO_4 and As, which reach 5,000 mg/L and 90 μg/L, respectively, after 100 years
Closure in 2018, with river inflows to underground no wastewater discharge	Pit void lake levels - recovery to 180 mAHD in about 40 years
	Water quality - long-term rises in concentrations of SO_4 and As, which reach 4,200 mg/L and 90 μg/L, respectively, after 100 years
Closure in 2018, no wastewater discharge and river inflows to underground	Pit void lake levels - recovery to 175 mAHD in about 85 years
	Water quality - long-term rises in concentrations of Zn (initially falls before rising to reach 40 mg/L), Cu (rises rapidly after 90 years. reaching 40 μg/L), and As (steadily rises to 90 μg/L)
Closure in 2037, with wastewater discharge and river inflows to underground	Pit void lake levels - still recovering at end of 100 year run duration, final lake level - 35 mAHD
	Water quality - long-term rises in concentrations of SO_4, Cu and As, which reach 2,500 mg/L, 1.8 μg/L and 110 μg/L, respectively, after 100 years
Closure in 2037, with river inflows to underground no wastewater discharge	Pit void lake levels - still recovering at end of 100 year run duration, final lake level -35 mAHD
	Water quality - long-term rises in concentrations of SO_4, Cu and As, which reach 2,200 mg/L 1.6 μg/L and 110 μg/L, respectively, after 100 years
Closure in 2037, no wastewater discharge and river inflows to underground	Pit void lake levels - still recovering at end of 100 year run duration, final lake level -135 mAHD
	Water quality - long-term rises in concentrations of Zn (initially falls before rising to reach 40 mg/L), Cu (steadily rises to 12 μg/L), and As (steadily rises to 4 mg/L)

The solute balance included solute movement with groundwater inflows and wastewater discharge, and loading through geochemical interaction with the pit walls. The influences of mineral saturation were incorporated through external modelling using programs such as PHREEQC.

Although the modelling is considered preliminary, it indicates that the pit lake is likely to rise above the invert level of the McArthur River diversion and that the lake water quality will exceed selected groundwater and surface water triggers values. These outcomes highlight the importance of managing the pit lake to ensure that contaminated water is not released to the environment. This particularly applies to McArthur River, contamination of which could lead to significant unacceptable off-site impacts. Because of the uncertainties associated with assessing large surface water bodies in a highly variable climate, it is likely that any future assessment needs to include:

- An initial investigation undertaken prior to closure to identify any fatal flaws associated with each closure option, based upon development of suitable models.
- A post-closure program of monitoring and model validation to verify modelling results prior to relinquishment of the mine site.

Recommendations regarding pit lake management are presented in Section 4.5.5.

Diesel Spill Remediation

Hydrocarbon spills have been recorded at McArthur River Mine on three occasions, the most recent being in 2011 when 28,000 L of diesel was released from the fuel storage near the old power station. The largest spill occurred in 1997 when 155,800 L of diesel was released in the same area.

Since the 2011 spill, MRM has been engaged in the remediation of the affected area. This work has included installation of 25 monitoring bores, implementation of a comprehensive monitoring program, and assessment and reporting of results both quarterly and annually. The IM concurs with the conceptual site contamination model and remedial approach presented in MRM's remediation action plan (Xstrata, 2011).

The results from the remediation program presented in the revised interim 2013-2015 MMP (MRM, 2015a) indicate that both the light non-aqueous phase liquid (LNAPL) and the dissolved contaminant plumes initially extended to the northwest and west, and to a lesser extent to the east. It is not possible to estimate the extent of migration to the west due to the lack of monitoring bores, which (it is understood) could not be installed due to topographic/operational constraints. The results presented in the 2013-2015 MMP suggest that the plume is stabilising (i.e., it is not moving), although the IM notes that the monitoring bore coverage to the east and northeast of the impacted area is minimal, particularly with the loss of bore URS03. Consideration should be given to installing a replacement bore at URS03 and an additional bore north or northeast of URS17.

The plume extents have been influenced by fracture flow rather than radial flow. Total product recovery as of 26 January 2015 was 3,055 L, which represents around 11.04% of the spill volume (MRM, 2016b). Natural attenuation appears to be active in the area of contamination, although there are large temporal variations in measured concentrations of indicator parameters (e.g., sulfate, alkalinity, nitrate, ferrous Fe and Mn). Importantly, the risks to Barney Creek and the McArthur River are considered to be negligible due to the capture zone around the pit and underground mine from dewatering activities.

4.5.4 Review of Environmental Performance

4.5.4.1 Incidents and Non-compliances

Incidents

No groundwater-related incidents were recorded over the review period.

Non-compliances

Non-compliances during the review period included the following:

- A number of monitoring bores were not sampled in accordance with the schedule provided in Table 4.14. It is understood that this was due to access constraints.
- Samples collected from a number of committed monitoring bores exceeded the livestock limits for calcium, sulfate, fluoride, lead and total dissolved solids (TDS). The groundwater quality exceedances are summarised in Table 4.17 and the locations of the mine site bores with unacceptably high sulfate and TDS concentrations (based on groundwater trigger values) are shown in Figure 4.13.

The locations of the mine site monitoring bores showing exceedances in sulfate and TDS are consistent with seepage from the TSF, SPROD and NOEF. They also correlate to high EC values in surveys of water quality along Surprise Creek and Barney Creek conducted during the last reporting period (Section 4.5.3.1).

Table 4.17 – Groundwater Quality Exceedances

Parameter	Stock Limit (mg/L)	Bores Where Groundwater Quality Exceeded Trigger Values
TDS	5000	Mine site - GW004, GW014, GW018, GW019, GW020A, GW020B, GW021, GW042A, GW043A, GW043B, GW045B, GW048, GW064D, GW064S, GW065D, GW065S, GW090, GW093, GW095D, GW095S, GW096D, GW096S, GW100, GW105 and GW132
		Loading facility - GWBB01A, GWBB01B, GWBB02, GWBB03A, GWBB03B, GWBB04A, GWBB04B, GWBB05A, GWBB05B, GWBB05C, GWBB06C, GWBB07B, GWBB08A, GWBB08B and GWBB08C
Calcium	1000	Loading facility - GWBB05C, GWBB06C, GWBB07B and GWBB08C
Sulfate	1000	Mine site - GW003A, GW004, GW014, GW018, GW019, GW020A, GW020B, GW021, GW042A, GW042B, GW043A, GW043B, GW045B, GW048, GW064D, GW064S, GW065D, GW065S, GW087D, GW090, GW093, GW095D, GW095S, GW095S, GW096D, GW096S, GW100, GW102, GW103D, GW103S, GW105, GW132, GW134 and GW135
		Loading facility - GWBB01A, GWBB01B, GWBB02, GWBB03A, GWBB03B, GWBB04A, GWBB04B, GWBB05A, GWBB05B, GWBB05C, GWBB06B, GWBB06B, GWBB06C, GWBB07B, GWBB08A, GWBB08B and GWBB08C
Fluoride	2	Mine site - GW004, GW006, GW014, GW018, GW096S, GW100, GW105, GW119D, GW119S, GW131, GW132 and GW134
		Loading facility - GWBB03A
Copper	0.5	Mine site - GW016
Lead	0.1	Mine site - GW016

GROUNDWATER TOTAL DISSOLVED SOLIDS AND SULFATE EXCEEDANCES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.13

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A significant number of the bores at the Bing Bond Loading Facility exceeded the livestock limits for TDS, calcium, sulfate and fluoride. However, the general groundwater quality at the loading facility indicates that the site is naturally affected by mixing groundwater with marine water and possibly evaporative concentrations of salt where groundwater levels lie close to surface immediately south of the dredge ponds. Under these conditions, the use of stock limits as trigger values is considered inappropriate and the IM recommends that site-specific trigger values be developed (see Table 4.19).

4.5.4.2 Progress and New Issues

Two new issues were identified during the reporting period: the adequacy of groundwater modelling and the development of a comprehensive site-wide conceptual model.

There will be a strong reliance on groundwater modelling in the future to assess the effectiveness of controls. The review of all groundwater models by an independent groundwater modelling specialist will help ensure that models are suitably constructed and adequately calibrated, and that the uncertainties associated with the modelling results are identified.

A comprehensive conceptual model is required for the mine site, which includes areas not immediately affected by the mine (e.g., the TSF, NOEF and water storages). The model would enable a better understanding of the impacts upon the general environment from these potential sources of contamination and would assist in the construction of representative groundwater flow models. It is strongly recommended that the site-wide conceptual model is developed in consultation with other disciplines to help ensure that a consensus is reached. This will promote the use of a single conceptual model when assessing impacts and mitigation options.

The progress related to the outcomes from the recent studies is summarised in Table 4.18.

Table 4.18 – Progress on Groundwater Issues

Progress Item	Risk Area
The site-wide hydrogeological assessment has initiated further development of a mine site conceptual hydrogeological model. The development of a robust site-wide model is crucial to managing both operational and post-closure risks as it enables: ♦ Reliable assessment of current and future impacts away from the immediate areas of concern (e.g., TSF, NOEF, PAF runoff dams and pit) ♦ Development of groundwater models that are representative of the groundwater system ♦ Development of effective controls to mitigate impacts	All mine site risks
The hydrogeological assessment of the TSF area has been progressed and includes identification of deep groundwater flow paths that extend under the facility and quantification of hydraulic parameters for the various aquifer units. An assessment has also been made of the effectiveness of existing controls (e.g., hydraulic barriers, recovery bores and drains). These outcomes will assist in development of new controls to mitigate groundwater impacts	TSF seepage contamination and TSF cover failure
A geotechnical and hydrogeological investigation of the NOEF was completed and has enabled an assessment of the conditions within the facility Monitoring bores were also installed to facilitate future data collection, and assessment of changes in the NOEF with time and the performance of controls (e.g., the CCL and cover system)	Oxidation of mine waste and OEF cover failure

Table 4.18 – Progress on Groundwater Issues (cont'd)

Progress Item	Risk Area
Investigations have been completed at the SPROD. These include the estimation of the seepage losses from the pond (which were significant at about 4,000 m^3/d), geotechnical site investigations, and short-term remediation of the clay liner. McArthur River Mining plans to install a synthetic liner later during the 2016 dry season which should further reduce seepage rates The construction of effective liners in all poor quality water storages is considered crucial to minimising seepage impacts. This is highlighted by the seepage assessment on SEPROD, which was constructed using a properly engineered CCL. Estimated losses from the SEPROD were 300 m^3/d, more than an order of magnitude lower than the losses estimated for the SPROD	Water storage seepage contamination
A water and solute pit lake balance was developed to estimate the pit lake recovery and water quality after closure. Although the estimate is considered preliminary, the results indicate that management of the pit lake will be a major issue with the potential for contaminated water to enter the environment	Pit void lake seepage
Remediation of the diesel spill impacts is continuing	Hydrocarbon spills and seepage

McArthur River Mining's performance against previous IM review recommendations relating to groundwater management is outlined in Table 4.19.

Table 4.19 – Groundwater Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
Trigger limits	The use of water quality guideline limits for stock watering is considered inappropriate given the background groundwater quality variation, particularly at Bing Bong Loading Facility. It is recommended that the available water quality data be used to develop trigger values that reflect this variation and the surrounding ecosystems and environment in accordance with the approach presented in ANZECC/ARMCANZ (2000)	McArthur River Mining is in the process of developing site-specific trigger values for all committed monitoring bores, based on up-gradient water quality and historic ranges (MRM, 2015b)
Open pit and underground mine	It is recommended that MRM continue to investigate options to dewater aquifers responsible for inflows to the pit and (in particular) the former underground mine. The high inflow rates estimated from water volume increases during the wet season strongly indicate the presence of high permeability aquifers, likely linking the McArthur River to the underground mine. There could be significant benefit in reducing the requirement to manage contaminated mine water if groundwater inflows to the mine can be reduced, assuming the quality of the intercepted groundwater is sufficient to enable controlled environmental release The investigation could include an assessment of possible aquifer locations based upon the recorded locations of groundwater inflows to underground mine, and the interpretation of	McArthur River Mining has started investigations into groundwater pathways linking the McArthur River diversion to the pit and underground as part of the development of a site-wide conceptual model. The investigations have been based upon a review of existing data, as recommended. However, no groundwater exploration drilling has been undertaken During the IM site visit, MRM staff also identified possible pathways between the lower reaches of Barney Creek (which commonly floods during the wet season) and the northern part of the underground mine. A pathway at this location is consistent with results from site investigations completed for the creek diversion in 2009 (KCB, 2015e) which identified near-surface karst development

Table 4.19 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period		
Open pit and underground mine (cont'd)	geological, structural and geophysical information. It is suggested that groundwater exploration drilling be conducted using reverse circulation methods with drill holes orientated to maximise the likelihood of intercepting groundwater features	Updated recommendations for managing inflows to the pit and underground are provided in Table 4.20
Diesel spill	It is recommended that diesel spill monitoring bore URS03, which was destroyed during the review period, be replaced and an additional monitoring bore be installed east or northeast of bore URS17 to increase the coverage to the east and northeast of the plume	There has been no progress on this item
2012 and 2013 Operational Periods		
OEF	Assessment of seepage impacts from the NOEF to confirm the effectiveness of the PAF containment system This should include installation of monitoring bores around the current footprint and progressive installation of monitoring bores around the expansion area and completion of EM geophysical surveys The IM recognises that MRM has commenced installation of monitoring bores in the area marked for NOEF expansion. However, there are no monitoring bores located along the northern, eastern and western perimeters of the facility, which could be used to assess the success of the PAF encapsulation system adopted by MRM In addition, a schedule should be prepared showing the progressive installation of future monitoring bores in the NOEF expansion area, which should correspond to the planned development of the facility The seepage from the SPROD needs to be addressed. McArthur River Mining should commit to option(s) to prevent seepage at source. This work is likely to include a commitment to design and install a full liner at the dam The IM recognises that MRM has identified seepage from the SPROD as a major issue and during the review period has completed a cost benefit analysis on three remedial options	No new committed monitoring bores were installed around the NOEF since the 2015 IM review. No information was sighted showing the locations of future monitoring bores, although the Overburden Management Project EIS is still in preparation (and is scheduled for completion in December 2016). The IM acknowledges that the outcomes from the EIS will determine future dump development. Revised recommendations for the NOEF are provided in Table 4.20 Work has been completed on the SPROD resulting in the reworking of the existing clay liner that is likely to reduce seepage from the facility, estimated at 4,000 m^3/d. A synthetic liner for the SPROD is planned to be installed before the 2016-2017 wet season, which should eliminate most of the seepage from the pond
TSF	The seepage from TSF Cell 1 needs to be addressed. McArthur River Mining should commit to option(s) to prevent seepage at source, e.g., installation of a permanent cover designed to limit recharge to the deposited tailings or reprocessing of the tailings McArthur River Mining has installed a temporary cover, which the available	A number of studies have been completed around the TSF, including development of a preliminary conceptual hydrogeological model and groundwater modelling. The former has identified deep groundwater pathways under the TSF, provided preliminary estimates of hydraulic properties for the various

Table 4.19 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
TSF (cont'd)	monitoring data suggest is (so far) ineffective in controlling recharge to the deposited tailings. The continued exceedances in salinity and sulfate concentrations in a number of monitoring bores contravene the groundwater trigger values for the mine site The seepage along the southeastern perimeter of the TSF Cell 3 WMD needs to be addressed. McArthur River Mining should commit to option(s) to prevent seepage under this section of the embankment which likely relates to the presence of higher permeability alluvium associated with the original Little Barney Creek channel. Preventative options include installation of an interception trench across the original channel and installation of recovery bores McArthur River Mining has already installed a geopolymer barrier along the southeastern wall of the Cell 3 WMD and a recovery sump within the original Little Barney Creek channel. The continued exceedance in sulfate concentrations in bores GW04 and GW14 indicate these measures are inadequate. The importance in addressing the seepage issue is highlighted by MRM's intention to use the dam to store dirty water as part of the mine water management strategy The seepage from the southeastern corner of TSF Cell 2 needs to be addressed. McArthur River Mining should identify suitable options to mitigate this seepage. Preventative options include installation of recovery bores to augment the existing interception trench and geopolymer barrier The importance of addressing this issue is highlighted by MRM's intention of using the active TSF cell to store contaminated water as part of their mine water management strategy	aquifer units, and provided further evidence of the ineffectiveness of existing controls. The IM supports the further development of the TSF conceptual hydrogeological model The groundwater modelling completed during the review period is considered of limited value given the uncertainties in the conceptual model. The IM notes that MRM no longer intends to store contaminated water in the active TSF Cell 2 Revised recommendations for the TSF are provided in Table 4.20
Open pit	See recommendation in Section 4.8.4.2	Preliminary water and solute pit lake modelling has identified potential environmental release of contaminated water post-closure. Further work is being undertaken as part of the Overburden Management Project EIS Revised recommendations for the pit lake are provided in Table 4.20

Table 4.19 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
General data interpretation and reporting	An annual independent review of the impacts from groundwater abstraction, including both groundwater supply from borefields and dewatering, should be undertaken by a suitably qualified hydrogeologist. The review should assess drawdown impacts on the groundwater and surface water systems and impacts on groundwater quality	An internal review of the groundwater monitoring data for the 2014-2015 period was completed. The review presented the data in a suitable graphical form. However, there was minimal interpretation of the results, with only generalised statements regarding bores impacted by seepage. More comprehensive interpretations are required in future MMPs and annual groundwater reviews
	A review should be carried out on the commitments presented in the MMP to include all MRM commitments, remove any duplicates and (where required) clarify wording	A listing of MRM's groundwater monitoring commitments was provided in Excel format (MRM, 2016c). It is recommended that these commitments be summarised along with any other commitments (e.g., groundwater trigger values) in future MMPs and annual groundwater reviews
	The commitments are currently presented over a number of sections and include repetitive comments from third parties. Clarification of MRM's commitments would assist in identifying where breaches have occurred	
	McArthur River Mining should commit to reporting all breaches of their groundwater commitments to the DME. In particular, there appears to be an acceptance that exceedance concentrations of sulfate and salinity in areas previously affected by seepage do not warrant reporting	There appears to be minimal change with respect to reporting breaches of MRM's commitments. This issue should be addressed in 2016
Analytical suite	A comprehensive groundwater monitoring schedule should be presented in the MMP and Annual Operational Performance Report, which lists the committed monitoring bores and details the monitoring requirements, i.e., parameter, detection limit and frequency	A listing of MRM's groundwater monitoring commitments was provided in Excel format (MRM, 2016c). It is recommended these commitments be summarised in future MMPs and annual groundwater reviews
2011 Operational Period		
General data interpretation and reporting	The provision of water quality data should be reviewed to ensure consistency in the format and units used	Completed. This issue has been addressed as part of MRM's procedures
Borefields	Monitoring water levels in borefield abstraction and surrounding observation bores prior to, during, and following cessation of pumping cycles (installation of pressure transducer data-loggers in at least some wells would be advantageous)	Completed. Loggers have been installed
	Constructing hydrographs of pressure levels in all borefield abstraction bores and nearby observation bores, including rainfall and abstraction volumes and rates	No production or observation bore hydrographs were identified. These should be provided in future MMPs and annual groundwater reviews
	Assessing data such as recovery rates following cessation of pumping and drawdown rates during constant discharge	No assessment of the drawdown or recovery rates was identified. These should be provided in future MMPs and annual groundwater reviews

Table 4.19 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2011 Operational Period (cont'd)		
OEF	Hydrographs be constructed for monitoring bores GW64S, GW64D, GW65S and GW65D to allow assessment of changes in groundwater pressure over time	Completed. Hydrographs are prepared for committed monitoring bores as part of the MMP and annual groundwater reviews
TSF	As over 500 m^3 of hydrocarbon-impacted soil has been taken to the TSF waste emplacement facility, bores GW04, GW06, GW14 and GW18 as a minimum should be monitored for TPH/BTEX/naphthalene (if not already done so)	Completed. Analyses of TPH/BTEXN is undertaken for GW04, GW06, GW14 and GW18
	Combining hydrogeological and hydrogeochemical data and development of a conceptual model for the TSF based on this data (updated annually)	The development of a conceptual model for the TSF has been initiated. This recommendation has been included in more recent recommendations
	The tailings stored in TSF Cell 1 should be removed for re-processing	The IM has been advised by MRM that the preferred strategy is to relocate the tailings to the open pit at closure
	A perimeter cut-off trench should be installed around the TSF	This recommendation has been superseded as part of ongoing investigations around the TSF
	A physical groundwater flow barrier should be installed around the TSF	This recommendation has been superseded as part of ongoing investigations around the TSF
	A limestone or calcium-rich cover should be installed on the TSF	McArthur River Mining plans to amalgamate Cells 1 and 2 as part of the life of mine tailings management option
	Kinetic tests should be carried out to estimate the attenuation characteristics of the alluvium underlying the TSF	No kinetic test data were sighted, although 11 soil samples from around the TSF were tested to estimate the distribution coefficient and provide an indication of their attenuation potential. This recommendation should be actioned
Analytical suite	A full cation and anion ionic balance be undertaken on all samples (pH, TDS, Na, Ca, Mg, K, Cl, SO_4, HCO_3, NH_3, NO_3, NO_2, PO_4 and F). The 2014 IM review recommended that analysis be limited to NO_3, i.e., exclude NH_3, NO_2 and PO_4	Nitrate is included in the parameters tested in all groundwater samples submitted for laboratory analysis, apart from the diesel spill monitoring bores (Table 4.14)
	Groundwater contours in each separate formation, but particularly the bedrock and the alluvium, need to be presented at least bi-annually: at the end of wet and end of dry seasons	Completed. Wet and dry season contours have been provided in the revised interim 2013-2015 MMP (MRM 2015a) and the 2014-2015 groundwater review (MRM, 2015b)
General data interpretation and reporting	Comparison of the actual groundwater contours and the modelled groundwater level contours	A comparison of measured and simulated groundwater level contours has not been identified for the review period. However, a groundwater flow model is currently being developed which should provide a more robust means of comparison

Table 4.19 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2011 Operational Period (cont'd)		
General data interpretation and reporting (cont'd)	Separate groundwater contour figures using all available bores should be provided for the TSF, the regional monitoring network and Bing Bong Loading Facility, as well as the OEF once further bores are installed	Wet and dry season contours were provided for the Bing Bong Loading Facility in the 2013-2015 revised interim MMP (MRM, 2015a). However, separate groundwater level contours for the areas around the TSF or OEFs have not been sighted. The IM considers the site-wide contours for the mine and loading facility sufficient
	Groundwater quality criteria should be based upon the potential environmental receptors to groundwater discharge or use	McArthur River Mining is in the process of developing site-specific trigger values for all committed monitor bores, based on up-gradient water quality and historic ranges (MRM, 2015b)
	Interpretation of groundwater flow direction(s) and hydraulic gradients and, in turn, provide visual representation of the significant factors in groundwater impacts from the MRM operations	This recommendation has been superseded by more recent recommendations
	Further assessment of the impacts from groundwater abstraction, including hydrographs for relevant bores comparing recharge influences (e.g., rainfall) and discharge influences (e.g., pumping)	This recommendation has been superseded by more recent recommendations
	Hydrographs should be prepared for all monitoring bores where groundwater level data is collected	Completed. Hydrographs for committed bores are provided in the 2013-2015 revised interim MMP (MRM, 2015a) and the 2014-2015 groundwater review (MRM, 2015b)
	A more robust hydrogeological and hydrochemical model should be developed and updated annually, and the results reported annually in the MMP	This recommendation has been superseded by more recent recommendations
	Future geophysical surveys should be completed and changes in conductivity over time assessed to identify seepage impacts	Completed. Additional geophysical surveys have been completed and interpretations carried out to identify changes in ground conductivity over time

4.5.4.3 Successes

Significant progress was made on a number of issues during the review period (Section 4.5.3.2). However, none of the issues, which are long-term and affect large areas of the mine site and loading facility, have been resolved. As a consequence, there have been no successes during the review period.

4.5.5 Conclusion

A summary of the findings during the review period is provided below:

- A preliminary site-wide conceptual hydrogeological model has been developed that has identified the various aquifer types at the mine site, recharge and discharge mechanisms, groundwater flow regimes and groundwater quality types. The model also recognises a possible link from the McArthur River to the underground mine, which could increase inflows to the mine, particularly during wet season floods.
- A more comprehensive conceptual hydrogeological model was developed for the TSF area, which identified a high permeability fault zone extending north of the TSF Cell 1 and having a hydraulic conductivity of around 100 m/d. Hydraulic conductivity values were also estimated for the aquifer types at the mine site. Local groundwater flow regimes were identified which suggest seepage from the TSF to Surprise Creek will continue under the current tailings deposition strategy and that engineered mitigation options were unlikely be effective. The attenuation properties of the subsurface materials appear to be sufficient to restrict metals contamination. However, this condition may be reversed if groundwater acidification occurs.
- An investigation at the NOEF indicates that the waste rock is unsaturated, although high gas moisture contents were recorded, and groundwater levels at the facility still lie below the natural ground surface suggesting seepage through the floor of the NOEF may be limited. The CCL at the base of the PAF cell was found to be moist but not saturated. High temperatures were measured within the waste rock, which is consistent with the high moisture content and unsaturated conditions. Groundwater flow modelling indicates that any seepage from the NOEF will be captured within the drawdown cone around the pit while dewatering is active.
- Estimates from water balance modelling shows high historic seepage losses from the SPROD, which is consistent with monitoring results that show local groundwater contamination. Recent improvements to the SPROD clay liner are expected to reduce seepage rates. Water balance modelling of the SEPROD indicate a much lower seepage rate, confirming that suitably engineered liners are effective in controlling seepage losses from water storages.
- Preliminary pit lake modelling suggests that there is an unacceptable risk that the final lake level will rise above the invert of the McArthur River and that water quality will exceed trigger values. This could result in the discharge of contaminated lake water to the environment.
- Monitoring of the area around the 2011 diesel spill indicates that the impacts have stabilised and that the plume is not extending further. Unacceptable impacts on local water courses are considered unlikely.

Ongoing and new IM recommendations related to groundwater issues are provided in Table 4.20.

Table 4.20 – New and Ongoing Groundwater Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Open pit and underground mine	The following revised recommendations are made regarding options to dewater aquifers responsible for inflows to the pit and underground mine: ♦ Field investigations should be undertaken to identify groundwater pathways associated with the pit and underground (including the McArthur River palaeochannel aquifer) and estimate their properties. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ The conceptual model for the pit and underground should be updated to include the field program results ♦ Once the conceptual models are sufficiently advanced, numerical models should be constructed to identify effective controls, which may include installation of production bores to intercept groundwater flows towards the pit or underground	High
OEF	The following revised recommendations are made regarding the assessment of seepage impacts around the NOEF to confirm the effectiveness of the PAF containment system, once the future development of the facility is approved: ♦ A schedule should be developed for the installation and testing of monitoring bores in areas planned for future NOEF expansion. The schedule should allow for the adequate collection of background data ♦ Electromagnetic surveys should be carried out in areas planned for future NOEF expansion to identify background responses. The timing of surveys should take into consideration seasonal changes in groundwater level ♦ Monitoring of the eight new NOEF bores should be included in MRM's list of commitments ♦ Field investigations should be undertaken to identify groundwater pathways in the vicinity of the NOEF and estimate their hydraulic properties. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ The outcomes from field investigations and ongoing monitoring should be used to routinely update the conceptual hydrogeological model for the NOEF ♦ Once the conceptual model is sufficiently advanced, numerical models should be constructed to identify effective controls	High
SPROD	The following revised recommendations are made regarding the SPROD: ♦ The synthetic liner should be installed as a long-term seepage control ♦ The simple water balance model should be reviewed once the synthetic liner has been installed to estimate seepage rates	High

Table 4.20 – New and Ongoing Groundwater Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
TSF	The following revised recommendations are made regarding the assessment of seepage impacts around the TSF: ♦ Field investigations should be undertaken to better identify groundwater pathways in the vicinity of the TSF and estimate their hydraulic properties. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ The conceptual model for the TSF should be updated to include the field program results ♦ Once the conceptual model is sufficiently advanced, numerical models should be constructed to identify effective controls.	High
Open pit closure	Further assessment of the post-closure pit lake is required to identify a robust option to control impacts. Options under consideration by MRM include maintaining the lake as a sink or designing a through-flow system incorporating the McArthur River. Revised recommendations to manage this issue are as follows: ♦ Scopes of work should be developed to assess closure options to identify potential fatal flaws prior to mine closure. These are likely to include further development of the water and solute balance and modelling of pit lake stratification ♦ An approach should be identified to assessing the verification of the results from these studies after mine closure. This would likely include collection of monitoring data and validation of the models developed prior to closure and revision of closure options (as required)	High
Diesel spill	Monitoring bore URS03 should be replaced and an additional monitoring bore installed east or northeast of bore URS17 to increase the coverage to the east and northeast of the plume	Medium
General data interpretation and reporting	A comprehensive interpretation of the groundwater monitoring data should be carried out as part of future MMPs and annual groundwater reviews. These should aim at identifying processes responsible for unacceptable groundwater impacts	Medium
	A summary of all groundwater commitments should be presented in future MMPs and annual groundwater reviews	Low
	McArthur River Mining should commit to reporting all breaches of their groundwater commitments to the DME. In particular, there appears to be an acceptance that exceedance concentrations of sulfate and salinity in areas previously affected by seepage do not warrant reporting	Low
	Hydrographs of pressure levels in all borefield abstraction bores and nearby observation bores should be constructed, including rainfall and abstraction volumes and rates	Low
	Data such as recovery rates following cessation of pumping and drawdown rates during constant discharge should be assessed	Low
	Kinetic tests should be carried out to estimate the attenuation characteristics of the alluvium underlying the TSF	Medium

Table 4.20 – New and Ongoing Groundwater Recommendations (cont'd)

Subject	Recommendation	Priority
New Items		
Groundwater model review	A strong reliance will be placed on groundwater modelling to assess controls. It is therefore recommended that all groundwater models be reviewed by a specialist modeller to help ensure: ♦ The adequacy of the conceptual hydrogeological model as a basis for a numerical model given the outcomes being sought ♦ Suitable construction using appropriate boundary conditions, mesh sizes and stress periods/time step lengths ♦ Adequate model calibration to both steady-state and transient data ♦ Adoption of suitable initial conditions ♦ Identification and understanding of model uncertainties	High
Site-wide conceptual hydro-geological model	A site-wide conceptual model is required to provide a better understanding of the impacts upon the general environment from potential sources of contamination. This will require the following: ♦ Field investigations to (i) confirm the presence of the overburden/alluvial, weathered bedrock and fresh rock aquifers, and features associated with preferred groundwater pathways, and (ii) estimate the hydraulic properties of these hydrogeological units. The field investigations should include: – Groundwater exploration drilling – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ Integration of this information with other field studies at the pit, TSF and NOEF (as recommended above) ♦ Collaboration with other disciplines to facilitate the incorporation of any additional hydrogeological information into the conceptual model and help ensure that a consensus is reached, thereby promoting the use of a single model when assessing impacts and controls	High

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4.6 Geochemistry

4.6.1 Introduction

The McArthur River Mine deposit is hosted by dolomitic carbonaceous-pyritic silts and shales of the Paleoproterozoic Barney Creek Formation. Ore occurs in layers of stratiform fine-grained sulfidic shales thought to be of exhalative origin. Both dolomite and pyrite occur to some degree in all rock types (KCB, 2014), with some strongly pyritic units (pyritic S greater than 5%). Oxidation of sulfides and the interaction of these sulfide oxidation products with other minerals is the main potential cause of acid, metalliferous and/or saline drainage at McArthur River Mine.

In addition to geochemical drainage issues, some materials have spontaneous combustion potential where there is abundant fine-grained pyrite and organic carbon.

These geochemical issues are a consideration for waste rock dumps, tailings storage facilities, open pits, stockpiles, and site engineered structures such as roads and embankments.

This section addresses MRM's performance during the 2015 operational period with regards to monitoring and management of geochemistry, and is based on review of:

- Observations and discussions with MRM personnel during the site inspection.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's mining management plan and monitoring reports (MRM, 2015a; 2015b; 2015c; 2015d and 2015e) and geochemical investigations by KCB (2015a; 2015b; 2015c; 2015d; 2016a; 2016b and 2016c).
- Excel spreadsheets provided by MRM that contain collated laboratory and in situ data.
- Various MRM documents such as procedures and manuals, incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the mine site provided by MRM.
- Reviews by consultants engaged by DME.

4.6.2 Key Risks

The efforts carried out by MRM in regards to site geochemistry issues since the last IM report are to be commended. Considerable progress has occurred in the current IM reporting period towards better defining the geochemical properties and risks of mine materials. A number of operational management strategies have also been implemented to better control currently identified geochemical issues and impacts. In addition, some initial investigations have been carried out to support development of closure strategies for long-term control of potential geochemical impacts on the receiving environment. However, development of operational controls for geochemically problematic mine materials is still in progress, closure management strategies have not been finalised, and approaches that ensure the successful long-term mitigation of potential impacts have not been demonstrated. Hence, since these mine materials are among the most strongly pyritic materials observed by the IM at any mining operation in Australia or internationally, generation of acid, metalliferous and/or saline drainage, and the associated potential adverse impacts both on site and downstream, remains the most significant environmental issue at McArthur River Mine, and many of the key risks identified in 2015 remain the same.

The key geochemical risks are outlined below, grouped by NOEF, TSF and open pit (see Appendix 2 – Risk Register for more detail).

NOEF

- Acid, metalliferous and/or saline leachate from waste rock could report to groundwater and surface drainage due to inadequate management of seepage during operations and failure of the cover system post closure, potentially impacting groundwater and terrestrial and aquatic ecosystems in perpetuity. Placement of a multi-layered cover system of the types modelled on the NOEF is expected to be challenging, with post-closure maintenance of these layers and their performance even more so. Given the highly pyritic nature of McArthur River Mine waste rock and the potential impact of cover failure, it is unlikely that any cover system adopted will be a 'walk-away' solution. Allowance should be made for long-term (i.e., until mitigation success can be demonstrated) monitoring, ongoing maintenance of any cover system, collection and treatment of leachates, and active water management post-closure. Monitoring should include measuring cover performance against design targets (e.g., infiltration rates, contaminant release rates/loadings), inspection of geotechnical integrity (e.g., erosion, failures, desiccation), checks of groundwater, and surface water quality, and impacts on terrestrial and aquatic ecosystems.

- A major factor that contributes to the above risk is historic end-dumping of PAF materials that has resulted in segregation of coarse and fine materials and creation of chimney structures that encourage rapid convective oxidation (including spontaneous combustion). This tends to promote greater rates of sulfide oxidation and release of acid, metalliferous and/or saline drainage, impacting groundwater and terrestrial and aquatic ecosystems. There is also potential for spontaneous combustion to affect the stability of the NOEF, and lead to breaches in the cover.

TSF

- Tailings leachate could report to groundwater and ultimately to surface drainage down-gradient, due to inadequate management of seepage during operations and failure of the cover system post closure, impacting groundwater and terrestrial and aquatic ecosystems. McArthur River Mine tailings are also highly pyritic and it is unlikely that any cover system adopted will be a 'walk-away' solution. Allowance would need to be made for long-term (i.e., until mitigation success can be demonstrated) monitoring and ongoing maintenance post closure. Monitoring would include measuring cover performance against design targets and inspection of geotechnical integrity (e.g., erosion, failures, desiccation). Progressing the in-pit disposal and flooded option for tailings would provide the most secure closure outcome and significantly reduce this risk.

Open Pit

- The open pit lake could become strongly acid and/or saline and metalliferous after closure due to oxidation of exposed pyritic PAF and NAF materials in pit walls, resulting in local impacts on flora and fauna and potential impacts on surface water quality through overtopping and groundwater through seepage, thereby affecting terrestrial and aquatic ecosystems.

4.6.3 Controls

The IM review of geochemical performance at McArthur River Mine considered controls on acid, metalliferous and/or saline drainage in regards to prediction, classification, monitoring, investigations/reviews and management of mine materials.

4.6.3.1 Previously Reported Controls

A major change in the waste rock geochemical classification system at the McArthur River Mine occurred in 2013. The original criteria were based on geochemical investigations by URS and comprised simple non–acid-forming (NAF) and potentially acid-forming (PAF) categories (ERIAS Group, 2015). Further geochemical investigations by MRM in collaboration with KCB undertaken in 2013 identified issues with the criteria and assumptions used in their derivation (MRM, 2013). Modified classification criteria with additional categories resulted in the estimated proportion of PAF to be mined (as opposed to in situ proportion) changing from 30% to over 50%, with saline and metalliferous NAF accounting for a further 30% (MRM, 2014)). This resulted in a major change in the mine's materials balance, with a greatly reduced availability of benign waste rock for use in controlling acid, metalliferous and/or saline drainage.

Last year's IM review identified considerable progress in geochemical prediction, classification and monitoring of mine materials, including:

- Improvement of the site waste rock classification system to cover all aspects of mining, with the following components:
  - Development of a resource block model of waste rock geochemical categories based on total S for planning the construction of the OEFs and, in particular, to assist in scheduling waste rock types ahead of mining.
  - Reconciliation of the block model with blast hole testing (1 hole in 10) on each bench using portable XRF (pXRF) results and geology to finalise boundaries of waste rock material types for selective mining.
  - Mark-up of the finalised waste rock boundaries in the field and integration into the dispatch system, allowing tracking of waste rock placement by material type and driver alerts if materials are being taken to the wrong location.
  - Check sampling and testing of dumped materials. Note that the check sampling had not been fully revised to cover materials types according to new criteria.
- Operation of 15 kinetic leaching field barrels to provide information on leachate quality and loadings from a variety of individual and blended rock types.
- Set-up of a number of laboratory-based kinetic tests (oxygen consumption tests, humidity cells, leach columns) to provide information concerning leaching characteristics under more controlled conditions to compare against assumed potential for acid, metalliferous and/or saline drainage, to refine and confirm classification, and to compare with field barrels.

- Set-up of erosion trials of variable materials at varying slopes to calibrate erosion models and help finalise thickness and slope angles on waste rock dump batters.
- Additional geochemical characterisation as part of the Overburden Management Project EIS and life-of-mine studies, with the data currently being incorporated into an updated resource model.
- Implementation of a geochemical sampling and test program to help assess potential for acid, metalliferous and/or saline drainage from materials classified NAF under the old NAF criteria and used in infrastructure around the site (MRM, 2015f).
- Initiation of more regular geochemical characterisation of tailings using monthly composite samples.

Management controls instigated in the last IM reporting period include:

- Selective handling and placement of waste rock based on the revised geochemical classification criteria.
- Control of spontaneously combusting reactive PAF zones by bulldozing PAF dump areas, and rehandling of reactive materials identified in the dump through excavation, placement in thin layers and compaction.
- Bulldozing most of the old end-tipped PAF batters to a lower gradient (1 in 4 slope) to allow better access of machinery and installation of an interim cover to help control convective oxidation and infiltration during the wet season. Note, however, that trials indicate that this cover does not effectively control infiltration into the NOEF.
- Placement of PAF materials mined during the IM reporting period in paddock-dumped and roller-compacted lifts to minimise oxidation and limit infiltration.
- Modifications to the design and operation of TSF Cell 2 to stop water storage against the embankment and remove excess ponded water with the aim of limiting seepage impacts and geotechnical risks. Note that the resulting increased beaching also increases the potential for tailings oxidation and generation of acid, metalliferous and/or saline drainage.
- Placement of temporary covers on TSF Cell 1 to help reduce seepage impacts on the adjacent Surprise Creek. However, this interim measure still resulted in saline seepage into that creek.

4.6.3.2 New Controls – Implemented and Planned

In the previous IM reporting period, MRM had commissioned a number of investigations to better understand the geochemical issues on site and to support an EIS (as described above). Although the EIS has not yet been completed, many of the contributing studies had been completed to at least draft stage during the current IM reporting period. A number of management actions were also planned or in progress at the time of the last review that have subsequently progressed.

Waste Rock Materials - Geochemical Prediction, Classification, Monitoring and Investigations/Reviews

The main mine lithostratigraphic units at McArthur River Mine are as follows:

Hanging wall:

- Alluvium.
- Upper Breccia.
- Upper Dolomitic Shale.
- Upper Pyritic Shale.
- Black Bituminous Shale.
- Lower Pyritic Shale.

Foot wall:

- Lower Dolomitic Shale.
- W Fold Shale.
- Teena Dolomite.
- Cooley Dolomite.

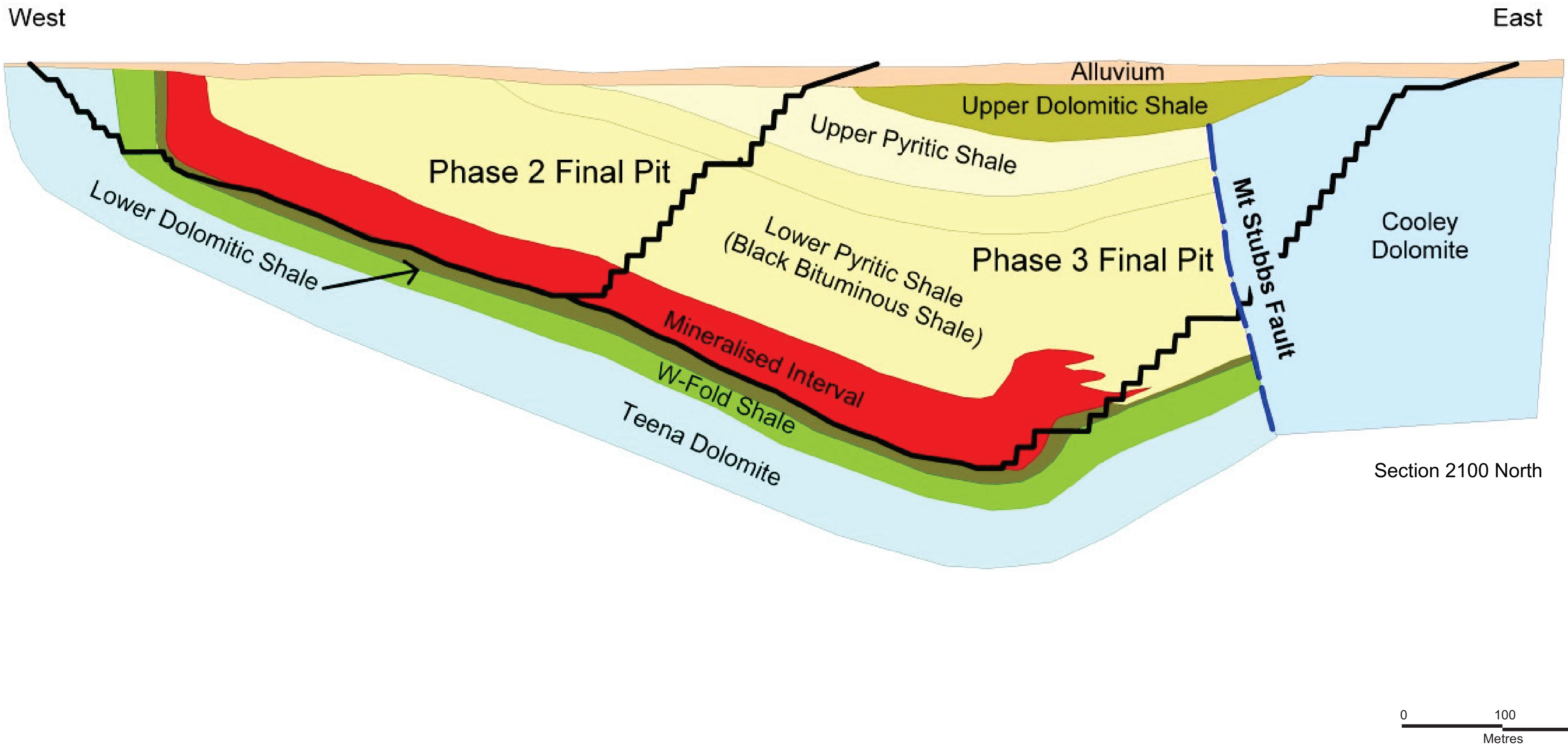
Figure 4.14 shows a simplified cross section of the above lithostratigraphic units with the Phase 2 and proposed Phase 3 pit outlines.

The geochemical waste rock classification scheme was unchanged from the last IM report, and is based on neutralisation potential ratio (NPR), S and key metals as shown in Table 4.21. The NPR is the ratio of the acid neutralising capacity (ANC) of a material in kg H_2SO_4/t to the maximum potential acidity (MPA) in the same units. The MPA is calculated from S content, assuming that all of the measured S is in the form of pyrite and will ultimately generate acid. Table 4.21 also includes a summary of the lithological units that dominate each class, based on sample numbers reporting to each class from static geochemical testing (KCB, 2015a). The distribution of rock types shows that although waste classes can be allocated to a large degree based on the general lithological unit, geochemical testing indicates variations within these units. The IM was advised during the site visit that the stratigraphy has been described in much more detail and is being geologically modelled with the aim of identifying more opportunities to selectively mine LS-NAF and MS-NAF. The Lower Pyritic Shale unit is a good example, with a number of continuous dolomitic breccia horizons within this unit that may be amenable to selective mining in the southern part of the pit as an additional source of LS-NAF.

CROSS-SECTION SHOWING WASTE ROCK TYPES AND OPEN PIT LIMITS

McArthur River Mine Project

FIGURE 4.14



Source: MRM, 2012

Table 4.21 – Waste Rock Classification Criteria

Class	Description	Criteria
LS-NAF(HC)	**Low Salinity High Capacity NAF**. Material considered to be at low risk of generating acid mine drainage and saline metalliferous drainage Generally characterised by moderate to high acid consumption capacity Restricted mainly to Upper Breccia and W Fold Shale, with some materials from the Lower Pyritic Shale and Upper Dolomitic Shale	NPR ≥ 2 and S < 1% and Zn < 0.4% and Pb < 0.04% and Cu < 0.07%
MS-NAF(HC)	**Metalliferous Saline High Capacity NAF**. Material considered to be at low risk of generating acid mine drainage but moderate to high risk of generating saline metalliferous drainage if not managed Generally characterised by a moderate to high acid consumption capacity. The Cooley Dolomite has particularly high acid consumption properties Mainly composed of Cooley Dolomite and W Fold Shale. Other lithologies include: Upper Breccia, Upper Dolomitic Shale, Lower Pyritic Shale and Lower Dolomitic Shale	NPR ≥ 2 and S ≥ 1% or Zn ≥ 0.4% or Pb ≥ 0.04% or Cu ≥ 0.07%
MS-NAF(LC)	**Metalliferous Saline Low Capacity NAF**. Material considered to be at low risk of generating acid mine drainage but higher risk of generating saline metalliferous drainage While non–acid-forming, this material is likely to provide very low to moderate acid consumption capacity Mainly composed mainly of Lower Pyritic Shale, Upper Pyritic Shale, Lower Dolomitic Shale, Upper Dolomitic Shale and Black Bituminous Shale	1 ≤ NPR < 2 and S ≥1%
PAF(HC)	**High Capacity PAF**. Material considered to be at higher risk of generating acid mine drainage, and is likely to have a significant capacity to do so Restricted mainly to the Black Bituminous Shale, Upper Pyritic Shale, Lower Pyritic Shale and Lower Dolomitic Shale	NPR < 1 and S < 10%
PAF(RE)	**Reactive PAF**. Material considered to be at high risk of generating acid mine drainage, and has the highest capacity to do so This material is at high risk of self-heating which may progress into spontaneously combusting, particularly Black Bituminous Shale which is high in organic carbon Restricted mainly to Upper Pyritic Shale and Black Bituminous Shale, with some materials from the Lower Pyritic Shale and Lower Dolomitic Shale	NPR < 1 and S ≥ 10%

Source: MRM (2015a) and KCB (2015a).

The waste rock classification system has been integrated into grade control and dispatch systems, and formalised in a number of technical work instructions manuals (MRM, 2016a; 2016b; 2016c).

The most recent mining management plan (MRM, 2015a) describes a modification of the above full classification criteria for use in the resource waste rock block model. At the time it was written, there was no block model for the ANC and hence no way of allocating an NPR to mining blocks, and total S was used as a proxy for the NPR classes. However, during the IM site visit, a newly-completed block model that is currently being used was demonstrated in which separate block models were generated for S, ANC, Zn, Pb and Cu, allowing calculation of NPR, and direct application of the above full classification criteria to each block as a function of NPR, S and metal content. The new resource waste rock block model was based on a relatively sparse sample set of around 3,000 data points for each parameter, but with the strong stratigraphic/ lithological controls on the distribution of sulfide and carbonate, the model appears suitable for planning and scheduling ahead of mining. Final definition of waste rock boundaries for selective handling is based on the grade control bench blast hole sample test result. Comparison of block model distributions of each parameter with sample composite distributions shows good correspondence (hanging wall examples are shown in Figure 4.15 for S and ANC), providing confidence in the assumptions used in building the model.

The previous resource waste rock block model proxy criteria are shown in Table 4.22 (MRM, 2015a), which are based on total S and selected metal concentrations. These proxy criteria were used after January 2014 and up until April 2016, covering the current IM reporting period. Table 4.23 compares the relative proportions of different waste rock types when the proxy criteria and the full criteria are applied to a set of 2,764 drill core samples (MRM, 2015a). The proportions compare reasonably well, indicating that the proxy criteria provided a suitable interim planning tool for the current IM reporting period.

As in the previous IM reporting period, a portable XRF is used on blast hole samples for in-pit waste rock grade control to finalise the boundaries of the various geochemical rock types. The device provides results for S, Ca, Mg, Zn, Pb and Cu, which are corrected against calibration with ICP-AES values, and with (Ca+Mg)/S used as a proxy for NPR. The calibration correction used in the last IM reporting period was based on 50 or so samples, with significant scatter for S, Zn, Pb and Cu being evident, and the IM recommended that additional calibration testing be carried out to validate the corrections (ERIAS Group, 2015). The IM understands that 10% of pXRF samples are also tested by ICP-AES and, while the ICP-AES data was supplied, the IM has not seen whether this data has been used to validate the pXRF calibration or check the field classifications. Site personnel indicated that use of site-based ICP testing of grade control sampling was being considered to replace the pXRF system. The IM would encourage this given that the grade control sampling is the primary method of defining waste rock type boundaries for selective handling, and the ICP data would provide more reliability and confidence in results.

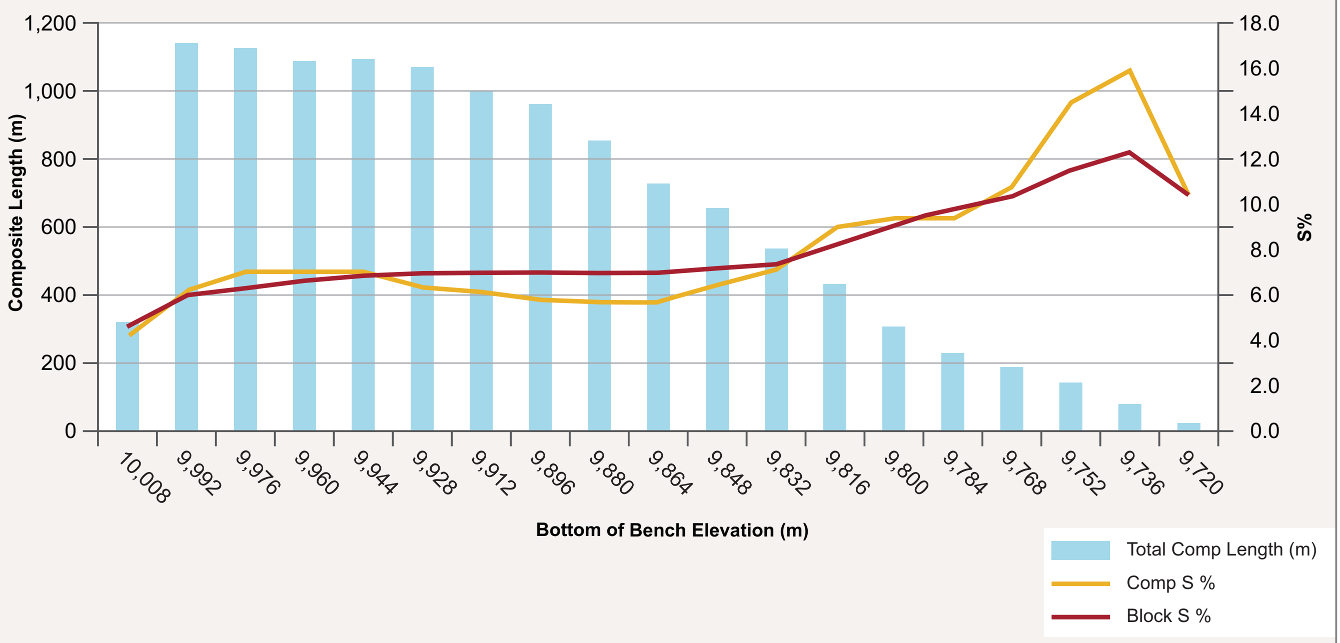
The current mining management plan includes a reconciliation of block model predicted tonnages by waste rock type against that actually mined for 2014 (Table 9-14; MRM, 2015a), which was viewed by the IM in the last reporting period. That reconciliation showed that the amount of materials classified PAF(HC) was significantly higher at 34% of waste rock moved than the 15% predicted by the block model, which was due to a degree of conservatism in allocating waste rock type boundaries in the pit. The IM has not seen an updated reconciliation, and it is unclear whether this block model underestimation of PAF(HC) has carried through to the current reporting period.

S AND ANC WITHIN THE HANGING WALL ZONE

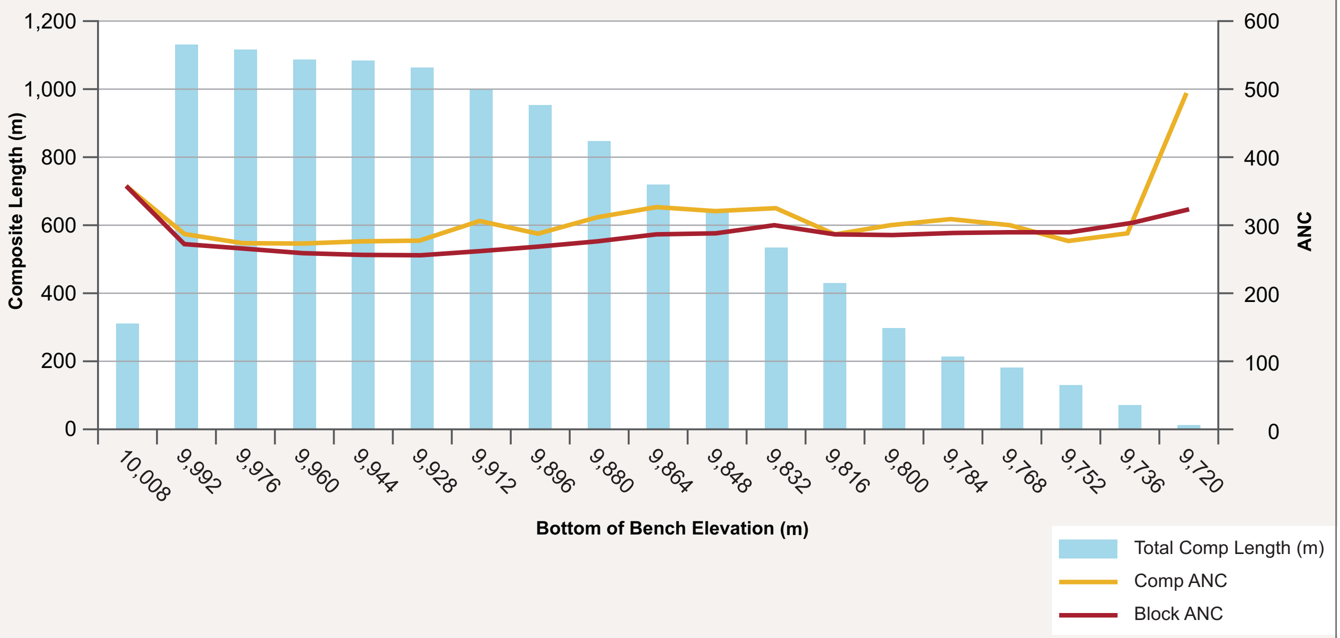
McArthur River Mine Project

FIGURE 4.15

A. S Within the Hanging Wall Zone



B. ANC Within the Hanging Wall Zone



Source: MRM, 2016e.

Table 4.22 – Resource Waste Rock Block Model Proxy Classification Criteria Used up to April 2016

Block Model Proxy Criteria		Class
S%	Metals	
S ≤ 1%	Zn < 0.4% and Pb < 0.04% and Cu < 0.07%	LS-NAF(HC)
1% < S ≤ 4%	Zn ≥ 0.4%, Pb ≥ 0.04% Cu ≥ 0.07%	MS-NAF(HC)
4% < S ≤ 7.5%	NA	MS-NAF(LC)
7.5% < S ≤ 10%	NA	PAF(HC)
10% < S	NA	PAF(RE)

Source: MRM (2015a).

Table 4.23 – Comparison of Waste Rock Types Proportions for Proxy Criteria and Full Criteria Applied to a Set of Drill Core Samples

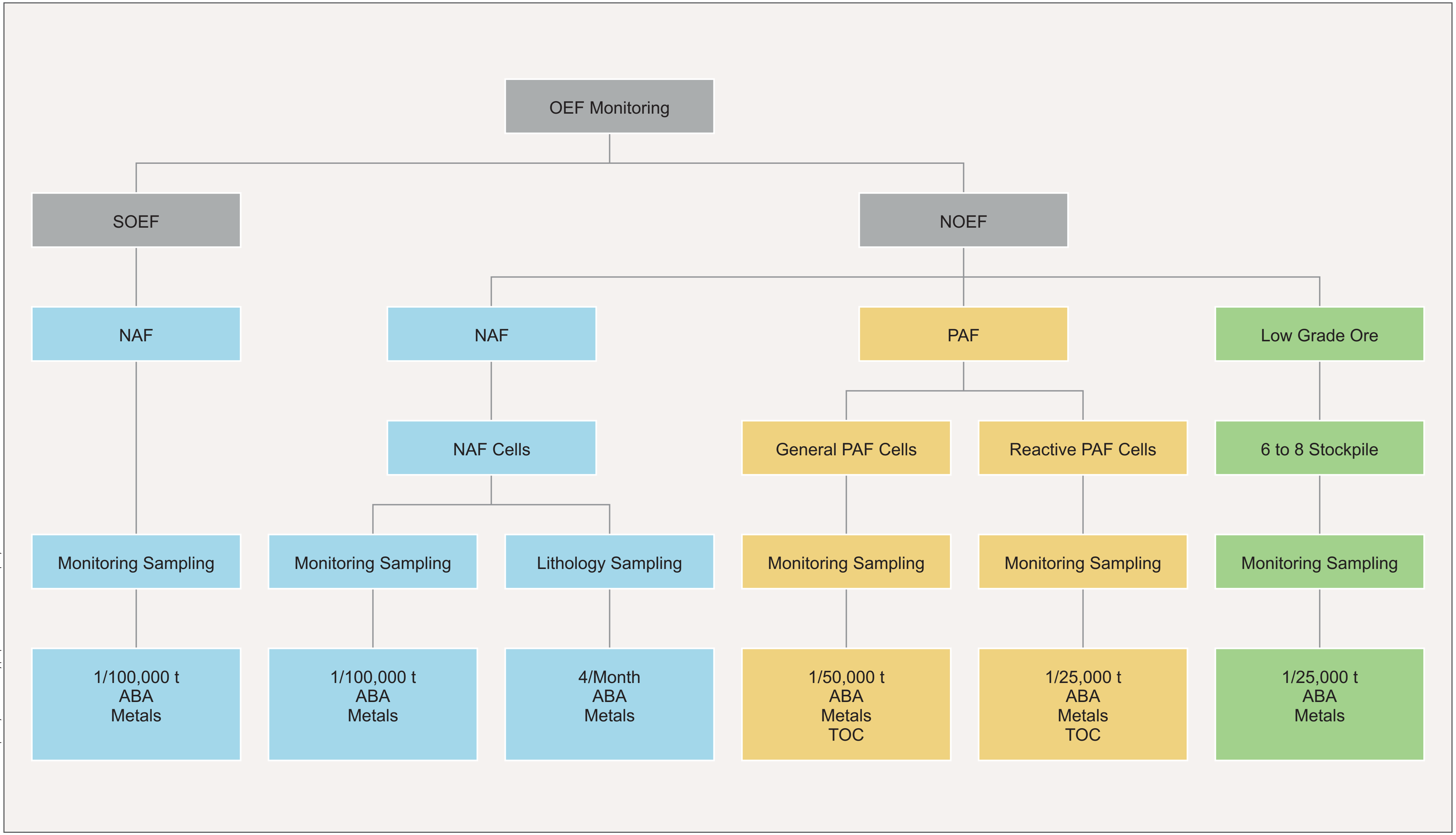
Class	Block Model Proxy Criteria	Full Criteria
LS-NAF(HC)	9%	9%
MS-NAF(HC)	27%	31%
MS-NAF(LC)	29%	26%
PAF(HC)	18%	16%
PAF(RE)	18%	18%

Source: MRM (2015a).

McArthur River Mining has continued the OEF monitoring program that was carried out in the previous IM reporting period, involving geochemical characterisation of dumped materials from the NOEF and SOEF, and low grade stockpiles as shown in Figure 4.16 (MRM, 2015a). Results for OEF check sampling and testing to February 2016 were provided by MRM. Figure 4.17 shows the proportions of different waste rock types from check sampling of cells within the NOEF from 2014 to 2016, representing the period when the updated classification of waste rock materials had been implemented. Not all of the dump cells sampled differentiated between MS-NAF(HC) and MS-NF(LC), and PAF(HC) and PAF(RE), and so the data was grouped into just LS-NAF, MS-NAF and PAF for comparison. A total of 559 samples were collected, most of which were obtained from PAF cells. Results show that over 80% of check samples from LS-NAF cells were classified as LS-NAF, with low median S values of 0.15%S and high median ANC values of 180 kg H_2SO_4/t, consistent with criteria (with a high factor of safety) for LS-NAF classification and providing some confidence in the overall system of waste rock segregation and handling. The MS-NAF cell samples are also generally MS-NAF, and the PAF cell samples mainly PAF. The PAF cells include around 30% of MS-NAF materials, most likely reflecting the degree of conservatism used in marking up PAF waste rock types in the pit. However, only 102 check samples of LS-NAF cells were collected over the 2014 to 2016 period, compared to 276 for the PAF cells. Given the importance of LS-NAF to the overall mitigation strategies for the NOEF, more focus on the LS-NAF is recommended.

McArthur River Mine Project

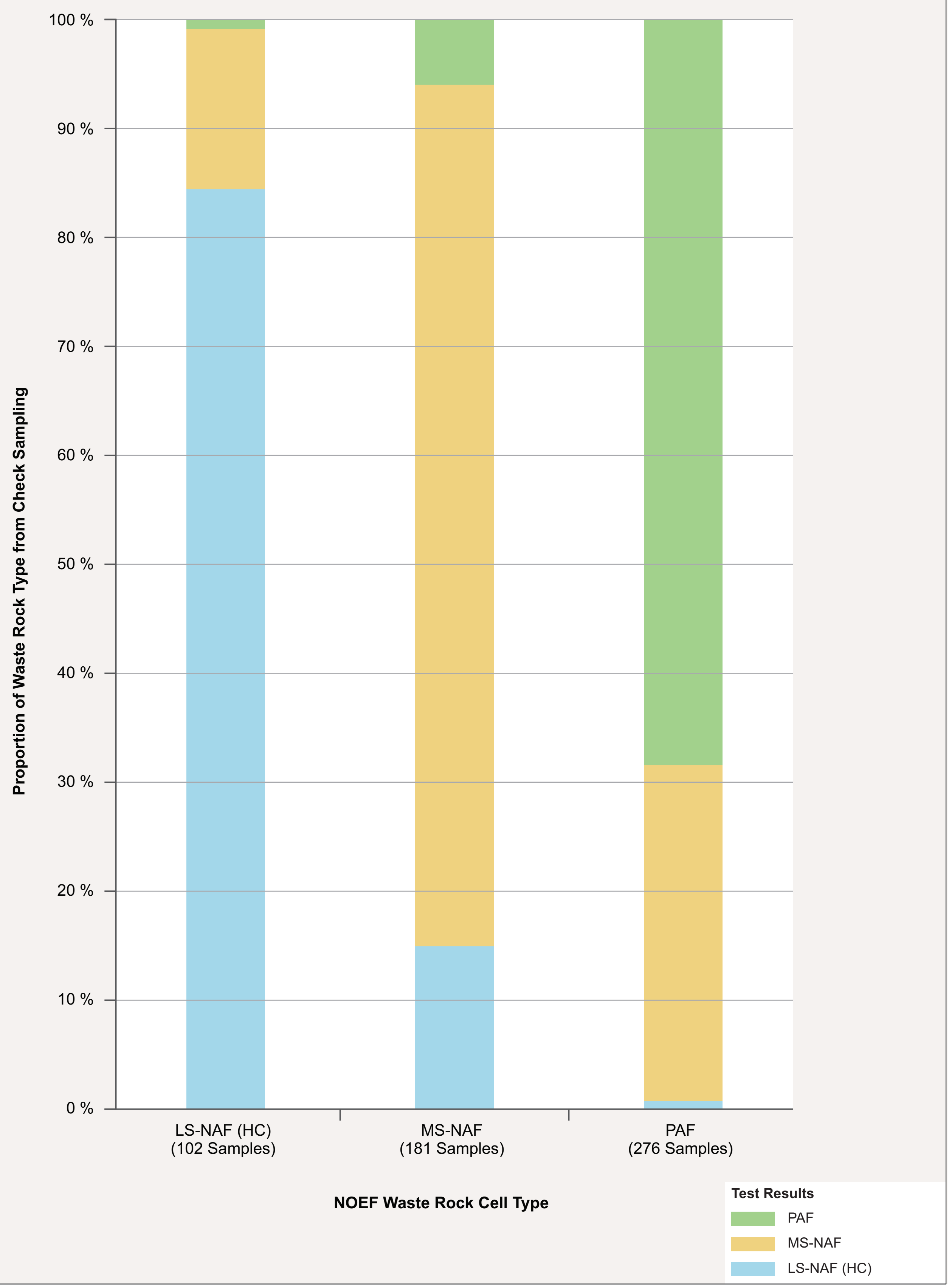
FIGURE 4.16



WASTE ROCK TYPE PROPORTIONS FROM CHECK SAMPLING OF NOEF WASTE ROCK CELLS

McArthur River Mine Project

FIGURE 4.17



The IM was not provided with data for low grade ore materials, but this would only be important if these are being stored long term, and to check for spontaneous combustion potential. At the time of the IM site visit, MRM advised that all the low grade ore stored in the NOEF will be processed.

In addition to the routine waste rock classification described above, MRM has undertaken a number of specific geochemical investigation programs to improve understanding of geochemical properties of waste rock materials, distribution in existing dumps, and refine classification criteria. These include:

- Geochemical characterisation of waste rock.
- Continuation of kinetic testing – barrels, leach columns, humidity cells and oxygen consumption rates (OCR).
- Drilling of the NOEF and associated geochemical and hydrological investigations.
- Review of spontaneous combustion, air quality monitoring and assessment of SO_2 emissions, and trial of chemical sealants for control of spontaneous combustion.
- Continuation of erosion trials.
- Sealant trial pads to assess alternate infiltration control on the NOEF.
- Cover design modelling and assessment.
- Drilling of hanging wall sediments to identify additional reserves of LS-NAF outside the pit.

Additional static geochemical testing of waste rock was undertaken by KCB (2015a) for inclusion in the EIS, following a review of existing data and identification of gaps. A total of 178 samples of overburden were tested. Results did not change criteria or management requirements, but added more certainty to previous conclusions, better defined the geochemical characteristics of the waste rock classes, and supported the validity of the current classification system. The main findings are as follows:

- Mineralogy results confirmed that pyrite is the dominant acid-forming sulfide mineral and dolomite is the dominant source of buffering. Both pyrite and dolomite occur together in all rock types, so all waste rock materials will show both acid generation and acid neutralisation reactions to varying degrees once exposed to atmospheric oxidation conditions.
- Kinetic NAG testing confirmed varying lag times depending on ANC content, with PAF(RE) and PAF(HC) samples showing lags of 15 to 360 minutes before reaching pH 4.5, indicating lags in the field of a few months to over 2 years. Note that the kinetic NAG temperature peak is due to the catalytic decomposition of H_2O_2 in the presence of dissolved metals (Stewart et. al., 2003), and is not due to exothermic pyrite oxidation reactions as stated on page 55 of the report.
- Acid buffering characteristic curve (ABCC) results showed that the Cooley Dolomite and Upper Breccia samples had the highest ANC values, with almost all likely to be readily available for acid buffering (based on the ABCC value to pH 4.5). The Lower Dolomitic Shale had the lowest ANC and low readily available proportions of around 40%. Most of the ANC in

the remaining rock types was readily available at around 70 to 80% of the total ANC. Results indicate that, in general, the ANC is readily available, confirming the dolomitic nature of the carbonate indicated by XRD work. The only exception is the Lower Dolomitic Shale, which may have a significant iron carbonate component not identified in the XRD work.

- The Upper Breccia and W Fold Shale were identified as the key sources of LS-NAF.
- The Upper Pyritic Shale, Black Bituminous Shale, Lower Dolomitic Shale and Lower Pyritic Shale lithology types were confirmed to be the main sources of PAF(RE) and PAF(HC).
- As expected given the strongly sulfidic and mineralised nature of the stratigraphic sequence, waste rock materials (and in particular the PAF pyritic shales) were elevated in a number of metals/metalloids, notably Zn but also Ag, Cd, Pb, S, Sb, Te, Ti and Tl.
- It is highlighted that metalliferous and saline drainage will be the main environmental issues from waste rock in at least the medium term due to lags before generation of acid drainage caused by dolomite buffering. There are lags due to the inherent dolomite content of the PAF materials, but also lags caused by interaction of acid generated by PAF materials with surrounding neutralising rock, and it is uncertain as to when acid seepage from the NOEF would occur.

An interim report on kinetic testing was prepared for MRM in 2015 (KCB, 2015b), which was then updated in a summary report in 2016 (KCB, 2016a). Kinetic test samples were selected from the 178 samples tested for the static geochemical characterisation (KCB, 2015a) described above. A total of 18 samples were selected to cover the range of lithological and geochemical rock types, with humidity cell testing carried out on all 18 samples, and column leach columns carried out on nine selected samples. While the approach to waste rock sample selection for kinetic testing was outlined in the KCB kinetic report (KCB, 2015b), it was not clear to the IM how the compositions of the kinetic test materials compared to the range of S, ANC and metals/metalloids in the various waste rock types (based on static testing to date). This should be made clear in future kinetic test reports. Results were reported for just over 52 weeks for humidity cells and 49 weeks for leach columns, with none of the leachates showing an acid pH of less than 4, but with some of the PAF materials showing increasing SO_4 release rates and one of the PAF(RE) columns (44072 CL) showing decreasing pH trends below pH 6. These results did not affect current classifications, and appear to confirm that LS-NAF materials represented by the column samples are likely to release low concentrations of SO_4 and metals (such as Zn) in the short term. It was recommended that the LS-NAF humidity cells/columns be terminated, but consideration should be given to continuing these columns to demonstrate longer-term low rates of contaminant release.

Oxygen consumption rate testing was carried out in support of the other kinetic test work. The results are discussed in a KCB report (KCB, 2016b) and confirm that the waste rock samples selected are among some of the most highly reactive when compared to global values, which is not unexpected given the high pyrite contents and very fine grained nature of the pyrite. The report notes that oxidation rates significantly increase once the NPR of a sample is below 0.8, and suggests that this could allow adjustment of the current NPR cut off value of 1, which would decrease the amount of PAF(HC). While the report acknowledges that further review and testing should be carried out before changing NPR values, the IM would caution some conservatism in any adjustment of the current cut off. The report also notes that the OCR results show a marked increase in oxidation rates for sulfide S values of greater than 8.5%S, whereas a 10%S value is currently used to segregate PAF(HC) from PAF(RE) (see Table 4.21), suggesting that the current cut off needs to be lowered. This would have the effect of increasing the amount of PAF(RE), not decrease as is stated in the report (page 20, fifth dot point).

McArthur River Mining provided Excel data for the kinetic field barrel tests, but there was no updated report. Results show that the barrel tests were continued into 2016, but the extended dry period meant that there were only 3 additional data points. None of the barrels showed acidic pH, although PAF(HC) Barrel 7 and PAF(RE) Barrel 15 showed a drop in pH below pH 5 and 6, respectively, on the 14 February 2015 collection before recovering to values of around pH 6 or more. Leachate volumes varied between barrels as with the previous IM reporting period. The IM again suggests that a controlled watering regime set to a particular climatic scenario would provide more data points and more interpretable results. McArthur River Mining personnel advised that the sealant joins around the various tubes connected to the barrels had perished, and that they would need overhauling with more robust sealant before continuing operations. Results for the field barrel tests are best reported together with humidity cell and leach column test results and compared.

Drilling of the NOEF was carried out in the current IM reporting period to better understand the geochemical and hydrological processes occurring in the dump. The holes were drilled in two campaigns, with first campaign comprising 18 holes drilled from August to November 2015 and the second comprising 12 holes drilled from January to February 2016. The 2015 holes were tested for temperature, gas composition, physical/hydrological characteristics, water levels, and geochemical characteristics (three holes). Fourteen of these holes were installed for continued monitoring of groundwater, temperature and gas composition. The 2016 holes focused just on temperature and were drilled into the upper (40 m) part of the NOEF dump only. There is not yet a report on the results, but MRM supplied a presentation outlining the main findings of the 2015 work (MRM, 2015g), together with data collected from the 2015 and 2016 drilling programs. Key findings are as follows:

- There was no water table or saturated rock within the NOEF, with the water table 4 to 12 m below the natural surface, indicating that infiltrating rainwater freely drains into the groundwater system, along with any acid, salinity and dissolved metals/metalloids generated by the waste rock materials.
- Temperature profiles showed high temperatures in PAF cells at depth, indicating that rapid oxidation is occurring throughout the dump. The highest temperatures corresponded to zones of PAF materials showing evidence of strong oxidation. Elsewhere, PAF materials appeared relatively fresh.
- Oxygen was highly depleted in the profile, most likely due to the highly reactive nature of the sulfidic waste rock.
- Thicknesses of clay layers were confirmed to be the correct thickness and match design, but layers were moist rather than saturated and hence not likely to be significantly controlling oxidation of PAF materials.

- There was more NAF material in the PAF zones than expected. Based on results from the three holes geochemically tested across the NOEF (GWNOEF-7S, GWNOEF-8S and GWNOEF-9S), approximately 70% of materials intercepted were NAF (MS-NAF and LS-NAF). A significant portion of weathered alluvial materials appeared to be in the base of the dump, an example of which can been seen on the northern face of the dump (Plate 4.1).

Plate 4.1 – Weathered Alluvial on North Face of NOEF

The new resource waste rock block model is being used to recreate the composition of the NOEF, by applying the full criteria to materials already mined and using historic dispatch data to estimate where it was placed. McArthur River Mining staff demonstrated the initial results and the modelled distribution of waste rock types appeared to correspond reasonably well to observations from the NOEF drilling. It is understood that this will be further developed and calibrated with drilling to better understand the distribution of rock types in the NOEF, which will assist finalising remediation options and cover system designs.

Investigations into SO_2 emissions from the NOEF due to spontaneous combustion were carried out in the 2015 dry season and 2015/2016 wet season. The primary aim was to calibrate an atmospheric dispersion model to assess the potential for off-site impacts (Todoroski Air Sciences, 2015; 2016). Some of the reported observations also help provide a guide to the success of the management measures undertaken to control rapid oxidation and self-heating in the dump. The dry season report notes the presence of 'smokers' in the NOEF during this IM reporting period, and emphasised that self-heating and SO_2 emissions may not always result in visible plumes. McArthur River Mining personnel confirmed on site that the management of self-heating material required continued effort, including removing and re-laying clay covers. The wet season SO_2 investigations showed that SO_2 emissions were significantly reduced after self-heating management efforts were implemented on the NOEF after the dry season investigations, indicating some success in reducing sulfide oxidation rates in the dump.

B3 Mining Services carried out a review of spontaneous combustion identification and management in 2015 (B3 Mining Services, 2015). The report comments on the fact that using visual triggers (i.e., presence of 'smokers') to initiate management actions can be too late, since their appearance indicates that the spontaneous combustion reaction is already well advanced. Routine inspection of the NOEF using thermal and gas monitoring techniques was encouraged. The report also recommends developing methods of better identifying materials prone to spontaneous combustion ahead of mining to allow pro-active control, and monitoring the performance of current techniques. B3 Mining Services also raised the possibility of using inhibiting products and sealants in conjunction with current management practice. McArthur River Mining provided field notes concerning some trials of sodium silicate (9114) for this purpose, with results showing some success when heavy media rejects (HMR) were applied to the surface of PAF(RE) before application of the sodium silicate. However, the process was deemed by MRM to be too expensive for widespread use and required more trials to optimise dosage rates.

Cover design modelling for the NOEF was carried out by O'Kane Consultants (2016) in this IM reporting period, updating modelling carried out previously with measured physical/hydrological properties of mine materials. The modelling indicates that controlling infiltration to very low rates (nominally set at <5% of annual rainfall) required a store and release type design with an underlying compacted clay layer (i.e., enhanced store and release). To also control oxidation rates to very low rates (nominally set at <5 mol O_2/m^2/year) required a more complex system comprising a store and release type design with an underlying clay layer, a capillary break, and another clay layer below that. The individual layer thicknesses modelled were relatively thin, with the store and release layer ranging from 0.9 to 1.4 m, the compacted clay layer(s) ranging from 0.2 to 0.6 m, and the capillary break layer ranging from 0.5 to 1.0 m. The performance of the designs relies on individual layers maintaining 'as placed' physical/hydrological properties into the long term. The capillary break layer performance is sensitive to fines washing into the layer, which would degrade its low suction, and would require a filter layer to help prevent this, further complicating cover designs. Placement of a multi-layered cover system of the types modelled on the NOEF is expected to be challenging, with long-term maintenance of these layers and their performance even more so. Controlling oxidation in addition to infiltration adds considerable complexity to the cover design, and requires careful assessment to determine whether the additional effort will result in long-term benefits. Drilling of the NOEF shows that rapid oxidation is occurring in the dump, generating heat and gas, and changing dump volumes/densities locally, increasing the possibility of differential settlement, development of cracks, and local pressure effects on any low permeability layers. These effects should be considered in evaluation of long-term cover system integrity. The IM notes that the modelling is preliminary and will be refined as other investigations progress. A more final design is expected in the EIS.

Synthetic alternatives to the compacted clay layer in the above cover design were reviewed by GHD (2016). The review focused on linear low-density polyethylene (LLDPE) geomembrane and elastomeric bituminous geomembrane (BGM) relative to the compacted clay. It was concluded that all have comparable costs for supply and installation, and that the geomembranes have much lower permeability but an uncertain service life. The review indicates these may be a viable alternative, but would require monitoring as with compacted clay layers.

No direct review document was provided that assessed the success of the interim clay covers placed on the NOEF in 2015 to control infiltration during the wet season. However, MRM did carry out some sealant trial pads to assess alternate infiltration control on the NOEF, with results provided to the IM as notes in Word and Excel format. Pads of 700 m^2 were prepared of standard clay, HMR and clay, alluvials, and HMR and alluvials, with various sealants including lime, latex, sodium silicate-based sealant (9114) and an oil-based sealant (9131). Results showed that the clay by itself (i.e., the current method of wet season infiltration control) showed severe erosion over the wet season, despite a relatively low rainfall, suggesting that the current method may be ineffective. Use of HMR appears to help and addition of lime may also assist. The trials strongly suggest that current methods using compacted clay will do little to control infiltration into the NOEF, and that alternate methods are required. The notes recommend further trials before the next wet season using HMR, lime and sodium silicate, and with simulated rainfall.

A total of 24 holes were drilled into the hanging wall sediments to identify additional reserves of LS-NAF outside of the pit but within the mine levee (MRM, 2015h). The drilling specifically targeted the Upper Breccia (UpX) south of the Woyzbun fault, which is down-thrown relative to the stratigraphy in the pit, resulting in a much thicker sequence of UpX than is intersected in the pit. The drilling outlined a significant resource of LS-NAF, which MRM could develop as a quarry (Woyzbun Quarry) for use in outer shell cover materials for the NOEF. The exact dimensions of the Woyzbun Quarry will depend on requirements for the final cover, and it is expected that an update will be available in the next IM reporting period.

Waste Rock Materials - Management

Updated waste rock handling recommendations are presented in KCB (2015a), based on additional static and kinetic test work and a better understanding of geochemical properties (which are reproduced in Table 4.24). The key recommendations were that MRM should:

- Conserve LS-NAF.
- Use compacted MS-NAF as an intermediate encapsulation zone with oxygen consumption properties.
- Use interim clay layers for PAF(HC) to manage infiltration during the wet season.
- Place PAF(HC) and PAF(RE) materials above the 1:100 flood level.
- Keep PAF(HC) away from batters, unless erosion studies show otherwise.
- Place MS-NAF(LC) (but not MS-NAF(HC)) materials above the 1:50 flood level unless managed in another way.
- Use thin layer lifts, compaction and clay encapsulation to manage spontaneous combustion from PAF(RE) materials, with rehandling required for materials in which combustion has already commenced.

Table 4.24 – Waste Rock Geochemical Rock Types and Handling

Class	Geochemical Properties	Description
LS-NAF(HC): low salinity high capacity NAF	♦ Materials are unlikely to generate AMD and present a low risk of generating SD and NMD ♦ Generally characterised as having moderate to high acid consumption capacity ♦ Materials are enriched in Zn, Ti, Bi and Te (relative to median crustal abundance); however, SFE and NAG extracts suggest that these metals will not leach at elevated concentrations under test conditions ♦ This waste class is restricted mainly to Upper Breccia and W Fold Shale, with some materials from the Lower Pyritic Shale and Upper Dolomitic Shale ♦ Generally low to negligible organic carbon content	♦ The material should be stockpiled and used conservatively due to its limited quantity and important geochemical properties ♦ No storage considerations or capping requirements are necessary ♦ Can be used as cover material and barriers to environmentally sensitive locations, or to encapsulate (and partially neutralise) PAF materials in the NOEF (among other things)
MS-NAF(HC): metalliferous saline high capacity NAF	♦ Materials are unlikely to generate AMD but have a moderate to high risk of generating SD or NMD over time if measures are not taken to minimise water/oxygen contact ♦ Characterised as having moderate to high acid consumption capacity; the Cooley Dolomite has particularly high acid consumption properties ♦ The waste class is mainly composed of Cooley Dolomite and W Fold Shale. Other lithologies include: Upper Breccia, Upper Dolomitic Shale, Lower Pyritic Shale and Lower Dolomitic Shale ♦ Generally low to negligible organic carbon content	♦ Minimise contact with water and oxygen because leachate water quality may exceed threshold values for salinity (SO_4) and/or some metals in the long term ♦ Final encapsulation of these materials with LS-NAF (HC) or a benign clay layer is necessary to prevent water and oxygen ingress (i.e., these materials cannot be used in the final NOEF cover) ♦ The material is ideal for construction of an oxygen consumption layer (due to the sulfide content), or as an acid neutralisation material (due to the high acid consumption properties); however, appropriate management options should be in place to capture water runoff ♦ The material can be used as an intermediate encapsulation layer for PAF in the dry season; however, material should be sufficiently compacted (trafficked) ♦ Ongoing water quality monitoring will be necessary to determine if metals/salinity is leaching from the materials
MS-NAF(LC): metalliferous saline low capacity NAF	♦ Material considered at low risk of generating AMD but higher risk of generating NMD and SD (particularly SO_4 production) ♦ While non–acid-forming, this material is likely to provide very low to moderate acid consumption capacity	♦ Minimise contact with water and oxygen because the leachate water quality is likely to exceed threshold values for salinity (SO_4) and/or some metals ♦ Material is ideal for construction of an oxygen consumption layer (due to the sulfide content); however, appropriate management options should be in place to capture water runoff

Table 4.24 – Waste Rock Geochemical Rock Types and Handling (cont'd)

Class	Geochemical Properties	Description
MS-NAF(LC): metalliferous saline low capacity NAF (cont'd)	♦ This waste class is composed mainly of Lower and Upper Pyritic Shale, Lower and Upper Dolomitic Shale, and Black Bituminous Shale ♦ Generally low to moderate organic carbon content	♦ Material can be used as an intermediate encapsulation layer for PAF in the dry season (only); however, material should be sufficiently compacted (trafficked) to reduce water infiltration and gas transport ♦ This material should not be placed below the 1:50 year flood (water table) level, unless appropriate management measures are in place
PAF(HC): high capacity PAF	♦ Material considered at higher risk of generating AMD, and is likely to have a significant capacity to do so ♦ Material likely to generate significant acidity, NMD and SD ♦ The waste class is restricted mainly to the Black Bituminous Shale, Upper and Lower Pyritic Shale, and Lower Dolomitic Shale ♦ Generally moderate to high organic carbon content, mainly associated with Black Bituminous Shale	♦ Material needs to be prevented from being in contact with water and oxygen because the leachate water quality is likely to significantly exceed threshold values for acidity, salinity (SO_4) and metals ♦ These materials require encapsulation with NAF and a clay layer to prevent/limit oxygen and water interaction. Any drainage water needs to be diverted to a PAF dam which should be regularly monitored ♦ Material should be encapsulated with an intermediate clay layer prior to each wet season ♦ This material should not be placed below the 1:100 year flood (water table) level ♦ This material should not be placed under the NOEF batters, unless erosion studies show otherwise
PAF(RE): reactive PAF	♦ Material considered a high risk of generating AMD, and has the highest capacity to do so. Material likely to generate significant acidity, NMD and SD ♦ This material is at higher risk of self-heating and spontaneously combusting if not managed appropriately, particularly the Black Bituminous Shale which is high in organic carbon ♦ The material is characterised by rapid oxidation and generation of SO_2 gas either in-pit or shortly after dumping ♦ The waste class is restricted mainly to Upper Pyritic Shale and Black Bituminous Shale, with some materials from the Lower Pyritic Shale and Lower Dolomitic Shale that were also classified as LS-NAF(HC)	♦ Material needs to be prevented from being in contact with water and oxygen because the leachate water quality is likely to significantly exceed threshold values for acidity, salinity (SO_4) and metals ♦ Spontaneously combustible materials are likely to generate excessive heat and produce toxic gases if not managed appropriately ♦ These materials require encapsulation with NAF and a clay layer to prevent/limit oxygen and water interaction. Any drainage water needs to be diverted to a PAF dam which should be regularly monitored ♦ The PAF cells should be constructed in thin-layer lifts (<2 m) from the base upwards by paddock dumping where compaction and moisture content is optimised to minimise oxygen diffusion and hydraulic conductivity; end-dumping construction methods need to be avoided ♦ The thin-layer PAF lift should be appropriately compacted prior to addition of an overlying NAF material lift ♦ This material should not be placed below the 1:100 year flood (water table) level ♦ Material that has already begun reacting needs to be treated separately in an individual storage compartment. These materials should be thinly spread on a compacted benign (clay) layer to allow cooling. Once cooled (no longer spontaneously combusting), the materials should be placed in PAF cells according to the method above

Source: KCB (2015a).

As in the previous IM reporting period, the existing waste rock dumps comprise:

- Northern overburden emplacement facility (NOEF) – this is the main waste rock dump (current and historic) containing all geochemical rock types.
- Western overburden emplacement facility (WOEF) – this was built as part of the original operations and located within the levee wall; this facility includes oxide materials but the proportion of other geochemical rock types is unclear.
- Southern overburden emplacement facility (SOEF) – this was constructed after the 2014 IM visit with MS-NAF(HC&LC) materials.

With review of the block model and materials requirements, MRM has confirmed the potential short fall in LS-NAF for construction of the outer surface of the cover system, and therefore proposes development of the Woyzbun Quarry south of the exiting pit. This would target the LS-NAF Upper Breccia unit. The final cover system design and hence requirement for LS-NAF has not been finalised, but is expected to be available when the EIS is complete.

Waste rock management is currently following the mining management plan (MRM, 2015a) approved in December 2015 (DME, 2015), pending completion of an EIS. It is understood that mine production rates have been reduced to ensure sufficient space for handling PAF materials in the NOEF up to early 2018, corresponding to MRM's planned completion of the EIS and submission of a new longer term mining management plan (MRM, 2016d).

Although the final design of the NOEF cover system is still in development, components of the dump construction that are important to the overall integrity of the dump and performance of the cover system are currently being implemented. These include:

- Placing LS-NAF at the dump base to the 1:100 flood level (Plate 4.2).
- Placing compacted clay (600 mm) over the LS-NAF base (Plate 4.3).
- Stockpiling LS-NAF materials in designated areas on the eastern side of the NOEF for use in specific zones requiring this material.
- Constructing the MS-NAF halo zone, using paddock dumping and traffic compaction (Plate 4.4).
- Paddock dumping PAF(HC) and PAF(RE) materials in lifts of 2 m or less with roller compaction.
- Monitoring and managing PAF(RE) materials as required.
- Placing interim clay layers to help control infiltration during the next wet season and spontaneous combustion in PAF(RE) materials.

Plate 4.2 – Paddock Dumped LS-NAF Materials at the Base of Central West Part of the NOEF

Plate 4.3 – Compacted Clay Layer (600 mm) Constructed on LS-NAF Materials on the South Side of the NOEF, with MS-NAF Materials Being Paddock Dumped over the Top

Plate 4.4 – Construction of MS-NAF Halo Zone on the South Side of the NOEF

These measures are a significant improvement on previous dump construction and are considered appropriate by the IM. However, MRM may modify current construction approaches and design as follows:

- Although PAF(HC) materials are currently being paddock dumped and roller compacted, this is primarily due to the current operational difficulty in separating PAF(HC) from PAF(RE), and both materials are being treated the same way. The updated Central West Phase operations manual (MRM, 2015e) confirms continued paddock dumping and compaction of PAF(RE), but also indicates that thin lifts of 2 to 3 m are planned for the PAF(HC). Given the very high sulfide contents of these materials, the IM would urge continued placement of PAF(HC) in <2 m paddock dumped and compacted lifts in the same way as PAF(RE).

- The current dump construction is being carried out to comply with existing approvals, and the IM understands that in the EIS, MRM proposes to use MS-NAF rather than LS-NAF in the 1:100 flood level zone, with investigations proposed to assess flood ingress into the dump and predicted water quality effects (KCB, 2015c). This aspect will be reviewed in the next IM report.

- To comply with existing approval, MRM's plan is that the LS-NAF base layer in the Central West Phase area will be built up into a clay-covered wedge with a slope angled downwards to the West PAF Runoff Dam (WRPROD) to encourage drainage towards the dam (MRM, 2016d). However, MRM considers this to be an inefficient use of LS-NAF since the company does not believe that the wedge will be effective in directing drainage/seepage (presentation by MRM on 27 April 2016), but does not have approval to modify this requirement. This aspect may be modified in the EIS, and again will be reviewed in the next IM report.

Advances have been made in regards to control of convective/advective oxidation and spontaneous combustion, although improvements are required. It appears that MRM has yet to achieve confident identification of reactive materials, and while management has reduced the severity and frequency of visually apparent spontaneous combustion events, convective/ advective oxidation processes are still occurring, as shown by:

- Elevated temperatures in the dump (see previous section).
- Elevated SO_2 detected at surface from time to time (the IM party was forced to leave the top of the NOEF during the site visit when significant concentrations of SO_2 gas were detected).
- The requirement for rehandling of previously managed spontaneous combustion zones that have re-ignited.

There has been no advancement in understanding the distribution of geochemical rock types placed in the WOEF, but MRM personnel advised that the WOEF was expected to contain some non-benign materials and they were aware that further work was required. A strategy for closure of the WOEF is expected in the EIS.

MS-NAF materials continued being placed in the SOEF during the reporting period, and this will continue into the next reporting period. No changes have occurred to the planned closure of the SOEF in the approved MMP (MRM, 2015a), but MRM has mentioned the option of re-locating materials into the final pit void (MRM, 2015i) as well as using some of the SOEF materials for closure of the WOEF (MRM, 2015j).

Management of NOEF run-off water involves a number of sumps and dams, with the SPROD, SPSD and SEPROD being the main storages. McArthur River Mining reviewed surface water and groundwater quality across the site over the 2014-2015 period (MRM, 2015c; 2015d). Figure 4.11 (see Section 4.4) shows results of a detailed EC field survey carried out in April 2015 of key mine site creeks and rivers (circle symbols), together with summary EC values from monitoring bores (square symbols) and surface storages (star symbols). The results show clear evidence of high EC in surface drainage and groundwater in proximity to, and down-gradient of, the NOEF and main water storages. The waste discharge licence monitoring report (MRM, 2015c) acknowledges the SPROD and SPSD as the likely sources of elevated EC (primarily controlled by SO_4) in the Surprise Creek and Barney Creek confluence area. McArthur River Mining plans to line these dams with HDPE before the next wet season, which is expected to reduce these impacts. Bores around the SEPROD (GW087, GW102 and GW103) also show elevated SO_4 (MRM, 2015d), but it is understood that the estimated seepage for this dam is low at around 0.3 ML/day, and it is uncertain whether the SEPROD is the source or if it is uncontrolled seepage from the NOEF. There are also elevated SO_4 concentrations in groundwater to the northeast of the NOEF, particularly bore GW105, which MRM attributes to in situ mineralisation rather than effects from the NOEF (MRM, 2015d). The northern part of the NOEF overlies drainage that flows towards these bores and intersects with Emu Creek (Figure 6-3; MRM, 2015a), which indicates a potential connection between seepage from the NOEF and the elevated SO_4 concentrations in GW105 (and also GW100, GW131 and GW134) that should be further investigated.

Control of seepage from the NOEF during operations has relied primarily on the interim clay covers placed on the dump before the wet season. The trial pads installed over the last wet season showed high levels of erosion, suggesting that this method is ineffective. The recent drilling of the NOEF showed an absence of any water table in the dump, indicating that infiltrating rainwater freely drains away into the groundwater system. The drilling also confirmed that the sulfidic materials in the dump are actively and strongly reacting, and are likely to be generating acid, salinity and dissolved metals/metalloids. Hence, given the likely ineffective infiltration control, the IM infers that the NOEF has been a continuous source of groundwater contamination, with peak loads over the wet season. Infiltration controls should be improved before the next wet season to minimise additional potential groundwater impacts. Understanding the extent and impact of groundwater contamination from the NOEF would require further investigation and may involve installation of additional bores. The current impacts from the SPROD/SPSD on groundwater and surface water are likely to mask impacts from NOEF seepage.

The closure options for the NOEF are still being finalised, but most of the components have been identified as discussed above. The IM strongly supports the approach and investigations that MRM is undertaking towards closure of this facility, which are unlikely to result in a 'walk away' solution but will clarify the most appropriate management approaches to minimise long-term impacts post closure. The IM expects that ongoing maintenance, monitoring and contingency for water treatment are likely to be required.

Tailings Materials - Geochemical Prediction, Classification, Monitoring and Investigations/ Reviews

Since the 2015 IM report, KCB has arranged additional geochemical testing of tailings and has reviewed historic data, significantly improving the understanding of tailings geochemical variation. Work carried out included (KCB, 2015c; 2016b):

- Testing of five recently-deposited (one day to more than two weeks) tailings from the margins of the Cell 2 facility.
- Review of analytical results for 200 tailings supernatant samples collected from 6 November 2002 to 3 May 2015.
- Review of analytical results for 67 tailings solid samples collected from 30 January 2008 to 28 February 2015.
- Oxygen consumption rate testing of two tailings samples, as a function of moisture content.
- Thiosalt testing of two tailings samples.

Tailings geochemistry results show that, overall, the tailings are expected to be PAF with very high acid generating capacity, but generally with high ANC, and a lag would be expected before acid conditions develop after exposure to atmospheric oxidation conditions. Total sulfur contents are very high relative to typical base metal mine tailings, varying from approximately 10 to 18%S, with S values showing an overall slight increasing trend over time. In the 2015 IM report, it was noted that the ANC results for tailings collected in December 2014 to March 2015 showed lower ANC values than expected, ranging from 60 to 95 kg H_2SO_4/t compared to median values of approximately 180 kg H_2SO_4/t. The historic data in Figure 4.18 shows that these low ANC values are anomalous, with the vast bulk of the tailings samples having ANC values greater than 150 kg H_2SO_4/t. Repeat testing of these samples (see Figure 4.18) showed a definite decrease in ANC relative to other samples, but the ANC values were significantly higher than the original test results at greater than 100 kg H_2SO_4/t. McArthur River Mining personnel indicated that these anomalous results were from samples that were tested by a different laboratory to that used for most of the other samples, and that the original results may have been in error. The IM recommends that the ANC results be checked with ANC testing carried out at other laboratories and include ABCC testing to be certain which set of results best reflects the available ANC in the tailings. Results from ABCC testing carried out on the five samples collected from the Cell 2 margins (KCB, 2015c) indicate that the effective ANC was around 60 to 70% of the total ANC.

The IM understands that kinetic leach testing of tailings is in progress, but results have not been provided. However, results were provided for OCR testing (KCB, 2016b), which confirm that the tailings are highly reactive when oxygen is freely available (i.e., when the tailings are not saturated); this is not unexpected given the high pyrite content and very fine grained nature of the pyrite. Kinetic NAG testing of tailings samples (KCB, 2015c) indicated a lag time of a few months before acid conditions would develop after exposure to atmospheric oxidation conditions. These preliminary results should be reviewed by MRM using results of the tailings leach testing.

Historic tailings supernatant water quality data was provided to the IM, and was also reviewed by KCB (2015c). Results show that the Cell 2 supernatant was generally acidic (pH <4.5) up until the end of 2006, and generally circum-neutral thereafter (Figure 4.19). This change in supernatant pH appears to correspond to commencement of open pit mining operations and possible changes to ore processing, such as addition of lime to the process stream. A decrease in the tailings supernatant pH was noted in early 2015, which corresponds to the period of low ANC in tailings (see Figure 4.18). The cause is not clear, with possible reasons including oxidation of pyrite in the tailings and consequent acidification, or the influence of the acidic PBOX effluent (Pb and Zn are high in the tailings solid around the same time, Figure 3-13, KCB (2015c); KCB also postulated possible effects of thiosalts in the supernatant caused by part oxidation of the sulfides during processing.

Results from water quality testing of the supernatant from the five samples collected from the margins of Cell 2 were reported in KCB (2015c). These show that the process water has high EC (over 10 dS/m) and is dominated by Ca, Cl, K, Mg, Na and SO_4. Not unexpectedly, dissolved Zn concentrations are high at 240 to 379 mg/L, with elevated dissolved Mn, Ni and Pb concentrations. Dissolved As is notably low at less than 0.05 mg/L.

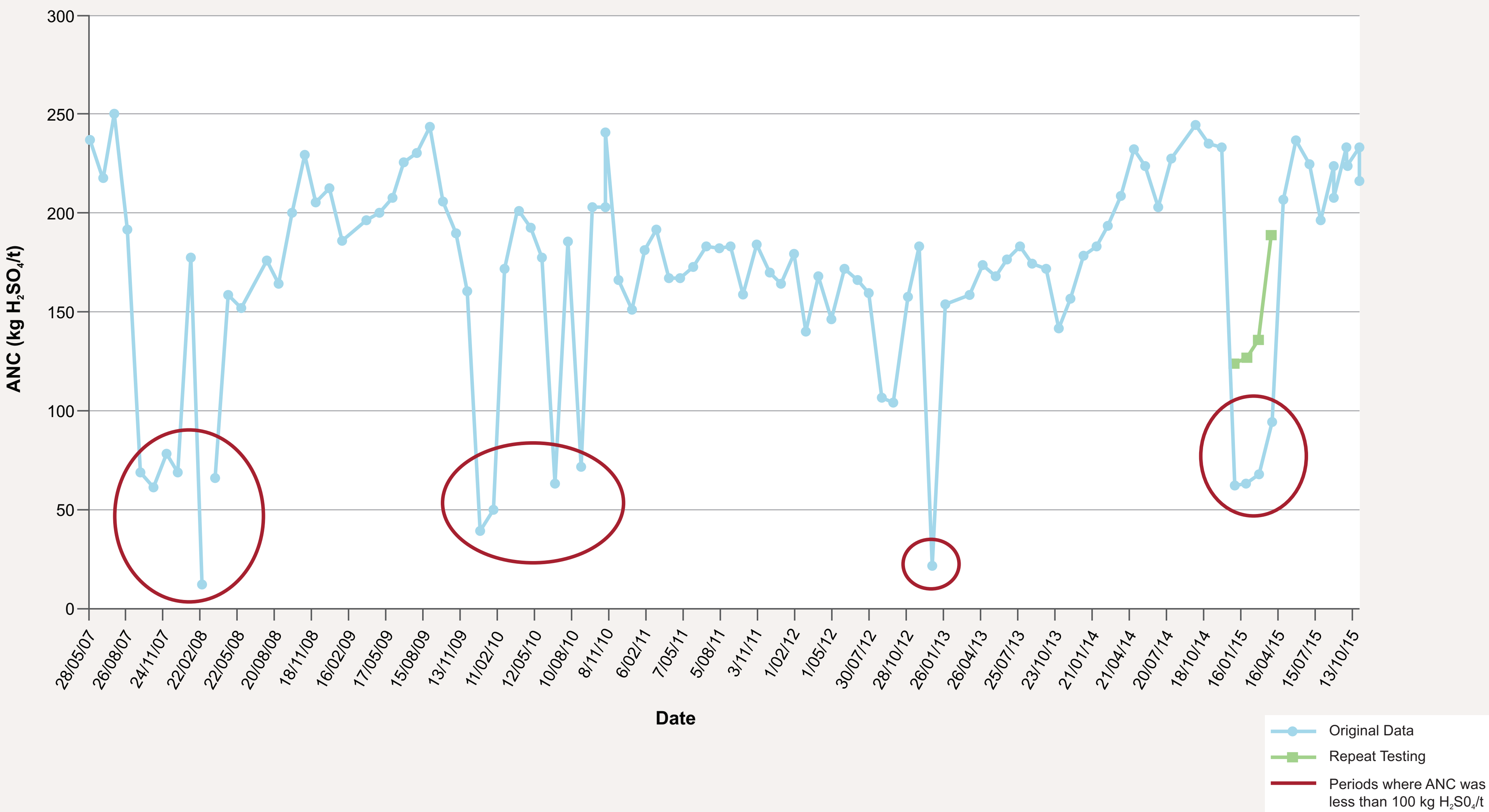
The KCB (2015c; 2016b) recommendations for further work are appropriate, including ongoing geochemical monitoring of discharged tailings, testing of the tailings profile to better understand historic variation, kinetic testing of tailings (in progress), and geochemical modelling. Further investigation into thiosalts and potential effects on supernatant acidification was also recommended, but given the dramatically increased beaching in Cell 2, the incremental effects of acid release from thiosalts over oxidation of the highly pyritic tailings may be relatively minor.

Assessment of tailings lag times and acid generation rates for beached tailings is a higher priority to assess operational treatment requirements and long-term AMD potential.

TAILINGS ANC TRENDS (2008 - 2015)

McArthur River Mine Project

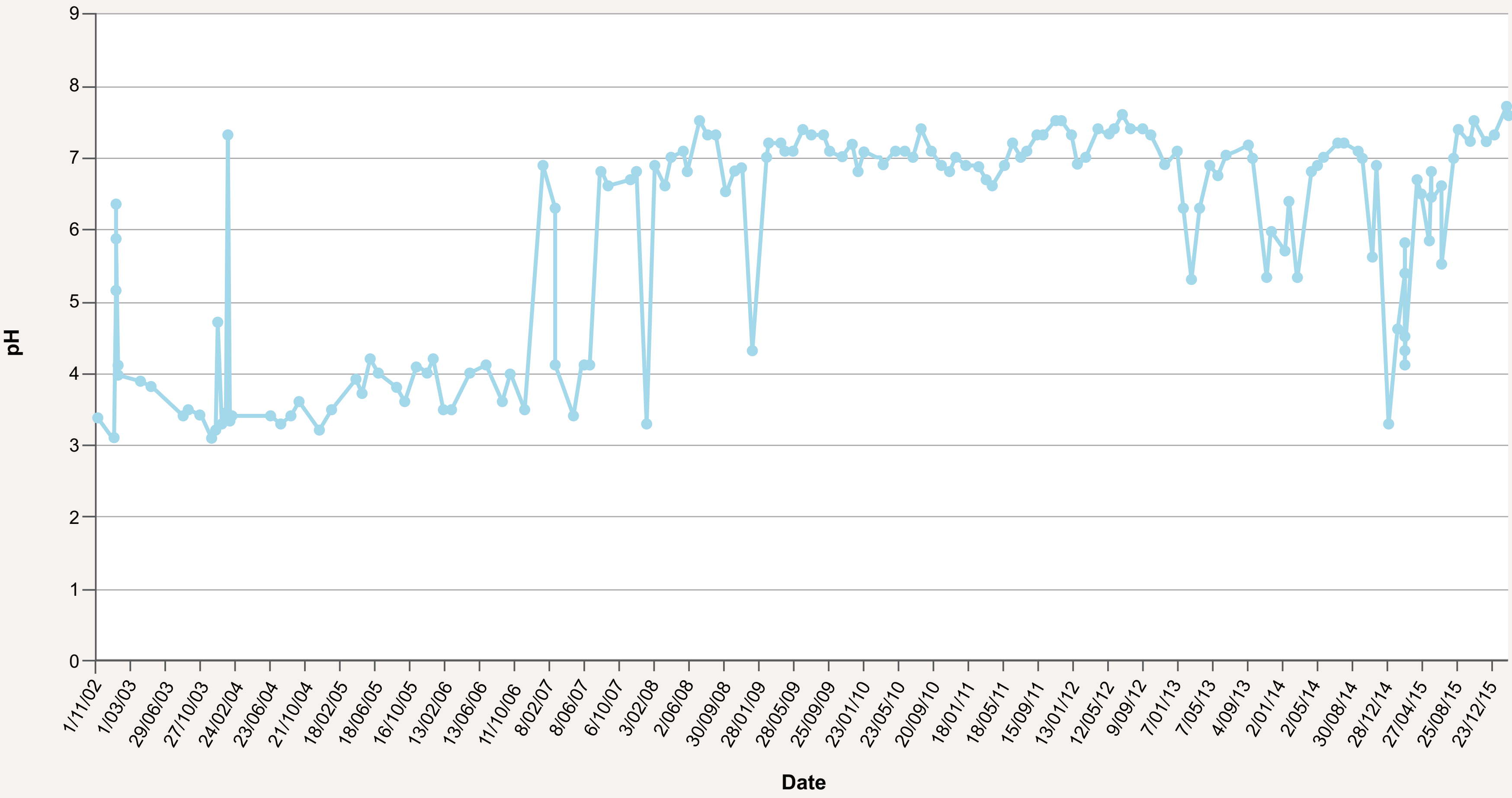
FIGURE 4.18



TAILINGS SUPERNATANT PH TRENDS (2002 - 2015)

McArthur River Mine Project

FIGURE 4.19



Tailings Materials - Management

The TSF is currently split into 3 cells, i.e., Cell 1 (which is filled and inactive), Cell 2 (which is active), and a water management dam (WMD).

Management of seepage from Cell 1 still relies primarily on placement of a temporary clay cover over the tailings before each wet season, with various drains and sumps in place to direct and handle the runoff. The IM understands that the clay cover used in the previous wet season, and that planned for the next wet season, will be similar to previous years, which tends to erode during the wet season. Previous monitoring results indicated that this was ineffective in controlling seepage impacts from Cell 1 to Surprise Creek. Groundwater quality data was not provided for the period during and after the last wet season, but previous results from bores located between Cell 1 and Surprise Creek show high concentrations of SO_4 (MRM, 2015d) due to seepage from Cell 1 and most likely also lateral seepage from Cell 2. Inspection of Surprise Creek during the IM site visit showed a distinct lack of the salt crusting on the creek bed that was evident the year before, and the creek was much drier. This is at least partly due to a low rainfall 2015-2016 wet season and the much reduced water storage in Cell 2 reducing the pressure head and the chance of interaction of the Cell 2 process water with Cell 1. It is not clear to the IM if current Cell 1 and Cell 2 management will successfully limit seepage into Surprise Creek if there is higher rainfall in the next wet season.

The modified design and operation of Cell 2 that was implemented in the last IM reporting period continued, with active beaching of tailings around the perimeter of the cell using multiple spigots, lower water content in the tailings discharge slurry, and removal of excess decant water. Inspection of the TSF during the IM's site visit confirmed the success of the beaching strategy and minimal water storage. The tailings are generally discharged from one spigot at a time, rotating clockwise around the 47 spigots installed on the Cell 2 perimeter, with a cycle time of around 35 to 40 days, so that older tailings are constantly being covered with fresh wet tailings. Inspection of the surface of beached areas showed that older areas still maintained high moisture content due to the fine and bi-modal nature of the tailings (50:50 mix of $<50\ \mu m$ and $<7\ \mu m$). There was no obvious dust issue, and most of the tailings surface showed little evidence of drying and salt formation (Plate 4.5 and 4.6). The main exception was an area of salt accumulation on tailings surfaces on the eastern side of the decant causeway (Plate 4.7). This area appears to be not as conducive to continued tailings deposition, resulting in drying out and oxidation of tailings. Control of dust and oxidation in this area may require water spraying if the deposition methods cannot be modified.

Plate 4.5 –TSF Cell 2 Surface, Showing Most Materials Being Moist with only Minor Drying Around the Edges

Plate 4.6 –TSF Cell 2 Surface in More Detail

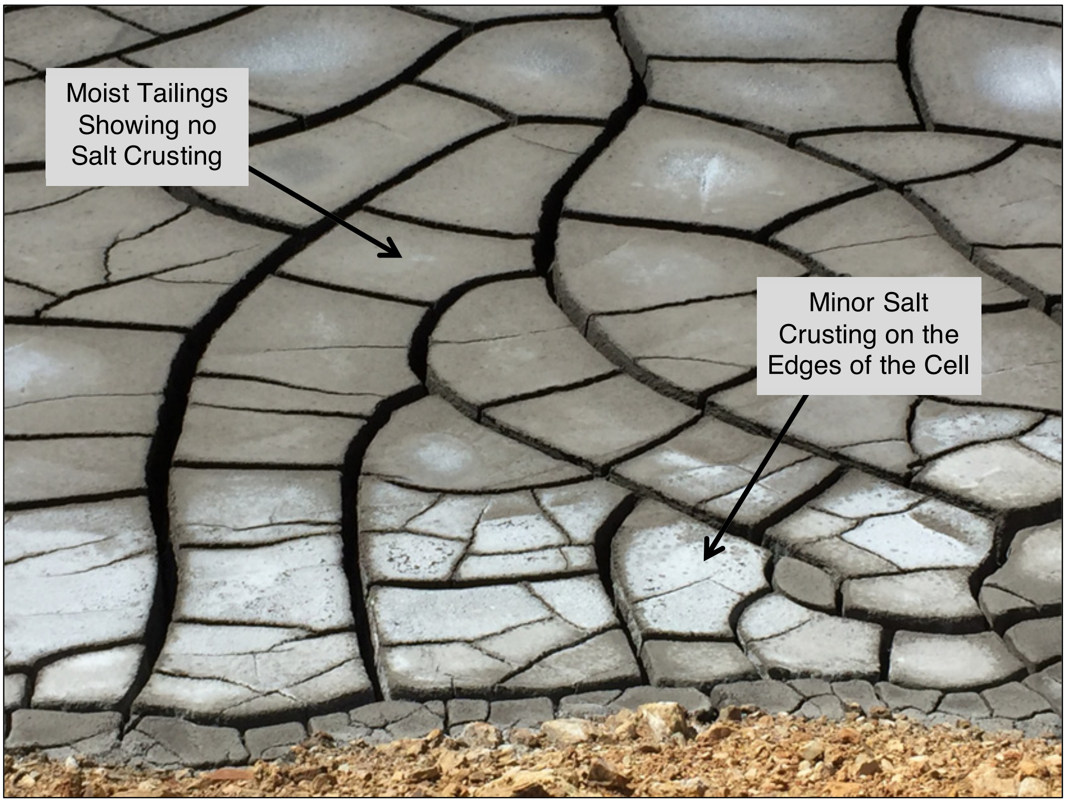


Plate 4.7 –TSF Cell 2 Showing Salt Accumulation on Tailings Surfaces East of the Decant Causeway

The current tailings and water management approach at Cell 2 will reduce seepage into groundwater, but it may take some time before this is evident in groundwater monitoring bores. The recent low rainfall wet season has obviously assisted in minimising water stored in the TSF and consequent seepage. Maintaining low seepage from the TSF may be more of a challenge in a high rainfall wet season.

Options discussed during the site visit for closure of the TSF include placement of a store and release type cover, re-processing/re-handling and ultimate pit disposal, and de-sulfurising tailings after re-processing (MRM, 2015j). The IM understands that tailings pit disposal is the current preferred option, with re-processing viability not necessarily a prerequisite (presentation by MRM on 27 April 2016). The IM strongly supports the pit disposal option. Placement of the tailings in the pit would have the benefit of consolidating potential sources of acid, saline and metal leaching, and it is understood that the tailings would remain saturated, thereby providing a much more secure closure outcome than would be achieved for the TSF.

Open Pit, Underground Workings and Infrastructure

Water from the pit and underground workings is classified as contaminated, and was managed by pumping and evaporation, with water initially pumped into the eastern levee storage (ELS). The IM understands that the ELS has been removed from service due to concerns that seepage from the ELS does not all drain back into the pit, as was assumed, but also reports to the McArthur River diversion channel. McArthur River Mining plans to investigate ELS seepage with a drilling program and groundwater assessment (MRM, 2015i).

Elevated EC related to SO_4 was observed in the McArthur River diversion channel in the 2015 dry season from monitoring point SW16 downstream through SW17, appearing to influence EC at SW11 (MRM, 2015e). Figure 4.7 (Section 4.3) shows SO_4 concentrations along McArthur River, with monitoring points ordered from upstream to downstream. Site SW15 is upstream of SW16, and showed SO_4 concentrations of less than 50 mg/L, compared to elevated SO_4 levels at SW16 and SW17 peaking at over 1,000 mg/L. These results clearly indicate a SO_4 source between SW15 and SW16. Geological inspection identified zones of mineralisation along the diversion, which MRM believes may be the source. However, the ELS is reasonably close to SW16 and could also be a potential source. The planned groundwater assessment of the ELS will address this aspect (MRM, 2015i). Figure 4.7 (Section 4.3) shows the location of two groundwater monitoring bores, GW129 and GW136, between the ELS and McArthur River diversion channel that have elevated EC, corresponding to SO_4 of over 2,000 mg/L, again possibly indicating seepage from the ELS into the diversion channel. Whatever the primary source of salinity in the McArthur River diversion channel, the presence of exposed sulfidic rock in the excavated banks will require management to prevent local impacts on water quality and revegetation success. The IM understands that MRM plans to clay line the ELS to control seepage.

4.6.4 Review of Environmental Performance

4.6.4.1 Incidents and Non-compliances

Incidents

No specific geochemical incidents were identified from documents supplied for this reporting period, apart from those related to water quality (see Section 4.3.4.1).

Non-compliances

No specific geochemical non-compliances were identified from documents supplied.

4.6.4.2 Progress and New Issues

McArthur River Mining's performance against previous IM review recommendations relating to geochemistry is outlined in Table 4.25.

Table 4.25 – Geochemistry Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
NOEF	Make allowance for monitoring and ongoing maintenance of NOEF cover system post closure	It is expected that this will be addressed in the EIS currently being prepared
	Extend paddock dumping and roller compacting to PAF(HC) materials, which are still highly pyritic, to maximise stability, and minimise oxidation and infiltration	Currently, PAF(HC) materials are being placed this way in the NOEF due to difficulty in separating PAF(HC) from PAF(RE) in the pit. The updated Central West Phase operations manual (MRM, 2015b) indicates that thin lifts of 2 to 3 m are planned for the PAF(HC). The IM urges continued placement of PAF(HC) in <2 m paddock dumped and compacted lifts
	Maintain a 100-m set back for PAF(HC&RE) materials, particularly in older 15-m end-tipped dump zones, to control convection	Cover system design is in progress and it is uncertain if this will be carried out

Table 4.25 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
NOEF (cont'd)	Review stability and success of interim clay layers during the wet season	No direct evaluation was undertaken, but trials carried out over the wet season indicated that clay layers are highly susceptible to erosion, suggesting this method is ineffective
	The DME and MRM should seek ways to accelerate the approval process for the revised interim 2013-2015 MMP so that ongoing remediation works are not compromised	Completed
	Adjust block model quantities to account for recoverable geochemical rock types to match conservatism applied in the pit	No reconciliation provided for the current IM review period
	Continue investigations into estimating ANC in the block model	Completed
WOEF	Review/compile existing data and/or carry out a test program to confirm the distribution of geochemical rock types at the WOEF	No progress
SOEF	Review kinetic test results and assess potential impacts on receiving drainages and the need for control of salt migration into growth horizon	Kinetic testing is in progress and fate of SOEF materials is yet to be finalised
Waste rock	Expand check testing to include specific geochemical rock types placed in the dump according to the new criteria	Completed
	Carry out more testing to better calibrate portable XRF	Testing carried out, but calibration not complete
	Identification of PAF(RE) currently based on S criteria only. Continue investigations into spontaneous combustion potential and confirm or modify current criteria	Work in progress. Results to date suggest that the current 10%S cut off is too high and should be lowered to 8.5%S, which would increase the amount of PAF(RE) being handled
	Consider instigating a controlled watering regime for barrel tests, set to a particular wet/dry climatic scenario, to make leachate volumes collected at each barrel more comparable to provide better and more interpretable results	Not carried out, and only a few sample collections in this reporting period due to a dry wet season. Controlled watering would have provided more information
	Collect samples during waste rock dump hydrology/ geotechnical drilling to help determine variation of geochemical properties in historic materials	Completed, and more drilling and sampling is planned
	Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should also be extended to cover the Barney Creek diversion channel, and other significant infrastructure sites not yet sampled	Not progressed. Recommendation updated in 2016 to include assessment of in situ sulfidic materials exposed through excavation of river diversions

Table 4.25 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
TSF	Make allowance for monitoring and ongoing maintenance of TSF cover system post closure	It is expected that this will be addressed in the EIS currently being prepared
	Assess the potential effects of pyrite oxidation and salt generation on the overall stability of the TSF embankment if compacted tailings are used in embankment construction	Not carried out. Unimportant if tailings are to be ultimately placed in the pit
Tailings	Carry out further geochemical characterisation of tailings to better understand acid, saline and metal/ metalloid leaching potential and variation. Include routine testing of discharged tailings and historical (deposited) tailings. Take advantage of planned TSF drilling to collect samples throughout the TSF profile for geochemical testing	Routine testing is being carried out. TSF samples from the drilling have been stored and testing is planned
	Carry out mixing tests between PBOX effluent and normal tailings to determine the effects on the tailings ANC	Not progressed, but it is understood the PBOX water is now recycled, and hence is no longer an issue
2012 and 2013 Operational Periods		
NOEF	Establish instrumented trial dump cover areas to confirm performance and construction methods	Dump instrumentation and cover trials not yet carried out, but are still planned
	Ensure that PAF-HC and PAF-RE materials are excluded from below batter zones (which have higher erosion risk) and set back 100 m from the outer face to control convective oxidation	Current designs and material balances indicate this may be possible. It is expected that this will be addressed in the EIS currently being prepared
	Review geochemical classification criteria with the objective of potentially identifying opportunities to increase the amount of lower acid/salinity/metal-leaching material to increase flexibility in scheduling and allow opportunities to improve the robustness of the dump cover	Addressed through identification of the LS-NAF resource south of the pit (Woyzbun Quarry) and the commitment to mine it specifically for outer shell cover materials. In addition, the geological model is being assessed in detail to identify more opportunities to selectively mine LS-NAF
	Review opportunities to further segregate mine materials during mining based on more detailed geological differentiation	As above
	Develop field reconciliation and NOEF field checks to reflect new geochemical criteria	Completed
	Continue barrel testing and set up leach column testing of a variety of waste rock materials to assist interpretation of leaching characteristics and assessment of leach barrel test results	Barrel, leach columns and humidity cells tests are continuing
	Extend paddock dumping to PAF(HC) in addition to PAF(RE) materials, or devise an equivalent construction method that prevents development of coarse chimney structures and convective oxidation	End-tip dumping of PAF in 15-m lifts has ceased. However, MRM plans to dump PAF(HC) materials in 2- to 3-m lifts. The IM is uncertain if this management strategy is adequate

Table 4.25 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
NOEF (cont'd)	Control convection in old dump areas by placement of paddock dumped (or equivalent) materials on the outer face with (ideally) a minimum 100 m horizontal thickness	MS-NAF halo is being paddock dumped and traffic compacted, which will help control convection
	Progressively place cover as soon as completed waste dump areas become available, and interim caps should be placed over active PAF dump areas prior to each wet season	Interim caps have been placed over most of the PAF dump
	Carry out additional surface water and groundwater monitoring along the northern and eastern edge of the NOEF as recommended by KCB (2014b)	Completed
TSF	Carry out further geochemical characterisation and kinetic testing of tailings to better understand acid, saline and metal/metalloid leaching potential and variation. Include routine testing of discharged tailings and historical (deposited) tailings	See 2015 IM Review recommendation on geochemical characterisation Kinetic leaching tests are understood to be in progress but no data provided
Open pit	See also recommendation in Section 4.8.4.2	
Mine site	Build on KCB (2014a) work with a specific monitoring review to feed back into leaching materials management. Surface water monitoring, groundwater monitoring and field checks of dump materials should be included in the review and assessed for any indications of geochemical impacts. The need to modify monitoring locations and frequency should also be assessed	Reports on surface water and groundwater monitoring were provided with greater depth of assessment in terms of geochemistry implications and sources
Bing Bong dredge spoil	Carry out acid sulfate soil assessment of spoon drain and other potential sources at Bing Bong Loading Facility	No specific acid sulfate soil assessment of the spoon drain at Bing Bong Loading Facility was provided
2011 Operational Period		
NOEF	Install lysimeters in NOEF to collect leachate from water percolating through the entire dump	Not installed, but setting up of leach column and field barrel testing has a higher priority
TSF	Seepage from TSF Cell 1 should be mitigated through re-processing of tailings and creating a liner to intercept seepage	Final fate of tailings is still being decided. Recommendation no longer relevant in isolation
	Evaluate and design a tailings seepage and closure management system	In progress
	Investigate seepage associated with TSF Cell 2 and assess impacts	Documentation was provided. Cell 2 water management is expected to reduce seepage impacts

4.6.4.3 Successes

As with the previous IM reporting period, MRM has made considerable progress in geochemical prediction and management of mine materials, including the following:

- Improvement of the resource waste rock block model to include ANC, and classification of waste rock types based on the full classification criteria.
- Completion of a number of studies and assessments to address information gaps, including infill waste rock geochemical characterisation, drilling of the NOEF to better understand geochemical and hydrological processes, cover design modelling and assessment, preliminary pit lake water quality modelling, and investigations into spontaneous combustion.
- Improved understanding of geochemical properties of key waste rock types based on static and kinetic testing, which supports the current classification criteria.
- Definition of a LS-NAF resource outside of the existing pit (i.e., Woyzbun Quarry) that can be quarried to make up shortfalls in cover design requirements.
- Use of the new resource waste rock block model to recreate the waste rock type composition of the NOEF, with NOEF drilling data used to check results. Results indicate more NAF materials than expected (70% of drilled samples were NAF).
- Continued placement of newly-mined PAF(HC) and PAF(RE) in paddock-dumped and roller-compacted (2 m) lifts to minimise oxidation and limit infiltration.
- Initiated construction of a MS-NAF halo zone as part of the broader cover system to help control convection/advection into PAF materials.

4.6.5 Conclusion

McArthur River Mining has expended considerable effort in the current IM reporting period towards better defining the geochemical properties and risks of mine materials, and has made a number of improvements in operational management to better control currently identified geochemical issues and impacts. However, the highly pyritic and reactive nature of the mine materials means that generation of acid, metalliferous and/or saline drainage, and the associated potential adverse impacts both on site and downstream, remains the most significant environmental issue at McArthur River Mine. The NOEF, TSF and open pit are the key potential long-term sources of contaminated drainage.

The main geochemical issues for the site relate to the need to:

- Improve operational controls to manage rapid oxidation and seepage.
- Better define the distribution of geochemical rock types and their geochemical properties.
- Develop closure management strategies that ensure the successful long-term mitigation of potential impacts.

New IM recommendations related to geochemistry issues have been consolidated in Table 4.26 with updated recommendations from previous IM reviews. The combined recommendations replace those listed previously (Table 4.25).

Table 4.26 – New and Ongoing Geochemistry Recommendations for the 2015 Review

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
NOEF	Continue paddock dumping and roller compacting PAF(HC) materials, which are still highly pyritic, to maximise stability and minimise oxidation and infiltration	High
	Maintain a 100-m set back for PAF(HC&RE) materials, particularly in older 15-m end-tipped dump zones, to control convection	High
WOEF	Review/compile existing data and/or undertake a test program to confirm the distribution of geochemical rock types at the WOEF and finalise closure options	Medium
SOEF	Review kinetic test results and assess potential impacts on receiving drainage during operations, and finalise closure options	Medium
Resource waste block model	Reconcile the block model predicted tonnages by waste rock type against tonnages actually mined, and adjust the block model if required. The amount of materials classified PAF(HC) in 2014 was significantly higher at 34% of waste rock moved than the 15% predicted by the block model	Medium
Waste rock kinetic testing	Consider instigating a controlled watering regime for barrel tests, set to reflect a particular wet/dry climatic scenario, to make leachate volumes collected at each barrel more comparable to provide better and more interpretable results	Low
In-pit waste rock grade control	Check calibration of hand-held XRF with new ICP check data	Medium
Waste rock criteria	Identification of PAF(RE) is currently based on S criteria only. Continue investigations into spontaneous combustion potential and develop criteria that provide more confident identification of PAF(RE). In particular, confirm whether the current 10%S cut off is too high and needs to be lowered to 8.5%S	Medium
TSF	Make financial allowance for long-term monitoring and ongoing maintenance of any TSF cover system post closure	High
	Assess the potential effects of pyrite oxidation and salt generation on the overall stability of the TSF embankment if compacted tailings are used in embankment construction	Medium
	Continue ongoing geochemical monitoring of discharged tailings and carry out geochemical characterisation of tailings collected as part of TSF drilling to obtain information on historic variation through the tailings profile	Low
Infrastructure sites	Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in situ sulfidic materials at the Barney Creek diversion and McArthur River diversion	Medium
Bing Bong Loading Facility dredge spoil	Carry out an acid sulfate soil assessment of the spoon drain around the dredge spoil ponds and other potential sources at Bing Bong Loading Facility	Low
New Items		
NOEF	Installation and maintenance of complex cover systems on the NOEF will be challenging. Performance criteria should be developed, and a cover system designed that is robust enough to be installed on the NOEF and provide satisfactory long-term performance Allowance should be made for long-term monitoring and ongoing maintenance of the NOEF cover system post closure	High

Table 4.26 – New and Ongoing Geochemistry Recommendations for the 2015 Review (cont'd)

Subject	Recommendation	Priority
New Items (cont'd)		
NOEF (cont'd)	Develop a new approach to wet season infiltration control given the apparent ineffectiveness of a clay cover	High
	Improve control of convective/advective oxidation and spontaneous combustion. Advances have been made, but these processes are still occurring	High
	Undertake further investigation and analysis of monitoring data to better understand the extent and impact of groundwater contamination from the NOEF	Medium
	Carry out more drill testing of dumped materials to more confidently define the distribution of historically dumped materials and check the reconstruction of dump material types based on the new block model. Knowing the rock type composition and distribution will help MRM predict contaminant loadings being generated	Medium
	Increase the frequency of check sampling of dumped materials, particularly for LS-NAF. Only 102 check samples of LS-NAF cells were collected over the 2014 to 2016 period	Medium
	Determine whether elevated SO_4 concentrations in groundwater bores to the northeast of the NOEF (GW105, GW100, GW131 and GW134) are related to shallow seepage from the NOEF along natural drainage	Low
In-pit waste rock grade control	Progress use of on-site ICP testing to replace portable XRF	Medium
Waste rock criteria	Maintain NPR cut offs for PAF(HC) materials at 1 unless there is compelling geochemical evidence to justify a reduction	Medium
Waste rock kinetic testing	Include results from all kinetic testing in future kinetic test reports, including barrel leach, humidity cells, leach columns, and for waste rock and tailings materials Provide a table of the S, ANC, ABA and key metal/metalloid compositions of samples used in kinetic testing and compare with ranges expected (based on static testing) in each waste rock class and tailings	Medium
	Repair barrel tests before the next wet season	Medium
	Consider continuing LS-NAF humidity cells/columns to demonstrate longer-term low rates of contaminant release	Low
TSF	Progress the in-pit disposal and flooded option for tailings, which will provide the most secure closure outcome	High
	Install a more robust cover on Cell 1 before the next wet season that will withstand erosion and control infiltration, and progress the Cell 1 dewatering bores. The previous interim clay covers installed did not appear adequate to control seepage and impacts on Surprise Creek	High
	Monitor sulfide oxidation and pore water quality in beach tailings during operations to check for evidence of acid and salinity production. This could include pH/EC measurements of surface tailings	High
	Continue kinetic leach testing of tailings and assess lag times and acid, salinity and metal/metalloid generation rates, and implications for operational control of tailings beach areas and water quality	Medium
	Maintain moisture in drier and less active areas of Cell 2 to minimise sulfide oxidation and dust. This may include spraying water onto the surface	Medium

Table 4.26 – New and Ongoing Geochemistry Recommendations for the 2015 Review (cont'd)

Subject	Recommendation	Priority
New Items (cont'd)		
TSF (cont'd)	Variation in ANC values was detected between different laboratories. Further checks should be carried out to determine which results best reflect the available ANC in the tailings, with inclusion of ABCC testing	Low
Mine site	Progress investigations into the eastern levee storage (ELS) and potential for saline seepage to McArthur River diversion channel	Low

4.6.6 References

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4.7 Geotechnical

4.7.1 Tailings Storage Facility

4.7.1.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of geotechnical issues at the TSF, and is based on:

- Observations and discussions with MRM personnel during the site inspection.
- Review of various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's environmental monitoring report, supplementary monitoring report, and mining management plan (MRM, 2015a; 2015b; 2015c).
- Review of Excel spreadsheets provided by MRM that contain collated laboratory and in situ data.
- Review of laboratory documents including sample receipt notification, certificates of analysis (analysis results) and quality control reports.
- Review of various MRM forms and similar documents such as chain of custody forms, field data forms, survey results, incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the MRM mine site provided by MRM.
- ALS (topographic) data of the MRM mine site provided by MRM.
- Review of other documents such as waste discharge licences and DME compliance audit reports.

4.7.1.2 Key Risks

The key risks to management of geotechnical issues at the TSF, as described in the risk assessment (Appendix 2), are:

- Embankment failure (loss of containment): embankment slope failure or excessive deformation due to static, seismic or pore pressure loading resulting in tailings and tailings water.
- Embankment failure (overtopping): embankment overtopping due to storm events leading to loss of water and tailings (due to subsequent scour) from the storage.
- Piping (internal embankment erosion): internal erosion within the embankment or foundation leading to loss of water and tailings from the storage.
- Foundation failure: embankment failure due to sliding resulting in loss of water and tailings from the storage.
- Tailings line failure: erosion leading to embankment failure, and loss of water and tailings from the storage.

- Seepage: seepage from the TSF polluting groundwater and surface water.
- Operation failure: operation of the tailings dam outside of its intended design, such as a water holding dam, leading to one of more of the above risks.
- Combination failure: a combination of more than one of the above at the same time resulting in embankment failure, and loss of water and tailings from the storage.

All of the above risks would potentially result in impacts to the terrestrial and aquatic flora and fauna in and around Surprise and Little Barney creeks and other downstream creeks and rivers.

4.7.1.3 Controls

Previously Reported Controls

The controls that have been implemented by MRM to minimise the likelihood of these hazards are shown in Figure 4.20 where applicable, and include:

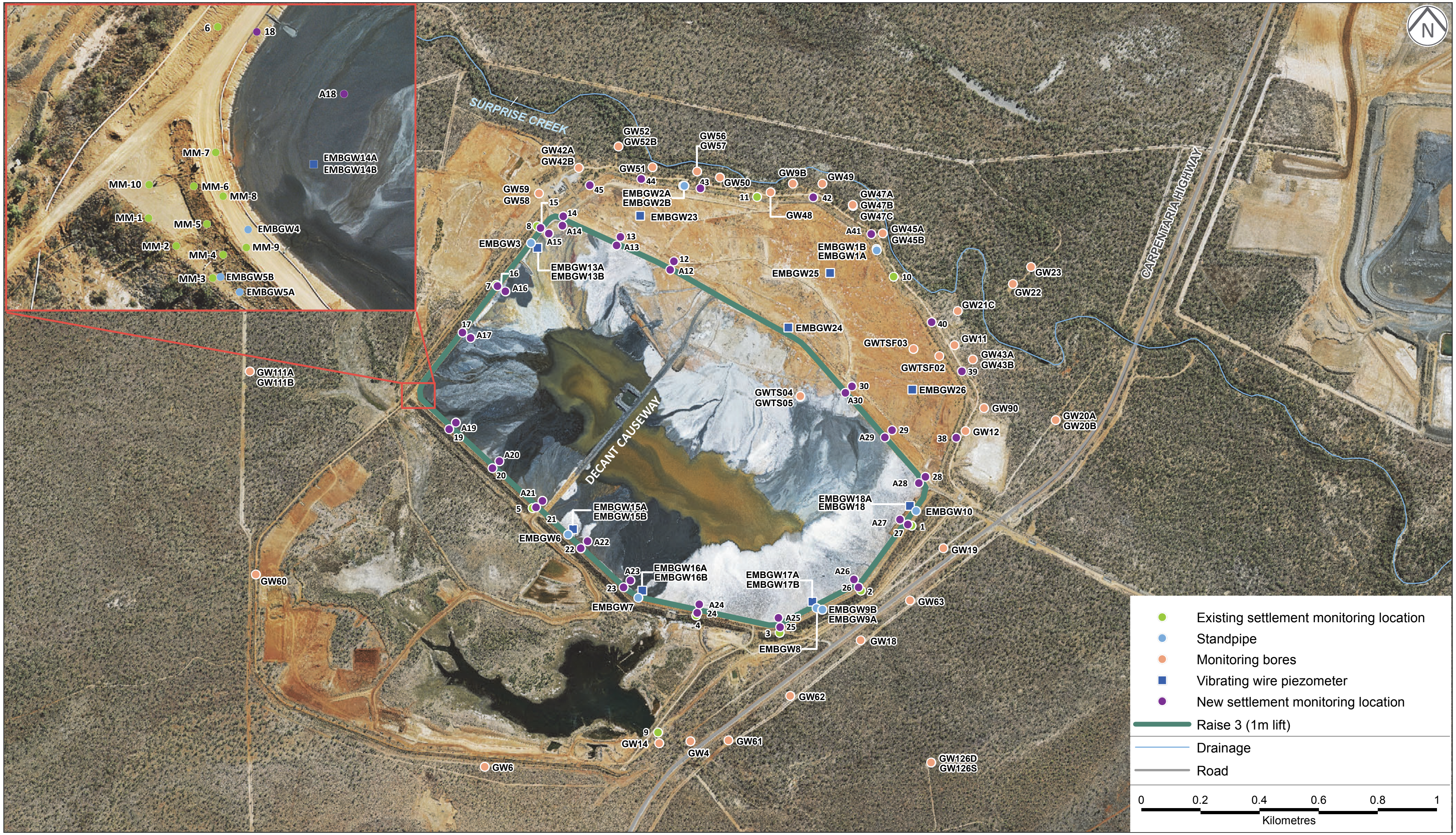
- Design and analysis of future TSF works to meet ANCOLD (2012a) guidelines for a 'High C' dam failure consequence and a 'Significant' dam spill consequence.
- Supervision during construction, and certification that the TSF has been constructed in accordance with design and is fit for purpose under the expected operating conditions.
- A perimeter discharge system that promotes formation of a tailings beach that allows movement of liberated surface water away from the embankments to a central decant pond.
- A decant system that allows the pond to be positioned well away from the perimeter walls and controlled in size so that the phreatic surface within the embankments can be kept below design limits.
- An operating manual prepared by the designer or suitable delegate that prescribes the correct operational parameters such that the TSF is operated within acceptable design limits.
- Monthly site inspections of the TSF recording climate, water levels, deposition quantities, construction or maintenance activities and observed impacts such as seepage and erosion.
- Monthly hydrographic surveys of the TSF pond aerial extent (undertaken from February to June 2015 inclusive during the reporting period).
- Quarterly level surveys of 11 monuments[12] within and around the TSF Cell 1 and TSF Cell 2 embankments and additional monthly surveys in the southwest corner of TSF Cell 2.
- Nominally weekly (average for 2015 is every 9 days) piezometric surveys of 14 standpipes within and around the TSF Cell 1 and TSF Cell 2 embankments.
- A site-wide water balance model updated annually.

[12] Survey stations used to measure any movement in the embankment wall.

OVERVIEW OF TSF SHOWING SETTLEMENT MONITORING LOCATIONS

McArthur River Mine Project

FIGURE 4.20



- Installation of a contoured capping over TSF Cell 1 to promote efficient surface water drainage and removal.
- A system of sumps, pumps and pipes to move collected surface or decant water such that the likelihood of overtopping and increased subsurface pore pressures is minimised.
- Regular pipeline inspections and monitoring of wall thickness identify potential pipeline breakage, or limit the impacts should such breaks occur.
- Inspections and measurements of known seepage from the southwest corner of TSF Cell 2 and its spillway including seepage volumes, water quality testing and additional survey marks.

In addition to the above, the DME undertake an annual inspection. The 2015 annual inspection was undertaken in August.

New Controls – Implemented and Planned

New controls implemented within the reporting period include:

- Upgraded TSF Cell 1 surface water detention sumps and water management system.
- Modifications to the TSF Cell 2 spillway to meet design requirements.
- An expanded network of tailings discharge points and deposition plan that completely encircles the TSF comprising 46 locations at approximately 100-m spacing.
- The appointment of an Independent Tailings Review Board (ITRB) and delivery of their initial report (dated December 2015).
- The appointment of a MRM Project Engineer to manage the TSF.
- Review of the TSF Cell 2 Raise 3 design undertaken by Bruce Brown Consulting in March 2015 with subsequent revision to the design report.
- The appointment of an Independent Certifying Engineer (ICE) to oversee and verify TSF embankment construction, specifically compaction.
- An annual dam safety inspection by the TSF designer (undertaken December 2015).
- Updated water balance modelling to account for TSF Cell 2 Raise 3, pond water reclamation, revisions to TSF Cell 1 surface water management and changes to WMD operation.
- Ongoing checks and reanalysis of embankment stability using measured piezometric levels.

Planned controls include:

- Additional investigations to further define the extent of faulting below the TSF.
- Capping of TSF Cell 1 contingent on the choice of future TSF management and expansion.

4.7.1.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents

One incident relating to the TSF was reported during the operating period. On 11 February 2015 tailings slurry was released through a split in the TSF Cell 2 perimeter pipeline onto the TSF Cell 2 perimeter road. The quantity of tailings slurry released was estimated to be 60 m^3.

TSF maintenance workers were within the vicinity of the spill and diverted the slurry to another pour point. Earthen bunds were used at the entry to the wall access road to prevent further movement of slurry. An industrial vacuum recovery tanker was deployed to collect the released material, which was then replaced back into TSF Cell 2.

The reporting sheet submitted to the DME states that this incident occurred on the 10 February, one day before the stated event date. It is likely the incident was reported to the DME on 11 or 12 February 2015.

Spills of this nature may happen from time to time due to pipe wear or coupling failure. McArthur River Mining employ a number of techniques to minimise the likelihood of pipe burst or the extent of flow if this occurs. These methods are:

- Thermal tomography is used on sections of steel pipeline situated near the process plant and extending to the TSF to check for pipe wear.
- Small earth ponds have been constructed along the pipeline at coupling points (about every 500 m) to capture and hold leaks. Two additional capture ponds were constructed in this reporting period.
- On the TSF itself, MRM employ regular pipeline inspections to detect such leaks as soon as possible and implement spill procedures to contain and remove spills when required.

The IM finds that these procedures are accepted practice and suitable for MRM. In most cases rupture of the TSF ring pipeline will result in tailings making their way into the TSF as the pipeline is located nearest the inside batter. In this case the spill made it’s way beyond the TSF, presumably due to the failure being located where tailings pressure was relatively high and the breach being directed away from the tailings. In future, MRM should consider sloping the embankment roadway towards the tailings to minimise loss of material outside the TSF.

Non-compliances

There are no non-compliance issues to report.

Progress and New Issues

Progress in the last reporting period includes:

- Tailings storage facility Cell 2 Stage 3 construction.
- Cessation of seepage from the southwest corner of Cell 2.

- Revised MRM monthly inspections and reporting.
- Appointment of an ITRB.
- Appointment of an ICE.
- Completion of a full perimeter TSF Cell 2 discharge system.
- Effective pond area management.
- Routine (usually monthly) inspections of the TSF by the DME.
- Improvements to the TSF Cell 1 western sump.
- Installation of a bentonite cut-off wall at the southern end of the decant access wall to limit TSF water into the rockfill platform.

The first four of these items are considered more significant and are expanded further below.

TSF Cell 2 Raise 3 Construction

The first phase of the TSF Cell 2 Stage 3 (or Raise 3) was commenced around August 2015 with the majority of a 1-m raise completed before the wet season. An additional 1-m lift is scheduled for June 2016. This raise encountered the following issues:

- Tailings removed at the edge of the embankment to accommodate Zone 1 material that spontaneously combusted when stockpiled.
- Only 80% of the work required for the lift was completed (a 1-m raise) due to delays in commencing construction, construction progress and the limited dry season window.
- The compaction specification required modification to allow use of a non-conforming material for Zone 1A.

Combusting tailings were managed by recompaction. It is unlikely the extent of this issue was anticipated by the designer.

The IM considers these changes relatively minor with the exception of changes to compaction specification for Zone 1A. Changes to the compaction specification were investigated by the IM as being a possible non-compliance. The issues considered by the IM were:

- Any modifications to the design of the TSF should be made or at least approved by the designer.
- Changes to the specification by the ICE may have had significant detrimental effects on the embankment because:
  - Their effectiveness was not measured in terms of permeability testing, an important design parameter.
  - The recommended moisture content in the revised specification of 12 to 15% is below the range of optimum moisture content measured during the site investigation in

February 2015, this being 16.5 to 25%. This is supported anecdotally by DME inspectors during the 4 August 2015 site visit who noted the 'high plasticity' of the Zone 1A material and that it required 'more water than planned'.

The IM also considered the independence of the ICE. Use of an ICE is common practice in embankment construction allowing construction to progress smoothly without the need for continual input from the designer and to ensure the structure is built to both the designer and the owner's requirements. In this case GHD is both the designer and the ICE, therefore the independence of the ICE is potentially compromised.

After the IM raised these and other related concerns, MRM subsequently provided the IM with a letter from GHD (2015a) that documents the testing undertaken and the designer's assessment of the revised method. It is understood this letter was provided to the DME when their original concerns were raised.

The IM accepts that the letter from GHD (2015a) represents the designer's acceptance of the revised compaction method. Although the IM maintains that permeability testing should have been part of compaction method verification.

The IM recommends that all correspondence on the TSF clearly state the capacity that each party is acting under, i.e., designer or ICE, but not both. This will improve transparency of roles and responsibilities and help to clarify the independence of the ICE.

This issue was exacerbated by a lack of communication between the DME and MRM. Information on changes to the TSF compaction design does not appear to have been communicated to the DME by MRM until identified by DME field officers and subsequently requested by the DME. It was then approximately another four weeks before these changes were communicated by MRM to the satisfaction of the DME.

The IM has seen discussions and comments by both MRM and the DME that suggest it is not always clear what information with respect to construction activities MRM must provide to DME voluntarily. In this instance, it seems that MRM did not feel obliged to inform the DME. At the same time, the written responses from the DME relating to this incident did not identify any specific commitment or approval condition that had been violated. The IM has previously recommended that all TSF Cell 2 Raise 3 construction documentation be provided to the DME. The IM recommends that the DME clarify this position again with MRM, together with the information they require, particularly with respect to construction quality control. At the same time, the IM recommends that MRM provide a formal response and commitment regarding the construction records they will provide in the future.

Another means by which the TSF is independently reviewed is through the ITRB. However, two of the three individuals on ITRB are currently undertaking work on behalf of MRM in other areas of the site. The IM recommends that all 'independent' appointments be assessed for potential conflicts of interest and conflicts avoided wherever possible to promote the safe and effective management of the TSF.

The above demonstrates the need for continued review of TSF construction and operation. The IM feels that the increased frequency of DME site inspections is positive and the department is to be commended for its diligence and efforts in this area. Similarly, the appointment of the ICE is viewed as a positive change in management of the TSF.

Cessation of Seepage from the Southwest Corner of TSF Cell 2

Seepage from the southwest corner of TSF Cell 2 was first reported in April 2014 and likely to have commenced before this date. Subsequent action by the DME and then MRM resulted in verification, quantification and remediation of the issue. Remedial works were undertaken with the assistance of a new TSF designer, GHD, and included investigation of the area, construction of a collection sump and pump and improving tailings beaching at the source of seepage. It was known that these measures would take time to stop seepage occurring, but were considered the most expedient options available at the time.

Recovered seepage has gradually declined since the sump and pump system was implemented and appears to have ceased around mid June 2015, over one year after initially being reported. It is likely some seepage is ongoing, but not at flows sufficient to report to the southwest sump system.

Revised MRM Monthly Inspections and Reporting

The IM made the following recommendations in the previous reporting period regarding:

- Staff training at specialist courses.
- Updating infrastructure inspection and operating reports to a single report.

Both of these recommendations have been implemented in this reporting period. The IM has been provided with copy of a TSF Operation and Surveillance Training manual (written by GHD) and copies of training completion certificates for seven (presumably MRM) staff.

The IM has been provided with 'TSF Communication' reports from April 2015 to January 2016. These reports appear to replace the monthly TSF Operating and TSF Inspection reports previously provided to the IM prepared at the direction of the DME. The TSF Communication reports include:

- A summary of rainfall, TSF Cell 2 pond levels, tailings input, seepage collection at the southwest corner of TSF Cell 2 and seepage monitoring at the spillway in tabulated and graphical form.
- A description of works carried out at the TSF accompanied by photographs.
- An update of any ongoing issues, such as seepage, deposition or other operation matters.
- A plot of piezometer monitoring data and TSF Cell 2 pond level.
- A review of piezometer data and trends.
- A summary of water quality testing in TSF Cell 2, at seepage points (such as the southwest corner and the spillway), at the TSF Mini Dam, the TSF 'water hole' immediately west of the southwest corner of TSF Cell 2 embankment and the WMD.

- TSF embankment level survey data.
- A summary of actions completed, pending and arising.
- Photographs taken for that month and daily records of water volumes.
- The extent of the TSF Cell 2 surface water pond was provided to the IM but only for March, April, May and June 2015. It is unclear whether the pond extent has been recorded by MRM for other months.

The TSF Communication reports appear to be an expanded form of the fortnightly TSF Cell 2 southwest seepage reports prepared since April 2014. These reports largely conform to that recommended by the IM with the exception of the missing pond extent for some months.

McArthur River Mining has advised that the monthly reports are being forwarded to the TSF designer, GHD. The IM has noted that the piezometric levels have been used by GHD to update embankment stability analyses.

Appointment of an ITRB

An ITRB comprising Professor David Williams of The University of Queensland, Dr Tamie Weaver of Environmental Resources Management and Dr Jeff Taylor of Earth Systems were engaged by MRM in September 2015. The main task of the ITRB was to review the proposed life of mine (LOM) design, management and closure plans for the TSF.

The ITRB identified a number of issues none of which the IM considered significant geotechnical issues regarding current operation of the TSF. The main focus of the ITRB findings concerned ongoing seepage from the TSF into Surprise Creek and the implications for closure.

Ongoing Seepage at the TSF Cell 2 Spillway

Seepage from the TSF Cell 2 spillway was first reported in the December 2013 TSF Operating report as follows:

> The seepage along the southern wall has recommenced at the spillway.

Seepage is generally attributed to the use of the rockfill platform used beneath the August 2012 and April 2013 TSF Cell 2 lifts. Seepage commenced earlier at the spillway than at the southwest corner of TSF Cell 2 and is likely due to the lower level of the rockfill platform in this area. Spillway seepage has reduced over time, but has not stopped.

Spillway seepage is likely to continue for some time, but is expected to gradually decrease over time. The consequences of seepage at the spillway are not as great as at the southwest corner. The majority if not all of seepage from the spillway is collected and returned to the TSF.

Ongoing Seepage Towards Surprise Creek

Seepage from TSF Cell 1 has been documented in at least 15 reports and investigations since 2006 and is likely to have been ongoing since construction in 1995. It has also been highlighted as a key concern of the ITRB. Investigations undertaken in the current reporting period include:

- TSF seepage investigation, report, May 2015 (KCB, 2015a).

- TSF seepage investigation, report updated, July 2015 (KCB, 2015b).
- TSF seepage interception bore assessment, memo, July 2015 (GHD, 2015b).
- TSF seepage extraction bore testing, memo, September 2015 (GHD, 2015c).
- EIS conceptual hydrogeology, report, October 2015 (KCB, 2015c).

More recently modelling has been developed by GHD for LOM design for the TSF:

- Detailed groundwater model - update and preliminary results, memo, March 2016 (GHD, 2016a).
- TSF remediation design groundwater model, report, March 2016 (GHD, 2016b).

A summary of the findings of these studies follows.

Klohn Crippen Berger (KCB, 2015a; 2015b) details the results of a borehole investigation undertaken in December 2014 around the TSF focussing on the TSF Cell 1 embankment in the vicinity of Surprise Creek. Twenty three boreholes were drilled to a maximum depth of 21 m terminating in fresh dolomite or shale. This investigation included the approximate locations of the major faults in the vicinity of the TSF, as provided by MRM.

These faults are:

- Surprise Fault.
- Bald Hills Fault.
- North Bald Hills Fault.

The KCB (2015b) investigation found a 1-m thick fault zone within borehole GW140B. This borehole was located along the northeastern perimeter of TSF Cell 1 embankment and interpreted by KCB as being slightly west of Surprise Fault. This was the only zone that KCB identified as being related to a fault. Hydraulic conductivity in the fault zone was measured as being over 100 m^3/day and therefore a preferential flow path. Other values of measured hydraulic conductivity from the same study were between 0.2 and 28.8 m^3/day.

The KCB (2015b) investigation reviewed a number of potential remedial strategies for TSF Cell 1 seepage and concluded that changing the tailings deposition practice, such as dry stacking, is likely the best option for managing seepage impacts from the TSF. Interception methods were only considered likely to be effective if used as a combination of interception pumping under the TSF, with reinstatement and upgrades to the existing system at the periphery of TSF Cell 1.

Additional work recommended by KCB included:

- Continue with water quality, water level, and piezometric monitoring.
- Install additional monitoring bores north of Surprise Creek.
- Conduct hydraulic testing.

- Undertake laboratory testing of vertical hydraulic conductivity on undisturbed tailings samples.
- Undertake 2D unsaturated/saturated seepage modelling.

In July 2015, GHD (2015b; 2015c) undertook hydraulic modelling to examine the potential efficiency of recovery bores beneath the TSF. The model incorporated four material layers and appears to analyse saturated flow in 3D.

Memos by GHD (2015b; 2015c) reported that capture of the current tailings dam plume was feasible with one or more bores inside the TSF and that the flow rate and number of bores required was dependent on the aquifer thickness.

It was subsequently recommended by GHD (2015b) that a detailed profile of hydraulic conductivity over the full aquifer profile be determined by drilling three 50-m deep holes. This proposal was expanded in GHD (2015c) to eight holes: four 20 m deep and four 50 m deep.

The 2 MRM 2015 EIS Conceptual Hydrogeology (KCB, 2015c) provided an update to the site conceptual groundwater model. There were no significant changes to the current model at the TSF apart from some observations of minor differences in vertical hydraulic gradient in the vicinity of GW140B.

The IM has identified a number of issues with TSF seepage investigations undertaken in the reporting period. These issues are:

- The extent of the fault region encountered in GW140B is unknown and may be only as wide as the borehole itself or up to 300 m wide based on the vicinity to other drilling.
- The dip and dip direction of the GW140B fault feature, and therefore the thickness encountered in the borehole, is not necessarily the true fault thickness. Therefore modelling based on this information alone may be erroneous.
- Neither the software nor the analysis method used by GHD (2015b) were reported and therefore the applicability and limitations of this assessment are unknown.
- The modelling undertaken by GHD (2015b) did not take into account the existence of faulting revealed in the KCB (2015b) investigation
- GHD (2015b) suggests seepage is relatively deep (>20 m) while KCB (2015c) suggests it is relatively shallow (<20 m).

It is expected that MRM will continue to pursue seepage investigation, interception and recovery at the TSF to try to minimise seepage impacts at Surprise Creek. Based on a review of recent studies the IM considers that improved understanding in these areas is required before such a strategy can be properly designed and implemented. Areas requiring further investigation include:

- Extent of known fault mapping:

  - The extent, thickness and orientation of faulting encountered in GW140B is unknown. Future drilling should target these unknowns to improve understanding and therefore predictive modelling.

- Veracity of likely fault mapping:

  - Fault mapping attributed to MRM is presented in several studies and in all cases no information is provided as to the origin, method of determination and reliability of the mapping. Consequently there is no information concerning the likely orientation, thickness and extent of these structures on which to base seepage modelling or future targeted investigations.

  - In some cases there appears to be alternate models of potential faults in the vicinity of the TSF. The Surprise, Bald Hills and North Bald Hills faults presented by KCB (2015c) in the MRM 2015 EIS Conceptual Hydrogeology appear to be different to the structures presented by Hinman (1995) included in the same KCB report.

  - It appears that all recent TSF seepage modelling is relying heavily on potentially unsubstantiated fault mapping, i.e., this mapping coincides with the only single mapped fault discovered by recent bore logs.

- Tailings hydraulic conductivity:

  - Tailings hydraulic conductivity is difficult to measure with standard laboratory equipment given its low strength consistency and susceptibility to volume change under testing.

  - Estimates include 1×10^{-7} m/s being used by GHD (2015d) for the TSF Cell 2 Raise 3 detailed design (within an expected range of 1×10^{-8} to 1×10^{-6} m/s), 6.4×10^{-9} to 6.4×10^{-6} m/s used by GHD for TSF seepage interception bore assessment, 9.25×10^{-9} used by GHD in the recent TSF remediation design groundwater model and 3.5×10^{-8} m/s used by WRM in the 2014-2015 site water balance.

  - The ITRB has provided an estimate of 5.6×10^{-8} m/s based on a simple water balance.

The veracity of faulting and tailings hydraulic conductivity can be improved through further investigation and testing. Fault mapping, in particular, is considered to be potentially very beneficial in testing the veracity of current observations, such as the fault mapped in borehole GW140B, against expected characteristics. Any future investigations should be targeted towards locating and defining highly permeable zones based on reliable, verified mapping. For example, if a fault is expected to be subvertical there is a low confidence that a vertical borehole would intercept and then detect the true fault thickness and therefore inclined holes may need to be considered.

Improvement of the current interception system being considered by MRM could possibly be in combination with seepage recovery directly below the TSF to intercept leachate and reverse the flow direction away from Surprise Creek.

Evaporation from the tailings beaches is acknowledged to be difficult to estimate due to a number of factors. In this case the use of lysimeters, and micro-lysimeters in particular, may provide a useful direct measure of actual evaporation from the tailings surface. These methods should be combined with Penman based atmospheric methods. Further information on micro-lysimeters is provided in Boast and Robertson (1981), Daamen et al. (1993) and Koupai et al (1995). More details on Penman based methods can be found in McMahon et al (2013).

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the TSF is outlined in Table 4.27.

Table 4.27 – Geotechnical (TSF) Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
TSF design	The revised interim 2013-2015 MMP currently refers to a preliminary design for Cell 2 Phase 3. The IM recommends that the final design be checked for the following: ♦ Compliance with ANCOLD (2012a) Guidelines on the Consequence Categories for Dams ♦ Compliance with ANCOLD (2012b) Guidelines on Tailings Dams - Planning, Design, Construction, Operation and Closure	Complete Cell 2 - Raise 3 Detailed Design Report Revision 2 (GHD, 2015d) has been submitted to and accepted by the DME. A review of this report by the IM found it complies with the ANCOLD 2012 guidelines
	Ensure the Cell 1 drainage and detention system can accommodate a 1 in 200 year storm event through assessment and modification as required	Ongoing Complete for TSF Cell 1 eastern sump only
TSF operation	Confirm assumed average tailings beach gradient from survey	Ongoing The IM estimates that the beach angles are between 1 in 100 to 1 in 200, or less than 0.5%. This is significantly less than anticipated and highlights the need for effective water management and rapid response to rainfall events
TSF seepage	The efficacy of the systems put in place to limit seepage to Surprise Creek need to be assessed, namely: ♦ The geopolymer barrier ♦ The interception bores Previously, the IM questioned the efficacy of the interception bore field and this was primarily based on the lack of such a means of assessment. This assessment was quoted by MRM as a reason to discontinue this recovery method. The IM recommend that MRM focus on a successful means of measuring the efficacy of these systems as the current methods do not appear to be conclusive. This will help to focus and improve recovery efforts	Incomplete Klohn Crippen Berger has investigated hydrogeological conditions in the vicinity of TSF Cell 1 and Surprise Creek and GHD has undertaken preliminary groundwater modelling of seepage from the TSF

Table 4.27 – Geotechnical (TSF) Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
TSF monitoring	The IM recommends that inspections be improved and standardised through (but not restricted to) the following actions: ♦ Staff training (if not undertaken already) at specialist courses such as the annual course on tailings dam inspections run by NSW Dam Safety, or training by the TSF designer or another provider ♦ Update the infrastructure inspection and operating reports to a single report that includes a proforma for all relevant operational information (discharge quantities, piezometric levels, survey levels, pond extent, water levels, rate of water reclamation) plotted over time, records of the inspected areas, current discharge, items in the TSF operating guidelines not listed here and any other features or activities indicated on a plan, photographs of pertinent areas (pond, discharge, embankment likely seep points) and a comparison of measured performance to safe operating limits. These reports should be forwarded to the designer	Complete MRM has revised their inspection protocols and now produce TSF Communications reports which meet these recommendations
TSF monitoring	All monthly reports including summaries of monitoring data to be provided to the IM to demonstrate compliance with MRM commitments	Complete
Commitments	McArthur River Mining provide a definitive list of commitments	Not undertaken
2012 and 2013 Operational Periods		
TSF design	McArthur River Mining to provide a better assessment of their TSF risk of release by estimating the rainfall return periods that would result in: ♦ Exceeding the Cell 1 stormwater capacity resulting in overtopping and potentially catastrophic failure of the embankment ♦ Exceeding the Cell 2 stormwater capacity (including spillway capacity) resulting in overtopping and potentially catastrophic failure of the embankment ♦ Exceeding the Cell 3 WMD stormwater capacity resulting in overtopping and potentially catastrophic failure of the embankment	Complete
	For MRM to confirm if the concrete works on the downstream channel of the emergency spillway have been completed	Complete
TSF construction	All future civil works should provide evidence of testing type and results, compliance (pass/fail), testing frequency and test distribution. For test failures evidence should be provided of what specific action and retesting has been undertaken to rectify areas where tests have failed	Only records of the trail pad have been provided. No other records of earthworks testing or other construction certification has been provided for TSF Cell 2 Raise 3 although it is understood these will be available once construction is complete (this is not ideal as the Stage 3 1-m raise is already being utilised)

Table 4.27 – Geotechnical (TSF) Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
TSF operation	For MRM and TSF designer to provide design evidence and clear operating guidelines under which the TSF embankments are proven to be effective with respect to stability, seepage, erosion control, piping and any other action that may lead to an uncontrolled release of tailings or water. This should include limits on the depth and extent of the surface water pond	Complete
	The discharge lines should be extended to facilitate deposition around the entire Cell 2 perimeter. This will significantly improve control of the location and extent of the surface pond water	Complete This has now occurred and the pond location and extent is better controlled as expected
TSF seepage	McArthur River Mining to review the current strategy for preventing seepage to Surprise Creek in light of recent groundwater monitoring, EM remote sensing and any other relevant data. This review should present evidence as to the effect of existing mitigation strategies, their longevity and long-term feasibility in consideration with other mitigation works such as final capping of Cell 1	Ongoing Planned work includes further drilling and water balance model improvements
	McArthur River Mining to consider discharge of collected seepage north of Cell 1 to other areas of the TSF and not back onto the Cell 1 surface	Complete McArthur River Mining has ceased operation of recovery bores at Cell 1
TSF monitoring	For MRM to fulfil their commitments with respect to monitoring piezometric levels within the Cell 2 embankments so that design factors of safety can be confirmed that the dam is being operated safely. This recommendation was made in the previous two IM reports. The previous IM report also requested that detailed stability analyses need to include monitored (as opposed to estimated) phreatic surfaces in the tailings and embankments. These items remain outstanding and were rated previously as high priority	Complete Fourteen piezometers installed in the TSF continue to be read every fortnight. Piezometers are scheduled for extension during embankment raises and most have already been reinstated
	Provide graphs in the MMP that clearly show groundwater levels (in RL), tailings pond surface water levels and maximum pond depth. These plots should also clearly show the monitoring locations in plan	Complete
	McArthur River Mining to provide a monitoring report which includes assessment by the relevant designer as to the implications of monitored piezometric levels, embankment settlements, pipeline wear, pond levels and any other TSF monitoring data with respect to design. This would essentially expand the Annual Regulated Dam Safety Reports that currently do not make any comment on these issues	Complete The new TSF Cell 2 Communications reports meet these recommendations

Successes

The most significant success for the TSF in this reporting period is the effective pond management with evidence that a beach of at least 50 m is being maintained, that pond water is being efficiently reclaimed and the establishment of safe operating levels.

Other successes include:

- The construction of 1-m raise[13] of TSF Cell 2 based on a successful field trial and subsequent approval by the DME, and relatively favourable reviews by Bruce Brown Consulting
(Brown, 2015) and the ITRB. This success is pending confirmation by the designer (GHD) that the compaction specification modifications do not have a significant detrimental impact on the raised embankments.
- Renewed efforts to identify and quantify TSF seepage affecting Surprise Creek.
- Improvements to TSF Cell 1 surface water management.
- Reductions in seepage through the spillway and southwest corner of TSF Cell 2.
- Training for personnel undertaking TSF inspections.
- The establishment of new operating guidelines, operating limits, triggers and actions.
- Establishing full perimeter discharge.
- Improved pond water reclamation.
- Ongoing checks and reanalysis of embankment stability using measured piezometric levels.
- Ongoing monitoring of piezometric levels, settlement, pond levels, reclaim volumes and beach angles.
- Ongoing thermal tomography to confirm integrity of the tailings pipeline.

4.7.1.5 Conclusion

The use of upstream construction employed for the TSF is attractive in terms of construction material efficiency with a modest reduction in storage volume over time. However optimal upstream construction is a balance between deposition and desiccation. The discharge must be continually rotated to ensure an even foundation and maximising storage so construction material and therefore lift load is minimised. However constant cycling limits the time available for desiccation and strength gain required to safely tolerate lift loads. The TSF, therefore, must be continually well managed to obtain an optimal balance between these competing objectives.

Overall, the TSF has been well managed in terms of operation, inspections and external review for the current reporting period. The TSF is expected to have ongoing dust and seepage emissions that are inherent limitations of the approved design and operation method. It is expected that dust emissions may increase and seepage emissions decrease as a consequence of better pond management. However these changes are not expected to be significant.

The IM has again not been provided with any documentary evidence that TSF construction activities have been undertaken within design specifications. The IM understands that the DME

[13] Noting that this raise was only 80% complete (see ' TSF Cell 2 Raise 3 Construction' in 'Progress and New Issues').

has not been provided with any information either, albeit both the IM and the DME have been provided with trial embankment records. The IM continues to request this information from MRM on an ongoing basis.

Ongoing and new IM recommendations related to TSF geotechnical issues are provided in Table 4.28.

Table 4.28 – New and Ongoing Geotechnical (TSF) Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
TSF design	Ensure the Cell 1 drainage and detention system can accommodate a 1 in 200 year storm event through assessment and modification as required	Medium
TSF seepage	The origin and veracity of fault mapping in the vicinity of the TSF need to be investigated Further investigations are needed to quantify preferential flow paths for seepage. These investigations should use all available geological information to maximise efficiency and improve the basis for subsequent modelling. Mapping should be used to set the depth of modelling which may need to be increased from 20 m to substantially greater depths. The hydraulic conductivity of the tailings needs to be reviewed and appropriate testing (such as low pressure oedometer or Rowe cell testing) be undertaken to reduce uncertainty in this parameter The effect of dissolution of the TSF foundation materials needs to be considered in conceptual and numerical models; particularly in light of the likelihood of increased tailings acidity due to reduced pond size The WRM water balance needs to be updated to include estimates of TSF evaporation and seepage. Seepage estimates are likely to be improved through the actions described above. Evaporation may require combined estimates based on Penman based methods and (micro-) lysimeters	High
	McArthur River Mining to review the current strategy for preventing seepage to Surprise Creek in light of recent groundwater monitoring, EM remote sensing and any other relevant data. This review should present evidence as to the effect of existing mitigation strategies, their longevity and long-term feasibility in consideration with other mitigation works such as final capping of Cell 1	High
TSF construction	Provide all records to the DME of earthworks testing or other construction certification for TSF Cell 2 Raise 3. The IM notes that this same request was given to MRM by DME on 27 August 2015	High
TSF operation	Confirm assumed average tailings beach gradient from survey	Medium
New Items		
TSF design	All future correspondence on the TSF should clearly indicate whether it is the advice of the designer or the ICE The independence of the ICE and the designer should be reviewed by MRM and the DME	High
TSF construction	The DME should seek a formal commitment from MRM as to the type and timing of construction quality records that need to be provided to the DME	High
TSF surface water management	There are discrepancies between GHD and WRM on the capacity and efficacy of the Cell 1 western sump. GHD states the capacity as 6 ML and inadequate to design while WRM states the capacity as being 8 ML and with only a 1% chance of spilling each year. At the same time this sump has been known to spill under a 1:20 year event. These discrepancies need to be resolved and the sump modified to meet design requirements	Medium

4.7.1.6 References

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4.7.2 Overburden Emplacement Facilities

4.7.2.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of geotechnical issues at the OEFs, and is based on:

- Observations and discussions with MRM personnel during the site inspection.
- Review of various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM (2015a), MRM's environmental monitoring report, supplementary monitoring report, and mining management plan (MRM, 2015b; 2015c; 2015d).
- Review of Excel spreadsheets provided by MRM that contain collated laboratory and in situ data.
- Review of laboratory documents including sample receipt notification, certificates of analysis (analysis results) and quality control reports.
- Review of various MRM forms survey results, incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the MRM mine site provided by MRM.
- Airborne laser scanning (ALS) (topographic) data of the mine site provided by MRM.

4.7.2.2 Key Risks

The key risks to management of geotechnical issues at the OEFs, as described in the risk assessment (Appendix 2), are:

- Failure of the clay liner material to provide a barrier against water ingress into the PAF material, and hence the formation of leachate and/or ingress of oxygen leading to oxidation of the PAF material. This may manifest by:
  - Erosion of the clay liner due to exposure, resulting in its failure.
  - Failure of the liner to form a continuous barrier due to slope instability under static or seismic loading, exposing PAF materials.
  - Desiccation of the liner due to drying and hence cracking of the liner, with a resulting increase in its permeability to air and water.
  - Construction quality control issues with liner placement, resulting in the liner not achieving the required permeability.
  - Differential settlement of waste rock leading to excessive strain and cracking of the liner.
- Slope instability or excessive displacement of the PAF runoff dams resulting in loss of fluids or excessive seepage.

4.7.2.3 Controls

Previously Reported Controls

The following controls were in place for management of OEF geotechnical risks in the previous reporting period:

- Design report for the NOEF including specifications for clay liner (URS, 2008).
- Sustainable Development Mining Management Plan 2013-2015 (MRM, 2015b; 2015d).
- Specification for clay liner, MIN-TEC-PRO-1000-0026 (MRM, 2012a).
- Sampling procedure, MIN-TEC-PRO-1000-0015 (MRM, 2012b).
- As-built review and signoff procedure, MIN-TEC-PRO-1000-0025 (MRM, 2011).
- Overburden emplacement facility management plan (MET Serve, 2012).
- Rehabilitation of the NOEF (OKC, 2014).

New Controls – Implemented and Planned

In the current reporting period, IM construction work commenced on the central west phase of the northern overburden emplacement facility (CWNOEF) and placement of waste continued at the SOEF.

The design and operation of the CWNOEF is detailed in MRM (2015a). This design incorporates changes to overcome shortcomings revealed after approval of the Phase 3 EIS.

The CWNOEF Design, Construction and Operations Manual has undergone ten revisions to date. The IM has been provided with version 1.2 dated November 2014 (MRM, 2014), version 2.0 dated February 2015 (MRM, 2015e) and version 2.1 dated August 2015 (MRM, 2015a). Version 2.0 was accepted by the DME as part of the approved MMP for the reporting period.

The CWNOEF has been approved in stages. The initial design (including version 1.2) proposed development of Stage 1 and Stage 2 expanding northwards from the existing NOEF. Construction of the Stage 1 sub-base layer of the CWNOEF was approved on 10 October 2014 and Stage 1 of the benign waste platform was granted on 24 December 2014.

The CWNOEF design was modified to three stages: Alpha, Bravo and Charlie as part of a revised submission to the DME. Stages Alpha and Bravo were approved by the DME on 7 July 2015 under the following conditions (DME, 2015a):

- The CWNOEF must be constructed and operated in accordance with the revised interim 2012-2013 MMP.
- The only waste rock considered as benign for the purposes of dumping or construction is LS-NAF(HC).
- All other rock (classes 2 to 6) must be managed as PAF and encapsulated.

- McArthur River Mining must continue to construct the base of the CWNOEF with a compacted clay liner (CCL) as per version 1.2 of the CWNOEF Design, Construction and Operations Manual (MRM, 2014).

On 11 August 2015, the DME required MRM to provide a consolidated design and MRM subsequently updated version 2.0 (MRM, 2015e) to version 2.1 (MRM, 2015a). The IM has reviewed performance of the CWNOEF against this version as this most closely represents construction within the reporting period.

Version 2.1 of the CWNOEF Design, Construction and Operations Manual (MRM, 2015a) supersedes all previous CWNOEF controls, namely MRM (2012a; 2012b; 2011) and MET Serve (2012). The IM understands MRM (2015a) applies to all OEF construction in this reporting period. This document contains a number of new controls for OEF construction, these being:

- A revised compaction specification for the subgrade (in situ material), subgrade base (benign waste placed within the 1 in 100 AEP flood level) and CCLs.
- Placement of all PAF rock using paddock dumping.
- A new campaign of testing to assess the suitability of in situ materials comprising over 160 test pits and 23 drill holes including particle size, Atterberg limits, compaction, moisture, strength, permeability and dispersion testing.
- Stability assessment of the NOEF using finite element analysis.
- Drilling of the hanging wall sediments to further develop LS-NAF (HC) reserves (termed UpX drilling).
- A CCL trial scheduled to commence in Q3 2015 is understood to have taken place in late 2015 and the results have not yet been finalised.
- Desiccation trials to assess the potential for clay liners to crack under prolonged exposed conditions.

The requirement for a 0.5 m CCL placed on the existing subgrade termed the basal CCL has been retained from the 2012-2013 MMP.

The previous clay liner compaction specification MRM (2012a) included the following:

- Compaction moisture content between 0 and +5% of optimum.
- Minimum dry density ratio of 95% maximum dry density (standard).
- Maximum loose layer thickness of 300 mm.
- At least 50% of material has a particle size less than 0.075 mm
- Minimum plasticity index of 10%.
- Maximum hydraulic conductivity of 1×10^{-9} m/s including laboratory and in situ testing.

- Testing frequency for density and moisture of 1 in 5,000 m^3.
- Testing frequency for particle size and Atterberg limits of 1 in 5,000 m^3.
- Testing frequency for hydraulic conductivity of 1 in 5,000m^3.

The current design (MRM, 2015a) specifies:

- A limit to the maximum particle size limit of 75 mm (no previous limit).
- A reduction in maximum moisture from +5 to +3% of optimum.
- An increase in minimum dry density ratio to 98% of maximum dry density (standard) for CCLs.
- A reduction in maximum loose layer thickness for CCLs from 300 to 200 mm.
- Use of a vibrating pad foot roller with a minimum static mass of 10 t.
- An increase in testing frequency for density and moisture for placed CCL material from 1 in 5,000 m^3 to 1 in 500 m^3.
- A decrease in testing frequency for particle size and Atterberg limits for placed CCL material from 1 in 5,000 m^3 to 1 in 20,000 m^3
- A decrease in testing frequency for hydraulic conductivity from 1 in 5,000 m^3 to 1 in 10,000 m^3. Version 1.2 of the CWNOEF Design, Construction and Operations Manual (MRM, 2014) originally required two hydraulic conductivity tests per lot. This has since been removed in versions 2.0 (MRM, 2015e) and 2.1 (MRM, 2015a).
- A new requirement for dispersion testing (Emerson Class & pinhole dispersion) at a rate of 1 per 20,000 m^3

Subgrade fill (NAF base) in the URS (2008) design report was simply to place NAF base in 2-m lifts and compact with loaded haul trucks or a 15-t compactor. MRM (2015a) calls for a combination of rockfill for the base with a final lift of earthfill of at least 200 mm.

The rockfill is to comprise:

- Fresh to moderately weathered, durable, angular rock with a maximum particle size of 0.6 m and a minimum size of 80% passing 0.2 m.
- Maximum lift height of 1 m in thickness and compacted using six passes of a vibratory, flat drum roller with a minimum static mass of 10 t.

The earthfill is to comprise:

- Moisture conditioned to the range -3 to +3% of optimum moisture content and to at least 95% of maximum dry density (standard).

- Use of a vibrating pad foot roller with a minimum static mass of 10 t when the subgrade materials are predominantly fined grained soils.

The IM finds these changes to be positive and likely to reduce seepage and other emissions, particularly given the increased density requirement for the CCL.

There are additional test frequencies for borrow material testing not listed here. The borrow material requirements of MRM (2012a) and the new central west phase design are essentially the same except for the addition of dispersion potential testing.

The IM notes that these specifications are the same as those presented in version 2.0 of the CWNOEF Design, Construction and Operations Manual (MRM, 2015e), which formed part of the approved, revised interim 2013-2015 MMP.

There are a number of planned controls specified in MRM (2015a). These are:

- Ongoing investigations of alluvial materials to examine their suitability for use in CWNOEF construction.
- Testing of waste rock density and permeability.
- A drilling investigation to identify and quantify the extent of possible faults or paleochannels beneath CWNOEF.
- Lysimeters are still planned to measure infiltration.

The IM is aware of recent modifications to the CWNOEF proposed by MRM on 5 February 2016. These modifications were approved by the DME on 21 March 2016. These changes were made to correct shortcomings in the previous version and to seek approval for expansion to the north. Changes include:

- Corrections where reference was made to the original stages 1 and 2 rather than stages Alpha, Bravo & Charlie. This included areas, volumes, and lot sizing.
- The addition of area Charlie to the north of Alpha and Bravo to complete the full CWNOEF footprint.

4.7.2.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents

There was no reportable incident related to management of geotechnical issues at the OEFs within the current reporting period.

Non-compliances

There was no identifiable non-compliance related to management of geotechnical issues at the OEFs within the current reporting period.

Progress and New Issues

CWOEF Design

There have been a number of improvements in the design of the CWNOEF such as the use of paddock dumping, compacting CCLs wet of optimum and the use of protective layers to limit desiccation and cracking of CCLs.

The CWNOEF Alpha and Bravo stages divide the works into 46 sublots. Alpha stage further comprises A and B sublots each of which has 10 sublots (numbered 0 to 9) for a total of 20 sublots. The area is not directly stated in MRM (2015a), but is estimated from the drawings provided and estimated quantities in Table 19 of MRM (2015a) to be an area of 392,000 m^2. Lot areas have also been estimated from drawings and vary from a maximum of around 50,100 m^2 for Lot 1 to 25,300 m^2 for Lot 9. Given CCL design thickness of 0.5 m, the required number of moisture and density tests is around 25 to 50 per lot to meet the specification of 1 test per 500 m^3 (Clause 9.5.3).

The IM has been provided with ICE construction reports for July to September 2015 and September to October 2015 and what is understood to be a current record of all testing for the CWNOEF in a spreadsheet named 'CW Test Register.xls'. This register only contains records dated April 2015 and later. All results appear to have been checked against the MRM (2015a) specification.

In summary, the register contains:

- Fifty five material tests in seven lots and in borrow areas.
- Four hundred and forty one compaction tests (density and moisture) in all 10 lots and in borrow areas.
- Nine permeability tests in six lots.

All testing identified as having failed the MRM (2015a) specification was found to have been retested and subsequently passed.

The CWNOEF test data that has passed the specification has been further divided into the design lots as shown in Table 4.29. This table includes the minimum test frequency requirements according to the MRM (2015a) specification.

Totals show in Table 4.29 do not include test results in borrow areas. Dashes within the table indicate where the IM understands construction of this component has not been undertaken at the date at which the test data was provided. These lots have not been included in totals or test frequency targets.

The IM understands that construction of the basal CCL in Lots 0 to 4 had not yet commenced at the time the database was provided.

Table 4.29 – Distribution of Testing for CWNOEF Construction

Lot	Number of Test Sites* (Target shown in brackets)		Number of Material Tests (Target of 1 for all Lots)					Number of Permeability Tests
	Subgrade	Basal CCL	PSD	Atterberg Limits	Pinhole Dispersion	Emerson Dispersion	Moisture	Permeability
0	13 (14)	-#	-	-	-	-	-	-
1	28 (15)	-	-	-	-	-	-	-
2	19 (13)	-	1	1	0	0	1	1
3	18 (12)	-	1	1	0	0	1	1
4	18 (11)	-	-	-	-	-	-	-
5	20 (10)	40 (32)	1	1	1	0	0	1
6	13 (9)	27 (28)	5	1	1	1	3	3
7	21 (9)	26 (31)	2	2	1	1	2	2
8	12 (9)	32 (29)	1	1	1	1	1	0
9	11 (8)	26 (25)	1	1	1	1	1	1
Totals	173 (109)	151 (145)	12 (7)	8 (7)	5 (7)	4 (7)	9 (7)	9 (20)

* Number includes density, field and optimum moisture content testing.
# Dashes indicate where the IM understands construction of this component has not been undertaken at the date at which the test data was provided. These lots have not been included in totals or test frequency targets.

Examination of Table 4.29 with a focus on completed or near completed Lots 5 to 9 reveals:

- Overall compaction testing frequencies generally meets or exceeds MRM (2015a) requirements.
- Material test frequency generally meets MRM (2015a) requirements with the possible exception of dispersion testing for Lots 2 and 3. However, the IM understands that construction of these lots may be ongoing.
- Permeability test frequency meets the approved version 2.0 of the CWNOEF Design, Construction and Operations Manual (MRM, 2015e); however, some lots were not tested. The test requirement in the originally approved version 1.2 of MRM (2014) was for two tests per lot.

Additionally, the IM was not provided with any chemical testing results as required by MRM (2015a), specifically Exchangeable Sodium Percent (ESP) and Sodium Absorption Ratio (SAR) tests. The IM has been advised by MRM that this is due to no tests of this type being undertaken during the reporting period.

The DME previously directed MRM to provide a copy of all testing on a monthly basis (DME, 2015a). The DME has told the IM that it has not received any of this testing.

The IM is concerned with the limited number of permeability tests per lot given that this is a primary design parameter in the prevention of seepage from the CWNOEF. In most cases only one test has been performed per lot. The IM recommends that MRM consider revising the specification in this aspect so that there are at least two permeability tests per lot as per version 1.2 of the CWNOEF Design, Construction and Operations Manual (MRM, 2014).

There are a number of other less significant issues relating to MRM (2015a) that require attention. These are:

- The current CWNOEF design version 2.1 (MRM, 2015a) appears to include references to Stage 1 that is no longer part of the approved CWNOEF design. This applies to Figure 41 and Section 9.10.2 of that document. Stage 1 appears to apply to an area of only 208,000 m^2 compared to 390,000 m^2 for Alpha and Bravo stages.
- There are references to a ‘Section 0’, which is not provided and likely in error.
- The finite element analysis makes reference to use of the Mohr-Coulomb material model, but parameters have not been provided.
- There are references to CCL 1, CCL 2 and CCL 3 within MRM (2015a) and the CWNOEF test register. Subsequent correspondence with MRM confirmed that these terms are not consistent across the documentation. This has made interpretation of test results prone to misinterpretation.

Unapproved Works at the SOEF

During a site inspection on 4 August 2015, DME mining officers noted the following (DME, 2015b):

> Unapproved works have been undertaken at the Southern Overburden Emplacement Facility (SOEF). Current approvals only allow for the placement of benign material however MRM has placed non-benign material (metalliferous saline LC and HC LS-NAF) approximately 30 m high and nearly 1000 m long using techniques no longer considered best practice. The use of non-benign material in close proximity to the McArthur River diversion channel and lack of adequate environmental controls represent a risk to the environment.

Subsequent enquiries by the DME revealed that MRM had used the SOEF to place MS-NAF(LC) and MS-NAF(HC) using end tipping. The DME registered this as a non-compliance with approvals that only allowed benign material to be stored in the SOEF. Consequently, the DME issued a number of directives to MRM including (DME, 2015c):

> MRM must transfer this material from the SOEF to the NOEF before the commencement of the 2015/16 wet season.
>
> MRM must undertake soil, sediment, dust monitoring as well as surface and groundwater monitoring before during and after the removal of this material from the SOEF.
>
> MRM must provide coordinates and construction logs for all new monitoring bores constructed in the last six months.
>
> MRM must provide coordinates and construction logs for all future monitoring bores within 30 days of construction.

McArthur River Mining complied with all but the first of these directives, electing instead for a review by the Mining Advisory Committee (MAC). The MAC ultimately found in favour of MRM who successfully argued that the SOEF is a temporary facility necessitated by a restriction on the placement of non-benign material while new designs for the NOEF or elsewhere were being developed.

While the IM respects the findings of the review, there remains a responsibility by MRM to limit impacts to the environment from the SOEF. Given that the SOEF is now receiving non-benign waste (albeit temporarily), it is unclear what monitoring is currently underway to detect the migration of contaminants given that placement of such materials was not originally envisaged within this facility.

McArthur River Mining has stated to the MAC that (MRM, 2015f):

> A submission was made to the DME on the 24th September 2015 by MRM's hydrogeologist directly in relation to the SOEF, where the conclusions were:
>
> "This clearly indicates that any potential seepage from the SOEF would not travel to the McArthur River Diversion but would instead travel to the open cut pit where it would be captured as shown on the hydrogeological conceptual model."

McArthur River Mining's submission was based on a formal engineering risk assessment and modelling. However, these types of assessment are normally reserved for design purposes and not for assessing operating facilities. The IM found evidence in aerial photographs to suggest that seepage from the SOEF could be migrating in a southerly direction midway along the southern batter, resulting in surface discolouration and dieback (Figure 4.21). This evidence has been

SOEF POTENTIAL SEEPAGE

McArthur River Mine Project

FIGURE 4.21

subsequently countered by MRM with other photographic evidence that suggests no visible impact. Additionally, the IM understands that work has been undertaken in November 2015 (outside the reporting period) to demonstrate that the direction of groundwater movement at depth in this area is northwards, away from the McArthur River diversion channel and towards the pit.

The IM has undertaken a preliminary review of the final cover design for the NOEF prepared by OKC (2014). This design comprises a storage layer (denoted 'GM'), overlying a CCL, overlying waste. The design concept is that the majority of intercepted rainfall is collected on top of the CCL within the storage layer and shed laterally. Some water is still expected to percolate through the CCL and enter the waste; termed net percolation. The IM notes that this design relies heavily on numeric modelling of unsaturated flow for verification. It is the IM's experience that:

- Estimates of net percolation rely almost entirely on the choice of water characteristic and unsaturated hydraulic conductivity properties.
- In particular, the contrast between the unsaturated hydraulic conductivity of the CCL and that of the underlying waste controls what is commonly termed the 'capillary barrier effect'. This barrier can dramatically reduce infiltration and this can be replicated in modelling.
- Unsaturated hydraulic properties and unsaturated hydraulic conductivity in particular is difficult to measure directly. In this case it appears that OKC (2014) provides estimates of these parameters based on particle size distributions. This approach is known to give estimates of unsaturated hydraulic properties to a low confidence level.

Given the importance of these parameters and their lack of direct testing, the IM recommends that MRM undertakes direct testing of candidate materials likely to be used for the final cover. The IM also recommends that MRM expands the limited sensitivity studies on the CCL saturated conductivity undertaken to date to examine how the hydraulic conductivity contrast between different materials may affect net percolation.

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the OEFs is outlined in Table 4.30.

Table 4.30 – Geotechnical (OEFs) Recommendations from Previous IM Reviews

Area	Recommendation	IM Comment
2014 Operational Period		
NOEF design	McArthur River Mining should provide a clear timetable of outstanding activities required to finalise clay cover and liner designs including compaction trials, improved assessment of clay types, exploratory drilling and lysimeter testing. The timetable should prioritise these tests and identify what the outcomes will achieve. McArthur River Mining needs to allocate test areas in accordance with these priorities and before the Overburden Management Project EIS has been finalised	Not complete
NOEF construction	A revised specification is required which contains clear testing procedures, test frequencies, consideration of a *none to fail* criteria and the action to be taken if an area fails. The method of analysis of test results (such as accuracy) should be stated in the specification	Complete The specification is much improved The pending NOEF Central West design manual appears to address many of these issues

Table 4.30 – Geotechnical (OEFs) Recommendations from Previous IM Reviews (cont'd)

Area	Recommendation	IM Comment
2014 Operational Period (cont'd)		
NOEF construction (cont'd)	All QA/QC construction records of both the clay and NAF foundation including retesting should be provided to the IM in a timely manner. Records for the IM should also detail the progress of dump construction on a monthly rather than quarterly basis	Complete The summary data provided suggests missing data or missing tests
	Records of retreatment, recompaction and retesting should be provided to the IM in a timely manner	Complete There is reasonable evidence of this
NOEF rehabilitation	A plan needs to be developed which describes how progressive rehabilitation will be undertaken and in what sequence. The IM understands that some of the detail of this may be pending future trials and/or approvals. However developing a plan would identify rehabilitation targets and clarify trial and approval priorities	Partially complete There is evidence of progress in terms of closure planning
2012 and 2013 Operational Periods		
Specification	The IM has found some significant inconsistencies within the MRM specification, the application of the specification and assessment of test data. The IM also understands that the current specification is likely to be revised. The IM accordingly recommends that MRM conducts an immediate review of the specification to correct and clarify inconsistencies with specific attention to the placement moisture content range and the type and frequency of hydraulic conductivity testing	Complete
	Any revised specification will need to be reviewed and agreed by the OEF designer	Complete
QA/QC assessment	The IM has found many instances where material in violation of the construction specification is being accepted for dumping of PAF waste (e.g., memo dated 19/9/2013). The IM has also found that the specification pass/fail criteria are being incorrectly applied. In light of these the IM recommends: ♦ McArthur River Mining review all test data to properly assess locations and approximate volumes of placed materials that have not met the reviewed specification including testing frequency ♦ The OEF designer(s) conduct a review of the above to ascertain whether the placed materials meet design requirements. If not, the OEF designer(s) should recommend remedial action that would be required such that OEF can function as per the approved design and therefore its intended purpose A revised encapsulation design may be required to accommodate these shortcomings depending on the severity and extent of test failures	Partially complete NOEF drilling undertaken September to November 2015 has provided important mapping of the distribution and reactivity of PAF within the existing NOEF The IM understands additional drilling is planned for the next reporting period

Table 4.30 – Geotechnical (OEFs) Recommendations from Previous IM Reviews (cont'd)

Area	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
QA/QC assessment (cont'd)	Full-time inspection and testing service on all earthworks (Level 1) to AS 3798 2007 (Standards Australia, 2007) should be carried out with the additional requirement that the testing authority (GITA) is independent of MRM (i.e., a geotechnical independent testing authority or GITA) and provides certificates verifying that the liner has been constructed in line with the specification and satisfies the nominated testing criteria as required by the standard (AS 3798 2007) Future testing should comprise lot testing with *a none to fail* criteria	Complete with the appointment of an ICE
PAF cap	A clay cap should be constructed above PAF material prior to the wet season to minimise infiltration during this period. This action should be documented	Complete
Foundation treatment	The foundation (subgrade) treatment should be documented and reviewed against the design (currently URS (2008)). Construction records and reports on foundation treatment should be kept and made available to the IM	Complete
General	Detailed plans and cross sections of the OEFs should be prepared and made available to the IM such that the construction of the OEF can be verified. This should include, where relevant, a system to identify the QA/QC testing lots for the relevant materials	Not provided

Successes

There have been a number of improvements this reporting period, namely:

- Improvement in the execution of construction quality control with evidence of tests passing, retesting of failed tests and test frequencies achieving the MRM (2015a) specification.
- Use of a lime addition and moisture conditioning system during CCL placement.
- Appointment of an ICE.
- Construction of a new sedimentation dam, Central West Charlie Stage (CWC) sedimentation dam designed to capture runoff from the NOEF.

The improvement in the application of construction quality measures is a significant improvement over previous years.

The use of special equipment to condition material prior to construction of CCLs is a promising development and may produce superior liners and require less testing. However, the IM does not have the documentation to support this.

At the direction of the DME, MRM appointed an ICE to oversee and manage quality control of OEF and TSF construction. The IM recognises this appointment as a positive step to improve construction quality for the CWNOEF.

The IM has not been provided with a definitive role statement for the ICE. The review of available documents, however, suggests that the ICE is to perform these tasks at MRM:

- Review key reports and models compiled for the initial CWNOEF design.
- Review the design and construction specifications for the development of CW Phase and make amendments/improvements where considered appropriate.
- Review MRM quality control processes and update these where it was deemed necessary.
- Define QA/QC processes that will enable GHD to certify the construction.
- Oversee all quality control activities including sampling, testing and reporting.
- Approve additional stages of work based on review of QA/QC activities including implementation of set and release hold points.
- Be present on site to oversee and certify the works that they meet design specifications.
- Hold appropriate public and professional indemnity insurance to cover the scope of works associated with the embankment raise.
- Sign off that the design is suitable and certify that it has been constructed in full compliance with the design.

4.7.2.5 Conclusion

There have been a number of design improvements for the CWNOEF and the evidence presented to the IM is that CWNOEF construction is being executed generally in accordance with the MRM (2015a) design. There are some minor improvements that can be made but the overall improvement in this area is significant compared to previous years.

Test frequency is generally in accordance with version 2.0 of the MRM (2015e) specification. However, the IM recommends consideration be made to reinstating the testing requirements adopted for version 1.2 of MRM (2014); specifically a minimum of two permeability tests per lot.

This review suggests that quality control for the CWNOEF is generally in accordance with the design. The IM has been provided with two ICE construction reports one for July to September and the other September to October 2015. The IM recommends that in future MRM makes this documentation available to the DME as soon it becomes available.

Use of the SOEF to temporarily store MS-NAF has been approved; however, the current impact on the environment remains unknown. The IM recommends ongoing monitoring to assess the potential impacts, particularly in areas south of the perimeter bund.

Ongoing and new IM recommendations related to OEFs geotechnical issues are provided in Table 4.31.

Table 4.31 – New and Ongoing Geotechnical (OEFs) Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
NOEF design	McArthur River Mining should provide a clear timetable of outstanding activities required to finalise clay cover and liner designs including compaction trials, improved assessment of clay types, exploratory drilling and lysimeter testing. The timetable should prioritise these tests and identify what the outcomes will achieve. McArthur River Mining needs to allocate test areas in accordance with these priorities and before the Overburden Management Project EIS has been finalised	Medium
NOEF rehabilitation	A plan needs to be developed which describes how progressive rehabilitation will be undertaken and in what sequence. The IM understands that some of the detail of this may be pending future trials and/or approvals. However developing a plan would identify rehabilitation targets and clarify trial and approval priorities	Medium
General	Detailed plans and cross sections of the OEFs should be prepared and made available to the IM such that the construction of the OEF can be verified. This should include, where relevant, a system to identify the QA/QC testing lots for the relevant materials	Medium
New Items		
SOEF	Storing MS-NAF is likely to lead to saline drainage from the SOEF. McArthur River Mining should provide more direct evidence that this drainage is not impacting beyond the mine perimeter bund	High
CWNOEF design	There are a number of recommended minor corrections and updates to the CWNOEF design report as described elsewhere	Low
CWNOEF construction	The compaction specification should be changed back to that approved originally (in version 1.2 (MRM, 2014)) with at least two permeability tests per lot	High
	McArthur River Mining should provide all ICE construction reports to the DME in a timely manner	High
NOEF closure	Currently the closure design relies on estimates of hydraulic properties from particle size distributions and not direct testing McArthur River Mining should undertake direct testing of candidate materials likely to be used for the NOEF final cover. McArthur River Mining should also expand the limited sensitivity studies on the CCL saturated conductivity to examine how differences in the hydraulic conductivity contrast may affect net percolation	Medium

4.7.2.6 References

DME. 2015a. Central West - Northern Overburden Emplacement Facility - Conditional Acceptance. Letter to Sam Strohmayr. Ref MDOC2015/05062. 7 July 2015. Northern Territory Department of Mines and Energy, Darwin, NT.

DME. 2015b. Field Inspection Report. MMP Reference MR2015/0076. 4 August 2015. Northern Territory Department of Mines and Energy, Darwin, NT.

DME. 2015c. Instructions following the August Site Inspection. Letter to Sam Strohmayr. Ref MDOC2015/06276. 21 August 2015. Northern Territory Department of Mines and Energy, Darwin, NT.

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MRM. 2012b. EOM NOEF Sampling Procedure. MIN-TEC-PRO-1000-0015. Rev 4. December. MRM Mining Department. McArthur River Mining Pty Ltd, Winnellie, NT.

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MRM. 2015a. Northern Overburden Emplacement Facility (Central West Phase) Design, Construction & Operations Manual. MIN-TEC-PLN-1000-0002. Version 2.1. August. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015b. Interim Mining Management Plan 2013-2015, Volume 2: Environmental Monitoring Report. January 2015. Reference Number GEN-HSE-PLN-6040-003, Issue Number: 7, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015c. Supplementary Environmental Monitoring Report 2014. February 2015. Reference Number GEN-HSE-RPT-6040-002, Issue Number: 1, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015d. Sustainable Development Mining Management Plan 2013-2015, Volume 1. 3rd March 2015. Reference Number GEN-HSE-PLN-6040-0003, Issue Number: 7, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

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Standards Australia. 2007. Australian Standard (AS) 3798 2007: Guidelines on earthworks for commercial and residential developments. Standards Australia, Sydney, NSW.

OKC. 2014. Rehabilitation of North Overburden Emplacement Facility, West A-B Cells. Draft Report No. 750/11-01. April. O'Kane Consultants.

URS. 2008. McArthur River Mine – Overburden Emplacement Facility (OEF) Design – Open Cut Project. Final Report, 30 July 2008. Prepared by URS Australia Pty Ltd for Xstrata, Winnellie, NT.

4.7.3 Bing Bong Loading Facility Dredge Spoil Area

4.7.3.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of geotechnical issues at the Bing Bong Loading Facility dredge spoil area, and is based on:

- Observations and discussions with MRM personnel during the site inspection.
- Review of various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's environmental monitoring report, supplementary monitoring report, and mining management plan (MRM, 2015a; 2015b; 2015c).
- Aerial and other photographs of the MRM mine site provided by MRM.
- Review of other documents such as inspection reports.

There has been no dredging activity for the reporting period.

4.7.3.2 Key Risks

The main geotechnical risk associated with the Bing Bong Loading Facility dredge spoil area is potential failure of the external cell walls, leading to inundation of adjacent areas with saline and/or dredged material. There are additional risks associated with excessive seepage of saline water.

The risk of wall failure is related to:

- The minimalist approach to engineering due to lesser containment requirements when compared to other storages, such as the TSF.
- The rapid flooding of the ponds when dredge operations are being undertaken.

The IM recognises that at Bing Bong Loading Facility, the approach taken to date is minimal design requirements given the height of embankments, the more benign nature of materials and water being contained and that dredge operations are of short duration and relatively infrequent. The IM also recognises the difficulties in maintaining well-engineered embankments at the site where inundation by flooding or seawater ingress is a regular occurrence. However, this approach must be compensated through effective monitoring, rapid response to repairs and rebuilding prior to major impact cycles such as dredging activities or the wet season.

There has been no dredging activity for the reporting period and therefore the risk of breach, embankment failure and inundation is relatively low. However, these events can still occur under storm events if embankments, spillways and drainage channels are not properly maintained.

4.7.3.3 Controls

Previously Reported Controls

The following controls are in place for management of the geotechnical risks at the Bing Bong Loading Facility dredge spoil area:

- Bing Bong dredging and spoil disposal management plan (EcOz, 2012).
- Hazardous dam stability assessment TSF and Bing Bong Loading Facility dredge spoil (AWA, 2012).
- Monthly visual inspections (none have been provided for the current reporting period).
- Water quality, dust and other chemical monitoring.

New Controls – Implemented and Planned

New controls undertaken within the reporting period are:

- Nine piezometers installed in the dredge ponds embankments.
- An unknown number of survey marks installed around the perimeter embankments.
- A dam safety inspection of the dredge ponds undertaken on 28 October 2015 (GHD, 2015).
- An updated water balance report for 2014-2015 (WRM, 2014).

The GHD (2015) inspection report is dated 1 April 2015, some seven months before the reported inspection date of 28 October 2015. The report should be corrected and reissued to confirm exactly when the inspection took place and when the report was issued.

The IM is aware of a further update of the Bing Bong Loading Facility water balance for 2015-2016 dated 3 December 2015 (WRM, 2015), which is outside the reporting period.

4.7.3.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents

There were no reportable incidents related to the management of geotechnical issues at the Bing Bong Loading Facility dredge spoil area for the reporting period.

Non-compliances

The IM is not aware of any non-compliance related to management of geotechnical issues at the Bing Bong Loading Facility dredge spoil area for the reporting period.

Progress and New Issues

As described in Section 4.7.3.3, new controls have been implemented including installation of embankment piezometers and an annual dam safety inspection.

The annual review assessed the dredge ponds to be a 'low' consequence category of failure based on ANCOLD (2012) guidelines. The IM agrees with this assessment given that no dredging has been undertaken in the current reporting period. The review also made a number of recommendations, which are reproduced in Table 4.32. The IM agrees with these recommendations. Additionally the IM recommends that MRM undertake all of these repairs.

Table 4.32 – Annual Dam Safety Review Recommendations for Bing Bong Loading Facility

Recommendation	Priority
Severely eroded areas on the embankments carry the risk of developing into a dam safety issue if left unaddressed. It is recommended that MRM establishes an embankment monitoring and maintenance program which includes scheduling repairs to address erosion issues in order of severity. Erosion on the external embankment should be prioritised over the internal embankments. Rip rap could be considered in areas of heavy erosion	3 to 12 months based on severity
It is recommended that trees be removed from the embankment. The priority is to remove large and dead trees on the external embankments	12 months
It is recommended that the operation and design of spillways be reviewed. This should include a review of the topography of the site to check that the arrangement is free draining and assess the likelihood of ingress from the external environment (i.e., sea water through the current drainage system)	12 months
It is recommended that MRM considers lining the Cell 5 spillway to the environment with rock	3 months
It is recommended that a review of the design and operation of the drainage system be undertaken	12 months
It is recommended that MRM considers repairs and rock lining of the more severely damaged sections of drain along Cell 5 embankment toe	3 to 12 months based on severity
It is recommended that clearing of sediment from the pipe culvert and rock lining of the outlet be undertaken	3 months

There are no other new geotechnical issues for the dredge ponds for the reporting period.

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the Bing Bong Loading Facility dredge spoil area is outlined in Table 4.33.

Table 4.33 – Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations from Previous IM Reviews

Area	Recommendation	IM Comment
2014 Operational Period		
Bing Bong Loading Facility dredge spoil – monitoring	Measurement of piezometric levels at key points within the embankments such as areas of known high water levels and the extremities of the site	Complete Nine piezometers have been installed in the embankments
	Measurement of the embankment crest RL at known areas of movement or likely instability and at the extremities	Ongoing LIDAR data has been provided but this does provide the means to compare periods for possible settlement
2012 and 2013 Operational Periods		
Bing Bong Loading Facility dredge spoil embankment design	A design should be prepared that outlines the geometry and method construction of embankments up to the anticipated maximum RL. This design should incorporate expected piezometric levels based on measurements taken to date and other assessments and freeboard requirements. This design does not need to be overly complicated given the nature of materials being stored and the observed performance of the embankments to date	No action This does not appear to have been undertaken

Table 4.33 – Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations from Previous IM Reviews (cont'd)

Area	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
Bing Bong Loading Facility dredge spoil – monitoring	It is recommended that the inspection regime include a more comprehensive assessment of key parameters and that action is taken when there is non-conformance. These parameters include: ♦ A numerical assessment of available freeboard and a comparison to design freeboard ♦ A visual assessment of slumping or excessive settlement	Complete An inspection was undertaken by GHD on 28 October 2015 (GHD, 2015)

Successes

The installation of nine piezometers and survey marks around the perimeter of the embankment and the commencement of annual inspections are significant improvements in the ability to monitor and manage embankment performance.

Currently the piezometers are all understood to be dry and therefore not recording any positive pressure. Monitoring frequency is quarterly but is increased to monthly three months prior to, and after, dredging activities. All piezometer readings should be provided to the designer for comparison with design assumptions.

4.7.3.5 Conclusion

There has not been any dredging activity in the current reporting period and consequently the risk of impacts from the Bing Bong Loading Facility dredge spoil area is relatively low. However, the annual inspection has highlighted a number of issues that need to be addressed. These issues relate to general maintenance and upkeep of the facility. The IM recommends that these actions be undertaken at least three months before any dredging activity or the next wet season, whichever comes first.

There has been a significant improvement in monitoring and managing the dredge pond embankments due to the installation of piezometers and survey marks, and the commencement of annual inspections.

Ongoing and new IM recommendations related to Bing Bong Loading Facility dredge spoil area geotechnical issues are provided in Table 4.34.

Table 4.34 – New and Ongoing Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Bing Bong Loading Facility dredge spoil embankment design	The IM is still unaware of a design document for the dredge ponds that can be used to measure performance against measurement, such as settlement and pore pressures, and details how future raises would be constructed. The IM understands that dredging may take place in the next reporting period. A design document needs to be produced well in advance of dredging activities so that the correct reviews and approvals can be completed	High

Table 4.34 – New and Ongoing Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (cont'd)		
Bing Bong Loading Facility dredge spoil – monitoring	Measurement of the embankment crest RL at known areas of movement or likely instability, and at the extremities, is required Dedicated monuments need to be installed to facilitate comparative measurements of embankment levels over time	Medium to high depending on planned dredging
New Items		
Maintenance	Undertake all of the recommendations given in the annual inspection report, GHD (2015) at least three months before dredging or the next wet season, whichever comes first. These recommendations are summarised as: ♦ Establish an embankment monitoring and maintenance program ♦ Remove trees from the embankment ♦ Review the design and operation of spillways ♦ Line the Cell 5 spillway to the environment with rock ♦ Repair damaged section of the Cell 5 embankment toe ♦ Clear out sediment from the pipe culvert and rock line the outlet	Medium to high depending on planned dredging
Monitoring	McArthur River Mining has reported that survey marks have been installed; however, there is currently no documentation to support this. The IM recommends the immediate commencement of monitoring reports that detail what has been installed, location and readings. Reports should be generated monthly when dredging is in operation and quarterly at other times	High
Reporting	The inspection report GHD (2015) is dated 1 April 2015, some seven months before the reported inspection date of 28 October 2015. The report should be corrected and reissued to confirm exactly when the inspection took place and when the report was issued	Low

4.7.3.6 References

ANCOLD. 2012. Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure. May. Australian National Committee on Large Dams Incorporated. Hobart, Tasmania.

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GHD. 2015. 2015 Dam Safety Inspection Report – Bing Bong Dredge Ponds. Report 32/17476. April. Prepared by GHD for McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015a. Interim Mining Management Plan 2013-2015, Volume 2: Environmental Monitoring Report. January 2015. Reference Number GEN-HSE-PLN-6040-003, Issue Number: 7, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

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WRM. 2015. 2015/16 Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility. Report 0790-21-B1. December. WRM Water & Environment Pty Ltd, Brisbane, QLD.

4.8 Closure Planning

4.8.1 Introduction

This section addresses MRM's performance during the reporting period with regards to closure planning, and is based on review of:

- Observations and discussions with MRM personnel during the site inspection.
- The current mine closure plan prepared by MET Serve (2012) as part of the Phase 3 Environmental Impact Statement.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's mining management plan (MRM, 2015a).
- Excel spreadsheets provided by MRM that contain mine closure costs (MRM, 2015b).

4.8.2 Key Risks

Key risks identified in the 2015 IM report have not changed – the management of mine wastes (tailings and waste rock) and the final pit lake water quality remain the key risks relating to mine closure. These key risks are outlined in Appendix 2 and are summarised as follows:

- Long-term stability of the NOEF landform. McArthur River Mining is currently undertaking studies investigating the proposed cover design that will be used to inform the final landform of the NOEF. Demonstrating that the material properties of the waste rock proposed to be used to construct the cover will achieve long-term stability (i.e., 500 to 1,000 years) of the landform is essential in being able to demonstrate a successful closure strategy.
- Availability of suitable NAF materials to construct the cover for the NOEF. The reclassification of waste rock into six separate classes has highlighted that the availability of NAF material may be insufficient to implement the original NOEF cover design. It is estimated that 9% of the waste rock is NAF and presents no risk of saline or metalliferous drainage. Insufficient material or use of materials with soil properties that do not align with modelled assumptions may result in the cover not performing as predicted with the consequence being the discharge of acid, saline and/or metalliferous drainage impacting terrestrial and aquatic ecosystems, together with the bioaccumulation of metals. McArthur River Mining has indicated that a possible solution may be the selective mining of NAF rock which is currently outside the mine plan, i.e., mining of NAF rock with its sole purpose being for rehabilitation rather than to access ore.
- Integrity of the cover placed over the NOEF fails to meet design specifications. In the short- or long-term the cover may not meet design specifications resulting in increased rates of oxygen diffusion and water infiltration through the cover and into waste rock, which has the potential to generate acid, saline and/or metalliferous drainage. The resulting impact of the full or partial failure of the cover is therefore the generation of poor quality runoff, which could adversely impact terrestrial and aquatic ecosystems, including increased bioaccumulation of metals.

- Long-term stability of the TSF landform. The current proposed TSF landform involves retaining the existing series of benches and batters. No drainage is provided to safely remove surface water from the outer surface of the TSF. There is a consequent risk to the long-term stability (1,000 years) of the TSF as a result of surface water ponding on a bench and then overtopping, resulting in concentrated flow eroding the batter, which, if left unchecked, will develop a gully and potentially result in the exposure of tailings. As the tailings are PAF, their exposure to oxygen and water will/may result in acid drainage and discharge of salts (sulfates) and trace metals (Pb, Zn, As, Cd and Cu) to the terrestrial and aquatic environments.
- The final pit lake is a key feature that will remain after closure. The current proposed strategy is that the pit will remain a sink, i.e., with no discharge to the McArthur River. The revised geochemical classification of the waste rock has the potential to change previous assumptions with regard to pit lake water quality following closure. There remains some uncertainty regarding potential for water within the pit to drain to the McArthur River with consequent adverse impact on aquatic ecosystems.
- Long-term stability of the mine levee wall surrounding the open pit after closure. The mine levee wall has been designed for a 1:500 year event. There is evidence of erosion of the mine levee wall since its construction in 2009. Ongoing monitoring and maintenance of the mine levee wall is currently not specifically included in the post-closure monitoring and maintenance costs.
- Long-term stability of dredge spoil ponds at the Bing Bong Loading Facility. The embankments of the dredge spoil ponds have not been constructed to the same standard as those of the TSF. No strategy currently exists with regard to how the dredge spoil ponds will be rehabilitated. There is evidence of erosion of the embankments. There is potential to impact terrestrial ecosystems due to sedimentation and or sediment blocking drains resulting in flooding.
- Post-closure monitoring and maintenance period funding. The post-closure monitoring and maintenance period has recently been increased to 25 years, at which time (assuming MRM has met all commitments) the lease will be relinquished to the NT Government. There remains uncertainty with regard to the period of post-closure monitoring and maintenance and the IM expects that additional detail will be provided in the Overburden Management Project EIS.
- Closure criteria do not have specific performance indicators by which MRM can demonstrate the orderly progression of outcomes to achieve closure success. Closure criteria are the measures by which MRM will demonstrate that they have met their commitments and request the mine lease to be relinquished. If closure criteria are not specific, and can't be measured, it will be very difficult for MRM to demonstrate success and therefore have evidence to support the request for lease relinquishment.

The EIS terms of reference for the Overburden Management Project issued by the NT Environment Protection Authority (EPA, 2014) identified the following key risks in relation to rehabilitation and mine closure:

- Following closure and rehabilitation, potential may exist for the mine to negatively impact the environment and/or associated communities.
- The project may create an ongoing environmental, social and/or economic legacy if operations are required to cease ahead of schedule due to unforeseen circumstances, prior to the planned closure and rehabilitation of the site.

4.8.3 Controls

4.8.3.1 Previously Reported Controls

As outlined above, the key risks with regard to mine closure relate to management of waste rock, tailings, final pit void (and lake) and implications for post-closure monitoring and maintenance. McArthur River Mining prepared a mine closure plan as part of the Phase 3 EIS (MET Serve, 2012); this is the current plan used by the operation. The revised interim 2013-2015 MMP (MRM, 2015a) provides a summary of the mine closure plan and outlines the closure objectives, closure criteria and measurement tools that will guide the mine closure process. The MMP details the closure concepts for individual areas of the site, e.g., TSF, OEFs.

The changes in the geochemistry of the waste rock and the subsequent implications for cover design and material availability has effectively meant that the existing closure plan is no longer valid.

4.8.3.2 New Controls – Implemented and Planned

A new mine closure plan is currently being prepared as part of the Overburden Management Project EIS. At the time of the IM review this plan was in an early draft stage and will be reviewed in detail in the 2016 IM report.

4.8.4 Review of Environmental Performance

4.8.4.1 Incidents and Non-compliances

Incidents

No incidents relating to mine closure were recorded during the reporting period.

Non-compliances

No non-compliances relating to mine closure were recorded during the reporting period.

4.8.4.2 Progress and New Issues

Overburden Emplacement Facility

Risk Assessment

A failure mode and effects analysis was undertaken by MRM and facilitated by O'Kane Consultants during the reporting period (OKC, 2015a). The workshop was conducted at a high level and developed a list of potential failure modes that were specific to the site and identified the potential pathway for these failure modes to occur and the effect of this failure in terms of:

- Environmental impact.

- Community.
- Health and safety.
- Cost.

Sixty two failure modes were identified, with a number of these being split into different effects and/or pathways. The information from the workshop was used to:

- Identify risks.
- Identify whether further work was required to understand these risks, i.e., further investigations.
- Identify through the risk ranking process the priorities for further work.

The workshop was the first step in the process, with MRM planning to revisit the risks identified (and add new risks) as the results of further investigations become available. At this stage the IM is unable to provide comment on whether the risk assessment is adequate with respect to assessing risks associated with proposed closure strategies, and such comment will need to wait until these strategies are finalised. The IM, however, is pleased that MRM is taking a risk-based approach to the development of closure strategies.

NOEF Erosion Trials

Erosion trials comprise six sites, which were observed by the IM during the 2015 and 2016 site visits. The purpose of the trials is to collect data over the long term on surface erosion with varying materials and slopes which can be used in conjunction with predictive modelling to evaluate proposed landform designs. Table 4.35 outlines the six erosion trials that have been established. A LIDAR survey of each trial has been completed to establish a baseline with future LIDAR surveys being used to measure erosion rates and surface feature evolution, i.e., development of rills and/or gullies.

Table 4.35 – Erosion Trials

Site	Material	Slope
1	Shale	4H:1V
2	Breccia	4H:1V
3	Shale	2.4H:1V
4	Breccia	2.4H:1V
5	Shale	1.3H:1V (angle of repose batter)
6	Breccia	1.3H:1V (angle of repose)

The IM understands that because of the low rainfall over the last wet season, the erosion trials did not provide useful data.

Long-term erosion modelling was undertaken to assess various overburden emplacement facility landform shapes. The modelling helps to inform MRM how different landform shapes perform over the long term with respect to stability and erosion development (OKC, 2015b). The objectives of the modelling were to:

- Determine erosion rates for different landform shapes.
- Determine the depth of erosion (and therefore potential impact on the cover).

The information was used to understand the performance of different landform shapes and the required cover thickness to:

- Prevent exposure of contaminated waste over time scales ranging from 100 to 1,000 years.
- Determine the landform shape which required the minimal amount of clean non–acid-forming material on the outer portion of the landforms profile.

The modelling indicated that:

- Steeper angle of repose slopes did not show evidence of gully erosion formation.
- Deep erosion of 2.2 to 2.6 m occurred on longer slopes with moderated slope angles.
- A longer concave slope was predicted to be erosionally stable.

Following this initial modelling, MRM undertook laboratory testwork (OKC, 2016) to assess the erosion potential of the following materials:

- Shale.
- Breccia.
- Topsoil.
- Alluvium.

Results indicated a low to very low erosion potential for the shale and breccia samples, a moderate to high erosion potential for the alluvium samples, and high erosion potential for the topsoil sample. Further modelling is planned and the results will be reviewed in the next IM report.

The IM commends MRM on initiating the collection of material properties and the establishment of the erosion trials to gather real data on erosion and surface water runoff rates. While it is acknowledged that several years of wet season data will be required before results can be used to calibrate the modelling, the collection and establishment of these trials is a positive step.

NOEF Cover Design

An update on MRM's further investigations with regard to a cover design for the NOEF is outlined in Section 4.6.3.2.

TSF Expansion and Closure

McArthur River Mining has notified the DME that it will no longer be seeking approval for the expansion of the TSF to the west into the area previously designated Cell 4. Consequently MRM, in consultation with the designer, is considering alternate TSF expansion options. These options include combining TSF Cell 1 and Cell 2 into a single storage facility, dry stacking tailings, and paste disposal. Currently, the favoured option is retaining the current discharge consistency (around 50% solids content) and discharging into a single combined cell.

Expansion of the TSF in this manner is likely to exacerbate the current seepage issues. Therefore, additional seepage investigations and management is key to the success of this approach. McArthur River Mining is also considering other improvement techniques such as ‘mudfarming’ to increase the rate of desaturation and stabilisation, which may also reduce seepage. McArthur River Mining recognises that in the longer term, capping alone may not be sufficient to ensure a stable landform with negligible impact at closure. Consequently, MRM is considering ways of further stabilising the existing tailings facility, including retreatment of the tailings, mechanical dewatering and dry stacking. Retreatment of tailings is likely to result in tailings being relocated to the pit.

Pit Lake Modelling

Numerical modelling has been undertaken to assess the condition of the pit lake after mine closure. Initial modelling was conducted by URS as part of the Stage 3 EIS (URS, 2012), using outputs from their 3-D groundwater model. Klohn Crippen Berger carried out preliminary pit void modelling in the last quarter of 2015, considering various scenarios, including early closure in 2018 as well as life of mine (LOM) cases, and with and without a water treatment plant and inflows from the underground workings (KCB, 2015). Modelling also assumed development of the Woyzbun Quarry. The modelling was run over a 100-year period post closure, and predicted that at the end of the modelling period, the pit lake will contain elevated SO_4 concentrations in the order of 500 to 5,000 mg/L and Zn concentrations of 5 to 40 mg/L. The modelling predicted circum-neutral pH throughout the 100-year simulation, but alkalinity tended to show a decreasing trend in all simulations, which indicates that acid conditions may eventually occur, with concurrent much higher salinity and metal/metalloid concentrations. The assumed alkalinity input from the underground workings was significant, and where it was excluded the alkalinity in the pit lake dropped much more rapidly. The time period for modelling should be extended to better assess longer-term potential impacts, including the possibility of ultimate pit lake acidification.

The IM understands that further pit lake quality modelling will be carried out and options for pit lake management will be developed as part of the Overburden Management Project EIS.

Mine Closure Plan

Mine Closure Criteria

McArthur River Mining has commenced preparation of a revised mine closure plan. As part of this process MRM has engaged a number of peer reviewers (Golder, 2015; Mine Earth, 2015; OKC, 2015c) to review the plan and provide feedback with regard to the strategies being proposed. The IM believes that this engagement of peer reviewers is an important step in the development of a robust closure plan.

Mine Closure Costs

Mine closure costs were reviewed during 2015 (MRM, 2015b) and an increase was agreed between MRM and DME. In reviewing the mine closure costs the IM could not find any allowance for the closure of the dredge spoil ponds at the Bing Bong Loading Facility (BBLF). McArthur River Mining advised that some earthworks had been allowed for in relation to closure of the dredge spoil ponds. The closure costs make reference to rehabilitation of ponds 2 and 3 which are located at the loading facility, but it is not clear what other infrastructure costs have been included. The IM was advised that closure costs of the camp and main concentrate storage shed have been included but that the wharf facility itself is proposed to remain as an asset for other stakeholders. The IM would recommend that the BBLF be considered as a domain separate from the mine so that costs can be clearly identified.

As outlined above, the current mine closure plan is being revised as part of the Overburden Management Project EIS and this will include revised closure costs. The changes in the geochemistry of the waste rock have potential significant implications with regard to costs associated with the post-closure monitoring and maintenance of the site. A key consideration is determining the timeframe that post-closure monitoring and maintenance will be required. As part of the preparation of the closure plan and review of these costs, allowance should be made for the following:

- Long-term monitoring of cover performance.
- Maintenance of the cover system, including inspection of geotechnical integrity.
- Collection and treatment of leachates (surface and groundwater), and active water management post-closure including potentially the pit lake.
- Monitoring and maintenance of the mine levee wall.
- Monitoring and maintenance of McArthur River diversion channel.

McArthur River Mining's performance against previous IM review recommendations relating to closure planning issues is outlined in Table 4.36.

Table 4.36 – Closure Planning Recommendations from Previous IM Reviews

Subject	Recommendation	Status
2014 Operational Period		
NOEF	A Failure Mode Effects Analysis (FMEA) should be undertaken on the preferred cover and landform design. The FMEA should clearly outline how likelihood and consequence are determined and the mitigation strategies in place. Where the confidence levels are low or medium, actions to improved confidence should be detailed	Ongoing. A FMEA was undertaken at a high level to identify those risks where more investigations are required to improve confidence regarding their likelihood and consequence. McArthur River Mining is planning additional FMEA workshops
Materials balance	A comprehensive materials balance should be prepared following finalisation of the cover and landform design to identify potential shortfall in materials and: ♦ Confirmation that LS-NAF(HC) material can be selectively mined to make up this shortfall ♦ Costs (drill, blast and haul) associated with the selective mining of LS-NAF(HC) is included in the revised mine closure cost estimate	Ongoing. ♦ Design of the cover is continuing and will be detailed in the Overburden Management Project EIS ♦ McArthur River Mining has identified a source of LS-NAF(HC) and has completed designs for a quarry in the footwall and Woyzbun area

Table 4.36 – Closure Planning Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2014 Operational Period (cont'd)		
Materials balance (cont'd)		♦ The IM has been advised that costs for drill, blast and haul of LS-NAF(HC) material are included in the current mine closure costs
Mine closure commitments	As part of the review of the mine closure plan, the IM recommends that MRM review all previous rehabilitation and closure commitments which have been made since the project commenced as an underground mining operation. All commitments should be upgraded to reflect the current status of the operation, community expectations and industry practice	Ongoing. The mine closure plan is currently being updated and will be finalised as part of the Overburden Management Project EIS. An early draft closure plan was provided to the IM which included comments from peer reviewers with regard to mine closure commitments
Mine closure costs	A comprehensive review is required of the closure costs. The IM understands that this will occur as part of the Overburden Management Project EIS. A specific focus of this review should be on developing a comprehensive understanding of post-closure management, monitoring and maintenance costs with any assumptions clearly documented	Ongoing. ♦ Mine closure costs were updated in 2015 which resulted in a material increase in these costs ♦ A further update will occur as part of the Overburden Management Project EIS
2012 and 2013 Operational Periods		
NOEF	Review the current dump design in relation to the sustainability and performance of the 0.6-m compacted clay infiltration/oxidation control layer. Test the sensitivities of the cover design to: ♦ Changes in material properties ♦ Changes in depth of NAF cover as a result of erosion ♦ Changes in climate	Ongoing. Studies are currently being undertaken to develop a new cover design strategy to address this recommendation
	Undertake erosion and sediment transport modelling of the proposed NOEF landform to identify depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years. The IM supports MRM's decision to evaluate alternative landform designs which eliminate the need for engineered structures	Ongoing. Erosion trials established but no data due to below average wet season. Modelling of NOEF landform being undertaken as part of Overburden Management Project EIS
	Undertake a trial to construct a cover to the required specification and regularity of thickness to prevent seepage in perpetuity. Samples from the trial compacted clay liner to be tested for density and permeability after compaction with testing to be undertaken at intervals over the full thickness of the liner	Ongoing. Cover design has not been finalised. Trial to commence following finalisation of cover design
	Evaluate the potential for differential settlement of the NOEF to compromise the cover design. In particular, the potential implications for highly reactive PAF material to settle faster than other waste rock contained in the NOEF	Ongoing. The IM understands that differential settlement is being addressed as part of current cover design investigations

Table 4.36 – Closure Planning Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2012 and 2013 Operational Periods (cont'd)		
Open pit	The seepage of contaminated water from the pit lake after closure should be assessed. This would best be carried out using a water and solute balance model for the pit void lake, which would include inflows, outflows, storage volumes, effects of salinity on lake evaporation rates and geochemical process associated with interaction between lake water and the pit wall rocks Under the 2015 West Australian mine closure guidelines (DMP, 2015) (revision of the 2011 guidelines), which MRM has adopted for closure planning purposes, an assessment of the pit lake condition is required to identify whether a groundwater sink or flow through will develop after closure	Ongoing. Pit lake water quality modelling has commenced. Further investigations currently being undertaken and will be reported in the Overburden Management Project EIS
TSF	An interim cover design has been developed for TSF Cell 1. MRM currently does not have any plans for retreatment of the tailings within Cell 1, although with further technological advances retreatment may be possible. An opportunity exists for MRM to develop its TSF closure strategy by implementing a final cover over either all or part of Cell 1. The IM recommends that a final cover strategy trial be undertaken on Cell 1 for at least part of the area	Ongoing. Repairs to the clay placed over the tailings have been undertaken. A new closure plan is currently being prepared which is considering all options with regard to closure of the TSF, including relocation of tailings to the open pit
	Undertake erosion and sediment transport modelling of the proposed TSF landform to identify depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years	See above
Closure objectives, criteria and performance indicators	Revise the current mine closure objectives, criteria and performance indicators. The objectives should be outcome based and focused on the proposed post-mining land use. The closure criteria and performance indicators should be site specific and capable of objective measurement or verification	Ongoing. Closure objectives and criteria are being prepared as part of the revised mine closure plan. McArthur River Mining has engaged peer reviewers to review draft closure objectives and criteria. Engagement with stakeholders has also commenced with regard to the closure objectives. The final objectives and criteria will be outlined in the Overburden Management Project EIS

4.8.4.3 Successes

Significant progress has been made on a number of issues during the review period (Section 4.8.4.2), which has resulted in an improved level of understanding of closure issues for the site. However, as the strategies are continuing to be developed and refined, none of the key closure issues, i.e., NOEF cover and landform design, TSF cover and landform design, and pit lake water quality, have been resolved and therefore no successes have been noted during the reporting period.

4.8.5 Conclusion

McArthur River Mine has continued to undertake a number of investigations that have increased the understanding of the key mine components (NOEF, TSF and open pit) and their inter-relationships. During the IM's 2016 site visit, there was a noticeable emphasis among MRM personnel that the various investigations (e.g., geochemical, groundwater, surface water) currently being undertaken as part of the Overburden Management Project EIS required a focus on meeting closure requirements rather than simply developing a strategy which would be acceptable during operations.

Significant work remains to be undertaken to draw together the results of the investigations currently underway to develop satisfactory closure strategies. Once developed, these strategies are likely to require ongoing review and modification as further information is collected which can be used to validate (or refine) assumptions and update models.

Ongoing and new recommendations which impact on mine closure have also been included in other sections of the report, in particular Sections 4.3, 4.5, 4.6 and 4.7. Recommendations of the IM which relate specifically to closure are outlined in Table 4.37. Two new recommendations have been included regarding preparation of mine closure costs for BBLF (currently it appears that not all costs have been included) and extending the period of modelling of the pit lake beyond 100 years. The recommendation concerning mine closure costs has been updated to reflect its importance and provide further clarity regarding specific aspects of the post-closure monitoring and maintenance costs and in particular the need to determine the likely period of post-closure monitoring and maintenance.

Table 4.37 – New and Ongoing Closure Planning Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Materials balance	A comprehensive materials balance should be prepared following finalisation of the cover and landform design to identify potential shortfall in materials and: ♦ Confirmation that LS-NAF(HC) material can be selectively mined to address this shortfall ♦ Costs (drill, blast and haul) associated with the selective mining of LS-NAF(HC) is included in the revised mine closure cost estimate	High
Mine closure commitments	As part of the review of the mine closure plan, MRM should review all previous rehabilitation and closure commitments that have been made since underground mining commenced. All commitments should be upgraded to reflect the current status of the operation, community expectations and good industry practice	High
Mine closure costs	A comprehensive review is required of the closure costs. Determining the timeframe that post-closure monitoring and maintenance will be required should be a key aspect of this review. Allowance should be made for: ♦ Long-term monitoring of cover performance ♦ Maintenance of the cover system, including inspection of geotechnical integrity ♦ Collection and treatment of leachates (surface and groundwater), and active water management post-closure including potentially the pit lake ♦ Monitoring and maintenance of the mine levee wall ♦ Monitoring and maintenance of McArthur River diversion channel	High

Table 4.37 – New and Ongoing Closure Planning Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
NOEF	A Failure Mode Effects Analysis (FMEA) should be undertaken concerning the preferred cover and landform design. The FMEA should clearly outline how likelihood and consequence are determined and the mitigation strategies in place and proposed. Where the confidence levels are low or medium, actions to improved confidence should be detailed	Medium
	The current dump design should be reviewed in relation to the sustainability and performance of the 0.6-m compacted clay infiltration/oxidation control layer. The sensitivities of the cover design should be tested in relation to: ♦ Changes in material properties ♦ Changes in depth of NAF cover as a result of erosion ♦ Changes in climate	High
	Erosion and sediment transport modelling of the proposed NOEF landform should be undertaken to identify the depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years. The IM supports MRM's decision to evaluate alternative landform designs which eliminate the need for engineered structures	Medium
	A trial should be undertaken to construct a cover to the required specification and regularity of thickness to prevent seepage in perpetuity. Samples from the trial compacted clay liner should be tested for density and permeability after compaction, with testing to be undertaken at intervals over the full thickness of the liner	Medium
	The potential for differential settlement of the NOEF to compromise the cover design should be evaluated, with particular focus on the potential implications for highly reactive PAF material to settle faster than other waste rock contained in the NOEF	Medium
Open pit	The seepage of contaminated water from the pit lake after closure should be assessed. This would best be carried out using a water and solute balance model for the pit lake, which would include inflows, outflows, storage volumes, effects of salinity on lake evaporation rates and geochemical process associated with interaction between lake water and the pit wall rocks Under the 2015 West Australian mine closure guidelines (DMP, 2015) (revision of the 2011 guidelines), which MRM has adopted for closure planning purposes, an assessment of the pit lake condition is required to identify whether a groundwater sink or flow through will develop after closure	High
TSF	An interim cover design has been developed for TSF Cell 1. MRM currently does not have any plans for retreatment of the tailings within Cell 1, although with further technological advances retreatment may be possible. An opportunity exists for MRM to develop its TSF closure strategy by implementing a final cover over either all or part of Cell 1. A final cover strategy trial should be undertaken on Cell 1 for at least part of the area. The IM understands that MRM's preferred closure strategy for the TSF has changed and relocation of tailings to the open pit is the preferred strategy. This change in strategy once confirmed will change the IM's recommendations with regard to TSF closure	High
	Erosion and sediment transport modelling of the proposed TSF landform should be undertaken to identify the depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years	Medium

Table 4.37 – New and Ongoing Closure Planning Recommendations (cont'd)

Subject	Recommendation	Priority
New Items		
Closure objectives, criteria and performance indicators	The current mine closure objectives, criteria and performance indicators should be revised. The objectives should be outcome based and focused on the proposed post-mining land use. The closure criteria and performance indicators should be site specific and capable of objective measurement or verification	Medium
Open pit	Extend pit void quality modelling to a longer period and assess the possibility of the pit lake ultimately acidifying under different assumptions	High
Bing Bong Loading Facility	Prepare detailed closure costs for the Bing Bong Loading Facility and present these as a separate domain from the mine closure costs	High

4.8.6 References

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4.9 Terrestrial Ecology

4.9.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of terrestrial ecology, and is based on the review of:

- Various reports prepared by MRM and its consultants (as listed in Appendix 1), including MRM's mining management plan (MRM, 2015a; 2015b).
- Revegetation, planting, nursery stock and weed control registers in the form of Excel spreadsheets provided by MRM.
- Various MRM forms and similar documents such as field data forms, survey results, incident notification letters and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the McArthur River Mine, Bing Bong Loading Facility and surrounds, provided by MRM and/or taken during the IM site visit in April 2016.

4.9.2 Key Risks

The key risks to terrestrial ecology as described in the risk assessment (Appendix 2) are:

- Slow revegetation of the McArthur River diversion channel as a result of:
  - Flooding during the wet season, causing significant erosion of the embankment (see Section 4.4), redistributing and/or preventing retention of soils, and removal of planted tubestock.
  - Trampling and grazing of surviving vegetation by large herbivores, predominantly cattle, which has significantly reduced rehabilitation success.

  The lack of vegetation along the diversion channels impacts the stability of soil on the channel banks and, in turn, ecosystem development and health. Slow revegetation retards the development of important riparian habitat for terrestrial flora and fauna. It also affects the ecological health of the McArthur River through lack of shade, potential long-term increase in downstream sedimentation, and weed infestation.
- Creation of vegetation communities along the diversion channels that are different to the natural communities found along Barney Creek and the McArthur River. This occurs through planting and seeding of non-local species along the diversion channels and encroachment of weeds. Efforts should be made to match the riparian vegetation of original channels as closely as possible. Incorrect habitat can also be created through the establishment of weeds or weedy opportunistic natives in revegetation areas. An example of this is at the McArthur River diversion channel lookout, where the encroachment of *Acacia holosericea, Vachellia farnesiana* and weeds onto riparian habitat is occurring.
- Fragmentation of habitat (excluding that related to the river diversion channels as described above) as a result of vegetation clearing or slow revegetation. Habitat fragmentation can prevent the movement of fauna species, restricting breeding and safe access to food and

water resources, as the lack of vegetation cover can leave small mammals, reptiles and grassbirds vulnerable to predation.

- Presence of noxious weed species at the mine site and Bing Bong Loading Facility due to:
  - Historical mining and pastoral activities.
  - Additional land clearing by MRM, which has allowed weeds to encroach into new areas.

  Weed infestations can exclude native flora species and/or reduce the quality of habitat for native fauna, as well as affecting the success of rehabilitation works.

- Development of salt and/or heavy metal loads in vegetation, soils and sediments, potentially causing vegetation dieback. Salt and heavy metals can affect vegetation by entering soils and sediments through deposition of airborne dust, runoff of settled dust from roadways and/or seepage of contaminated waters from MRM's operation areas. This results in assimilation of sulfate and heavy metals into vegetation through the roots, changes in the pH of the soil, and/or reduced photosynthetic ability of plants, causing poor health and/or death of vegetation. Vegetation dieback may result in the reduction of habitat for terrestrial fauna, shade for aquatic fauna, and/or soil stability, increasing erosion potential and facilitating the spread of weeds.

- Localised mortality of vegetation surrounding the Bing Bong Loading Facility dredge spoil ponds, with associated alteration of habitat, due to factors such as:
  - Saline leachate draining from the dredge spoil.
  - Seawater being retained against the outside of the drain bund for a prolonged period of time after the tide recedes.
  - The historical placement of dredge spoil on a minor drainage line, resulting in floodwaters ponding to the west of the spoil ponds and causing trees to drown. This issue has since been rectified but vegetation is slow to recover.

- Failure of vegetation to establish on the dredge spoil ponds at Bing Bong Loading Facility, leading to the creation of dust, with potential impacts on adjacent habitat.

- Potential heavy metal bioaccumulation in the food sources of important migratory bird and wader populations, as a result of dust migration and/or concentrate spillage from Bing Bong Loading Facility.

- Reduced availability of suitable habitat for the Gouldian finch (*Erythrura gouldiae*) due to vegetation clearing near the mine site.

4.9.3 Controls

4.9.3.1 Previously Reported Controls

Summary

The following controls relating to terrestrial ecology were previously reported for the 2014 operational period and were also completed in the current reporting period:

- Annual revegetation monitoring program along the Barney Creek and McArthur River diversion channels (EcOz, 2015a).
- Bi-annual riparian bird monitoring program along McArthur River and Barney Creek diversion channels (Barden, 2015a; 2016).
- Annual vegetation condition monitoring of the Barney Creek diversion channel and Surprise Creek to monitor impacts of saline and metal contamination (EcOz, 2015b).
- Annual Gouldian finch (*Erythrura gouldiae*) monitoring program conducted in suitable habitat in the project area (Barden, 2015b).
- Bi-annual migratory shorebird and wader survey along the Port McArthur coast and between Rosie Creek and Limmen Bight River to the northwest, along with testing of sediments in important shorebird feeding locations (Barden, 2015c; 2015d).
- Weed management register updated annually and weeds controlled in liaison with Weeds District Officer (MRM, 2015c).
- Annual vegetation monitoring program surrounding the Bing Bong Loading Facility dredge spoil ponds (EcOz, 2015c).
- Targeted planting along the McArthur River and Barney Creek diversion channels of tubestock grown in the MRM nursery and/or sourced from suppliers (MRM, 2015d; 2015e).
- Placement of large woody debris (LWD) in the river bed of the McArthur River diversion channel.
- Dust monitoring at McArthur River Mine and Bing Bong Loading Facility to assess the risk of heavy metal contamination from operational dust emissions on terrestrial and aquatic biota and watercourses.
- Livestock management, including cattle exclusion fences along Barney Creek and McArthur River diversion channels and surrounding the Bing Bong Loading Facility dredge spoil ponds.
- Maintenance of a perimeter drain surrounding dredge spoil ponds at Bing Bong Loading Facility to facilitate the flow of salt water out to sea.

Rehabilitation of the Diversion Channels

A range of controls are in place for the purpose of promoting successful rehabilitation of the McArthur River and Barney Creek diversion channels. These include:

- Vegetation monitoring. A monitoring program is conducted annually as per the Rechannel Vegetation Monitoring Procedure (MRM, 2015f), assessing revegetation sites along the diversion channels and control sites along the natural channels of Barney Creek and McArthur River. Within the 2015 operational period, monitoring undertaken in September (EcOz, 2015a) assessed 18 sites, with most consisting of both slope and batter plots (Figure 4.22). All but one of these sites were established in previous operational periods. The aim of the diversion channels monitoring program is to:
    - Assess the success of rehabilitation of riparian habitat along the diversion channels in comparison to undisturbed sites on Barney Creek and McArthur River.
    - Enable revegetation works to be targeted at locations requiring further work and methods to be reassessed if required.
- Riparian bird monitoring. The riparian bird assemblage is an indicator of habitat health, and as such is relevant to rehabilitation of the diversion channels. Bi-annual surveys (early and late dry season) are conducted along McArthur River and Barney Creek (diversion and natural channels) to record bird species using revegetation and control sites (Barden 2015a; 2016). All bird species are recorded, but the purple-crowned fairy wren (PCFW) (*Malurus coronatus*) and buff-sided robin (BSR) (*Poecilodryas cerviniventris*) are targeted, as they are riparian health indicator species. Habitat condition data is also recorded, and its relationship to species recorded is assessed.
- Revegetation. Tubestock of desirable flora species are planted along the diversion channels where soil pockets are present (MRM, 2015f). The placement of coir logs and large woody debris helps to gather soil and reduce erosion in some areas. The majority of tubestock is grown in MRM nurseries located on site (MRM, 2015e).
- Livestock management. Livestock impact on diversion channel rehabilitation by trampling or grazing on channel vegetation, disturbing soil and causing erosion, and spreading weeds. Fencing restricts livestock from the mine site and diversion channels and is inspected, repaired and upgraded regularly. Livestock which find their way into restricted areas are mustered or culled with the help of Department of Primary Industries and Fisheries.

Impact of Saline Seepage on Vegetation

Monitoring of the impact of saline seepage on vegetation along the Barney Creek diversion channel and Surprise Creek was initiated in 2014 in areas in the vicinity of potential sources of saline seepage as recommended by the IM in previous review reports (ERIAS Group, 2014). Potential sources of seepage and/or contamination include the TSF and PAF runoff dams, dust from the processing plant and haul roads, and runoff from the Barney Creek haul road bridge. Impact monitoring is undertaken within 18 plots across three locations near the processing plant, the southeast PAF runoff dam, and the southern PAF runoff dam (Figure 4.23).

REVEGETATION AND CONTROL MONITORING SITES ON THE BARNEY CREEK AND McARTHUR RIVER DIVERSION CHANNELS

McArthur River Mine Project

FIGURE 4.22

ERIAS GROUP

Source: EcOz, 2015a.

MONITORING SITES FOR ASSESSMENT OF SALINE SEEPAGE IMPACT ON VEGETATION NEAR BARNEY AND SURPRISE CREEKS

McArthur River Mine Project

FIGURE 4.23

Impact on the Gouldian Finch

Regular surveys targeting the Gouldian finch were implemented as a result of the species being observed within the mine lease in 2013. This species is listed as endangered under the EPBC Act and therefore it is important to protect habitat suitable for this species. The annual Gouldian finch monitoring program is conducted in April and June in the vicinity of the mine, Carpentaria Highway and NOEF expansion areas (Barden, 2015b), as shown in Figure 4.24 (see also sections 4.9.3.2 and 4.9.4.2).

Impact on Migratory Birds

As a condition of Commonwealth government approval, MRM is required to undertake migratory bird surveys twice per year (Barden, 2015c; 2015d) due to concerns that operations at Bing Bong Loading Facility may result in dust migration or concentrate spillage leading to heavy metal bioaccumulation in Port McArthur flora and fauna. The aim of the survey is to assess if migratory bird populations are being affected through the use of shorebird counts. Migratory bird monitoring is completed during the northern staging period (April) and austral summer (February/March) (Barden, 2015c; 2015d), as shown in Figure 4.25. Sediment sampling is typically completed as part of this program at important feeding areas to assess the concentrations of metals which may be transferred to the shorebirds while feeding (this was not undertaken during the 2015 operational period due to dry conditions).

Weed Management

Controls in places at McArthur River Mine for the exclusion and eradication of weeds include:

- A weed management plan outlining targets and recommended actions for weeds known from the mine site and surrounds (MRM, 2015b).
- Weed management register which provides an inventory of weeds recorded and actions taken (MRM, 2015c).
- Spraying and/or removal of weeds as appropriate (MRM, 2015b).
- Exclusion of cattle to reduce the disturbance of native vegetation and spread of weed seeds.
- Wash down pad for vehicles moving to and from the mine site. The main purpose of this equipment is to reduce the amount of mine-derived dust being transported from the processing area, although it has a secondary function of removing flora seeds.

Dredge Spoil Vegetation Monitoring Program

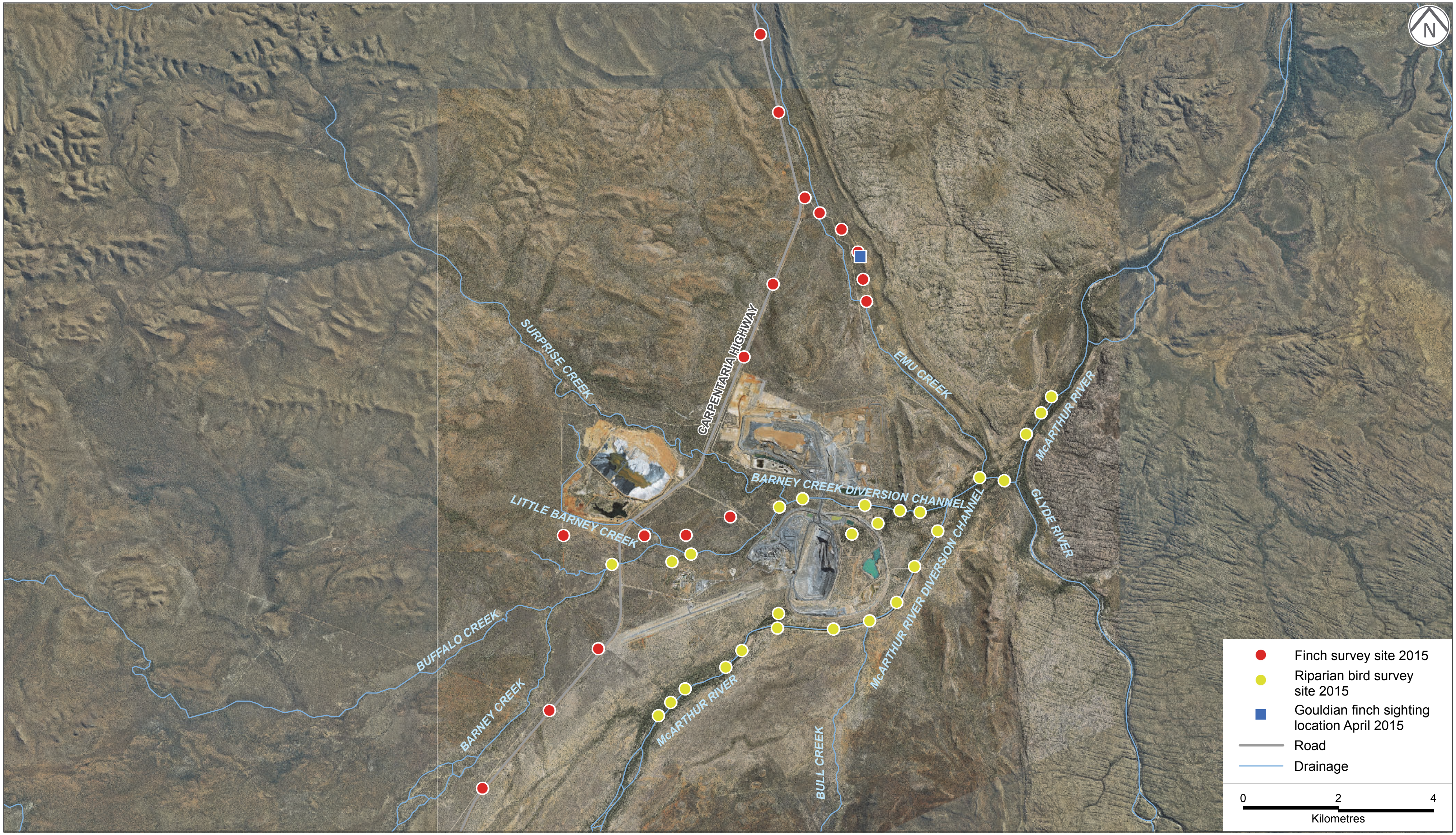
The fourth round of annual monitoring of vegetation surrounding the Bing Bong Loading Facility dredge spoil ponds was conducted in July 2015 (EcOz, 2015c). Transects (Figure 4.26) are surveyed annually and compared with previous data. Transects are located within salt-affected areas and in un-impacted reference sites. Surface soil samples are taken at each site to assess the levels of salt present through the determination of EC levels and to ascertain if changes in vegetation corresponded to changing salt levels in soil.

FINCH SURVEY SITES AND GOULDIAN FINCH HABITAT AT EMU CREEK

McArthur River Mine Project

FIGURE 4.24

ERIAS GROUP



MIGRATORY BIRD AERIAL TRANSECTS SURVEYED DURING THE 2015 OPERATIONAL PERIOD

McArthur River Mine Project

FIGURE 4.25

Source: Google Image 2005

ERIAS Group | 01164C_1_F4-25_v1.pdf

VEGETATION MONITORING SITES AT THE BING BONG LOADING FACILITY DREDGE SPOIL EMPLACEMENT AREA

McArthur River Mine Project

FIGURE 4.26

ERIAS GROUP

Source: EcOz, 2015c.

4.9.3.2 New Controls – Implemented and Planned

Addition of Survey Sites

Several monitoring programs were improved in 2015 with the addition of new monitoring or control sites:

- Vegetation monitoring program. At the request of the IM (ERIAS Group, 2015), MRM added an additional monitoring site (BCI2B) downstream of the Barney Creek haul road bridge, as shown in Figure 4.22. There were previously no monitoring sites in the downstream half of the Barney Creek diversion channel. This site is in an important location as not only will it help to provide a whole-of-channel view of rehabilitation, but it will also aid in determining the impact of contamination from the mine due to its close vicinity to the Barney Creek haul road bridge, where metal contamination continues to be reported.

- Saline seepage impact program. McArthur River Mining has expanded monitoring for assessing the impact of saline seepage on vegetation near Barney and Surprise creeks to include two control sites – one on Surprise Creek upstream of the TSF (SCC1) and one on Barney Creek upstream of the mine (BCC1) (see Figure 4.23). Control sites are essential for determining if any impacts recorded are a result of mine-derived saline seepage or have a natural cause.

- Gouldian finch monitoring program. McArthur River Mining has included new woodland bird monitoring sites near the Carpentaria Highway and in the vicinity of the NOEF (see Figure 4.24). Gouldian finches were observed incidentally east of the Carpentaria Highway in 2014 and the addition of sites is a response to this. Due to the survey area increase, the number of sites surveyed was reduced from 84 to 64 to allow for the increased distance travelled.

Livestock Management

McArthur River Mining has developed a Livestock Management Plan (MRM, 2015g) that details the impact caused by livestock, proposed fencing designs, procedures for mustering and culling, stakeholder consultation, security and future actions. The management plan recognises the following potential impacts from livestock entering the mine site:

- Overgrazing, erosion and/or damage to rehabilitation efforts.

- Damage to infrastructure.

- Traffic management and interaction of livestock with people.

- Possible metal contamination of livestock.

A decision matrix has been designed to facilitate decisions regarding the removal of cattle from the mine site. Table 4.38 outlines the matrix included in the management plan.

Table 4.38 – Livestock Management Decision Matrix

Cattle	Estimated Length of Tenure	Number of Head	Location	Action
Cleanskin/ scrub bull	Any length	Any number	Any location	Remove with firearms as long as safe
Branded	Short term (1-3 weeks)	<5	Any location	Remove by mustering by vehicle or others means (MRM)
Branded	Short term (1-3 weeks)	<5	High risk area with regards to infrastructure	Remove by mustering by vehicle or others means (McArthur River Station)
Branded	Short term (1-3 weeks)	>5	Any location	Remove by mustering by vehicle or others means (MRM). Contact McArthur River Station for possible relocation
Branded	Short term (1-3 weeks)	>5	High risk area with regards to infrastructure	Remove by mustering by vehicle or others means (McArthur River Station). Look at relocating to different area
Branded	Long term (>3 weeks)	<5	Any location	Remove with firearms as long as safe and under instruction from McArthur River Station
Branded	Long term (>3 weeks)	>5	Any location	Remove by mustering with aid from McArthur River Station in order to identify by shoulder branding and tagging for identification of possible contamination

Source: MRM, 2015g.

4.9.4 Review of Environmental Performance

4.9.4.1 Incidents and Non-compliances

Incidents

No incidents directly related to terrestrial ecology were reported during the 2015 operational period.

Non-compliances

The revised interim 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances.

4.9.4.2 Progress and New Issues

McArthur River Mining's performance against previous IM review recommendations relating to terrestrial ecology issues is outlined in Table 4.39. Where further discussion is required, this occurs following Table 4.39 and is indicated within the table.

Table 4.39 – Terrestrial Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	Status
2014 Operational Period		
Rehabilitation	Include new revegetation sites MRR7 and MRR8 in the analysis of data with other sites. This will assist to better indicate how channel revegetation is progressing	Completed. Results for MRR7 and MRR8 were reported alongside the other sites. This gives a better whole-of-channel view of the success of the rehabilitation

Table 4.39 – Terrestrial Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2014 Operational Period (cont'd)		
Rehabilitation (cont'd)	Investigate using the saline seepage assessment sites located on the Barney Creek diversion channel as part of the revegetation monitoring program, as they will provide representation for an area downstream of the Barney Creek haul road bridge which is lacking data. Many of the methods already conducted are very similar and would allow the data to be analysed with the diversion channel revegetation monitoring program as well as the saline impact monitoring program	Not completed. Currently the saline seepage impact program assesses six plots downstream of the Barney Creek haul road bridge, one of which is included in the revegetation monitoring program. Including data from the other plots would require little additional effort as the methods used in each program are the same and would increase the programs' cover on the Barney Creek diversion channel
	Include a monitoring site in the rocky gorge area of the McArthur River diversion channel (downstream, below MRR6) along with a suitable control site, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate stage. It is unlikely that areas such as this would meet completion criteria set out for more sloped sites	Not completed. The IM recommends that MRM includes an additional downstream site to represent all habitat types along the McArthur River diversion channel.
Flora	Control sites need to be found for comparison with impact monitoring sites as part of the saline seepage impact monitoring program. Investigate whether control sites used for the diversion channel revegetation monitoring program can also be used in this case	Completed. Two control sites were included in the 2015 saline seepage monitoring program. One of these sites (BCC1) is used as a control site as part of the revegetation monitoring program, while the second (SCC1) is a new site. The suitability of BCC1 as a control site should be investigated, as vegetation on slopes and batters at this location is experiencing a downward trend in the density of foliage from 2012 to 2015 (discussed further below)
	Include a monitoring site next to the TSF along Surprise Creek where seepage has previously occurred, as part of the saline seepage impact monitoring program	Not completed. While vegetation monitoring has been established in Surprise Creek sites potentially affected by saline seepage from the NOEF, as well as control sites upstream of the TSF, it is still recommended that additional site/s be placed along Surprise Creek to the northeast of the TSF, where previous seepage has occurred. The health of the vegetation in this area should be monitored to determine if the long-term saline seepage impact issue has been rectified
Bing Bong Loading Facility dredge spoil ponds	Fix fencing surrounding the Bing Bong Loading Facility dredge spoil ponds to ensure that cattle and donkeys are excluded from the ponds and drains, ensuring that their integrity is protected	Completed. During the site inspection, fencing was observed to be in good condition and no signs of cattle were seen inside the fenced area

Table 4.39 – Terrestrial Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2012 and 2013 Operational Periods		
Rehabilitation monitoring	Revise revegetation monitoring program to include sites on the Barney Creek diversion channel downstream of the Barney Creek haul road bridge, and additional sites in the downstream half of the McArthur River diversion channel. Monitoring of diversion channel revegetation control sites every year rather than every three years	Completed. Two additional sites were added in 2014 in the downstream half of the McArthur River diversion channel and data was included in the analysis for the first time in 2015. In 2015, a site was added downstream of the Barney Creek haul road bridge
	Research the use of a more landscape function-based monitoring program such as Drainage-line Assessment to provide more information on erosion and stability of Barney Creek and McArthur River diversion channels	Not completed. Erosion assessment has been improved by measuring the distance of terracing from the site start marker, with the aim of monitoring change over time. A landscape function-based monitoring program has not been researched to date, however, the forthcoming geomorphological study of the diversion channels will help to assess and inform mitigation of erosion issues
Cattle exclusion	Redesign current cattle fencing surrounding McArthur River diversion channel to increase flood-proofing and ensure that cattle exclusion fences are monitored for damage	Completed. McArthur River Mining has developed a livestock management plan (MRM, 2015g), which addresses fencing
Rehabilitation	Conduct a review of rehabilitation works to date including total tubestock and kilograms of seed used, total areas planted and percentage of successful revegetation to assess the likely timeframe and cost for diversion channel rehabilitation, including an expected completion year in future MMPs	Partially completed. McArthur River Mining keeps a detailed register of available tubestock, amount of seed used and areas planted. This needs to be compared to some measure of revegetation success to allow determination of a reasonable expected completion date (discussed further below)
Bing Bong Loading Facility dredge spoil ponds	Establish reference sites for dredge spoil transects which do not currently have controls. If this is not possible, it is recommended that additional sites be selected in the same habitats sufficient to provide statistically significant assessment of changes occurring within bands of vegetation in the landscape	Completed. Previously unpaired sites have been matched with controls that have similar vegetation assemblage and structure as the monitoring sites
Fauna	Continue migratory bird monitoring bird program for one additional year with comparison of survey data to older data collected for the gulf by Garnett and Chatto. Reassess need to continue surveys based on trend of fluctuations compared to historical data	Partially completed. Some comparison with data from previous years has been undertaken but it is still unclear whether the Bing Bong Loading Facility is having an impact on migratory birds or not. A review of the survey should be conducted. See discussion below
Flora	Conduct bi-annual vegetation monitoring at Surprise Creek to evaluate effects of tailings seepage	See 2014 recommendation

Table 4.39 – Terrestrial Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2012 and 2013 Operational Periods (cont'd)		
Rehabilitation monitoring	Reassess the list of key and primary species to which revegetation on the diversion channels is compared to and/or reassess control site selection, as many of those listed are not recorded at current control sites	♦ Not completed ♦ Given that the 2013 survey found that many of the key and primary flora species (habitat species) were not present at control sites, in 2014 the IM
	Investigate separate key and primary species lists for McArthur River and Barney Creek as vegetation assemblages at the control sites show different assemblages	recommended that either the species list be reassessed or that the location of control sites be reassessed. This was not conducted during the 2015 operational period. ♦ In 2015, control sites met completion criteria for primary species but not for key species. The previous recommendation is ongoing
Bing Bong Loading Facility dredge spoil ponds	Include an inspection of the outside of the drain bund wall in monthly inspections of the dredge spoil cells, to assess if tidal seawater is ponding against the bund	No evidence sighted

Rehabilitation of the Diversion Channels

A trend has been observed of decreasing foliage cover at Barney Creek control sites from 2012 to 2015 (EcOz, 2015a). Although this may be due to natural causes (such as two of the preceding three wet seasons being drier than usual), it is advised that an investigation is conducted to ensure that control sites are not being impacted by mine activities. As the control sites are located upstream of the mine, water quality is unlikely to be the issue. Cattle are also unlikely to be the cause as foliage loss was recorded in the canopy. Results from dust monitoring sites DMV25 and DMV23 should be assessed against foliage cover results from vegetation control sites BCC1 and BCC2 respectively, to identify whether airborne dust is a causal factor.

A timeframe has not been provided by MRM for when the diversion channels are expected to be rehabilitated and self-sustaining. It is important to have a target completion year to gauge required effort each year and to enable an assessment of environmental performance. At the current rate of revegetation, the McArthur River diversion channel is not likely to meet completion criteria within a number of decades, and MRM should assess if it is feasible to continue to rehabilitate using current methods or whether alternative avenues need to be investigated. The findings of the forthcoming geomorphology assessment will contribute to this, in the context of erosion issues.

Migratory Bird Monitoring

Migratory bird monitoring was completed in 2015. Some comparison with data from previous years was included but it is still unclear how the survey is providing information on whether the Bing Bong Loading Facility is having an impact on migratory birds or not. Without an assessment of trends, and comparison with historical data (for example, Garnett (2008)) and data from other locations on the East Asian-Australasian (EAA) flyway, it is difficult to determine whether the surveys are informative for this purpose. Although the survey provides excellent data on the importance of Port McArthur area as a whole for migratory birds, it is unclear to what extent population numbers fluctuate naturally and/or whether species have a wide home range, such that disturbances at the local scale may not be detected. The 2015 survey marks the sixth year of migratory bird monitoring and a review of the survey should be conducted.

Gouldian Finch

Three sub-adult Gouldian finches were recorded during the April survey, north of Emu Creek on a southern hill slope (Barden, 2015b). Adult individuals were also observed incidentally in March 2015 drinking from a pool on upper Emu Creek (Figure 4.24). These two sightings highlight the Emu Creek area as an important foraging area and possibly a breeding site for Gouldian finches. The hills in this catchment contain suitable old large trees which may be used as breeding hollows during the breeding season.

The Gouldian finch is a highly mobile species and it can be difficult to determine if they are using a certain area through presence/absence surveys. The IM recommends that instead of continuing the Gouldian finch monitoring program in its current form, an assessment should be undertaken of suitable breeding and foraging habitats located within, and in the vicinity of, the mine. The examination of aerial photographs and ground-truthing for areas of suitable seeding grasses and breeding hollows would enable preparation of a habitat map, graded as to its suitability for Gouldian finches. This would inform any future clearing and construction projects, allowing disturbance of important habitat to be avoided.

4.9.4.3 Successes

In the 2015 operational period, successes relating to terrestrial ecology have included:

- The 2015 revegetation monitoring report (EcOz, 2015a) highlighted that weed infestations are decreasing along the diversion channels, with many sites that previously contained noogoora burr and hyptis now being weed free. Weed densities were very low or absent from revegetation monitoring sites in 2015, a very encouraging result of the weed management plan and the livestock management plan.
- During the IM site visit in April 2016, vegetation along the McArthur River diversion channel was observed to have increased significantly, particularly near the lookout and along the waterline where establishment of vegetation is difficult. This is a result of high density planting by MRM staff and drier than normal wet seasons in 2014-15 and 2015-16 (lower flows enabled improved retention of soil and seedlings). McArthur River revegetation slope sites located at the beginning of the diversion channel (upstream) are improving well with the number of seedlings, saplings and trees increasing in density as well as foliage cover.
- Overall, the vegetation assemblage and condition along the Barney Creek diversion channel is improving and becoming comparable to reference sites.
- The nursery successfully produced 48,000 tubestock during the 2015 operational period, surpassing the target of 45,000 tubestock available for planting in 2015.
- McArthur River Mining has developed a livestock management plan to aid in the exclusion of cattle from the diversion channels and the greater mine area. It is a comprehensive document and is a valuable addition to MRM's efforts to restrict livestock form the mine site.

4.9.5 Conclusion

Significant improvements have been made to existing monitoring programs in the 2015 operational period, increasing the robustness of the data collected. The control of risks has been thorough; particular areas of note include MRM's dedication to revegetating the diversion channels through tubestock planting, and achieving great success in the exclusion of livestock along the river and creek diversion channels.

Some areas for improvement remain, mainly the rehabilitation of the McArthur River diversion channel. While progress is evident, much work still has to be done and this must be viewed as a long-term goal with regular milestones to complete. As in previous IM reports, it is strongly recommended that MRM develops a revegetation plan which includes a reasonable completion date for when the diversion channels are expected to be self-sustaining and a series of milestones with which performance can be assessed. This will allow MRM to determine the effort required yearly to meet goals and assess if rehabilitation is on track at an early stage.

Ongoing and new IM recommendations related to terrestrial ecology issues are provided in Table 4.40.

Table 4.40 – New and Ongoing Terrestrial Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Rehabilitation	Investigate including the saline seepage impact assessment sites located downstream of the Barney Creek haul road bridge (six plots) as part of the revegetation monitoring program, as they will provide representation for this area which is lacking data. Many of the methods already conducted (for the saline seepage program) are very similar to those used in the revegetation monitoring program	Medium
	Include a revegetation monitoring site in the downstream area of the McArthur River diversion channel (below MRR6) along with a suitable control site, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate stage	Medium
Flora	Include a saline seepage impact monitoring site next to the TSF along Surprise Creek where seepage has previously occurred	High
Rehabilitation monitoring	Research the use of a more landscape function-based monitoring program such as Drainage-line Assessment, in conjunction with the findings and recommendations of the forthcoming geomorphological study, to provide more information on erosion and stability of Barney Creek and McArthur River diversion channels	High
	Prepare a rehabilitation plan for the diversion channels which states a timeframe when the diversion channels are expected to be rehabilitated and self-sustaining, along with clear, achievable, regular milestones against which performance can be measured. McArthur River Mining should assess if it is feasible to continue to rehabilitate using current methods or whether alternative avenues need to be investigated	High
	Reassess the list of key and primary species to which revegetation on the diversion channels is compared to and/or reassess control site selection, as many of those listed are not recorded at current control sites. Investigate separate key and primary species lists for McArthur River and Barney Creek as vegetation assemblages at the control sites show different assemblages	High

Table 4.40 – New and Ongoing Terrestrial Ecology Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Fauna	Compare data collected during the migratory bird monitoring program with historical data for the region and surveys completed in other locations on the EAA flyway. Conduct a review of the current monitoring program to assess if it is sufficient to determine if MRM activities are impacting migratory birds	Medium
Bing Bong Loading Facility dredge spoil ponds	Include an inspection of the outside of the drain bund wall in monthly inspections of the dredge spoil cells, to assess if tidal seawater is ponding against the bund	Medium
New Items		
Revegetation monitoring	Results from dust monitoring sites DMV25 and DMV23 should be assessed against foliage cover results from vegetation control sites BCC1 and BCC2 respectively, to identify whether airborne dust is a causal factor in decreasing foliage density	Medium
Fauna	Replace the current Gouldian finch monitoring program with an assessment of suitable breeding and foraging habitats located within, and in the vicinity of, the mine. Construct a map of habitat, graded as to suitability for Gouldian finches, for use in future clearing and construction projects, allowing disturbance of important habitat to be avoided	Medium
Bing Bong Loading Facility	Investigate and rectify recent ponding of seawater against the bund wall and damage to the surrounding drain at Bing Bong Loading Facility dredge spoil ponds	High

4.9.6 References

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4.10 Freshwater Aquatic Ecology

4.10.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of freshwater aquatic ecology, and is based on review of:

- Various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's environmental monitoring report, supplementary monitoring report, and mining management plan (MRM, 2015a; 2015b; 2015c).
- Observations and discussions with MRM personnel during the site inspection.
- Survey results, incident notification letters, and correspondence between MRM, regulators and third parties.

Specific surveys conducted include:

- Freshwater fish diversity and abundance, including the threatened freshwater sawfish (*Pristis pristis*).
- Metals and Pb isotopes in aquatic fauna.
- Freshwater macroinvertebrates.

4.10.2 Key Risks

The key risks to aquatic ecosystems as outlined in the risk assessment (Appendix 2) relate to contamination, habitat loss and slow rehabilitation of the diversion channels. Specifically, the key risks are:

- The contamination of Surprise, Barney and Little Barney creeks by seepage, dust and/or runoff from the TSF, ROM pad, crushing circuit, processing plant, and the NOEF and its associated water storage dams that causes loss of flora/fauna and/or bioaccumulation of metals within tissues of aquatic biota. The contamination and contaminated biota could migrate downstream to McArthur River.
- Failure of infrastructure (such as pipelines, bund, TSF walls or water storage dams) leading to contamination of McArthur River, Barney Creek, Little Barney Creek and Surprise Creek. This could lead to uptake of contaminants by aquatic biota and/or mortalities in the immediate vicinity of the mine and/or downstream of activities.
- The river diversions create a physical and/or biological barrier to fish migration. This may prevent fish from migrating upstream to breed, grow and/or disperse, and reduce replenishment of waterholes upstream of McArthur River Mine.
- Slow revegetation of the river diversion channels limits the restoration of in-channel habitat and provision of shade, leading to reduced diversity and abundance of aquatic fauna in the diversions and reduced ecosystem function.

- Inability to recreate riparian habitat and/or creation of incorrect habitat along the river diversions banks prevents the diversion channels returning to an environment approaching that of the original channel. This may provide unsuitable habitat for aquatic fauna, reducing aquatic fauna diversity and abundance in the diversions.
- Contaminated biota migrating off the lease are caught and consumed by local fishers, potentially leading to human health impacts.

4.10.3 Controls

4.10.3.1 Previously Reported Controls

McArthur River Mine has controls in place to minimise the risk to aquatic fauna, and these controls are underpinned by monitoring of the aquatic fauna and environment. This monitoring program is explained below and includes:

- Freshwater fish diversity and abundance, including the threatened freshwater sawfish (*P. pristis*) (Thorburn, 2015a; 2016).
- Freshwater macroinvertebrate diversity and abundance (Barden, 2015).
- Metals and Pb isotopes in aquatic fauna (Thorburn, 2015b).
- Riparian revegetation program along the diversion channels (EcOz, 2015).

Large woody debris (LWD) is also added to the McArthur River diversion channel to provide in-stream habitat.

Since aquatic biota are contaminated as a consequence of contamination of other aspects of the physical environment (e.g., water and sediments), monitoring of aquatic ecosystems is informed and supplemented by MRM's other monitoring programs, including (but not limited to):

- Surface water and groundwater quality, outlined in Sections 4.3 and 4.5.
- Contamination of fluvial sediments, soil and dust, outlined in Sections 4.12 and 4.13.

In addition to monitoring, MRM has ongoing controls to minimise/eliminate contamination as a result of mining operations. These controls are discussed in more detail in other sections of the report, but include:

- A water management system to prevent contaminated water from entering the river system (Sections 4.2 and 4.3).
- Dust emission controls to prevent contamination of waterways via dust (Section 4.13).
- A waste discharge license which outlines the conditions under which water may be released into the surrounding waterways to minimise contamination (Section 4.3).

- Seepage-capture sumps to prevent contaminated seepage from entering waterways (Section 4.5).
- Routine inspections and monitoring of infrastructure to ensure that it is in good condition and unlikely to fail (since failure may lead to potential broad-scale contamination).

Aquatic Fauna

Aquatic fauna were surveyed in the early and late dry season (May and December 2015, respectively) by Indo-Pacific Environmental (Thorburn, 2015a; 2016). Aquatic surveys assist in meeting the commitments outlined in the revised interim 2013-2015 MMP (MRM, 2015a) to:

- Prevent the loss of listed species.
- Ensure that mining activities are not impacting aquatic communities.
- Adhere to the Freshwater Sawfish Management Plan.
- Monitor abundance and diversity of freshwater biota and performance of the diversions (including migration of biota through the diversions).

The aquatic surveys monitor fish abundance and diversity in permanent and semi-permanent pools in McArthur River (within, upstream and downstream of the diversion channel), Surprise Creek and the Barney Creek diversion channel. Specifically, the surveys:

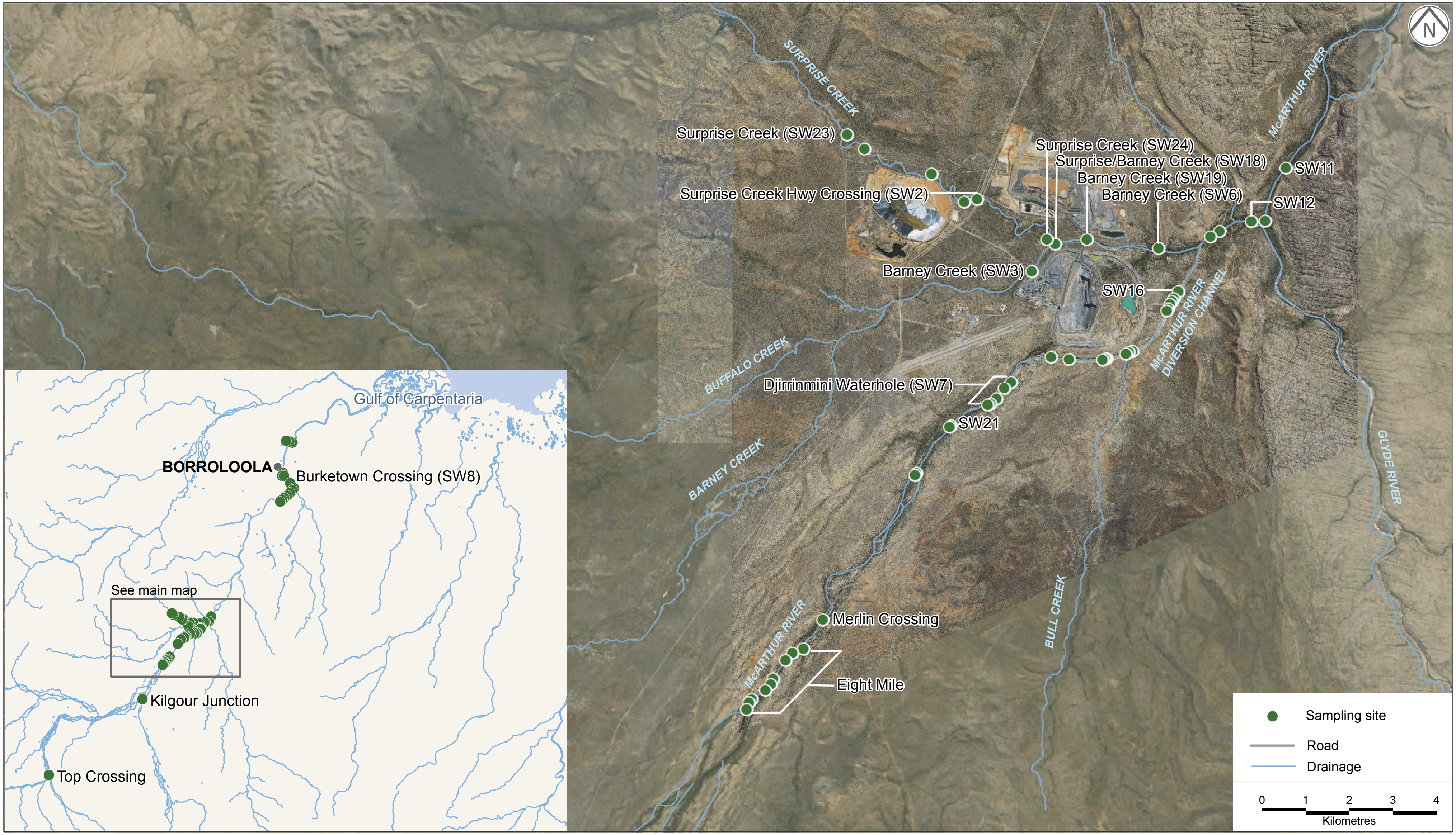
- Monitor the presence of freshwater sawfish, *P. pristis*, in and above the McArthur River diversion. The sawfish is listed as vulnerable under the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999*. Long-term freshwater sawfish recapture and sighting data is also collated.
- Compare fish communities in the McArthur River diversion channel with those in the original McArthur River prior to the diversion.
- Compare fish communities in the McArthur River with sites upstream and downstream of the diversion channels.
- Assess the effectiveness of LWD in the McArthur River diversion.
- Assess fish passage through the diversion channels by tagging key migratory fish species.
- Compare the size, distribution and abundance of freshwater prawns (*Macrobrachium* spp.) within and outside the McArthur River diversion channel.
- Allow the collection of size and distribution data on aquatic reptiles known to occur in the McArthur River.

Twenty new sites have been added to the survey program; of particular note, new sites have been added along Barney and Surprise creeks to assess the performance of the Barney Creek diversion channel. Survey locations are shown in Figure 4.27.

SAMPLING LOCATIONS OF FRESHWATER FISH, CRUSTACEANS AND OYSTERS IN THE VICINITY OF McARTHUR RIVER IN 2015

McArthur River Mine Project

FIGURE 4.27



Source: Thorburn, 2015a
Note: labels refer to sites that are either discussed in the text or are other key sites.

Freshwater Macroinvertebrates

Aquatic macroinvertebrates are surveyed annually, four to six weeks after the first major wet season flood (generally March to April) by Ecological Management Services (Barden, 2015). As the 2014-2015 wet season was poor, surveys were conducted in April and many minor drainage line sites normally surveyed could not be sampled due to a lack of water. Diversity, abundance and community structure of aquatic macroinvertebrates are included in the monitoring program for receiving waters as they are early indicators of change in aquatic ecosystems, e.g., as a result of contamination from mining operations or ineffective river diversion channels. Twenty-seven sites were surveyed for macroinvertebrates in 2015, covering the McArthur River and Barney Creek diversion channels, minor and major reference drainage lines, and exposed sites (below the TSF and ROM pad). Figure 4.28 shows the macroinvertebrate sampling sites around the McArthur River Mine. At each site, macroinvertebrates were sampled in two habitats, i.e., along river edges and in riffles. As each habitat hosts a different suite of species, it is important to cover both habitat types separately. Environmental data and fluvial sediment and surface water samples are also collected from the same sites as the macroinvertebrates, so inferences can be made about the processes affecting macroinvertebrate communities. The monitoring program was developed with the Northern Territory Department of Primary Industry and Fisheries and is based on the NT AUSRIVAS protocol (Lloyd and Cook, 2002). The macroinvertebrate surveys meet the MMP commitments to survey aquatic invertebrates and to monitor the impact of activities on biota (MRM, 2015a).

Metals and Lead Isotope Ratios in Aquatic Fauna

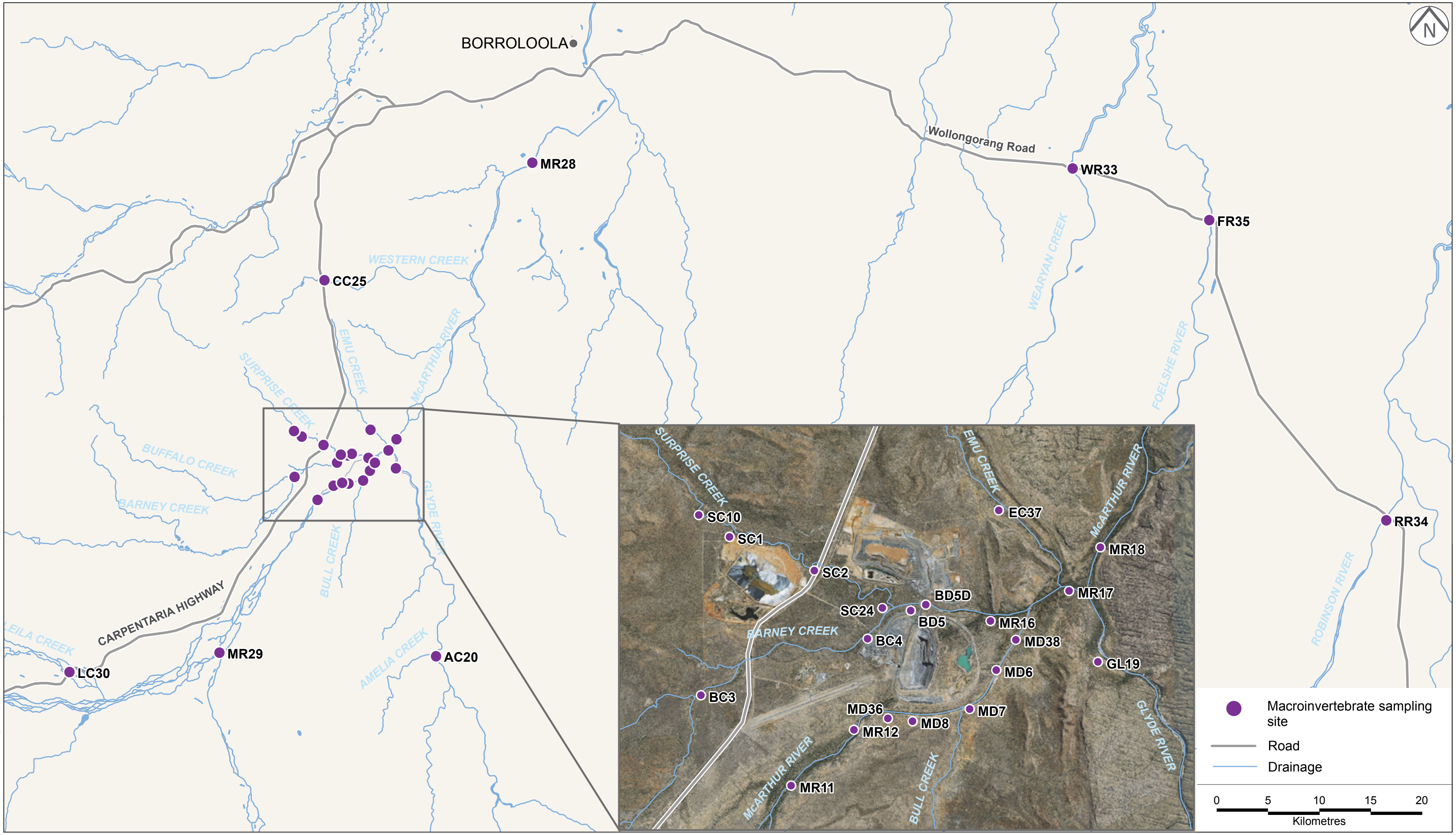
The concentrations of metals and Pb isotopes in aquatic fauna were assessed over the dry season in 2015 (Thorburn, 2015b). Six species of fish (sooty grunter (*Hephaestus fuliginosus*), barramundi (*Lates calcarifer*), bull shark (*Carcharhinus leucas),* bony bream (*Nematalosa erebi),* chequered rainbowfish (*Melanotaenia splendida)* and spangled grunter (*Leiopotherapon unicolor*)), one crustacean species (freshwater prawn, *Macrobrachium* spp.) and the freshwater mussel (*Velesunio angasi*) were collected. Muscle tissue as well as liver (if the individual organism was of sufficient size) was analysed in all fish except for *M. splendida*. In *M. splendida* the trunk (the body with the head, tail, fins and gut removed) was analysed. The tail from prawns and tissue with the gut removed from mussels were analysed. Sites where samples were collected for the monitoring program are shown in Figure 4.29.

Tissue was analysed using inductively coupled plasma mass spectrometry for 16 metals, As and Pb isotope ratios for 207Pb:206Pb and 208Pb:206Pb. Assessing Pb isotope ratios tests whether aquatic organisms are bioaccumulating mine ore-derived Pb, which has elevated isotopic ratios compared to the average for naturally occurring Pb. This can be used to determine whether Pb is entering the environment as a result of McArthur River Mine operations. Due to other areas in the region with naturally elevated Pb isotopic ratios similar to that of the McArthur River Mine orebody, the McArthur River area is not ideal for using Pb isotope ratios to determine sources of contamination. However, using this approach does give a good indication of whether or not ore-derived Pb is entering the system, as long as the results are interpreted cautiously.

MACROINVERTEBRATE SAMPLING SITES IN 2015

McArthur River Mine Project

FIGURE 4.28



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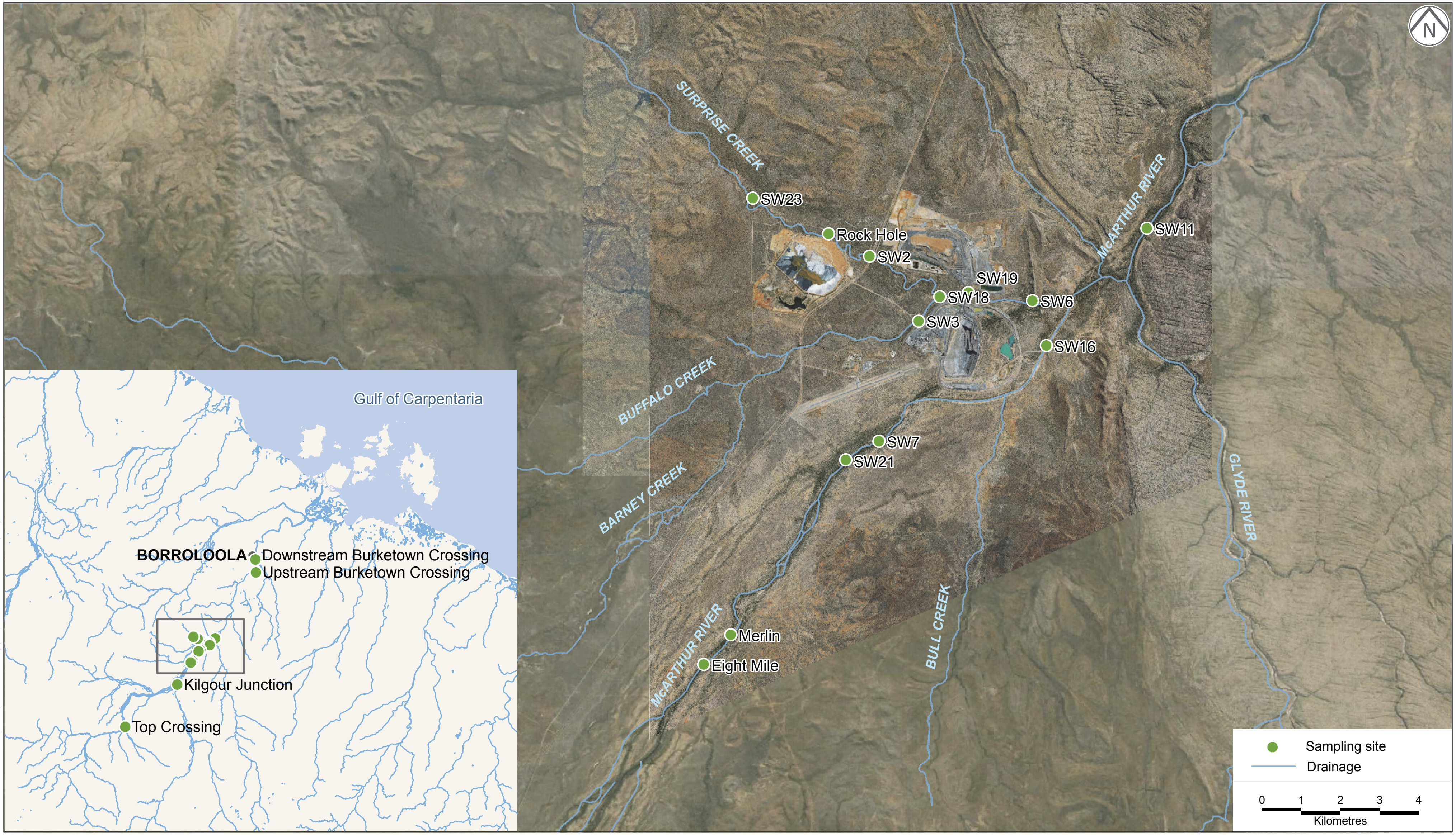
LOCATIONS SAMPLED FOR AQUATIC BIOTA AS PART OF THE METAL AND LEAD ISOTOPE RATIOS MONITORING PROGRAM

McArthur River Mine Project

FIGURE 4.29



Source: Thorburn, 2015b

Samples are collected annually to assess metal concentrations in aquatic fauna and whether concentrations within and downstream of the mine site are higher than those found at undisturbed reference sites. At the request of the DME, Thorburn (2015b) on behalf of MRM has modified the assessment approach to focus on comparison of median concentration values, rather than maximum permitted concentrations under the Australia New Zealand Food Standards Code (FSANZ, 2015). However, mean concentrations and maximum permitted levels of metal contaminants (FSANZ, 2015) were also assessed in 2015 to provide context and enable comparison with previous years.

The assessment of metal concentrations in biota meets commitments in the MMP (MRM, 2015a) to monitor contamination of the aquatic environment. In response to elevated levels of Zn and Pb in fish collected from SW19 adjacent to the Barney Creek haul road bridge in 2012 and 2013, the IM recommended adding higher trophic level fish targeted by fishers to the monitoring program. As a result, barramundi (*L. calcarifer*) and sooty grunter (*H. fuliginosus*) were last minute additions to the 2014 monitoring program and were only collected from a handful of sites. For the 2015 survey, they were included as part of the entire monitoring program. In 2015, bull sharks (*C. leucas*) were added to the program. As recreational fishers often target these fish, the IM and the DME wanted to investigate whether these fish were also accumulating metals. If metals were elevated in these fish, this could potentially pose a health risk to local fishers.

New sites along Surprise and Barney creeks were added to the monitoring program to better assess the distribution of contaminated biota in these creeks.

Monitoring metals and Pb isotopes also helps to assess whether commitments to minimise dust, soil, and surface water and groundwater contamination as a result of operations are being met (MRM, 2015a).

4.10.3.2 New Controls – Implemented and Planned

Modified Electrofishing Surveys

The increasing complexity of the McArthur River diversion channel has allowed a new approach for the 2015 electrofishing surveys. Rather than treating all habitats within, upstream and downstream of the McArthur River diversion channel as equal, where possible habitats were split into complex and bare bank, as the availability of habitat is thought to be the most important factor inhibiting fish abundances and diversity in the diversion channel. However, there is no bare bank habitat upstream of the diversion that can safely be electrofished, and during the late dry season, bare bank sites downstream of the diversion were dry. Fish abundance and diversity was lower at bare bank habitats both within and upstream/downstream of the diversion channel. Complex habitats supported similarly diverse and abundant fish communities within and upstream/ downstream of the diversion (Table 4.41). Analysis of similarity (ANOSIM) on early dry season data indicated that differences between bare bank sites and complex habitats were statistically significant, with one exception between the diversion channel and upstream sites due to the high abundance of *Amniataba percoides* at both sites influencing the diversity values and subsequent analysis. Bare bank sites within and upstream/downstream of the diversion were comparable (i.e., the difference was not statistically significant). Similar patterns were found in the late dry season. Where complex habitat is provided, the fish communities in the McArthur River diversion channel are not statistically different to areas upstream/downstream of the diversion.

This new approach further highlights the importance of complex habitats for fish communities. Large-scale additions of long, continuous patches of LWD, like the program in late 2014, should be continued as such additions greatly improve the availability of complex habitats in the diversion with major benefit to the fish community.

Table 4.41 – Electrofishing Catch Upstream, Downstream and Within the McArthur River Diversion Channel During the 2015 Aquatic Surveys

Section	Upstream		McArthur River Diversion Channel				Downstream		
Habitat	Complex Habitat		Bare Bank		Complex Habitat		Bare Bank	Complex Habitat	
Season	ED	LD	ED	LD	ED	LD	ED	ED	LD
Density of fish (per metre)	2.59	6.81	1.16	0.51	2.37	6.55	0.4	3.13	4.16
Diversity (species)	13	9	9	8	10	8	4	10	7
Density of *Macrobrachium* (per metre)	1.01	0.67	0.32	0.44	0.4	0.23	0.03	0.72	0.12

Notes: ED – early dry season survey. LD – late dry season survey.

Additional Monitoring Sites and Species

The inclusion of both additional monitoring sites along Surprise and Barney creeks and larger fish species that are targeted by fishers in the aquatic biota monitoring program are excellent improvements. Adding new sites along Surprise and Barney creeks has identified other potential sources of contamination leading to elevated loads of metals in biota, such as the TSF, SPROD and ROM pad, in addition to the Barney Creek haul road bridge. Adding larger fish targeted by fishers to the program has provided information as to whether contaminants are moving up the food chain and if there are potential human health effects associated with eating fish from the McArthur River outside the mine area.

Investigation of Potential Health Effects

During the current reporting period, the DME commissioned two reports into potential health affects of consuming fish from the McArthur River, i.e., Skov (2015) and Hydrobiology (2016). These reports indicate that there is a low risk to human health from eating biota from McArthur River, particularly given known and/or modelled consumption patterns. Hydrobiology (2016) notes that ‘even the most ardent fisherperson is not going to breach the tolerable intake of a particular contaminant in the study area’.

Decommissioning of ELS and Upgrade of SPROD

In addition, potential sources of contamination are being eliminated at the mine site. The ELS dam has been decommissioned due to potential seepage into the McArthur River diversion channel above SW16. The SPROD, which was seeping large volumes of water into Surprise and Barney creeks, was drained in 2015 and its clay lining improved, and during the 2016 dry season it will be lined with HDPE. Both these measures should reduce contaminant loads entering watercourses around the McArthur River Mine.

Installation of LWD

McArthur River Mining plans to install more LWD along the diversion channel during the 2016 dry season in a single or few long section(s) of the diversion. The exact location(s) is yet to be determined.

4.10.4 Review of Environmental Performance

4.10.4.1 Incidents and Non-compliances

Incidents

Waste Discharge License Exceedances

Electrical conductivity (EC) trigger values were exceeded on the 18 and 25 November 2014, and almost weekly from 17 June 2015 until the end of the current reporting period in September 2015. These exceedances were largely driven by low flow in the McArthur River. However, EC and sulfate levels suddenly jumped between sites SW15 and SW16 in the McArthur River diversion channel. McArthur River Mining attributes this jump in EC to subsurface mineralisation along the diversion. However, this would also coincide with potential locations of seepage discharge from the ELS water storage dam. Further work is required to determine the source of sulfates and other salts in this section of the McArthur River Diversion (see Section 4.3 for further information).

Trigger values for dissolved oxygen and aluminium were exceeded three times each in January. These exceedances were not related to MRM's activities and are likely due to initial wet season flows in the McArthur River.

These exceedances were unlikely to have any effect on aquatic biota, as biota in northern Australia is relatively well adapted to peaks in salinity and low oxygen levels at the end of the dry season. Data from the late dry season survey indicates that fish communities at SW16 were not impacted by elevated salinities during the reporting period.

Fish Kill at South Eastern Levee

While taking water quality measurements on 4 February 2015, MRM personnel observed over 500 dead fish in the southeastern levee (SEL). The fish died of asphyxiation as a result of low water levels, high water temperatures and a high percentage of organic matter leading to very low oxygen levels. Immediately following the incident, the dissolved oxygen level in the water in the SEL was very low, measuring 2.9% saturation compared to 113% on 7 January 2015 and 150% on 9 Feb 2015.

Water began being pumped out of the SEL within the water management system (WMS) prior to the fish kill on 16 January 2015. The pumps were switched off on 2 February 2015 leaving the SEL with very little water. Two days later the oxygen in the water had depleted to lethal levels. In addition to the direct (asphyxiation) and indirect causes (low water levels, high temperatures and abundant organic matter) of the fish kill, the incident report noted that the lack of consideration of fish in the management of the water management system was a 'system/cultural cause' of the kill. Based on the findings, MRM classed the fish kill as an act of nature.

The SEL was designed to be overtopped in a 1 in 3 year flood event and as a result is regularly overtopped by floodwaters (Plate 4.8), leading to regular mixing of captured runoff with floodwaters. During the 2013-2014 wet season, it was breeched three times allowing 300 ML of floodwaters behind the levee. It is likely that fish also swam over the levee at this time.

Plate 4.8 – SEL in April 2016 (Numerous Fish Were Visible at the Site)

The SEL was originally designed to contain seepage from the east side of the NOEF and also to provide minor flood protection (MRM, 2015c). The former purpose (capture of NOEF seepage) was superseded by the SE Bund, which was constructed to the west of the SEL around Q2 2015 (MRM, 2015d). McArthur River Mining has advised that since this time, the SEL has been used as a holding and staging pond for managed release water collected from sediment traps and borrow pits to the northeast of the NOEF. The multi-purpose function (and later changed function) of the SEL may have resulted in incident reporting being inconsistent. The initial incident report said that the SEL was to protect the NOEF from floodwaters. However, while providing additional information to the DME, MRM subsequently reported that the SEL was constructed to catch runoff during rainfall events and intercept NOEF leachate.

The intended purpose/s of the SEL at the time of the incident reflect on the implications of that incident. In terms of the SEL being a floodwater protection levee, the fish kill is not of particular concern since fish kills are common in the ephemeral watercourses of northern Australia as many waterholes contract and water temperatures increase in the lead up to the wet season. However, it does raise concerns regarding the value of a flood protection levee that is regularly overtopped and, potentially, the role and need for the SEL in relation to floodwaters should be reviewed.

In terms of the SEL's other purpose (at the time of the incident) to capture potentially contaminated seepage, the fish kill incident was of more concern. However, the IM considers that MRM's subsequent actions in relation to construction of the SE Bund and the changed purpose of the SEL are appropriate controls to reduce the risk of potential contamination of the environment and biota at this site.

Non-compliances

The revised interim 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances.

4.10.4.2 Progress and New Issues

Freshwater Fauna Surveys

Results of the aquatic surveys are outlined in Table 4.42. No sawfish were caught in the early dry season survey and no juvenile sawfish were caught over the current reporting period, likely due to the poor wet season. This is consistent with data from previous years in the McArthur River and other rivers of northern Australia, which indicates that sawfish recruitment is positively correlated with the intensity and duration of the wet season. In addition, recruitment of juvenile sawfish may have been reduced by the large numbers of bull sharks (*Carcharhinus leucas*), which are known to predate on juvenile sawfish, which were congregated at Burketown Crossing. In the late dry season survey, two large sawfish (over 2.5 m in length) were caught in the McArthur River near Burketown Crossing. Based on the size of these individuals, they are thought to have entered the river in the above average 2010-2011 wet season, and are preparing to navigate back downstream to the sea. This indicates that the McArthur River supports juvenile sawfish for several years until they grow large enough to return to sea.

In the 2015 surveys, marine-dependent fish continue to be caught within and above the diversion channel, indicating that these species are able to traverse the diversion channel. Two barramundi, 17 bull sharks and 2 sawfish were tagged in the 2015 surveys. No tagged fish were recaptured during the routine monitoring program, although MRM has advised that tagged fish were recaptured in other monitoring programs.

Table 4.42 – Number of Species of Bony Fish and Elasmobranchs and Abundance of Fish Caught During Aquatic Fauna Surveys at All Sites from 2012 to 2015

	2012		2013		2014		2015	
	ED	LD	ED	LD	ED	LD	ED	LD
Number of species of bony fish	30	23	31	28	28	30	27	17
Number of species of elasmobranch	2	2	1	2	2	2	2	2
Total number of fish caught	1,596	1,954	2,194	5,152	2,214	4,933	2,953	2,858
Number of sawfish caught	3	1	0	1	3	2	0	2

Notes: ED – early dry season survey. LD – late dry season survey.

Consistent with survey data since 2008, in 2015 the aquatic communities of the McArthur River diversion channel continue to be impaired compared with the original channel, and this is largely driven by the absence of suitable habitat. During the 2015 early dry season survey, catches of fish in the McArthur River diversion channel using standardised fyke netting (i.e., the same method each year) were 3.67 fish per net per night, compared to 16.78 fish upstream of the diversion and 7.67 downstream (Table 4.43).

Table 4.43 – Fyke Net Catch Upstream, Downstream and Within the McArthur River Diversion During Early Dry Season Surveys in 2014 and 2015

	Upstream		McArthur River Diversion Channel		Downstream	
	2014	2015	2014	2015	2014	2015
Number of fish per net per night	3.17	16.78	2.00	3.67	3.83	7.67
Diversity (species)	7	10	9	9	10	7
Macrobrachium per net per night	8.00	6.11	1.33	5.56	22.0	9.67

Fyke catch in the McArthur River diversion channel had improved slightly in 2015 compared to the historic low of 2014 (2.0 fish per net per night, see Table 4.43). However, fyke net catches remain below those recorded between 2009 and 2013 (an average 7.08 fish per net per night) and 47.4 in the original river channel before the diversion channel was built. The reduced abundance in 2014 and 2015 compared with 2009 to 2013 was likely associated with the low flow rates in the river resulting in reduced fish movement, since fyke nets predominantly catch fish that are moving up and downstream. The most numerous species before the diversion (gobies [*Glossogobius* spp.], giant gudgeon [*Oxyeleotris selheimi*] and chequered rainbowfish [*Melanotaenia splendida*]) have declined in abundance in the McArthur River diversion channel, and are no longer the most abundant species. Mobile predatory fish have increased their relative abundances in the diversion channel. Potentially, these predators are performing well in the diversion channel as the lack of complex habitat and shelter allow predators to easily locate and catch prey. Due to very low water levels, fyke nets were not used in the late dry season 2015 survey.

Macrobrachium spp. were far more abundant in 2015 compared to the previous year (see Table 4.43). For the first time, abundances were only slightly lower in the diversion channel compared to natural sites. This may be related to the addition of large amounts of woody debris into the lower end of the diversion channel creating much more suitable habitat for *Macrobrachium*. As mentioned above (Section 4.10.3.2), when complex habitat is provided, the diversion performs well.

In the early dry season survey, diversity in the limited number of sites sampled along the Barney Creek diversion channel appears to be similar to sites upstream in Barney and Surprise creeks. Abundance data is not presented from these sites and there is no statistical analysis of the potential impacts of the Barney Creek diversion channel. Due to the lack of water, sites were too dry in the Barney Creek diversion for a meaningful comparison using the late dry season data.

Overall, these results indicate that McArthur River and its tributaries continue to support a diverse and regionally representative freshwater fish community. Outside the diversion channels, MRM's operations do not appear to be having an impact on fish communities. Within the McArthur River diversion channel, where complex habitat is provided, fish communities and *Macrobrachium* abundances are similar to natural areas outside the diversion channel. However, throughout the majority of the diversion channel there is little or no complex habitat and, as a result, aquatic fauna communities continue to be impaired, indicating that the diversion channel is still in the early stages of establishing appropriate habitat. The high number of predators and low levels of cover in the diversion channel suggests that predation is likely high and lack of habitat is restricting fish communities. Results show marine vagrants and migrants, such as barramundi, are able to traverse the diversion channel. However, it is unclear whether they can only traverse the diversion channel while the floodplain is inundated, and if smaller fish can traverse through the diversion at all.

Macroinvertebrate Surveys

Surface Water and Fluvial Sediments

Multi-dimensional scaling (MDS, a visualisation of the degree of similarity between sites) of surface water and fluvial sediment data in 2015 divided survey sites into three groups with similar water chemistry, roughly equating to:

- Regional reference sites on Caranbirini and Amelia creeks and the Glyde River.
- Remaining major river sites including the McArthur River and the McArthur River diversion channel, Surprise Creek above the TSF (SC1 [equivalent to SW01 surface water monitoring point] and SC10 [SW26]) and Leila Creek.
- Sites on Barney Creek above (BC3 [SW04] and BC4 [SW03]), within (BD5 [SW18] and BD5D [SW19]) and below (MR16 [SW06]) the Barney Creek diversion channel and SC2 (SW02) and SC24 (SW24) on Surprise Creek below the TSF.

These results indicate that the chemistry of surface water and fluvial sediment from sites in the McArthur River diversion channel and reference sites was similar. Pairwise tests confirm that there were no statistically significant differences between the McArthur River diversion channel and reference sites in water chemistry. However, at site MD6 (SW16) in the diversion channel, salt-related parameters (e.g., EC and sulfates) were elevated compared to other sites. Barden (2015) indicates that this is possibly due to inflows of groundwater into the mid to downstream end of the diversion channel in the vicinity of mineralised sub-surface geology. However, this also correlates with the location of potential seepage pathways from the ELS dam.

PERMANOVA analyses found a statistically significant difference between minor drainage line regional reference sites and the sites on Barney and Surprise creeks within and below the TSF, NOEF and the ROM pad and associated ore stockpiles. Consistent with the previous operational year, sulfates are particularly elevated at sites below the TSF and SPROD (MR16, SC24, BD5, BC3). Sites affected by dust emissions from the Barney Creek haul road bridge (BD5 and BD5D) and the ROM pad and associated stockpiles (BC4) had elevated levels of Zn and Pb. These results are consistent with previous years where salts and metals are elevated at these sites due to MRM's activities.

Edge Macroinvertebrates

Multi-dimensional scaling plots for edge macroinvertebrates revealed three distinct communities:

- Reference sites and the McArthur River diversion channel.

- Sites below the SPROD to the confluence of Barney Creek and McArthur River (SC24, BD5, BD5D and MR16).
- Sites on Surprise Creek above the SPROD and Barney Creek above the Barney Creek diversion channel.

PERMANOVA analyses found a statistically significant difference between edge macroinvertebrate communities in the reference minor drainage lines and exposed/diversion channel minor drainage lines, with exposed sites having lower diversity. These patterns are largely due to reduced water quality related to increased salinity and modified habitat on Surprise and Barney creeks below the TSF and ROM pad. These patterns are consistent with previous years.

Within the McArthur River, there were three distinct groups of edge macroinvertebrate communities. These equated to the McArthur River diversion channel, McArthur River reference sites and MR12 just above the McArthur River diversion channel. The diversity of edge macroinvertebrates in the McArthur River diversion channel was lower compared to reference sites. This difference is statistically significant, and likely related to the lack of proper edge habitat (no established riparian vegetation, low sinuosity and atypical bank structure). Site MR12, located just above the McArthur River diversion channel, has reduced edge macroinvertebrate abundance compared to reference sites, as bank and in-stream structures are being impacted by erosion moving upstream from southern end of the diversion.

Overall, edge macroinvertebrate diversity declined between 2014 and 2015. The lowest diversity scores were from sites in the Barney Creek and McArthur River diversion channels, and abundance scores were generally lower at impacted sites.

Riffle Macroinvertebrates

A reduced number of sites were sampled for riffle macroinvertebrates as a result of poor flows associated with the short and weak wet season. Multi-dimensional scaling plots for riffle invertebrates again reveal three distinct communities:

- Reference sites and the McArthur River diversion channel.
- Sites on Surprise and Barney creeks below the TSF (SC24 and BD5).
- Site BD5D below the Barney Creek haul road bridge.

The reduced diversity in macroinvertebrate communities at impacted and diversion channel sites on Barney and Surprise creeks compared to reference sites was likely related to impaired water quality (elevated metals and salts), altered habitat in the diversion channel and fine sediment covering riffle habitat. While sites in the McArthur River diversion channel were grouped with reference sites in the MDS plot, further analysis (PERMANOVA) found a significant difference between riffle macroinvertebrate communities in the McArthur River diversion channel and McArthur River reference sites. Riffle macroinvertebrate diversity within the McArthur diversion was reduced compared to reference sites. This is consistent with long-term data which indicates that, while the riffle macroinvertebrates in the McArthur diversion channel normally resemble those found in reference sites, within the McArthur River diversion channel, communities tend to be less resilient in years of high and low flow.

Overall, riffle macroinvertebrate diversity declined between 2014 and 2015. The lowest diversity was found in exposed/diversion sites along Barney and Surprise creeks.

Macroinvertebrate Survey Conclusions

Along the McArthur River diversion channel, the diversity of edge macroinvertebrate communities is impaired due to a lack of suitable habitat and riffle macroinvertebrate diversity is less resilient to environmental perturbations in years of high and low flows. Edge habitats within the McArthur River diversion channel are less diverse and tend to support macroinvertebrate communities more typical of riffle habitats. This is likely due to the absence of natural edge habitat in the diversion channel (e.g., overhanging vegetation, root mats, plant litter). Even at the downstream and upstream ends of the diversion channel, where rehabilitation efforts have been extensive, communities are less diverse. While not surprising given the relatively recent construction of the McArthur River diversion channel, it indicates that ongoing work is required to accelerate rehabilitation of the diversion channel to a condition approaching that of the McArthur River itself. Programs revegetating the riparian zone and adding large and small woody debris need to continue. Of concern for the first time was impaired water quality (particularly sulfates and salts) in the diversion channel at site MD6. This is possibly due to groundwater inflows in the vicinity of mineralised sub-surface geology, but also potentially due to seepage from the ELS water storage. In addition, bed erosion travelling upstream from the southern end of the diversion channel is affecting macroinvertebrate communities immediately upstream of the McArthur River diversion channel (site MR12).

The reduced diversity of macroinvertebrate communities at impacted sites along Barney and Surprise creeks due to the effects of impaired water quality is of concern. Sites between the SPROD and the junction of Barney Creek with the McArthur River diversion channel have elevated levels of sulfate potentially due to seepage from the TSF and the SPROD (EMS, 2015). Site BC3 on Barney Creek (upstream of the Carpentaria Highway) also has elevated sulfate for the first time in this survey; this should be investigated. Sites BC4, BD5, BD5D and MR16 had elevated concentrations of Zn and Pb, which may relate to dust emissions and/or contaminated runoff from the ROM pad and/or Barney Creek haul road bridge.

It is noted by EMS (2015) that poor surface water quality is likely to have negatively impacted macroinvertebrate edge assemblages at site MR16 in the old McArthur River channel, downstream from the Barney Creek haul road bridge but upstream from the confluence with the McArthur River diversion channel. Other influences at this location are likely to include changes to stream flow and channel structure since construction of the McArthur River diversion channel, and sediment deposition. This indicates that metal contaminants are travelling downstream from points of contamination where they may enter the trophic cycle, potentially impacting larger fauna (e.g., *Macrobrachium* and fish).

Dust emissions from the ROM pad may be reducing the diversity of macroinvertebrate communities at site BC4. Metal concentrations are elevated at site BD5D, potentially due to dust emissions and/or runoff in the vicinity of the Barney Creek haul road bridge.

The SPROD was recently identified as a major source of seepage (see Section 4.5), which may have increased salt-related parameters at sites SC24 and BD5. The SPROD will be lined in 2016, which should reduce salt-related parameters. As MRM is taking steps to reduce seepage from these sources, it is expected that water quality will improve. However, as it appears the ROM pad is the likely source of contamination at sites BC4 and SC24, further work is required to minimise potential emissions from this site. As few minor drainage line reference sites were visited, inferences drawn regarding macroinvertebrate communities in Surprise and Barney creeks should be interpreted with caution. However, as the results of the macroinvertebrate surveys from Barney and Surprise creeks are consistent with those recorded in previous years, they indicate that macroinvertebrate communities at exposed sites on these creeks are affected by operations.

Metals in Freshwater Biota

This report section refers to exposed sites, i.e., sites that may be exposed to contaminants in the immediate vicinity of McArthur River Mine (sites adjacent to or downstream of the TSF and ROM pad [SW02, SW03, SW06, SW18 and SW19] and SW16 on the McArthur River diversion channel). Other sites further from mining activities and will be referred to as reference sites.

Lead in Freshwater Biota

Concentrations of Pb were elevated in biota from six exposed sites (Table 4.44). The 22 highest concentrations of Pb were all from exposed sites, and 36 of the highest 40 Pb concentrations were from exposed sites. The maximum permitted concentration (MPC) for Pb was exceeded at SW19 (adjacent to Barney Creek haul road bridge) in all muscle tissue samples for *N. erebi*, three out of four liver samples from *H. fuliginosus* and one of five *M. splendida.* Lead isotope ratios in biota were elevated at SW19, indicating that the Pb from the mine is the likely cause of contamination at this location. Concentrations of Pb in *M. splendida* trunks at SW19 have dropped considerably since 2013, as have concentrations in *N. erebi* muscle since 2014 (Table 4.45), likely due to controls implemented by MRM. These controls include:

- Sediment traps installed at the Barney Creek haul road bridge to capture contaminated runoff and sediments that are washed off the haul road during rain events and by water trucks spraying roads to suppress dust.
- Excavating sediments from the creek bed at SW19 at the end of the dry season to remove contaminants that may be deposited at the site. The pool at SW19 effectively operates as a natural sediment trap where contaminated sediments may settle out of the water column, as the creek gets slightly wider and deeper at this point, and flow rates reduce.
- Installing a bund at SW19 and pumping water captured in the bund to the WMS. McArthur River Mining argues that any flow at SW19 after the wet season is contaminated seepage from the TSF and SPROD, so it needs to be captured. Without this seepage there would be no flow, so MRM is only depriving water from sites which would not naturally have flow. In addition, the bund allows contaminated sediments to settle out of the water column, to be excavated at the end of the dry season. However, the relative contribution of seepage and natural sources to flow rates in Surprise and Barney creeks should be investigated and, if necessary, clean water should be added to Barney Creek below the SW19 bund.
- Efforts by MRM to reduce seepage from the TSF and the SPROD.

Table 4.44 – Sites and Biota with Elevated Concentrations of Metals in 2015 (Compared to the Same Species from the Same Sites in Previous Years) (mg/kg)

Metal and MPC#	Site	Organism	2015				2014			2013		
			All Values from Site	Mean	Median	Species Mean*	Mean	Median	Max.	Mean	Median	Max.
Pb Fish – 0.5, Crustaceans – 1.5, Molluscs – 2.0	SW19	*N. erebi*	**2.4, 2.3, 1.8, 1.7, 1.7**	2.0	1.8	0.3 (0.02)	3.84	2.7	8.9	NA	NA	NA
		H. fuliginosus (liver)	**1.20, 0.86, 0.71**, 0.36	0.78	0.79	0.11 (0.006)	NA	NA	NA	NA	NA	NA
		M. splendida	**0.59,** 0.49, 0.36, 0.30, 0.23	0.39	0.36	0.12 (0.048)	0.68	0.62	0.9	2.16	1.4	4.7
	SW18	*M. splendida*	**0.51,** 0.48, 0.41, 0.40, 0.36	0.43	0.41	0.12 (0.048)	NA	NA	NA	NA	NA	NA
		H. fuliginosus (liver)	0.17, 0.16, 0.13, 0.13, 0.062	0.13	0.13	0.11 (0.006)	NA	NA	NA	NA	NA	NA
		L. unicolor	0.048, 0.036, 0.013, 0.008, 0.002	0.021	0.013	0.007 (0.003)	NA	NA	NA	NA	NA	NA
	SW03	*N.erebi*	0.36, 0.27, 0.27, 0.24, 0.12	0.25	0.27	0.3 (0.02)	NA	NA	NA	NA	NA	NA
		Macrobrachium	0.073, 0.031, 0.012, 0.008, 0.006	0.03	0.012	0.009 (0.007)	NA	NA	NA	NA	NA	NA
	SW16	*N. erebi* (liver)	0.26	0.26	0.26	0.09 (0.06)	NA	NA	NA	NA	NA	NA
	SW02	*M. splendida*	0.24, 0.19, 0.11, 0.10, 0.10	0.15	0.11	0.12 (0.048)	0.038	0.036	0.057	0.068	0.066	0.1
	Surprise Ck RH†	*L. unicolor*	0.023, 0.022, 0.014, 0.002	0.015	0.018	0.007 (0.003)	NA	NA	NA	NA	NA	NA
	SW23	*M. splendida*	0.2, 0.19, 0.095, 0.025, 0.023	0.11	0.095	0.12 (0.048)	0.032	0.031	0.041	0.085	0.057	0.22
	SW11	*V. angasi*	**2.2**	2.2	2.2	0.3	NA	NA	NA	NA	NA	NA
	SW21	*V. angasi*	0.5, 0.31	0.41	0.41	0.3	NA	NA	NA	NA	NA	NA

Table 4.44 – Sites and Biota with Elevated Concentrations of Metals in 2015 (Compared to the Same Species from the Same Sites in Previous Years) (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2015				2014			2013		
			All Values from Site	Mean	Median	Species Mean*	Mean	Median	Max.	Mean	Median	Max.
Cu (no MPCs apply)	8 Mile	*L. calcarifer* (liver)	210, 29, 27, 23, 16, 13, 5.1	64	23	22	3.5	2.5	8.6	NA	NA	NA
		N. erebi (liver)	16, 14, 12, 10, 6.8	11.8	12	24.3	NA	NA	NA	NA	NA	NA
		Macrobrachium	10, 9.8, 7.6, 7.4, 7.4	8.4	7.6	10.0	6.8	6.6	7.6	7.83	7.7	8.3
	SW16	*N. erebi* (liver)	87	87	87	24.3	NA	NA	NA	NA	NA	NA
		L. calcarifer (liver)	44, 15, 11, 9.4, 8.4, 3.2	15.2	10.2	22	6.7	2.4	22	NA	NA	NA
		Macrobrachium	19, 15, 12, 8, 6.2	12	12	10.0	6.7	6.0	8.8	7.26	7.4	8.2
	SW21	*Macrobrachium*	22, 14, 12, 11, 11	14	12	10.0	7.6	8.0	9.8	11.0	10	18
	SW03	*Macrobrachium*	17, 14, 13, 11, 8.5	12.7	13	10.0	NA	NA	NA	NA	NA	NA
	SW11	*Macrobrachium*	15, 11, 11	12.3	11	10.0	7.3	6.9	8.9	5.8	5.8	5.9
	Kilgour Junction	*L. calcarifer* (liver)	13, 7.9	10.5	10.5	22	8.9	8.9	8.9	NA	NA	NA
	SW08	*Macrobrachium*	13, 7.2, 6.1	8.8	7.2	10.0	7.85	7.1	12	5.6	5.6	5.6
Zn (no MPCs apply)	SW11	*V. angasi*	62	62	62	31.3	NA	NA	NA	NA	NA	NA
As (MPC cannot be applied**)	DS† of SW08	*C. leucas* (liver)	3.0, 0.72, 0.31	1.3	0.72	1.5	NA	NA	NA	NA	NA	NA
	US† of SW08	*C. leucas* (liver)	2.7, 1.0	1.85	1.85	1.5	NA	NA	NA	NA	NA	NA
		V. angasi	1.4, 0.93, 0.85, 0.78, 0.66	0.92	0.85	0.82	NA	NA	NA	1.4	1.4	1.4

Notes: Concentrations are taken from muscle tissue unless stated, except in the case of M. splendida where concentrations are taken from the whole trunk of the animal. **Bold** values indicate concentrations exceed the MPC. Shaded cells are in the immediate vicinity of McArthur River Mine, and as a result may be exposed to higher levels of contamination. Concentrations were below detection limits in some biota. To determine the mean, these individuals were conservatively given the value of the detection limit, even though concentrations may well have been lower.
[#]MPC = Maximum permitted concentration value for fish, crustaceans and molluscs. FSANZ (2015) does not include MPCs for Cu or Zn..
*Mean value concentration for this species for the entire 2015 survey. Values in parentheses represent the mean concentration from all reference sites, that is, sites away from the influence of the mine.
[†]RH = rock hole; US = upstream; DS = downstream.
**MPC for As is for inorganic As only; results for As are for Total As, as such MPC cannot be applied.

Table 4.45 – Exceedances of Pb MPCs in Aquatic Fauna at SW19 (2012 to 2015)

Organism	Year	Number Exceeding MPC*	Concentration (mg/kg)		
			Exceedance Values	Mean	Median
M. splendida (trunk)	2012	2 of 4 caught	1.3, 0.6	0.6	0.8
	2013	5 of 5 caught	4.7, 2.1, 1.4, 1.4, 1.2	2.2	1.4
	2014	4 of 5 caught	0.9, 0.9, 0.6, 0.6	0.7	0.6
	2015	1 of 5 caught	0.6	0.4	0.4
L. unicolor (muscle and trunk)	2013	4 of 5 caught	1.8, 1.5, 0.6, 0.5	1.0	0.6
L. unicolor (liver)	2014	1 of 1 caught	0.5	0.5	0.5
N. erebi (muscle)	2014	5 of 5 caught	8.9, 2.8, 2.7, 2.6, 2.2	3.8	2.7
	2015	5 of 5 caught	2.4, 2.3, 1.8, 1.7, 1.7	2.0	1.8
Macrobrachium spp.	2012	1 of 1 caught	2.9	2.9	2.9
H. fuliginosus (liver)	2015	3 of 4 caught	1.2, 0.9, 0.7, 0.4	0.8	0.8

For the first time, the MPC for Pb was also exceeded at another exposed site, SW18, at the confluence of Surprise and Barney creeks. A single *M. splendida* from this site exceeded its MPC. Sites SW18 and SW19 are in close proximity, and Thorburn (2015b) considers it possible that despite the very shallow riffle zone between the two sites, fish including *M. splendida* may be actively moving between the sites. However, as concentrations in other *M. splendida* from this site were also elevated at levels close to the MPC, this contaminant load may have accumulated at this site alone. Lead concentrations were also elevated in *L. unicolor* muscle tissue and *H. fuliginosus* livers from this site. In addition, lead isotope ratios were elevated, indicating that mine-derived ore was probably the source of the elevated concentrations of Pb at SW18.

Lead concentrations in biota at three more sites (SW02, SW03 and Surprise Creek Rockhole) were also elevated compared to reference sites. Lead isotope ratios indicated that contaminants at SW02 and SW03 were likely mine-derived (see Table 4.44). In addition, Pb was elevated in the liver of a single *N. erebi* from SW16, but the isotopic ratios did not indicate that mine-derived ore was the source of contamination in this individual (see Table 4.44).

Finally, Pb was above the MPC in the single mussel collected from SW11. Lead isotope ratios in this individual were elevated compared to other mussels, indicating that mine-derived Pb might be accumulating in this individual. Zinc in this individual was also the highest recorded of the 15 mussels collected during the monitoring program (see Table 4.44). The elevated Pb and Zn in this individual may indicate mine-derived contaminants are migrating downstream in low concentrations, which are then only measurable in efficient bioaccumulators like mussels. However, as it is the first mussel collected from this site, it is impossible to draw any strong conclusions.

The monitoring in 2015 was the first year that included more fine-scale sampling in Barney and Surprise creeks. It suggests that Pb contamination is widespread in these two creeks adjacent to, and downstream of, the TSF and the ROM pad, with dust and/or seepage from MRM's infrastructure being potential causes. For example, in Surprise Creek, Pb isotopic ratios increase from the lowest on average of any site of the entire survey at SW23, to elevated above all reference sites at SW02 and then almost identical to that of the ore body at SW18. Unfortunately, all known waterholes on Barney Creek above the mine site were dry at the time of sampling, so comparisons with sites upstream of the mine in this creek were not possible.

Although there is evidence of contamination in the vicinity of the mine site, the majority of biota collected had concentrations of Pb and other metals well below their respective MPCs. Fish with the highest concentrations of Pb in their muscle tissues were either very small (*M. splendida*, generally <5 g) or generally small and very unpalatable (*N. erebi*). If one were to consume *L. unicolor* livers (not commonly consumed) and *Macrobrachium* spp. (cherabin) with the highest recorded concentrations in this survey, very large amounts of flesh (at a minimum roughly 400 g for a 16 kg toddler, 1.2 kg for a 70 kg adult) would need to be consumed daily for any potential health impacts to occur. Similarly, it is highly unlikely that human health impacts would result from consumption of *H. fuliginosus* livers, given that: a) there is no record of people consuming these organs; b) the livers of a large number of fish would need to be consumed to have an effect; and c) there would be a limited number of fish present at SW19 given its depth. At sites away from the immediate vicinity of the mine where concentrations of contaminants are much lower, a toddler would need to eat at least 1.4 kg of aquatic biota daily for there to be any potential impacts on human health and adults would need to consume 4.2 kg. Again, this scenario is unlikely and the risk is negligible. To dissuade fishers, MRM has installed 'no entry' signage at potential fishing sites in the immediate vicinity of McArthur River Mine.

In addition, while metals in biota exceeded MPCs for human consumption on occasion, there was no evidence of elevated concentrations causing any potential health effects in the biota.

While it is probable that MRM's operations are largely responsible for elevated Pb concentrations in the sampled biota from Surprise and Barney creeks, there are two possible alternative mechanisms which may contribute to elevated metal concentrations throughout these systems:

- Firstly, fish are migrating from SW19 after receiving a contaminant load at the site. As *M. splendida, N. erebi, H. fuliginosus* and *L. unicolor* are known to move considerable distances, this is doubtless happening in some instances. For example, at SW23, there is circumstantial evidence of some migration from downstream sites, as two rainbowfish had Pb isotope ratios very close to that of the orebody, and well above other fish at the site. However, due to the pervasiveness of elevated concentrations of Pb and raised Pb isotopic ratios at exposed sites on Surprise and Barney creeks, this is unlikely to be the major cause of contamination.

- A second possible cause of the contamination in Surprise and Barney creeks is the natural mineralisation of these creeks and the surrounding catchment. There are exposed areas of galena, a natural mineral form of lead sulfide, in Surprise and Barney creeks. There are unconfirmed anecdotes of prospectors collecting Pb nuggets from Surprise Creek to make bullets back in the 1950s. While this probably adds to the contaminant load in fish from these creeks, MRM's operations are likely a major contributor to contamination in exposed sites.

Even though there is negligible risk to human health from consuming contaminated biota from McArthur River, MRM should consider including the potential movement of contaminated biota between contaminated areas and regional reference sites in its monitoring program. Many freshwater fish (including the fish species – *M. splendida*, *N. erebi* and *L. unicolor* – with elevated concentrations of Pb at SW19) in northern Australia are known to migrate upstream and downstream, especially during flood events when connectivity is maximised. Barramundi migrate from rivers to marine environments when they reach maturity, and the MRM tagging program has demonstrated this in the McArthur River. The report by Hydrobiology (2016) into the potential health effects of contaminated biota in McArthur River recommends that:

> The sampling design needs to take into account the high mobility of fishes in the McArthur River, via use of appropriate analyses and interpretation, such as via considerations of gradients of exposure.

The IM supports this recommendation. In addition the IM recommends completion of a desktop report investigating potential movement of contaminated biota in McArthur River and how long biota needs to spend at exposed sites to uptake elevated levels of contaminants.

Other Metals in Freshwater Biota

Copper results in fish and crustaceans were higher in 2015 than 2014, at both reference sites and exposed sites (see Table 4.44). As Cu is elevated in sites ranging from roughly 20 km upstream of the mine (Kilgour Junction) to 40 km downstream (SW08), elevated levels are unlikely to be caused by MRM's operations (see Table 4.44).

Total As was elevated in bull shark livers caught 1 km downstream or 5 km downstream of SW08. Given that the MPC relates to inorganic As only, it cannot be applied to these total As results. Since these concentrations are from sites at least 40 km downstream of the mine, they are unlikely to be caused by MRM's operations (see Table 4.44).

Monitoring of Large Woody Debris

As for 2014, there was no monitoring of the persistence of LWD in the McArthur River diversion channel in 2015. As MRM has invested considerable time and effort into installing the LWD and the debris supports aquatic communities similar to those found in the natural river channel, it would be in MRM's interest to know what methods work best to keep woody debris in place. The monitoring of debris is a relatively short and simple process.

Diversion Channel Revegetation

Healthy riparian vegetation is essential for ecosystem function in the diversion channels. During the 2016 site visit, the IM noted that revegetation along the waterline in the McArthur River diversion channel had noticeably improved since the previous visit (Plate 4.9). Two poor wet seasons in a row has likely benefitted the revegetation program. Some of the planting in sediment pockets around the LWD at the downstream end of diversion channel had remained in place. Vegetation was creating small patches of shade in the diversion channel which is a positive outcome. Assessment of the stability of the vegetation and LWD following more intense wet seasons will determine whether current rehabilitation approaches are effective in the long term, or whether methods need to be revised.

Despite these improvements, the McArthur River diversion channel continues to underperform compared to reference sites. Canopy cover, ground cover and tree species richness were all much lower in rehabilitation sites compared to reference sites, especially on the riverbank slopes, and erosion is far greater in rehabilitation sites along the diversion channel (EcOz, 2015). While this is unsurprising considering the age of the diversion channel, considerable improvement will be required over many more years to return the diversion channel to a condition approaching that of the surrounding environment. Improvement may require altering of the 'chute-like' structure of the diversion channel to allow debris and soil to accumulate.

Revegetation along the Barney Creek diversion channel is performing relatively well compared to reference sites, likely due to the lower flow rates and shorter periods of high flow compared to the McArthur River diversion channel. However, the slopes have high levels of erosion.

The considerable erosion along both diversion channels will make rehabilitation increasingly difficult.

Plate 4.9 – Habitats along the McArthur River and Barney Creek Diversion Channels

Clockwise from top left: 1. Barney Creek diversion channel at the confluence with Surprise Creek (SW18) looking up Barney Creek. 2. At the same location looking downstream. 3. Good revegetation at the upstream end of the McArthur River diversion channel. 4. Sparse vegetation along the rocky walls of the middle section of the McArthur River diversion channel. 5. Large woody debris, sediment deposits and low vegetation at the downstream end of the McArthur River diversion channel. 6. Reasonable low water shoreline revegetation towards the upstream end of the McArthur River diversion channel.

Riparian vegetation plays a vital role in creating habitat, shading waterways, and reducing flow speeds and erosion in the diversion channel, and lack of such vegetation may create a barrier to dispersal of biota during high flow events and during high water temperatures late in the dry season. Additionally, the lack of in-stream habitat has likely increased predation risk in the McArthur River diversion channel. While there has been improvement in the riparian rehabilitation program, this needs to continue to fully rehabilitate the diversion channels. McArthur River Mining should continue intensive planting of suitable species (such as *Pandanus, Barringtonia* and

Melaleuca) along the riparian zone in the early dry season and in patches of sediment deposited around LWD.

Erosion Upstream of the McArthur River Diversion

There is considerable bed erosion immediately upstream of the McArthur River diversion channel (Site SW07/MR12) (Plate 4.10), and this erosion of the river bed is extending upstream. This erosion is potentially driven by increasing flow velocities immediately upstream of the diversion channel, caused by the high flow velocities in the diversion channel. In addition, damage from cattle and the low-lying sandy land at the site may exacerbate the erosion.

Plate 4.10 – Erosion Immediately Upstream of the McArthur River Diversion Channel (SW7/MR12)

For the first time, the edge macroinvertebrate communities at this site were impacted, most likely as a result of this erosion. Bank and in-stream structures are also being impacted by the erosion at this site. McArthur River Mining should investigate the underlying causes for this erosion (which may be covered as part of the upcoming geomorphological assessment of the McArthur River and Barney Creek diversion channels; (see Section 4.4)), and if it is occurring as a result of the McArthur River diversion channel, mitigation measures should be implemented.

Contamination at SW16

The macroinvertebrate survey highlighted elevated electrical conductivity and sulfates at site MD6 (SW16) in the McArthur River diversion channel, between MD6 and the next site roughly 1,500 m upstream (SW15). This region of the diversion channel was also highlighted as a point of contamination in the trigger value exceedance reports at the compliance point (SW11). McArthur River Mining suggests that the elevated values at this site are due to groundwater inflows in the vicinity of mineralised sub-surface geology of the diversion upstream of SW16. However, this site is also in the immediate vicinity of the unlined ELS water storage, which may seep towards SW16 (see sections 4.3 and 4.5 for further information). This potential contamination is of concern, as it is the first time that mining activities have potentially contaminated surface waters in the McArthur River main channel above trigger values. While the elevated salts are currently not having a quantifiable impact on the diversity and abundance of macroinvertebrates and fish at this site, it may cause an impact in the future. As a result, MRM should investigate the relative contributions of natural processes and potential seepage from the ELS in this section of the diversion.

Progress Against IM Recommendations

McArthur River Mining's performance against previous IM review recommendations relating to aquatic ecology issues are outlined in Table 4.46. It should be noted that the monitoring of metals in aquatic biota, the macroinvertebrate surveys and early dry season fish surveys took place before the release of the 2015 IM report into the 2014 operational period. As a result many of the IM's recommendations could not be incorporated into the monitoring undertaken in the current reporting period.

Table 4.46 – Aquatic Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should conduct a full review and synthesis of the monitoring programs, including metals in aquatic fauna, macroinvertebrates, surface water, groundwater, fluvial sediments, dust and soil to identify additional sources of contamination at the mine site. Potential sources may include dust emissions from the haul road and the processing plant and associated stockpiles and seepage from the ROM sump. Legacy impacts should also be addressed If additional sources of contamination are identified, suitable controls can be implemented	This has not been addressed, each individual monitoring program is treated independently and there is little, if any, synthesis of the overall monitoring program at McArthur River Mine. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013)

Table 4.46 – Aquatic Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Additional monitoring of contaminants along Barney Creek diversion channel	Every effort should be made to monitor aquatic communities along Barney Creek and the Barney Creek diversion channel between SW22 and the McArthur River diversion channel to assess the extent of contamination. The monitoring should be conducted as quickly as possible following the wet season when creeks still contain water. A flexible method should be utilised that allows collections to be made at sites containing water, rather than only at the designated surface water sites, should the surface water sites not contain water	Additional sites along Barney and Surprise creeks were added to the 2015 monitoring program. However, an additional site should be added to the program between SW19 and SW06 An adaptive monitoring program should be maintained to maximise the likelihood of being able to sample these creek lines in dry years
Dam at SW19	The dam constructed to extract water and trap sediment at SW19 is likely having an impact on the aquatic ecosystem downstream of SW19 on Barney Creek diversion channel. It may also be having an impact on the main McArthur River, due to reduced inflows. If the dam remains in place, then the effects on sites downstream should be formally investigated, and potential mitigation strategies, such as pumping water from the water management dam to below the dam at SW19, could be considered	The dam remains in place and MRM has not investigated the impacts on sites downstream of SW19. However, MRM argues that Surprise and Barney creeks continue to flow into the dry season largely due to seepage from the TSF and SPROD. As a result the potentially contaminated water needs to be captured. In addition, sites below SW19 would not naturally receive surface flows far into the dry season. No evidence supporting this latter statement has been provided
Monitoring of aquatic fauna in Barney Creek	Additional monitoring of aquatic fauna in natural sites along Barney Creek or equivalent reference sites and multiple sites in the Barney Creek diversion channel should be included, so the performance of the diversion can be properly assessed	There is still minimal assessment of the performance of the Barney Creek diversion channel. However, effective assessment will be problematic, as few sites on Barney Creek hold water following the dry season
Monitoring LWD	McArthur River Mining should continue annual monitoring of LWD to ensure that the wood remains in position and the best method of establishing LWD sites can be determined. McArthur River Mining should commit to additional large-scale projects to install LWD along poorly revegetated sections of the diversion channel, to ensure continuity of habitat along the diversion In addition, MRM should consider excavation or blasting of lateral bank and central river bottom in areas of poorest rehabilitation to create eddies. Creating eddy sites would facilitate soil deposition and eventual vegetation establishment to improve aquatic habitat	No monitoring of LWD took place during the current monitoring program

Table 4.46 – Aquatic Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods		
Contamination of biota	The IM recommends additional aquatic fauna abundance, diversity and metal concentration monitoring along Barney, Little Barney and Surprise creeks to identify potential sources of contamination. This should include sites SW4, SW22, SW3, SW18, SW6 and SW28 until sources of contamination are determined. This monitoring can also be used to assess the effectiveness of the diversion channel rehabilitation	Many of these sites were added to the 2015 monitoring program. However, several of these sites (SW04, SW22, SW28) do not hold water into the dry season
Drawdown at Djirrinmini Waterhole	An investigation should be undertaken into the impacts of potential drawdown at Djirrinmini Waterhole, and possible mitigation of its impacts, as this is one of the most upstream waterholes visited by freshwater sawfish	No progress has been made with respect to this recommendation
New background Pb isotope ratio	Monitoring would benefit from the establishment of a more regionally relevant background level for Pb isotopes, as for all monitoring sites the average isotopic ratios were closer to the orebody than background levels. Establishing a regionally relevant background isotope ratio would be better for determining whether ore-derived Pb is entering aquatic fauna	Not addressed. A more relevant background ratio could be established by taking the average ratio from sites along McArthur River upstream of the mine and tributaries downstream of the mine site

4.10.4.3 Successes

The monitoring of the aquatic ecosystem around McArthur River Mine continues to improve yearly. The most positive developments in the current reporting period include:

- Improving the monitoring of metals in aquatic fauna program to include more sites from Surprise and Barney creeks, where the potential for contamination is higher than the McArthur River. This allows for a far better understanding of the potential sources of contamination in these creek lines and the scale of the contamination of biota in these creeks.
- Declining levels of contamination in biota from SW19 likely due to controls implemented by MRM. For example, the maximum concentration of Pb recorded in *M. splendida* has declined almost eight fold since 2013, and the mean by more than five times.
- The findings of two reports commissioned by the DME into the potential human health impacts of contaminants in biota caught in the McArthur River. These reports indicate that the risks to human health posed by consuming fish from McArthur River are low. Very large amounts of fish (0.6 kg for a toddler, 1.7 kg for an average adult) with the maximum recorded levels of contamination in fish targeted by anglers would need to be consumed daily for potential impacts to human health. The low levels of contamination in areas away from the mining lease and the high quantities of biota that would need to be consumed over extended

periods should allay concerns about whether or not fish from the McArthur River can be consumed.

- Reducing seepage at the SPROD, a known source of contaminated water. The SPROD has been drained and will be lined with HDPE over the 2016 dry season. In addition, the ELS, a potential source of contamination to the McArthur River diversion channel, has been decommissioned.
- Establishing a new method to monitor the performance of the McArthur River diversion channel that compares complex and bare bank habitats within and outside the diversion. This approach indicates that when complex habitats are provided, fish communities are similar to those found in the natural channel. If MRM provides more habitat such as LWD, the performance of the diversion channel will improve dramatically.
- Revegetation of the McArthur River diversion channel continues to improve incrementally and as a result is providing shade and habitat in the diversion channel.
- The extensive amounts of LWD installed at the downstream end of the McArthur River diversion channel has remained in place for two wet seasons and fish communities in the area are comparable to those in the natural channel.
- Installing no entry signage at sites along Barney and Surprise creeks where biota may be contaminated on the mining lease, such as the Barney and Surprise creek bridges along the Carpentaria Highway. Safe consumption of fish posters have also been developed by the Department of Health for the Borroloola Community Health Centre.

4.10.5 Conclusion

Monitoring of aquatic biota at McArthur River Mine continues to improve. The McArthur River diversion channel is performing better as more habitat is provided. Contamination at SW19 is declining. However, monitoring of additional exposed sites on Barney and Surprise creeks indicates that Pb contamination is more widespread in this system than previously recognised. For the first time, macroinvertebrate communities are impaired at sites immediately upstream of the McArthur River diversion channel, likely due to erosion potentially caused by increased flow velocities in the diversion channel. Water at SW16 at the lower end of the McArthur River diversion channel had elevated salts and sulfates, also for the first time, potentially due to seepage from the ELS.

Ongoing and new IM recommendations related to aquatic ecology issues are provided in Table 4.47.

Table 4.47 – New and Ongoing Aquatic Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should conduct a full review and synthesis of the monitoring programs at McArthur River Mine, including metals in aquatic fauna, macroinvertebrates, surface water, groundwater, fluvial sediments, dust and soil to identify additional sources of contamination at the mine site. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013). Potential sources may include dust emissions from the haul road and the processing plant and associated stockpiles and seepage from the ROM sump. Legacy impacts should also be addressed If additional sources of contamination are identified, suitable controls can be implemented	Medium
Monitoring of aquatic fauna in Barney Creek	Additional monitoring of aquatic fauna in natural sites along Barney Creek or equivalent reference sites and multiple sites in the Barney Creek diversion channel should be included, so the performance of the Barney Creek diversion channel can be properly assessed The IM is aware that many sites only hold water for a short period following the wet season. As a result, potentially monitoring programs should be split in two, one as soon as practical following the wet season to survey smaller creeks and tributaries and a second later to survey the McArthur River and other major tributaries. This would also benefit other aspects of the monitoring program	Medium
Dam and natural flows in Surprise/ Barney creeks	One of the justifications for the bund and water extraction at SW19 was that there was only flow at that site due to seepage, however, no evidence for this was provided. McArthur River Mining should investigate the natural flow rates in Surprise and Barney creeks, so ceasing dry season flow to sites below SW19 can be properly justified	Low
LWD	The IM recommends continuing to add and monitor LWD in the McArthur River diversion channel. McArthur River Mining should commit to additional large-scale projects to install LWD along poorly revegetated sections of the diversion channel, to ensure continuity of habitat along the diversion. McArthur River Mining should continue to add small woody debris and leaf litter to the diversion channels at the end of the wet season to provide habitat and detritus for small fish and invertebrates In addition, MRM should consider excavating or blasting of riverbanks and/or the central channel in areas of poorest rehabilitation to create eddies and improve sinuosity. Creating eddy sites would slow flow rates and facilitate soil deposition and eventual vegetation establishment to improve aquatic habitat Finally, MRM should continue annual monitoring of LWD to ensure that the wood remains in position and the best method of establishing LWD sites can be determined	Medium
Drawdown at Djirrinmini Waterhole	An investigation should be undertaken into the impacts of potential drawdown at Djirrinmini Waterhole, and possible mitigation of its impacts, as this is one of the most upstream waterholes visited by freshwater sawfish	Medium
New background Pb isotope ratio	Monitoring would benefit from the establishment of a more regionally relevant background level for Pb isotopes. At all monitoring sites, the average isotopic ratios were closer to the orebody than background levels. Establishing a regionally relevant background isotope ratio would be better for determining whether ore-derived Pb is entering aquatic fauna	Low

Table 4.47 – New and Ongoing Aquatic Ecology Recommendations (cont'd)

Subject	Recommendation	Priority
New Items		
Movement of contaminated biota	A desktop investigation should be undertaken regarding potential movement of contaminated biota in McArthur River and how long biota needs to spend at exposed sites to uptake elevated levels of contaminants	High
Reduce emissions at ROM pad	Additional monitoring of Barney and Surprise creeks in the vicinity of the ROM pad (SW03, SW18) shows that there are elevated levels of Pb in biota from these sites, likely as a result of dust emissions from the mill and associated concentrate stockpiles. McArthur River Mining should investigate ways to reduce dust emissions from this site	High
Contamination at end of dry season	The current elevated concentrations of metals in biota are measured in the early dry season, when sites would have recently been flushed with freshwater and sediments and biota may have recently arrived from uncontaminated sites. By the end of the dry season, biota would have persisted for roughly six or more months in increasingly contaminated areas and, as a result, the contamination of biota would likely have increased. Monitoring of metals in conjunction with the late dry season survey would provide useful information on the potential elevated concentrations at the end of the dry season, just before fish may disperse away from the mine site in wet season floodwaters. It would also provide a better indication of the maximum contaminant loads taken up by biota	Medium
Erosion in McArthur River	There is evidence of erosion moving upstream from the southern end of the McArthur River diversion channel, potentially as a result of increased flow velocities at the start of the diversion. In the 2015 surveys, macroinvertebrate edge communities were impaired at MR7, likely due to reduced habitat quality as a result of this erosion. McArthur River Mining should investigate the causes of this erosion and potential mitigation measures if required. This should be covered in the upcoming geomorphological assessment of the McArthur River and Barney Creek diversion channels	Medium
Contamination at SW16	McArthur River Mining should investigate the sources of contamination entering the McArthur River diversion channel just upstream of SW16. McArthur River Mining should determine the relative contribution of groundwater flows through natural mineralisation and seepage from mining infrastructure, particularly the ELS	Medium
Visit reference sites annually	Hydrobiology (2016) raised the issue of including more regional reference material in the annual assessment of metals in biota. Analysis of collections made in 2010-2011 from the Limmen Bight and Wearyan rivers indicate naturally elevated Pb, but the amount of Pb taken up will depend on the strength and duration of the wet season. To account for this variation, reference material should be collected annually	Medium
Management of the SEL	McArthur River Mining needs to determine the primary role of the SEL and investigate whether the SEL is adequately designed to meet its purpose, and whether it should be modified so it better fulfils its role either as flood protection or for capturing and containing contaminated water	Low

4.10.6 References

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4.11 Marine Ecology

4.11.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of marine ecology, and is based on review of:

- The annual marine monitoring program (AMMP) which covers the monitoring of water, sediment and biota (fish, crustaceans, molluscs and seagrass) in the vicinity of Bing Bong Loading Facility, the mouth of the McArthur River and the Sir Edward Pellew Group of Islands (SEPI) (Thorburn, 2015a).
- The annual seagrass surveys which assess the extent and species composition of seagrass around Bing Bong Loading Facility, and whether seagrass meadows are expanding or contracting (Thorburn, 2015b; 2016a).
- Observations and discussions with MRM personnel during a site visit.
- Incident notification letters and correspondence between MRM, regulators and third parties.

These are supplemented by additional assessments of nearshore sediments, trans-shipment area sediments and seawater during the operational period, as addressed in sections 4.3 and 4.12 of this report.

4.11.2 Key Risks

The key risks to marine ecosystems as outlined in the risk assessment (Appendix 2) are:

- While loading concentrate onto the MV Aburri and from the MV Aburri onto larger transport vessels, dust and spillage contaminates seawater and sediments in the Bing Bong Loading Facility swing basin, the trans-shipment area and the surrounding area. Metals in the dust and spilled concentrate can bioaccumulate in marine biota, which may have lethal and/or sub-lethal chronic effects on biota.
- Dust migration and surface water runoff from the Bing Bong Loading Facility concentrate storage shed and road vehicles causes contamination of marine sediments and seawater in Bing Bong Loading Facility and surrounding areas, which may potentially contaminate local biota.
- Shipping activities and dredging of the shipping channel increases turbidity, leading to the loss of seagrass by reducing light availability and, in turn, photosynthesis. In extreme cases, turbidity can result in the smothering of seagrass. This affects seagrass-dependent communities or populations (e.g., fish, dugongs, turtles).
- In the absence of adequate controls for managing dust and surface water, runoff at the McArthur River Mine site leads to contaminated water and sediments washing down McArthur River, resulting in the accumulation of metals in sediments and marine biota in the vicinity of SEPI and the mouth of the McArthur River. This may have unknown sub-lethal/ chronic effects on marine fauna and higher trophic species.

- Biota such as barramundi (*Lates calcarifer)* may be contaminated by Pb, Zn and other metals as a result of MRM's activities. Potentially contaminated biota may be caught and consumed by local fishers, which then has the potential to affect human health.

4.11.3 Controls

4.11.3.1 Previously Reported Controls

McArthur River Mining has monitoring and controls in place to minimise the risk to marine biota. These controls remain largely unchanged from last year and include:

- Covered conveyor belts at the loading facility to reduce dust while loading the MV Aburri.
- The dust extraction system on the concentrate storage shed has been replaced and is now fully operational, although the doors to the concentrate storage shed remain open and have not been fixed.
- Vehicle wash down facility at Bing Bong Loading Facility to prevent dust emissions from vehicles.
- Covers on concentrate transport vehicles to prevent dust blowing from concentrate loads.
- Dredge spoil settled in ponds on land to reduce turbidity and contamination from resuspended sediments during dredging.
- Monitoring of the marine environment through the annual marine monitoring program (Thorburn, 2015a) and annual seagrass surveys (Thorburn, 2015b; 2016a). These are discussed in more detail below.

Previously, MRM monitored *Vibrio* bacteria concentrations at the mouth of McArthur River and the surrounding area. *Vibrio* bacteria monitoring began in 2009 after three cases of severe necrotising fasciitis (flesh-eating bacteria syndrome) from *Vibrio* bacteria in the Gulf of Carpentaria. *Vibrio* bacteria possess Zn-containing proteases and availability of Zn may affect abundances. If Zn concentrations are increasing as a result of emissions from MRM's activities, this could result in conditions conducive to *Vibrio* bacteria reproduction and lead to increased *Vibrio* abundance. In surveys in 2009, 2012 and 2013, there was no correlation between *Vibrio* abundance and Zn concentrations and no evidence of increased numbers of bacteria as a result of mining activities. In the 2014 IM report, the IM recommended a final *Vibrio* survey in 2015, however this survey did not take place.

Dust suppression sprinklers have previously been operational on the roadways at the Bing Bong Loading Facility. During the 2015 and 2016 site visits, the IM learned these have not been operational due to limited water availability associated with poor wet seasons. In addition, the concentrate storage shed has doors to reduce dust emissions; these doors have been non-operational since the last IM site visit in June 2015.

In addition to the monitoring listed above, MRM also assesses sediment and seawater contamination. This includes:

- Annual assessment of metals and lead isotope ratios of seafloor sediments in the McArthur River Mine trans-shipment area (Thorburn, 2015c).
- Annual assessment of metal contaminants in nearshore sediments to meet the requirements of the waste discharge licence (Thorburn, 2016b).
- Monthly monitoring of seawater contaminants by diffusive gradients in thin films (DGTs) (Tsang, 2015).

These monitoring programs are discussed further in sections 4.3 and 4.12.

Annual Marine Monitoring Program

The AMMP was established to ensure that MRM is meeting its commitments to monitor the environment and that operations are not contaminating Bing Bong Loading Facility and the surrounding area via dust emissions and concentrate spillage while loading and unloading ships. The aims of the AMMP are to:

- Assess seawater and sediment quality in the vicinity of Bing Bong Loading Facility, McArthur River estuary and SEPI.
- Quantify impacts to sediment and seawater quality as a result of MRM's operations.
- Determine whether there is any contamination of biota as a result of MRM's activities within the vicinity of Bing Bong Loading Facility.

The AMMP sampling was carried out in December 2014 by Indo-Pacific Environmental (Thorburn, 2015a).

Survey sites in the 2014 program are shown in Figure 4.30. Sites at SEPI provide baseline data for the monitoring program. Two new sites immediately west of Bing Bong Loading Facility shipping channel were added to the AMMP in 2014. A third site (Site 107) was moved 1 km southwest from its former location which was identified as culturally significant. Sediment was collected at an additional ten sites in the swing basin and shipping channel. In accordance with the IM's recommendations, three species targeted by fishers – mangrove clam (*Polymesoda* spp.), barramundi (*Lates calcarifer*) and giant queenfish (*Scomberoides commersonnianus*) — were added to the monitoring program to further assess potential impacts on human health (Thorburn, 2015a).

Annual Seagrass Monitoring

Seagrass is monitored annually to ensure that seagrass communities are not being impacted as a result of activities at Bing Bong Loading Facility, which could then affect seagrass-dependent fauna such as dugong (*Dugong dugon*) and fish species. Monitoring generally occurs in October or November and aims to:

- Identify and describe broad-scale patterns in the seagrass assemblage structure occurring around Bing Bong Loading Facility.
- Identify and categorise the relative cover and/or abundance of seagrass.

SURVEY SITES FOR THE 2014 ANNUAL MARINE MONITORING PROGRAM

McArthur River Mine Project

FIGURE 4.30

ERIAS GROUP

Source: Google image 2005; Thorburn, 2015a.
Note: AMMP sampling for the 2015 operational period was undertaken in December 2014.

- Provide an assessment of spatial and temporal patterns in seagrass assemblages relative to past monitoring results.
- Provide an assessment and comparison of the seagrass assemblages in the broader region with those adjacent to the Bing Bong Loading Facility.
- Identify any key changes in seagrass communities around Bing Bong Loading Facility and implications for future management of the site.
- Provide recommendations for future monitoring events (Thorburn, 2015b; 2016a).

Since 2012, monitoring has included two control sites (Figure 4.31) so that the underlying causes of seagrass community dynamics can be better understood. However, one control site (Sector 4) was deemed unsuitable following the 2013 survey due to differences in seagrass cover and species dominance and the presence of rocky substrate. In the 2014 report, the IM recommended establishing more relevant control sites. As a result, Sector 4 was replaced by Sector 5 in 2015. An additional control site was added in 2015 (Sector 6). The control sites are between 7 and 14 km from the Bing Bong Loading Facility.

It should be noted that the passage of Ex-Tropical Cyclone Grant close to Bing Bong Loading Facility in late 2011 anecdotally impacted seagrass communities. Cyclones are a major disturbance to seagrass communities and play an important role in shaping these communities in northern Australia (Roelofs et al., 2005). In addition, maintenance dredging occurred in 2013.

The two new control sites (Sectors 5 and 6) are a welcome addition to the monitoring program as one of the previous control sites (Sector 4) was unsuitable given that the seagrass meadows were very different to those at the Bing Bong Loading Facility. The addition of the new quantitative approach using video transects will help improve fine-scale comparisons between years and sites, and remove potential observer biases associated with the purely qualitative data collected in previous years.

4.11.3.2 New Controls – Implemented and Planned

McArthur River Mining has made significant improvements to their marine monitoring programs. In the AMMP, two new sites (Bing Bong West 1 and 2) have been added immediately west of the Bing Bong Loading Facility. As the prevailing winds and currents travel from east to west, dust emissions, resuspended sediments and spillages will travel towards these sites. As a result, these sites will be useful for determining how far contaminants are travelling from the Bing Bong Loading Facility, if at all. The inclusion of species targeted by fishers (giant queenfish, barramundi and mangrove clams) is a welcome addition. Adding these higher trophic level fish will help determine whether contaminants are moving up the food chain and bioaccumulating in predatory fish and if there are any potential human health impacts associated with MRM's operations. Combined with the reports into potential impacts of contaminated biota on human health commissioned by the DME and the Department of Health (Skov, 2015; Hydrobiology, 2016), there is a more complete picture of potential impacts to human health in the area.

The seagrass monitoring program has added two new control sites since the previous IM report. These seagrass communities at the two control sites are analogous to those at the site at the Bing Bong Loading Facility, and hence are far more suitable control sites than previously used.

LOCATION OF SEAGRASS SURVEY AREAS IN 2014 AND 2015

McArthur River Mine Project

FIGURE 4.31

Source: Google, 2005; Thorburn, 2016a.

Since the 2015 IM report, MRM has repaired the dust extraction system on the concentrate storage shed at the Bing Bong Loading Facility. This should aid in reducing dust emissions at the site. In addition, MRM is planning to replace the broken roller doors on the concentrate storage shed to further reduce dust emissions. However, it should be noted that the IM was told that the doors would be replaced during the 2015 site visit. In addition, cracks and potholes in the road surface will be repaired shortly, which should improve site cleanliness.

As operations have ceased at the Western Desert Resources (WDR) facility, MRM results will no longer be confounded by the potential influence of WDR operations. As a result, more robust conclusions can be drawn about MRM's impact on the marine environment.

4.11.4 Review of Environmental Performance

4.11.4.1 Incidents and Non-compliances

Incidents

There was a single reported incident at the Bing Bong Loading Facility that could impact the marine environment. Following planned maintenance, the MV Aburri was started and the engineer noticed oil in the discharge water. The engine was immediately stopped and containment booms were deployed. Less than 2 L of diluted oil was spilt into the swing basin and it was entirely contained and recovered. As a result, there was no impact on the marine environment and the incident was ranked as a level one incident.

The exceedances of ANZECC/ARMCANZ (2000) interim sediment quality guidelines (ISQG) and maximum permitted concentrations (MPCs) in biota from the Bing Bong Loading Facility shipping channel and immediate area as part of the AMMP (see below) constitute unreported incidents. Any exceedances should be reported to the DME as soon as possible in future years.

Non-compliances

The revised interim 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances.

4.11.4.2 Progress and New Issues

Monitoring of Marine Environment

Seawater Monitoring

The majority of metal concentrations in filtered and unfiltered seawater collected during the AMMP was consistent across the monitoring sites. At all sites, Cu concentrations were above trigger values set by ANZECC/ARMCANZ (2000) guidelines for marine water quality for 99% species protection. The trigger values for Co were exceeded at all sites for unfiltered seawater and 12 of 20 sites for filtered seawater. It is likely that trigger values for Co were exceeded at all sites, but the detection limit (<0.05 µg/L) is above the trigger value (0.005 µg/L). Most sites had Co concentrations close to the detection limit. This is consistent with results from 2010 to 2013 and background levels across the marine waters of northern Australia. Due to their widespread occurrence, it is unlikely that exceedances of Co and Cu are due to MRM's operations.

Lead and Zn in unfiltered seawater were noticeably elevated in the vicinity of Bing Bong Loading Facility (Table 4.48). This was mostly as a result of data from two new survey sites (Bing Bong West 1 and 2), particularly Bing Bong West 1 (BBW1), which is 700 m west of the loading facility. At BBW1, concentrations of Pb and Zn were three and four times higher, respectively, than the next highest recorded concentrations. Zinc concentrations at BBW1 were above the ANZECC/ ARMCANZ (2000) trigger values for 99% species protection. Concentrations of Pb were just below the trigger value (2.2 µg/L). Bing Bong West 1 is located in a channel draining off the tidal flat west of the loading facility. Since monitoring began in 2012, metal concentrations in nearshore sediments at sites immediately west of the Bing Bong Loading Facility have been consistently elevated compared to other sites near the facility. The prevailing winds at the Bing Bong Loading Facility are southeasterlies, and the currents travel predominantly from east to west, so contaminated dust and spillages generated at the facility generally travel towards this site. It is likely that some contaminants get washed into the channel as the tide recedes.

Table 4.48 – Concentrations of Metals in Seawater that are Elevated at Bing Bong West 1 Compared to Other Survey Sites in the Vicinity of Bing Bong Loading Facility (µg/L)

Metal and Trigger Values*	Sample Type	Concentration at Bing Bong West 1	Highest Concentration from Other Survey Sites	Overall Mean
Zn – 7	Filtered	3	2 (109 Pine Reef)	<1.6#
	Unfiltered	**9**	2 (multiple sites)	<3.2#
Pb – 2.2	Filtered	0.3	0.3 (Pine Creek)	<0.2#
	Unfiltered	1.8	0.6 (107 SW Little Reef)	0.42
Fe – ntv†	Filtered	5	17 (Pine Creek)	4.18
	Unfiltered	750	240 (multiple sites)	215
Al – ntv†	Filtered	<5	<5 (all sites)	<5#
	Unfiltered	300	160 (107 SW Little Reef)	105
Mn – ntv†	Filtered	33	9.7 (Mule Creek)	5.9
	Unfiltered	59	20 (Mule Creek)	14.2
Co – 0.005	Filtered	**0.23**	**0.24** (Mule Creek)	**0.11**
	Unfiltered	**0.54**	**0.35** (Mule Creek)	**0.17**
Ni – 7	Filtered	0.5	0.4 (Mule Creek)	<0.4#
	Unfiltered	0.8	0.4 (multiple sites)	<0.4#*
As – ntv†	Filtered	2.8	1.7 (Pine Reef)	1.6
	Unfiltered	3.2	1.9 (Pine Creek)	1.8

Bold results indicate concentrations exceed the trigger values.
*Trigger values are ANZECC and ARMCANZ (2000) or 99% species protection in marine waters.
#Many values below detection limit.
†ntv = no trigger value.

During the IM's 2015 site visit to the Bing Bong Loading Facility, the dust extractor system and roller doors on the concentrate shed were broken, which may have contributed to dust emissions. The roller doors were still broken at the time of the 2016 IM site visit.

The AMMP emphasised that the construction of the WDR wharf from mid-2013 and increased boat traffic likely stirred up contaminated sediments which had been buried by naturally deposited benign sediments. Based on a single data point, it is impossible to differentiate between the contribution of WDR works resuspending contaminated sediments and everyday MRM operations to this contamination, but it may be a combination of the two. At the very least, the contaminated sediments are a legacy of MRM's historic operations, and may be resuspended in future as a result of dredging by MRM. As WDR is no longer operating, future monitoring will determine the cause of Pb and Zn contamination in seawater at the Bing Bong West 1 and 2 sites. McArthur River Mining contractors indicate that data from the AMMP in December 2015 suggests that these elevated concentrations have declined well below trigger values, and Pb concentrations in seawater from BBW1 are no longer the highest in the region. This initial evidence supports the hypothesis that the elevated metal concentrations in seawater at BBW1 were caused by WDR operations stirring up contaminated sediments.

Iron was also elevated in unfiltered seawater at BBW1, likely due to dust emissions from the WDR facility. There is a visible coating of iron ore dust around the WDR site, although this is starting to dissipate. In addition, Al, Mn, Co, Ni and As concentrations were elevated in unfiltered seawater at BBW1. These levels are again likely due to the transport of dust deposited on the tidal flat into the channel.

Lead isotope ratios from DGT monitoring (Tsang, 2015; see Section 4.3) indicate that concentrate derived Pb is entering marine waters and is traceable at reference sites roughly 7 km in both directions from Bing Bong Loading Facility, but at background concentrations. This is consistent with the 2013-2014 DGT surveys.

Marine Sediment Monitoring

In December 2014, sediment sampling was undertaken at two new sites to the immediate west of the Bing Bong Loading Facility shipping channel (Bing Bong (BB) West 1 and 2), as well as ten new sites within the swing basin and shipping channel (see Figure 4.30) (Thorburn, 2015a).

Sediment samples were analysed in two ways. The first involved using the whole sediment sample (<2 mm particle size to remove large particles such as shells) and second involved the <63 µm fraction. The latter analysis was included as it may provide a closer indication of what contaminants are available to biota and adheres more closely to ANZECC/ARMCANZ (2000) interim sediment quality guidelines (ISQG). These guidelines are provided as low and high values; low values indicate that there is unlikely to be an effect on local biota, but further investigation is required. High values indicate that there may well be adverse effects on organisms.

For sites outside the swing basin, there were only three exceedances of ISQG low values; all were for As at sites GB, 117 and BBW1. Iron concentrations were elevated at BBW1 (69,000 mg/kg), but surprisingly, given the visible red iron ore dust present at BBW1, concentrations were lower than at sites 117 (83,000 mg/kg) and GB (120,000 mg/kg). Cadmium results were highest in the shipping channel, at 0.09 mg/kg compared to 0.03 mg/kg on average. Zinc concentrations were also highest in sediments from the shipping channel site (43 mg/kg) compared to other sites (average 11.75 mg/kg); however, the next three highest results were from the Sir Edward Pellew Group of Islands (33, 36 and 37 mg/kg). Concentrations of Pb in sediments at BBW1 (16 mg/kg) were above average (7.2 mg/kg), but within the range of concentrations at reference sites (maximum recorded 27 mg/kg at GB).

No ISQG values were exceeded for the <63 µm fraction of the sediment samples outside the swing basin. At Bing Bong West 2, levels of Mn were elevated (1,100 mg/kg) compared to all other sites (average 311 mg/kg). Concentrations of Ni and Co were also highest at this site, but only slightly. Concentrations of Cu (14 mg/kg), Zn (47 mg/kg) and Pb (37 mg/kg) were elevated in the channel compared to other sites (average 6, 9 and 13 mg/kg, respectively). These patterns are consistent with sediment monitoring in previous years, which found elevated Pb and Zn in the immediate vicinity of the swing basin.

For sediment samples collected within the swing basin, the Zn ISQG high value (410 mg/kg) was exceeded at three sites (440 to 510 mg/kg), and the ISQG low value (200 mg/kg) at two sites (270 and 300 mg/kg). The ISQG low value was exceeded for Pb (50 mg/kg) at six sites (52 to 110 mg/kg) and for As (20 mg/kg) at a single site (28 mg/kg). Exceedances were recorded in the sites closest to the shore. Within the swing basin, average concentrations of Zn and Pb were 20 and 11 times those recorded outside the swing basin. Concentrations of Cu, Ag, Cd were also considerably higher in the swing basin than the surrounding area. For the <63 µm fraction of the sediment samples, ISQG low values were exceeded at six sites for Pb (75 to140 mg/kg) and a single site for Zn (210 mg/kg). Concentrations of Cd and Cu were also elevated in the fine sediments. While these very high concentrations of Pb and Zn are concerning, they are not altogether surprising as one would expect some level of contamination within the swing basin and this is consistent with previous sampling. However, regional sampling indicates that the impacts are localised to the swing basin, shipping channel and tidal flats immediately west of Bing Bong Loading Facility.

Lead isotope ratios of sediments collected in the swing basin were very close to that of the orebody, indicating that the source of the Pb, and likely Zn, is concentrate. The next highest Pb isotope ratios are found in the shipping channel, albeit far lower than the orebody itself. All other sites, including Bing Bong West 1 and 2, had isotope levels similar to the crustal average. This indicates that while seawaters are contaminated at the Bing Bong West sites, sediments are not being contaminated as a result of MRM operations. Overall, consistent with surveys in 2011, 2012 and 2013, the AMMP sediment monitoring indicates that outside of the swing basin and shipping channel, MRM's operations are not contaminating marine sediments.

Marine Biota

The biota assessed for levels of contamination in the current reporting period were:

- Barramundi (*Lates calcarifer*).
- Giant queenfish (*Scomberoides commersonnianus).*
- Bluetail mullet (*Valamugil buchanani*).
- Giant mud crab (*Scylla serrata*).
- Rock oyster (*Saccostrea* spp.).
- Mangrove clam (*Polymesoda* spp.).
- A gastropod mollusc (*Terebralia semistriata,* referred to as *Terebralia*).

- A gastropod mollusc (*Telescopium telescopium,* referred to as *Telescopium*).
- Seagrass (*Halodule uninervis*).

For ease of interpretation, this report will refer to species by their common name, except for the two gastropod molluscs (snails) which will be referred to by their genera (*Terebralia* and *Telescopium*).

Two additional species of fish (barramundi and giant queenfish) and the mangrove clam (*Polymesoda* spp.) were added to the program in 2014 to investigate potential impacts to human health, as these species are targeted by fishers. The fish may be bioaccumulators of contaminants due to their higher position in the food chain. It should be noted that due to variation in abundance, catchability, habitat requirements and patchy distribution, some species were collected in low numbers and from few sites, particularly mangrove clams and barramundi.

In the AMMP report (Thorburn, 2015a), exceedances of the MPCs set by the Australia New Zealand Food Standards Code (FSANZ, 2009) were reported in relation to Pb, inorganic As and Cd. The maximum permitted levels of these metals in fish and molluscs are unchanged in the current version of the Code (FSANZ, 2015). No criteria are currently set for Zn and Cu.

Table 4.49 shows which metals were elevated in the immediate vicinity of the Bing Bong Loading Facility (the shipping channel and BBW1).

Concentrations of Zn, As, Cu and Cd were elevated in the vicinity of the Bing Bong Loading Facility when compared to results from other sites in the monitoring program. Specifically:

- Oysters collected from the shipping channel had mean and median Zn results of 550 mg/kg. This was well above the mean (93.3 mg/kg) and median (57 mg/kg) for all oysters collected during the monitoring program. Concentrations of Zn in oysters from the shipping channel have been consistently elevated since the AMMP began in 2012. Oysters are well known bioaccumulators of metals and can live at least five years, so this result is unsurprising based on long-term evidence of elevated Zn levels in sediments and biota from the shipping channel.

  To put these results in the context of moderately disturbed ecosystems, oysters collected from around Darwin also had elevated Zn; individuals taken from Rapid Creek had concentrations 488 to 787 mg/kg and from East Point 180 to 305 mg/kg. Commercially produced Sydney Rock Oysters often had Zn concentrations comparable to, or exceeding, those recorded at Bing Bong Loading Facility (see references in Thorburn (2015a)). Monitoring indicates that contamination is restricted to the channel and immediate surrounds, so the scale of impact is minimal. The highest concentrations of Zn in *Terebralia* and *Telescopium* molluscs, barramundi and bluetail mullet were also recorded from the shipping channel. However, concentrations were only slightly higher than those recorded at other sites in the region. Further, the means and medians for Zn concentration in the shipping channel were consistent with other sites in the McArthur River region.

Table 4.49 – Metal Concentrations in Biota that are Elevated at the Bing Bong Loading Facility Shipping Channel or Bing Bong West 1 Compared to Regional Sites (mg/kg)

Metal	Taxonomic Group and MPC Where Applicable	Species/ Genus	Bing Bong Loading Facility Concentration	Next Highest Concentration	Bing Bong Loading Facility Mean/Median	Next Highest Site Mean/Median	AMMP Mean/Median
Al	Mollusc	*Terebralia**	590, 460, 280, 210, 130	560, 510, 370, 300, 69 (Carrington)	334/280	361/370	136/64.5
Mn	Mollusc	*Terebralia**	43, 24, 10, 9.3, 6.3	16, 7.4, 6.8, 6.2, 3.5 (Bing Bong Creek)	18.5/10	7.98/6.8	6.4/2.6
		Terebralia	19, 14, 13, 9.4, 4.7	16, 7.4, 6.8, 6.2, 3.5 (Bing Bong Creek)	12.2/13	7.98/6.8	6.4/2.6
Fe	Mollusc	*Terebralia**	1500, 1200, 590, 490, 270	760, 460, 460, 230, 85 (Carrington)	810/590	399/460	238/110
	Fish	Barramundi (liver)	720, 480	660, 550, 480, 460, 250 (Mule Creek)	600/600	480/480	521/515
		Barramundi (muscle)	2.3, 1, 0.9	2, 1.4, 1.1, 1, 0.9 (Mule Creek)	1.4/1	1.3/1.1	1.3/1.1
Co	Mollusc	*Terebralia**	0.44, 0.36. 0.22, 0.18, 0.11	0.25, 0.13, 0.12, 0.09, 0.08 (Bing Bong Creek)	0.26/0.22	0.13/0.12	0.09/0.06
Ni	Mollusc	*Telescopium*	0.39, 0.32, 0.09, 0.09, 0.03	0.29, 0.09, 0.09, 0.05, 0.03 (SEPI 8)	0.18/0.09	0.11/0.09	0.09/0.07
	Crustacean	Mud crab	0.6, <0.03, <0.03, <0.03, <0.03	0.23, 0.14, 0.08, 0.05, 0.05 (Carrington)	0.14/<0.03	0.11/0.08	0.06/0.04
	Fish	Barramundi (liver)	0.14, <0.03	0.03, <0.03, <0.03, <0.03, <0.03 (Mule Creek)	0.08/0.08	0.02/<0.03	0.02/<0.03
		Barramundi (muscle)	0.06, <0.03, <0.03	<0.03, <0.03, <0.03, <0.03, <0.03 (Mule Creek)	0.03/<0.03	<0.03/<0.03	<0.03/<0.03
		Giant Queenfish	0.11, 0.04, <0.03, <0.03, <0.03	0.05, <0.03, <0.03, <0.03, <0.03 (Carrington)	0.042/<0.03	0.026/<0.03	0.026/<0.03

Table 4.49 – Metal Concentrations in Biota that are Elevated at the Bing Bong Loading Facility Shipping Channel or Bing Bong West 1 Compared to Regional Sites (mg/kg) (cont'd)

Metal	Taxonomic Group and MPC Where Applicable	Species/ Genus	Bing Bong Loading Facility Concentration	Next Highest Concentration	Bing Bong Loading Facility Mean/Median	Next Highest Site Mean/Median	AMMP Mean/Median
Zn	Mollusc	*Terebralia*	16, 14, 13, 12, 11	16, 12, 12, 11, 7.9 (Pine Creek)	13.2/13	11.78/12	9.2/8.8
		Telescopium	15, 13, 12, 12, 12	14, 13, 13, 12, 12 (Pine Creek)	12.8/12	12.7/13	11.18/11.5
		Oyster	650, 580, 550, 490, 480	180, 110, 87, 61, 61 (Pine Reef)	550/550	106/110 (Carrington)	93.3/57
	Fish	Barramundi (muscle)	6, 2.8, 2.4	4.1, 4.1, 2.7, 2.5, 2.4 (Mule Creek)	3.7/2.8	3.16/2.7	3.3/2.7
		Mullet	0.16, 0.06, 0.05, 0.05, 0.04	0.13, 0.1, 0.06, 0.04, 0.04 (Mule Creek)	0.07/0.05	0.074/0.06	0.05/0.04
As	Mollusc[#]	*Terebralia**	7.8, 7.1, 6.7, 6.4, 5.2	5.5, 4.7, 3.9, 3.6, 2.6 (Site 104)	6.6/6.7	4.1/3.9	3.1/2.6
		Terebralia	5.2, 5.1, 4.9, 4.9, 4.5	5.5, 4.7, 3.9, 3.6, 2.6 (Site 104)	4.9/4.9	4.1/3.9	3.1/2.6
		Telescopium	11, 7.1, 6.8, 6.1, 5.5	5.5, 5.4, 4.6, 3.5, 3.5 (SEPI 12)	7.3/6.8	4.5/4.6	3.6/3.2
Cd	Mollusc – 2.0	*Terebralia**	0.29, 0.329, 0.18, 0.18, 0.18	0.24, 0.2, 0.14, 0.11, 0.08 (Site 104)	0.22/0.18	0.16/0.14 (SEPI 8)	0.11/0.1
		Telescopium	0.08, 0.076, 0.074, 0.066, 0.062	0.061, 0.027, 0.02, 0.018, 0.013 (Bing Bong Creek)	0.072/0.074	0.036/0.035 (SEPI 8)	0.035/0.032
Pb	Mollusc – 2.0	*Terebralia**	1.2, 0.81, 0.38, 0.37, 0.21	0.37, 0.26, 0.22, 0.11, 0.04 (Carrington)	0.59/0.38	0.2/0.22	0.19/0.048
		Terebralia	1.1, 0.87, 0.82, 0.4, 0.2	0.37, 0.26, 0.22, 0.11, 0.04 (Carrington)	0.68/0.82	0.2/0.22	0.19/0.048
		Telescopium	0.25, 0.16, 0.05, 0.031, 0.062	0.14, 0.066, 0.05, 0.019, 0.017 (Pine Creek)	0.1/0.05	0.058/0.05	0.041/0.025
		Oyster	0.29, 0.2, 0.12, 0.1, 0.093	0.1, 0.027, 0.027, 0.025, 0.022	0.16/0.12	0.04/0.027	0.034/0.024

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Table 4.49 – Metal Concentrations in Biota that are Elevated at the Bing Bong Loading Facility Shipping Channel or Bing Bong West 1 Compared to Regional Sites (mg/kg) (cont'd)

Metal	Taxonomic Group and MPC Where Applicable	Species/ Genus	Bing Bong Loading Facility Concentration	Next Highest Concentration	Bing Bong Loading Facility Mean/Median	Next Highest Site Mean/Median	AMMP Mean/Median
Pb (cont'd)	Crustacean	Mud crab	0.052, 0.05, <0.004, <0.004, <0.004	0.023, 0.014, 0.008, 0.007, 0.006 (SEPI 12)	0.014/<0.004	0.011/0.008	0.008/0.005
	Fish – 0.5	Barramundi (liver)	0.022, 0.007	0.009, 0.006, 0.005, 0.005, 0.004 (Mule Creek)	0.015/0.015	0.006/0.005	0.008/0.006
		Barramundi (muscle)	0.042, 0.011, <0.004	0.013, 0.008, <0.004, <0.004, <0.004 (Mule Creek)	0.019/0.011	0.006/<0.004	0.01/0.003

MPC – maximum permitted concentration. Unless otherwise stated, the site with the next highest mean/median value is the same as the location of the next highest concentration.
Bold values indicate concentrations exceed the MPC.
* indicates organisms collected from Bing Bong West 1. All other records are from biota collected from the shipping channel.
[#] Although an MPC is specified for inorganic As, this does not apply to the presented total As results.

- Total As concentrations in gastropod molluscs were elevated in the shipping channel and at BBW1, the four highest concentrations of As in *Terebralia* were recorded at BBW1 and the five highest concentrations of As in *Telescopium* were recorded in the shipping channel. Mean and median values in *Terebralia* and *Telescopium* were also elevated at these sites. For gastropods from other sites and all other biota, the relative consistency of As concentrations indicates that these exceedances are unlikely due to MRM's operations. Arsenic speciation analysis of oysters, mud crabs and seagrass indicates that concentrations were largely consistent between sites, and no MPCs for inorganic As were exceeded Thorburn (2015a).

- Elevated Cu was identified in 18 of 47 mud crabs analysed from a variety of sites in the McArthur River region, suggesting that this is a natural occurrence likely due to the presence of oxygen-binding Cu-based proteins in their haemocyanin (blood). Copper was also elevated in 10 of 75 oysters; elevated background levels of Cu in oysters is consistent with previous surveys and these exceedances are unlikely to be related to MRM's activities, as they were mostly sampled from regional and reference sites. Finally, Cu was elevated in six of eight barramundi livers; due to the widespread distribution of these exceedances, this is unlikely to be caused by MRM's operations.

- Cadmium MPC was exceeded in 32 of 35 fish livers collected and 4 of 75 oysters sampled, 1 each from SEPI 9 and SEPI 11, and 2 from SEPI 10. The MPC for Cd was also exceeded in a single mud crab from both Site 104 and Bing Bong Creek. Due to the distribution of these exceedances, elevated concentrations of Cd are unlikely to be due to MRM's operations. Cadmium concentrations were also elevated in *Telescopium* and *Terebralia* molluscs from the shipping channel, although concentrations were well below the MPC.

Concentrations of other metals were elevated in the Bing Bong Loading Facility shipping channel and at Bing Bong West 1 compared to regional sites, as follows:

- Lead was elevated in biota from the shipping channel. The highest concentrations of Pb in oysters, *Terebralia*, *Telescopium*, mud crabs and barramundi muscle and liver all came from the Bing Bong Loading Facility shipping channel, but values were at least 10 times below the MPC for Pb. The mean and median Pb concentrations for these species were also well above the average values collected for the monitoring program. This is the first time that elevated Pb has been recorded in barramundi and mud crabs. Historically it was thought that these more mobile species would not spend sufficient time in the swing basin to receive elevated doses of metals. However, as the swing basin has comparatively deep sheltered waters and an abundance of prey species are present, it is unsurprising that some mobile species may spend extended periods there. Data for barramundi should be treated with caution, as fish were only collected from two sites in addition to the shipping channel, and at one of these sites, only a single individual was caught. In addition, Pb concentrations were elevated in one barramundi caught at Mule Creek, roughly 4 km east of the Bing Bong Loading Facility.

- The highest concentrations of Al in *Terebralia* and Ni in *Telescopium,* mud crabs, barramundi and giant queenfish were recorded in the immediate vicinity of Bing Bong Loading Facility, although the means and medians for these species from the shipping channel were largely consistent with the regional survey.

- *Terebralia* collected from BBW1 had elevated Fe, Mn and Co compared to regional sites. Mean concentrations of Fe at BBW1 were twice that of the next highest site, likely driven by dust emissions from the WDR loading facility.
- The highest concentrations of Fe in barramundi muscle and tissue were recorded from the Bing Bong Loading Facility shipping channel. However, the mean and median Fe concentrations at this site were consistent with the regional patterns. Again, due to a low number of samples, the barramundi data should be treated with caution.

Concentrations of metals in seagrass (*Halodule uninervis*) were consistent across all sites. No metals were elevated.

Metals have been elevated in some biota collected from the shipping channel since 2011, as shown in Table 4.50.

Table 4.50 – Elevated Concentrations of Zn and Pb in Biota from the Bing Bong Loading Facility Shipping Channel Since 2011 (mg/kg)

Organism		Oyster	Oyster	*Telescopium*	*Terebralia*	Mud crab	Barramundi
Metal: MPC*		*Zn: N/A*	*Pb: 2.0*			*Pb: N/A*	*Pb: 0.5*
Mean	2011	-	-	0.91#	0.871#	-	-
	2012	553	0.069	0.64	0.82	0.014	-
	2013	480	0.32	0.078	0.32	0.006	-
	2014	550	0.16	0.1	0.68	0.014	0.019
	2014 Prog†	93.3	0.03	0.04	0.19	0.008	0.01
Median	2014	550	0.12	0.05	0.82	<0.004	0.011
	2014 Prog	57	0.02	0.03	0.05	0.005	0.006
Maximum	2014	650	0.29	0.25	1.2	0.052	0.042
	2014 Prog	180	0.1	0.14	0.37	0.023	0.013

*MPC – maximum permitted concentration (mg/kg), where applicable. Under FSANZ (2015) there is currently no MPC for Zn or for Pb in crustaceans.
#In 2011 *Telescopium* and *Terebralia* were collected from a slightly different location in the shipping channel compared to subsequent years.
†2014 Prog – mean, median and maximum values (excluding Bing Bong Loading Facility sites) from the entire AMMP.

Zinc concentrations in oysters collected from the shipping channel have remained well above the regional average since 2012 and there is no indication of a decline in concentrations. Lead has remained elevated in molluscs and mud crabs caught in the shipping channel compared to regional sites. McArthur River Mining should ensure that best practice is being implemented at the Bing Bong Loading Facility, and that dust controls are being maintained and kept operational. If concentrations of metals continue to remain high with best practice procedures being implemented, MRM should investigate other possible management options to reduce contamination.

Lead Isotope Ratios in the Marine Environment

Lead isotope ratios (207Pb:206Pb and 208Pb:206Pb) can be used to assess whether Pb present in organisms is derived from the McArthur River Mine orebody. The mine ore has higher isotopic ratios than background levels, so if biota have elevated isotopic ratios, they have potentially been contaminated with mine-derived ore.

Sediment Pb isotope ratios were elevated in the shipping channel and swing basin, with sites closest to the Bing Bong Loading Facility having an isotopic ratio very similar to that of the orebody. Of note, sediments from BBW1 and BBW2 have isotopic ratios very close to the crustal average, indicating that sediments at these sites are not being contaminated by MRM's operations.

For oysters, *Telescopium* and *Terebralia,* Pb isotope ratios in individuals from the shipping channel are very close to that of the orebody compared to other sites. For *Terebralia*, Pb isotope ratios are consistently elevated for individuals from Bing Bong West 1. The Pb isotope ratios in mud crab are inconsistent, and ratios for the individuals from the shipping channel were not elevated compared to other sites. The two barramundi from the shipping channel with elevated Pb concentrations have Pb isotopic ratios similar to that of the orebody, whereas the single barramundi with an average Pb concentration from the same site did not have elevated Pb isotopic ratios. This may indicate that some barramundi are resident in the shipping channel for extended periods and others may be vagrants (and there is anecdotal evidence of a school residing in the swing basin). In addition, a single barramundi caught at Mule Creek had isotopic ratios very close to that of the orebody, indicating it may have spent time in the shipping channel before migrating to Mule Creek 4 km away. This individual also had the highest recorded concentration of Pb for barramundi at Mule Creek. However, as mentioned, due to the low numbers of barramundi collected, results should be treated with caution. Lead isotope ratios in giant queenfish are inconsistent, with individuals from sites such as Rosie Creek having isotopic ratios ranging from that reflecting the crustal average to the orebody. At other sites, such as Pine Creek, all individuals have elevated Pb isotopic ratios consistent with the orebody. Due to the high degree of variation and potentially naturally elevated lead isotopic ratios in queen fish, if this species has elevated Pb concentrations, it may be difficult to determine the origin of the contamination.

Lead isotopic ratios in seagrass taken from the shipping channel were slightly elevated compared to other sites, but still below the isotopic ratios of the orebody.

Annual Marine Monitoring Program Conclusion

The AMMP combined with evidence from the annual monitoring of nearshore sediment and monthly DGT monitoring of metals in seawater in the Bing Bong Loading Facility swing basin (discussed in Sections 4.12 and 4.3, respectively) demonstrate that the measurable impacts from MRM operations are limited to animals and sediments from sites within 700 m of the loading facility, beyond which there is no measureable impact on the environment. It is concerning that elevated Pb was recorded in mobile species (barramundi and mud crabs) that are targeted by local fishers. For the barramundi, the limited evidence suggests these elevated concentrations are caused by mine-derived ore, and this is possibly the case for the mud crabs as well. In addition, there is evidence that barramundi contaminated with ore-derived Pb are moving away from the Bing Bong Loading Facility to Mule Creek which is used by fishers. It is unclear how long fauna would need to spend at the loading facility to uptake ore-derived Pb, what the pathways of Pb uptake are (i.e., is it from the consumption of other contaminated biota or merely persisting in the area) and how common large-scale movement is in the marine biota of the area. However, it must be stressed that the maximum concentration of Pb recorded in barramundi was ten times lower than the MPC. Additionally, due to small sample size, these results need to be treated very cautiously. The collection of this data is an important step forward in understanding any potential impacts on species targeted by fishers, and additional collections in future years will determine whether MRM's operations are impacting these species. Unfortunately, MRM contractors reported that the 2015 AMMP was only able to catch two barramundi, despite substantial fishing effort.

Based on reports by Skov (2015) and Hydrobiology (2016), a 16 kg child would need to consume 0.6 or 1.4 kg of fish, and a 77 kg adult, 1.7 or 11 kg of fish, daily, to exceed tolerable daily intakes for Pb and Zn, respectively. Therefore, it is highly improbable that current contamination of the marine environment at Bing Bong Loading Facility will have a measurable impact on human health, particularly if fishers are excluded from the immediate vicinity of the swing basin.

Overall, results were relatively consistent between surveys from 2010 to 2014 and inclusion of this long-term data in the AMMP would be beneficial.

Seagrass Monitoring Program

Qualitative analysis indicates seagrass coverage was very high in 2014 and 2015, with seagrass being present at 99% of monitoring sites at the Bing Bong Loading Facility in both years (Table 4.51). The control site at Sector 3 had 86% coverage in 2014 and 73% coverage in 2015. The other two control sites had 100% coverage both years. The new quantitative approach first adopted in 2013 shows similar results (Table 4.52), with coverage increasing by an average of 13% at Bing Bong Loading Facility and 14% at Sector 3 between 2013 and 2015. Coverage declined by 3% at Sector 5 between 2014 and 2015. Likewise, seagrass diversity continues to increase; while meadows are dominated by two species – *Halophila ovalis* and *Halodule uninervis* – the coverage and density of other species continues to increase (Table 4.53). In addition, the number of patches dominated by the less common species (*Cymodocea serrulata, Syringodium isoetifolium,* and *Halophila spinulosa*) also continues to increase.

Seagrass cover, density and diversity largely continue to improve throughout the region, as seagrass meadows recover following Cyclone Grant. Cyclones are a major disturbance to seagrass communities, and play an important role in shaping seagrass communities in northern Australia (Roelofs et al., 2005).

Operations and works at the Bing Bong Loading Facility and WDR facility are not having a measurable impact on seagrass communities.

As noted previously, the two new control sites (Sectors 5 and 6) will be beneficial since one of the previous control sites (Sector 4) was unsuitable due to the different nature of the sites compared with those at the Bing Bong Loading Facility. The new quantitative approach using video transects will also help improve comparisons between years and sites, and will remove potential observer biases associated with the qualitative data collected previously.

Table 4.51 – Seagrass Coverage Adjacent to Bing Bong Loading Facility from 2011 to 2015 and for Control Sites from 2012 to 2015 (%)

Seagrass Coverage	2011	2012	2013	2014	2015
Bing Bong Loading Facility					
Bare substrate	1	1	3	1	1
Very sparse	0	0	5	2	5
Sparse	12	52	44	21	23
Moderate	54	44	51	55	53
Dense	27	3	8	17	13
Very dense	6	0	0	4	4
Sites with seagrass	99	99	97	99	99
*Sector 3**					
Bare substrate	-	57	26	14	27
Very sparse	-	0	33	31	15
Sparse	-	6.	10	28	15
Moderate	-	17	31	28	37
Dense	-	13	0	0	7
Very dense	-	6	0	0	0
Sites with seagrass	-	43	74	86	73
*Sector 4**					
Bare substrate	-	43	26	-	-
Very sparse	-	0	13	-	-
Sparse	-	23	22	-	-
Moderate	-	34	26	-	-
Dense	-	0	13	-	-
Very dense	-	0	0	-	-
Sites with seagrass	-	57	74	-	-
*Sector 5**					
Bare substrate	-	-	-	0	0
Very sparse	-	-	-	11	11
Sparse	-	-	-	6	22
Moderate	-	-	-	58	31
Dense	-	-	-	25	25
Very dense	-	-	-	0	11
Sites with seagrass	-	-	-	100	100
*Sector 6**					
Bare substrate	-	-	-	-	0
Very sparse	-	-	-	-	19
Sparse	-	-	-	-	6
Moderate	-	-	-	-	50
Dense	-	-	-	-	25
Very dense	-	-	-		0
Sites with seagrass	-	-	-		100

*Control sites. Data from sectors 3 and 4 was first collected in 2012, from sector 5 in 2014 and sector 6 in 2015. Due to its unsuitability as a control site, data collection from sector 4 stopped following the 2013 survey.

Table 4.52 – Percentage Cover of Seagrass and Change in Cover at Bing Bong Loading Facility and Control Sites from 2013 to 2015

Transect	Percentage Cover of Seagrass			Percentage Change in Cover		
	2013	2014	2015	2013-2014	2014-2015	2013-2015
Bing Bong Loading Facility						
1	45	43	61	-2	18	16
2	24	38	68	14	30	44
3	28	42	17	14	-29	-11
4	39	58	35	22	-23	-1
5	50	55	56	5	1	6
6	27	63	82	36	19	55
7	40	82	43	43	-40	3
8	34	63	47	29	-16	13
9	54	68	44	14	-24	-10
10	43	55	55	12	0	12
11	31	63	60	32	-3	29
12	42	48	43	6	-5	1
Average	38	57	51	19	-6	13
*Sector 3**						
1	50	22	60	-28	38	10
2	32	38	57	6	19	25
3	43	53	71	11	17	28
4	16	18	24	2	6	8
5	19	30	41	11	11	22
6	17	5	22	-12	18	6
7	0	28	17	28	-11	17
8	19	21	13	3	-8	-5
Average	21	24	34	3	11	14
*Sector 5**						
1	-	64	24	-	-40	-
2	-	67	31	-	-35	-
3	-	60	47	-	-13	-
4	-	48	65	-	17	-
5	-	43	76	-	33	-
6	-	39	61	-	22	-
Average	-	53	51	-	-3	-
*Sector 6**						
1	-	-	47	-	-	-
2	-	-	44	-	-	-
3	-	-	53	-	-	-
4	-	-	46	-	-	-
5	-	-	45	-	-	-
6	-	-	63	-	-	-
Average	-	-	50	-	-	-

*Control sites. Data from Bing Bong Loading Facility and Sector 3 was first collected in 2013, from Sector 5 in 2014 and Sector 6 in 2015.

Table 4.53 – Percentage of Sites in the Bing Bong Shipping Channel and Control Sites Where Each Species of Seagrass was Recorded (%)

Seagrass Species	2011	2012	2013	2014	2015
Bing Bong Loading Facility					
Halophila ovalis	68	60	83	99	78
Halodule uninervis	92	94	92	97	89
Cymodocea serrulata	5	6	10	22	13
Syringodium isoetifolium	31	16	24	45	56
Thalassia hemprichii	4	0	0	0	0
*Sector 3**					
Halophila ovalis	-	36	46	67	61
Halodule uninervis	-	34	56	42	37
Cymodocea serrulata	-	0	8	17	10
Syringodium isoetifolium	-	15	26	22	22
Thalassia hemprichii	-	0	0	0	0
*Sector 4**					
Halophila ovalis	-	36	61	-	-
Halodule uninervis	-	45	65	-	-
Cymodocea serrulata	-	0	7	-	-
Syringodium isoetifolium	-	43	65	-	-
Thalassia hemprichii	-	6	0	-	-
*Sector 5**					
Halophila ovalis	-	-	-	100	78
Halodule uninervis	-	-	-	81	92
Cymodocea serrulata	-	-	-	11	22
Syringodium isoetifolium	-	-	-	33	78
Thalassia hemprichii	-	-	-	0	0
*Sector 6**					
Halophila ovalis	-	-	-	-	81
Halodule uninervis	-	-	-	-	94
Cymodocea serrulata	-	-	-	-	22
Syringodium isoetifolium	-	-	-	-	42
Thalassia hemprichii	-	-	-	-	0
Halophila spinulosa	-	-	-	-	14

*Control sites. Data from Sectors 3 and 4 was first collected in 2012, from Sector 5 in 2014 and sector 6 in 2015. Due to its unsuitability as a control site, data collection from Sector 4 stopped following the 2013 survey.

Progress

McArthur River Mining's performance against previous IM review recommendations relating to marine ecology issues is outlined in Table 4.54.

Table 4.54 – Marine Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
Inclusion of long-term datasets in reports	As the AMMP, the seagrass monitoring and the DGT program have now been running for several years, long-term datasets should be included in the reports so consistent patterns and inconsistencies can be more easily identified	Long-term datasets were included in the most recent seagrass monitoring program. The DGT report continued to focus on the most recent findings, without presenting data from previous years. The AMMP for 2015 is still being prepared, so it is unknown whether this report will include comparisons with long term data
2012 and 2013 Operational Periods		
Establish proper control sites for seagrass	Establish better control sites for the annual seagrass monitoring. Current control sites, especially Sector 4, are inherently different from seagrass meadows around the Bing Bong Loading Facility such that the processes underlying community change cannot be accurately assessed. Roelofs et al. (2005) indicate that more suitable seagrass controls may be present to the east of Bing Bong Loading Facility. Establishing better control sites will facilitate the collection of good quality baseline data	A new control site was added to the 2014 monitoring program and second new control site was added to the 2015 program. These sites are analogous to the Bing Bong Loading Facility site and as a result are excellent control sites This recommendation been addressed and is now complete
Add sites to the AMMP	Establish an additional site in the AMMP immediately west of the Bing Bong Loading Facility to determine the extent of contaminants. Prevailing currents carry sediments, and therefore contaminants, to the west. Sites to the far east of Bing Bong Loading Facility, such as SEPI 3, could be removed to accommodate these new sites	Two new sites, Bing Bong West 1 and 2, were added to the 2014 monitoring program. While habitat for most species is limited at this site, sediment, water and *Terebralia* snails could be collected This recommendation been addressed and is now complete
Sample fish from higher trophic levels	Use adult fish for the metal contaminants assessment in the AMMP, as they will have had more time to accumulate contaminants, and will likely have a higher trophic position	High trophic level species that are targeted and consumed by fishers (barramundi and giant queenfish) were added to the 2014 monitoring program This recommendation been addressed and is now complete
Timing of dredging	Do not dredge during rain events to ensure that particulate matter will have enough time to settle out before flowing out of the dredge spoil ponds. Dredging only in the dry season would be preferable, as there will be minimal chance of intense rain	No dredging was undertaken during the reviewed reporting period

4.11.4.3 Successes

The marine monitoring program continues to expand and improve, taking on recommendations from the IM, government departments and MRM specialists. Specifically, in the 2014-2015 operational period, MRM has:

- Expanded the AMMP to include two sites immediately west of the Bing Bong Loading Facility (Bing Bong West 1 and 2). These were established as the prevailing currents and winds probably push contaminants in a westerly direction from the loading facility. The monitoring program now includes fish from a higher trophic level that are targeted by fishers (barramundi and giant queenfish). Data from these species help to determine whether contaminants are moving up the food chain and to address potential concerns regarding effects on human health.
- The seagrass monitoring program is now comprehensive and effective. With the addition of two new control sites, the effects of operations on seagrass communities can be properly assessed. The inclusion of a quantitative method for assessing seagrass cover allows for robust comparisons of seagrass meadows over time.
- Two reports investigating the potential effects on human health from consuming biota from the McArthur region will aid in allaying community concerns by indicating the extreme amounts of fish that would need to be consumed daily to affect health.
- Improved signage to dissuade fishers from fishing in the immediate vicinity of the Bing Bong Loading Facility.

4.11.5 Conclusion

Overall, impacts to the marine environment at the Bing Bong Loading Facility are almost exclusively restricted to the shipping channel and the area immediately west of the facility. Where metal concentrations were detected in biota, they fell well below applicable MPCs. Barramundi were added to the AMMP for the first time in 2014 and concentrations of Pb were elevated, but markedly below MPC levels, in individuals collected from the loading facility. When more data becomes available an assessment of the source of contamination will be possible. In addition, another barramundi caught at Mule Creek had elevated Pb with an isotopic ratio close to that of the ore body; this indicates that individual fish may be taking up Pb at the Bing Bong Loading Facility, then moving offsite carrying elevated levels of contaminants.

Ongoing and new IM recommendations related to marine ecology issues are provided in Table 4.55.

Table 4.55 – New and Ongoing Marine Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Inclusion of long-term datasets in reports	As the AMMP and the DGT program have now been running for several years, long-term datasets should be included in the reports so consistent patterns and inconsistencies can be more easily identified. Long-term data was included in the seagrass monitoring program in 2015, and may be included in the latest AMMP, which is currently being prepared	Low

Table 4.55 – New and Ongoing Marine Ecology Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Timing of dredging	Do not dredge during rain events to ensure that particulate matter will have enough time to settle out before flowing out of the dredge spoil ponds. Dredging only in the dry season would be preferable, as there will be minimal chance of intense rain	Low
New Items		
Contaminant uptake and dispersal in biota	As barramundi with elevated, mine-derived Pb were caught in the Bing Bong Loading Facility shipping channel, and a single fish with elevated, mine-derived Pb may have moved away from the loading facility, a report should be prepared covering the available literature on: ♦ The time it takes for a measurable contaminant load to be taken up in mobile species (e.g., barramundi, giant queenfish, mud crab, blue-tailed mullet) ♦ Sources of contamination in these species – are contaminants absorbed by consuming contaminated prey species and/or merely by persisting in the Bing Bong Loading Facility swing basin? ♦ Likelihood of dispersal in these species and potential dispersal distances	Medium
New DGT monitoring sites	As seawater from Bing Bong West 1 had elevated levels of contaminants, the IM suggests establishing DGT monitoring stations at Bing Bong West 1 and 2, if feasible, to determine fine-scale patterns of contamination at these sites	Medium
Monitoring of *Vibrio* bacteria	The last monitoring of *Vibrio* bacteria in the vicinity of McArthur River was carried out in 2013. In the 2014 report, the IM suggested a final *Vibrio* survey in 2015, which was not undertaken. A final *Vibrio* survey should be undertaken to confirm that *Vibrio* bacteria abundances are not increasing as a result of MRM's activities	Low

4.11.6 References

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FSANZ. 2009. Standard 1.4.1. Contaminants and Natural Toxicants, issue 103. Food Standards Australia New Zealand, Canberra, ACT.

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Thorburn, D. 2015b. Annual Seagrass Survey of the Bing Bong Loading Facility, 2014. Prepared by Indo-Pacific Environmental for McArthur River Mining Pty Ltd, Winnellie, NT.

Thorburn, D. 2015c. Assessment of Metals and Lead Isotope Ratios of Seafloor Sediments in the McArthur River Mine Transshipment Area, December 2014. Prepared by Indo-Pacific Environmental for McArthur River Mining Pty Ltd, Winnellie, NT.

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Thorburn, D. 2016b. Metal and Arsenic Concentrations of Near Shore Sediments of Bing Bong Loading Facility, August 2015. Prepared by Indo-Pacific Environmental for McArthur River Mining Pty Ltd, Winnellie, NT.

Tsang, J., 2015. Monitoring the Concentrations of Bioavailable Metals and Lead Isotope Ratios in Seawater by Diffusive Gradients in Thin-Films Deployed around Glencore Xstrata McArthur River Mine's Bing Bong Loading Facility: Review of 2014-15 data. November. Report Prepared by Australian Institute of Marine Science for McArthur River Mining Pty Ltd, Winnellie, NT

4.12 Soil and Sediment Quality

4.12.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of soil and sediment quality, and is based on review of:

- Observations and discussions with MRM personnel during the site inspection, and subsequent email correspondence.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's environmental monitoring report (MRM, 2015a) and fluvial sediment monitoring report (MRM, 2015b), along with operational period reports on annual marine monitoring, nearshore sediment and trans-shipment sediment (Thorburn, 2015a; 2015b; 2015c).
- Responses by MRM to recommendations raised in the previous IM report, as well as responses to comments raised by the DME.
- Laboratory analysis results and/or spreadsheets provided by MRM that contain collated laboratory analysis data.
- Various MRM forms and similar documents such as chain of custody forms and correspondence between MRM and the DME.

4.12.2 Key Risks

The risk assessment undertaken to support the review identified a number of key risks concerning soils, fluvial sediments[14] and marine sediments (see Appendix 2). These remain largely as described in last year's IM report and are summarised below.

Soils

The three main causes of soil contamination at the mine site and Bing Bong Loading Facility are:

- Direct and localised contamination as a result of operations (as discussed in Section 4.3.2).
- Soil contamination as a result of groundwater seepage 'daylighting' on the ground surface.
- Soil contamination from depositional dust generated by:
  - Mining and processing operations, primarily from the OEFs, haul roads, TSF, ore crushing plant, ROM pad and external concentrate storage area at the mine site.
  - Barge loading (and other materials handling tasks) at Bing Bong Loading Facility and, to a lesser extent, placement of dredge spoil in the dredge spoil emplacement area[15].

[14] Fluvial sediments are those associated with McArthur River and its tributary streams.
[15] No dredging occurred during either the 2014 or 2015 operational periods.

In addition to affecting soil quality, soil contamination may:

- Impact on the health of native vegetation and/or pasture, which can have adverse impacts on terrestrial fauna and/or livestock.

- Contribute to poor water quality (pH, salts, trace metals) in adjacent surface waters and increase the costs of mine closure. As noted previously (Section 4.3.2), this can have adverse impacts on aquatic or marine flora/fauna and, potentially, human or animal health via bioaccumulation.

Fluvial Sediments

As for surface water, a number of related risks have been recognised in terms of fluvial sediment quality at the mine site:

- Poor quality seepage and surface runoff, primarily from areas such as the TSF and NOEF, may result in poor sediment quality in Surprise Creek and Barney Creek diversion channel and, ultimately, McArthur River. The environmental impacts are as described in relation to surface water quality at McArthur River Mine (Section 4.3). This type of risk also includes impacts such as those that might be associated with TSF embankment failure (in which case the tailings solids themselves would also present a significant hazard) and the TSF overtopping, neutral or saline leachates from waste rock[16], and saline seepage from areas such as the ELS potentially reporting directly to McArthur River. Changes in water quality in McArthur River due to the suggested (by MRM) influence of the Cooley deposits and oxidising pyritic shale that is intercepted by the McArthur River diversion channel also requires consideration in terms of potential impacts on fluvial sediments.

- Dust generated by mining and processing operations may deposit directly into watercourses or may contaminate soil, thereby contributing to poor quality surface runoff. These processes may cause poor water quality (pH, salts, trace metals) in Surprise Creek, Barney Creek or McArthur River diversion channels, and/or McArthur River below the mine site. The environmental impacts are as described for surface water quality risks (Section 4.3).

Marine Sediments

Risks associated with marine sediment are as described in terms of water quality risks in the marine environment:

- Contamination of bed sediments in the nearshore environment by poor quality surface runoff (which has been contaminated by depositional dust generated by loading operations and/or dredge spoil). This can have adverse impacts on aquatic and marine flora/fauna and, potentially, human health or marine animal health via bioaccumulation.

- Contamination of bed sediments in the nearshore and offshore environments, as a result of concentrate spillages or direct dust deposition during barge loading or trans-shipment, also affecting coastal or marine water quality, with resulting adverse impacts as described above.

[16] As noted elsewhere in this report, the waste rock classification was amended in 2013 to include rock that potentially produces acid, saline and/or metalliferous drainage.

Additional risks are also as previously described:

- Acidic leachate from acid sulfate soils.
- Contamination in the vicinity of the Sir Edward Pellew Group of Islands and/or the McArthur River estuary from MRM upstream mine activities or Bing Bong Loading Facility operations.

4.12.3 Controls

4.12.3.1 Previously Reported Controls

Soils

General Controls

In terms of the main sources of contaminants that can affect soils, existing controls are discussed in the relevant sections that address:

- Surface water management (Section 4.3).
- Materials management and generation of contaminated dust (Section 4.13).

An additional soil contamination control implemented at the mine site and at the Bing Bong Loading Facility is the removal and stockpiling of topsoil prior to undertaking activities that may result in contamination of soil.

Monitoring Program

The MRM surface soil monitoring program has been undertaken annually since 2008. As noted in MRM (2015a), the purpose of this program at both the mine site and Bing Bong Loading Facility is to provide a health and environmental risk assessment of soil strata to which people and other receptors could feasibly be exposed. The specific objectives of the surface soil monitoring program are to:

- Assist in identifying potential sources of impacts from mining operations and activities associated with the Bing Bong Loading Facility.
- Assess soil metal and physicochemical properties, provide accurate assessment of soil contamination, and identify trends that may be occurring.
- Provide data to complement the current dust monitoring program.

The key elements of the surface soil monitoring program include:

- Sampling sites as shown in Figure 4.32 (McArthur River Mine) and Figure 4.33 (Bing Bong Loading Facility) for the 2015 operational period:
  - Sampling sites at the mine site are grouped according to an identified point source of potential dust generation in operation, e.g., reference sites and potential impact sites associated with each of the ore crushing plant/ROM pad, NOEF and TSF.

SOIL MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.32

ERIAS Group | 01164C_1_F4-32_v1.pdf

SOIL MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.33

ERIAS Group | 01164C_1_F4-33_v1.pdf

  - Sampling at Bing Bong Loading Facility included sampling of surface soil from two sites (BBS03 and BBS04) in the dredge spoil emplacement area, as well as sites near the Bing Bong Loading Facility concentrate shed/loading conveyor and swing basin.

- Sampling soils on an annual basis in the middle of the dry season. Soil monitoring sites correspond to dust monitoring sites, which are sampled via a separate program (Section 4.13).

- Laboratory testing including pH and EC (paste), cation exchange capacity, major ions and trace metals in the <2 mm fraction (analysed after strong acid (aqua regia) digestion).

- Assessment of soil quality results by comparison with the National Environmental Protection (Assessment of Site Contamination) Measure 1999[17] (the NEPM) (NEPC, 1999). Results from samples that are aimed at assessing impacts associated with the ore crushing plant and ROM pad are compared with health investigation levels (HILs), while results from other samples are compared with ecological investigation levels (EILs) so as to provide a more conservative assessment than would be the case using HILs for all sample results.

Monitoring site S43 near Barney Creek haul road bridge (first sampled in the 2014 operational period) was not sampled as part of the 2015 program. This site has been removed from the program as it was located in a heavily modified area, and results may therefore reflect the waste rock used to build up this location rather than identify contamination from depositional dust (Dobson, 2016a).

Fluvial Sediments

General Controls

In terms of the main sources of contaminants that can affect fluvial sediments, existing controls are discussed in the relevant sections that address:

- Surface water management (Section 4.3).

- Materials management and generation of contaminated dust (Section 4.13).

As indicated in Figure 4.34, additional controls that are specific to fluvial sediments at Barney Creek haul road bridge include:

- Northwest of the bridge (northern side of Barney Creek diversion channel, on the western side of the bridge) – a permanent settlement sump system to intercept surface water runoff reporting to this area (MRM, 2014).

[17] The original NEPM (NEPC, 1999) has been revised, with the updated version becoming effective in 2013 (with transitional provisions), although still referenced as 'NEPC, 1999'. Volume 2 of the revised interim MMP 2013-2015 (MRM, 2015a) uses criteria from the pre-amendment (1999) version of the NEPM. The IM (in this report) has applied the same criteria.

SEDIMENT CONTROL STRUCTURES AT BARNEY CREEK HAUL ROAD BRIDGE

McArthur River Mine Project

FIGURE 4.34

ERIAS GROUP

- Southeast of the bridge – a permanent 'Type F' sediment basin[18] (MRM, 2015c), which reduces contaminated sediment supply to the creek.
- Northeast of the bridge – a minor silt trap/sediment pond.
- Southwest of the bridge – two minor silt traps.
- Immediately downstream of the bridge at FS19/SW19 – a bund/small dam constructed within the Barney Creek diversion channel during the 2014 operational year remains in place to capture contaminated water and sediment (although flow still occurs to varying degrees in all but the driest months).

The IM has been advised by MRM (Dobson, 2016b) that sediment captured within these control structures is currently cleared out annually after the wet season, if required. Water levels in the Barney Creek diversion channel have been known to overtop the lowest silt traps during the peak wet season, by which time they may have captured additional contaminated sediment contained in runoff. This is discussed further in Section 4.12.4.2.

Monitoring Program

As noted in MRM (2015a), the purpose of the fluvial sediment monitoring program is to assess potential sediment-associated pollutant fluxes in the McArthur River and its tributaries in proximity to the mine site.

The specific objectives of the program are to:

- Identify potential variations in sediment physicochemical parameters relating to river or creek flow in the survey area.
- Provide information regarding long-term trends in water quality through sediment sample analysis.
- Allow contaminated runoff – should this occur – to be traced.

The key elements of the program include:

- Fluvial sediment sampling sites as shown in Figure 4.35 for the 2015 operational period. These are the same locations as the natural surface water sampling sites (see Figure 4.1).
- Sampling annually in the early to mid dry season (in 2015, this occurred in April/May).
- Laboratory testing including pH and EC (paste), particle size distribution, major ions, Pb isotope ratios, and trace metals in the <63 μm fraction (analysed separately after weak acid (1M HCl) digestion and after strong acid ($HNO_3/HClO_4/HF/HCl$) digestion).

[18] 'Type F' soils contain a significant proportion of fine-grained particles and require extended settlement periods to achieve settlement. A Type F sediment basin is a wet basin (i.e., not free-draining), which is designed for settling out fine sediment before draining of water.

FLUVIAL SEDIMENT MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.35

ERIAS Group | 01164C_1_F4-35_v1.pdf

Assessment of the data obtained from fluvial sediment sampling in the 2015 operational period primarily involved comparison with the ANZECC/ARMCANZ (2000) sediment quality guidelines. The ISQG-low values/trigger values represent concentrations below which the frequency of adverse biological effects is expected to be low, while ISQG-high values represent concentrations above which adverse biological effects are expected to be more likely to occur. The sediment quality aspects of the ANZECC/ARMCANZ guidelines have been updated by Simpson et al. (2013), but the guideline values applicable to parameters monitored by MRM have not changed. Nonetheless, the next version of MRM's MMP, as well as future fluvial sediment monitoring reports, should reference Simpson et al. (2013).

Marine Sediments

General Controls

In terms of the main sources of contaminants that can affect marine sediments, existing controls are discussed in the relevant sections that address:

- Surface water management (Section 4.3).
- Materials management and generation of contaminated dust (Section 4.13).

Monitoring Program

The aim of the marine sediment monitoring program is to assess impacts and manage risks of activities at Bing Bong Loading Facility with regards to the local marine environment. The specific objectives of the program are to (MRM, 2015a):

- Determine the sediment characteristics and chemistry of the receiving environment.
- Assess the impact of loading facility operations on the receiving environment, and determine if any detected impact is acceptable or unacceptable.
- Provide data to guide management decisions.
- Complete statutory monitoring and monitor compliance in accordance with requirements of the waste discharge licence.

The key elements of the program include:

- Seasonal marine sediment sampling events during the 2015 operational period, as part of:
  - The annual marine monitoring program (AMMP) undertaken in December 2014, with sampling sites as shown in Figure 4.30.
  - The nearshore sediment assessment undertaken in August 2015, with sampling sites as shown in Figure 4.36.
  - The trans-shipment area seafloor sediment assessment, undertaken in December 2014, with sampling sites as per Figure 4.37.

NEARSHORE SEDIMENT ASSESSMENT SAMPLING SITES

McArthur River Mine Project

FIGURE 4.36

TRANS-SHIPMENT AREA SAMPLING SITES

McArthur River Mine Project

FIGURE 4.37

Source: Google Image 2005

ERIAS Group | 01164C_1_F4-37_v1.pdf

- Laboratory testing including particle size distribution and Pb isotope ratios. Trace metals in marine sediments were analysed for the three programs as follows:
  - The AMMP analysed trace metals in both the <2 mm fraction (after strong acid (HCl/HNO_3) digestion) and the <63 μm fraction (analysed separately after weak acid (1M HCl) digestion).
  - The nearshore sediment assessment analysed trace metals in the <63 μm fraction (after weak acid (1M HCl) digestion).
  - The trans-shipment area seafloor sediment assessment analysed trace metals in the <2 mm fraction (after strong acid (HCl/HNO_3) digestion).

As with the fluvial sediment program, assessment of data obtained from marine sediment sampling involved comparison with the ANZECC/ARMCANZ (2000) sediment quality guidelines, which have now been updated by Simpson et al. (2013) but with applicable guideline values unchanged. The next version of the MMP, as well as future reports addressing marine sediment monitoring (the AMMP, nearshore and trans-shipment sediment assessments), should reference Simpson et al. (2013).

4.12.3.2 New Controls – Implemented and Planned

All new soil and sediment controls in the 2015 reporting period relate to the various monitoring programs, as follows:

- At the mine site, two additional surface soil monitoring sites have been established (see Figure 4.32), correlating with new dust monitoring sites:
  - Site S47 (1.5 km east-northeast of the mine pit, between the mine bund wall and the McArthur River diversion channel).
  - Site S48 (approximately 600 m west of the western-most point of TSF Cell 2).
- The soil sampling program now includes sampling from the 40 to 50 cm depth range, as well as from the surface (1 to 10 cm depth).
- At the Bing Bong Loading Facility, soil monitoring site BBS06 has been replaced by new site BBS07 (see Figure 4.33), correlating with a new dust monitoring site, due to the former site being overtaken by development associated with the Western Desert Resources iron ore loading dock and conveyor (MRM, 2015d). Site BBS07 is located approximately 30 m west of site BBS06, near the Bing Bong Loading Facility boundary fence.
- In relation to fluvial sediment management at the mine site:
  - One additional fluvial sediment monitoring site has been established on Emu Creek (FS31), approximately halfway between existing sites FS26 and FS30. This is classified as a mid-reach site, and is upstream of mine-affected catchments (MRM, 2015b). This site corresponds to a new natural surface water monitoring site (SW31), however, water was not sampled at this site during the 2015 operational period due to the site being

established when water was not flowing at that location (i.e., during the 2015 dry season).

- At FS26, two sets of samples were collected, upstream (A) and downstream (B) of the creek crossing point (road) at this location, instead of the usual single sample. This approach was in response to concerns raised by DME in March 2015 (MRM, 2015e) regarding unusually high Ca, Mg and SO_4 results in samples from FS26 in August 2014, which MRM suspected was due to the sample being taken from the road crossing material rather than the fluvial bed sediments. Results from 2015 are discussed under Section 4.12.4.3.

- For marine sediment management, new controls were confined to the AMMP, which in 2015 included sampling from two additional sites to the immediate west of the Bing Bong Loading Facility shipping channel (Bing Bong (BB) West 1 and 2), as well as ten new sites within the swing basin and shipping channel (see Figure 4.30) (Thorburn, 2015a).

4.12.4 Review of Environmental Performance

4.12.4.1 Incidents and Non-compliances

Incidents

There were no reported incidents related to soil or sediment associated with the McArthur River Mine or Bing Bong Loading Facility during the 2015 operational period. However, the IM believes that the following should also have been reported as incidents:

- Exceedances of soil HILs for Pb within 1 km of the processing plant, and exceedances of EILs for other metals throughout the mine site and at Bing Bong Loading Facility.

- Exceedances of ANZECC/ARMCANZ (2000) interim sediment quality guideline trigger values in fluvial sediments at the mine site, including exceedances of ISQG-high criteria for Pb and Zn in the Barney Creek diversion channel near the crushing plant and at the haul road bridge.

- Exceedances of ANZECC/ARMCANZ (2000) interim sediment quality guideline trigger values in marine sediments in the Bing Bong Loading Facility shipping channel and immediate area, including exceedances of ISQG-high criteria for Zn at a number of sites.

These are discussed under non-compliances below.

Non-compliances

The revised interim 2013-2015 MMP (MRM, 2015c) does not contain a definitive list of commitments against which to assess non-compliances (see Section 3.2.4), however, a summary of the soil and sediment guideline exceedances at the mine site and at or near Bing Bong Loading Facility are provided in the following sections.

Soils

In the absence of a soil monitoring report for the operational period[19], the IM has reviewed provided soil analysis data from the 2015 operational period against the criteria specified in Volume 2 of the revised interim MMP 2013-2015 (MRM, 2015a), that is, EILs and HILs from the pre-amendment version of the NEPM (NEPC, 1999).

Table 4.56 summarises those soil analysis results for metals in the <2 mm fraction (which underwent strong acid (aqua regia) digestion prior to analysis) that exceeded NEPM (NEPC, 1999) guideline levels – yellow cells indicate exceedances of EIL criteria, while pink cells indicate exceedances of HIL(F) criteria (where ‘F’ relates to industrial sites). Blank cells relate to sites and sample depths for which no exceedance was recorded for the specified metal.

Table 4.56 – Soil Metal Results From 2015 Exceeding NEPM (NEPC, 1999) Criteria

Group	Site No.	Sample Depth	Concentration (mg/kg) (Dry Weight) (Total Fraction)					
			As	Cd	Cu	Pb	Mn	Zn
Ore crushing plant/ROM pad <1 km group[*]	S22	0 to 10 cm	63	7		1,450	1,430	2,700
	S22	40 to 50 cm					1,270	248
	S23	0 to 10 cm					672	399
	S23	40 to 50 cm					686	
	S27	0 to 10 cm					803	
	S28	0 to 10 cm	81	6		2,270	3,750	2,700
	S28	40 to 50 cm	66			5,960		750
	S44	0 to 10 cm	57			1,540	1,320	1,800
	S44	40 to 50 cm	47			1,640	597	1,570
Ore crushing plant/ROM pad 1 to 2 km group	S08	0 to 10 cm	25				3,400	632
	S08	40 to 50 cm	38				2,820	855
	S47[#]	0 to 10 cm					806	
	S47[#]	40 to 50 cm					710	
NOEF <2 km	S30	0 to 10 cm	20			641	1,890	320
	S30	40 to 50 cm					1,090	
	S45	40 to 50 cm	28					237
TSF <2 km	S06	0 to 10 cm					823	
	S07	0 to 10 cm					998	
	S07	40 to 50 cm	27					
	S12	0 to 10 cm					555	
	S12	40 to 50 cm					1,250	
	S13	0 to 10 cm					702	
	S42	0 to 10 cm					936	553
	S42	40 to 50 cm					816	
	S48[#]	0 to 10 cm	23				858	
	S48[#]	40 to 50 cm	26				859	

[19] McArthur River Mining has advised that the next soil monitoring report will cover both the 2014-2015 and 2015-2016 monitoring periods (Dobson, 2016c).

Table 4.56 – Soil Metal Results From 2015 Exceeding NEPM (NEPC, 1999) Criteria (cont'd)

Group	Site No.	Sample Depth	Concentration (mg/kg) (Dry Weight) (Total Fraction)					
			As	Cd	Cu	Pb	Mn	Zn
TSF 2-3 km	S03	0 to 10 cm	24				3,730	236
	S17	0 to 10 cm					1,100	
	S19	0 to 10 cm					745	
	S20	0 to 10 cm					758	
	S20	40 to 50 cm					580	
Reference sites	S01	0 to 10 cm					612	
	S05	0 to 10 cm	253			956	2,330	2,750
	S05	40 to 50 cm	143				1,310	1,790
Bing Bong Loading Facility†	BBS01	0 to 10 cm						317
	BBS02	0 to 10 cm	21					744
	BBS03	0 to 10 cm	22					203
	BBS07	0 to 10 cm						1,050
HIL (F) criteria*			500	100	5,000	1,500	7,500	35,000
EIL criteria*			20	3	100	600	500	200

* Results from the ore crushing plant/ROM pad <1 km group are compared to the HILs in the first instance, while all other groups are compared to EILs. # New soil monitoring sites in the 2015 operational period. † Monitoring sites at Bing Bong Loading Facility were sampled in June 2015, while sites at McArthur River Mine were sampled in July/August 2015.

Exceedances of HILs only occurred within 1 km of the processing plant, for Pb at sites S28 and S44. Lead concentrations were particularly high at site S28 (which only had a minor exceedance in the previous operational period), being 1.5 times the HIL in surface soils (0 to 10 cm) and nearly four times the HIL at depth (40 to 50 cm). This may be indicative of mineralised soils in the area or, alternatively, may indicate that soils at this location contain significant amounts of introduced or mine-derived materials. Results from these sites should be reviewed within the context of long-term trends and current MRM management measures.

Exceedances of the EIL for Mn were common throughout the mine site (including new sites S47 and S48) as well as reference sites. This may reflect background levels of Mn in the local area, however, as with the Pb results referred to above, MRM should review long-term trends in the next soil monitoring report. Exceedances of EILs for Zn and As occurred at a number of sites within 1 km of the processing plant as well as Site S08 to the west of the mill, in both surface (0 to 10 cm) and deeper (40 to 50 cm) soil profiles. Elsewhere at the mine site, exceedances of the EILs for Zn and As tended to be minor, as were surface exceedances of the Cd EIL near the processing plant.

At Bing Bong Loading Facility, surface exceedances of As and/or Zn occurred at sites BBS01, 02 and 07, as well as BBS03 in the dredge spoil ponds area.

Reference site S05 continues to be an outlier with results exceeding EILs, given that it is located in the immediate vicinity of a quarry that was closed in the late 1970s (MRM, 2015a). As such, the IM (ERIAS Group, 2015) has previously recommended that S05 is inappropriate as a reference site and should be removed from this group. Site S05 should be replaced by a more suitable reference site in the 2016 operational period.

Fluvial Sediments

Fluvial sediment monitoring sites with elevated concentrations of metals (in the bioavailable fraction, i.e., trace metals in the <63 μm fraction after weak acid digestion) are shown in Table 4.57 (see also Figure 4.35). Exceedances of ANZECC/ARMCANZ (2000) sediment quality guidelines were recorded for Pb and Zn only. Yellow cells indicate exceedances of ISQG-low criteria, while pink cells indicate exceedances of ISQG-high criteria. As for the previous operational year, results from FS03 (near the old PACRIM ROM pad and crushing plant) exceeded ISQG-high criteria for both of these metals. Results from FS19 (Barney Creek haul road bridge) exceeded the ISQG-high criterion for Pb, but were below the ISQG-high criterion (though exceeding ISQG-low) for Zn. There were also exceedances of the ISQG-low Pb criterion at FS02, FS06 and FS18.

As shown in Table 4.57, results from strong acid digestion (near-total metals) were consistently higher than those from weak acid digestion (representing the bioavailable fraction), as expected. Exceedances for Pb were the same (i.e., in terms of sample results that exceeded the same criteria) regardless of digestion method. Results for Zn were notably higher after strong (as opposed to weak) acid digestion, exceeding the ISQG-high criteria at FS03 and FS19, and the ISQG-low criteria at FS06 and FS18. However, the differences between results for the strong acid digestion as opposed to those for the weak acid digestion for these samples suggest that a substantial proportion of the Zn was present in forms that are not likely to be bioavailable.

Table 4.57 – Fluvial Sediment Results from 2015 Showing Elevated EC and/or Elevated Concentrations of Metals in the <63 μm Fraction (by Acid Digestion Method)

Monitoring Site		EC (μS/cm)	Concentration (mg/kg) (Dry Weight)			
Number	Location		Pb		Zn	
			Weak Acid	Strong Acid	Weak Acid	Strong Acid
FS02	Surprise Creek, downstream of the TSF	775	57.9	72.4	98	184
FS03	Barney Creek diversion channel next to crushing plant	350	233	269	389	765
FS04#	Barney Creek (upstream of diversion channel) at the Carpentaria Highway crossing	6,840	33.6	49.4	56.8	136
FS06	Barney Creek diversion channel/ unnamed creek confluence	3,730	63.8	78.4	160	240
FS18	Barney Creek diversion channel/ Surprise Creek confluence	3,180	83.3	109	128	212
FS19	Barney Creek haul road bridge	650	235	268	466	711
ISQG-high criteria*			220		410	
ISQG-low criteria*			50		200	

FS04 is included here due to high EC results, despite no exceedances of metals criteria. *Criteria are as per ANZECC/ ARMCANZ, 2000. Source: MRM, 2015a. Laboratory analysis reports sighted.

While FS04 had no metals exceedances, this site returned higher EC results than any other site (including diversion channel sites FS06 and FS18), and as such is included in Table 4.57 for comparison. Moisture content results (MRM, 2015b; 2016a) indicate that FS04 was near dry at the time of sampling (i.e., the upper reaches of Barney Creek were not flowing); therefore, EC results may have been influenced by evapo-concentration. However, other sites that had similarly low (or lower) moisture levels at the time of sampling (FS23, 27, 28, 29, 30 and 31) all had low EC results (≤335 μS/cm). It is speculated by MRM (2015b) that high EC results may indicate a potential source or sources of major ions in the vicinity of FS04. The IM notes that FS04 is situated at the Carpentaria Highway crossing of Barney Creek, and that (during the April 2016 site visit) there were signs of cattle access to the creek bed at this location.

Marine Sediments

Within sediments sampled as part of the AMMP, analysis of the bioavailable fraction (<63 μm using a weak acid digestion) showed no exceedances of ANZECC/ARMCANZ (2000) criteria for As, and no exceedances of ISQG-high criteria. In this fraction, exceedances of ISQG-low criteria for Pb and Zn were confined to the swing basin, as shown in Table 4.58, with concentrations of these metals being significantly higher at the swing basin sites than at other sites. This is comparable to results for the 2012 and 2013 operational periods, when the swing basin and shipping channel were sampled as part of MRM's internal monitoring programs (ERIAS Group, 2014).

Table 4.58 – AMMP Results from 2015 Showing Elevated Concentrations of Metals in Marine Sediment (by Size Fraction and Acid Digestion Method)

Monitoring Site		Concentration (mg/kg) (Dry Weight)					
		As		Pb		Zn	
Name	Location	Weak Acid*	Strong Acid	Weak Acid	Strong Acid	Weak Acid	Strong Acid
GB	Northeast of BBLF	9	59	20	27	7.5	8.3
117	East of BBLF	7	40	14	18	6.7	4.7
BB West 1	West of BBLF	6	28	16	16	11	7.7
MS1B	Northeast of BBLF	4	28	7	14	5.2	5.7
MS5A	Swing basin northwest	7	18	130	110	190	510
MS5B	Swing basin northeast	4	15	75	52	97	190
MS6A	Swing basin west	7	18	130	110	190	490
MS6B	Swing basin east	5	13	100	57	150	270
MS7A	Swing basin southwest	6	15	140	91	210	440
MS7B	Swing basin southeast	4	12	130	68	180	300
ISQG-high criteria*		70		220		410	
ISQG-low criteria*		20		50		200	

Data source: Thorburn, 2015a. *Weak acid digestion was performed on the <63 μm sediment fraction; strong acid digestion was performed on the <2 mm fraction.

As shown in Table 4.58, exceedances for Pb were the same (i.e., in terms of sample results that exceeded the same criteria) regardless of digestion method, although results after strong acid digestion were lower than those after weak acid digestion, reflecting analysis of different size fractions (strong acid on the <2 mm fraction, and weak acid on the <63 μm fraction) with lower total surface area in the coarser fraction. However, results for Zn were notably higher after strong (as opposed to weak) acid digestion, exceeding the ISQG-high criteria along the western side of the swing basin at MS5A, MS6A and MS7A, and the ISQG-low criteria at MS6B and MS7B. As for fluvial sediments, the differences between marine sediment results for strong acid digestion versus those for weak acid digestion for these samples suggest that a substantial proportion of the Zn was present in forms that are not likely to be bioavailable. Analysis of the <2 mm fraction after strong acid digestion showed exceedances of ISQG-low criteria for As outside the swing basin, at sites MS1B, BB West 1, GB and 117, but not within the swing basin itself.

Nearshore sediment results (for the <63 μm size fraction after weak acid digestion) during the operational period showed no exceedances of ANZECC/ARMCANZ (2000) criteria. For those metals that do not have ISQG criteria, Thorburn (2015b) calculated interim criteria based on concentrations in control zones. Two exceedances of these interim values were recorded during the operational period, both within the 'Eastern Control' (EC) zone – at EC-2, a Mn results of 729 mg/kg exceeded the interim criterion of 557 mg/kg, while at EC-2, a Co result of 16.4 mg/kg exceeded the interim criterion of 10.49 mg/kg (Thorburn, 2015b).

Within the trans-shipment area sediment results (for the <2 mm size fraction after strong acid digestion), there were no exceedances of ANZECC/ARMCANZ (2000) criteria during the 2015 operational period, and results within the trans-shipment area continued to be generally lower than those in the control area (Thorburn, 2015c).

4.12.4.2 Progress and New Issues

Progress

McArthur River Mining's progress and performance against previous IM review recommendations relating to soil and sediment issues is summarised in Table 4.59.

Table 4.59 – Soil and Sediment Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
Surface soil contamination near Barney Creek haul road bridge	Given the surface soil Pb HIL(F) exceedances at S43 (correlating with dust exceedances at site D43), MRM should investigate the main sources of this issue and develop a formal plan for dust minimisation in the vicinity	♦ McArthur River Mining has not prepared a soil monitoring report for the 2014-2015 year, as this will be combined with the 2015-2016 report. As such, the exceedances at S43 in 2014 have not yet been formally discussed ♦ Site S43 was not sampled in 2015, as results were deemed likely to reflect introduced material rather the impacts of dust (Dobson, 2016a). While the reason for removing site S43 from the program is valid, its absence makes it difficult to determine the extent to which dust deposition may be impacting on soils (and potentially sediment runoff) near the bridge. A replacement site in this vicinity, but situated on natural soils, would be useful to understand the issues at this location ♦ While a formal plan for dust management at the mine site has not yet been developed, MRM's investigation of dust issues at DMV43 (which may or may not have contributed to soil contamination at S43, as well as fluvial sediment contamination at FS19) is discussed in Section 4.13 of this report

Table 4.59 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Fluvial sediment contamination at Barney Creek haul road bridge	Given ongoing contamination issues at FS19, MRM should: ♦ Review options to close off drainage holes in Barney Creek haul road bridge, and instead drain the bridge to either end and via sediment traps	♦ With regards to the status of drain holes in the bridge, conflicting information was provided by MRM during preparation of the 2014 IM report. It has now been confirmed that the majority of the holes have been closed (with runoff directed into silt traps on either side of the bridge), but a number remain open (MRM, 2016b). It is recommended that the remaining holes be closed
	♦ Continue to monitor sediment traps on both sides of the bridge to ensure that they are functioning effectively to capture sediment-laden runoff and prevent inputs to the creek, and upgrade these or review if necessary	♦ McArthur River Mining has advised that silt traps at this location are cleaned out annually after the wet season, if required (Dobson, 2016b). Water levels in the Barney Creek diversion channel have been known to overtop the lowest silt traps during the peak wet season, by which time they may have captured additional contaminated sediment contained in runoff. As such, it is recommended that MRM adopts a more flexible approach to silt trap maintenance, for example cleaning out traps again in the early wet season/before significant floods are experienced, i.e., on an opportunistic basis ♦ The quality of water in sediment traps was monitored during the 2015/16 wet season (outside of the 2015 operational period), with poor quality water in the southeastern and northwestern traps being dewatered to Pete's Pond and the SPSD/SPROD, respectively. This practice is commended and should continue
Routine marine sediment monitoring	The biannual routine marine sediment sampling program in the Bing Bong Loading Facility swing basin and shipping channel was not undertaken during the 2014 operational year. This program should be reinstated in 2015	Periodic sediment sampling within the swing basin and shipping channel has now been incorporated into the AMMP. During the 2015 operational period, sediments from 10 sites within this area were sampled in December 2014 (Thorburn, 2015a). MRM has advised that this was repeated in 2015 as part of the 2016 operational year (MRM, 2016b)
Nearshore sediment monitoring	As reiterated by Thorburn (2015) the nearshore Eastern Control site should be moved slightly to the west in the next sampling event, to reduce possible impacts/influences of outputs from Mule Creek	The Eastern Control location was not modified for the 2015 operational year (Thorburn, 2015b), which was reflected in elevated Mn and Co results in this group. Indo-Pacific Environmental has been instructed to modify this control group for the 2016 operational year (MRM, 2016b)

Table 4.59 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Surface soil contamination north/northeast of the TSF	Results from the new soil site S42 have shown exceedances at this location correlating with dust results. MRM should determine whether elevated results are a consequence of contamination due to mine operations, or if the area surrounding S42 is naturally high in Pb and other minerals	♦ Site S42 was sampled again in August 2015, with Pb results well below the HILs and EILs (down to 310 mg/kg from 2,410 mg/kg in 2014). While there was no dust sampling at this location (DMV42) in August, sampling in July and September 2015 had Pb results below the reporting limit, and PM_{10} results below the NEPM (2013) criterion (MRM, 2015d) ♦ If the next sampling event shows an increase in Pb at S42, MRM should investigate the reason for these temporal fluctuations at this site
Marine sediments analysis	Laboratory analysis of major cations for marine sediments should be reinstated within the 2015 program	♦ Major cations and anions have been analysed as part of the nearshore sediment assessment, but not the AMMP or trans-shipment sediment program in the 2015 operational year ♦ MRM (2016b) has stated that marine consultants Indo-Pacific Environmental (who undertake the marine sediment studies) has advised that analysis of cations is not required for the marine sediment studies ♦ While the determination of major cations allows a more complete chemical characterisation of sediment samples, the IM agrees that this is not essential. This item can be closed
Surface soil monitoring	S05 should be removed from the surface soil sampling program as it is not an appropriate control site	♦ MRM (2016b) has stated that this site has been 'removed as a control but kept as an impact site'. Data provided by MRM (2016a) for the 2015 operational year includes S05 in the 'reference sites' list ♦ Given that S05 is not appropriate as a reference site, and is not an impact site in terms of current/ongoing mine impacts, the IM recommends that this site be excluded from the upcoming 2014-2015/2015-2016 soil monitoring report ♦ Additionally, within the 2016 operational year, S05 should be replaced with a new reference site that is not in the immediate vicinity of the 1970s quarry
2012 and 2013 Operational Periods		
Soil monitoring data – assessment	Soil monitoring data obtained subsequent to 2012-2013 should be evaluated within the context of the revised NEPM (NEPC, 1999) (as amended, 2013)	♦ This issue was not actioned during the 2014 or 2015 operational periods. The current revised interim MMP (MRM, 2015a) continues to compare soils data to the original NEPM (NEPC, 1999) (pre-2013 update)

Table 4.59 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
Soil monitoring data – assessment (cont'd)		♦ There were no new or updated versions of the MMP (including Vol. 2, Monitoring Report) or a standalone soil monitoring report prepared during the 2015 operational period. MRM (Dobson, 2016c) has advised that the next soil monitoring report (covering both 2014-2015 and 2015-2016) will compare soil results to the 2013 amendment of the NEPM (NEPC, 1999). This will be confirmed in the next IM review ♦ Similarly, the sediment quality aspects of ANZECC/ARMCANZ (2000) have been superseded by Simpson et al. (2013). Although the guideline values applicable to MRM have not changed, the next version of MRM's MMP, as well as future fluvial and marine sediment monitoring reports, should reference Simpson et al. (2013)
Fluvial sediments – monitoring results and responses	Particular focus should be placed on sites FS22 (low pH), FS18 (elevated sulfate), and FS06, FS20 and FS25 (elevated Zn and Pb). Where required, mitigation implementation measures should be designed and implemented	♦ FS22 had pH results within the range of background levels during 2014 and 2015. No further focus is required ♦ While FS18 sulfate results were the highest recorded at the mine site in 2015 at 3,280 mg/kg, they have reduced significantly from 2013 and 2014, when results were 70,900 mg/kg and 7,750 mg/kg, respectively. No specific ongoing recommendations apply to FS18 at this time ♦ FS06 had Zn results below ISQG-low levels in 2014 and 2015. Pb results were below ISQG-low levels in 2014, and slightly above ISQG-low levels (though well below ISQG-high levels) in 2015. No specific ongoing recommendations apply to FS06 at this time ♦ FS20 (downstream extent of Barney Creek diversion channel) and FS25 (Emu Creek just upstream of Barney Creek confluence) are not mentioned in the revised interim 2013-2015 MMP (MRM, 2015a) and no laboratory data has been provided to the IM for these sites for the 2014 or 2015 operational years. MRM has advised that sampling ceased at FS25 in 2013 as this location was often dry (Moreno, 2016). Sampling ceased at FS20 in 2013 due to its proximity to FS06, however it has been reinstated and sampled during the 2016 operational year
Fluvial sediments – mitigation	A plan for mitigating contaminated runoff into Barney Creek diversion on the southern side of the channel should be formalised and implemented	♦ Existing sediment controls at Barney Creek haul road bridge (mostly installed since 2012-2013) are described in Section 4.12.3 of this report. Other current actions are discussed above under 2014 recommendations

Table 4.59 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
Fluvial sediments – mitigation (cont'd)		♦ While there is currently no formal plan for management of contaminated runoff to Barney Creek diversion channel, the IM commends the various controls implemented to date, along with MRM's investigations into sources of contamination related to dust (see Section 4.13) ♦ This line item can be closed as it has been brought forward into more recent fluvial sediment and dust recommendations
Marine sediment – monitoring sites	Additional sampling should be undertaken to the west of Bing Bong Loading Facility to reflect the westward movement of water and/or sediment containing elevated metal (e.g., Pb and Zn) concentrations, as determined by the Bing Bong Loading Facility coastal modeling investigation and taking into account the findings of the nearshore sediment assessment	Completed. The AMMP in 2014 included sampling at new sites to the west of Bing Bong Loading Facility, including Bing Bong Creek, Pine Creek and Rosie Creek (Thorburn, 2014); in 2015 the AMMP included sampling sites BB West 1 and BB West 2
	The search for more appropriate sediment reference (control) sites should be continued, given the lack of suitability of the current control sites as shown by the PSD	As noted under 2014 recommendations above, Indo-Pacific Environmental has been instructed to adjust the Eastern Control group for the 2016 nearshore sediment monitoring program. No other marine sediment programs require adjustment of control sites at this time
General data interpretation and reporting	A reconciliation of actual versus proposed/committed sampling events should be provided	No information was sighted for the 2014 or 2015 operational periods. The IM recommends this be done as part of 2016 reporting
Soil, fluvial sediment and marine sediment monitoring program – reporting	Quality assurance/quality control data for sample analyses, and subsequent discussion, should be presented in the MMP	As previously reported (ERIAS Group, 2014; 2015), QA/QC data for soil and sediment analyses is not adequately presented or discussed in the revised interim 2013-2015 MMP (MRM, 2015a). While some discussion of QA/QC is provided in the fluvial sediment monitoring report (MRM, 2015b), this could also be improved. The various reports addressing marine sediments (Thorburn, 2015a; 2015b; 2015c) provide no discussion of QA/QC. The discussion provided for the surface water quality monitoring program within the current MMP (MRM, 2015a) provides a possible model for the soil/ sediment program
	Figures in the MMP that show sampling sites should show ALL sampling sites, including control sites	♦ Figures in the revised interim 2013-2015 MMP (MRM, 2015a) were up to date as at January 2015

Table 4.59 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
Soil, fluvial sediment and marine sediment monitoring program – reporting (cont'd)		♦ Since the MMP has not been updated since that time, it does not show all sampling sites reported in the 2015 operational period (e.g., surface soil sites S47 and S48, and fluvial sediment site FS31, are not included). This is acceptable ♦ While FS08 is not shown on Figure 2-275 of the MMP (MRM, 2015a), a footnote indicates that this site is located at the Burketown Crossing in Borroloola (beyond the scope of the map) ♦ This item considered closed

New Issues

The IM commends the addition of soil monitoring site S47 (and associated dust site DMV47) to the north-northeast of the open pit. However, a gap in soil monitoring sites still remains between S47 and S31, i.e., between the mine levee and the McArthur River diversion channel, to the southeast of the open pit. As previously noted (ERIAS Group, 2015), this area has potential to be contaminated by activities at the SOEF, which was developed during the 2014 operational year.

The next soil monitoring report to be prepared by MRM should:

- Review results from surface soil sites S28 and S44 within the context of long-term trends to clarify reasons for Pb HIL exceedances and the variation in results between years.
- Review long-term trends in Mn results across the mine site to assess the likely cause of widespread Mn EIL exceedances.

The unusually high EC results at FS04 in Barney Creek (more than eight times higher than the 2014 result at this site, 1.8 times higher than the next highest result in 2015, and 1.6 times higher than the highest result in 2014) may reflect evapo-concentration, and/or a potential new source(s) of major ions in this vicinity. This should be investigated during the 2016 operational year.

No fluvial sediment results were provided for FS08 (located at Burketown Crossing in Borroloola) in relation to the 2015 operational period. Monitoring at this site should be reinstated in the 2016 operational period.

As noted, the reporting of environmental incidents is an important component of any continuous improvement system. Failure to report exceedances of soil and sediment criteria as incidents has resulted in no investigation as to why the guidelines against which MRM is monitoring and reporting were exceeded. Reasons for the exceedances may be due to the natural mineralisation of the area or procedural errors when collecting the sample, or may reflect direct impacts from the operation. Without reporting exceedances as incidents and undertaking subsequent investigation, the reasons remain unknown and changes to management measures will not be implemented.

Recommendations to address these new issues are listed in Table 4.60, which also includes recommendations that are ongoing (and in some cases have been modified).

4.12.4.3 Successes

Soils

In the 2015 operational period, successes relating to surface soils have included:

- The addition of surface soil monitoring site S47, which has improved the soil monitoring program by addressing a gap in knowledge regarding impacts on soils to the east-northeast of the open pit. Similarly, new site S48 will contribute to understanding of possible impacts on soils due west of the TSF.
- Soil sampling from both the 1 to 10 cm and 40 to 50 cm depth ranges, with the results potentially contributing to understanding the impacts of depositional dust on surface soils.
- Exceedances of HILs being confined to Pb results from sites within 1 km to the west and south of the ore crushing plant/ROM pad.

Fluvial Sediments

In the 2015 operational period, successes relating to fluvial sediments have included:

- The addition of fluvial sediment monitoring site FS31, which has addressed a gap in the monitoring of Emu Creek.
- Further downstream, the dual sampling at FS26 (upstream and downstream of the crossing point) to address DME's concerns regarding 2014 major ions results. Results have shown that FS26 had slightly higher major ion concentrations downstream of the crossing point, but both upstream and downstream results (FS26A and FS26B) were low and comparable to other Emu Creek results (MRM, 2015b). This supports MRM's assertion that the 2014 sample was likely taken from the road crossing material rather than from the fluvial bed sediments (MRM, 2015e).
- Exceedances of ISQG-high criteria were minor, and were confined to known impacted sites in the Barney Creek diversion channel (FS19 at the haul road bridge and FS03 next to the crushing plant). Both sites had results much improved from the previous operational period, i.e., at FS03, Pb was down from 1,100 to 233 mg/kg, while Zn fell from 477 to 389 mg/kg; at FS19, Pb reduced from 1,590 to 235 mg/kg, and Zn was down from 2,210 to 466 mg/kg. Furthermore, FS19 has no ISQG exceedances of the bioavailable fraction for As or Cd. The improvements at FS19 are consistent with MRM's efforts to collect and/or clean out contaminated sediment. The IM commends MRM on the improvements to date at this location.

Marine Sediments

In the 2015 operational period, successes relating to marine sediments have included:

- The addition of sites BB West 1 and BB West 2 to the AMMP, which will contribute to improved understanding of the impacts of Bing Bong Loading Facility on marine sediments to the near west.

- The reinstatement of swing basin and shipping channel marine sediment sampling, now included as part of the AMMP (previously undertaken directly by MRM).
- Both nearshore sediment and trans-shipment area results demonstrating continued low risk, as shown by being below ISQG-low values.

4.12.5 Conclusion

The 2015 IM review has found that while there are ongoing issues relating to soil and sediment at the mine site and in the vicinity of Bing Bong Loading Facility, with a few exceptions, results are stable or improving. Monitoring programs as well as management practices continue to improve.

Ongoing and new IM recommendations related to soil and sediment issues are provided in Table 4.60. These recommendations have been categorised as either high, medium or low. High priority recommendations focus on the need to utilise current assessment frameworks for soil and sediment monitoring data (i.e., the 2013 update of NEPM (NEPC, 1999), and Simpson et al. (2013) as replacement for ANZECC/ARMCANZ (2000)), along with the continuing need to address soil and sediment issues near the Barney Creek haul road bridge, and a new issue of high EC at FS04 on Barney Creek.

Table 4.60 – New and Ongoing Soil and Sediment Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Surface soil monitoring	♦ Soil site S05 should be removed from the sampling program, as it is neither an appropriate control site (being in the immediate vicinity of an ex-quarry) nor an appropriate impact site (as the impacts are more likely to be related to past quarry operations than to recent/current mine operations). A replacement reference site will be required away from the quarry in a more 'natural' location	Medium
Surface soil contamination north/northeast of the TSF	♦ If the next sampling event shows an increase in Pb at S42, MRM should investigate the reason for these temporal fluctuations at this site	Low
Surface soils near Barney Creek haul road bridge	♦ A replacement site for S43 should be established in the vicinity of Barney Creek haul road bridge, but situated on an area of natural (in situ) soils	High
Fluvial sediments at Barney Creek haul road bridge	♦ The remaining open drain holes in Barney Creek haul road bridge should be closed, with runoff directed into silt traps on either side of the bridge	High
	♦ As well as being cleaned out annually after the wet season, silt traps at Barney Creek haul road bridge should be inspected periodically and cleaned out as required at other times of the year, e.g., in the early wet season/before significant floods are experienced (taking into account logistical constraints)	Medium
	♦ The ongoing monitoring of water quality in silt traps at Barney Creek haul road bridge during the wet season, along with dewatering of poor quality water in the southeast and northwest traps to Pete's Pond/SPSD/SPROD, is commended and should continue	High

Table 4.60 – New and Ongoing Soil and Sediment Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Fluvial sediments – monitoring results and responses	♦ Data for reinstated fluvial sediment site FS20 should be reported in the 2016 operational year	Low
Nearshore sediment monitoring	♦ The Eastern Control group should be modified (moved slightly to the west) in the 2016 operational year, to reduce possible impacts/influences of outputs from Mule Creek and thereby be a more useful control group	Medium
Soil monitoring data – assessment	♦ The next version of the MMP, as well as all future soil monitoring reports (including the next one, covering both 2014-2015 and 2015-2016), should evaluate soil monitoring data within the context of the revised NEPM (NEPC, 1999) (as amended, 2013)	High
	♦ The next version of the MMP, as well as future fluvial and marine sediment monitoring reports, should reference Simpson et al. (2013) instead of ANZECC/ARMCANZ (2000)	High
Soil, fluvial sediment and marine sediment monitoring program – reporting	♦ Quality assurance/quality control data for sample analyses, and subsequent discussion, should be presented in the next version of the MMP as well as surface soil, fluvial sediment and marine sediment (AMMP, nearshore, and trans-shipment) monitoring reports for the 2016 operational year	Medium
General data interpretation and reporting	♦ A reconciliation/discussion of actual versus proposed/committed sampling events should be provided as part of 2016 operational year reporting	Low
New Items		
Gaps in monitoring programs	♦ A gap in soil monitoring remains between S47 and S31, i.e., between the mine levee wall and the McArthur River diversion channel, to the southeast of the mine pit and potentially influenced by activities at the SOEF. MRM should consider installing a soil monitoring site in this area during the 2016 operational year	Medium
Surface soil HIL exceedances	The next soil monitoring report to be prepared by MRM should: ♦ Review results from surface soil sites S28 and S44 within the context of long-term trends to clarify reasons for Pb HIL exceedances and the variation in results between years ♦ Review long-term trends in Mn results across the mine site to assess the likely cause of widespread Mn EIL exceedances	Medium
EC results at FS04	♦ The cause of high EC results at FS04 should be investigated during the 2016 operational year	High
Fluvial sediment monitoring at FS08	♦ Fluvial sediment monitoring at FS08 should be reinstated in the 2016 operational period	High
Incident reporting	♦ Exceedances of soil and sediment guideline levels should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures	High

4.12.6 References

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4.13 Dust

4.13.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of dust, and is based on review of:

- Notes of observations and discussions with MRM personnel during the site inspection, and subsequent email correspondence.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1).
- Responses by MRM to recommendations raised in the previous IM report, as well as responses to comments raised by the DME.
- Excel spreadsheets provided by MRM that contain collated laboratory analysis data.

4.13.2 Key Risks

The key risks associated with dust as described in the risk assessment (Appendix 2) are:

- Fugitive dust emissions from operations at the ROM pad, crushed ore stockpile and bulk concentrate stockpile, and from spilled materials surrounding the process plant at the mine site, leading to heavy metal contamination of water and sediments in receiving waterways and diversion channels, and potentially, bioaccumulation in freshwater biota.
- Dust emissions from exposed areas of the tailings storage facility (TSF), the northern overburden emplacement facility (NOEF), western OEF (WOEF), southern OEF (SOEF) and haul roads, causing water, sediments and biota of receiving waterways and diversion channels to be exposed to heavy metal contamination.
- Generation of dust during loading of concentrate onto transport vehicles at the mine site and during transport to Bing Bong Loading Facility, causing heavy metal contamination of water and sediment in diversion channels and waterways, with potential impacts on biota.
- Emissions of dust from the Bing Bong Loading Facility concentrate storage shed and road vehicles to the marine environment resulting in heavy metal contamination of seawater, marine sediments and, potentially, marine biota.
- Generation of dust during loading of concentrate onto the MV Aburri at Bing Bong Loading Facility and from the MV Aburri onto export vessels in the offshore transport zone, leading to contamination of seawater and marine sediments and, potentially, bioaccumulation in marine biota.

4.13.3 Controls

4.13.3.1 Previously Reported Controls

Monitoring Program

As noted in MRM (2015a), the MRM dust monitoring program aims to:

- Assess the concentration of particulate contaminants in the air around the mine site and Bing Bong Loading Facility, and compare these concentrations to national guidelines.
- Assess the effectiveness of the current dust controls in place at both locations.
- Provide data to justify additional dust controls if necessary, to ensure that the values of the surrounding environment (including the McArthur River and the marine environment) are protected.

The key elements of the dust monitoring program include:

- An extensive network of dust monitoring sites. Within and near the mine site, 28 sites[20] were sampled during the 2015 operational year, as shown in Figure 4.38. Monitoring locations have been selected on the basis of the prevailing wind directions and potential sources of fugitive dust emissions. Key dust sources at the mine site include:
  - The processing plant, ore crushing circuit and run of mine (ROM) pad.
  - Overburden emplacement facilities: NOEF, WOEF and SOEF.
  - Haul roads.
  - The TSF.
- At Bing Bong Loading Facility, seven sites[21] were sampled during the operational year, as shown in Figure 4.39. Key dust sources in the vicinity of the loading facility include:
  - The MRM concentrate shed and loading conveyor.
  - The dredge spoil ponds located to the south of the loading facility.
  - External to MRM's operations, adjacent to the northwest of Bing Bong Loading Facility, the Western Desert Resources (WDR) iron ore stockpile and loading conveyor. This facility ceased operations during 2014. Limited rehabilitation activities have occurred.
- Throughout the 2015 operational year, low-volume portable air samplers (referred to as 'Dust MiniVol' (DMV) samplers[22]) were deployed at all monitoring sites, typically monthly for a 24-hour period. The samplers collect ambient dust (i.e., airborne particulate matter) with an aerodynamic diameter equal to or less than 10 µm ($\leq PM_{10}$).

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[20] The mine site dust monitoring program included 27 sites in the previous (2014) operational period. Of these, two sites – DMV21 and DMV29 – were replaced by nearby sites DMV44 and DMV45 respectively during the 2014 operational period due to operational changes in the vicinity. There were three additional new and/or temporary sites in the 2015 operational period, discussed in Section 4.13.3.2 of this report.

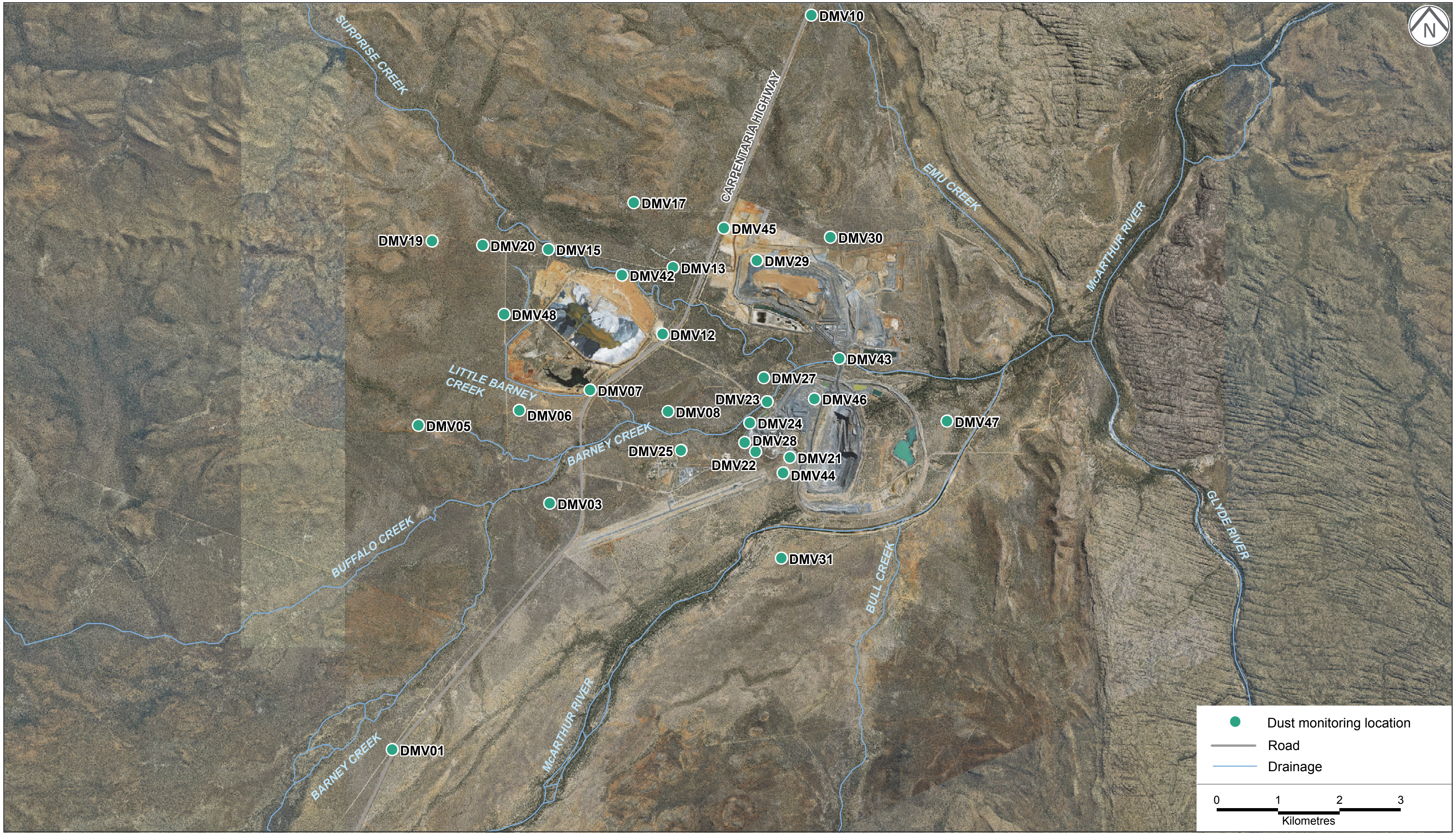
[21] Although a total of seven dust monitoring sites were sampled at Bing Bong Loading Facility during the 2015 operational period, there were effectively six sites as site BBDMV06 was replaced by BBDMV07 in July 2015.

[22] The low-volume dust samplers used are Airmetric MiniVol Tactical Air Samplers.

DUST MONITORING LOCATIONS - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.38



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DUST MONITORING LOCATIONS - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.39

ERIAS GROUP

- Samples were analysed by a NATA-accredited laboratory for parameters associated with airborne particulate matter, including:
  - Total suspended particulates (PM_{10}).
  - Particulate base metals: As, Cd, Cu, Pb, Mn and Zn.

General Controls

Measures to control dust at the mine site include:

- Regular watering or other dust suppression treatment of haul roads, ore stockpiles and other exposed areas around the mine site subject to vehicle and machinery movements (MRM, 2015b).
- At the NOEF, dust is managed through the operation of two water carts that spray the operating 'muck piles', roads and dumps. A compacted clay liner was also placed over PAF material before the 2014-2015 wet season. While this liner is primarily intended to minimise infiltration of water, a secondary benefit is encapsulation of potentially contaminated materials that could be mobilised via wind.
- At the TSF:
  - Capping of TSF Cell 1 with a clay layer to minimise generation of tailings dust.
  - Tailings deposition via 47 spigots around the periphery of Cell 2, where these spigots are operated on a rotation/cycle of approximately 35 to 40 days to keep the exposed tailings surface at least periodically damp, thereby reducing dust generation.
- At the mine site external concentrate storage area (bulk concentrate stockpile), the previous compacted pad surface has been replaced by a concrete base, which is graded towards contaminated water drainage systems.
- At the processing plant:
  - Covered dust generation points, including transfer points between conveyors and at the base and top of the secondary crusher.
  - Water addition point to the head drum of the stockpile feed conveyor.
  - A booster pump and spray bar for the head drum to improve suppression of dust as the crushed material falls to the stockpile surface.
  - Watering around the general area by water trucks.
  - Use of water sprays in the primary crushing plant and conveyors.
  - Double-layered skirting on horizontal rubber guarding.
  - A dust extraction system fitted to the secondary tertiary crusher building.

- A vehicle washdown facility for all vehicles prior to leaving the mine site for Bing Bong Loading Facility and other destinations.
- A dust extraction system in the concentrate shed at the mine site (consisting of an extraction fan and a wet scrubber) to reduce particulate emissions from the shed.
- A mini street-sweeper, which is used around the process plant to remove small spills.

Measures to control dust at the Bing Bong Loading Facility include:

- Doors on the concentrate shed to reduce fugitive emissions (during the 2014, 2015 and 2016 site visits, the IM was informed that the doors were not operational and remained open at all times – this ongoing issue is discussed in Section 4.13.4).
- A system designed to maintain a negative pressure differential in the concentrate shed, with dust extraction around the main entry and exit point, from which extracted air passes through a bag house filter. This system is intended to reduce fugitive dust emissions during transport vehicle unloading, moving concentrate and loading the MV Aburri. (The current effectiveness of this system is limited – this issue is discussed in Section 4.13.4).
- Covered conveyor belts at the loading facility to minimise fugitive dust emissions during loading of concentrate to the MV Aburri.
- Covers on concentrate transport vehicles to minimise dust.
- The concrete apron (at the ship-loader) is washed down following completion of every ship-loading event.
- A truck wheel wash (Plate 4.11) to minimise dust emissions from heavy vehicles leaving the facility.

Plate 4.11 – Truck Wheel Wash at Bing Bong Loading Facility

4.13.3.2 New Controls in the Reporting Period

Existing

The majority of new dust controls implemented in the 2015 operational year relate to the monitoring program:

- At the mine site, three additional low-volume dust monitoring sites were established (see Figure 4.38):
  - Site DMV46 (at the southeastern end of LV workshop, immediately to the northeast of the WOEF): a temporary investigative site for human health purposes, operated from November 2014 to May 2015. Sampling at this site has now been discontinued. Given its location in a highly modified area, DMV46 was a dust monitoring site only (no soil sampling was undertaken in conjunction with dust monitoring).
  - Site DMV47 (1.5 km east-northeast of the mine pit, between the mine bund wall and the McArthur River diversion channel): commenced operation in September 2015, co-located with a new soil monitoring site. This site fills a previous gap in the dust and soil monitoring programs coverage.
  - Site DMV48 (approximately 600 m west of the westernmost point of TSF Cell 2): also commenced operation in September 2015, co-located with a new soil monitoring site. This site fills a previous a gap in the dust and soil monitoring programs coverage.
- At Bing Bong Loading Facility, dust monitoring site BBDMV06 has been replaced by new site BBDMV07 (see Figure 4.39), correlating with a new soil monitoring site. The original site BBDMV06 was overtaken by development associated with the WDR iron ore loading dock and conveyor (MRM, 2015c) and a temporary site (of the same name) was established in a slightly different location. Site BBDMV07 is a new site located approximately 30 m west of site BBDMV06, near the Bing Bong Loading Facility boundary fence.
- Quality assurance/quality control at the mine site (MRM, 2015c):
  - Duplicate sampling was initiated at the beginning of 2015 and undertaken at 12 of the 28 dust sites sampled during the operational year.
  - Field blank sampling was also initiated during the operational year, with 22 such samples taken as part of the dust monitoring program (field blank results are presented as ‘monitoring locations’ DMV40 and 41 in MRM’s data).

Controls Planned for or Implemented After the 2015 Operational Year

The following dust controls were planned during the 2015 operational year, and have been or are intended to be implemented during 2016 or later operational years. They will be addressed in future IM reports as appropriate:

- During the IM site visit in April 2016, a new tapered element oscillating microbalance (TEOM) unit, which samples particulates as PM_{10}, was observed at Bing Bong Loading Facility, near the camp (Plate 4.12). This unit is also fitted with weather monitoring equipment. The IM has been informed that a similar unit has been installed near the mine site accommodation. As these units were installed during the 2016 operational year (in January/February, 2016), they will be discussed further in next year's IM report.

Plate 4.12 – New TEOM Unit at Bing Bong Loading Facility

- In addition to the new TEOM units, MRM has installed a high-volume air sampler at the mine site, between the primary crusher and Barney Creek, to increase the frequency, duration and accuracy of dust monitoring in this area. As this unit was also installed during the 2016 operational year (January/February 2016), it will be discussed further in next year's IM report.
- As stated in MRM (2015c), in addition to those measures already initiated, MRM intends to:
  - Develop formal dust mitigation plans for both the Bing Bong Loading Facility and the mine site, targeting the most impacted areas as identified by dust monitoring.
  - Implement duplicate sampling and field blank sampling as part of the Bing Bong Loading Facility dust monitoring program to assist with quality assurance/quality control.
  - Implement methods to enable comparison of total metals and PM_{10} metals in ambient air, to ensure that dust results can be accurately compared to air quality standards.
  - Investigate options to increase sample frequency and/or duration at monitoring sites.
  - Calculate gradient contours based on ambient dust data, so that adopted guidelines can be applied at the mine lease boundaries and at nearby public and recreational areas.

4.13.4 Review of Environmental Performance

4.13.4.1 Incidents and Non-compliances

Incidents

There were no reported incidents related to dust at the McArthur River Mine or Bing Bong Loading Facility during the 2015 operational period. However, the IM believes that the following should also have been reported as incidents:

- Greater than five days per year of PM_{10} exceedances at sites DMV22 and 43, in accordance with the National Environment Protection (Ambient Air Quality) Measure ('the NEPM') (NEPC, 2013) guidelines.
- Average Pb results greater than the NEPM (NEPC, 2013) stated maximum concentration at sites DMV22, 24 and 28.

These are discussed under non-compliances below.

Non-compliances

The revised interim 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances (see Section 3.2.4). However, some general observations are listed below, along with review of air quality guideline exceedances. Air quality standards as shown in Table 4.61 have been adopted by MRM.

Table 4.61 – Adopted Air Quality Standards

Pollutant	Averaging Period	Maximum Concentration	Max. Allowable Exceedances	Source
Particulates as PM_{10}	24 hours	50 µg/m^3	5 days per year	NEPC (2013)
Pb	1 year	0.5 µg/m^3	None	NEPC (2013)
Zn	24 hours	120 µg/m$^{3\#}$	1 day per year*	Ontario MOE (2012)
As	24 hours	0.3 µg/m$^{3\#}$	-	Ontario MOE (2012)
Cu	24 hours	50 µg/m$^{3\#}$	-	Ontario MOE (2012)
Mn	24 hours	0.2 µg/m^3 (Mn in PM_{10})$^\#$	-	Ontario MOE (2012)

* As stated in MRM (2015a), but not identified within the Ontario MOE (2012) document.
\# Ambient air quality criteria (AAQC) which is defined as 'a desirable concentration of a contaminant in air, based on protection against adverse effects on health or the environment'.

The NEPM (NEPC, 2013) specifies that the maximum PM_{10} concentration of 50 µg/m^3 is to be applied in terms of an allowable maximum of five days per year exceeding this level. Similarly, the maximum Pb concentration of 0.5 µg/m^3 is specified in relation to a one-year averaging period (NEPC, 2013). As such, individual exceedances of these levels (within a single 24-hour period) do not exceed their respective standards. Nonetheless, given that dust monitoring is currently conducted at a frequency of 12 or less 24-hour sampling events per year, MRM does not consider the collected data directly comparable to the NEPM (MRM, 2015c). Instead, individual (24-hour) exceedances of the specified maximum concentrations have been used as thresholds for discussion of results, and to illustrate the air quality of the mine site and of Bing Bong Loading

Facility and surrounds. A summary of the individual 24-hour air quality exceedances at the mine site and Bing Bong Loading Facility during the operational year is provided in Table 4.62.

Table 4.62 – 24-hour Air Quality Exceedances in the 2015 Operational Period

Monitoring Group	Site	Exceedances of the Mean Maximum Concentration Within a 24-hour Monitoring Period			
		PM_{10} ≥50 µg/m^3		Pb ≥0.5 µg/m^3	
		Days/Total*	Results	Days/Total*	Results
McArthur River Mine Site					
<1 km from processing plant	DMV22	**6/11**#	63.9, 67.5, 116.9, 57.4, 63.1, 83.6	**8/11**#	1.0, 1.0, 0.8, 4.4, 0.8, 1.5, 0.6, 2.5
	DMV23	4/10	137.6, 77.6, 54.4, 78.5	4/10	1.2, 0.6, 1.0, 0.7
	DMV24	1/10	56.0	**2/10**#	0.9, 0.7
	DMV27	2/11	61.7, 68.8	1/11	0.7
	DMV28	1/10	70.1	**1/10**#	0.5
	DMV44	1/11	60.8	-	-
	DMV46	2/6†	76.4, 62.2	-	-
1 to 3 km from processing plant	DMV25	1/10	51.9	-	-
<2 km from NOEF	DMV30	1/10	61.1	-	-
	DMV43	**6/11**#	110.3, 132.1, 71.8, 113.5, 56.4, 64.7	-	-
	DMV45	1/10	51.1	-	-
<2 km from TSF	DMV06	1/11	52.8	-	-
	DMV07	1/12	78.8	-	-
	DMV12	1/11	87.2	-	-
	DMV15	2/11	61.9, 53.8	-	-
	DMV42	2/12	62.5, 62.2	-	-
2 to 3 km from TSF	DMV05**	1/11	78.9	-	-
	DMV19	2/11	79.3, 58.2	-	-
	DMV20	1/11	53.6	-	-
>3 km (reference sites)	-	-	-	-	-
Bing Bong Loading Facility					
Bing Bong Loading Facility	BBDMV02	1/12	67.6	2/12	1.0, 0.9
	BBDMV05	1/12	179.2	-	-
	BBDMV06	-	-	2/9##	0.5, 0.7
	BBDMV07	1/3##	71.8	1/3##	0.7
Dredge spoil ponds	BBDMV04	1/12	50.1	-	-

*Represents number of days of exceedances out of total sampling events in the period, e.g., for DMV22, there were six (6) PM_{10} exceedances and 11 sampling events in total during the 2015 operational period.
Results in **bold** indicate sites where the standard for maximum allowable PM_{10} exceedances per year (five) was exceeded, or where the standard for Pb over a one-year averaging period was exceeded at some point during the operational year, based on a 12-month rolling average.

† DMV46 was a temporary site and was only sampled for part of the operational year.
** DMV05 is not within 2 to 3 km of the TSF, but has been reported in this group by MRM (2015c) during the operational period. Further discussion on this site is provided in Section 4.13.4.2.
BBDMV06 was sampled for the first 9 months of the operational year; it was replaced by BBDMV07 for the remainder.

McArthur River Mine

Within the 2015 operational period, particulates as PM_{10} regularly exceeded the maximum concentration standard of 50 µg/m^3 during single 24-hour averaging periods within all monitoring groups at the mine site, except for reference sites (see Table 4.62). Exceedances were as follows:

- Individual 24-hour exceedances (noting that the NEPC (2013) limit is 5 days per year):
  - As expected, the majority of individual exceedances (17) occurred within 1 km of the processing plant (see Table 4.62). Site DMV23 had the highest PM_{10} results at the mine site, with 137.6 µg/m^3 on 3 November 2014. Within this monitoring group, only site DMV22 exceeded the maximum of 5 days per annum (which it also did in the 2014 operational period).
  - A number of exceedances (eight) occurred within 2 km of the NOEF, with site DMV43 again exceeding the maximum of 5 days per annum.
  - Individual exceedances also occurred within 1 to 3 km of the processing plant (one), within 2 km of the TSF (seven), and within 2 to 3 km of the TSF (four).
- While individual daily PM_{10} results illustrate the air quality of the site, the NEPC (2013) specifies that the PM_{10} criterion of 50 µg/m^3 is to be exceeded a maximum of five days per year. Sites DMV22 and DMV43 both exceeded the criterion:
  - Site DMV22 had 6 days of PM_{10} exceedances, the highest of which was 117 µg/m^3 on 1 March 2015. Although this exceedance was towards the end of the 2014-2015 wet season, it should be noted that February 2015 received less than half the mean monthly rainfall BoM (2016). Site DMV22 is one of the closest sites to the crushing circuit, located within 500 m to the southwest and in the path of prevailing winds.
  - Site DMV43 had 6 days of PM_{10} exceedances, the highest of which was 132 µg/m^3 on 26 November 2014, towards the end of the 2014 dry season. This site is located to the northwest of Barney Creek haul road bridge; the 2015 operational year was its second year of operation, and results demonstrate that dust issues in this vicinity are ongoing.

At the mine site, exceedances of the standard for Pb as PM_{10} during the 2015 operational year were as follows:

- The maximum Pb concentration standard of 0.5 µg/m^3 was exceeded during individual 24-hour periods (noting that the NEPC (2013) averaging period is one year) at five mine site monitoring locations (DMV22, 23, 24, 27 and 28) (see Table 4.62). These sites are all within 1 km to the west or south of the processing plant (see Figure 4.38), and ore/concentrate materials processed by the facilities in this vicinity are likely to be the source of these dust exceedances. The highest individual Pb result was 4.39 µg/m^3 at DMV22 on 1 March 2015.

- While daily Pb results illustrate the air quality of the site, the NEPC (2013) specifies that the Pb standard of 0.5 µg/m^3 is in relation to a one-year averaging period. As such, MRM (2015c) has assessed mine site Pb results in terms of a one-year rolling average. On this basis, sites DMV22, 24 and 28 each exceeded the standard at some point during the 2015 operational year.
- There were no exceedances of Pb criteria in other monitoring groups at the mine site. Of note, there were no Pb exceedances (or other metals exceedances) at site DMV43, which had metals results well below that of the monitoring group within 1 km of the processing plant. This supports the assertion proposed in the 2014 operational year that dust issues at DMV43 derive from lower grade waste rock being hauled to the NOEF.

There were no exceedances of other metals criteria (Zn, Mn, As or Cu) as specified by the Ontario MOE (2012) at the mine site during the 2015 operational year.

Bing Bong Loading Facility

Within the 2015 operational period, particulates as PM_{10} exceeded the maximum concentration standard of 50 µg/m^3 during single 24-hour averaging periods at Bing Bong Loading Facility monitoring sites as follows (see Table 4.62):

- Individual results of >50 µg/m^3 were recorded at three dust monitoring sites to the immediate west of the Bing Bong Loading Facility (BBDMV02, BBDMV05 and BBDMV07), while one individual result of >50 µg/m^3 was recorded within the dredge spoil ponds (at BBDMV04), all within the 2015 dry season.
- The highest of these exceedances occurred at BBDMV05 in 6 June 2015, with a result of 179.2 µg/m^3, which was also higher than any result at the mine site during the operational period. No explanation has been provided for this exceedance by MRM (2015c); data from the BoM (2016) shows that it was a windy day.
- There were no exceedances of the NEPC (2013) criterion of five days per year within the Bing Bong Loading Facility monitoring groups.

At Bing Bong Loading Facility, exceedances of criteria for Pb as PM_{10} during the 2015 operational year were as follows:

- The maximum Pb concentration standard of 0.5 µg/m^3 was exceeded during individual 24-hour periods at two monitoring locations (BBDMV02 and BBDMV06/07) (see Table 4.62). These sites are both to the west of the ship loader and to the northwest of the concentrate shed (see Figure 4.38), in the path of prevailing winds from these facilities. The highest Pb result from loading facility sites was 0.99 µg/m^3 on 22 May 2015.
- In terms of the NEPC (2013) one-year averaging period for Pb results, MRM (2015c) has assessed all Bing Bong Loading Facility Pb results in terms of a one-year rolling average and determined that on this basis, all monitoring sites have remained well below the criterion during the 2015 operational year.
- There were no exceedances of Pb criteria in the dredge spoil ponds monitoring group.

There were no exceedances of other metals criteria (Zn, Mn, As or Cu) as specified by the Ontario MOE (2012) at the Bing Bong Loading Facility during the 2015 operational year.

4.13.4.2 Progress and New Issues

Progress

McArthur River Mining's progress and performance against previous IM review recommendations relating to dust issues is outlined in Table 4.63.

Table 4.63 – Dust Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2014 Operational Period		
Dust monitoring	Install high-volume air samplers in the area adjacent to the WOEF ROM Pad and at the Bing Bong Loading Facility, to improve the overall quality and type of data collected. Target completion date: 30 November 2015	♦ Air sampling (TEOM) units that sample PM_{10} were installed at Bing Bong Loading Facility and near the mine site accommodation in early 2016. Data from these units should be reported during the 2016 operational period ♦ A high-volume air sampler was installed at the mine site in early 2016, between the primary crusher and Barney Creek, to increase the frequency, duration and accuracy of dust monitoring in this area. Data from this unit should be reported during the 2016 operational period
Dust management at McArthur River Mine	Given the high number and level of dust exceedances at site D43, MRM should investigate the main sources of this issue and develop a formal plan for dust minimisation in the vicinity	♦ Results from the 2015 operational period show that there is still a high number and level of dust exceedances at DMV43 ♦ The IM commends MRM's investigation into dust issues at this location, as described in the 2014-15 Ambient Dust Monitoring Report (MRM, 2015c). MRM (2015c) states that: 'the potential sources of dust to this location included heavy equipment movements along the unsealed entrance ramps to the bridge and dust from haul trucks loaded with waste rock travelling from the open pit to the NOEF'. Data has shown that PM_{10} concentrations at DMV43 strongly correlate with volume of waste rock haulage, outside of the peak wet season (MRM, 2015c). The latter is likely to reflect dust suppression by rainfall ♦ McArthur River Mining has been active in controlling contaminated runoff and sediment at this location (which relates to depositional dust), as described in Section 4.12 of this report ♦ No formal plan for dust minimisation at DMV43 has been developed to date. This should be completed during the 2016 operational period
Dust management at Bing Bong Loading Facility	The doors of the concentrate shed should be repaired so that they can be closed except during truck access and egress	♦ During the April 2016 site visit, the IM observed that as per the past two years, the concentrate shed doors were still not operational (Plate 4.13). McArthur River Mining advised that their engineers have been instructed to consider options for the replacement of these doors. MRM (2016) has also stated that a cost benefit analysis is being completed

Table 4.63 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Dust management at Bing Bong Loading Facility (cont'd)		♦ The IM recommends that the doors be repaired or replaced as soon as practicable, as the continuously open state of the shed is very likely to be a source of ongoing contamination in the local area (e.g., PM_{10} and Pb exceedances at BBDMV02, 05 and 06/07)
	The dust extractor system in the concentrate shed should be repaired to an operational condition	♦ The dust extraction system was repaired during the 2015 operational period, however, given the non-operational shed doors, there will be little to no pressure differential at present ♦ Despite the operational dust extraction system, dust is still readily mobilised and transported from the concentrate shed by airflow through the open doorways on either side, which align with the prevailing easterly winds ♦ While the IM acknowledges the need to keep at least one shed door open at all times while unloading trucks (due to the length of trucks vs. the width of the shed), it is recommended that in order for the dust extraction system to operate as intended: – The shed doors be repaired or replaced as soon as possible (as per above recommendation) – When doors are operational, they should be kept closed as often as possible
	Roads and sealed areas surrounding Bing Bong Loading Facility should be sprayed with water at least once per day during the dry season to control dust	♦ Completed. McArthur River Mining (MRM, 2016) states that this item is completed
	The bitumen surface surrounding the Bing Bong Loading Facility is failing in a number of areas, with formation of potholes apparent. These should be repaired to avoid future soils, water and/or dust management issues	♦ McArthur River Mining (MRM, 2016) states that this item is in progress, with works currently ongoing ♦ During the April 2016 site visit: – The IM observed that the bitumen surface was in worse repair than during the previous (2015) site visit – McArthur River Mining advised that repairs are due to start by June 2016, with degraded bitumen to be replaced by concrete in high traffic areas, and new bitumen in lower traffic areas ♦ Progress on this item will be reported in the next IM report (for the 2016 operational period)
	While it was noted that the concrete apron at the wharf is washed down after each ship loading event, dust issues may be reduced further by washing down the apron and barge after every barge load	♦ The April 2016 site visit to Bing Bong Loading Facility occurred just after MRM had loaded two ships, but before the concrete apron had been washed down. Despite this, the IM observed that there was limited dust present. As such, washdown after each ship loading event appears to be adequate. This recommendation can be discontinued

Table 4.63 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods		
Dust monitoring	Depositional dust gauges and low-volume samplers should be maintained at a number of monitoring sites for a two-year period. This will allow a comparison of different monitoring methods to occur such that correlation between historical data sets and new data sets, both utilising different monitoring techniques, may be possible	♦ As noted in the previous IM report, this recommendation has not been adopted. McArthur River Mining has continued to monitor ambient dust using low-volume samplers, but has not recommenced simultaneous use of depositional dust gauges for comparison ♦ The IM notes that in a response to DME queries, MRM commented that between the low-volume air samplers and other monitoring programs (e.g., surface soil monitoring), they believe that there is no further benefit in continuation of depositional dust gauge sampling (MRM, 2015d; MRM, 2015e) ♦ Given the timeframe since replacement of depositional dust gauges with low-volume air samplers (four years as of August 2016), there is reduced value in reinstating the former for comparison purposes at this time ♦ This item is now closed
	The IM understands low-volume air monitors cannot measure total insoluble matter and therefore it may no longer be possible to measure project dust emissions against project nuisance level dust targets. The IM therefore recommends new project dust targets be developed and adopted to monitor performance against parameters now being measured	♦ Completed. Refer commentary in previous IM report

Plate 4.13 – Non-operational Doors at Bing Bong Loading Facility Concentrate Shed

Photo taken in April, 2016.

New Issues

Most dust issues identified in the current IM review are ongoing aspects of previously identified issues, and are detailed in Table 4.63, and Table 4.64 where the issue is ongoing.

An issue previously identified with regards to surface soil monitoring site S05 also relates to dust monitoring site DMV05. Specifically, the IM contends that S05/DMV05 is not an appropriate control site, as it is in the immediate vicinity of a quarry that operated in the 1970s, and is also near currently active dirt tracks. In response to an IM recommendation to remove this site from the monitoring program (ERIAS Group, 2015), MRM has removed the site from the dust and soil control/reference monitoring groups in the 2015 operational period. However, dust monitoring data from DMV05 has instead been reported as an 'impact site' (i.e., a monitoring site impacted by mine operations), within the '2 to 3 km of TSF' monitoring group (MRM, 2015c). This was not part of the previous IM recommendation (ERIAS Group, 2015) and is not appropriate, as site DMV05 is greater than 3 km from the TSF. Furthermore, DMV05 is unlikely to be an impact site in terms of current/ongoing TSF dust impacts, but instead is more likely to be impacted by dust from nearby tracks. The IM recommends that for the upcoming 2015-2016 ambient dust monitoring report, data from this site should be provided with a caveat reflecting the above or, alternatively, excluded from the report. In addition, this site should be replaced with a new control site that is not in the immediate vicinity of the 1970s quarry or currently active dirt tracks.

Given the progressive reduction in water storage at the TSF over the past two years (a positive result from a geotechnical perspective), there has been potential for increased dust generation from the TSF surface. During the site inspection, MRM advised that one or two discharge points are active at any one time and it takes approximately 40 days to complete a full rotation around TSF Cell 2. Therefore, it is expected that some areas of the tailings may be prone to wind erosion and the formation of dust. The IM did not see direct evidence of TSF dust emissions during the site inspection but did note an area immediately east of the decant wall on the TSF Cell 2 north wall that was not being covered by tailings during the current deposition cycle. In this area the tailings had dried out and a salt crust had formed. McArthur River Mining should investigate how to keep tailings in this area damp by either covering with fresh tailings or water (see also Section 4.13.4.3).

The 2014-15 Ambient Dust Monitoring Report (MRM, 2015c) adequately reports data from the reporting period, as well as presenting approximately two years of data for Pb 12-month rolling averages and for Pb, Zn and PM_{10} results at DMV43. However, in the experience of the IM, review of long-term trends is required to fully understand dust issues in light of operational changes (such as changing from underground to open pit operations) and seasonal influences (such as dry years). The IM recommends that MRM reviews and presents all available long-term dust data (in particular, PM_{10} and Pb results) for the mine site and Bing Bong Loading Facility, to inform understanding and management of dust issues at each site.

It is acknowledged by MRM (2015c) that the current dust monitoring program (24-hour sampling events undertaken up to 12 times per year at each site) is not of sufficient frequency to compare results to the NEPM (NEPC, 2013) standards for PM_{10} and Pb. As such, the IM recommends that the frequency of sampling be temporarily increased at selected sites, to determine whether the current monthly monitoring approach is statistically valid. It is suggested that two high impact sites

(DMV22 or 23, and DMV43) and one reference site (DMV01 or DMV10) be sampled once every six (6) days for a one-year period.

As noted above, the reporting of environmental incidents is an important component of any continuous improvement system. Failure to report exceedances of dust criteria as incidents has resulted in no investigation as to why the guidelines against which MRM is monitoring and reporting were exceeded. Reasons for the exceedances may be due to the procedural errors when collecting the sample, or may reflect direct impacts from the operation. Without reporting these exceedances as incidents and undertaking a subsequent investigation, the reasons remain unknown and changes to management measures will not be implemented.

4.13.4.3 Successes

In the 2015 operational period, successes relating to dust have included:

- The addition of site DMV47 has improved the dust monitoring program by filling a gap in knowledge regarding any impacts on soils to the east-northeast of the mine pit. Similarly, new site DMV48 will contribute to understanding of any dust impacts due west of the TSF.
- The total number of PM_{10} exceedances within 1 km of the processing plant has reduced from 25 out of 70 sampling events in the 2014 operational period to 17 out of 69 sampling events in the 2015 operational period. This may reflect limited mining during the operational period (operations were predominantly reprocessing of low grade ore from the NOEF).
- The dust extraction system in the Bing Bong Loading Facility concentrate shed has been repaired during the operational period. This will assist in reducing fugitive dust emissions from the concentrate shed, once the shed doors have been repaired or replaced.
- During the April 2016 site visit, the IM observed that despite the previous 14 months having been drier than usual, the whole of Bing Bong Loading Facility appeared to be cleaner/less dusty than during the previous site visit, possibly due to better ‘housekeeping’ with regards to dust management.
- Despite the increased potential for dust emissions from the TSF during the operational period, dust results from monitoring sites within 2 km of the TSF show that there were the same number of individual (24-hour) PM_{10} exceedances over each of the 2014 and 2015 operational periods (7 out of 58 and 57 sampling events, respectively). The maximum PM_{10} results in this monitoring group have reduced, with the highest result in the 2015 operational period being 87.2 µg/m^3 at DMV12, whereas the maximum in the 2014 operational period (also at DMV12) was 137.4 µg/m^3. The stable or reducing dust impact from the TSF, despite reduced water storage, is commended. The IM notes that even under recent dry conditions, the current practice of an approximate 40-day spigot cycle (to complete a circuit of the TSF) appears to be adequate to keep the surface sufficiently damp and resistant to wind erosion.
- The initiation of duplicate and field blank sampling at the mine site is commended as an improvement to quality assurance/quality control of the dust monitoring program.

4.13.5 Conclusion

The 2015 IM review has found that while there are ongoing issues relating to dust at the mine site and in the vicinity of Bing Bong Loading Facility, results are generally stable or improving. Monitoring programs as well as management practices continue to improve. The key ongoing dust concerns relate to dust management near Barney Creek haul road bridge, and the inoperability of concentrate shed doors at Bing Bong Loading Facility.

Ongoing and new IM recommendations related to dust issues are provided in Table 4.64.

Table 4.64 – New and Ongoing Dust Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Dust monitoring	♦ Data from the new TEOM units at Bing Bong Loading Facility and near the mine site accommodation should be reported during the 2016 operational period ♦ Data from the new high-volume air sampler installed at the mine site (between the primary crusher and Barney Creek) should be reported during the 2016 operational period	High
Dust management planning – mine site	♦ McArthur River Mining should develop a formal plan for dust minimisation in the vicinity of DMV43. This may be part of a formal dust mitigation plan for the mine site as a whole, targeting the most impacted areas as identified by dust monitoring	High
Dust management – Bing Bong Loading Facility	♦ The doors of the Bing Bong Loading Facility concentrate shed should be repaired or replaced as soon as practicable. Once doors are operational, they should be kept closed as often as possible	High
	♦ Progress on repairs to failed areas of the bitumen surface at Bing Bong Loading Facility should be reported in the next IM report (for the 2016 operational period)	Medium
New Items		
Dust management planning – Bing Bong Loading Facility	♦ McArthur River Mining should develop a formal dust mitigation plan for Bing Bong Loading Facility, targeting the most impacted areas as identified by dust monitoring (i.e., BBDMV02 and BBDMV07)	High
Dust monitoring and analysis	♦ McArthur River Mining should implement duplicate sampling and field blank sampling as part of the Bing Bong Loading Facility dust monitoring program to assist with quality assurance/quality control	High
	♦ McArthur River Mining should calculate gradient contours based on ambient dust data from the mine site, so that adopted guidelines can be applied at the mine lease boundaries and at nearby public and recreational areas	Medium
	♦ The IM recommends that the frequency of monitoring for PM_{10} and Pb be temporarily increased at two high impact sites (DMV22 or 23, and DMV43) and one reference site (DMV01 or DMV10), to be sampled once every six (6) days for a one-year period, in order to determine whether the current monthly monitoring approach is statistically valid	Medium
	♦ The IM recommends that MRM reviews and presents all available long-term dust data (in particular, PM_{10} and Pb results) for the mine site and Bing Bong Loading Facility, to inform understanding and management of dust issues at each site	Medium

Table 4.64 – New and Ongoing Dust Recommendations (cont'd)

Subject	Recommendation	Priority
New Items (cont'd)		
Dust management – TSF	♦ An area immediately east of the decant wall on the TSF Cell 2 north wall is not being covered by tailings during the current deposition cycle. Discharge pipelines should be extended to this area to reduce dust emissions from this area	Medium
Incident reporting	♦ Exceedances of dust guideline levels should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures	High

4.13.6 References

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MRM. 2015a. Interim Mining Management Plan 2013-2015, Volume 2: Environmental Monitoring Report. January 2015. Reference Number GEN-HSE-PLN-6040-003, Issue Number: 7, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015b. Sustainable Development Mining Management Plan 2013-2015, Volume 1. 3rd March 2015. Reference Number GEN-HSE-PLN-6040-0003, Issue Number: 7, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015c. Ambient Dust Monitoring Report 2014/15. Reference Number GEN-HSE-PLN-6040-0008, Issue Number: 001, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015d. Environmental Monitoring Report – Response to DME Comments – McArthur River – 2015. Reference Number: MRM-HSE-RPT-0002, Issue Number: 001, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015e. Environmental Monitoring Report – Request for Further Additional Information – Response to DME – McArthur River Mine. Reference Number MRM-HSE-RPT-0003, Issue Number 001, Revision Number 0. Approved 17 May 2015. McArthur River Mining Pty Ltd, Winnellie, NT.

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NEPC. 2013. National Environment Protection (Ambient Air Quality) Measure. National Environment Protection Council, Canberra, ACT.

Ontario MOE. 2012. Ontario's Ambient Air Quality Criteria. A WWW publication accessed on 20 May 2016 at http://www.airqualityontario.com/downloads/AmbientAirQualityCriteria.pdf. Ontario Ministry of the Environment, Standards Development Branch, Toronto, Canada.

4.14 Review of DME's Monitoring

The Department of Mines and Energy (DME) provided a number of files relating to the regulation of the McArthur River Mine during the reporting period. These files related to:

- Assessments and inspections to evaluate the environmental performance of the mine, including:
  - 2013-2015 revised interim MMP.
  - 2015 site inspections (some of which were conducted outside the operational period).
  - Third party expert advice (e.g., Independent Tailings Review Board (ITRB), Robertson GeoConsultants).
  - Investigations (e.g., heavy metal bioaccumulation in aquatic biota).
  - Instructions (e.g., in relation to conditional acceptance of the central west area of the NOEF and the western PAF run-off dam (WPROD)).
  - Environmental incidents.
  - Department of Mines and Energy procedures and manuals.

The IM conducted a review of DME in regulating the environmental performance of MRM under the MM Act and regulations. This included review of:

- Department of Mines and Energy's assessment of the MMP.
- Instructions and investigations initiated by DME.
- Independent Monitor recommendations tracking.
- Previous IM recommendations regarding DME performance.

It should also be noted that no DME audits were undertaken in 2015, nor were any DME check monitoring reports available for the same period. The only check monitoring data that was available for IM review related to surface water and groundwater samples taken in November 2015, which is after the IM reporting period.

4.14.1 Review of Compliance Auditing and Site Visits

4.14.1.1 Compliance Audits

As noted in last year's IM report, the DME undertook a site inspection in November 2014, where the objectives were to:

- Meet with management and staff from MRM who are involved in the overall management of the operations.
- Inspect MRM's preparedness for the 2014-2015 wet season.

- Assess MRM's progress in addressing the high priority IM recommendations.
- Inspect specific areas of concern and assess MRM's management strategies relating to those concerns.

As also noted in last year's report, the DME identified 18 items requiring action. Eight days following the site inspection, the DME issued an instruction to MRM concerning water management. The instruction was amended and reissued on 11 February 2015 following meetings with the DME and MRM, with the DME requesting that MRM provide evidence of action taken to address issues identified during the site inspection in the next MMP that was due for submission on 30 October 2015.

Notwithstanding a close out meeting with MRM and the DME's issue of an instruction shortly after the site inspection, the IM previously noted that the main report was not delivered for a further five months following the site inspection. In the 2014 IM report, the IM recommended that the DME establish a goal of finalising audit reports within six weeks of the audit. While this was not an audit, the 2015 IM report noted that the recommendation remained valid for site inspection reports. The IM still believes this to be the case.

4.14.1.2 Site Visits

In addition to the November 2014 site visit described above, the DME implemented a series of field inspections in the second half of 2015 that were aimed at:

- Informing the assessment by DME mining officers of the 2013-2015 MMP (as further described below).
- Providing an update to management on the status of operations and assessing compliance with DME conditional approvals.

The IM commends the DME on undertaking these site visits and notes that such visits should be used to facilitate the exchange of technical information and minimise misunderstandings between the two parties. The IM therefore encourages the conduct of regular site visits by DME technical personnel and the availability during these visits of relevant MRM staff. Notwithstanding the inevitable demands that these visits place on all involved, the opportunity to facilitate the approvals process and improve relationships should not be underestimated. However, the IM also recommends that actions arising from the site visits be documented in a register, together with MRM's responses and relevant dates.

4.14.2 Review of DME Annual Assessment of MMP

As described in detail in the previous IM report, a 2013-2018 MMP was submitted to the DME on 21 November 2013. This document was then the source of considerable correspondence between the DME and MRM concerning (i) its assessment and finalisation, and (ii) the role of the NT EPA given the changes in the project that were described therein. Based on advice from the DME (which reflected the NT EPA's position that the proposed changes required assessment under the *Environmental Assessment Act*), MRM subsequently withdrew the 2013-2018 MMP. McArthur River Mining is currently preparing an EIS that addresses overburden management and related matters, under the *Environmental Assessment Act* and the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

Following the withdrawal of the 2013-2018 MMP, MRM submitted to DME on 2 May 2014 an updated MMP covering an interim period of operations from 2013 to 2015 (to enable operations to continue while further assessment was undertaken via the environmental assessment process), i.e., the 2013-2015 MMP referred to as the interim 2013-2015 MMP. The interim 2013-2015 MMP comprised two volumes:

- Volume 1: Sustainable Development Mining Management Plan 2013-2015 (MRM, 2015a).
- Volume 2: Interim Mining Management Plan 2013-2015. Environmental Monitoring Report (MRM, 2015b).

At the DME's request, MRM also prepared a supplementary monitoring report (MRM, 2015c) that addressed environmental monitoring data collected between 1 July and 30 November 2014.

Key actions regarding assessment of the interim 2013-2015 MMP were summarised in the previous IM report, which also comments on the above process. Such comments will not be repeated herein, other than to reinforce the findings that:

- Notwithstanding the complexity of the issues being addressed, a better process is required around the submission and approval of MRM's MMPs.
- There is an opportunity to review the assessment processes to determine if there is a more efficient process to assess, request additional information and understand information submitted by MRM that would result in a more rapid approval of the MMP.

This need to refine the process extends to the revised interim MMP, where this was prepared in response to the DME's direction on 12 December 2014. This direction reflected the DME's view that MRM's ongoing submission of additional information in relation to the Central West section of the NOEF, and the significance of the changes to the information being supplied, rendered the interim MMP obsolete. The revised interim 2013-2015 MMP was approved by the DME on 23 December 2015.

4.14.3 Review of Instructions, Investigations and Incidents

4.14.3.1 Instructions

During the operational period (October 2014 to September 2015), the DME issued a series of instructions to MRM. A number of these related to requesting additional information to assist in the assessment of the revised 2013-2015 MMP or MRM's monitoring data. Some key instructions issued by DME to MRM during the operational period are summarised in Table 4.65.

Table 4.65 – Key Instructions Issued to MRM by the DME

Date	Instruction
21 November 2014*	♦ Department of Mines and Energy request for information regarding wet season preparations and, in particular, actions to reduce the risk of uncontrolled releases, actions to ensure structural integrity of all ponds, and actions to minimise seepage of contaminated water ♦ Department of Mines and Energy request for installation of continuous monitoring at six sites with provision for DME to directly access monitoring data at any time
20 March 2015	♦ Department of Mines and Energy request for additional information with regard to the environmental monitoring report, and specifically concerning: – The need for further interpretation of MRM's monitoring data, including identifying areas for improvement or actions to be undertaken – Using feedback from the monitoring program to minimise risk to the receiving environment in areas such as surface water, groundwater, dust, soil and fluvial sediments
20 March 2015	♦ Department of Mines and Energy request for additional information with regard to the SEL fish kill incident and tailings discharge incident
25 March 2015	♦ Department of Mines and Energy request for additional information with regard to assessment of the revised interim 2013-2015 MMP, and specifically with regard to: – Waste rock classification – Design of infrastructure – Absence of information relating to EPBC Act and departmental approvals
30 April 2015	♦ Department of Mines and Energy request for additional information with regard to the environmental monitoring report (as for the instruction issued on 20 March 2015)
26 June 2015	♦ Department of Mines and Energy request for additional information with regard to assessment of the revised interim 2013-2015 MMP, and specifically with regard to the western PAF run-off dam (WPROD)
2 July 2015	♦ Department of Mines and Energy conditional approval to construct the WPROD, with subsequent instructions to MRM concerning: – Provision of construction reports to the DME – Protection of the NOEF from the 1:100 AEP floodwaters – Dewatering sampling and analysis – Hydrogeological investigative drilling and provision of bore logs for selected monitoring bores
7 July 2015	♦ Department of Mines and Energy approved the request to place waste rock in the CWNOEF and issued an instruction that MRM provide written agreement concerning matters such as: – Construction and operation of the CWNOEF – Sampling and analysis of the waste rock – Engaging an Independent Certifying Engineer (ICE) to warrant and accept both the design and construction works
11 August 2015	♦ Department of Mines and Energy requirement for further information or actions following a mine site visit, and specifically with regard to: – TSF Cell 2 Raise 3 – Livestock access to the mine site – Lack of approval for the use of non-benign material in the SOEF† and EOEF, and other aspects of dump construction – Repairs to the SPROD and SPD

Table 4.65 – Key Instructions Issued to MRM by the DME (cont'd)

Date	Instruction
21 August 2015	♦ Department of Mines and Energy request for additional information with regard to assessment of the revised interim 2013-2015 MMP
10 September 2015	♦ Department of Mines and Energy conditional approval to construct a Pb filtration facility and acid tanks, with subsequent instructions to MRM concerning: – Design, construction and operation of the facility, particularly the associated surface water management infrastructure – Storage and handling of hazardous and corrosive materials – Implementation of a preventative maintenance schedule for the additional bulk storage tanks and associated infrastructure

[*] This was included in the previous IM report.
[†] This is addressed in some detail in Section 4.7.

The IM commends the DME on the level of detail provided in various comments and responses attached to the various instructions, and notes the application of considerable technical knowledge to the challenges posed by the McArthur River Mine. However, the various requests would benefit from some type of ranking so that MRM personnel could prioritise their responses. Consideration should also be given to a forum whereby a number of the information gaps and inconsistencies could be readily addressed by direct discussion between DME and MRM technical staff (as appears to already occur to some extent, e.g., in the site visits described above).

The IM also notes that a register of instructions issued by the DME to MRM was not available for review. Such a register should include as a minimum the information contained in Table 4.65, plus additional information such as the status of MRM's response and key dates.

Although well beyond the IM reporting period, the IM notes an instruction from the DME of 18 January 2016 concerning submission of the next MMP. In particular, the IM notes the requirement that MRM not submit another MMP until assessment of the Overburden Management Project EIS is complete, and that MRM submit an operational performance report (OPR) to the department. As required by the DME, this OPR should detail performance against objectives and targets, trigger levels, and performance criteria to demonstrate that the management systems on site are minimising impacts to the environment. The IM suggests that, where relevant, the recommendations summarised above and detailed in last year's IM report in reference to the MMP be adopted for the OPR.

4.14.3.2 Incidents

Documents that were reviewed by the IM included reference to the following incidents:

- A fish kill within the SEL (4 February 2015).
- Tailings discharge from a ruptured tailings line (11 February 2015).
- A fire at the contaminated waste dump on the TSF (16 March 2015).
- Detachment of two trailers from a road train (a near miss) (22 March 2015).

The DME also issued a notice on 24 April 2015 to carry out an environmental audit program in relation to airborne pollutants from the NOEF.

While the available documentation is appropriate concerning the initial notification and subsequent requests for additional information, there seems to be little acknowledgement from the DME that MRM's subsequent actions were appropriate and that the matter can be considered closed. This should be addressed in the future.

The IM also notes that the number of environmental incidents and near misses seems to be very low for an operation of this size and recommends that the DME investigate further with MRM how incidents and near misses are identified and reported.

4.14.3.3 Investigations

The focus of documents that were reviewed by the IM in relation to DME investigations (other than those concerning reported incidents) concerned elevated levels of metals in fish and other aquatic biota. The findings of these reports are presented in Section 4.10. The IM endorses the process whereby the DME, in association with other government departments as necessary, commissions such investigations.

4.14.4 Review of Expert Advice

4.14.4.1 Independent Certifying Engineer and Independent Tailings Review Board

As noted in last year's IM report, DME requested that MRM appoint an ICE. Although the IM has not seen a definitive role description, the primary task of the ICE seems to include overseeing and managing quality control of the OEFs and TSF. Specific comment concerning the ICE is provided in Section 4.7. However, it is worth noting that that section concludes that deficiencies associated with construction of the TSF Cell 2 Raise 3 brings into question the effectiveness of the ICE to fulfil these requirements. That section also refers to a potential conflict of interest given that the principal designer of the TSF and CWOEF and the role of the ICE are both filled by GHD. While the IM supports the role of the ICE and appreciates that GHD's dual role will ensure that the ICE is intimately familiar with the relevant facilities, it seems that resolution of GHD's potential conflict and clarification of the roles is warranted and is a task that the DME could facilitate.

In addition to the ICE, MRM engaged (at the DME's direction) an ITRB in September 2015. The role of the ITRB is to review the proposed life of mine (LOM) design, management and closure plans for the TSF, and relevant aspects of the ITRB's findings are described in Section 4.7. While additional expertise is always welcome in relation to a potentially high-risk matter such as tailings management, the IM recommends that DME promote clarity of roles between the ICE and ITRB and encourage MRM to explore possible synergies to ensure that maximum benefit is obtained from their engagement.

4.14.4.2 Robertson GeoConsultants and Geonet Consulting

While the ICE and ITRB were engaged by MRM, the DME directly engaged the following consulting companies:

- Robertson GeoConsultants – to provide expert technical advice in relation to matters such as current mining practices and site conditions, and TSF construction.

- Geonet Consulting – to provide expert technical advice in relation to the design, construction, placement methods and management of the proposed CWNOEF.

As is the case with both the ICE and ITRB, the IM supports the engagement of external specialist advice. This is particularly the case where the relevant consultants are engaged directly by the DME, where such advice is used to supplement internal expertise, and the IM anticipates that this will facilitate the DME's review and approval processes.

4.14.5 Review of DME Environmental Monitoring Unit

As noted above, no check monitoring reports were available for IM review for 2015, with the only available data being beyond the reporting period. The IM therefore offers no comment additional to that provided in last year's report concerning the Environmental Monitoring Unit (EMU), other than to note that a schedule for EMU's check monitoring would be useful. Preparation of such a schedule (which could also include regular site visits by other DME officers) would also allow the objectives of the check monitoring and criteria for assessment of performance to be documented.

4.14.6 Review of Previous IM Recommendations Regarding DME Performance

Progress

The DME's progress and performance against previous IM review recommendations is summarised in Table 4.66.

Table 4.66 – Recommendations from Previous IM Reviews Concerning DME Performance

Subject	Recommendation	IM Comment
2014 Operational Period		
MMP	Department of Mines and Energy reviews, in more detail, MMP commitments being developed by MRM to ensure they are reduced and collated into a single list contained within the main MMP document	Department of Mines and Energy should take this recommendation into account within the context of the operational performance report (OPR) that MRM will submit to the department in lieu of an MMP (where the latter will not be submitted until assessment of the Overburden Management Project EIS is complete)
Review of MMP and other approval documents	Department of Mines and Energy to ensure its review processes include a convention with regard to a consistent method for referring to the dates of correspondence/ documents. Ideally, reference should be the date of correspondence/document (and this can be qualified with date received, if required)	As above
	Department of Mines and Energy to revise the current MMP review process (including requests for additional information) with the objective of devising a more efficient process. In particular, a review to be undertaken of the 2013-2018 and 2013-2015 MMPs' assessment processes to identify what actions could have been taken to improve the efficiency of the process	As above

Table 4.66 – Recommendations from Previous IM Reviews Concerning DME Performance (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Review of MMP and other approval documents (cont'd)	Rather than refer whole documents to EPA for consideration, ensure that the particulars of the project requiring assessment are clearly defined. Referring the entire MMP resulted in confusion regarding aspects of the project which had not substantially changed and for which MRM had approval to implement	The IM understands that DME highlighted areas of the MMP that they believed the EPA should look at. These highlighted areas were changes that DME believed were material and therefore potential matters that EPA would consider triggered assessment under the *Environmental Assessment Act*
EMU check monitoring	Department of Mines and Energy to review EMU procedures and include content on the purpose and objectives of the check monitoring site visit. The purpose of these check monitoring site visits is not clear	Information provided by DME does not indicate that progress has been made
	Department of Mines and Energy to prepare a field report for their check monitoring site visit that is provided to MRM. The report should clearly document the objectives of the check monitoring and provide an analysis of the results (in the context of MRM's monitoring results)	Information provided by DME does not indicate that progress has been made in relation to check monitoring site visits. Field inspection reports prepared in the second half on 2015 provide objectives but would benefit from consistent inclusion of recommendations
2012 and 2013 Operational Periods		
Auditing	Department of Mines and Energy reviews its compliance audit protocol to include as part of its assessment of MMP compliance whether the operator is also complying with guidelines, e.g., ANZECC/ARMCANZ guidelines for water quality rather than simply completing an action, e.g., groundwater monitoring being undertaken quarterly	Information provided by DME does not indicate that progress has been made
	Department of Mines and Energy to define and document what constitutes best practice for specific areas of the operation and include this as part of the DME audit protocol	Information provided by DME does not indicate that progress has been made
	Department of Mines and Energy establishes a goal that audit reports are finalised within six weeks of the audit being conducted	Site visit reports prepared by the DME in the second half on 2015 are dated within a month of the actual site visit

Table 4.66 – Recommendations from Previous IM Reviews Concerning DME Performance (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
IM review findings	Department of Mines and Energy requests from MRM an action plan detailing how MRM will address the high priority recommendations including a timeline to complete these actions. The DME requests on a quarterly basis an update from MRM on the progress towards implementing the high priority recommendations	Department of Mines and Energy requested on 4 September 2014 that MRM include in the MMP an action plan outlining actions to complete IM recommendations. McArthur River Mining provided a response in the revised interim 2013-2015 MMP. The IM notes however that MRM has responded to the risk assessment and not the IM recommendations McArthur River Mining has subsequently provided an Excel spreadsheet (file 'IM Summary of Recommendations 2014 v2.xlsx') that describes the status of the various recommendations and MRM's response where relevant
	Department of Mines and Energy prepares an action plan detailing how DME will address high priority recommendations including a timeline to complete these actions and report quarterly on progress	Last year's IM report noted that DME has developed a draft action plan to address IM recommendations, and that a system of quarterly reminders has been established to report on progress regarding implementing IM recommendations. However, information provided to the IM as part of the current review indicates that the DME does not have a tracking system for IM recommendations
MMP	Department of Mines and Energy to review in more detail MMP commitments being developed by MRM so that they are specific, measureable, attainable, relevant and time-based	Department of Mines and Energy should take this recommendation into account within the context of the operational performance report (OPR) that MRM will submit to the department in lieu of the next MMP (where the latter will not be submitted until assessment of the Overburden Management Project EIS is complete)
Review of MMP and other approval documents	Department of Mines and Energy to revise the procedure for review of documents to include assessment of whether the project may trigger the EPBC Act. If the project in DME's opinion may trigger the EPBC Act, DME to advise MRM to refer the project	Procedure has not been reviewed. The DME advised that EPA is responsible for determining if project may trigger EPBC Act

New Issues

During the 2015 operational year, the DME has progressed approval of the revised interim MMP, undertaken a number of site visits, sought external expert advice in a number of key areas, and responded to a number of environmental incidents. After reviewing the performance of DME in regulating MRM, the IM's new recommendations are summarised in Table 4.67, which also includes items brought forward and/or modified from previous IM reports.

Table 4.67 – New and Ongoing DME Performance Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
MMP	The DME should ensure that MMP commitments (and OPR commitments where applicable) are: ♦ Reduced and collated into a single list contained within the main MMP document ♦ Specific, measureable, attainable, relevant and time-based	High
Review of MMP and other approval documents	The DME should ensure that a convention is adopted with regard to a consistent method for referring to the dates of correspondence/documents. Ideally, reference should be the date of correspondence/document (and this can be qualified with date received, if required)	Low
	The DME should revise the current MMP review process (including requests for additional information) so as to improve its efficiency (and ensure that it is applicable to the OPR). In particular, this should include review of the 2013-2018 and 2013-2015 MMP's assessment processes to identify deficiencies in the process and opportunities for improvement	High
EMU check monitoring	The DME should: ♦ Prepare a schedule for EMU's check monitoring ♦ Review EMU procedures and include content on the purpose and objectives of the check monitoring site visit	Low
	The DME should prepare a field report for the check monitoring site visit that is provided to MRM. The report should clearly document the objectives of the check monitoring and provide an analysis of the results (in the context of MRM's monitoring results)	Medium
Auditing	The DME should review its compliance audit protocol to include as part of its assessment of MMP compliance whether the operator is also complying with guidelines, e.g., ANZECC/ARMCANZ guidelines for water quality rather than simply completing an action, e.g., groundwater monitoring being undertaken quarterly	Medium
	The DME should define and document 'best practice' for specific areas of the operation and include this as part of the DME audit protocol	Medium
	The DME should establish a goal that audit reports are finalised within six weeks of the audit being conducted	Medium
IM review findings	The DME should request that MRM submits: ♦ An action plan detailing how the high priority recommendations will be addressed, including a timeline ♦ Quarterly updates on progress towards implementing the high priority recommendations	High

Table 4.67 – New and Ongoing DME Performance Recommendations (cont'd)

Subject	Recommendation	Priority
New Items		
IM review findings (cont'd)	The DME should prepare: ♦ An action plan detailing how high priority recommendations will be addressed, including a timeline ♦ Quarterly updates on progress towards implementing the high priority recommendations	High
Site visits	The DME should: ♦ Continue the regular site visits that were undertaken in the second half of 2015 and use these to facilitate the exchange of technical information, address information gaps and inconsistencies, and minimise misunderstandings between the two parties ♦ Ensure that field inspection reports adopt a consistent approach to including recommendations and required actions	Medium
Documentation	The DME should establish a database or register that captures instructions issued to MRM, and similar actions. This should include the date of the instruction, key points, status of MRM's response, and key dates	High
	The DME should investigate further with MRM how incidents and near misses are reported, and ensure that incidents and near misses are appropriately closed-out with relevant actions being captured in the database referred to above	Medium
ICE and ITRB	The DME should: ♦ Facilitate the resolution of GHD's potential conflict of interest given that GHD is both the ICE and TSF design engineer ♦ Promote clarity of roles between the ICE and ITRB and encourage MRM to explore possible synergies to ensure that maximum benefit is obtained from their engagement	High

4.14.7 References

MRM. 2015a. Sustainable Development Mining Management Plan 2013-2015, Volume 1. 3rd March 2015. Reference Number GEN-HSE-PLN-6040-0003, Issue Number: 7, revision Number: 0.

MRM. 2015b. Interim Mining Management Plan 2013-2015, Volume 2: Environmental Monitoring Report. January 2015. Reference Number GEN-HSE-PLN-6040-003, Issue Number: 7, revision Number: 1.

MRM. 2015c. Supplementary Environmental Monitoring Report 2014. February 2015. Reference Number GEN-HSE-RPT-6040-002, Issue Number: 1, revision Number: 1.

5. Summary of Recommendations

5.1 2015 Recommendations

New IM recommendations are provided in Table 5.1. These have been grouped by topic and categorised as high, medium or low. High recommendations are considered a priority and relate to the more significant risks and information deficiencies.

Table 5.1 – New Recommendations

Subject	Recommendation	Priority
Mine Site Water Balance		
Documentation and reporting	Reporting in the main body of the MMP: ♦ The water management gap analysis should be reconfigured to provide: – Specific and measureable actions – Estimated commencement and completion times – An 'effectiveness ranking' (say 1 to 5) of the impact the task will have on the site water balance – A 'priority ranking' (say 1 to 5) for completing the task. This will most likely be based upon the results of a cost/benefit analysis ♦ The gap analysis should be updated regularly (say every 6 or 12 months) and produced as a separate document, outside of the MMP Water balance model reporting: ♦ It is recommended that more tables are used to improve clarity, understanding and error checking ♦ Sensitivity analysis results should be consolidated in one section of the water balance modelling report	Medium
Water balance sensitivity testing	Pump or pipe failure: ♦ An assessment of the impact of pump or pipe failure should be undertaken Sensitivity analysis: ♦ Needs to be undertaken for all subsequent annual water balance modelling reports	Medium
Water storage ponds and tailings storage facilities	♦ The risk of spills from the TSF Mini Dam to the WMD, thereby making it unsuitable for off-site release, needs to be assessed ♦ The MRM intent of improving TSF Cell 1 runoff quality is not reflected in current management of the cell's clay capping. This needs to be resolved	Medium
Risk management of the site water balance	Use of the underground void/open pit for water storage ♦ MRM needs to provide a medium- to long-term plan which resolves the conflict between mine operations and using the underground void/open pit as a water storage	Medium
Accurate quantification of water balance processes	♦ Surface water monitoring at Bing Bong Loading Facility needs to be resumed	Medium

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Surface Water Quality		
TSS loads	An assessment that validates (or otherwise) MRM's assertion about the low risk associated with mine-derived TSS is required. This assessment should also address TSS from the operations at the Bing Bong Loading Facility	Medium
Monitoring	Results of the release calculator should be validated by concurrent water quality measurements at SW11	Low
	Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows)	Low
	The feasibility of deploying DGTs to monitor seawater quality in the trans-shipment area during transfer of the concentrate should be determined	Medium
Diversion Channel Hydraulics Management		
Diversion channel erosion monitoring	Photo monitoring of the diversion channel was not reported on in the 2014 or 2015 reporting periods. It is recommended that this be undertaken every year to ensure an accurate record of erosion along the diversion	Low
Groundwater		
Groundwater model review	A strong reliance will be placed on groundwater modelling to assess controls. It is therefore recommended that all groundwater models be reviewed by a specialist modeller to help ensure: ♦ The adequacy of the conceptual hydrogeological model as a basis for a numerical model given the outcomes being sought ♦ Suitable construction using appropriate boundary conditions, mesh sizes and stress periods/time step lengths ♦ Adequate model calibration to both steady-state and transient data ♦ Adoption of suitable initial conditions ♦ Identification and understanding of model uncertainties	High
Site-wide conceptual hydro-geological model	A site-wide conceptual model is required to provide a better understanding of the impacts upon the general environment from potential sources of contamination. This will require the following: ♦ Field investigations to (i) confirm the presence of the overburden/alluvial, weathered bedrock and fresh rock aquifers, and features associated with preferred groundwater pathways, and (ii) estimate the hydraulic properties of these hydrogeological units. The field investigations should include: – Groundwater exploration drilling – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ Integration of this information with other field studies at the pit, TSF and NOEF (as recommended above) ♦ Collaboration with other disciplines to facilitate the incorporation of any additional hydrogeological information into the conceptual model and help ensure that a consensus is reached, thereby promoting the use of a single model when assessing impacts and controls	High

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Geochemistry		
NOEF	Installation and maintenance of complex cover systems on the NOEF will be challenging. Performance criteria should be developed, and a cover system designed that is robust enough to be installed on the NOEF and provide satisfactory long-term performance Allowance should be made for long-term monitoring and ongoing maintenance of the NOEF cover system post closure	High
	Develop a new approach to wet season infiltration control given the apparent ineffectiveness of a clay cover	High
	Improve control of convective/advective oxidation and spontaneous combustion. Advances have been made, but these processes are still occurring	High
	Undertake further investigation and analysis of monitoring data to better understand the extent and impact of groundwater contamination from the NOEF	Medium
	Carry out more drill testing of dumped materials to more confidently define the distribution of historically dumped materials and check the reconstruction of dump material types based on the new block model. Knowing the rock type composition and distribution will help MRM predict contaminant loadings being generated	Medium
	Increase the frequency of check sampling of dumped materials, particularly for LS-NAF. Only 102 check samples of LS-NAF cells were collected over the 2014 to 2016 period	Medium
	Determine whether elevated SO_4 concentrations in groundwater bores to the northeast of the NOEF (GW105, GW100, GW131 and GW134) are related to shallow seepage from the NOEF along natural drainage	Low
In-pit waste rock grade control	Progress use of on-site ICP testing to replace portable XRF	Medium
Waste rock criteria	Maintain NPR cut offs for PAF(HC) materials at 1 unless there is compelling geochemical evidence to justify a reduction	Medium
Waste rock kinetic testing	Include results from all kinetic testing in future kinetic test reports, including barrel leach, humidity cells, leach columns, and for waste rock and tailings materials Provide a table of the S, ANC, ABA and key metal/metalloid compositions of samples used in kinetic testing and compare with ranges expected (based on static testing) in each waste rock class and tailings	Medium
	Repair barrel tests before the next wet season	Medium
	Consider continuing LS-NAF humidity cells/columns to demonstrate longer-term low rates of contaminant release	Low
TSF	Progress the in-pit disposal and flooded option for tailings, which will provide the most secure closure outcome	High
	Install a more robust cover on Cell 1 before the next wet season that will withstand erosion and control infiltration, and progress the Cell 1 dewatering bores. The previous interim clay covers installed did not appear adequate to control seepage and impacts on Surprise Creek	High
	Monitor sulfide oxidation and pore water quality in beach tailings during operations to check for evidence of acid and salinity production. This could include pH/EC measurements of surface tailings	High

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Geochemistry (cont'd)		
TSF (cont'd)	Continue kinetic leach testing of tailings and assess lag times and acid, salinity and metal/metalloid generation rates, and implications for operational control of tailings beach areas and water quality	Medium
	Maintain moisture in drier and less active areas of Cell 2 to minimise sulfide oxidation and dust. This may include spraying water onto the surface	Medium
	Variation in ANC values was detected between different laboratories. Further checks should be carried out to determine which results best reflect the available ANC in the tailings, with inclusion of ABCC testing	Low
Mine site	Progress investigations into the eastern levee storage (ELS) and potential for saline seepage to McArthur River diversion channel	Low
Geotechnical		
TSF design	All future correspondence on the TSF should clearly indicate whether it is the advice of the designer or the ICE The independence of the ICE and the designer should be reviewed by MRM and the DME	High
TSF construction	The DME should seek a formal commitment from MRM as to the type and timing of construction quality records that need to be provided to the DME	High
TSF surface water management	There are discrepancies between GHD and WRM on the capacity and efficacy of the Cell 1 western sump. GHD states the capacity as 6 ML and inadequate to design while WRM states the capacity as being 8 ML and with only a 1% chance of spilling each year. At the same time this sump has been known to spill under a 1:20 year event. These discrepancies need to be resolved and the sump modified to meet design requirements	Medium
SOEF	Storing MS-NAF is likely to lead to saline drainage from the SOEF. McArthur River Mining should provide more direct evidence that this drainage is not impacting beyond the mine perimeter bund	High
CWNOEF design	There are a number of recommended minor corrections and updates to the CWNOEF design report as described elsewhere	Low
CWNOEF construction	The compaction specification should be changed back to that approved originally (in version 1.2 (MRM, 2014)) with at least two permeability tests per lot	High
	McArthur River Mining should provide all ICE construction reports to the DME in a timely manner	High
NOEF closure	Currently the closure design relies on estimates of hydraulic properties from particle size distributions and not direct testing McArthur River Mining should undertake direct testing of candidate materials likely to be used for the NOEF final cover. McArthur River Mining should also expand the limited sensitivity studies on the CCL saturated conductivity to examine how differences in the hydraulic conductivity contrast may affect net percolation	Medium
Bing Bong Loading Facility dredge spoil area maintenance	Undertake all of the recommendations given in the annual inspection report, GHD (2015) at least three months before dredging or the next wet season, whichever comes first. These recommendations are summarised as: ♦ Establish an embankment monitoring and maintenance program	Medium to high depending on planned dredging

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Geotechnical (cont'd)		
Bing Bong Loading Facility dredge spoil area maintenance (cont'd)	♦ Remove trees from the embankment ♦ Review the design and operation of spillways ♦ Line the Cell 5 spillway to the environment with rock ♦ Repair damaged section of the Cell 5 embankment toe ♦ Clear out sediment from the pipe culvert and rock line the outlet	
Bing Bong Loading Facility dredge spoil area monitoring	McArthur River Mining has reported that survey marks have been installed; however, there is currently no documentation to support this. The IM recommends the immediate commencement of monitoring reports that detail what has been installed, location and readings. Reports should be generated monthly when dredging is in operation and quarterly at other times	High
Bing Bong Loading Facility dredge spoil area reporting	The inspection report GHD (2015) is dated 1 April 2015, some seven months before the reported inspection date of 28 October 2015. The report should be corrected and reissued to confirm exactly when the inspection took place and when the report was issued	Low
Closure Planning		
Closure objectives, criteria and performance indicators	The current mine closure objectives, criteria and performance indicators should be revised. The objectives should be outcome based and focused on the proposed post-mining land use. The closure criteria and performance indicators should be site specific and capable of objective measurement or verification	Medium
Open pit	Extend pit void quality modelling to a longer period and assess the possibility of the pit lake ultimately acidifying under different assumptions	High
Bing Bong Loading Facility	Prepare detailed closure costs for the Bing Bong Loading Facility and present these as a separate domain from the mine closure costs	High
Terrestrial Ecology		
Revegetation monitoring	Results from dust monitoring sites DMV25 and DMV23 should be assessed against foliage cover results from vegetation control sites BCC1 and BCC2 respectively, to identify whether airborne dust is a causal factor in decreasing foliage density	Medium
Fauna	Replace the current Gouldian finch monitoring program with an assessment of suitable breeding and foraging habitats located within, and in the vicinity of, the mine. Construct a map of habitat, graded as to suitability for Gouldian finches, for use in future clearing and construction projects, allowing disturbance of important habitat to be avoided	Medium
Bing Bong Loading Facility	Investigate and rectify recent ponding of seawater against the bund wall and damage to the surrounding drain at Bing Bong Loading Facility dredge spoil ponds	High
Aquatic Ecology		
Movement of contaminated biota	A desktop investigation should be undertaken regarding potential movement of contaminated biota in McArthur River and how long biota needs to spend at exposed sites to uptake elevated levels of contaminants	High
Reduce emissions at ROM pad	Additional monitoring of Barney and Surprise creeks in the vicinity of the ROM pad (SW03, SW18) shows that there are elevated levels of Pb in biota from these sites, likely as a result of dust emissions from the mill and associated concentrate stockpiles. McArthur River Mining should investigate ways to reduce dust emissions from this site	High

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Aquatic Ecology (cont'd)		
Contamination at end of dry season	The current elevated concentrations of metals in biota are measured in the early dry season, when sites would have recently been flushed with freshwater and sediments and biota may have recently arrived from uncontaminated sites. By the end of the dry season, biota would have persisted for roughly six or more months in increasingly contaminated areas and, as a result, the contamination of biota would likely have increased. Monitoring of metals in conjunction with the late dry season survey would provide useful information on the potential elevated concentrations at the end of the dry season, just before fish may disperse away from the mine site in wet season floodwaters. It would also provide a better indication of the maximum contaminant loads taken up by biota	Medium
Erosion in McArthur River	There is evidence of erosion moving upstream from the southern end of the McArthur River diversion channel, potentially as a result of increased flow velocities at the start of the diversion. In the 2015 surveys, macroinvertebrate edge communities were impaired at MR7, likely due to reduced habitat quality as a result of this erosion. McArthur River Mining should investigate the causes of this erosion and potential mitigation measures if required. This should be covered in the upcoming geomorphological assessment of the McArthur River and Barney Creek diversion channels	Medium
Contamination at SW16	McArthur River Mining should investigate the sources of contamination entering the McArthur River diversion channel just upstream of SW16. McArthur River Mining should determine the relative contribution of groundwater flows through natural mineralisation and seepage from mining infrastructure, particularly the ELS	Medium
Visit reference sites annually	Hydrobiology (2016) raised the issue of including more regional reference material in the annual assessment of metals in biota. Analysis of collections made in 2010-2011 from the Limmen Bight and Wearyan rivers indicate naturally elevated Pb, but the amount of Pb taken up will depend on the strength and duration of the wet season. To account for this variation, reference material should be collected annually	Medium
Management of the SEL	McArthur River Mining needs to determine the primary role of the SEL and investigate whether the SEL is adequately designed to meet its purpose, and whether it should be modified so it better fulfils its role either as flood protection or for capturing and containing contaminated water	Low
Marine Ecology		
Contaminant uptake and dispersal in biota	As barramundi with elevated, mine-derived Pb were caught in the Bing Bong Loading Facility shipping channel, and a single fish with elevated, mine-derived Pb may have moved away from the loading facility, a report should be prepared covering the available literature on: ♦ The time it takes for a measurable contaminant load to be taken up in mobile species (e.g., barramundi, giant queenfish, mud crab, blue-tailed mullet) ♦ Sources of contamination in these species – are contaminants absorbed by consuming contaminated prey species and/or merely by persisting in the Bing Bong Loading Facility swing basin? ♦ Likelihood of dispersal in these species and potential dispersal distances	Medium

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Marine Ecology (cont'd)		
New DGT monitoring sites	As seawater from Bing Bong West 1 had elevated levels of contaminants, the IM suggests establishing DGT monitoring stations at Bing Bong West 1 and 2, if feasible, to determine fine-scale patterns of contamination at these sites	Medium
Monitoring of *Vibrio* bacteria	The last monitoring of *Vibrio* bacteria in the vicinity of McArthur River was carried out in 2013. In the 2014 report, the IM suggested a final *Vibrio* survey in 2015, which was not undertaken. A final *Vibrio* survey should be undertaken to confirm that *Vibrio* bacteria abundances are not increasing as a result of MRM's activities	Low
Soil and Sediment Quality		
Gaps in monitoring programs	♦ A gap in soil monitoring remains between S47 and S31, i.e., between the mine levee wall and the McArthur River diversion channel, to the southeast of the mine pit and potentially influenced by activities at the SOEF. MRM should consider installing a soil monitoring site in this area during the 2016 operational year	Medium
Surface soil HIL exceedances	The next soil monitoring report to be prepared by MRM should: ♦ Review results from surface soil sites S28 and S44 within the context of long-term trends to clarify reasons for Pb HIL exceedances and the variation in results between years ♦ Review long-term trends in Mn results across the mine site to assess the likely cause of widespread Mn EIL exceedances	Medium
EC results at FS04	♦ The cause of high EC results at FS04 should be investigated during the 2016 operational year	High
Fluvial sediment monitoring at FS08	♦ Fluvial sediment monitoring at FS08 should be reinstated in the 2016 operational period	High
Incident reporting	♦ Exceedances of soil and sediment guideline levels should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures	High
Dust		
Dust management planning – Bing Bong Loading Facility	♦ McArthur River Mining should develop a formal dust mitigation plan for Bing Bong Loading Facility, targeting the most impacted areas as identified by dust monitoring (i.e., BBDMV02 and BBDMV07)	High
Dust monitoring and analysis	♦ McArthur River Mining should implement duplicate sampling and field blank sampling as part of the Bing Bong Loading Facility dust monitoring program to assist with quality assurance/quality control	High
	♦ McArthur River Mining should calculate gradient contours based on ambient dust data from the mine site, so that adopted guidelines can be applied at the mine lease boundaries and at nearby public and recreational areas	Medium
	♦ The IM recommends that the frequency of monitoring for PM_{10} and Pb be temporarily increased at two high impact sites (DMV22 or 23, and DMV43) and one reference site (DMV01 or DMV10), to be sampled once every six (6) days for a one-year period, in order to determine whether the current monthly monitoring approach is statistically valid	Medium

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Dust (cont'd)		
Dust monitoring and analysis (cont'd)	♦ The IM recommends that MRM reviews and presents all available long-term dust data (in particular, PM_{10} and Pb results) for the mine site and Bing Bong Loading Facility, to inform understanding and management of dust issues at each site	Medium
Dust management – TSF	♦ An area immediately east of the decant wall on the TSF Cell 2 north wall is not being covered by tailings during the current deposition cycle. Discharge pipelines should be extended to this area to reduce dust emissions from this area	Medium
Incident reporting	♦ Exceedances of dust guideline levels should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures	High

5.2 Ongoing Recommendations

In addition to the new recommendations summarised in Table 5.1, there are a number of recommendations that have been identified from previous IM reviews that have either been partially addressed or not advanced at all. These ongoing recommendations, which in some cases have been modified to better address current site risks, are summarised in Table 5.2.

Table 5.2 – Ongoing Recommendations

Subject	Recommendation	Priority
Mine Site Water Balance		
Documentation and reporting	The following improvements in reporting are required: ♦ The MMP should provide the broad goals and objectives for mine water management (i.e., MRM's vision). For example: – A list of mine site water management commitments – A statement of intent to continually improve water balance monitoring and reporting – A statement of intent to manage the risk of water in the base of the pit – A list of the current limitations in the mine site water balance, ranked by impact on the water balance – An outline of the proposed mine expansion during the MMP and the site water management changes that may be required (e.g., additional levees, ponds and/or pumps) – A prioritised list of options that may be considered to improve mine site water management. This should include commentary on each option (e.g., ease of implementation) and a feasibility-level cost/benefit analysis ♦ The water balance modelling reporting needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty Increased detail is required in the reporting of the following items: ♦ The rainfall-runoff model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted ♦ The water balance model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Mine Site Water Balance (cont'd)		
Documentation and reporting (cont'd)	♦ The monitoring of water balance components, in particular what is monitored, the frequency of monitoring and the accuracy of the measurement ♦ How the monitoring data is used in the water balance modelling	
Water balance scenario testing	Changes in climate: ♦ The possible impact of climate change on the site water balance needs to be addressed Changes in water chemistry: ♦ The water balance needs to assess the risks posed by possible deterioration in site runoff and seepage water quality ♦ The adopted change in site water quality needs to be justified with: – Current water quality monitoring data and/or predictions (e.g., pond water quality estimates, TSF/NOEF seepage estimates) – Input from professionals with expertise in geochemistry Modelling of multiple years: ♦ An assessment should be undertaken that involves modelling to the start of the EIS project (April 2018)	Medium
Water storage ponds and tailings storage facilities	♦ While the risk of TSF Cell 2 spills to the WMD has been modelled, the impact (on the site water balance) of contaminating water stored in the WMD, thereby making it unsuitable for off-site release, needs to be assessed	Medium
Risk management of the site water balance	Variation in rainfall: ♦ McArthur River Mining needs to develop the surface water management system to the point where there is sufficient capacity that variation in rainfall between years (and sequences of consecutive wet/dry years) is treated as business as usual and not something abnormal	Medium
Accurate quantification of water balance processes	The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: ♦ The amount of simultaneous calibration of multiple parameters needs to be reduced ♦ Evaporation fan/sprinkler/fountain performance needs to be accurately quantified ♦ Groundwater inflow rates need more accurate estimation ♦ Seepage rates and runoff rates need more accurate estimation ♦ A strategy needs to be developed to reduce predictive uncertainty over time While the reduction in uncertainty is implicit in most of the recommendations, the key requirement here is that the reporting quantifies how the uncertainty is reduced in each successive year	Medium
Surface Water Quality		
NOEF and TSF/ surface water monitoring program	Given the ongoing issues associated with the NOEF and TSF: ♦ The surface water monitoring program should be reviewed on an ongoing basis to ensure that sufficient early warning is provided concerning potential impacts on surface water quality from NOEF and TSF leachates and runoff (or other potential failures of these project infrastructure components) ♦ This should include implementing a formal procedure whereby the review process, outcomes and required actions are documented and available for IM review	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Surface Water Quality (cont'd)		
McArthur River/ SW11/other surface water sites	A risk assessment should be undertaken concerning: ♦ Possible implications associated with elevated sulfate concentrations and conductivity levels at SW11 (and sites within the ML that are next to or downstream of MRM facilities) exceeding the respective SSTVs ♦ Likely causes ♦ If MRM operations are found to be a major contributing factor, mitigation measures commensurate with the level of risk	High
Monitoring	Real-time in situ monitoring at SW11 should be implemented with the issues observed during the 2015-2016 wet season (i.e., burial of the probe) being appropriately addressed	High
	Continued focus should be placed on QA/QC as part of the water sampling program, including: ♦ Elevated trip blank Zn and Al levels ♦ Occasional poor precision for DGT analyses ♦ Potential contamination issues associated with operating an environmental laboratory on a mine site	Medium
	Alternative labeling of natural surface water sampling sites when no flow is evident at the sites should be further investigated; these sites are not artificial and should preferably not be labeled as such	Low
	Additional effort should be devoted to the following in relation to mine-derived loads of contaminants*: ♦ Contaminant load estimates should be determined, where these reflect both natural and mine-associated sources (including but not limited to the TSF, OEFs, ELS, run-off dams and open pit) reporting to Surprise Creek, Barney Creek (and diversion channel), Emu Creek, and McArthur River (and diversion channel). Glyde River should also be included in these estimates (although this is a lower priority) ♦ Load calculations (and load balances) should take into account current and predicted natural and mine-derived loads, and seasonal variation ♦ The need to sample over specific flood events in McArthur River, Barney Creek, Surprise Creek and Emu Creek (and Glyde River) to complement the weekly sampling program and obtain robust load estimates should be considered ♦ Using the results from the above, mine-associated sources should be ranked in terms of contributions of contaminants to McArthur River at SW11 and further downstream, and used to prioritise management and mitigation actions	High
Water management system	Specific surface water quality management objectives should be formalised for Bing Bong Loading Facility and incorporated into relevant MRM documents	Low
	Additional information about the use of water quality monitoring data from the ASW program should be provided for IM review, i.e., this additional information should describe how the ASW data is used on a day-to-day or week-to-week basis	Low
General data interpretation and reporting	All relevant water quality data (in situ and laboratory) should be collated on a yearly basis in a format that is readily accessible and able to be interrogated (e.g., a single spreadsheet or similar); this should include a reconciliation of all actual versus proposed/committed sampling events	High
	Comparison of metal/metalloid results with ANZECC/ARMCANZ (2000) values should include 95th percentile values as well as median values	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Diversion Channel Hydraulics Management		
Geomorphology	A full geomorphic condition assessment and erosion mitigation study of both diversions is recommended as follows: ♦ The study should utilise on ground inspection in addition to recent and future ALS ♦ The study should be carried out for both the Barney Creek and McArthur River diversion channels with priority on McArthur River diversion channel ♦ The study should include the watercourses for at least 1 km upstream and downstream of the diversion channels ♦ The study should aim to identify areas of erosion and deposition, and the current geomorphic processes causing erosion, and to quantify the degree and rate of erosion along the entire reach ♦ The study should draw upon the results of the Phase 3 Development Project Surface Water Assessment (WRM, 2012a) and the Review of the 'As-Designed' and 'As-Constructed' McArthur River and Barney Creek Diversions (WRM, 2012b) ♦ Locations of channel constriction and/or high flow velocities should be prioritised, along with areas that have undergone erosion ♦ The study should consider previous attempts at erosion control, including revegetation attempts ♦ This study should then be used to assess the methods of erosion control that can be used and prioritise areas for corrective works	High
Erosion	Ongoing monitoring of diversion channel and bank erosion should continue utilising ALS complemented by photograph monitoring, and visual inspection. It is recommended that an annual report on observed erosion should then be completed. These reports should detail: ♦ The observed erosion ♦ The existing mitigation measure (if any) ♦ The planned mitigation measure ♦ The status of implementation of the planned mitigation measure	Medium
Integrity of the mine levee wall	It is recommended that the mine levee wall be assessed by a qualified geotechnical engineer, particularly at the sites identified in Figure 4.8. While runoff is predicted to be minor, it is recommended that these sites be repaired to ensure stability. It is also recommended that MRM produces a plan for revegetation, stabilisation and monitoring to ensure that the levee remains intact after mine closure	High
Sourcing materials	Given the need for additional LWD in the diversion channels and the potential requirement for additional rock armouring (both on the diversions and the levee wall), it is recommended that future sources for these materials be investigated	Low
Erosion at toe of mine levee wall	Erosion at the toe of the mine levee wall appears to be due to local runoff rather than fluvial erosion from flood events; however, it may pose a threat to long-term stability. It is recommended that the erosion be assessed by a qualified geomorphologist (included in the scope of the planned assessment)	High
Overland flow path	The rock protection of the overland flow path appears to be adequate at present; however, it is recommended that the rock protection be inspected after each wet season to ensure its stability. This site should be included in the detailed geomorphic assessment	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Diversion Channel Hydraulics Management (cont'd)		
Ponding of water	The site referred to in the 2011 IM Report (EES, 2012) as 'ponding of water between the diversion channel and mine bund' has yet to be inspected. The 2011 IM Report (EES, 2012) recommended re-contouring the section to provide adequate drainage. It is recommended that the location of this site be identified and that the status of the recommended actions be reported on	Low
Groundwater		
Open pit and underground mine	The following revised recommendations are made regarding options to dewater aquifers responsible for inflows to the pit and underground mine: ♦ Field investigations should be undertaken to identify groundwater pathways associated with the pit and underground (including the McArthur River palaeochannel aquifer) and estimate their properties. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ The conceptual model for the pit and underground should be updated to include the field program results ♦ Once the conceptual models are sufficiently advanced, numerical models should be constructed to identify effective controls, which may include installation of production bores to intercept groundwater flows towards the pit or underground	High
OEF	The following revised recommendations are made regarding the assessment of seepage impacts around the NOEF to confirm the effectiveness of the PAF containment system, once the future development of the facility is approved: ♦ A schedule should be developed for the installation and testing of monitoring bores in areas planned for future NOEF expansion. The schedule should allow for the adequate collection of background data ♦ Electromagnetic surveys should be carried out in areas planned for future NOEF expansion to identify background responses. The timing of surveys should take into consideration seasonal changes in groundwater level ♦ Monitoring of the eight new NOEF bores should be included in MRM's list of commitments ♦ Field investigations should be undertaken to identify groundwater pathways in the vicinity of the NOEF and estimate their hydraulic properties. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ The outcomes from field investigations and ongoing monitoring should be used to routinely update the conceptual hydrogeological model for the NOEF ♦ Once the conceptual model is sufficiently advanced, numerical models should be constructed to identify effective controls	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater (cont'd)		
SPROD	The following revised recommendations are made regarding the SPROD: ♦ The synthetic liner should be installed as a long-term seepage control ♦ The simple water balance model should be reviewed once the synthetic liner has been installed to estimate seepage rates	High
TSF	The following revised recommendations are made regarding the assessment of seepage impacts around the TSF: ♦ Field investigations should be undertaken to better identify groundwater pathways in the vicinity of the TSF and estimate their hydraulic properties. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ The conceptual model for the TSF should be updated to include the field program results ♦ Once the conceptual model is sufficiently advanced, numerical models should be constructed to identify effective controls.	High
Open pit closure	Further assessment of the post-closure pit lake is required to identify a robust option to control impacts. Options under consideration by MRM include maintaining the lake as a sink or designing a through-flow system incorporating the McArthur River. Revised recommendations to manage this issue are as follows: ♦ Scopes of work should be developed to assess closure options to identify potential fatal flaws prior to mine closure. These are likely to include further development of the water and solute balance and modelling of pit lake stratification ♦ An approach should be identified to assessing the verification of the results from these studies after mine closure. This would likely include collection of monitoring data and validation of the models developed prior to closure and revision of closure options (as required)	High
Diesel spill	Monitoring bore URS03 should be replaced and an additional monitoring bore installed east or northeast of bore URS17 to increase the coverage to the east and northeast of the plume	Medium
General data interpretation and reporting	A comprehensive interpretation of the groundwater monitoring data should be carried out as part of future MMPs and annual groundwater reviews. These should aim at identifying processes responsible for unacceptable groundwater impacts	Medium
	A summary of all groundwater commitments should be presented in future MMPs and annual groundwater reviews	Low
	McArthur River Mining should commit to reporting all breaches of their groundwater commitments to the DME. In particular, there appears to be an acceptance that exceedance concentrations of sulfate and salinity in areas previously affected by seepage do not warrant reporting	Low
	Hydrographs of pressure levels in all borefield abstraction bores and nearby observation bores should be constructed, including rainfall and abstraction volumes and rates	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater (cont'd)		
General data interpretation and reporting (cont'd)	Data such as recovery rates following cessation of pumping and drawdown rates during constant discharge should be assessed	Low
	Kinetic tests should be carried out to estimate the attenuation characteristics of the alluvium underlying the TSF	Medium
Geochemical		
NOEF	Continue paddock dumping and roller compacting PAF(HC) materials, which are still highly pyritic, to maximise stability and minimise oxidation and infiltration	High
	Maintain a 100-m set back for PAF(HC&RE) materials, particularly in older 15-m end-tipped dump zones, to control convection	High
WOEF	Review/compile existing data and/or undertake a test program to confirm the distribution of geochemical rock types at the WOEF and finalise closure options	Medium
SOEF	Review kinetic test results and assess potential impacts on receiving drainage during operations, and finalise closure options	Medium
Resource waste block model	Reconcile the block model predicted tonnages by waste rock type against tonnages actually mined, and adjust the block model if required. The amount of materials classified PAF(HC) in 2014 was significantly higher at 34% of waste rock moved than the 15% predicted by the block model	Medium
Waste rock kinetic testing	Consider instigating a controlled watering regime for barrel tests, set to reflect a particular wet/dry climatic scenario, to make leachate volumes collected at each barrel more comparable to provide better and more interpretable results	Low
In-pit waste rock grade control	Check calibration of hand-held XRF with new ICP check data	Medium
Waste rock criteria	Identification of PAF(RE) is currently based on S criteria only. Continue investigations into spontaneous combustion potential and develop criteria that provide more confident identification of PAF(RE). In particular, confirm whether the current 10%S cut off is too high and needs to be lowered to 8.5%S	Medium
TSF	Make financial allowance for long-term monitoring and ongoing maintenance of any TSF cover system post closure	High
	Assess the potential effects of pyrite oxidation and salt generation on the overall stability of the TSF embankment if compacted tailings are used in embankment construction	Medium
	Continue ongoing geochemical monitoring of discharged tailings and carry out geochemical characterisation of tailings collected as part of TSF drilling to obtain information on historic variation through the tailings profile	Low
Infrastructure sites	Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in situ sulfidic materials at the Barney Creek diversion and McArthur River diversion	Medium
Bing Bong Loading Facility dredge spoil	Carry out an acid sulfate soil assessment of the spoon drain around the dredge spoil ponds and other potential sources at Bing Bong Loading Facility	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Geotechnical		
TSF design	Ensure the Cell 1 drainage and detention system can accommodate a 1 in 200 year storm event through assessment and modification as required	Medium
TSF seepage	The origin and veracity of fault mapping in the vicinity of the TSF need to be investigated Further investigations are needed to quantify preferential flow paths for seepage. These investigations should use all available geological information to maximise efficiency and improve the basis for subsequent modelling. Mapping should be used to set the depth of modelling which may need to be increased from 20 m to substantially greater depths. The hydraulic conductivity of the tailings needs to be reviewed and appropriate testing (such as low pressure oedometer or Rowe cell testing) be undertaken to reduce uncertainty in this parameter The effect of dissolution of the TSF foundation materials needs to be considered in conceptual and numerical models; particularly in light of the likelihood of increased tailings acidity due to reduced pond size The WRM water balance needs to be updated to include estimates of TSF evaporation and seepage. Seepage estimates are likely to be improved through the actions described above. Evaporation may require combined estimates based on Penman based methods and (micro-) lysimeters	High
	McArthur River Mining to review the current strategy for preventing seepage to Surprise Creek in light of recent groundwater monitoring, EM remote sensing and any other relevant data. This review should present evidence as to the effect of existing mitigation strategies, their longevity and long-term feasibility in consideration with other mitigation works such as final capping of Cell 1	High
TSF construction	Provide all records to the DME of earthworks testing or other construction certification for TSF Cell 2 Raise 3. The IM notes that this same request was given to MRM by DME on 27 August 2015	High
TSF operation	Confirm assumed average tailings beach gradient from survey	Medium
NOEF design	McArthur River Mining should provide a clear timetable of outstanding activities required to finalise clay cover and liner designs including compaction trials, improved assessment of clay types, exploratory drilling and lysimeter testing. The timetable should prioritise these tests and identify what the outcomes will achieve. McArthur River Mining needs to allocate test areas in accordance with these priorities and before the Overburden Management Project EIS has been finalised	Medium
NOEF rehabilitation	A plan needs to be developed which describes how progressive rehabilitation will be undertaken and in what sequence. The IM understands that some of the detail of this may be pending future trials and/or approvals. However developing a plan would identify rehabilitation targets and clarify trial and approval priorities	Medium
OEFs general	Detailed plans and cross sections of the OEFs should be prepared and made available to the IM such that the construction of the OEF can be verified. This should include, where relevant, a system to identify the QA/QC testing lots for the relevant materials	Medium
Bing Bong Loading Facility dredge spoil embankment design	The IM is still unaware of a design document for the dredge ponds that can be used to measure performance against measurement, such as settlement and pore pressures, and details how future raises would be constructed. The IM understands that dredging may take place in the next reporting period. A design document needs to be produced well in advance of dredging activities so that the correct reviews and approvals can be completed	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Geotechnical (cont'd)		
Bing Bong Loading Facility dredge spoil – monitoring	Measurement of the embankment crest RL at known areas of movement or likely instability, and at the extremities, is required Dedicated monuments need to be installed to facilitate comparative measurements of embankment levels over time	Medium to high depending on planned dredging
Closure Planning		
Materials balance	A comprehensive materials balance should be prepared following finalisation of the cover and landform design to identify potential shortfall in materials and: ♦ Confirmation that LS-NAF(HC) material can be selectively mined to address this shortfall ♦ Costs (drill, blast and haul) associated with the selective mining of LS-NAF(HC) is included in the revised mine closure cost estimate	High
Mine closure commitments	As part of the review of the mine closure plan, MRM should review all previous rehabilitation and closure commitments that have been made since underground mining commenced. All commitments should be upgraded to reflect the current status of the operation, community expectations and good industry practice	High
Mine closure costs	A comprehensive review is required of the closure costs. Determining the timeframe that post-closure monitoring and maintenance will be required should be a key aspect of this review. Allowance should be made for: ♦ Long-term monitoring of cover performance ♦ Maintenance of the cover system, including inspection of geotechnical integrity ♦ Collection and treatment of leachates (surface and groundwater), and active water management post-closure including potentially the pit lake ♦ Monitoring and maintenance of the mine levee wall ♦ Monitoring and maintenance of McArthur River diversion channel	High
NOEF	A Failure Mode Effects Analysis (FMEA) should be undertaken concerning the preferred cover and landform design. The FMEA should clearly outline how likelihood and consequence are determined and the mitigation strategies in place and proposed. Where the confidence levels are low or medium, actions to improved confidence should be detailed	Medium
	The current dump design should be reviewed in relation to the sustainability and performance of the 0.6-m compacted clay infiltration/oxidation control layer. The sensitivities of the cover design should be tested in relation to: ♦ Changes in material properties ♦ Changes in depth of NAF cover as a result of erosion ♦ Changes in climate	High
	Erosion and sediment transport modelling of the proposed NOEF landform should be undertaken to identify the depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years. The IM supports MRM's decision to evaluate alternative landform designs which eliminate the need for engineered structures	Medium
	A trial should be undertaken to construct a cover to the required specification and regularity of thickness to prevent seepage in perpetuity. Samples from the trial compacted clay liner should be tested for density and permeability after compaction, with testing to be undertaken at intervals over the full thickness of the liner	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Closure Planning (cont'd)		
NOEF (cont'd)	The potential for differential settlement of the NOEF to compromise the cover design should be evaluated, with particular focus on the potential implications for highly reactive PAF material to settle faster than other waste rock contained in the NOEF	Medium
Open pit	The seepage of contaminated water from the pit lake after closure should be assessed. This would best be carried out using a water and solute balance model for the pit lake, which would include inflows, outflows, storage volumes, effects of salinity on lake evaporation rates and geochemical process associated with interaction between lake water and the pit wall rocks Under the 2015 West Australian mine closure guidelines (DMP, 2015) (revision of the 2011 guidelines), which MRM has adopted for closure planning purposes, an assessment of the pit lake condition is required to identify whether a groundwater sink or flow through will develop after closure	High
TSF	An interim cover design has been developed for TSF Cell 1. MRM currently does not have any plans for retreatment of the tailings within Cell 1, although with further technological advances retreatment may be possible. An opportunity exists for MRM to develop its TSF closure strategy by implementing a final cover over either all or part of Cell 1. A final cover strategy trial should be undertaken on Cell 1 for at least part of the area. The IM understands that MRM's preferred closure strategy for the TSF has changed and relocation of tailings to the open pit is the preferred strategy. This change in strategy once confirmed will change the IM's recommendations with regard to TSF closure	High
	Erosion and sediment transport modelling of the proposed TSF landform should be undertaken to identify the depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years	Medium
Terrestrial Ecology		
Rehabilitation	Investigate including the saline seepage impact assessment sites located downstream of the Barney Creek haul road bridge (six plots) as part of the revegetation monitoring program, as they will provide representation for this area which is lacking data. Many of the methods already conducted (for the saline seepage program) are very similar to those used in the revegetation monitoring program	Medium
	Include a revegetation monitoring site in the downstream area of the McArthur River diversion channel (below MRR6) along with a suitable control site, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate stage	Medium
Flora	Include a saline seepage impact monitoring site next to the TSF along Surprise Creek where seepage has previously occurred	High
Rehabilitation monitoring	Research the use of a more landscape function-based monitoring program such as Drainage-line Assessment, in conjunction with the findings and recommendations of the forthcoming geomorphological study, to provide more information on erosion and stability of Barney Creek and McArthur River diversion channels	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Terrestrial Ecology (cont'd)		
Rehabilitation monitoring (cont'd)	Prepare a rehabilitation plan for the diversion channels which states a timeframe when the diversion channels are expected to be rehabilitated and self-sustaining, along with clear, achievable, regular milestones against which performance can be measured. McArthur River Mining should assess if it is feasible to continue to rehabilitate using current methods or whether alternative avenues need to be investigated	High
	Reassess the list of key and primary species to which revegetation on the diversion channels is compared to and/or reassess control site selection, as many of those listed are not recorded at current control sites. Investigate separate key and primary species lists for McArthur River and Barney Creek as vegetation assemblages at the control sites show different assemblages	High
Fauna	Compare data collected during the migratory bird monitoring program with historical data for the region and surveys completed in other locations on the EAA flyway. Conduct a review of the current monitoring program to assess if it is sufficient to determine if MRM activities are impacting migratory birds	Medium
Bing Bong Loading Facility dredge spoil ponds	Include an inspection of the outside of the drain bund wall in monthly inspections of the dredge spoil cells, to assess if tidal seawater is ponding against the bund	Medium
Aquatic Ecology		
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should conduct a full review and synthesis of the monitoring programs at McArthur River Mine, including metals in aquatic fauna, macroinvertebrates, surface water, groundwater, fluvial sediments, dust and soil to identify additional sources of contamination at the mine site. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013). Potential sources may include dust emissions from the haul road and the processing plant and associated stockpiles and seepage from the ROM sump. Legacy impacts should also be addressed If additional sources of contamination are identified, suitable controls can be implemented	Medium
Monitoring of aquatic fauna in Barney Creek	Additional monitoring of aquatic fauna in natural sites along Barney Creek or equivalent reference sites and multiple sites in the Barney Creek diversion channel should be included, so the performance of the Barney Creek diversion channel can be properly assessed The IM is aware that many sites only hold water for a short period following the wet season. As a result, potentially monitoring programs should be split in two, one as soon as practical following the wet season to survey smaller creeks and tributaries and a second later to survey the McArthur River and other major tributaries. This would also benefit other aspects of the monitoring program	Medium
Dam and natural flows in Surprise/ Barney creeks	One of the justifications for the bund and water extraction at SW19 was that there was only flow at that site due to seepage, however, no evidence for this was provided. McArthur River Mining should investigate the natural flow rates in Surprise and Barney creeks, so ceasing dry season flow to sites below SW19 can be properly justified	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Aquatic Ecology (cont'd)		
LWD	The IM recommends continuing to add and monitor LWD in the McArthur River diversion channel. McArthur River Mining should commit to additional large-scale projects to install LWD along poorly revegetated sections of the diversion channel, to ensure continuity of habitat along the diversion. McArthur River Mining should continue to add small woody debris and leaf litter to the diversion channels at the end of the wet season to provide habitat and detritus for small fish and invertebrates In addition, MRM should consider excavating or blasting of riverbanks and/or the central channel in areas of poorest rehabilitation to create eddies and improve sinuosity. Creating eddy sites would slow flow rates and facilitate soil deposition and eventual vegetation establishment to improve aquatic habitat Finally, MRM should continue annual monitoring of LWD to ensure that the wood remains in position and the best method of establishing LWD sites can be determined	Medium
Drawdown at Djirrinmini Waterhole	An investigation should be undertaken into the impacts of potential drawdown at Djirrinmini Waterhole, and possible mitigation of its impacts, as this is one of the most upstream waterholes visited by freshwater sawfish	Medium
New background Pb isotope ratio	Monitoring would benefit from the establishment of a more regionally relevant background level for Pb isotopes. At all monitoring sites, the average isotopic ratios were closer to the orebody than background levels. Establishing a regionally relevant background isotope ratio would be better for determining whether ore-derived Pb is entering aquatic fauna	Low
Marine Ecology		
Inclusion of long-term datasets in reports	As the AMMP and the DGT program have now been running for several years, long-term datasets should be included in the reports so consistent patterns and inconsistencies can be more easily identified. Long-term data was included in the seagrass monitoring program in 2015, and may be included in the latest AMMP, which is currently being prepared	Low
Timing of dredging	Do not dredge during rain events to ensure that particulate matter will have enough time to settle out before flowing out of the dredge spoil ponds. Dredging only in the dry season would be preferable, as there will be minimal chance of intense rain	Low
Soil and Sediment Quality		
Surface soil monitoring	♦ Soil site S05 should be removed from the sampling program, as it is neither an appropriate control site (being in the immediate vicinity of an ex-quarry) nor an appropriate impact site (as the impacts are more likely to be related to past quarry operations than to recent/current mine operations). A replacement reference site will be required away from the quarry in a more 'natural' location	Medium
Surface soil contamination north/northeast of the TSF	♦ If the next sampling event shows an increase in Pb at S42, MRM should investigate the reason for these temporal fluctuations at this site	Low
Surface soils near Barney Creek haul road bridge	♦ A replacement site for S43 should be established in the vicinity of Barney Creek haul road bridge, but situated on an area of natural (in situ) soils	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Soil and Sediment Quality (cont'd)		
Fluvial sediments at Barney Creek haul road bridge	♦ The remaining open drain holes in Barney Creek haul road bridge should be closed, with runoff directed into silt traps on either side of the bridge	High
	♦ As well as being cleaned out annually after the wet season, silt traps at Barney Creek haul road bridge should be inspected periodically and cleaned out as required at other times of the year, e.g., in the early wet season/before significant floods are experienced (taking into account logistical constraints)	Medium
	♦ The ongoing monitoring of water quality in silt traps at Barney Creek haul road bridge during the wet season, along with dewatering of poor quality water in the southeast and northwest traps to Pete's Pond/SPSD/SPROD, is commended and should continue	High
Fluvial sediments – monitoring results and responses	♦ Data for reinstated fluvial sediment site FS20 should be reported in the 2016 operational year	Low
Nearshore sediment monitoring	♦ The Eastern Control group should be modified (moved slightly to the west) in the 2016 operational year, to reduce possible impacts/influences of outputs from Mule Creek and thereby be a more useful control group	Medium
Soil monitoring data – assessment	♦ The next version of the MMP, as well as all future soil monitoring reports (including the next one, covering both 2014-2015 and 2015-2016), should evaluate soil monitoring data within the context of the revised NEPM (NEPC, 1999) (as amended, 2013)	High
	♦ The next version of the MMP, as well as future fluvial and marine sediment monitoring reports, should reference Simpson et al. (2013) instead of ANZECC/ARMCANZ (2000)	High
Soil, fluvial sediment and marine sediment monitoring program – reporting	♦ Quality assurance/quality control data for sample analyses, and subsequent discussion, should be presented in the next version of the MMP as well as surface soil, fluvial sediment and marine sediment (AMMP, nearshore, and trans-shipment) monitoring reports for the 2016 operational year	Medium
General data interpretation and reporting	♦ A reconciliation/discussion of actual versus proposed/committed sampling events should be provided as part of 2016 operational year reporting	Low
Dust		
Dust monitoring	♦ Data from the new TEOM units at Bing Bong Loading Facility and near the mine site accommodation should be reported during the 2016 operational period ♦ Data from the new high-volume air sampler installed at the mine site (between the primary crusher and Barney Creek) should be reported during the 2016 operational period	High
Dust management planning – mine site	♦ McArthur River Mining should develop a formal plan for dust minimisation in the vicinity of DMV43. This may be part of a formal dust mitigation plan for the mine site as a whole, targeting the most impacted areas as identified by dust monitoring	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Dust (cont'd)		
Dust management – Bing Bong Loading Facility	♦ The doors of the Bing Bong Loading Facility concentrate shed should be repaired or replaced as soon as practicable. Once doors are operational, they should be kept closed as often as possible	High
	♦ Progress on repairs to failed areas of the bitumen surface at Bing Bong Loading Facility should be reported in the next IM report (for the 2016 operational period)	Medium

6. Conclusions

McArthur River Mining has continued to progress a number of technical studies during the 2015 operating period as part of the Overburden Management Project EIS. Most of these studies are still to be finalised and hence have been largely excluded from IM review, apart from draft versions of particularly relevant technical reports that provide context and additional insight into how MRM proposes to address a number of significant issues. The IM understands that the EIS will be released for public comment in late 2016.

During the reporting period, MRM has further defined the geochemical properties and risks of mine materials, and has made a number of improvements in operational management to better control currently identified geochemical issues and impacts. However, the highly pyritic and reactive nature of the mine materials means that potential generation of acid, metalliferous and/or saline drainage, and the associated potential adverse impacts both on site and downstream, remains the most significant (and challenging) environmental risk at McArthur River Mine. The NOEF, TSF and open pit are the key potential long-term sources of contaminated drainage. The main geochemical issues for the site therefore relate to the need to:

- Improve operational controls to manage rapid oxidation and seepage.
- Better define the distribution of geochemical rock types and their geochemical properties.
- Develop closure management strategies that ensure the successful long-term mitigation of potential impacts.

The IM was pleased to observe, both during the site visit and in review of documentation, MRM's focus on collecting information (e.g., drilling into the NOEF, establishing erosion trials) to inform the design of closure strategies, and particularly that for the NOEF.

Three core areas of the site (OEFs, TSF and open pit) require detailed closure plans that outline the objectives, closure criteria (including how these will be measured) and impacts (if any) following completion of works. The IM believes that an important component of the closure plan is that post-closure monitoring and maintenance requirements, and in particular the timeframe for these activities, are detailed. While much remains to be done to finalise the proposed closure strategies, which the IM understands will be described in the EIS, the progress being made is encouraging.

Operation of the TSF continues to improve with effective pond management being evident and a subaerial tailings beach of at least 50 m being maintained. Process water is efficiently reclaimed and safe operating levels have been established.

There have been a number of design improvements for the CWNOEF and the evidence presented to the IM is that CWNOEF construction is being executed generally in accordance with the MRM design. Some minor improvements could be made, but the overall improvement in this area is significant compared to previous years.

McArthur River Mining continues to devote considerable effort to water management at both the mine site and Bing Bong Loading Facility. Surface water quality monitoring data up to October 2015 indicates that adverse impacts on downstream surface waters due to the mine are currently limited, although some effects are noticeable in watercourses within the mine lease boundaries (and this is not unexpected), and some non-compliance with SSTVs due to mine activities has occurred.

Water sampling sites at SW16 at the lower end of the McArthur River diversion channel recorded elevated salt concentrations, particularly sulfates. McArthur River Mining investigated these monitoring results and attributed an observed step change in EC between SW15 and SW16 to two zones of mineralisation, i.e., the Cooley deposits and pyritic shale, with the influence of these features becoming apparent at low flows in the river. The eastern levee storage (ELS) was also identified as a potential source, which MRM noted as requiring further investigation.

In the previous two IM reports, it was recommended that 'Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river'. While this has been a high priority recommendation in the last two IM reports, only limited progress has been made. The IM's view is that, until load estimates (and load balances) are available, possible downstream impacts associated with the mine potentially remain unknown to some degree, and quantification and targeting of mine-associated sources remains poorly defined.

Monitoring of aquatic biota at McArthur River Mine continues to improve. The McArthur River diversion channel is performing better where complex habitat is provided, with fish communities and Macrobrachium abundances being similar to those found in natural areas outside the diversion channel. Metal concentrations in freshwater biota at SW19 (located on the Barney Creek diversion channel) are declining. However, monitoring of additional sites on Barney and Surprise creeks indicates that Pb contamination is more widespread in this system than previously recognised. For the first time, macroinvertebrate communities are impaired at sites immediately upstream of the McArthur River diversion channel, likely due to erosion potentially caused by increased flow velocities in the diversion channel.

The DME commissioned two reports into the potential human health impacts of contaminants in biota caught in the McArthur River. These reports indicate that the risks to human health posed by consuming fish from McArthur River are low.

Overall, impacts to the marine environment at the Bing Bong Loading Facility are almost exclusively restricted to the shipping channel and the area immediately west of the facility. Only Zn in oysters exceeded the MPC for human consumption, and other metal concentrations in biota, where detectable, were well below their respective MPCs. Barramundi were added to the AMMP for the first time in 2014 and concentrations of Pb in these fish were elevated, but markedly below MPC levels, in individuals collected from the loading facility. An assessment of the source of contamination will be possible when more data becomes available.

Significant improvements have been made to MRM's existing terrestrial ecology monitoring programs which greatly increases the robustness of the data collected. The control of risks has been thorough and particular areas of note include MRM's dedication to revegetating the diversion channels through tubestock planting (48,000 planted during the operational period) and the implementation of the livestock management plan which has resulted in the exclusion of cattle along the river and creek channels.

While progress is evident, much work is still to be done to revegetate the McArthur River diversion channel. As in previous IM reports, it is strongly recommended that MRM develops a revegetation plan which includes a reasonable completion date for the diversion channel to be self-sustaining and a series of milestones against which performance can be assessed. This will allow MRM to determine the effort required on a yearly basis to meet this goal and assess if rehabilitation is on track at an early stage.

The 2015 IM review has found that, while there are ongoing issues relating to dust at the mine site and in the vicinity of Bing Bong Loading Facility, dust monitoring results are generally stable or improving. Monitoring programs as well as management practices continue to improve. The key ongoing dust concerns relate to dust management near Barney Creek haul road bridge, and the inoperability of concentrate shed doors at Bing Bong Loading Facility.

During the 2015 operational period, the DME initiated a series of field inspections that were aimed at:

- Informing the assessment by DME mining officers of the 2013-2015 MMP.
- Providing an update to management on the status of operations and assessing compliance with DME conditional approvals.

The IM commends the DME on undertaking these site visits and notes that such visits should be used to facilitate the exchange of technical information and minimise misunderstandings between the two parties.

Two independent roles were established during the 2015 operational period, namely the appointment of an independent certifying engineer (ICE) and an independent tailings review board (ITRB). Both of these initiatives are positive steps. The DME also engaged other independent external advice to supplement internal expertise and the IM supports this approach, particularly if this external advice facilitates DME's review and approval processes.

7. Limitations

7.1 Introduction

The following statements remain the same as those included in previous IM reports and are intended to advise the reader of the scope of this report and the level to which conclusions may be drawn from the findings contained herein. These statements are not intended to reduce the level of responsibility accepted by ERIAS Group, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes by doing so.

7.2 General Limitations

ERIAS Group has prepared this environmental performance report in response to the following items and subject to the limitations contained therein:

- The McArthur River Mining Pty Ltd mining Authorisation Number 0059-02, and in particular Schedule 2 – McArthur River Mine Independent Monitoring Assessment Conditions (IMACs).
- The specific scope of services set out in the Request for Tender issued by the DME, and the subsequent notification of award of contract issued by the Department of Corporate and Information Services on behalf of the DME (Contract No.: D12-0274) on 9 December 2013.

This environmental performance report:

- Relates only to the areas referred to in the scope of works, being the McArthur River Mine and Bing Bong Loading Facility, Borroloola region, Northern Territory.
- Has reviewed environmental matters only. Issues relating to mine safety, health and/or social issues, personnel and administration matters or governance arrangements resulting from the operation of the mine have not been included in the assessment.
- Has been prepared for the particular purpose outlined in the DME scope of services and no responsibility is accepted for the use of this report, in whole or in part, in other contexts or for other purposes. This report may not be relied upon by any third party not named herein for any purpose except with the prior written consent of ERIAS Group.

7.3 Information Relied Upon

ERIAS Group has reviewed the information provided by MRM with regards to the environmental assessments and monitoring activities that the company has undertaken, as well as environmental assessments and audits undertaken by DME. This report has been prepared on the basis of:

- Information provided by MRM and DME, which was not verified by ERIAS Group except to the extent required by the scope of services. ERIAS Group has assumed that this information is correct unless otherwise stated, but does not accept responsibility for the accuracy or completeness of the provided information with respect to MRM's environmental performance.

- Information that existed at the time of production of this report and under the conditions specified. This report relates to the McArthur River Mine and Bing Bong Loading Facility as at the date of the most recent information provided by MRM, at the date of reporting. It is recognised that conditions may have changed thereafter due to site activities and/or natural processes. The scope of services allowed ERIAS Group to form an opinion of the actual performance of the site at the time of this assessment and cannot be used to assess the effect of any subsequent changes at the site, or associated aspects.

7.4 Specific Constraints

Due to constraints of time during the assessment of environmental performance, ERIAS Group did not perform a complete assessment of all possible conditions or considerations at the site. For example, ERIAS Group has not:

- Undertaken a detailed site visit of the McArthur River Mine or Bing Bong Loading Facility (for example, not all monitoring locations were visited).
- Reviewed in detail all of the files provided by MRM or DME.
- Verified performance against commitments or IM recommendations for which information was not available at the time of this assessment.
- Assessed performance against MMP commitments as these were numerous and not consolidated into a consistent format to allow meaningful assessment.

As noted in last year's IM report, the Overburden Management Project EIS, and related studies, is in progress and, as such, assumptions and findings contained in this report with regards to overburden management (including current NOEF designs and overburden geochemical classification) may have limited applicability.

It should also be noted that:

- No information was provided by MRM relating to the ongoing monitoring of the McArthur River diversion channel and bank erosion, and this has limited the IM's assessment of the diversion channel's performance during the operational period.
- Reporting and interpretation of environmental monitoring data by MRM, which generally reflects the financial year (i.e., 1 July to 30 June) but is also supplemented by additional data where available, is not entirely consistent with the IM review period (i.e., 1 October to 30 September). This provides additional complexity to the IM's review of MRM's data and reports, and requires the IM to undertake data analysis and interpretation that is additional to that provided by MRM.

8. Definitions

8.1 Acronyms and Abbreviations

µg/m^3	micrograms per cubic metre
AEP	annual exceedance probability
ANC	acid neutralisation capacity
AMD	acid and metalliferous drainage or acid mine drainage
AMMP	annual marine monitoring program
ANCOLD	Australian National Committee on Large Dams
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	average recurrence interval
As	arsenic (element)
AS	Australian Standard
AS/NZS	Australian/New Zealand Standard
BBDDP	Bing Bong dredge discharge point
BCM	bank cubic metre, representing the content of a cubic metre of material in place, before it is drilled and blasted
BPEM	best practice environmental management
Cd	cadmium (element)
CCL	compacted clay liner
Cu	copper (element)
CWNOEF	northern overburden emplacement facility (central west phase)
DME	Department of Mines and Energy
DPIF	Department of Primary Industry and Fisheries

EIS	environmental impact statement
ELS	eastern levee storage
EMP	environmental management plan
EMS	environmental management system
EPROD	east PAF runoff dam
GDE	groundwater dependent ecosystem
IM	Independent Monitor
ISSTV	interim site-specific trigger value
ISQG	interim sediment quality guideline
L/s	litres per second
LS-NAF(HC)	low salinity non—acid-forming rock (high capacity)
LWD	large woody debris
Mdmt	million dry metric tonnes
ML	megalitres
ML/d	megalitres per day
MLN	mining lease number
Mm^3	million cubic metres
MMP	mining management plan
Mn	manganese (element)
MPA	maximum potential acidity
MPC	maximum permitted concentration
MRM	McArthur River Mine
MS-NAF(HC)	metalliferous saline non—acid-forming rock (high capacity)
MS-NAF(LC)	metalliferous saline non—acid-forming rock (low capacity)

Mt CO_2-e	million tonnes of carbon dioxide equivalent
Mtpa	million tonnes per annum
NAF	non–acid-forming
NAG pH	net acid generation pH
NAPP	net acid production potential
NEPM	National Environment Protection Measure
NOEF	northern overburden emplacement facility
OEF	overburden emplacement facility
OCR	oxygen consumption rate
NPR	neutralisation potential ratio
pa	per annum
PAF	potentially acid-forming
PAF(HC)	potentially acid-forming rock (high capacity)
PAF(RE)	potentially acid-forming rock (reactive)
Pb	lead (element)
PM_{10}	particulates with aerodynamic diameter less than 10 μm
$PM_{2.5}$	particulates with aerodynamic diameter less than 2.5 μm
PPE	personal protective equipment
ppm	parts per million
PSD	particle size distribution
QA/QC	quality assurance/quality control
RL	reduced level
ROM	run of mine

SEL	south east levee
SEPI	Sir Edward Pellew Group of Islands
SOEF	southern overburden emplacement facility
SPSD	southern PAF sediment dam
SPROD	southern PAF runoff dam
SEPROD	southeast PAF runoff dam
SOEF	southern overburden emplacement facility
t	tonne(s)
TDS	total dissolved solids
tpa	tonnes per annum
TSF	tailings storage facility
TSP	total suspended particulates
WDL	waste discharge licence
WMD	water management dam
WMP	water management plan
WOEF	western overburden emplacement facility
Zn	zinc (element)

8.2 Glossary

abiotic	Of or relating to the non-living components of an ecosystem; physical rather than biological; not involving biological activity
abundance	(Biological and other sciences) the quantity or amount of something present in an particular area, volume, or sample, e.g., total numbers of individual animals or of taxonomic groups of animals

acid neutralising capacity (ANC)	Natural resistance of soils or rock to acid generation. It is the number of moles of protons per unit mass of soil required to raise the pH of the soil by one pH unit. ANC is measured as percentage $CaCO_3$
acid sulfate soil (ASS)	A soil containing iron sulfides deposited during either the Pleistocene or Holocene geological epochs (Quaternary aged) as sea levels rose and fell
acidify	To make acid; convert or change into an acid.
alluvial	Describes material deposited by, or in transit in, flowing water
aquifer	A rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit quantities of water to wells and springs
background	The circumstances, situation, or levels of a particular parameter prevailing at the time of assessment; natural or pre-existing level of a variable
baseline	An initial value of a measure, parameter or variable
base metal	A general term applied to relatively less expensive metals, such as copper, zinc, nickel, lead, tin, iron and aluminium
benthic zone	The ecological region at the lowest level of a body of water, including the sediment surface and some sub-surface layers
berm	A cross-slope earthen bank constructed on reshaped spoil areas, typically at horizontal intervals of approximately 50 m and 1 to 1.5% longitudinal gradient, to reduce the effective slope length and control the runoff flow rate
biodiversity	Biological diversity; the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in relation to a particular habitat. A high level of biodiversity is usually considered to be desirable and/or important
bioremediation	The use of naturally occurring micro-organisms for the restoration of polluted environments, in particular of contaminated land, and/or the groundwater associated with it
bioaccumulation	A process of concentration or accumulation within a ‘food chain’ of organisms

bore	A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or extraction (or injection) of groundwater. Also known as a well, monitoring well or piezometer, although piezometers are typically of small diameter and only used for measuring the groundwater elevation or potentiometric surface
borehole	An uncased well drill hole
buffer	(Chemistry) a solution which resists changes in pH when acid or alkali is added to it. An ionic compound, usually a salt of a weak acid or base, added to a solution to resist changes in its acidity or alkalinity and thus stabilise its pH
catchment area	A recharge area or drainage basin and all areas that contribute water to it. The area that contributes water to a particular watercourse; a watershed
cation exchange capacity (CEC)	A measure of the potential or total capacity of a soil to retain exchangeable cations. The units are milliequivalents per 100 grams of material or centimoles of charge per kilogram of exchanger
clay	A fine-grained soil material composed of particles finer than 0.002 mm. When used as a soil texture group such soils contain at least 35% clay
commissioning	Process of testing, checking and inspecting all systems and components of a newly constructed facility, plant or piece of equipment to verify that it is installed and functioning according to design specifications and operational requirements
competent rock	Rock that has been proven by wetting and drying techniques to resist rapid weathering and thus maintain erosion resistant capability and durability
competent spoil	Non-acid, non-dispersive durable spoil with sufficient rock content to resist erosion
composite sample	(Soil, sediment or water sampling) a technique that combines a number of discrete samples collected from a body of material (one sampling location) into a single homogenised sample for the purpose of analysis, in order to represent the average conditions in the sampled body of material
concentrate	The product of the milling process, enriched in the valuable metal or mineral relative to the ore; typically a fine powder. The waste product of the concentration process is typically discarded as tailings

conductivity (EC)	Conductivity, or electrical conductivity (EC), is the degree to which a specified material (such as water) conducts electricity. This property is related to the ionic content of the sample, which is in turn a function of the total dissolved (ionisable) solids (TDS) concentration
confined aquifer	An aquifer that is confined between two low-permeability aquitards. The groundwater in these aquifers is usually under hydraulic pressure, i.e., its hydraulic head is above the top of the aquifer
confining layer	A layer with low vertical hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. A confining layer is an aquitard. It may lie above or below the aquifer
contaminant	Something which contaminates, i.e., renders impure via pollution. In ecology, a substance which may degrade an environment (e.g., soil or water) due to toxicity to humans, animals or plants, or detriment to beneficial uses
contamination	Making or being made contaminated; to pollute a substance with another, unwanted, substance. Considered to have occurred when the concentration of a specific element or compound is established as being greater than the normally expected (or actually quantified) background concentration
controlled discharge	Release of a substance (e.g., wastewater) from a project area onto/into receiving land/water under conditions that meet a predetermined quality standard
cover material	Soil, alluvium, weathered basalt or other suitable plant growth medium placed on reshaped spoil surfaces; typically non-crusting and low salinity
density	(Botany, zoology, population geography) the quantity of plants, animals or people within a given area, or the average number of individuals per area sampled or assessed. For example, the number of animals or plants (individuals or taxa) per unit area
detritus	Particulate material that enters into a marine or aquatic system. If derived from decaying organic matter it is organic detritus
diversion channel	Structures for the controlled diversion of drainage lines and watercourses around open cut pits and infrastructure areas

diversity The state of being diverse. A diversity index is a quantitative measure that reflects how many different types (e.g., species) there are in a dataset, and takes into account how evenly the individuals are distributed among those types. Biological diversity (biodiversity) is the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in a particular habitat

diffusion A process by which chemical species in solution move, driven by concentration gradients (from high to low)

dilution Making a solution diluted/weaker (lower concentration) by the addition of water or another solvent

discrete sample (Soil, sediment or water sampling) samples collected from different locations and/or depths that will not be composited but analysed individually

dispersion The act of dispersing; the state of being dispersed. A mixture of one substance dispersed in another medium, such as water or air. Ecology: the movement of individual animals, plants, etc., between sites; the pattern of distribution of individuals within a habitat

dissolved oxygen (DO) The level of oxygen in the gaseous phase dissolved in water (and available to aquatic organisms). Measured either as a concentration in mg/L or as a percentage of the theoretical saturation point, which is inversely related to temperature

disturbance The interruption of a settled condition. Ecology: a temporary change in environmental conditions causing a change or impact to an ecosystem.

diversity The state of being diverse. A diversity index is a quantitative measure that reflects how many different types (e.g., species) there are in a dataset, and takes into account how evenly the individuals are distributed among those types. Biological diversity (biodiversity) is the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in a particular habitat

drawdown Lowering of hydraulic head

ecosystem A community of organisms and their immediate physical, chemical and biological environment

elasmobranch An animal within the subclass of cartilaginous fishes which includes sharks, rays, skates and sawfish

electrical conductivity (EC)	Conductivity, or electrical conductivity (EC), is the degree to which a specified material (such as water) conducts electricity. This property is related to the ionic content of the sample, which is in turn a function of the total dissolved (ionisable) solids (TDS) concentration
environmental aspect	An element of an organisation's activities that can interact with the environment
environmental value	Particular values or uses of the environment that are important for healthy ecosystems or for public benefit, safety or health and that require protection from the effects of pollution
erosional stability	The ability of a rehabilitated area to resist the natural forces of soil erosion
externally drained	Rainfall runoff water that discharges to the external environment (off lease) via local drainage systems
flow path	The direction in which groundwater is moving
fluvial	A material deposited by, or in transit, in streams or watercourses
fracture	A break in the geological formation, e.g., a shear or a fault
geotechnical stability	Resistance of a slope to mass movement
gradient	The rate of inclination of a slope. The degree of deviation from the horizontal; also refers to pressure
groundwater	The water held in the pores in the ground below the watertable
groundwater elevation	The elevation of the groundwater surface measured relative to a specified datum such as the Australian Height Datum (m AHD) or an arbitrary survey datum onsite, or 'reduced level' (m RL)
gully erosion	The displacement of soil by running water that forms clearly defined, narrow channels that generally carry water only during or after heavy rain
hazard	A danger or risk; a situation that poses a level of threat to the environment, life, health or property
head space	The air space at the top of a soil, sediment or water sample

heavy metal	A metal of relatively high density, or of high relative atomic weight. There is no universally agreed definition, however, heavy metals commonly include (among others) cadmium (Cd), copper (Cu), lead (Pb), tin (Sn) and zinc (Zn)
horizon	Any definite position or interval in the stratigraphic column or the scheme of stratigraphic classification; generally used in a relative sense (geological)
hydraulic conductivity (K)	A coefficient describing the rate at which water can move through a permeable medium. It has units of length per time. The units for hydraulic conductivity are typically m^3/day/m^2 or m/day
hydraulic continuity	A water bridge or connection between two or more geological formations
hydraulic gradient (i)	A vector gradient between two or more hydraulic head measurements (liquid pressure at a given point) over the length of a flow path, i.e., the rate of change in total liquid pressure per unit of distance of flow in a given direction
hydraulic head (h)	A measure of liquid pressure above a geodetic datum, typically measured as a liquid surface elevation above a fixed datum, such as sea level. A measure of the mechanical energy that causes groundwater to flow
hydrocarbon	Any of the class of organic compounds containing only hydrogen and carbon, such as those which are the chief compounds in petroleum and natural gas
hydrocarbon, volatile	A hydrocarbon with a low boiling point (high vapour pressure). Normally taken to mean those with ten (or less) carbon atoms per molecule
impact	A marked effect or influence. Negative or positive effect/s caused directly or indirectly by an event or activity, or by the release of a substance into the environment, causing a change in the biological, physical and/or socio-economic environment
in situ bioremediation	Bioremediation of contaminated soil or (ground)water undertaken without excavation (i.e., removal); literally ‘bioremediation in place’
infiltration	The passage of water, under the influence of gravity, from the land surface into the subsurface
injection well	A groundwater bore constructed for the purpose of pumping water into an aquifer

ion	An electrically charged atom or molecule formed as a result of loss or gain or one or more electrons. Positively charged ions are called cations ($^+$), while negatively charged ions are called anions ($^-$). The major aqueous ions are those that dominate total dissolved solids (TDS). These include: Cl^-, SO_4^{2-}, HCO_3^-, Na^+, Ca^{2+}, Mg^{2+}, K^+, NH_4^+, NO_3^-, NO_2^-, F^- and PO_4^{3-}, and the heavy metals
ionic exchange	A reversible interchange of one kind of ion present on an insoluble solid with another of like charge present in a solution surrounding the solid
iron concretions	The accumulation of dissolved iron that results in the formation of soft to hard orange to red to maroon nodules, and can be diffuse or concentrated. A result of periodic wetting and drying
leachate	Water that has percolated through a solid or semi-solid material (e.g., soil or mine waste) and leached out some of the constituent impurities
lysimeter	A device for collecting drainage passing through overlying material. The term lysimeter is primarily used for field test apparatus. Lysimeters are installed in waste rock to measure the quality and/or quantity of drainage
massive	Refers to the condition of the soil layer in which the layer appears to be as a coherent or solid mass which is largely devoid of peds
maximum potential acidity	Determined by multiplying the sulfide-S values (in %) by 30.6, which accounts for the reaction stoichiometry for the complete oxidation of pyrrotite and pyrite by O_2 to $Fe(OH)_3$ and H_2SO_4. MPA does not take into account the effect of any acid-consuming materials in the rock material
metalloid	A class of elements chemically intermediate in properties between metals and non-metals including boron, silicon, germanium, arsenic and tellurium
micro-organism	A microscopic organism; includes viruses, bacteria, yeasts and fungi, and others
mitigation	Action(s) taken to avoid or reduce the impact of an activity on the environment, sociocultural and/or socioeconomic interests
mottled masses	Blobs or blotches of subdominant, varying colours in the soil matrix
net acid generation potential (NAGP)	The difference between the maximum potential acidity and acid neutralisation capacity reported on a kilogram H_2SO_4 production per tonne of soil or rock

organics	Chemical compounds comprising atoms of carbon, hydrogen and others (commonly oxygen, nitrogen, phosphorous, sulfur). Opposite is inorganic, referring to chemical species not containing carbon
overburden	The layers of clay, rock and similar covering or overlying a useful ore deposit. Also referred to as waste rock
oxidation	The act or process of being oxidised; loss of electrons or increase in oxidation state by a molecule, atom or ion; particularly used to refer to the addition of oxygen to elements
paddock dumping	Dumping loads on level ground, side by side, as opposed to over the windrow at the dump
parameter	Any constituent variable quality; a characteristic, feature or measurable factor forming one of a set that defines a system or sets the conditions of its operation
permeability (k)	(Fluid mechanics and earth sciences) a measure of the ability of a porous material (often, a rock or an unconsolidated material) to allow fluids to pass through it
piezometric or potentiometric surface	A surface that represents the level to which water will rise in cased bores. The water table is the potentiometric surface in an unconfined aquifer
pH	A figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline
plume	A mass of material, typically a pollutant/contaminant, spreading from a point source
precipitation (chemical)	The precipitating of a substance from a solution; the condensation of a solid from a solution during a chemical reaction
profile	The solum. This includes the soil A and B horizons and is basically the depth of soil to weathered rock
purge (wells)	The pumping out of well water to remove drilling debris or impurities; also conducted to bring fresh groundwater into the casing for sample collection. The later ensures that a more representative sample of an aquifer is taken
putrescible waste	Food waste, waste consisting of animal matter (including dead animals or animal parts) or biosolids

receptor	An entity (which may include an environmental value, conservation significance value, individual/s or communities of flora or fauna, as well as individuals, households or communities of people) that is exposed to a stressor. The sensitivity of a receptor interacts with the magnitude of an impact to derive an impact significance rating
recharge area	Location of the replenishment of an aquifer by a natural process such as addition of water at the ground surface, or by an artificial system such as addition through a well
recovery	The rate at which a water level in a well rises after pumping ceases
remediation	The action of remedying something, in particular of reversing or stopping environmental damage. Ecology: the restoration of an environment, land or groundwater contaminated by pollutants, to a state suitable for other, beneficial uses
representative sample	A subset of a statistical population that accurately reflects the members of the entire population; assumed not to be significantly different than the population of samples available
residual (impact)	Those impacts that remain after the effective implementation of avoidance, mitigation and management measures, which are designed to reduce the likelihood, consequence, magnitude or severity of the impact
rock mulch	Durable or competent rock purposely placed on an area under rehabilitation to provide additional resistance to erosion
sediment pond	Natural or constructed drainage impoundment used to reduce the concentration of suspended particles in surface run-off water or mine effluent prior to re-use or discharge to the environment
silt	Sediment with particles finer than sand and coarser than clay (comprised of particles between 0.002 and 0.075 mm in size)
silt trap	A small impoundment structure built within a drainage line that retards water flow and allows suspended sediments to settle out
species richness	The number of different species represented in a sample, taxonomic group, ecological community, landscape or region. Species richness is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions
stand basal area	The cross-sectional area of trees at breast height per hectare of forest or planted area

standing water level (SWL)	The depth to the groundwater surface in a well or bore measured below a specific reference point – usually recorded as metres below the top of the well casing or below the ground surface
stratigraphy	A branch of geology dealing with the classification, nomenclature, correlation, and interpretation of stratified rocks, i.e., the order and relative position of strata and their relationship to the geological timescale. The structure of a particular set of strata or sequence of geological units
subaerial	Exposed to the atmosphere
subaqueous	Below water
subsidence	The downward settling of material with little horizontal movement
subsoil	Subsurface material comprising the B and C horizons of soils which lies below the topsoil or A horizon. The subsoil is not enriched with organic material as is the topsoil and often has higher clay content
sulfide oxidation	Exothermic oxidation of chemically reduced sulfide (S^{2-}) to a partially or fully oxidized form, such as sulfate (SO_4^{2-}). One indication of sulfide oxidation is elevated sulfate concentrations in minesite drainage
sump	Temporary excavation for the storage of water
suspended solids (SS)	Small solid particles which remain in suspension in water as colloids or due to the motion of the water. Used as one indicator of water quality
topsoil	Part of the soil profile, typically the A1 horizon, usually containing more organic matter than the underlying layers
total dissolved solids (TDS)	A measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionised or micro-granular suspended form
toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism
transmissivity	The rate at which water is transmitted through a unit width aquifer under a unit hydraulic gradient
turbidity	A measure of the relative clarity of a liquid, particularly water, as a result of the amount of suspended particulate matter present, such as sediment particles, algae, plankton, microbes and other substances. One indicator of water quality

volatile	Having a low boiling or subliming pressure (a high vapour pressure)
waste rock	Rock with insufficient amounts of economically valuable elements to warrant its extraction, but which has to be removed to allow physical access to the ore. Waste rock is typically blasted into smaller particles to allow its removal by truck and shovel
water balance	A term used in the context of mining to describe an inventory of drainage inputs and outputs, water volumes and the rate of flow
water quality criteria	Maximum or minimum values of physical, chemical or biological characteristics of water, biota or sediment whose exceedance under specified conditions may result in detrimental effects to a water use
water table	The interface between the saturated zone and unsaturated zones. The surface in an aquifer at which pore water pressure is equal to atmospheric pressure
well	A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or the extraction (or injection) of groundwater. Also known as a bore

Appendix 1

List of Files

Table 1 – MRM-Supplied Files Used in the Assessment

MRM-Supplied Files as Provided to ERIAS Group
01. Independent Monitor Recommendations/IM Summary of Recommendations 2014 v2.xlsx
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/CF7-001 Notification of an Environmental Incident - Barney Creek Fish changes accepted.pdf
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/ICAM Incident Investigation Report Lead Contamination in Aquatic Organisms.pdf
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2004.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2005.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2006.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2007.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2008.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2009.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2010.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2011.JPG
02. Incident Reports and Complaints/140713 Lead in Fish Barney Creek/Photos - sediment clean out/DSCF2012.JPG
02. Incident Reports and Complaints/140925 EC Exceedance/140915 Barney Creek Pump 1.JPG
02. Incident Reports and Complaints/140925 EC Exceedance/140915 Barney Creek Pump 2.JPG
02. Incident Reports and Complaints/140925 EC Exceedance/141015 Final NT EPA Exceedance Letter.pdf
02. Incident Reports and Complaints/140925 Exact Oil Spill/CF7001 Notification of Environmental Incident.pdf
02. Incident Reports and Complaints/140925 Exact Oil Spill/McArthur River Mine ICAM Waste Oil Spill Sth Levee Wall.pdf
02. Incident Reports and Complaints/140925 Exact Oil Spill/RE Notification of Environmental Incident.msg
02. Incident Reports and Complaints/141018 GE Mining Oil Spill/CF7-001 Notification of an Environmental Incident 141018.pdf
02. Incident Reports and Complaints/141018 GE Mining Oil Spill/Incident Investigation (ICAM) 2014 Report HT16 Lost 800L Oil.pdf
02. Incident Reports and Complaints/141029 EC Exceedance/141029 WDL174-06 Exceedance for Electrical conductivity.msg
02. Incident Reports and Complaints/141029 EC Exceedance/141118 Final NT EPA Exceedance Letter.pdf
02. Incident Reports and Complaints/141106 Aburri Oil Spill/CF7-001 Notification of an Environmental Incident 141106.pdf
02. Incident Reports and Complaints/141106 Aburri Oil Spill/IMG_20141106_145517.jpg
02. Incident Reports and Complaints/141106 Aburri Oil Spill/RE CF7-001 Notification of an Environmental Oil leak from Bulk Carrier.msg
02. Incident Reports and Complaints/141120 Concentrate Shed Fire/HPRI MRM Concentrate Shed Fire _141120.pdf

MRM-Supplied Files as Provided to ERIAS Group
02. Incident Reports and Complaints/141125 EC Exceedance/141125 NT EPA Exceedance EC - unsigned.pdf
02. Incident Reports and Complaints/141201 DO and Al Exceedance/WDL 174-06 Exceedance in the McArthur River.msg
02. Incident Reports and Complaints/150120 Al Exceedance/WDL 174-07 Exceedance in the McArthur River.msg
02. Incident Reports and Complaints/150128 DO% Exceedance/WDL 174-07 Exceedance in the McArthur River 150208.msg
02. Incident Reports and Complaints/150204 SEL Incident/150204 CF7-001 Notification of an Environmental Incident MRM.pdf
02. Incident Reports and Complaints/150204 SEL Incident/MRM Incident Investigation (ICAM) Report S29 150204.pdf
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/150210 CF7-001 Notification of an Environmental Incident MRM.pdf
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/150331 - Attachment A - MRM Response - Requirement to provide additional information.pdf
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/150331 LTTR - MRM Response - Requirement to provide additional information.pdf
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_115527.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_115639.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_115659.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_115715.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_120304.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_120309.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_120311.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_120458.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_120519.jpg
02. Incident Reports and Complaints/150210 TSF Cell 2 Line Split/Images/20150211_120523.jpg
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/1503120 Fire located at MRM - Air Pollution - 16 March 2015.pdf
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/150316 CF7-001 Notification of an Environmental Incident MRM.pdf
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Incident Investigation (ICAM) Report Final.pdf
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03871.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03872.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03873.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03874.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03875.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03876.JPG

MRM-Supplied Files as Provided to ERIAS Group
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03877.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03878.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03879.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03880.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03881.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03882.JPG
02. Incident Reports and Complaints/150316 Community Complaint - Fire at Contaminated Waste Dump/Photos/DSC03883.JPG
02. Incident Reports and Complaints/150322 Hamptons Road Train Trailer Detachment/20150324 DME Section 29 Hamptons roadtrain trailer detachment.pdf
02. Incident Reports and Complaints/150413 Fire at Contaminated Waste Dump/150412 Fire located at MRM - Air Pollution - 13 April 2015.pdf
02. Incident Reports and Complaints/150413 Fire at Contaminated Waste Dump/Photos/IMG_1122.JPG
02. Incident Reports and Complaints/150413 Fire at Contaminated Waste Dump/Photos/IMG_1123.JPG
02. Incident Reports and Complaints/150709 EC Exceedance/150728 Final NT EPA Exceedance Letter.pdf
02. Incident Reports and Complaints/150709 EC Exceedance/150815 CD Response to EPA Questions.docx
02. Incident Reports and Complaints/150709 EC Exceedance/MRM WDL174-07 elevated EC.msg
02. Incident Reports and Complaints/150824 SO4, EC Exceedance/150921 Final NT EPA Exceedance Letter.pdf
02. Incident Reports and Complaints/150824 SO4, EC Exceedance/Exceedance of Trigger Value.msg
02. Incident Reports and Complaints/151117 Leakage at APP Suction Line/151117 CF7-001 Notification of an Environmental Incident_ Leakage at APP suction line.pdf
02. Incident Reports and Complaints/151117 Leakage at APP Suction Line/151117 MRM APP water leak ICAM.pdf
02. Incident Reports and Complaints/151117 Leakage at APP Suction Line/FW MRM _Notification of an Environmental Incident.msg
02. Incident Reports and Complaints/151222 NO3, Fe, Al, DO Exceedance/160215 NT EPA Exceedance Letter - Signed.pdf
02. Incident Reports and Complaints/151222 NO3, Fe, Al, DO Exceedance/WDL 174-07 Exceedance in the McArthur River.msg
05. Mining Management Plan/150401 MRM-HSE-RPT-0002 Response to DME Comments I001 Rev 1.pdf
05. Mining Management Plan/150519 LTTR MRM Response to DME comments.pdf
05. Mining Management Plan/150519 MRM-HSE-RPT-0003 Response to DME Comments - Attachments/Attachment A/Attachment A - Bore Logs.pdf
05. Mining Management Plan/150519 MRM-HSE-RPT-0003 Response to DME Comments - Attachments/Attachment B/Attachment B - Groundwater Water Data.xlsx
05. Mining Management Plan/150519 MRM-HSE-RPT-0003 Response to DME Comments - Attachments/Attachment C/Attachment C1 - Sb Plan at 4mbGL.PDF
05. Mining Management Plan/150519 MRM-HSE-RPT-0003 Response to DME Comments - Attachments/Attachment C/Attachment C2 - U Plan at 4mbGL.PDF

MRM-Supplied Files as Provided to ERIAS Group
05. Mining Management Plan/150519 MRM-HSE-RPT-0003 Response to DME Comments.pdf
05. Mining Management Plan/MDOC2015-09658 MRM - Acceptance of the 2013-2015 MMP.pdf
05. Mining Management Plan/MDOC2015-10144 MRM - Request for Prioritised Approval of Infrastructure.pdf
05. Mining Management Plan/MDOC201506436 MRM 201507 Request For Additional Information Letter.pdf
05. Mining Management Plan/MDOC201506436 MRM Response - Attachment A.pdf
05. Mining Management Plan/MDOC201506436 MRM Response - Cover Letter.pdf
05. Mining Management Plan/MMP 2013_2015 Volume 1 I007 Rev0.pdf
05. Mining Management Plan/MMP 2013_2015 Volume 1 I007 Rev1.pdf
05. Mining Management Plan/MMP 2013-2015 Supplementary EMR I001 Rev 1.pdf
05. Mining Management Plan/MMP 2013-2015 Volume 2 I007 Rev1.pdf
05. Mining Management Plan/MRM 201503 EMR - Request for Additional Information Letter_Final.pdf
05. Mining Management Plan/MRM 201504 EMR - Further Request for Additional Information Letter.pdf
05. Mining Management Plan/MRM20160329 - Instruction on Submission of the next MMP and OPR.pdf
06. Flora Monitoring/160330 2015 Register - Nursery.xlsx
06. Flora Monitoring/160330 2015 Register - Permits to Clear.xlsx
06. Flora Monitoring/160330 2015 Register - Planting and Rehabilitation.xlsx
06. Flora Monitoring/160330 2015 Register - Weed Management.xlsx
06. Flora Monitoring/MRM Rechannel Vegetation Monitoring Report 2015_1.0.pdf
06. Flora Monitoring/Vegetation Monitoring Bing Bong Dredge Spoil 2015_1.0.pdf
07. Fauna Monitoring/2015 MACRO MRM FIN 2 Nov 2015 L.pdf
07. Fauna Monitoring/Aquatic fauna of the McArthur River - Early Dry Season 2015 Report ID 15007 Rev 0.pdf
07. Fauna Monitoring/Aquatic fauna of the McArthur River - Late Dry Season 2014 Report ID 14002 Rev 0.pdf
07. Fauna Monitoring/Aquatic Fauna of the McArthur River - Late Dry Season 2015 Report ID 15009 Rev 0.pdf
07. Fauna Monitoring/GEN-ENV-PLN-6040-0007 MRM 2014-2015 Livestock Management Plan.pdf
07. Fauna Monitoring/Hydrobiology Metals in Fauna Review - IPE Response to Comments.xlsx
07. Fauna Monitoring/Hydrobiology Metals in Fauna Review.pdf
07. Fauna Monitoring/MRM Dec 2015 Mosquito Count.xlsx
07. Fauna Monitoring/MRM Gouldian Finch 2014 FINAL 26-11-14 L.pdf
07. Fauna Monitoring/MRM Jul 2015 Mosquito Count.xls
07. Fauna Monitoring/Mustering and Culling Correspondence/FW MRM Testing 25112015.msg
07. Fauna Monitoring/Mustering and Culling Correspondence/MRM Muster 28116.msg
07. Fauna Monitoring/Mustering and Culling Correspondence/MRM Muster 50316.msg
07. Fauna Monitoring/Mustering and Culling Correspondence/MRM muster 8122015.msg
07. Fauna Monitoring/Mustering and Culling Correspondence/MRM Testing 15102015.msg
07. Fauna Monitoring/Mustering and Culling Correspondence/MRM Testing 23102015.msg
07. Fauna Monitoring/Mustering and Culling Correspondence/MRM Testing 30102015.msg
07. Fauna Monitoring/PM MIG BIRDS NTHN STAGE 2015 FINAL 29-06-2015.pdf

MRM-Supplied Files as Provided to ERIAS Group
07. Fauna Monitoring/PM MIG BIRDS SUM FINAL 2015 24-05-2015 R2 L.pdf
07. Fauna Monitoring/RIP Birds SEPT 2014 FIN 26-11-2014 L.pdf
08. Marine/Annual Marine Monitoring 2014 ID 14009 Rev 1.pdf
08. Marine/Bing Bong DGT Report 2014-15.pdf
08. Marine/Bing Bong Near Shore Sediment Report 2014 ID 14006 Rev 0.pdf
08. Marine/Bing Bong Near Shore Sediment Report 2015 ID 15012 Rev 0.pdf
08. Marine/Bing Bong Seagrass Suvery 2014 ID 14007 Rev 0.pdf
08. Marine/Bing Bong Seagrass Suvery 2015 ID 15013 Rev 0.pdf
08. Marine/Bing Bong Transhipment Sediment 2014 ID 14010 Rev 0.pdf
09. Surface Water and Artificial Water Monitoring/0790-17-Q2 - McArthur River SW11 Flows - daily averaged levels and flows.xlsx
09. Surface Water and Artificial Water Monitoring/0790-18-B3 TSF Water Storage Assessment.pdf
09. Surface Water and Artificial Water Monitoring/0790-24-A1 Barney and Surprise Creeks Flow Volumes.pdf
09. Surface Water and Artificial Water Monitoring/0790-25-B1 TSF Cell 1 Pump Assessment.pdf
09. Surface Water and Artificial Water Monitoring/0790-25-C TSF Cell 1 Spillway Performance.pdf
09. Surface Water and Artificial Water Monitoring/150515Pr NOEF flood seepage - no costs.pdf
09. Surface Water and Artificial Water Monitoring/150922L Revised Cost and Schedule - no costs.pdf
09. Surface Water and Artificial Water Monitoring/151215 LTTR MRM RE addition of NOEF sediment traps to WDL174 07.pdf
09. Surface Water and Artificial Water Monitoring/151223 Transfer TSF cell 1 to TSF Mini Dam 1 Approval Letter.pdf
09. Surface Water and Artificial Water Monitoring/2015 Bing Bong Conceptual Model.jpg
09. Surface Water and Artificial Water Monitoring/2015 MRM Conceptual Model.jpg
09. Surface Water and Artificial Water Monitoring/20160218 CWC Sed Dam - Fig 1.pdf
09. Surface Water and Artificial Water Monitoring/20160218 CWC Sed Dam - Fig 2.pdf
09. Surface Water and Artificial Water Monitoring/32-17428-C201 REV A.pdf
09. Surface Water and Artificial Water Monitoring/32-17428-C202 REV A.pdf
09. Surface Water and Artificial Water Monitoring/64506 The NOEF Central West and West D Hydrology Analysis Report.pdf
09. Surface Water and Artificial Water Monitoring/Appendix A - MRM WTP Tender Preliminary Design Report V2.pdf
09. Surface Water and Artificial Water Monitoring/Appendix B - MRM WTP Tender Technical Specs.pdf
09. Surface Water and Artificial Water Monitoring/CW Charlie Sediment Trap SOW v1.docx
09. Surface Water and Artificial Water Monitoring/Diversion EC.jpg
09. Surface Water and Artificial Water Monitoring/GE sealants trial pads observations.xlsx
09. Surface Water and Artificial Water Monitoring/McArthur River SW11 Flow Days Statistics - daily averaged levels and flows to Q1-2016.xlsx
09. Surface Water and Artificial Water Monitoring/Monitoring Program 2015-16 Water (Committed and Non Committed).xlsx
09. Surface Water and Artificial Water Monitoring/MRM 2014-15 Surface Water Monitoring Report I001 Rev 0.pdf
09. Surface Water and Artificial Water Monitoring/MRM draft report NOEF infiltration 29Mar16 - DH2.pdf

MRM-Supplied Files as Provided to ERIAS Group
09. Surface Water and Artificial Water Monitoring/MRM draft report runoff 26Mar16 - DH2.pdf
09. Surface Water and Artificial Water Monitoring/MRM GW, ASW, SW Data 01-01-14 to 31-12-15.xlsx
09. Surface Water and Artificial Water Monitoring/MRM WDL 2014-15 Monitoring Report I001 Rev 0.pdf
09. Surface Water and Artificial Water Monitoring/MRM WTP Design Report RevD.pdf
09. Surface Water and Artificial Water Monitoring/NOEF - Flood Protection Master Plan - 00.pdf
09. Surface Water and Artificial Water Monitoring/NOEF - Toe Seepage - 00.pdf
09. Surface Water and Artificial Water Monitoring/Sealant trial pads summary 2016-03-31.docx
09. Surface Water and Artificial Water Monitoring/SMI McArthur River NOEF Water Management-evaporation-20151109 - no prices.pdf
09. Surface Water and Artificial Water Monitoring/SPROD Construction GHD Review Letter Rev 1.pdf
09. Surface Water and Artificial Water Monitoring/Surface Water - Groundwater EC.jpg
09. Surface Water and Artificial Water Monitoring/Waste Discharge Licence 174-07.pdf
09. Surface Water and Artificial Water Monitoring/Waste Discharge Licence 174-08.pdf
09. Surface Water and Artificial Water Monitoring/Water balance modelling in support of the 201516 TARP - Mining.pdf
09. Surface Water and Artificial Water Monitoring/Water Balance Report 0790-21-B1 2015-16.pdf
09. Surface Water and Artificial Water Monitoring/WDL Amendment Documents/Appendix A - MRM WTP Tender Preliminary Design Report.pdf
09. Surface Water and Artificial Water Monitoring/WDL Amendment Documents/GEN-HSE-RPT-6040-007 WDL Amendment - Supporting Information I001 Rev 0.pdf
09. Surface Water and Artificial Water Monitoring/WDL Amendment Documents/Signed Application Form.pdf
09. Surface Water and Artificial Water Monitoring/WDL Amendment Documents/Supporting Data.xlsx
09. Surface Water and Artificial Water Monitoring/WRM 0790-15-C2 Water balance report.pdf
10. Groundwater Monitoring/2015 Bore Logs/bbemb01a.pdf
10. Groundwater Monitoring/2015 Bore Logs/bbemb01b.pdf
10. Groundwater Monitoring/2015 Bore Logs/bbemb05a.pdf
10. Groundwater Monitoring/2015 Bore Logs/bbemb05b.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_BBEMB02A_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_BBEMB02B_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_BBEMB03A_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_BBEMB03B_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_BBEMB04A_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_BBEMB04B_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GW148I_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWBB009A_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWBB009B_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWBB010A_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWBB010B_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWTSF06A_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWTSF06B_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWTSF07A_Bore Log.pdf

MRM-Supplied Files as Provided to ERIAS Group
10. Groundwater Monitoring/2015 Bore Logs/G1782.MRM_GWTSF07B_Bore Log.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw143d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw143s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw144d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw144s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw145d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw145s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw146d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw146s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw147d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw147s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw148d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw148s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw149d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw149s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw150d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw150s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw151.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw152d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw152s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw153d.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw153s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw154a.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw154b.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw155a.pdf
10. Groundwater Monitoring/2015 Bore Logs/gw155b.pdf
10. Groundwater Monitoring/2015 Bore Logs/gwnoef10.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef3nsl.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef3s.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef4nsl.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef4s.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef5d.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef5nsl.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef5s.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef6nsl.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef6s.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef7ccl.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef7nsl.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef7s1.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef7s2.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef8s_21.jpg

MRM-Supplied Files as Provided to ERIAS Group
10. Groundwater Monitoring/2015 Bore Logs/gwnoef8s_22.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef8s1.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef8s2.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef8sl1.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef8sl2.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef911.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef912.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwnoef9s.pdf
10. Groundwater Monitoring/2015 Bore Logs/gwtp18.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwtp39.jpg
10. Groundwater Monitoring/2015 Bore Logs/gwtp54.jpg
10. Groundwater Monitoring/63728 CW NOEF EM and Magnetics Reprocessing Report Appendix B.pdf
10. Groundwater Monitoring/63728 CW NOEF EM and Magnetics Reprocessing Report.pdf
10. Groundwater Monitoring/CWNOEF Drilling data.docx
10. Groundwater Monitoring/MRM Groundwater Monitoring 2014-15 Report I001 Rev 0.pdf
10. Groundwater Monitoring/MRM_DRP_Quarterly_Report_JAN-MAR-2015.pdf
10. Groundwater Monitoring/MRM_DRP_Quarterly_Report- APRIL-JUNE-2015_rev0.pdf
10. Groundwater Monitoring/MRM_DRP_Quarterly_Report- JULY-SEPTEMBER-2015.pdf
10. Groundwater Monitoring/MRM_DRP_Quarterly_Report- OCTOBER-DECEMBER-2015.pdf
10. Groundwater Monitoring/SEPROD seepage tests 2015-11.pdf
10. Groundwater Monitoring/so4.jpg
10. Groundwater Monitoring/SPROD GHD Investigation Letter 20151006.pdf
10. Groundwater Monitoring/SPROD seepage tests 2015-06.pdf
10. Groundwater Monitoring/SPROD_QAQC_REPORT_151118.pdf
11. Sediment Monitoring incl. Dust and Soil/2015-16 Sediment, Soil, Dust Co-ordinates.xlsx
11. Sediment Monitoring incl. Dust and Soil/Dust, Fluvial and Soil Data.xlsx
11. Sediment Monitoring incl. Dust and Soil/MRM 2014-15 Ambient Dust Monitoring Report I001 Rev 0.pdf
11. Sediment Monitoring incl. Dust and Soil/MRM 2014-15 Fluvial Sediment Monitoring Report I001 Rev 0.pdf
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Desktop Model- Initial/MRM_SO2_InitialDesktopAssessment.docx
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Update -Dry Season/DrySeason_Campaign Report_Final.pdf
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Update -Dry Season/LTTR Model Validation Dry Season Report.pdf
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Update -Dry Season/MRM_SO2_ModelValidation_DrySeason_150828.docx
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Update- Wet Season/_SO2_ModelValidation_WetSeason_R2.docx
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Update- Wet Season/LTTR - Model validation Wet season Report.pdf
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Update- Wet Season/MRM WetSeason_Campaign Report_Final.pdf

MRM-Supplied Files as Provided to ERIAS Group
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Dispersion Model and Report/Update- Wet Season/SO2_ModelValidation_WetSeason_R1.docx
11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Air Science/Plan validation/TAS DRAFT_15020410_MRM_EnvironmentalAudit_PLAN_150522 kl comments (3).docx
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11. Sediment Monitoring incl. Dust and Soil/SO2 emission study/Ecotech/Monthly Reports/02 2016/MRM Borroloola and Devils Spring Monthly Report February 2016.pdf
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12. Tailings Storage Facility/1- Summary Data/2015 tailings Statistics.xlsx
12. Tailings Storage Facility/1- Summary Data/Cell 2 Deposition Plan 1.pdf
12. Tailings Storage Facility/1- Summary Data/Water Quaility Monitoring Spreadsheet.xlsx
12. Tailings Storage Facility/10- OPerational control of seepage and surface water control/0790-25-C1.pdf
12. Tailings Storage Facility/10- OPerational control of seepage and surface water control/Cell1 Drainage Concept.pdf
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12. Tailings Storage Facility/2-External Consultants/150615 - 0790-18-B2 - TSF water volume behaviour assessment.pdf
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12. Tailings Storage Facility/3-TSF Monitoring Reports/20150211/20150211R1 - TSF Fortnightly Report.pdf
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12. Tailings Storage Facility/3-TSF Monitoring Reports/20150226/180215 2339 Cell 2 Spillway Seepage Assessment.pdf
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12. Tailings Storage Facility/3-TSF Monitoring Reports/20150226/20150226_R2 - TSF Report.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150312/20150312_R2 - TSF Fortnightly Report.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150312/20150312_R2 - TSF Report.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150312/Additional beaching on SW Embankment.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150312/Curriculum Vitae of Bruce Brown.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150312/Photos/IMG_2520.JPG
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12. Tailings Storage Facility/3-TSF Monitoring Reports/20150408/Attachment 2 - GHD Memo - Stability Analysis of TSF Cell 2 Current Conditions.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150408/Attachment 3 - Current Extent of Beaching.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150408/Attachment 4 - Spillway Seepage Return System.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150506/20150506_R3 - TSF Report.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150506/Attachment 1 - TSF Monitoring Survey Report.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150506/Attachment 2 - Piezometer Readings - Excel.xlsx
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150506/Attachment 3 - MRM response to DME Comments.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150506/Attachment 4 - Current Extent of Beaching - Cell 2.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150506/Attachment 5 - SW Corner EMBGW4 vs Seepage.pdf
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12. Tailings Storage Facility/3-TSF Monitoring Reports/20150608/Attachment B - Trial Embankment Location.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150608/Attachment C - Current Extent of Beaching.pdf
12. Tailings Storage Facility/3-TSF Monitoring Reports/20150608/Attachment D - Standpipe Piezometer Interpretation June 2015.pdf
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12. Tailings Storage Facility/3-TSF Monitoring Reports/20150708/Attachment A - GHD Memo - Trial Embankment 1 - Findings.pdf
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_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info2/27.08.15 - DME - RFI and Response/22935-R-96-1.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info2/27.08.15 - DME - RFI and Response/22935-R-97-1.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info2/27.08.15 - DME - RFI and Response/22935-R-98-1.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info2/27.08.15 - DME - RFI and Response/22935-R-99-1.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info2/27.08.15 - DME - RFI and Response/Attachment 2 Roller Trial Photographic Record.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info2/27.08.15 - DME - RFI and Response/Daily Photographic Record_R1.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info2/27.08.15 - DME - RFI and Response/GHD Letter - 30.08.15 - TSF Cell 2 Zone 1A Materials Assessment.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info3/Conceptual model sketch and LiDAR SOEF.docx
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info3/ERM SOEF Groundwater Review.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info3/SOEF Fig 4.21 2009.jpg
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info3/SOEF Fig 4.21 2010.jpg
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info3/SOEF Fig 4.21 2011.jpg
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info4/MRM Monthly Construction Progress Report - 01 - Jul Aug Sept 2015 - signed.pdf
_Additional provided after main batch/20160721_frSebastien-viaDAB_files in relation to review comments/Info4/MRM Monthly Construction Progress Report - 02 - Sept Oct 2015 - signed.pdf
_Additional provided after main batch/Monitoring of Saline Seepage Veg Impacts at Barney and Surprise Creeks.pdf

Table 2 – DME-Supplied Files Used in the Assessment

DME-Supplied Files as Provided to ERIAS Group
1MiningManagementPlan/01 Preliminary Review of MRM MMP.msg
1MiningManagementPlan/02 EMR Request addtional Information Letter.PDF
1MiningManagementPlan/03 Initial MMP Review - Request for Additional Information.pdf
1MiningManagementPlan/04 EMR - Further Request for Additional Information Letter.pdf
1MiningManagementPlan/05 Request For Additional Information Letter.pdf
1MiningManagementPlan/06 Conditional Approval of Lead filtration Plant and Acid Tanks.PDF
1MiningManagementPlan/07 MRM MMP Approval Letter.pdf
1MiningManagementPlan/08 Transfer TSF cell 1 to TSF Mini Dam 1 Approval Letter.pdf
1MiningManagementPlan/09 Approval and Request for additional information sediment Traps and WTP.PDF
1MiningManagementPlan/10 Instruction on submission of future MMPs and OPRs - McArthur River Mining Pty Ltd - McArthur River Mine.PDF
1MiningManagementPlan/WPROD/01 Request for Additional Information - Wes~ Runoff Dam (WPROD).PDF
1MiningManagementPlan/WPROD/02 Conditional Approval and Summary of Meet~tern PAF Runoff Dam.PDF
2ComplianceAuditsandInspections/201506 Site Inspection Report.pdf
2ComplianceAuditsandInspections/201508 InstructionsFollowingInspection.pdf
2ComplianceAuditsandInspections/201508 Request for Additional Information.pdf
2ComplianceAuditsandInspections/201508 Site Inspection Map.pdf
2ComplianceAuditsandInspections/201508 Site Inspection Report.pdf
2ComplianceAuditsandInspections/201510 Site Inspection Report.pdf
2ComplianceAuditsandInspections/201511 Site Inspection Report.pdf
2ComplianceAuditsandInspections/201512 Site Inspection Report.pdf
2ComplianceAuditsandInspections/NoAuditsUndertakenIn2015.txt
3IndependentMonitorReports/DoNotHaveATrackingSystemForIMRecommendations.txt
3IndependentMonitorReports/SeeMMPRequestForAdditionalInfoforCommstoMRM.txt
4WasteRock/Memorandum_Review-MRM_NOEF CW_Final.pdf
4WasteRock/SeeMMPforWasteRockManagementDocs.txt
4WasteRock/SeeRGCReportIn5TailinsStorageFacility.txt
5TailingsStorageFacility/MRM 201505 Final Report RGC Review of Current Mining Practices and Site Conditions at MRM.pdf
5TailingsStorageFacility/Review of TSF Construction, McArthur River Mine, NT.docx
6MineClosure/SeeMMPRequestforAdditionalInfoREMineClosure.txt
7Health/16-0121-sec_final_Report.pdf
7Health/MRM letter fish report.pdf
8CheckMonitoring/ELS north_2015-11-17_14-09-27_log.csv
8CheckMonitoring/ELS south_2015-11-17_14-01-49_log.csv
8CheckMonitoring/GW7 MRM.pdf
8CheckMonitoring/MRM 2015.xlsx
8CheckMonitoring/MRM Groundwater .txt

DME-Supplied Files as Provided to ERIAS Group
8CheckMonitoring/Nocheckmonitoringreportsfor2015.txt
9incidents/FireTSF/Investigation Report - Fire at TSF Contaminated Waste Area - McArthur River Mining Pty Ltd - McArthur River Mine.PDF
9incidents/FireTSF/Photo - Fire Adjacent to MRM TSF - McArthur River Mining Pty Ltd - McArthur River Mine.JPG
9incidents/FireTSF/S29 Incident Notification - Fire Adjacent to TSF - McArthur River Mining Pty Ltd - McArthur River Mine.PDF
9incidents/SELeveeFishKill/Letter In - SEL Fish Kill Incident Additional Information - McArthur River Mining.PDF
9incidents/SELeveeFishKill/Letter Out - MRM Fish Kill Incident Inve~or Additional Information - McArthur River Mining.PDF
9incidents/SELeveeFishKill/MRM Fish Kill Incident Investigation Report - McArthur River Mining.PDF
9incidents/SO2Monitoring/MRM 24042015 Letter to S Strohmayr - issue of section 48 notice (signed).pdf
9incidents/SO2Monitoring/MRM 24042015 Section 48 Notice issued to MRM (signed).pdf
9incidents/SO2Monitoring/MRM MRM SO2 Initial Desktop Assessment - McArthur River Mining Pty Ltd - McArthur River Mine.PDF
9incidents/SO2Monitoring/MRM SO2 Monitoring Locations - Devils Spring - McArthur River Mining Pty Ltd - McArthur River Mine.JPG
9incidents/SO2Monitoring/MRM SO2 Monitoring Station - Mabunji Lot 47 - McArthur River Mining Pty Ltd - McArthur River Mine.JPG
9incidents/SO2Monitoring/MRM SO2 Monitoring Station - Borroloola - McArthur River Mining Pty Ltd - McArthur River Mine.JPG
9incidents/TruckTrailerNearMiss/Investigation Report - Truck Trailer Near Miss - McArthur River Mining Pty Ltd - McArthur River Mine.PDF
9incidents/TruckTrailerNearMiss/S29 Incident Notification - Truck Near Miss - McArthur River Mining Pty Ltd - McArthur River Mine.PDF
9incidents/TSF Seepage/01 TSF Cell 2 Fortnightly Report - 26 February 2015 - Feedback.msg
9incidents/TSF Seepage/02 TSF Communication - DME Feedback.msg
9incidents/TSFTailingsSpill/Attachment - MRM Additional Information ~dent Investigation Report - McArthur River Mining.PDF
9incidents/TSFTailingsSpill/Letter In - MRM Additional Information -~dent Investigation Report - McArthur River Mining.PDF
9incidents/TSFTailingsSpill/Letter Out - Tailings Discharge Incident~tional Information Letter - McArthur River Mining.PDF
9incidents/TSFTailingsSpill/MRM Tailings Discharge Incident Investigation Report - McArthur River Mining Pty Ltd - McArthur River Mine.PDF
10CommonwealthGovernment/DMEDidNotProvideAdvicetoDoEOnEPBCMatters.txt
11EPA/01 MRM exceedance report and BiologicalSediment Monitoring Plans.msg
11EPA/02Comments on WDL 174-07 Exceedance Report and Monitoring Plans.msg
11EPA/03 Response to NT EPA regarding Clause 14A Assessment.PDF
11EPA/04Cover letter accompanying r~use 14a Assessment CWNOEF.PDF
11EPA/05 NT EPA - Environmental Impact Statement ~ Facility (CWNOEF).PDF
12ProceduresAudit/CP4-001 Audits and Site Inspection Procedure.doc
13proceduressampling/AA7-024 Ground Water Sampling Methodology.docx
13proceduressampling/AA7-025 Surface Water Sampling Methodology.docx

DME-Supplied Files as Provided to ERIAS Group
13proceduressampling/EMU Procedures Manual/0.0 Procedure Template.dotx
13proceduressampling/EMU Procedures Manual/0.1 Procedures Title Page.doc
13proceduressampling/EMU Procedures Manual/0.2 Procedures Manual Table of Contents.doc
13proceduressampling/EMU Procedures Manual/1.1 Field Trip Paper trail.doc
13proceduressampling/EMU Procedures Manual/1.2 Flow Chart.doc
13proceduressampling/EMU Procedures Manual/1.3 Field Trip Check List.xls
13proceduressampling/EMU Procedures Manual/1.3.1 Rum Jungle Field Trip Check List 2014.xls
13proceduressampling/EMU Procedures Manual/1.4 Packing the Lab Truck_xx.doc
13proceduressampling/EMU Procedures Manual/1.5 Inventory for Lab Truck Mud Maps_xx.xls
13proceduressampling/EMU Procedures Manual/1.5.1 Lab Truck Mud Map-Roof and Cabin_xx.doc
13proceduressampling/EMU Procedures Manual/1.5.2 Lab Truck Mud Map-Laboratory Module_xx.doc
13proceduressampling/EMU Procedures Manual/1.6 EC Standard Selection for the Field.doc
13proceduressampling/EMU Procedures Manual/1.7 pH Standard Selection for the Field.doc
13proceduressampling/EMU Procedures Manual/1.8 Quality Control Check List.doc
13proceduressampling/EMU Procedures Manual/10.1 Returning from a Field Trip-Flow Chart.doc
13proceduressampling/EMU Procedures Manual/10.2 Sample Bottle and Equipment Washing Chart.doc
13proceduressampling/EMU Procedures Manual/10.3 Sample Bottles and Equipment Cleaning.doc
13proceduressampling/EMU Procedures Manual/11.1 Lab Truck Cleaning Procedure.doc
13proceduressampling/EMU Procedures Manual/11.3 Washroom Cleaning Procedure.doc
13proceduressampling/EMU Procedures Manual/11.4 Daily Checks.doc
13proceduressampling/EMU Procedures Manual/11.5 Emergency Eyewash and Shower Maintenance.xls
13proceduressampling/EMU Procedures Manual/12.1 Sample Security During a Cyclone.doc
13proceduressampling/EMU Procedures Manual/13.3 Purchasing Procedure.docx
13proceduressampling/EMU Procedures Manual/13.5 EMU OBIS Field Visit Entry .docx
13proceduressampling/EMU Procedures Manual/13.6 TRIM Documents.docx
13proceduressampling/EMU Procedures Manual/13.7 OK TO PAY NTEL Invoices.docx
13proceduressampling/EMU Procedures Manual/13.8 Users of Schedule 7 substances.pdf
13proceduressampling/EMU Procedures Manual/14.1 Winch Operation, Safety and Maintenance.doc
13proceduressampling/EMU Procedures Manual/14.2 Generator Maintenance.doc
13proceduressampling/EMU Procedures Manual/14.2.1 Generator Notice.docx
13proceduressampling/EMU Procedures Manual/14.3 Logger Placement Procedure.docx
13proceduressampling/EMU Procedures Manual/14.4 Solinst Loggers.docx
13proceduressampling/EMU Procedures Manual/14.7 Satellite Phone.docx
13proceduressampling/EMU Procedures Manual/14.8 Redox geochemistry.ppt
13proceduressampling/EMU Procedures Manual/15.1 Generator Manual.pdf
13proceduressampling/EMU Procedures Manual/15.2 Motorola-9505-phone-user-guide.pdf
13proceduressampling/EMU Procedures Manual/15.3 Brother MFC-6490CW LAN Manual.pdf
13proceduressampling/EMU Procedures Manual/15.4 SMEG Washer Gw1160_USER_MANUAL-EN.pdf
13proceduressampling/EMU Procedures Manual/15.5 Digital Titrator Manual.pdf
13proceduressampling/EMU Procedures Manual/15.5 Mini Troll Barometric presure.pdf
13proceduressampling/EMU Procedures Manual/2.1 pH Standards Preparation.doc

DME-Supplied Files as Provided to ERIAS Group
13proceduressampling/EMU Procedures Manual/2.2 Zobells Standard Solution Preparation.doc
13proceduressampling/EMU Procedures Manual/2.3 Electrical Conductivity Standards Preparation.doc
13proceduressampling/EMU Procedures Manual/3.1 Specs DO Meter table.tif
13proceduressampling/EMU Procedures Manual/3.1 YSI DO200 Dissolved Oxygen Meter Calibration.doc
13proceduressampling/EMU Procedures Manual/3.11 Specs YSI EC300 table.tif
13proceduressampling/EMU Procedures Manual/3.12 Specs YSI pH100 table.tif
13proceduressampling/EMU Procedures Manual/3.13 Calibrating Smart Troll.doc
13proceduressampling/EMU Procedures Manual/3.2 pH Calibration-Bench TPS labCHEM-C.doc
13proceduressampling/EMU Procedures Manual/3.2 Specs Bench EC pH table.tif
13proceduressampling/EMU Procedures Manual/3.3 pH Calibration-Field YSI pH100.doc
13proceduressampling/EMU Procedures Manual/3.4 Pipette Calibration.doc
13proceduressampling/EMU Procedures Manual/3.4.1 Pipette Calibration Sheet.xls
13proceduressampling/EMU Procedures Manual/3.5 EC Calibrations-Bench Meters.doc
13proceduressampling/EMU Procedures Manual/3.6 EC Calibration-Field Meter YSI EC300.doc
13proceduressampling/EMU Procedures Manual/3.7 mV Calibration-Field Meter YSI pH100.doc
13proceduressampling/EMU Procedures Manual/3.8 GW and SW Field Sampling Sheets.xlsx
13proceduressampling/EMU Procedures Manual/3.8.1 Stability Criteria.xlsx
13proceduressampling/EMU Procedures Manual/3.9 Turbidity-Field Meter Orion AQ3010 Calibration.doc
13proceduressampling/EMU Procedures Manual/4.1 Quality Control Samples.doc
13proceduressampling/EMU Procedures Manual/4.10 Acidity Digital Titrator Test Method.doc
13proceduressampling/EMU Procedures Manual/4.11 Alkalinity Digital Titrator Test Method.doc
13proceduressampling/EMU Procedures Manual/4.12 Discharge or Flow Rate Procedure.doc
13proceduressampling/EMU Procedures Manual/4.12.1 Discharge or Flow Rate Calculation Sheet.xls
13proceduressampling/EMU Procedures Manual/4.12.2 Discharge or Flow Rate Record Field Sheet.xls
13proceduressampling/EMU Procedures Manual/4.13 Turbidity-Field Meter HI 93703 Operation .doc
13proceduressampling/EMU Procedures Manual/4.14 Dissolved Oxygen - DO200 Meter Operation.doc
13proceduressampling/EMU Procedures Manual/4.15 pH Operation-Field YSI pH100.doc
13proceduressampling/EMU Procedures Manual/4.16 EC Operation-Field YSI EC300.doc
13proceduressampling/EMU Procedures Manual/4.17 mV Operation-Field YSI pH100.doc
13proceduressampling/EMU Procedures Manual/4.18 Alkalinity and Acidity Method.doc
13proceduressampling/EMU Procedures Manual/4.19 TSS in Clear flow for short and long periods.docx
13proceduressampling/EMU Procedures Manual/4.2 Blank Sampling Procedure.doc
13proceduressampling/EMU Procedures Manual/4.3 Duplicate Sampling Procedure.doc
13proceduressampling/EMU Procedures Manual/4.4 Control Sampling Procedure.doc
13proceduressampling/EMU Procedures Manual/4.5 Sampling a Bore.doc
13proceduressampling/EMU Procedures Manual/4.6 Cyanide WAD and Total Sampling Procedures.doc
13proceduressampling/EMU Procedures Manual/4.7 Surface Water Sampling Procedure.doc
13proceduressampling/EMU Procedures Manual/4.8 Suspended Solids Procedure.doc
13proceduressampling/EMU Procedures Manual/4.9 Alkalinity and Acidity chart.JPG
13proceduressampling/EMU Procedures Manual/4.9 Alkalinity and Acidity Method.doc
13proceduressampling/EMU Procedures Manual/5.1 Inline Filtering Procedure.doc

DME-Supplied Files as Provided to ERIAS Group
13proceduressampling/EMU Procedures Manual/5.2 Syringe Filtering Procedure.doc
13proceduressampling/EMU Procedures Manual/5.3 Vacuum Filtering Procedure.doc
13proceduressampling/EMU Procedures Manual/5.4 Washing Filter Units in the Field.doc
13proceduressampling/EMU Procedures Manual/6.1 Preservation Techniques.doc
13proceduressampling/EMU Procedures Manual/6.2 Sample Preservation and Storage.xls
13proceduressampling/EMU Procedures Manual/6.3 Sediment Sample Preparation Separation.docx
13proceduressampling/EMU Procedures Manual/6.4 Sediments Sieving Calculation.xlsx
13proceduressampling/EMU Procedures Manual/6.5 Ionic Balance Calculations.xlsx
13proceduressampling/EMU Procedures Manual/7.1 Acid Dispensing.doc
13proceduressampling/EMU Procedures Manual/7.2 Acidification Notice.doc
13proceduressampling/EMU Procedures Manual/8.0 DEEP Data Management.doc
13proceduressampling/EMU Procedures Manual/8.1 DEEP Site Naming Protocol.doc
13proceduressampling/EMU Procedures Manual/8.3 Zobell calculations.xlsx
13proceduressampling/EMU Procedures Manual/DEEP QUICK GUIDE.docx
13proceduressampling/EMU Procedures Manual/EMU_Procedures_May2015.xlsx
13proceduressampling/EMU Procedures Manual/Mercury Preservation.pdf
13proceduressampling/Environmental Monitoring Unit Field Manual (Updated 2014).doc
13proceduressampling/Environmental Monitoring Unit Laboratory Safety Manual (Updated2014).doc
14ProceduresAcceptingPlans/AP2-003 Document Review Procedure.docx
15Correspondence/ReferToMMPRequestForAdditionalInformation.txt
_Additional provided after main batch/01164C_E_DME to DAB_additional DME docs.pdf
_Additional provided after main batch/Amendment CWNOEF West D.zip
_Additional provided after main batch/Approval for CWNOEF West D.zip
_Additional provided after main batch/ITRB Review of MRM TSF LOM and Tailings Management Plan.pdf
_Additional provided after main batch/MDOC201505062CWNOEFConditionalAcceptance Signed.pdf
_Additional provided after main batch/MRM Sampling Report 1.docx
_Additional provided after main batch/MRM Sampling Report 2.docx
_Additional provided after main batch/Report on MR region fish Final 31 March 2015.pdf

Appendix 2

Risk Register

RISK MATRIX

		Likelihood (regardless of potential time latency)				
		1	2	3	4	5
Consequence		Certain	Likely	Possible	Unlikely	Improbable
1	Catastrophic	2	3	4	5	6
2	Major	3	4	5	6	7
3	Moderate	4	5	6	7	8
4	Minor	5	6	7	8	9
5	Insignificant	6	7	8	9	10

RISK RATING EXPLANATIONS

Risk Matrix result	Risk Rating	Description
2 to 3	E	Extreme- Immediate intervention required to eliminate or reduce
4 to 5	H	High Risk - It is essential to eliminate or reduce risk to a lower
6 to 7	M	Moderate - Corrective action required, and monitoring and
8 to 10	L	Low Risk - Corrective action should be implemented where

KEY TO RISK REGISTER

Location of impact	
RI	Regional impact (>2km radius outside mining lease)
OM	Impact outside mine lease area - (<2km radius)
WM	Wide impact within mining lease boundaries
L	Localised area within mining lease boundaries
P	Small point source within mining lease boundary
Potential Duration of impact	
G	Geological long term (>100 years)
L	Long term (30- 100)
M	Medium term (5-30 years)
S	Short term (1-5 years)
E	Ephemeral/seasonal impact
Risk Rating number and letter colour coding	
Black	Risk rating has remained the same since the last IM audit
Red	Risk has increased in consequence and/or likelihood since last IM audit
Green	Risk has decreased in consequence and/or likelihood since last IM audit
Grey	This risk item has been added since the last IM audit.

Consequence Definitions

Consequence		Definition
1	Catastrophic	Severe environmental impact. Local species destruction and likely long recovery period. Extensive clean up involving external resources. Impact on regional scale.
2	Major	Major environmental impact. Considerable clean up effort using site and external resources. Impact may extend beyond lease boundaries.
3	Moderate	Moderate environmental impact. Clean up by site staff and/or contractors. Impact confined within lease boundaries. Or, minor impact off site: however, no irreversible damage.
4	Minor	Low environmental impact. Rapid clean up by site staff and/or contractors. Impact controlled to area currently impacted by operations.
5	Insignificant	No or very low environmental impact. Impact confined to small area. Site impact only.

Likelihood		Definition
1	Certain	Expected to occur frequently at this operation.
2	Likely	Expected to occur occasionally at this operation.
3	Possible	Has occurred or could occur for this or a comparable operation.
4	Unlikely	Known to occur in the global industry but unlikely.
5	Improbable	Not known to occur in the global industry but plausible.

Report Section	Asset	Consideration	Hazard / Aspect	Incident / Event	Consequence / Impact	Potential duration of impact	Location of impact	Existing Controls/ Monitoring and Assessment undertaken	Consequence	Likelihood	Matrix Result	Risk Rating	Additional Controls, monitoring , assessment or actions required
4.2	Bing Bong Loading Facility	Water Balance Modelling	The climate in the vicinity of the loading facility is wetter than that experienced historically Water balance modelling has assumed the climate from 1889 to the present is representative of the future climate over the life of the loading facility. The impact of a wetter climate has not been assessed Further, the impact of one or more years of extreme rainfall has not been assessed. These would be considered rare events with or without climate change	Uncontrolled releases of contaminated water from the Bing Bong surface runoff ponds (BBSRP)	Poor quality water (metals, acid) affect terrestrial and aquatic ecosystems	M	L	Existing controls outlined in WRM report Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility	1	3	4	H	Scenarios need to be included in the water balance modelling to assess the impact and develop a management plan to mitigate this impact
4.2	Bing Bong Loading Facility	Water Management	Overflow of Bing Bong surface runoff pond (BBSRP)	High rainfall, or failure to clean out sediment from pond, or mismanagement of water volumes leads to overflow of one or more of the Bing Bong surface runoff ponds (BBSRP)	Poor quality water (metals, acid) affect terrestrial and aquatic ecosystems	M	L	Three adjacent surface runoff containment ponds. Annual water balance modelling undertaken. Evaporation of pond water through use of pond water as dust suppression across site. Annual marine heavy metal monitoring. Trucks transporting water to TSF (as previously required)	4	4	8	L	All three runoff ponds should be cleaned out prior to the wet season. Confirmation that water balance modelling will be undertaken annually
4.2	McArthur River	Water Balance Modelling	Deterioration in mine site seepage and/or runoff water quality beyond current estimates Cause is changes in the AMD from the NOEF. This may be due to 1) changes in the PAF/NAF ratio and/or 2) changes in the chemical reactions occuring	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	M	RI	Existing controls outlined in WRM report Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility	1	3	4	H	Scenarios need to be included in the water balance modelling to assess the impact and develop a management plan to mitigate this impact
4.2	McArthur River	Water Balance Modelling	The climate in the vicinity of the mine is wetter than that experienced historically Water balance modelling has assumed the climate from 1889 to the present is representative of the future climate over the life of the mine. The impact of a wetter climate has not been assessed Further, the impact of one or more years of extreme rainfall has not been assessed. These would be considered rare events with or without climate change	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	M	RI	Existing controls outlined in WRM report Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility	1	3	4	H	Scenarios need to be included in the water balance modelling to assess the impact and develop a management plan to mitigate this impact
4.2	McArthur River	Water Balance Modelling	The water balance model fails to accurately predict site water balance under changed site conditions.	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	M	RI	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components	1	3	4	H	Substantial additional effort in model calibration, reporting and monitoring to identify the most sensitive parameters. Steps taken to reduce the parameter uncertainty based upon the prioritisation of their sensitivity
4.2	McArthur River	Water Balance Modelling	Use of the Underground Void/Open Pit (UG&OP) for Water Storage conflicts with mine operations	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	M	RI	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components	1	3	4	H	Medium to long term plans to reduce the risk of water ponding in the open pit.
4.2	McArthur River	Water Balance Modelling	Failure of pumps or pipes during periods of heavy rain	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	M	RI	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components	1	3	4	H	Sensitivity analysis of the impact of pump and pipe failure on mine site water management. Build a level of resiliance in the system so that it can accommodate a pipe or pump failure without unplanned off-site releases.
4.3	McArthur River	Water management	Poor management of excess dirty/ contaminated water during operations	Release of dirty/contaminated water during operations	Discharge of excess dirty/contaminated water to the McArthur River, impacting aquatic ecosystems and other beneficial uses	E	OM	Groundwater monitoring, surface water monitoring, MRM discharge calculation tool	4	2	6	M	Background and mine-derived load calculations required, including site load balance
4.4	Mine levee wall	Long-term structural integrity	Erosion at several points along the Mine Levee Wall	Failure of the mine levee wall during flood	Failure of the mine levee wall in extreme events and runoff from the mine site to the river	M	WM	Minor erosion sites have been inspected and are to be repaired in dry season. General erosion of the mine levee wall is to be invetsigated as part of the Geomorphic Assessment currently being undertaken. Plan for the long term stability of the mine levee wall to be detailed in the upcoming EIS	1	3	4	H	It is recommended that the long term plan for the stability of the mine levee wall is reported on in detail, given the potential consequence of failure
4.4	River diversions	River diversion design performance	Erosion at toe of mine levee wall and along unplanned overland flow path from the old McArthur River Channel into diversion channel	Flood flows returning to river from the direction of the remnant river channel	Potential breach of the mine levee wall leading to runoff from the mine site to the river	E	L	To be investigated as part of the Geomorphic Assessment currently being undertaken	3	3	6	M	Reccomendation pending outcomes of the geomorphic assessment
4.4	River diversions	River diversion design performance	Poor drainage design and bunds formed by mine access roads	Ponding of water between channel and mine bund.	Increased seepage through shallow soil zone and mobilisation of salts impacting terrestrial and aquatic ecosystems	L	L	Small diameter pipes (<100mm) pipes to allow drainage	4	2	6	M	Previous reccomendation - Reshape area to ensure no ponding of water occurs. It is reccomended that this are be re-assessed for erosion potential and reported on

Report Section	Asset	Consideration	Hazard / Aspect	Incident / Event	Consequence / Impact	Potential duration of impact	Location of impact	Existing Controls/ Monitoring and Assessment undertaken	Consequence	Likelihood	Matrix Result	Risk Rating	Additional Controls, monitoring , assessment or actions required
4.4	River diversions	River diversion design performance	Major erosion/failure of river diversions channel during flood	Flood event	Altered flood behavior. Increased sediment load downstream in the McArthur River. Impact on aquatic and terrestrial ecosystems	S	L	No controls in place. To be investigated as part of the Geomorphic Assessment currently being undertaken	3	4	7	M	No photograph monitoring this operation year or the 2014 operation year. No ALS topography appears to have been assessed. Despite the current geomorphic assessment, it is recommended that a formal, documented assessment of the ALS, aerial photographs and site photographs, combined with a visual inspection of key risk areas is conducted annually
4.4	River diversions	River diversion design performance	Mine levee wall	A greater than >500 ARI flood event leading to erosion of mine levy wall	Flooding of the pit from McArthur River resulting in reduced volume of water downstream in McArthur River impacting downstream ecosystems	L	L	Implementation of the revised Early Flood Warning System Procedure. The revised early flood warning system establishes relationships between flood levels at gauges and flood hazard benchmarks (spill way and mine levee) (Document Reference Number: ADM-ENV-PRO-6040-0011). The Site Emergency Response Plan has been updated to include procedure for flooding in the Mine Pit (Document Reference Number: GEN-GEN-PLN-6040-0001)	3	5	8	L	The control does not mitigate the risk of failure of the mine levee wall. It is reccomended that the long term plan for the stability of the mine levee wall is reported on in detail, given the potential consequence of failure
4.5	Bing Bong dredge spoil	Dredge spoil pond management	Management of entrained dredge spoil water	Release of marine water	Seepage of marine water from the dredge spoil ponds, impacting groundwater quality and aquatic and terrestrial ecosystems	E	L	Operation of drainage system on and around the ponds, groundwater monitoring, surface water monitoring	4	3	7	M	All proposed actions have been implemented
4.5	Bing Bong Loading Facility	Hydrocarbon storage	Management of stored hydrocarbons	Release of contaminated water	Seepage of NAPL and aqueous phase hydrocarbons, impacting on groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/ rivers/ sea or to the surface	S	OM	Containment system design, hydrocarbon audits, inspection procedures, monitoring of storages	3	3	6	M	Installation of high level alarm on storages
4.5	Bing Bong Loading Facility	Concentrate Storage	Management of stored concentrate	Discharge of metaliferous/low pH water	Seepage of contaminated water, impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/rivers/sea or to the surface	E	OM	Operation of containment system (lined drains, paved catchments, lined containment ponds), groundwater monitoring, surface water monitoring	4	3	7	M	All proposed actions have been implemented
4.5	Groundwater resource	Groundwater supply	Poor operation of borefields and dewatering systems	Over abstraction of groundwater	Over pumping, resulting in depletion of the groundwater resource, aquifer depressurisation, subsidence, reduced groundwater quality	S	L	Groundwater monitoring, groundwater modelling	4	4	8	L	All proposed actions have been implemented
4.5	Mine site	Hydrocarbon storage	Management of stored hydrocarbons	Release of contaminated water	Seepage of NAPL and aqueous phase hydrocarbons, impacting on groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/ rivers or to the surface	S	OM	Containment system design, hydrocarbon audits, inspection procedures, monitoring of storages, groundwater monitoring	3	3	6	M	Installation of high level alarm on storages
4.5	Water storages	Water storage design	Poor water storage design/construction	Release of dirty/contaminated water	Seepage of dirty/contaminated water, impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/rivers or to the surface	L	OM	Storage design, seepage monitoring, surface water monitoring and groundwater monitoring	3	1	4	H	Lining of all storages
4.6	Bing Bong dredge spoil	Drainage	Potential for acid sulfate soils around the outer spoon drain	Acid sulfate soils exposed by excavation of the outer spoon drain, which causes acid leachate	Local impacts on re-vegetation, water quality	M	L	None	4	3	7	M	Progress acid sulfate soil assessment of spoon drain and other potential sources at Bing Bong Loading Facility
4.6	Mine site	Geochemical	Potentially acid, saline and metal leaching materials are used for construction purposes across site	Materials used in construction previously classified NAF may now be a geochemical hazard under the new criteria Material types used in construction not adequately tracked	Local impacts on re-vegetation, water quality. Potential influence on SW11 EC Compliance	L	P	Initial geochemical sampling and test program carried out on infrastructure around site	4	2	6	M	Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in-situ sulfidic materials at the Barney Creek diversion channel and McArthur River diversion channel
4.6	NOEF	Geochemical	Failure of NOEF cover	Cover breached through erosion, slumping, differential movement, cracking/heaving due to convective oxidation, and/or undermining of dump due to extreme flooding event, leading to exposure of highly pyritic waste rock to oxidation and infiltration	Acid, saline and metalliferous drainage impacts in perpetuity on groundwater, terrestrial and aquatic ecosystems	G	OM-RI	Initial cover system modelling and design has been carried out, which indicates the use of multi-layered cover system with relatively thin layers	1	2	3	E	Placement of a multi-layered cover system of the types modelled on the NOEF is expected to be challenging, with long term maintenance of these layers and their performance even more so. Controlling oxidation in addition to infiltration adds considerable complexity to the cover design, and should be assessed to determine whether the additional effort will result in long term benefits. Drilling of the NOEF shows that rapid oxidation is occurring in the dump, generating heat and gas, and changing dump volumes/densities locally, increasing the possibility of differential settlement, development of cracks and local pressure effects on any low permeability layers. These effects should be considered in evaluation of long term cover system integrity. Given the highly pyritic nature of MRM waste rock and the potential impact of cover failure, it is unlikely that the cover system adopted will be a walk-away solution. Allowance would need to be made for long term monitoring and ongoing maintenance post closure. Dump construction should include the following components: - Paddock dumping and roller compacting PAF(HC) materials, which are still highly pyritic, to maximise stability, and minimise oxidation and infiltration. - maintain a 100m set back for PAF(HC&RE) materials, particularly in older 15m end tipped dump zones, to control convection.

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4.6	NOEF	Geochemical	NOEF Seepage	NOEF seepage reports to groundwater during operations and ultimately to surface drainage down-gradient	Acid, saline and metalliferous drainage impacts on groundwater, terrestrial and aquatic ecosystems	M	WM	Monitoring of groundwater Leaking interception ponds SPROD/SPDS are being HDPE-lined, which will reduce a major source of seepage. Interim clay cap was completed over most of the areas with exposed PAF prior to the last wet season, but trials indicate these may be ineffective. Alternate potential infiltration controls identified. Drilling into NOEF provided more information on dump hydrology.	3	1	4	H	Carry out trials of alternate infiltration controls before the next wet season to minimise additional potential groundwater impacts. Further investigation and analysis of monitoring data should be carried out to better understand the extent and impact of groundwater contamination from the NOEF. The current impacts from the SPROD/SPSD on groundwater and surface water are likely to mask impacts from NOEF seepage. Carry out more drill testing of dumped materials to more confidently define the distribution of historically dumped materials and check the reconstruction of dump materials types based on the new block model. Knowing the rock type composition and distribution will help in predicting contaminant loadings being generated.
4.6	NOEF	Geochemical	Development of convection cells in end tip dump areas.	End dumping of PAF materials resulting in segregation of coarse and fine materials and creation of chimney structures that encourage rapid convective oxidation, including spontaneous combustion	Greater rates of oxidation and generation of acid, salinity and dissolved metals, consequent impacts on groundwater, terrestrial and aquatic ecosystems Spontaneous combustion impacts from PAF(RE) affects the stability of the NOEF and results in breaches the of the final cover	L	WM	PAF(RE) and PAF(HC) are currently paddock-dumped and roller-compacted. Spontaneously combusting materials are managed through excavation and compaction. Investigations into sealants carried out. Initiating construction of a MS-NAF halo zone as part of the broader cover system to help control convection/advection into PAF materials.	2	2	4	H	Develop criteria to confidently identify reactive materials. Convective/advective oxidation processes are still occurring and further controls need to be developed. Dump construction should include the following components: - Paddock-dumping and roller-compacting PAF(HC) materials, which are still highly pyritic, to maximise stability, and minimise oxidation and infiltration. - maintain a 100m setback for PAF(HC&RE) materials, particularly in older 15m end-tipped dump zones, to control convection.
4.6	NOEF	Geochemical	Misclassification of geochemical rock types	Classification criteria not sufficiently discriminating, or the geochemical properties of geochemical rock types are different from what was expected based on results to date	Acid, saline and metalliferous drainage from unexpected parts of the dump and consequent impacts on groundwater, terrestrial and aquatic ecosystems Mis-placement of PAF(RE) leads to spontaneous combustion and consequent impacts on dump stability and increased acid, saline and metalliferous drainage	G	OM-RI	Improvement of the resource waste rock block model to include ANC, and classification of waste rock type based on the full classification criteria. Improved understanding of geochemical properties of key waste rock types based on static and kinetic testing, which support the current classification criteria.	3	3	6	M	Check calibration of hand held XRF with new data. Progress use of on-site ICP testing to replace XRF. Adjust block model quantities to account for recoverable geochemical rock types to match conservatism applied in the pit. Develop criteria that provides more confident identification of PAF(RE). Maintain NPR cut offs for PAF(HC) materials at 1 unless there is compelling geochemical evidence to justify a reduction.
4.6	NOEF	Geochemical	Mis-placement of waste rock materials.	Materials placed in the wrong locations Use of the older classification system in older dump areas	Acid, saline and metalliferous drainage from unexpected part of the dump and consequent impacts on groundwater, terrestrial and aquatic ecosystems	G	L	A system for tracking excavation and placement of geochemical rock types in place. A system of field checks in place. Use of the new resource waste rock block model to recreate the waste rock type composition of the NOEF, with NOEF drilling data used to check results.	3	4	7	M	Carry out more drill testing of dumped materials to more confidently define the distribution of historically dumped materials and check the reconstruction of dump material types based on the new block model. Knowing the rock type composition and distribution will help in predicting contaminant loadings being generated. Increase the frequency of check sampling of dumped materials, particularly for LS-NAF. Only 102 check samples of LS-NAF cells were collected over the 2014 to 2016 period.
4.6	Open pit	Geochemical	Pit water quality after closure	The open pit lake becomes strongly acid and/or saline and metalliferous after closure due to oxidation of exposed pyritic PAF and NAF materials in pit walls, with potential for overtopping to surface water systems and seepage to groundwater	Acid, saline and metalliferous drainage impacts on groundwater, terrestrial and aquatic ecosystems	G	OM	Preliminary pit water quality modelling carried out, and will be further progressed as part of the EIS	2	2	4	H	Extend modelling to a longer period and assess the possibility of the pit lake ultimately acidifying under different assumptions. Develop options for post closure pit lake management. Options of isolation of the pit from natural drainage versus permanent river diversion through the pit will need to be carefully considered. In the long term, without direct maintenance, the natural drainage is likely to eventually breach the bund walls and pass through the pit, potentially mobilising a concentrated volume of contaminated water into the McArthur River. Deliberate diversion of the McArthur River through the pit would continually dilute the pit water quality, but would need to be carefully managed and monitored (including consideration of lake stratification), and is likely to require contingency for direct treatment.
4.6	SOEF	Geochemical	Saline and metalliferous drainage	SOEF composed of mainly MS-NAF but there is no cover system in place to control water and oxygen flux	Saline and metalliferous drainage and consequent impacts on groundwater, terrestrial and aquatic ecosystems Impacts on rehabilitation success	G	L	Kinetic testing in progress to assess the leaching characteristics of MS-NAF	3	3	6	M	Review kinetic test results and assess potential impacts on receiving drainage during operations, and finalise closure options.
4.6	TSF	Geochemical	Failure of TSF cover	Cover breached through erosion, slumping, embankment failure etc , leading to exposure of highly pyritic tailings to oxidation and infiltration	Water quality impacts on impacts on groundwater and surface drainage down-gradient Short Term - mainly elevated SO_4 salts and electrical conductivity Longer Term - acid and elevated metals once tailings acidify	G	OM-RI	Conceptual cover design produced Testing of tailings, including monthly composites of freshly discharged tailings. Option of backfilling tailings into pit proposed.	1	2	3	E	As for NOEF, given the highly pyritic nature of MRM tailings and the potential impact of TSF failure, it is unlikely that any cover system adopted will be a walk-away solution. Allowance for long term monitoring and ongoing maintenance of any TSF cover system post closure. Progress the in-pit disposal and flooded option for tailings, which will provide the most secure closure outcome and chage the risk rating. Assess the potential effects of pyrite oxidation and salt generation on the overall stability of the TSF embankment if compacted tailings are used in embankment construction.
4.6	TSF	Geochemical	Tailings leachate from Cell 1	Poor design of TSF and incomplete rehabilitation of Cell 1 leads to TSF leachate into Surprise Creek	Water quality impacts on groundwater, terrestrial and aquatic ecosystems Currently mainly elevated SO_4 salts and electrical conductivity	M	RI	Shallow cut-off barrier, seepage interception sump. Monitoring of surface water and groundwater. Placement of 0.5m clay cap on cell 1 for dust control. Geophysical analysis to track saline plumes. Aquatic fauna surveying in Surprise Creek Overflow ponds completed Piezometers installed	3	2	5	H	Install a more robust cover on Cell 1 before the next wet season that will withstand erosion and control infiltration, and progress the Cell 1 dewatering bores. The previous interim clay covers installed did not appear adequate to control seepage and impacts on Surprise Creek.

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4.6	TSF	Geochemical	Tailings leachate from Cell 2	Tailings leachate reports to groundwater during operations and ultimately to surface drainage down-gradient, or an uncontrolled release occurs due to high flow event	Water quality impacts on impacts on groundwater and surface drainage down-gradient Mainly elevated SO_4 salts and electrical conductivity, and possibly Zn and Mn. Could include acid and elevated metals if tailings acidify	M	WM	Monitoring of groundwater Shallow Interception trenches in place Oxidation of the tailings minimised during operations by frequent layering of fresh tailings to limit exposure time Reduced water storage in Cell 2, reducing seepage rates.	3	2	5	H	Monitor acid and salinity generation in the tailings surface. Continue kinetic testing of tailings and assess lag times and acid, salinity and metal/metalloid generation rates, and implications for operational control of tailings beach areas and water quality. Carry out geochemical characterisation of tailings collected as part of TSF drilling to obtain information on historic variation through the tailings profile. Maintain moisture in drier and less active areas of the Cell 2 tailings to minimise sulfide oxidation and dust. This may include spraying water onto the surface.
4.6	WOEF	Geochemical	Failure of WOEF cover	Cover breached through erosion, slumping, differential movement, and/or undermining of dump due to extreme flooding event, leading to exposure of MS-NAF and PAF materials	Acid, saline and metalliferous drainage from unexpected part of the dump and consequent impacts on groundwater, terrestrial and aquatic ecosystems Impacts on rehabilitation success	G	L	The PAF core of the dump has been encapsulated by clay, and covered with undifferentiated NAF materials. A nominal multi layered cover system has been outlined.	3	3	6	M	Review/compile existing data and/or carry out a test program to confirm the distribution of geochemical rock types at the WOEF and finalise an appropriate approach to closure.
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Embankment failure due to instability	Release of tailings and process water into the environment causing impacts to terrestial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, operation manual	1	4	5	H	Monitoring reports to be forwarded to the designer. Provide proof that construction was undertaken to designer specifications
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Excessive settlement of the embankment or execssive flooding leading to overtopping	Release of tailings and process water into the environment causing impacts to terrestial and aquatic flora and fauna, sedimentation of Surprise Creek damage to embankment requiring minor to major repair works	S	WM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring and reporting of embankment levels, monthly reports, annual dam safety review	2	4	6	M	Monitoring reports to be forwarded to the designer. Provide proof that construction was undertaken to designer specifications
4.7.1	TSF	Geotechnical	Tailings pipeline	Burst tailings pipeline	Release of tailings and process water into the environment causing impacts to terrestial and aquatic flora and fauna, sedimentation of Surprise Creek damage to embankment requiring minor repair works	S	WM	Visual inspections of the pipeline, annual monitoring of wear and reporting, spill bunds at pipe joins, emergency procedures, routine maintenance	4	3	7	M	
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Piping through the embankment	Release of tailings and process water into the environment causing impacts to terrestial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, operation manual	1	6	7	M	Monitoring reports to be forwarded to the designer. Provide proof that construction was undertaken to designer specifications
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Poor operation, monitoring or management leading to overtopping	Release of tailings and process water into the environment causing impacts to terrestial and aquatic flora and fauna, sedimentation of Surprise Creek damage to embankment requiring minor to major repair works	S	WM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual	2	5	7	M	
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Piping through the foundation	Release of tailings and process water into the environment causing impacts to terrestial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual	2	6	8	L	Further investigation of seepage through the base of the TSF
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Seepage through embankment or the foundation	Release of process water into the environment causing impacts to terrestial and aquatic flora and fauna	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual	3	4	7	M	Provide proof that construction was undertaken to designer specifications
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Embankment failure due to excessive erosion due to wave action	Release of tailings and process water into the environment causing impacts to terrestial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual	3	5	8	L	
4.7.3	Bing Bong dredge spoil	Geotechnical	Storage of dredge spoil and seawater	Embankment failure due to instability	Release of sediment and sea water into the environment causing impacts to terrestial and aquatic flora and fauna requiring major repair works - most likely during active discharge	S	OM	Construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment piezometers, annual dam safety review	2	4	6	M	Settlement monitoring, erosion and other monitoring, set and assess performance against safe operating limits (incl. freeboard), routine maintenance and repairs
4.7.3	Bing Bong dredge spoil	Geotechnical	Storage of dredge spoil and seawater	Excessive settlement of the embankment or excessive flooding leading to overtopping	Release of sediment and sea water into the environment causing impacts to terrestial and aquatic flora and fauna, damage to embankment requiring minor to major repair works - most likely during active discharge	S	OM	Construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment piezometers, annual dam safety review	2	4	6	M	Inspections in immediate reponse to high rainfall events, settlement and freeboard monitoring during active discharge, undertake maintenance and repairs before and after active discharge
4.7.3	Bing Bong dredge spoil	Geotechnical	Storage of dredge spoil and seawater	Piping through the embankment	Release of sediment and sea water into the environment causing impacts to terrestial and aquatic flora and fauna requiring major repair works - most likely during active discharge	S	OM	Construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, annual dam safety review	3	4	7	M	Inspections in immediate reponse to high rainfall events, settlement and freeboard monitoring during active discharge, undertake maintenance and repairs before and after active discharge
4.8	Mine site	Security bonds	NOEF	Reclassification of waste rock results in insufficient material being available to construct a cover over the NOEF that can be demonstrated to be stable in the long term (period to be agreed between MRM and DME).	Significant financial impact.	S	WM	Investigations currently ongoing with regard to development of a cover for the NOEF, erosion trials and calculation of materials balance. MRM have identified a source of LS NAF to be mined specifically for the cover. Information to be available in the Overburden Management Project EIS.	2	2	4	H	Additonal investigations into material balance and cover design options to determine if a cover can be constructed which will provide long term stability which is acceptable to all stakeholders.

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4.8	Mine site	Security bonds	Long term post closure monitoring and maintenace costs	Current closure costs allow for a period of 25 years post closure water monitoring with limited costs associated with management and maintenance of the site. Costs insufficient to manage and maintain the site post closure.	Management of the site declines and failure to undertake regular maintenance results in failure of cover system and/or structures resulting in impacts to terrestrial and aquatic environments.	L	OM	Some costs provided for post clousre management and maintenance.	2	3	5	H	A comprehensive review is required of the closure costs. Determining the timeframe that post-closure monitoring and maintenance will be required should be a key aspect of this review. Allowance should be made for: · Long-term monitoring of cover performance. · Maintenance of the cover system, including inspection of geotechnical integrity. · Collection and treatment of leachates (surface and groundwater), and active water management post-closure including potentially the pit lake. · Monitoring and maintenance of the mine levee wall. · Monitoring and maintenance of McArthur River diversion channel. The IM understands that these issues will be addressed in the Overburden Management Project EIS.
4.8	Mine site	Closure criteria	Measurement of success	Some closure criteria are not specific or measureable and consequently there is uncertainty regarding whether MRM has met agreed closure criteria	MRM and DME fail to agree that aspects of the site have achieved closure criteria	NA	WM	Closure criteria have been developed, but they are not specific (measureable) to determine if an aspect has been competed					Is is not possible to subscribe a risk rating. The current mine closure objectives, criteria and performance indicators should be revised. The objectives should be outcome based and focused on the proposed post-mining land use. The closure criteria and performance indicators should be site specific and capable of objective measurement or verification. MRM are currently preparing revised closure criteria as part of the review of the mine clousre plan for the Overburden Management Project EIS
4.8	Mine site	Security bonds	Mine closure liability - no approved closure strategy for OEF's, TSF or pit lake	MRM Closes unexpectedly, leaving NOEF, TSF, river diversions, and mine site rehabilitation unfinished.	Sudden closure results in shortfall in materials to complete rehabilitation resulting in increaesed costs and bond unable to cover cost.	S	WM	Revegetation has started on river diversions but is not complete, monetary bond in place.	2	3	5	H	OEF should be progressively rehabilitated to confirm that cover design is appropriate and will work. Improve closure model calibration (i.e., costs, materials balance etc.) to confirm assumptions in the model. Approval of TSF and pit lake closure strategies. Development of rehabiltation plan for McArthur River diversion channel to enable progress to be measured and remaining cost to be accurately estimated. Closure plan should include contingencies for sudden closure.
4.8	Bing Bong Loading Facility	Security bonds	Dredge spoil ponds at Bing Bong Loading Facility are not included in the mine closure costs.	Closure of mine reveals shortfall in funds	Insufficient funds to rehabilitate Bing Bong Loading Facility following clousre.	M	OM	Nil	2	2	4	H	Detailed closure costs be prepared for the Bing Bong Loading Facility and that these are presented as a separate domain from the mine closure costs
4.9	Bing Bong dredge spoil	Terrestrial Flora	Drain surrounding dredge spoil not protecting habitat surrounding dredge spoil from highly saline water	Seepage of highly saline water from dredge spoil into undisturbed habitat surrounding dredge spoil, seawater being retained for extended periods by drain bund wall or previous obstruction of creek line to the east of the spoil	Dieback of vegetation in undisturbed habitat surrounding the dredge spoil and alteration and/or extended periods of inudation by seawater	M	L	Annual maintenance of drain which drains saline water out to sea. Annual vegetation monitoring of vegetation surrounding spoil area. South west corner of dredge spoil removed	2	3	5	H	Continue vegetation monitoring program. Inspect outside wall of drain for pooling of seawater and log in monthly inspections. Conduct remedial works if pooling or damage to drain is identified
4.9	Bing Bong dredge spoil	Terrestrial Flora	Sections of dredge spoil left unvegetated and use of incorrect seed mix in revegetated areas	Areas of dredge spoil left unvegetated due to use of cells for storage of future dredging spoils. Area of cells revegetated and seeded with incorrect species. Spoil material is difficult for non-salt tolerant species to establish on	Alteration or loss of habitat, creation of dust	M	L	Previous monitoring by orthophoto mapping and ground truthing of vegetation. CDU PhD student began revegetation trials on a section of the spoil but was not completed. Vegetation monitoring within cell 1. Area of dredge spoil ponds reseeded with grasses in 2011.	4	4	8	L	Continue with rehabilitation of dredge spoils - utilise landscaping of cells to promote veg growth despite future dredge plans. Use seed mixes consisting of salt tolerant species present in the coastal habitat surrounding the spoil. Continue to monitor dust from the dredge spoils
4.9	Mine site	Terrestrial fauna and flora	Fragmentation of habitat as a result of the operations development	Cleared or areas slow to revegetate leave patches of open land between vegetated areas.	The lack of vegetation cover prevents the movement of small fauna including small mammals, reptiles and grass birds.	M	L	Planting of tubestock, bi-annual riparian bird surveys, annual vegetation surveys along diversions, exclusion of cattle, weed control	5	3	8	L	Leave vegetation corridors where possible
4.9	Mine Site and Bing Bong load-out facility	Weed management	Infestation of weeds	Weeds present on mine leases from historical mining and pastoral activities are colonising cleared areas uncolonised by native vegetation	Weed infestations exclude native vegetation and reduces habitat for fauna	L	RI	Weed Management Plan in place with targeted weed control carried out with liaison from Weeds District Officer Parkinsonia biological control trials at Bing Bong dredge spoils ponds. Employment of local residents from Borroloola in weed management, including 3/7 local people in the monitoring section and 3/5 local people in the rehabilitation section. All seasonal workers (tree planters) are employed locally	2	3	5	H	Follow Weed Management Plan. Continue to investigate possibility of cooperative weed control with pastoral properties upstream on McArthur River
4.9	PACRIM, ROM and TSF	Terrestrial fauna and flora	Fugitive dust emissions from Pacrim Yard and ROM Pad. Dust migration from unvegetated TSF. Dust transported to vegetation by air or as run-off	Heavy metal loads in vegetation, soils and sediments causing vegetation die-back	Loss of plants, reduction of habitat for flora and fauna, compromised success of rehabilitation areas, compromised stability of diversion banks, contamination of waterways, mortality of aquatic fauna	M	WM	Dust monitoring program, sediment monitoring, vegetation monitoring, dust mitigation measures at mine site including water spray trucks, Introduction of double-lipped rubber lining to sides of PACRIM conveyors. Roller doors installed on concentrate storage shed, sediment traps at Barney Creek diversion bridge. Cell 1 of TSF capped and seeded with shrubs and grass	3	3	6	M	Testing of heavy metals in vegetation in additon to current aquatic fauna heavy metal monitoring program (conducted in 2015, but will be included in next audit)
4.9	River diversions	River diversion revegetation	Slow revegetation of McArthur River diversion	Flooding in wet season causes erosion and soil redistribution on unvegetated areas. Removal of planted vegetation by flooding and trampling/grazing by feral herbivores	Channel banks are unstable with erosion occuring, reduced riparian habitat, lack of shade for aquatic species, facilitating the spread of weeds	M	L	Annual revegetation monitoring. Use of coir logs and large woody debris to create soil pockets and tubestock planting, including targeted planting in soil pockets. MRM have mustered cattle and undertaken extensive repairs and upgrading of existing fencing surrounding diversions to exclude feral herbivores	3	2	5	H	Undertake erosion assessment reports, as committed in PER
4.9	River diversions	Terrestrial fauna and flora	Creation of unsuitable habitat along Barney Creek and McArthur River diversion channels	Planting along Barney Creek and McArthur River diversion channels not found at control sites, failure of growth of tubestock and seeds, infestation of weeds	Different vegetation community than that found up and downstream of channels, unsuitable habitat for fauna	L	L	Key and Primary species for riparian habitats identified. Table provided in riparian bird monitoring report detailing suitable riparian plant species. Progation of riparian flora in MRM nursery	4	3	7	M	Investigate the suitability of current control sites. Include flora species highlighted as important for riparian bird species in the Riparian bird monitoring reports in Key and Primary species. Increase survey sites on the Barney diversion downstream of the Barney Bridge
4.9	TSF	Terrestrial fauna and flora	Clearing of Gouldian finch habitat	Removal of feeding or breeding habitat for Gouldian finches	reduced habitat for Gouldian Finches	M	L	Preliminary gouldian finch survey conducted in 2013. Annual Gouldian finch monitoring program conducted	4	4	8	L	Survey mine lease for potential breeding habitat and important foraging habitat, create habitat map showing locations of important habitat. Avoid clearing these areas

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4.10	Mine site	Aquatic Fauna	Fugitive dust emissions and seepage as a reult of operatons.	Dust emissions from the TSF, haul roads, ROM pad, concentrate stores other aspects of operations and seepage from the TSF, SPROD, ROM sump and NOEF affects water and fluvial sediment quality in McArthur River and Barney, Little Barney and Surprise creeks	Reduction in water quality reduces diversity and abundance of aquatic fauna. Metals bioaccumulate in aquatic fauna causing unknown lethal and/or sub-lethal/ chronic effects. Contaminants then migrate downstream from MRM. Contaminated biota move from exposed sites around McArthur River Mine to regional reference sites.	M	RI	Dust emission controls, such as watering roads and a clay cap on TSF cell 1. Drains constructed around TSF and NOEF to capture seepage and lining the SPROD to stop seepage. Diverting drainage from the Barney Creek haul road bridge to silt traps and increased spraying of roads.Monitoring dust, contaminants in fluvial sediments, water quality, aquatic fauna diversity and abundance and assessing bioaccumulation of metals in fish around MRM. Routine inspections of infrastructure	3	2	5	H	Expand dust mitigation measures, such as regular removal of built up sediments along the haul road. Explore ways to minimise dust emissions from the ROM pad and processing plant and seepage from the ROM sump. A desktop survey should be conducted to investigate the potential for migration in contaminated fauna and its ecological effects.
4.10	Mine site	Aquatic Fauna	Infrastructure, pipelines etc, on site.	Infrastructure fails on site, leading to contamination of waterways with metals and salts.	Reduction in water quality reduces diversity and abundance of aquatic fauna. Metals bioaccumulate in aquatic fauna causing unknown lethal and/or sub-lethal/ chronic effects. This then migrates downstream from MRM	M	RI	Regular inspections and maintenance of infrastructure. Regular water and sediment monitoring, annual monitoring of metals and other contaminants in aquatic fauna	2	4	6	M	NIL
4.10	River diversions	Aquatic flora and fauna	Inadequate, slow or incorrect rehabilitation of the McArthur River and Barney Creek and Little Barney Creek diversions	River diversion rehabilitation creates poor quality aquatic habitat and a physical /biological barrier to fish migration	Loss of in stream habitat, changed flow regimes and reduced water quality leads to lower diversity and abundance of aquatic fauna in the diversions. Lack of shelter means predation rates are high. No "edge" macroinvertebrate community. Fish, including marine migrants such as freshwater sawfish, are unable to migrate through the diversion to breed or disperse, impacting upstream fish communities	L	RI	Freshwater Sawfish Monitoring and Management Programme in place. Aquatic fauna monitoring takes places twice annually. Revegetation of diversions to increase shade and habitat in the future. Addition of large woody debris to improve fish habitat and provide resting areas for fish migrating through the diversion	3	3	6	M	Continue to add and monitor large woody debris to provide additional habitat for fish and capture sediment. Continue planting riparian vegetation in sediment deposited around large woody debris as soon as possible following the wet season to maximise the likelihood of vegetation taking hold prior to the onset of the wet season. Increase the number of fish monitoring sites on Barney Creek within and upstream/downstream of the diversion channel to assess the impacts of this diversions on fish fauna.
4.11	Bing Bong Loading Facility	Fauna	Dust migration or concentrate spillage from Bing Bong Port	Bioaccumulation of metals in small marine crustaceans and fish	Heavy metal bioaccumulation in food sources of migratory birds causing poisoning affecting important migratory bird and wader populations	L	RI	Monitoring of heavy metals in sediments and biota. Bi-annual Migratory Bird surveys. Monthly monitoring of seawater using DGTs. Dust monitoring and control measures implemented including sprinkler system at port	2	5	7	M	Further reduce dust emissions from Bing Bong Port e.g. by enclosing concentrate shed with roller doors, use sprinklers to suppress dust on roads.
4.11	Bing Bong Loading Facility	Heavy metals	Storage of concentrate and transfer of concentrate to MV Aburri barge at Bing Bong Port	Spillage and dust emissions of concentrate from on sites storage and during barge load out causes contamination of marine and terrestrial environment with metals	Contamination of seawater and sediments with metals in the swing basin, shipping channel and surrounding area. Biota in the area bioaccumulate metals with unknown lethal and/or sub-lethal/chronic effects and potential health impacts for local fishers	M	RI	Dust monitoring programme and dust mitigation measures. Annual marine monitoring of heavy metals in seawater, sediments and biota. Monthly monitoring of seawater using DGTs. Fully contained conveyor system at the loading facility. Dust extractor and positive pressure differential in concentrate shed to minimise dust emissions. Watering roads to minimise dust kicked up by vehicles	3	2	5	H	Replace doors on the concentrate shed which remain closed unless vehicles are entering or exiting the shed. Continual spraying down of road surfaces at Bing Bong. Investigate dust and spillage minimisation measures being utilised at best practice facilities to minimise dust and spillage, and implement them at Bing Bong Port
4.11	Bing Bong Loading Facility	Marine ecology	Dredging operations and regular passage of the MV Aburri barge.	Dredging and regular passage of the MV Aburri stirs up contaminated and uncontaminated sediments at the Bing Bong Loading Facility and increases contamination, sedimentation and turbidity in the waters around the laoding facility	Biota in the area bioaccumulate metals with unkown lethal and/or sub-lethal/chronic effects and potential health impacts for local fishers. Increased sedimentation smothers seagrass and/or increased turbidity reduces photosynthesis of seagrass, leading to a loss of seagrass coverage, density and/or diversity. This then impacts seagrass dependent communities, such a dugong.	M	OM	Annual seagrass monitoring program with relevant control sites to determine the relative importance of impacts from MRM's operations and natural phenomena (e.g. cyclones). Annual marine monitoring of heavy metals in seawater, sediments and biota. Monthly monitoring of seawater using DGTs. Dredge spoil settled in ponds on land to minimise impacts of dredging on turbidity.	3	3	6	M	Continue current monitoring and controls
4.11	Sir Edward Pellew Islands and McArthur River estuary	Heavy metals	Mining operations adjacent to McArthur River and its tributaries. Operations at Bing Bong Port.	Contaminants entering McArthur River travel downstream and settle in sediments around the McArthur River estuary and Sir Edward Pellew Islands. Dust travels across from Bing Bong Port.	Bioaccumulation of metals in sediments and biota in vicinity of McArthur River estuary and Sir Edward Pellew Islands. Unknown sub-lethal/ chronic effects, effects on higher trophic species (including humans that eat fish caught in the area)	L	RI	Numerous controls at Bing Bong loading facility and McArthur River Mine to minimise dust emissions, seepage and spills, including fully contained loading systems, watering of roads and seepage capture drains. Monitoring of contamination of soils, dust, fluvial sediments, surface water and groundwater around McArthur River Mine and Bing Bong Loading Facility Monitoring of contaminants in seawater, marine sediments and biota at Bing Bong Loading Facility and surrounds, McArthur River estuary and Sir Edward Pellew Islands	2	4	6	M	Continue current monitoring and controls. Eliminate sources of contamination along Barney Creek, including the haul road brige and the ROM pad and sump
4.11	Sir Edward Pellew Islands, McArthur River and Bing Bong Port	Vibrio bacteria	Operations at MRM	Mining and associated activities leads to an increase in zinc concentrations in waters and sediments at the McArthur River estuary and Sir Edward Pellew Island. Zinc leads to and increase in *Vibrio* bacteria.	Vibrio bacteria may infect local population with necrotising fasciitis (flesh eating bacteria syndrome), leading to severe illness and, in some cases, death	M	RI	Vibrio monitoring. Monitoring water and sediments for zinc contamination and correlation between zinc and Vibrio	3	5	8	L	One further Vibrio monitoring program should be conducted in 2016. If there is no change in results from the previous three surveys, then there is likely no relationship between MRM's operations and Vibrio bacteria, and no further monitoring will be necessary
4.11	Transhipment area	Heavy metals	Transfer of concentrate from MV Aburri barge to larger vessel in the transhipment area	Load out from the MV Aburri to larger transport causes dust emissions and spillage of concentrate, which contaminate the marine environment with lead and zinc	Contamination of seawater and sediments with metals in the transhipment area and surrounds. Biota in the area bioaccumulate metals with unknown lethal and/or sub-lethal/ chronic effects	M	RI	Monitoring of metals and lead isotopes in sediments from the transhipment area, based on the location of anchoring points of bulk carriers. Compare these results with control sites outside the transhipment zones	3	3	6	M	Monitor seawater quality in the transhipment area, particularly in the vicinity of active transfer between the MV Aburri and larger transport vessels.
4.12	Bing Bong Loading Facility	Marine sediment monitoring	Lack of appropriate marine sediment monitoring	Insufficient spatial density and/or inappropriate control sites, application of inappropriate guidelines, and poor optimisation of analytes	Contamination of particular areas is not noticed	M	OM	Marine sediment sampling program at Bing Bong Loading Facility, the trans-shipment area, and nearby marine and nearshore areas	3	3	6	M	· The nearshore sediment Eastern Control group should be moved slightly to the west in the 2016 operational year, to reduce possible impacts/influences of outputs from Mule Creek and thereby be a more useful control group · Present QA/QC information for marine sediment analysis as part of the MMP reporting of laboratory results

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4.12	Bing Bong Loading Facility	Marine sediment management	Lack of appropriate marine sediment management	Contamination of marine sediments in the nearshore and/or offshore environment due to poor quality surface runoff, concentrate spillage or dust deposition	Consequent impacts on marine environments and ecology, and potentially health of people consuming fish and shellfish	M	OM	Measures to manage marine sediment quality include dust management and surface water management	3	3	6	M	See dust recommendations
4.12	Mine site and Bing Bong Loading Facility	Soil monitoring	Lack of appropriate soil monitoring	Insufficient spatial density and/or inappropriate control sites, application of inappropriate guidelines, and poor optimisation of analytes	Contamination of particular areas is not noticed	L	WM	Soil sampling program at mine site and Bing Bong Loading Facility	4	3	7	M	· The next version of the MMP as well as all future soil monitoring reports should evaluate soil monitoring data within the context of the revised NEPM (1999) (as amended, 2013) ·Soil site S05 should be removed from the sampling program, as it is neither an appropriate control site nor a mine 'impact' site. A replacement reference site will be required away from the quarry in a more 'natural' location · A replacement site for S43 should be established in the vicinity of Barney Creek haul road bridge, but situated on an area of natural (in situ) soils · A gap in soil monitoring remains between S47 and S31. MRM should consider installing a soil monitoring site in this area during the 2016 operational year The next soil monitoring report to be prepared by MRM should: · Review results from surface soil sites S28 and S44 within the context of long-term trends to clarify reasons for Pb HIL exceedances and the variation in results between years · Review long-term trends in Mn results across the mine site to assess the likely cause of widespread Mn EIL exceedances · Present QA/QC information for soil analysis as part of reporting of results
4.12	Mine site and Bing Bong Loading Facility	Surface soil management	Lack of appropriate surface soil management	Contamination of surface soils due to direct/ localised contamination, depositional dust, or groundwater seepage	Consequent impacts on vegetation, with adverse impacts on terrestrial fauna or livestock; potential for runoff to transport contaminated soil, with flow-on effects to aquatic environments	L	WM	Measures to manage surface soil quality include dust management, surface water management, and removal and stockpiling of topsoil prior to undertaking activities that may result in contamination of soil	4	3	7	M	· If the next sampling event shows an increase in Pb at S42, MRM should investigate the reason for these temporal fluctuations at this site
4.12	Mine site and surrounds	Fluvial sediment monitoring	Lack of appropriate fluvial sediment monitoring	Insufficient spatial density and/or inappropriate control sites, application of inappropriate guidelines, and poor optimisation of analytes	Contamination of particular areas is not noticed	M	OM	Fluvial sediment sampling program at creeks, rivers and diversion channels in and surrounding the mine site	3	3	6	M	· Present QA/QC information for fluvial sediment analysis as part of the MMP reporting of laboratory results · Data for reinstated fluvial sediment site FS20 should be reported in the 2016 operational year · The potential input of major ions to FS04 should be investigated during the 2016 operational year · Fluvial sediment monitoring at FS08 should be reinstated in the 2016 operational period
4.12	Mine site and surrounds	Fluvial sediment management	Lack of appropriate fluvial sediment management	Contamination of fluvial sediments due to poor quality seepage and/or surface runoff, the risk of TSF embankment failure, neutral or saline leachate from wate rock, or input of depositional dust	Consequent impacts on aquatic environments and ecology, and potentially health of people consuming fish	M	OM	Measures to manage fluvial sediment quality include dust management, surface water management, and various sediment/silt traps and related controls surrounding Barney Creek bridge	3	3	6	M	Given ongoing contamination issues at FS19, MRM should: · The remaining open drain holes in Barney Creek haul road bridge should be closed, with runoff directed into silt traps on either side of the bridge · As well as being cleaned out annually after the wet season, silt traps at Barney Creek haul road bridge should be inspected periodically and cleaned out as required at other times of the year, e.g., in the early wet season/before significant floods are experienced (taking into account logistical constraints) · The ongoing monitoring of water quality in silt traps at the haul road bridge during the wet season, along with dewatering of poor quality water in the SE and NW traps to Pete's Pond/SPSD/SPROD, should continue
4.13	Bing Bong Loading Facility	Dust migration	Concentrate storage at Bing Bong Loading Facility	Emissions of dust from the Bing Bong Loading Facility concentrate storage shed, and from road vehicles at the facility, to the marine environment	Heavy metal contamination of seawater, marine sediments and potentially marine biota	M	Loc	Dust monitoring program and dust mitigation measures including maintenance of a negative pressure differential and dust extractor system in the concentrate shed to reduce dust fugitive emissions A new TEOM dust sampler has been installed at the Loading Facility near the accommodation area	4	2	6	M	· The doors of the concentrate shed should be repaired so that they can be closed except during truck access and egress; this is also important so that the dust extractor system in the concentrate shed can operate effectively Data from the new TEOM dust sampler should be reported in 2016 · Duplicate and field blank sampling should be initiated, as for the mine site The IM recommends that MRM review and present all available long-term dust data (in particular, PM10 and Pb results) for loading facility, to inform understanding and management of dust issues · MRM should develop a formal dust mitigation plan for Bing Bong Loading Facility, targeting the most impacted areas as identified by dust monitoring (i.e., BBDMV02 and BBDMV07)
4.13	Bing Bong Loading Facility	Dust migration	Concentrate loading onto MV Aburri and from MV Aburri onto export vessels	Fugitive dust emissions to the marine environment	Heavy metal contamination of seawater, marine sediments and potentially marine biota	L	OM	Dust monitoring program and dust mitigation measures including covered conveyor belt, and washdown of the concrete apron after each ship loading event	4	3	7	M	NIL

Report Section	Asset	Consideration	Hazard / Aspect	Incident / Event	Consequence / Impact	Potential duration of impact	Location of impact	Existing Controls/ Monitoring and Assessment undertaken	Consequence	Likelihood	Matrix Result	Risk Rating	Additional Controls, monitoring , assessment or actions required
4.13	Crushing plant and ROM	Dust emissions	Operation of ROM Pad, crushing plant and bulk concentrate stockpile at the mine site	Fugitive dust emissions from processing plant facilities	Heavy metal contamination of water and fluvial sediments in receiving waterways and diversion channels, and potential bioaccumulation in freshwater biota	M	Loc	Extensive dust monitoring program including: · a new high-volume air sampler installed between the primary crusher and Barney Creek, and a TEOM unit has been installed near the mine site accommodation area · duplicate and blank sampling has been initiated as part of QA/QC in 2015 Dust mitigation measures at curshing plant and ROM pad include: · Covered dust generation points, including transfer points between conveyors and at the base and top of the secondary crusher · Water addition point to the head drum of the stockpile feed conveyor. A booster pump and spray bar for the head drum to improve suppression of dust as the crushed material falls to the stockpile surface · Watering around the general area by water trucks. · Use of water sprays in the primary crushing plant and conveyors. · Double-layered skirting on horizontal rubber guarding. · A dust extraction system has been fitted to the secondary tertiary crusher building At the bulk concentrate stockpile, MRM has removed the top layers of the existing compacted pad and poured a concrete base which is graded towards contaminated water drainage systems · A mini street-sweeper, used around the process plant to remove small spills · Crushing facility has been relocated and is now further away from Barney Creek at the WOEF	4	2	6	M	· Data from the new high-volume air sampler and TEOM dust sampler should be reported in 2016 · The IM recommends that the frequency of monitoring for PM10 and Pb be temporarily increased at two high impact sites at the mine site, and one reference site, to be sampled once every 6 days for a 1-year period, in order to determine whether the current monthly monitoring approach is statistically valid · The IM recommends that MRM review and present all available long-term dust data (in particular, PM10 and Pb results) for the mine site, to inform understanding and management of dust issues
4.13	Mine site	Dust emissions	Operation of the TSF, NOEF, WOEF, SOEF and haul roads	Dust emissions from exposed areas of facilities and haul roads	Heavy metal contamination of water and fluvial sediments in receiving waterways and diversion channels, and potential bioaccumulation in freshwater biota; deposition of dust on vegetation with potential uptake by terrestrial biota	M	Loc	Measures to control dust include: · Regular watering of haul roads, ore stockpiles, exposed construction areas and other exposed areas around the project site, subject to vehicle and machinery movements. · At the NOEF, operation of two water carts that spray the operating 'muck piles', roads and dumps. In addition, a compacted clay liner was placed over PAF material before the 2014/15 wet season, which helps to encapsulate potentially contaminated materials that could be mobilised via wind. · At the TSF, tailings deposition rotation via the use of the spigots around the periphery to keep the exposed tailings surface damp, thereby reducing dust generation. Capping of TSF Cell 1 with a clay layer to minimise generation of tailings dust.	4	2	6	M	MRM should develop a formal plan for dust minimisation in the vicinity of DMV43. This may be part of a formal dust mitigation plan for the mine site as a whole, targeting the most impacted areas as identified by dust monitoring An area immediately east of the decant wall on the TSF Cell 2 north wall is not being covered by tailings during the current deposition cycle. Discharge pipelines should be extended to this area to reduce dust emissions from this area
4.13	Vehicluar transport fleet	Dust emissions	Loading of concentrate onto transport vehicles at the mine site/transport of concentrate to Bing Bong Loading Facility	Fugitive dust emissions during loading and transport	Heavy metal contamination of water and fluvial sediments in receiving waterways and diversion channels, with potential bioaccumulation in freshwater biota; deposition of dust on vegetation with potential uptake by terrestrial biota	M	OM	Extensive dust monitoring program and dust mitigation measures including covered dust generation points, watering for dust suppression around the mine site and NOEF by water trucks, dust extraction system fitted to the crusher building, washdown of all vehicles prior to leaving the mine site for Bing Bong Loading Facility and other destinations, maintenance of a dust extraction system and wet scrubber in the concentrate shed, and street sweeper used around the site and in particular the concentrator to remove dust which has settled to the ground, truck wheel-wash facilities and covers on concentrate transport vehicles	3	2	5	H	The bitumen surface surrounding the Bing Bong Loading Facility is failing in a number of areas, with formation of potholes apparent. These should be repaired to avoid future soils, water and/or dust management issues

Appendix 3

Gap Analysis

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category 1	Gap Category 2	Gap Category 3	Recommendations/ Comments
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	General documentation and reporting needs improving		x		There needs to be consistency between on-site water management practice, the MMP and water balance modelling reporting. The water balance modelling reporting needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	MMP water management gap analysis needs improving		x		The water management gap analysis in the main body of the MMP should be reconfigured to provide: – Specific and measureable actions – Estimated commencement and completion times – An 'effectiveness ranking' of the impact the task will have on the site water balance – A 'priority ranking' for completing the task. This will most likely be based upon the results of a cost-benefit analysis The MMP gap analysis should be updated regularly (e.g., every 6 or 12 months) and produced as a separate document, outside of the MMP
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	The water balance modelling documentation and reporting needs improving		x		• It is recommended that more tables are used to improve clarity, understanding and error checking • Sensitivity analysis results should be consolidated in one section of the water balance modelling report Increased detail is required in the reporting of the following: • The rainfall-runoff model calibration, in particular how calibration was undertaken and how parameters were adjusted • The water balance model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted • The monitoring of water balance components, in particular what is monitored, the frequency of monitoring and the accuracy of the measurement • How the monitoring data is used in the water balance modelling
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	Insufficient water balance sensitivity testing is undertaken		x		Changes in climate: The possible impact of climate change on the site water balance needs to be addressed Changes in water chemistry: • The water balance needs to assess the risks posed by possible deterioration in site runoff and seepage water quality • The adopted change in site water quality needs to be justified with: – Current water quality monitoring data and/or predictions (e.g. pond water quality estimates, TSF/NOEF seepage estimates). – Input from professionals with expertise in geochemistry. Modelling of multiple years: An assessment of three consecutive years with the same site configuration should be undertaken Pump or pipe failure: An assessment of the impact of pump or pipe failure should be undertaken Sensitivity analysis: Needs to be undertaken for all subsequent annual water balance modelling reports

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.2	Mine Site	Water Balance	TSF Cell 2	The risk and impact of TSF Cell 2 spills contaminating water stored in the WMD, thereby making it unsuitable for off-site has not been assessed	x			The risk and impact needs to be assessed
4.2	Mine Site	Water Balance	TSF Cell 2	The risk of spills from the TSF Mini Dam to the WMD, thereby making it unsuitable for off-site release, has not been assessed	x			The risk and impact needs to be assessed
4.2	Mine Site	Water Balance	TSF Cell 1	The MRM intent of improving TSF Cell 1 runoff quality is not reflected in current management of the cell's clay capping.		x		This needs to be resolved
4.2	Mine Site	Water Balance	Mine Site	Wet season rainfall totals too far from the mean are treated as unusual events that require a unique response.		x		MRM needs to develop their surface water management system to the point where there is sufficient capacity that variation in rainfall between years (and sequences of consecutive wet/dry years) is treated as business as usual and not something abnormal
4.2	Mine Site	Water Balance	Underground void/open cut	The underground void/open pit is used for water storage		x		MRM needs to provide a medium to long-term plan which resolves the conflict between mine operations and using the underground void/open pit as a water storage
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	The uncertainty in model parameter estimation requires reduction		x		While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: • The amount of simultaneous calibration of multiple parameters needs to be reduced • Evaporation fan/sprinkler/fountain performance needs to be accurately quantified • Groundwater inflow rates need more accurate estimation • Seepage rates need more accurate estimation • Runoff rates need more accurate estimation • A strategy needs to be developed to reduce predictive uncertainty over time
4.2	Mine Site	Water Balance	Bing Bong Loading Facility	Surface water monitoring has been ceased at Bing Bong Loading Facility	x			Surface water monitoring at Bing Bong Loading Facility needs to be resumed
4.3	Mine Site	Surface WQ	River monitoring	Installation of a real time in situ monitoring capability at all relevant sites is yet to be completed		x		Issues associated with installing this capability at SW11 should be resolved
4.3	Mine Site	Surface WQ	River monitoring	No reporting of mine-derived and background loads			x	Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river. Load calculations (and mine-site load balances) should take into account current and predicted natural and mine-derived loads, and seasonal variation. The results should be used to rank mine-associated contaminant sources and hence prioritise management and mitigation actions
4.3	Mine Site	Surface WQ	River monitoring	Additional data interpretation			x	Further interpretation and analysis of data should be presented in the MMPs, including further detail about water quality changes with river/stream flow (over single flood events if necessary) and mine-derived influences (including mine-derived loads)
4.3	Mine Site	Surface WQ	River monitoring	Additional data interpretation			x	Comparison of metal and metalloid results with ANZECC/ ARMCANZ (2000) values should include the 95th percentile values

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.3	Mine Site	Surface WQ	River monitoring	Reinstatement of monitoring program component		x		Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows)
4.3	Mine Site	Surface WQ	River monitoring	Additional data interpretation			x	Further analysis is required concerning surface water TSS data and the risk posed by mine-derived suspended particulates on downstream beneficial uses, including consideration of flood event sampling if necessary
4.3	BBLF	Seawater quality	Surface water/ seawater monitoring	Additional data interpretation			x	Further analysis is required concerning surface water/seawater TSS data and the risk posed by BBLF-derived suspended particulates on nearby beneficial uses, including consideration of additional sampling sites if necessary
4.3	BBLF	Seawater quality	Seawater monitoring	No current water quality monitoring in trans-shipment area	x			The feasibility of deploying DGTs to monitor seawater quality in the trans-shipment area during transfer of the concentrate should be determined
4.4	Mine Site	Hydraulics	McArthur River and Barney Creek Diversion Channel	Erosion identification and quantification		x		Ongoing monitoring of channel and bank erosion should be undertaken utilising the ALS surveys complimented by photograph monitoring, and visual inspection. No monitoring has been reported in the 2014-2015 operational period
4.4	Mine Site	Hydraulics	Mine Levee Wall	Monitoring of erosion along the mine levee wall		x		It is recommended that erosion along the levee wall is monitored and reported on
4.5	Mine Site	Groundwater	Groundwater Resource	Assessment of impacts from groundwater production		x		An annual independent hydrogeological report should be prepared by suitably qualified hydrogeologist to evaluate effects of groundwater production on the groundwater and surface water environments
4.5	Mine Site	Groundwater	Groundwater Quality	Lack of site specific groundwater quality trigger levels	x			Groundwater quality trigger values are currently based upon guideline limits for livestock (ANZECC 1992). These should be updated to reflect the actual background water quality taking into consideration the surrounding ecosystems and environment in accordance with the approach presented in ANZECC 2000
4.5	Mine Site	Groundwater	Groundwater Quality	Assessment of seepage processes and impacts on the groundwater environment			x	There is insufficient interpretation of groundwater monitoring results to identify processes controlling seepage and contaminant migration from the TSF, NOEF and water storages. This interpretation should be carried out as part of the MMP and annual groundwater review
4.5	Mine Site	Groundwater	Groundwater Environment	Assessment of groundwater models			x	There will be an increasing reliance on groundwater models to predict seepage impacts and identify suitable mitigation methods. It is important that all groundwater models are independently assessed by a modelling specialist to help ensure they are fit for purpose, adequately calibrated and the uncertainties are identified
4.5	Mine Site	Groundwater	Background Groundwater Conditions	The background groundwater quality and levels should be assessed prior to future development	x			The background groundwater quality and levels should be assessed in areas schedule for future development (e.g. extension of the NOEF). This should include installation of new monitoring bores and geophysical surveys ahead of development
4.5, 4.12 and 4.13	Mine Site /BBLF	Soil & sediment quality, dust and groundwater	Soil, fluvial sediment, marine sediment, dust and groundwater reporting	Addressing guideline exceedances			x	Exceedances of the various guideline levels for soils and sediments, dust and groundwater should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	pXRF criteria for field classification have been calibrated based on only limited data (approx. 50 samples) and the correlations for S, Zn, Pb and Cu show significant scatter			x	Check calibration of hand-held XRF with new ICP check data

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category 1	Gap Category 2	Gap Category 3	Recommendations/ Comments
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	The pXRF monitoring system is likely to always have some uncertaity relative to ICP methods and may not necessarily be cost effective if onsite ICP testing capability is availible		x		Progress use of on-site ICP testing to replace pXRF
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	The frequency of check sampling of dumped materials is insuffient		x		Increase the frequency of check sampling of dumped materials, particularly for LS-NAF
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Criteria for PAF(RE) require more development to provide confident identification		x		Develop criteria that provide more confident identification of PAF(RE) and check whether the current 10%S cut off is too high and needs to be lowered to 8.5%S
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	A reconcilliation of block model predicted tonnages by waste rock type against tonnages actually mined was not provided for the current IM report period			x	Reconcile the block model predicted tonnages by waste rock type against tonnages actually mined, and adjust block model if required
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	The extent and impact of groundwater contamination from the NOEF not well understood			x	Carry out further investigation and analysis of monitoring data
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Uncertain proportions of geochemical rock types in NOEF		x		Carry out more drill testing of dumped materials in the NOEF to more confidently define the distribution of historically dumped materials and check the reconstruction of dump material types based on the new block model
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Uncertain proportions of geochemical rock types in WOEF		x		Review/compile existing data and/or carry out a test programme to confirm the distribution of geochemical rock types at the WOEF and finalise closure options
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Potential impacts from MS-NAF placed in SOEF uncertain		x		Review kinetic test results and assess potential impacts on receiving drainage during operations, and finalise closure options
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Waste rock cover performance not verified		x		Set up instrumented dump cover trials as planned
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	A new method is required to control infiltration into the NOEF during operations		x		Carry out trials into infiltration control with the aim of impementation prior to the next wet season
4.6	Mine Site	Geochemistry	Tailings Geochemistry	The effects and impacts of oxidation and acid, salinity and metal/metalloid generation from the more extensive tailings beach in Cell 2 is not well understood	x			Monitor sulfphide oxidation and pore water quality in beach tailings during operations to check for evidence of acid and salinity production
4.6	Mine Site	Geochemistry	Tailings Geochemistry	ANC values vary between laboratories and it is uncertain which best represents the effective ANC		x		Further checks should be carried out with other laboratories with inclusion of ABCC testing.
4.6	Mine Site	Geochemistry	Tailings Geochemistry	No final TSF cover design and no performance checks	x			Produce a final TSF cover design and carry out field trials to measure performance and develop construction methods
4.6	Mine Site	Geochemistry	Open Pit	Preliminary pit water modelling was carried out but only considered a 100 year timeframe		x		Extend pit void quality modelling to a longer period and assess the possibility of the pit lake ultimately acidifying under different assumptions
4.6	Mine Site	Geochemistry	Mine Site	Some testing was carried out of waste rock materials placed outside of the NOEF but it is incomplete.	x			Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in situ sulfidic materials at the Barney Creek diversion channel and McArthur River diversion channel

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category 1	Gap Category 2	Gap Category 3	Recommendations/ Comments
4.6	BBLF	Geochemistry	Bing Bong Dredge Spoil	There is no acid sulfate soil assessment of the spoon drain around the dredge spoil ponds and other potential sources at Bing Bong Loading Facility	x			Carry out acid sulfate soil assessment of spoon drain and other potential sources at Bing Bong Loading Facility
4.7	Mine Site	Geotechnical	TSF Cell 1	Seepage monitoring		x		Further monitoring is required to improve quantification of seepage rates from Cell 1 towards Surprise Creek. Currently there is no strategy in place to manage this seepage
4.7	Mine Site	Geotechnical	TSF Cell 1	Safe operating limits			x	Beach angles should be confirmed from the annual bathymetry survey (or other reliable means) to confirm maximum pond height to accommodate design storm event. Last survey was 5 June 2014
4.7	Mine Site	Geotechnical	TSF Cell 2	Earthworks verification		x		Quality control records for the Raise 3 have not been provided to the DME. The specification was also modified by the ICE with limited evidence that it met design requirements or signoff from the designer
4.7	Mine Site	Geotechnical	CWNOEF	Earthworks quality control		x		The summary QA/QC data provided to the IM fails the specification in terms of frequency and distribution. Records have not been forwarded to the DME as per consent conditions
4.7	Mine Site	Geotechnical	CWNOEF	Basal CCL	x			The summary QA/QC data provided to the IM shows no basal CCL testing over 60% of the approved CWNOEF construction area. This deficiency needs to be explained and if any omission of the CCL fully justified and approved
4.7	Mine Site	Geotechnical	CWNOEF	Design documentation			x	The CWNOEF design (version 2.0) contains a number of errors and omissions that need to be addressed. The IM also recommends a change to the specification so that at least two permeability tests per lot
4.7	Mine Site	Geotechnical	NOEF	Closure modeling		x		Current closure modeling relies upon low confidence permeability estimates. Direct testing should be undertaken to conform these parameters and also their sensitivity checked more thoroughly
4.7	Mine Site	Geotechnical	SOEF	Surface water management and seepage		x		Use of SOEF as a temporary facility for MS-NAF has been approved by the NT Mining Advisory Committee. However monitoring of potentially saline drainage and seepage at the SOEF appears to be limited and should be improved
4.7	BBLF	Geotechnical	Bing Bong Loading Facility Soil Piles	Settlement monitoring		x		Dedicated survey monuments on the embankment crest are required to detect settlement and track over time. The airborne laser survey curently undertaken is unlikely to be able to detect and track settlement accurately
4.7	BBLF	Geotechnical	Bing Bong Loading Facility Soil Piles	Freeboard		x		Include a numerical assessment of the available freeboard in each monitoring report and check against design minimum
4.7	BBLF	Geotechnical	Bing Bong Loading Facility Soil Piles	Monitoring reports			x	Generally improve monitoring reports to include safe operating limits, record adherence to those limits and document corrective action when these limits are exceeded
4.7	BBLF	Geotechnical	Bing Bong Loading Facility Soil Piles	Inspection triggers		x		Inspections should be undertaken monthly and immediately following storm events. This needs to be included in the MMP
4.8	BBLF	Dredge spoil ponds	Closure costs	No closure costs for rehabilitation of dredge spoil ponds	x			Detailed closure costs be prepared for the Bing Bong Loading Facility and that these are presented as a separate domain from the mine closure costs
4.9	Mine Site	Terrestrial ecology	Revegetation	Insufficient surveying of control sites planned in revegetation monitoring program		x		The current survey program outlines that the revegetation sites will be monitored annually while control site will be monitored every three years. It is recommended that analogue sites are monitored annually to provide more timely and comparable data
4.9	Mine Site	Terrestrial ecology	Rehabilitation	Insufficient quantitative assessment of the stability of the channel or erosion levels included in rehabilitation monitoring		x		It is recommended that a landscape function method of assessing the rehabilitation of the diversions is investigated such as Ephemeral Drainage-line Assessment. This method allows the quantitative assessment of the stability of the channel, gives annual quantitative data of erosion change from year to year and guides remedial actions which need to be undertaken

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.9	Mine Site	Terrestrial ecology	Flora	Lack of synergistic weed management with upstream pastoral properties		x		Work in conjunction with pastoral properties upstream on the McArthur river on weed control, with the aim of decreasing likelihood of McArthur river diversion being repopulated with weeds from sources outside of the mine boundary. Will save costs in weed control and promote community relations
4.9	Mine Site	Terrestrial ecology	Flora	Lack of monitoring of flora in Surprise Creek to evaluate effect of TSF seepage	x			Currently there is monitoring in the vicinity of the processing plant and PAF run-off dams, a site at Surprise Creek in the vicinity of the TSF should be added to the program
4.9	BBLF	Terrestrial ecology	Fauna	There is insufficient comparison of migratory shorebird survey data to available long term data collect by Garnett and Chatto since 1987 in the gulf			x	Comparison to data collected in previous surveys would help to discern if fluctuations in species numbers are natural or due to anthropogenic causes. A review of the migratory bird monitoring program should be conducted to determine if it is suitable for assessingwhether MRM is having an impact on migratory birds
4.9	BBLF	Terrestrial ecology	Flora	Trials for dredge spoil rehabilitation	x			Proposal sighted, but has not been undertaken as yet. CDU student failed to commence study
4.9	Mine Site	Terrestrial ecology	Rehabilitation	Lack of long-term planning and accountability for the rehabilitation of the diversion channels		x		There is no specified completion date for the rehabilitation of the diversion channels and no milestones with which to compare performance
4.9	Mine Site	Terrestrial ecology	Rehabilitation	No revegetation monitoring site in the rocky gorge habitat along the diversion channel		x		Include a monitoring site in the rocky gorge area of the McArthur River diversion channel (downstream, below MRR6) along with a suitable control site, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate stage. It is unlikely that areas such as this would meet completion criteria set out for more sloped sites
4.9	Mine site	Terrestrial ecology	Rehabilitation	The list of key and primary flora species used in the rechannel vegetation monitoring program completion criteria is inappropriate		x		Reassess the list of key and primary species to which revegetation on the diversion channels is compared with, as many of those listed are not recorded at control sites. Investigate separate key and primary species lists for McArthur River and Barney Creek as vegetation assemblages as the control sites show different assemblages
4.10	Mine Site	Aquatic ecology	Fauna	Minimal assessment of the effects of the Barney Creek diversion channel and the success of the rehabilitation program on fish and *Macrobrachium* communities		x		Expand the monitoring of aquatic fauna to cover additional survey sites within and outside the Barney Creek diversion channel. Use appropriate regional reference sites if there is no water in Barney Creek, or survey Barney and Surprise creeks as soon as practical after the wet season to ensure that sites contain water
4.10	Mine Site	Aquatic ecology	River Diversion	There is no monitoring of large woody debris persistence and movement in the McArthur River diversion channel	x			MRM should monitor whether large woody debris installed in the McArthur River diversion channel stays in place over the wet season. This can be used to inform woody debris programs in the future, and ensure woody debris placed in the diversion does not move during high flow events
4.10	Mine Site	Aquatic ecology	Fauna	No assessment of how drawdown at Djirrinmini waterhole will impact freshwater fauna	x			MRM should assess the impacts of drawdown at Djirrinmini waterhole on freshwater fauna and assess whether habitat will be lost, especially for freshwater sawfish
4.10	Mine Site	Aquatic ecology	Fauna	No assessment of the proportion of flows at SW19 that are natural versus the proportion that are due to seepage from the TSF and SPROD. In addition there is no assessment of impacts on fauna of the bund constructed in the Barney Creek diversion channel at SW19 to capture contaminated water and sediment	x			MRM needs to assess what proportion of flow during the dry season at SW19 is natural compared with what is due to seepage from the TSF and SPROD. If the bund is stopping natural surface flows, MRM needs to assess the impacts of the reduced flows on sites downstream of the bund

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.10	Mine Site	Aquatic ecology	Movement of contaminated biota	Currently there is no assessment of the movement of contaminated biota and how long biota would need to spend at a site to uptake contaminants	x			As dektop review should use available literature to investigate likelihood and distance of dispersal of contaminated biota from McArthur River Mine, and how long biota would need to spend at a site to uptake measurable levels of metals, in particular lead and zinc
4.10	Mine Site	Aquatic ecology	Fauna, flora, fluvial sediments and water quality	Little synthesis of entire monitoring program, each part (monitoring of water quality, contamination of fluvial sediments and diversity, abundance and contaminants in aquatic fauna) treated in isolation. In addition other monitoring programs, such as dust, soil and groundwater are not included in synthesis			x	An annual monitoring program report, which synthesises data, rather than just reproducing results, would help provide a better overall view of the impacts of mining operations on the aquatic environment. The report could then inform better management of watercourses around the mine, and aid in targeting source of contamination
4.10 and 4.11	Mine Site	Aquatic & marine ecology	Fauna	Currently fauna from all sites have average lead isotope ratios closer to that of the ore body than background levels, hence background levels are inappropriate			x	Using data from control sites and regional reference sites, establish a more relevant background lead isotope ratio
4.11	BBLF	Marine ecology	Flora/Fauna	Lack of documentation regarding current practices involving ballast water from ship at Bing Bong Loading Facility e.g., ballast water source, dumping location	x			Desktop assessment of requirements and current practices with results documented, possibly in SDMMP if not stand-alone document
4.12	Mine Site	Soil & sediment quality	Soil	Insufficient number of sampling locations, which are also limited to dust locations		x		The number of soil samples is currently considered to be insufficient considering the large area of the mining leases. It is recommended that additional soil monitoring locations be included in the soil monitoring program to increase the sample size. As soil is monitored at the dust monitoring locations, increasing the number of dust monitoring locations will also increase the number of soil monitoring locations. We recommend that a complete soil landscape study of the mine leases be conducted in the next 2-5 years to update the study already undertaken as part of the EIS for the Mine's expansion in 2007 In particular, it is noted that soil monitoring gaps include: - A gap between S47 and S31 (between the mine levee wall and the McArthur River diversion channel, to the southeast of the mine pit) - A replacement site for S43 should be established near the haul road bridge, situated on an area of natural (in situ) soils
4.12	Mine Site	Soil & sediment quality	Soil	Inappropriate control site to be replaced		x		Soil site S05 should be removed from the sampling program, as it is neither an appropriate control site nor a mine impact site. A replacement reference site will be required away from the quarry in a more 'natural' location
4.12	Mine Site	Soil & sediment quality	Soil	Lack of site specific trigger levels; assessment framework			x	No site-specific trigger criteria have been derived for the mine site. Developing triggers and general assessment of soil monitoring data will need to take into account the revised version of NEPM (1999)
4.12	BBLF	Soil & sediment quality	Fluvial Sediments	No monitoring of sediments within the McArthur River Delta	x			McArthur River Delta sediments should be included in the fluvial sediment monitoring program. Suspended sediments have not been reanalysed and monitored for lead isotopes to compare with the settled sediments on the delta floor
4.12	BBLF	Soil & sediment quality	Marine sediment monitoring	Reference sites		x		The nearshore sediment Eastern Control group should be moved slightly to the west to reduce possible impacts/ influences of outputs from Mule Creek and thereby be a more useful control group

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Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.12	Mine Site /BBLF	Soil & sediment quality	Soil, fluvial sediment and marine sediment reporting	Presentation of quality assurance data			x	Quality assurance/quality control data for sample analyses, and subsequent discussion, should be presented in the MMP for surface soils, fluvial sediments and nearshore/marine sediments
4.12 and 4.13	Mine Site	Soil & sediment quality	Dust, Soil and Sediments	Background heavy metal concentrations have not been determined			x	Determine background heavy metal levels as recommended in the Independent Monitor Technical Review in order to assess potential mining impacts and current conditions, and improve development of site-specific criteria. It is noted that control sites have been established by the macroinvertebrate assessment and data has been collected that can potentially be used as background heavy metal concentrations
4.13	Mine Site	Dust	Dust monitoring	More intensive monitoring required in areas of highest dust impacts		x		The frequency of monitoring for PM_{10} and Pb should be temporarily increased at two high impact sites and one reference site (e.g., once every 6 days for a 1-year period) to determine whether the current monthly monitoring approach is statistically valid
4.13	Mine Site /BBLF	Dust	Dust monitoring	Review of long-term data required			x	MRM should review and present all available long-term dust data for the mine site and Bing Bong Loading Facility, to better inform understanding and management of dust issues

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