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Appendix J – Reassessment of Risk to Aquatic Fauna from an altered base case of the McArthur River Mine Overburden Management Project

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Environmental

REASSESSMENT OF RISK TO AQUATIC FAUNA FROM AN ALTERED BASE CASE OF THE MCARTHUR RIVER MINE OVERBURDEN MANAGEMENT PROJECT

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Project ID: 17014

Document Control

Revision	Version	Author	Date	Reviewer	Date
A	Internal Draft	J. Keleher S. Longbottom D. Thorburn	31-11-2017	D. Thorburn	02-11-2017
B	Draft to Client	D. Thorburn	02-11-2017	G. Taylor (Glencore) J. Barker (MetServe) C. Wiley (MetServe)	09-11-2017
C	Draft to Client	D. Thorburn J. Keleher	24-11-2017	J. Barker (MetServe)	29-11-2017
D	Draft to Client	D. Thorburn	30-11-2017	J. Barker (MetServe) C. Wiley (MetServe)	06-12-2017
E	Final Draft	D. Thorburn	06-12-2017	G. Taylor (Glencore) J. Hacker (Glencore) P. Bowen (Glencore) J. Barker (MetServe)	12-12-2017
0	Final to Client	D. Thorburn	15-12-2017	Glencore Management	26-02-2018
1	Final to Client	D. Thorburn	27-02-2018		

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1.0 INTRODUCTION

1.1 *Assessment Premise*

Appendix W of the McArthur River Mine (MRM) Overburden Management Project (project) Draft Environmental Impact Statement (EIS) provided information on the aquatic ecology of the McArthur River and tributaries in the vicinity of MRM. That document also assessed the risk of the project to the aquatic fauna and habitat present. As a result of the stakeholder review of the Draft EIS, the review of performance of a number of aspects of the project and updated modelling inputs, several large changes to both infrastructure and management of that infrastructure have been proposed. These changes were outlined by MRM in late 2017 and summarised in the WRM Water and Environment (WRM) (2018) report titled 'Updated Water Balance and Waterways Modelling for the MRM OMP EIS'. That report also provided a revised waterways impact assessment which reflected predicted surface water conditions throughout the project area during operational and closure project stages. In relation to the assessment of potential impacts on surface waters, and subsequently the aquatic fauna and habitat present in the McArthur River, relevant operational period changes included:

- The HDPE lining of the Tailings Storage Facility (TSF) Water Management Dam (WMD); and
- A composite CCL/HDPE liner on the North Overburden Emplacement Facility (NOEF) East Perimeter Runoff Dam (EPROD).

In relation to the post-closure period, proposed changes included:

- The use of a Geo-synthetic Liner (GSL) within the final cover for the NOEF instead of a Compacted Clay Liner (CCL).

In light of the proposed changes to the project and updated modelling results, reassessment of the potential impact on aquatic fauna and habitat of the McArthur River and its tributaries was required. The current assessment, for inclusion in the Supplementary EIS, was therefore based on these changes and the updated water quality modelling outputs provided by WRM (2018).

1.2 *Information Limitations, Updates and Review*

Identification of the potential risks of the project, and rankings of those risks, within the current assessment relied largely on the updated findings of WRM (2018). Updated modelling data of a back flow scenario was not available at the time of reporting with modelling outputs by WRM (2018) based upon a scenario of rapid filling by pumping then simultaneous opening of both the downstream and upstream levee openings to facilitate the flow-through of water. In light of the fact a three stage scenario remains the preferred option for closure of the final void; data from WRM (2016) which was included in the Draft EIS was referred to and used in the assessment of risk for the back flow phase of the Mine Pit Lake closure. Updated groundwater, final void water quality and hydrodynamic modelling outputs were also reviewed in reports by Klohn Crippen Berger (KCB) (2017a, 2017b) and Tropical Water Solutions (TWS) (2017). In addition, details of the GSL and the modelled performance of the proposed cover system were provided by O'Kane (2017). It was apparent that a number of assumptions were incorporated into the surface water modelling undertaken by WRM (2018).

One particularly notable difference between the waterways assessment in the Draft EIS and the updated waterways assessment (WRM 2018) was the significant decline in sulphate (and zinc) concentrations flowing out of the Mine Pit Lake waterbody upon closure. In the Draft EIS, average annual sulphate concentrations in water flowing out from the Mine Pit Lake were estimated as being 1087 mg/L between the years 2060 and 2070, declining to 455 mg/L between the years 2071 and 2100 (WRM 2016). In contrast, the updated waterways model indicated concentrations of 83 mg/L under a mixed scenario and 31 mg/L under a stratified scenario between the years 2060 and 2100 (WRM 2018). As outlined by KCB (2017b), differences in the predicted sulphate concentrations between the two models arose from a number of project and model updates and improvements including:

- The reduced NOEF seepage associated with the GSL cover system;
- The NOEF intercepted seepage being piped to the deeper limnion of the mine pit lake;
- The inclusion of mine stratification in the mine pit lake modelling;
- Inclusion of oxygen depletion mechanics in the mine pit lake water quality modelling; and
- Secondary minerals formed during tailings deposition are assumed to settle and eventually become isolated in the tailings voids

Section 4.2 of Appendix W in the Draft EIS stated that risk rankings and the justifications applied to the identified risks relied heavily on the model predictions being accurate. It also stated that deviation from the modelled predictions would ultimately affect these risk rankings. It was considered critical that ongoing monitoring of surface and groundwater quality be conducted to determine the accuracy of the model predictions. In light of the information available at the time of the current assessment, ongoing monitoring throughout the life of the project to determine the accuracy of modelled predictions remains vital. Indeed, immediate revision of this risk assessment needs to be undertaken in the event model predications are found to be inaccurate.

1.3 Potential Variation to Closure Scenario

In relation to the long-term maintenance of environmental values of the McArthur River region, the Mine Pit Lake and its continual influence on downstream water quality has been considered to be amongst the most significant factors of the project. A three stage closure process has been proposed which includes:

- A period of rapid filling of the Mine Pit Lake by pumping water from the McArthur River,
- Connection of the Mine Pit Lake and the McArthur River via a downstream levee opening to facilitate backflow of water into the Mine Pit Lake during wet season high flow periods, and
- Connection of the Mine Pit Lake and the McArthur River via an upstream levee opening to facilitate the flow-through of water during wet season high flow periods.

It is understood that the progression of the closure through the three stages is dependent upon water quality and the alignment with modelled outcomes. If surface water modelling results under a back flow scenario are found to differ from the expected, whereby water quality in both the Mine Pit Lake and the McArthur River are found to be poorer than that modelled under the current flow through scenario, a review of the current risk assessment needs to be undertaken. Alternative closure scenarios may also be developed, including a scenario where the Mine Pit Lake remains isolated from the McArthur River.

1.4 Approach

Background data on the aquatic fauna and habitat present in the McArthur River and tributaries can be found in Sections 2.0 and 3.0 of Appendix W of the Draft EIS. The current report relates to the assessment of risks associated with the scenario outlined by WRM (2018). The assessment approach was consistent with that presented in Appendix W of the Draft EIS and considered potential risks associated with three project components (domains) outlined in the project description by METServe (2016) including:

- Open cut operation (operation and closure);
- Expansion of the North Overburden Emplacement Facility (NOEF); and
- Development of the existing Tailings Storage Facility (TSF).

2.0 ECOLOGICAL IMPACT ASSESSMENT

2.1 Assessment Process and Risk Identification

Effective risk management requires the potential impacts of an action to be clearly identified and that existing knowledge of the receiving environment and fauna present is sufficient to make informed decisions. Potential impacts of the project were based on the description outlined in Chapter 3 of the project EIS 'Project Description and Justification'. Consistent with the project description assessment of potential impacts on aquatic fauna were considered in relation to broad 'domains' which included:

- Open Cut;
- North Overburden Emplacement Facility (NOEF); and
- Tailings Storage Facility (TSF);

The risk assessment requirements for the project were identified in the Terms of Reference (TOR) for the McArthur River Mine – Overburden Management Project drafted by the Northern Territory Environment Protection Authority (NTEPA) in September 2014. The TOR states that the 'risk assessment should be based on international best practice. Processes for risk management are formalised in Standards Australia / Standards New Zealand (e.g. AS/NZS ISO 31000:2009; HB 436:2004; HB 158:2010; HB 203:2012).'

ISO 31000 for risk management describes a staged process for risk management, which includes the following elements:

- Establishing the Context
- Risk Identification
- Risk Analysis
- Risk Evaluation
- Risk Treatment
- Risk Monitoring

Based on this, the approach taken to assess potential impacts on aquatic fauna was therefore to quantify the risk using a combination of likelihood and consequences to determine the inherent risks of an action (i.e. before the application of any risk mitigation measures) and residual risks after the application of any risk mitigation measures. Tables 1 and 2 outline the likelihood and consequence definitions used during the current study. Likelihood definitions are consistent with those of the Glencore's Corporate Risk Framework. Whilst this Framework was also referred to for consequence definitions these definitions were augmented with those outlined by the 'Leading Practice Sustainable Development Program for the Mining Industry' (Department of Resources Energy and Tourism 2008). This was due to the fact the environmental consequence definitions in the Glencore Corporate Risk Framework are very broad and contained few criteria. As such these were not considered appropriate to assess the risk of impact to a sufficient level when considering potential effects on a complex aquatic ecosystem. Table 3 indicates the risk rating matrix which is based on the Glencore's Corporate Risk Framework.

Table 1. Likelihood Definitions

Basis of Rating	E - Rare	D - Unlikely	C - Possible	B - Likely	A - Almost certain
Lifetime	Unlikely to occur during lifetime	Could occur about once during a lifetime	Could occur more than once during a lifetime	May occur about once per year	May occur several times per year
or	or	or	or	or	or
Project or trial or fixed time period	Very unlikely to occur	More likely NOT to occur than to occur	As likely to occur as not to occur	More likely to occur than not occur	Expected to occur
or	or	or	or	or	or
New process / plant / R&D	No known occurrences in broader worldwide industry	Has occurred at least once in broader worldwide industry	Has occurred at least once in the mining / commodities trading industries	Has occurred at least once within Glencore	Has occurred several times within Glencore

Table 2. Environment Consequence Definitions.

Consequence	Description
5 - Catastrophic	• Serious long-term impairment of ecosystem function • Off lease • Local extinctions are imminent/immediate or population no longer viable • Long term and possibly irreversible damage to one or more ecosystem functions
4 - Major	• Extensive deleterious effect on valued ecosystem component with medium-term impairment of ecosystem function. • Off mine lease, d/s catchment • Measurable changes to the ecosystem components with a major change in function • Detectable change to population size and/or behaviour, with no detectable

	impact on population viability, or dynamics • Recovery 5-20 years
3 - Moderate	• Deleterious effect on valued ecosystem component • Within mine lease • Measurable changes to the ecosystem components without major change in function • Detectable change to population size and/or behaviour, with no detectable impact on population viability • Recovery 1-5 years
2 - Minor	• Minor localised or short-term effects • Within domain • Measurable changes to the ecosystem components without major change in function • Detectable change to population size and/or behaviour, with no detectable impact on population viability • Recovery 6-12 months
1 - Negligible	• No observable effect • No detectable change outside natural variation/occurrence

Table 3. Risk Rating Matrix. Risk classifications include L: Low, M: Moderate and H: High.

	E - Rare	D - Unlikely	C - Possible	B - Likely	A – Almost Certain
5 Catastrophic	15 (M)	19 (H)	22 (H)	24 (H)	25 (H)
4 Major	10 (M)	14 (M)	18 (H)	21 (H)	23 (H)
3 Moderate	6 (L)	9 (M)	13 (M)	17 (H)	20 (H)
2 Minor	3 (L)	5 (L)	8 (M)	12 (M)	16 (M)
1 Negligible	1 (L)	2 (L)	4 (L)	7 (M)	11 (M)

The TOR outlined a series of 'Environmental Objectives' (NTEPA 2014). When conducting this risk assessment these objectives were referenced with those for water, biodiversity, and rehabilitation and mine closure considered particularly relevant when assessing the potential impacts to aquatic fauna and habitat. The Environmental Objectives included:

- Water
    - Ensure that ground and surface water resources and quality are protected both now and in the future, such that ecological health and land uses, and the health, welfare and amenity of people are maintained.
- Biodiversity

  - To maintain the conservation status, diversity, geographic distribution and productivity of flora and fauna at species and ecosystem levels through the avoidance or management of adverse impacts; and
  - To minimise the risk of significant impacts to EPBC Act listed threatened species and communities during construction, operation and closure of the altered project
- Rehabilitation and Mine Closure
  - As far as practicable, rehabilitation achieves a stable and functioning landform which is compatible with the surrounding landscape and other environmental values; and
  - The risks associated with closure and rehabilitation of the project, including the ongoing generation of AMD and contamination of the downstream environment, can be mitigated

In determining management controls, the following hierarchy of control principles was also adopted:

- Elimination of the Hazard;
- Substitution with a lower risk activity or product;
- Engineering solutions to reduce the impact of the Hazard;
- Implementation of administrative procedures to control the Hazard; and
- Clean up or remediation measures to mitigate impacts after an event.

2.2 Risk Assessment

Table 4 presents the ecological risk assessment undertaken in relation to aquatic fauna. A total of 28 project aspects were identified based on the project description provided by METServe (2016) and the updated scenario presented by WRM (2018). In addition to mitigation measures outlined in the project description, this risk assessment considers additional measures defined in this report. Expanded discussion of these measures is outlined in Section 3.0.

Rankings and the justifications applied to these risks were also based on the project description and relied heavily on model predictions provided being accurate. Deviation from the modelled predictions will ultimately affect these outputs. Ongoing monitoring is to be conducted to determine the accuracy of the model predictions, and subsequent risk assessments are to be undertaken in the event model predications are found to be inaccurate.

Table 4. Environmental Risk Assessment indicating rankings (R) for inherent risk (based on existing mitigation and management actions) and residual risk (based on existing and additional mitigation and management actions). Risk rankings were quantified by comparing the likelihood (L) and consequence (C) definitions outline in Section 2.1. Proposed new project aspects (which have no existing mitigation or management) are indicated by N/A. Justifications are based on information provided by MRM. As these justifications rely heavily on model predictions, deviation from the modelled predictions may ultimately affect these outputs.

#	Activity/Aspect and Potential Hazard	Potential Impact	Existing Mitigation and Management	Inherent L	Inherent C	Inherent R	Additional Mitigation and Management	Residual L	Residual C	Residual R	Justification
	Open Cut: Operation										
1	Discharge of contaminated site waters into Barney Creek and McArthur River.	- Reduction in water quality at discharge point and downstream including the McArthur River. - Localised effect on habitat quality and fauna from, for example, elevated metal concentrations, sulphates or changes in pH. - Exceedance of Site Specific Trigger Values (SSTVs) at SW11.	- Adherence to Waste Discharge Licence (WDL) conditions and discharge of waters with the appropriate dilution ratio. The WDL outlines specific discharge locations, various waters which can be discharged and environmental objectives. Conditions include: - Prior to discharge water quality assessment determines discharge frequency and rate; - Periodic monitoring is conducted during discharge; - Discharge conducted only when receiving waters are at sufficient flow to facilitate mixing and contaminant dilution; and - Monitoring of McArthur River water quality downstream at SW11 and adherence to SSTVs.	C	1	4 (L)	- Treatment and/or storage of 'high risk' waters (i.e. Class 4-6 as per WRM 2016). - Adherence to annual Water Management Plan (WMP) - Construction of a 6 ML/d RO Plant will commence in November 2017 to treat poorer quality mine affected water, with its capacity upgraded to 15 ML/d in November 2020. In addition a 2 Module 'lime treatment plant' will be constructed to treat PbOx water and brine from the RO water treatment plant for recycling back through the Mill circuit (WRM 2018). - Strategy to pump excess poor quality waters to the pit void if the water management system cannot cope and an environmental impact could be expected if waters were released.	C	1	4 (L)	- Demonstrated adherence to WDL conditions and compliance at SW11 including SSTVs. - Low risk of large volumes of high contaminant concentrations being released. In the event 'high risk' waters are unintentionally released, discharge volumes would be small and likely loads highly diluted under flood conditions. - Incident reporting and investigation (including any remedial works recommendations) in the event SSTVs are exceeded.
2	Mining below groundwater level leads to drawdown in adjacent McArthur River and creeks.	- Reduced river height and groundwater supplementation. - Reduced water level in refuge pools in the late dry season including Djirrinmini Waterhole. - Reduction in habitat availability and loss of ecological function.		A	3	20 (H)	- Assessment of drawdown effects during mining phase including change in river height and fauna response. This should include a comparison to historical dry season water heights at permanent waterholes (e.g. Djirrinmini Waterhole). - Supplementary flow provided to permanent refuge pools such as Djirrinmini Waterhole should water levels be found to be atypical of seasonal variation.	C	3	13 (M)	- Drawdown predicted to occur during mining and pit filling phases (up to 2047). - Modelling predicts groundwater drawdown at Djirrinmini to be a maximum of 0.7 m and that recovery will occur within ten years after termination of mining (KCB 2016a). As a majority of Djirrinmini has less than two metres water depth in the late dry season, a decrease of 0.7 m will reduce available habitat. Supplementary flow may be used to maintain water levels during the period of peak drawdown to maintain habitat present. - Modelling predicts pit drawdown decreases rapidly once pit filling has commenced (KCB 2016b).
3	Increased rate of production and higher frequency of heavy vehicles movements on haul road increase dust and runoff into Barney and Surprise Creeks.	- Increase in total suspended solids (TSS) and metals in surface water and sediments. - Subsequent increase in metal concentrations in creek sediment and uptake by aquatic fauna which exceed reference concentrations on an ongoing basis. - Transport of metal-laden sediment into McArthur River proper and measureable increase in metal concentration in fauna at SW11. - Reportable environmental incident.	- Adherence to Dust Management Plan including ongoing dust monitoring and contingency for increased management. - Dust suppression through use of watercarts. - SW19 specific management including sediment traps adjacent to the haul road and creek batters to catch runoff. Periodic removal of sediment from sediment traps and ongoing maintenance. - Erection of bund on downstream end of SW19 to capture water and sediment and thus carriage into McArthur River during operation. - Mechanical excavation and removal of sediment from SW19. - Monitoring of McArthur River water quality downstream at SW11 and adherence to SSTVs. - Annual monitoring of fauna tissues at SW19, reference and downstream locations to	B	2	12 (M)	- Installation of Barney Creek Sump 2 (BCS2) will capture water prior to reaching the McArthur River in low to moderate flow events. - Monthly monitoring of water quality and fluvial sediment to determine metal loads and setting criteria for additional management.	B	2	12 (M)	- Historical evidence shows existing mitigation measures employed to supress dust and capture run-off has effectively reduced metal concentrations in fluvial sediments and subsequently fauna (Indo-Pacific Environmental 2016a).

#	Activity/Aspect and Potential Hazard	Potential Impact	Existing Mitigation and Management	Inherent L	Inherent C	Inherent R	Additional Mitigation and Management	Residual L	Residual C	Residual R	Justification
			ascertain potential effect on aquatic biota and determine whether metals are entering food chain.								
	Open Cut: Closure										
4	Presence of exposed non-benign or acidic rock in pit and interaction with Mine Pit Lake water.	- Continual influence on Mine Pit Lake water quality with pH, electrical conductivity (EC) and/or metal concentrations of water beyond fauna tolerances. - Effects on water quality within receiving waters downstream upon release. - Adverse effect on aquatic habitat and fauna within and downstream of the Mine Pit Lake. - Exceedance of SSTVs at SW11 post mixing.	N/A				- Rapid filling of the Mine Pit Lake via pumping to reduce interaction between oxygen and potentially reactive rock. - Demonstration of acceptable water quality within the Mine Pit Lake prior to re-directing a portion of McArthur River waters into the Mine Pit Lake during high flow periods. - Regular inflow of river water will dilute the Mine Pit Lake and counteract effects of evapoconcentration (KCB 2017b). - Adaptive management allows for potential water treatment methods (for example, reverse osmosis) to improve Mine Pit Lake water quality. - Routine ongoing monitoring to determine accuracy of predictive modelling. - Routine ongoing monitoring to determine output water quality. Monitoring should continue until water quality is determined to be stable and acceptable for discharge. - Contingency to isolate the Mine Pit Lake from McArthur River should water quality of the Mine Pit Lake be determined to be causing detrimental and ongoing impact to the McArthur River.	C	2	8 (M)	- Pit wall rock is considered to have a lower reactivity due to absence of oxygen within the hypolimnion of the final Mine Pit Lake (KCB 2016b). - Modelling predicts limited mixing of water will occur below 50 m AHD and that the strength of stratification will ensure that the Mine Pit Lake does not completely mix under a flow-through scenario (TWS 2017). Outflows will therefore largely reflect river water contributions (inflows) post-flooding. - Comparison of the stratification case and mixing case models found surface water concentrations to be generally comparable, suggesting that surface water concentrations at SW11 are not sensitive to mixing of the Mine Pit Lake (WRM 2018). - Modelling predicts that a moderate salinity, neutral pH and low metal (Zn, As and Pb) Mine Pit Lake can be obtained (KCB 2017b). - Post-closure surface water modelling predicts Mine Pit Lake outflow concentrations for the mixing case (i.e. worst case scenario) of sulphate (up to 83 mg/L) and zinc (up to 13.8 µg/L) into the McArthur River are elevated when compared with inflow concentrations from the McArthur River (up to 3.4 mg/L for sulphate and 2.6 µg/L for zinc). These concentrations are however well below the SSTVs at SW11. Annual average concentrations of sulphate and zinc are predicted to decrease over time with ongoing annual flows from the McArthur River (WRM 2018). - Output from the Mine Pit Lake is predicted to occur for up to 40 days per year and during peak flow events associated with the wet season only (WRM 2018). These waters will be subject to high dilution once mixed with waters from the McArthur River. - Post-closure surface water modelling predicts sulphate, Zn, Pb and As to remain below Site Specific Trigger Values at downstream compliance point (SW11) (WRM 2018). - Connection to the McArthur River will not occur until water quality is determined to be stable and acceptable for discharge.
5	Placement of non-benign or acidic tailings into pit.	- Continual influence on Mine Pit Lake water quality with pH, EC and/or metal concentrations of flood water beyond fauna tolerances. - Mine Pit Lake water quality effects on receiving waters downstream upon	N/A				- Pumping of more concentrated water out of pit during tailings deposition will occur to remove contaminant mass. - Rapid filling of the final void via pumping and demonstration of acceptable water quality prior to re-directing a portion of McArthur River	D	2	5 (L)	- Regular addition of river water will dilute Mine Pit Lake and counteract effects of evapoconcentration (KCB 2016b). - Significant water coverage will reduce reactivity of tailings due to absence of oxygen. - Modelling predicts limited mixing of water will

#	Activity/Aspect and Potential Hazard	Potential Impact	Existing Mitigation and Management	Inherent L	Inherent C	Inherent R	Additional Mitigation and Management	Residual L	Residual C	Residual R	Justification
		release. - Adverse effect on aquatic habitat and fauna within and downstream of the Mine Pit Lake. - Exceedance of SSTVs at SW11post mixing.					waters into the Mine Pit Lake during high flow periods. - Limited connectivity to the McArthur River through downstream and upstream levee openings designed to facilitate inflow of river water for dilution. - Monitoring of McArthur River water quality downstream at SW11 and adherence to SSTVs. - Adaptive management allows for water treatment methods to improve Mine Pit Lake water quality. - Routine ongoing monitoring to determine output water quality. Monitoring should continue until water quality is determined to be stable and acceptable for discharge. - Contingency to isolate the Mine Pit Lake from McArthur River should water quality of the Mine Pit Lake be determined to be causing detrimental and ongoing impact to the McArthur River.				occur below 50 m AHD and that the strength of stratification will ensure that the Mine Pit Lake does not completely mix under a flow-through scenario (TWS 2017). Outflows will therefore largely reflect river water contributions (inflows) post-flooding. - Comparison of the stratification case and mixing case modelling found surface water concentrations to be broadly comparable in the longer term, suggesting that surface water concentrations at SW11 are not sensitive to mixing of the Mine Pit Lake (WRM 2018). - Post-closure surface water modelling predicts Mine Pit Lake outflow concentrations for the mixing case (worst case scenario) of sulphate (up to 83 mg/L) and zinc (up to 13.8 µ/L) into the McArthur River are elevated when compared with inflow concentrations from the McArthur River (up to 3.4 mg/L for sulphate and 2.6 µg/L for zinc). These concentrations are however well below the SSTVs at SW11. Annual average concentrations of sulphate and zinc are predicted to decrease over time with ongoing annual flows from the McArthur River (WRM 2018). - Output from the Mine Pit Lake is predicted to occur for up to 40 days per year and during peak flow events associated with the wet season only. These waters will be subject to high dilution once mixed with waters from the McArthur River. - Post-closure surface water modelling predicts sulphate, Zn, Pb and As to remain below SSTVs at downstream compliance point (SW11) (WRM 2018). - Connection to the McArthur River will not occur until water quality is determined to be stable and acceptable for discharge.
6	Infilling of pit and fine sediments.	- Small particulates lead to high TSS in Mine Pit Lake. - Adverse effect on aquatic habitat and fauna within and downstream of the Mine Pit Lake.	N/A				- Rapid filling of final void via pumping and extended period of settling prior to connection with the McArthur River. - Connection via upstream levee will see annual inflow of sediment creating a benign layer above tailings.	D	2	5 (L)	- Modelling predicts limited mixing of water will occur below 50 m AHD and that the strength of stratification will ensure that the Mine Pit Lake does not completely mix under a flow-through scenario (TWS 2017). As such there would be limited potential for re-suspension of fine particulates up to 210 m deep.
7	Rapid filling of final void.	- Pumping water at a rate of up to 500 ML/d when McArthur River flows are greater than 864 ML/d to ~ 14 m AHD - Potential to reduce downstream flow by 25% (and up to 58%) for up to 55% of the yearly flow period in low flow years, resulting in a reduction of flow (and level) in the McArthur River. - Reduced period of river connectivity and species migration/recruitment to upstream pools. - Reduce water level in the McArthur River to the extent flow ceases and/or is atypical	N/A				- Rapid filling predicted to occur over a number of years, currently expected to take approximately 3 years and potentially up to 10 years (WRM 2018). - Review minimum flow requirements for McArthur River functionality and refugia pools to be maintained. - Draw rate from McArthur River to be reduced during a low magnitude wet season. - Ongoing frequent monitoring of fauna assemblages to identify impacts associated with extraction. - Monitoring of *Pristis pristis* movements through	C	2	8 (M)	- Rapid filling will occur over a finite number of years to limit the impacts of reduced flows. - The magnitude of wet season flows within the McArthur River is highly variable. Aquatic fauna have resilience to successive low flow events. - Extraction volumes during poor wet seasons will be reassessed to ensure sufficient flows remain within the McArthur River.

#	Activity/Aspect and Potential Hazard	Potential Impact	Existing Mitigation and Management	Inherent L	Inherent C	Inherent R	Additional Mitigation and Management	Residual L	Residual C	Residual R	Justification
		of wet season magnitude. - Reduction of downstream floodplain inundation which affects fish spawning and recruitment at a measurable level.					the MRM lease during extraction				
8	McArthur River inflow to the Mine Pit Lake.	- Reduced flow in the McArthur River. - Reduced period of river connectivity and species migration/recruitment to upstream pools. - Reduce water level in the McArthur River to the extent flow ceases and/or is atypical of wet season magnitude. - Reduction of downstream floodplain inundation which affects fish spawning and recruitment at a measurable level.	N/A				- Initial connection to the McArthur River via the downstream levee opening (i.e. during the back flow only period) will only receive inflows when river stage height is greater than five metres above the channel invert to ensure sufficient flow remains in the McArthur River and average period of connectivity is not affected (WRM 2018). Low flows will not enter the final void and will flow down the McArthur River. - If progressed to a flow-through scenario via the construction of an upstream levee opening, inflows will only occur when river stage height is greater than five metres above the channel invert to ensure sufficient flow remains in the McArthur River and average period of connectivity is not affected. Low flows will not enter the final void and will flow down the McArthur River. - Inlet and outlet heights will result in pit flooding for a limited number of days per year.	D	2	5 (L)	- Modelling predicts that the Mine Pit Lake flooding through the downstream levee opening will only occur during wet seasons when flow rates exceed 100m^3/s and for a limited duration, estimated to be 10 days per year (WRM 2016). During this period annual net water loss to the Mine Pit Lake from the McArthur River is predicted to be low, being an average of 2200 ML annually or 0.2% of the total flow measured upstream of the Mine Pit Lake (SW21) (WRM 2016, 2018). - If the upstream levee opening is constructed modelling predicts flooding of the Mine Pit Lake will occur during wet season flows greater than 150 m^3/s for up to an average of 10 days per year. The McArthur River flow volume entering the Mine Pit Lake will be between 4% and 6% of the total flow measured upstream of the Mine Pit Lake (SW21) and a low percentage (0.2%) is retained within the Mine Pit Lake (WRM 2016, 2018).
9	Transport of sediment, particulates and detritus into Mine Pit Lake.	- Influence on river morphology as a result of reduced sediment load. - Reduced energy from allochthonous input resulting in food chain effects.	N/A				- Engineering of inlet and outlet means connection to the McArthur River is limited and only occurs when stage height is greater than five metres above the channel invert.	D	2	5 (L)	- Modelling predicts ~12% of the TSS load from the McArthur River measured upstream of the mine (SW21) will flow into and potentially be deposited in the Mine Pit Lake assuming no TSS flows from the Mine Pit Lake back into the McArthur River (WRM 2018). - Additional TSS enters the river from creeks and rivers downstream of the mine. Net loss of TSS in waters downstream of the mine will subsequently be low.
10	Fauna entering final void during initial flooding and connection of downstream levee opening (back flow period).	- Aquatic fauna mortality due to vertical fall whilst final void fills including listed threatened species.	N/A				- Initial rapid flooding by pumping from McArthur River during wet season to 14 m AHD means the Mine Pit Lake will be full prior to opening of the downstream levee. - Period of connectivity between McArthur River and the Mine Pit Lake is limited to when river stage height is greater than five metres above the channel invert. - Engineered solution to be used to restrict the entry of large fauna (e.g. *Pristis pristis*) moving upstream into the Mine Pit Lake during initial flooding e.g. vertical batters or gabions. - Engineered solution to create ramped design of inlet inside the Mine Pit Lake to slow flow and reduced vertical drop. - Assessment of fauna entering Mine Pit Lake to be undertaken to understand abundances and species. Adaptive management to allow for additional fauna exclusion measures to be considered if numbers of fish entering the Mine Pit Lake are shown to be high and detrimentally affecting McArthur River diversity or density.	C	1	5 (L)	- Inlet design and limited duration of connectivity will restrict opportunity for larger fauna to enter the Mine Pit Lake. - Relatively small barrages have been seen to be effective at impeding upstream movement of *Pristis pristis*, a bottom-dwelling species (Thorburn *et al.* 2003, 2004, 2007). The construction of a steep vertical barrage will restrict larger species entering the Mine Pit Lake. - Sloped design of the Mine Pit Lake side of the downstream levee will reduce vertical relief (fall). A ramped design of ~1:30 slope has been demonstrated to be sufficient for the up and downstream movement of *Pristis pristis* (Kirby *et al.* 2009).

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11	Fauna entering pit during annual flooding when connected to the McArthur River via the upstream and downstream levee openings.	- Stranding of fauna in the Mine Pit Lake leading to mortality including listed threatened species. - Lack of suitable physical habitat to sustain aquatic fauna leading to mortality. - Lack of functioning habitat to sustain aquatic food web including prey leading to mortality. - Population level effect due to isolation from breeding population and mortality.	N/A				- Period of connectivity between the McArthur River and Mine Pit Lake is limited by inlet and outlet design which reduces opportunity for fauna to enter. - Engineered solution to restrict the entry of large fauna (e.g., *P. pristis*) at both upstream and downstream levee openings such as vertical barriers. - Engineered solution to assist the egress of fauna, particularly *P. pristis*, through the upstream levee (e.g. fishway) and downstream levee (e.g. ramp). - Active and ongoing caretaking of site includes maintenance and repair of engineered solutions as required. - Benching of the Mine Pit Lake edges to provide aquatic fauna habitat at various water levels. - Rehabilitation and establishment of riparian vegetation to provide allochthonous input and physical habitat in the form of root mats. Riparian vegetation should be maintained until self-generating. - Emplacement and stabilisation of extensive large woody debris and in-water structure on benches to provide habitat, allochthonous input, varied depth and flows. - Assessment of fauna entering the Mine Pit Lake to be undertaken to understand abundances and species present to assess the effectiveness of engineered solutions at preventing ingress whist aiding egress. - Monitoring of fauna health within the Mine Pit Lake.	B	2	12 (M)	- Modelling predicts that Mine Pit Lake inflow after connection through the downstream and upstream levee openings will occur during wet season flows for up to an average of 10 days per year. Outflow of water from the downstream levee opening is predicted to occur for 40 days per year (WRM 2018). As such opportunity for fauna to enter the Mine Pit Lake is low whilst the opportunity to exit is greater. - Barrages have been seen to be effective at impeding upstream movement of *Pristis pristis*, a bottom-dwelling species (Thorburn et al. 2003, 2004, 2007). The construction of a steep vertical barrage will restrict larger species entering the Mine Pit Lake. - For the fishway, a ramp at ~1:30 slope has been demonstrated to be sufficient for the upstream movement of *P. pristis* (Kirby *et al.* 2009). The fishway should also be designed to maintain water flows of ~1 m^{-s} as juvenile *P. pristis* are known to be capable of traversing these velocities (Kirby *et al.* 2009). - Juvenile *Pristis pristis* have been shown to prefer shallow waters less than ten metres depth (Thorburn *et al.* 2003, Kyne *et al.* 2013). Furthermore, a vast majority of the species present in the McArthur River are considered to be non-pelagic and small-bodied, which have demonstrated preference for shallow water habitats (Horppila *et al.* 2000, Pusey and Arthington 2003, Storey and Creagh 2014). The vast majority of the Mine Pit Lake is considered to be unsuitable for sustaining the majority of aquatic fauna species present due to the fact a large proportion of the Mine Pit Lake will be open deep waters. If aquatic fauna enter the Mine Pit Lake edge habitat is the likely area of occupancy. - Studies conducted by Indo-Pacific Environmental on the McArthur River diversion since 2008 indicate the effectiveness in woody debris at providing fish habitat. Prior to the addition of woody debris in the McArthur River diversion the aquatic fauna was highly depauperate. Installation of complex woody debris habitat in recent years has resulted in a diversion fauna consistent with that of naturally vegetated sections of the McArthur River (see Indo-Pacific Environmental 2016b) - Bony fish species present in the McArthur River, which may enter the Mine Pit Lake, are regionally common (and generally in high abundance). As such Mine Pit Lake mortality is unlikely to have a population level effect. - *Crocodylus* are known to undergo long-range overland travel in response to periodic drying such as that experienced in monsoonal Australia (Lang 1987). As such, *Crocodylus* spp.

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											individuals would likely to retreat to the McArthur River if conditions are unfavourable. - Monitoring and maintenance of the fishway on the upstream leave may be reduced or cease if fauna is found to readily use the downstream levee opening to exit the Mine Pit Lake. - If the environment within the Mine Pit Lake is stable and conditions are favourable for *P. pristis*, monitoring and maintenance of the fishway on the upstream leave may be reduced or cease as individuals are known to persist in isolated waterbodies over a number of years before migrating downstream as they approach maturity.
12	Introduction of site waters to the Mine Pit Lake including captured surface water from Barney Creek sumps.	- Adverse effect on Mine Pit Lake water quality including elevation in metal content, pH and EC. - Mine Pit Lake water quality effects on receiving waters downstream upon release. - Adverse effect on aquatic habitat and fauna within and downstream of Mine Pit Lake. - Exceedance of SSTVs at SW11 post mixing	N/A				- Inlet design allows river water to enter Mine Pit Lake annually facilitating dilution (KCB 2017b). - Site waters are discharged into the lower layers (greater than 100 m depth) of the Mine Pit Lake. - Ongoing monitoring of site waters introduced to the Mine Pit Lake with contingency for treatment to improve water quality prior to release. Dewatering to the Mine Pit Lake will cease if introduced waters are seen to have a measurable effect on the Mine Pit Lake water quality. - Adaptive management allows for water treatment methods (for example reverse osmosis) to improve Mine Pit Lake water quality. Also allows for the treatment of Barney Creek sump waters prior to discharge into the Mine Pit Lake. - Routine ongoing monitoring to determine accuracy of predictive modelling. - Routine ongoing monitoring to determine output water quality with contingency to isolate the Mine Pit Lake from McArthur River. - Monitoring of McArthur River water quality downstream at SW11 and adherence to SSTVs.	D	2	5 (L)	- Volume of the Mine Pit Lake is vastly greater than likely volumes introduced from site sources. Large buffering and dilution capacity of Mine Pit Lake. - Post-closure surface water modelling predicts that Mine Pit Lake outflow concentrations for the mixing case (worst case scenario) of sulphate (up to 83 mg/L) and zinc (up to 13.8 µg/L) into the McArthur River are elevated when compared with inflow concentrations from the McArthur River (up to 3.4 mg/L for sulphate and 2.6 µg/L for zinc). These concentrations are however well below the SSTVs at SW11. Annual average concentrations of sulphate and zinc are predicted to decrease over time with ongoing annual flows from the McArthur River (WRM 2018). - Output from the Mine Pit Lake is predicted to occur for up to 40 days per year and during peak flow events associated with the wet season only (WRM 2018). These waters will be subject to high dilution once mixed waters from the McArthur River. - Post-closure surface water modelling predicts sulphate, Zn, Pb and As to remain below SSTVs at downstream compliance point (SW11) (WRM 2018).
13	Vertical mixing results in dissolved tailings mixing with surface waters.	- Adverse effect on Mine Pit Lake water quality. - Effects on water quality in receiving waters downstream upon release. - Adverse effect on aquatic habitat and fauna within and downstream of the Mine Pit Lake	N/A				- Connection via upstream levee will see annual inflow of sediment creating a benign layer above tailings over time. - Contaminated materials will not be placed in the Mine Pit Lake after flooding.	D	2	5 (L)	- Modelling predicts limited mixing of water will occur below 50 m AHD and that the strength of stratification will ensure that the Mine Pit Lake does not completely mix under a flow-through scenario (TWS 2017). There is limited potential for re-suspension of fine particulates up to 210 m depth (TWS 2017).
14	Management of water quality in the Mine Pit Lake upon connection of the upstream levee to create flow-through.	- Insufficient monitoring, management and treatment leads to reduction in water quality. - Mine Pit Lake water quality effects on receiving waters downstream upon release. - Adverse ongoing effect on aquatic habitat and fauna within and downstream of the Mine Pit Lake through effects of elevated	N/A				- Ongoing monitoring of Mine Pit Lake water quality and fauna to 3018. Frequency of monitoring should be determined from stability of water quality, performance against SSTVs and confirmation of modelled outcomes. - Monitoring of McArthur River water quality downstream at SW11 and adherence to SSTVs. - Adaptive management will allow for capability to run water treatment plant as and when required	D	3	9 (M)	- Current post-closure surface water modelling predicts that Mine Pit Lake outflow concentrations for the mixing case (worst case scenario) of sulphate (up to 83 mg/L) and zinc (up to 13.8 µg/L) into the McArthur River are elevated when compared with inflow concentrations from the McArthur River (up to 3.4 mg/L for sulphate and 2.6 µg/L for zinc). These concentrations are however well below

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		metals. - Exceedance of SSTVs at SW11 post mixing.					to manage discharge water quality. - Design of levee openings ensures outflow during high flow events only with subsequent high dilution rates. - Contingency to isolate the Mine Pit Lake from the McArthur River should water quality of the Mine Pit Lake be determined to be causing detrimental and ongoing impact to the McArthur River.				the SSTVs at SW11. In addition, after rapid filling of the Mine Pit Lake, concentrations are predicted to remain below the SSTVs at SW11 (KCB 2017b, WRM 2018). Annual average concentrations of sulphate and zinc are predicted to decrease over time with ongoing annual flows from the McArthur River (WRM 2018). - Several common fish species including *Hephaestus fuliginosus*, *Leiopotherapon unicolor*, *Melanotaenia splendida*, *Nematalosa erebi* and *Lates calcarifer* have been recorded in waters of the McArthur River catchment with sulphate concentrations up to ~2240 mg/L indicating tolerable limits for fauna are far higher than modelled concentrations. - Active caretaking and adaptive management will give high confidence that Mine Pit Lake water quality is maintained and SSTVs at SW11 are adhered to.
15	Uncontrolled discharge of water from the Mine Pit Lake during large flood years	- Extended period of unrestricted/uncontrolled water from Mine Pit Lake outlets. - Adverse effect on downstream water quality, habitat and fauna from elevated metal concentrations.	N/A				- Levee built to 1:500 year flood protection level. - Ongoing monitoring of Mine Pit Lake water quality. - Adaptive management will allow for capability to run water treatment plant as and when required to manage discharge water quality. - Monitoring of McArthur River water quality downstream at SW11 and adherence to SSTVs.	C	1	4 (L)	- Modelling (which considered infrequent large scale events) predicts that connectivity between the Mine Pit Lake and McArthur River occurs for a low number of days per year. - Low likelihood of overtopping due to construction of bund height and likely frequency of very large flood events. - During large flood years significant dilution would likely occur between escaped Mine Pit Lake waters and the McArthur River which would be in high flow.
16	Erosion and failure of Mine Pit Lake levee, inlet and outlet.	- Uncontrolled discharge of Mine Pit Lake water. - Potential effect on water quality adjacent McArthur River and downstream. - Reduction in river water quality and adverse effects on fauna and habitat.	N/A				- Mine Pit Lake levees constructed in accordance with relevant Australian National Committee on Large Dams (ANCOLD, 2003). - Levee seismic design criteria include building to 1:1000 AEP Max Design Earthquake (MDE) and 1:500 AEP Operating Basis Earthquake (OBE) criteria. - Ramp designed to flood to 1:100000 Annual Exceedance Probability (AEP) (Critical Storm Duration). - Frequent and ongoing bund integrity and stability checks. - Active and ongoing caretaking of site includes maintenance and repair schedule. - Contingency planning and budget allowances to rebuild damaged sections in the event of levee or bund failure, as required in the later dry seasons.	D	2	5 (L)	- Due to the construction standards, ongoing maintenance and repair contingency, levee failure would not be expected to be significant. - Failure of the Mine Pit Lake levee is most likely to occur during very large wet seasons. Significant dilution would likely occur between escaped Mine Pit Lake waters and the McArthur River which would be in high flow.
17	Permeability of Mine Pit Lake banks, walls and levees	- Head pressure from flooded Mine Pit Lake causes water outflow (uncontrolled release). - Adverse effect on surface water and groundwater. - Reduction in river water quality and adverse effects on fauna and habitat.	N/A				- Permeability testing undertaken to determine likelihood of Mine Pit Lake water outflow as required. - Frequent and ongoing monitoring of bund integrity. - Installation of groundwater monitoring bores installed between Mine Pit Lake and McArthur River.	C	2	8 (M)	- Post closure modelling predicted Mine Pit Lake outflows to be variable and not significant in comparison to the outflows through the engineered levee system (KCB 2016a). - Post closure modelling predicts annual groundwater inflow in the Mine Pit Lake to be far greater than outflow from the years 2047 to 3018 (i.e. 511 cf. 27 ML/year, respectively) (WRM

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							- Development of conceptual plans for mitigation measures that can be detailed further if monitoring indicates remediation is necessary.				2016). - Post closure modelling indicates reduction in sulphate and zinc concentrations over time (WRM 2018).
North Overburden Emplacement Facility (NOEF)											
18	Expansion of NOEF footprint	- Encroachment on Emu Creek catchment and reduction in available habitat and flow. - Effect on seasonally available habitat. - Effects on reproduction and dispersal of highly mobile aquatic fauna. - Reduction in available habitat for listed threatened species. - NOEF runoff entering Emu Creek resulting in decline in water quality. - Exceedance of SSTVs at SW11 post mixing.	N/A				- Current NOEF footprint has been minimised avoiding extensive expansion to the north and encroachment on Emu Creek. - Drain installed on the northern side of the NOEF where encroachment occurs. - Monitoring of Emu Creek and McArthur River water quality. - Adherence to SW11 SSTVs.	E	2	3 (L)	- The northern side of the NOEF encroaches on a small unnamed tributary of Emu Creek. The installation of a runoff drain will reduce the potential flow of water coming off (or from) the NOEF and flowing into Emu Creek thus reducing potential downstream effects. - The area of encroachment is small. A survey of Emu Creek fauna was conducted in 2015 which showed the creek was highly ephemeral and rapidly dried after the cessation of rain. As such this was not considered to represent critical habitat for any species of aquatic fauna. - Appendix W of the Draft EIS contains results of a survey of Emu Creek aquatic fauna. These results indicated the species recorded are all widely distributed in the McArthur River catchment. As such Emu Creek was not considered to be critical habitat and loss of a small portion of the catchment will not lead to a population-level effect. - *Pristis pristis* was not captured in the survey of Emu Creek fauna. Emu Creek is not considered to represent suitable habitat for the species due to its temporary nature and lack of favourable habitat for the species (Thorburn *et al.* 2003). As such the likelihood of occurrence is considered to be very low.
19	Inappropriate storage and disposal of waste rock leads to contamination of surface water and groundwater systems	- Contamination of surface water and groundwater systems through exposure to metalliferous or high acidity contaminants or outflow of contaminated waters. - Extensive and long-term effects on downstream water quality (adjacent Creeks and McArthur River) and exceedance of SSTVs. - Influence on water pH and thus metal bioavailability and toxicity. - Extensive adverse lethal and sub-lethal effects on aquatic fauna including listed threatened species. - Extensive adverse effects on aquatic habitat quality.	- NOEF design includes encapsulation of high risk materials to limit oxidation and seepage of oxidation products into groundwater and surface water systems. - NOEF performance objectives include physical stability of structure.	C	4	18 (H)	- NOEF performance objectives include chemical stability through material placement and compaction techniques, cover system designs, seepage collection and treatment structures. - In-pit grade control of all overburden at the blast block level is undertaken to validate classification prior to load and haul operations. - The geochemistry of benign rock used as covers on OEFs is monitored monthly to ensure correct waste placement. - Ongoing periodic monitoring of NOEF stability and maintenance. - Ongoing frequent monitoring of groundwater and surface water in proximity to the NOEF and downstream. This should include fate and transport studies to determine pathways and rates of transport of contaminants of concern. - Adaptive management allows for contingency planning and remediation if unacceptable impacts on the receiving environment are predicted or measured.	D	4	14 (M)	- The internal architecture of the NOEF places the materials with the highest risk of creating environmental harm furthest away from the receiving environment, with progressively lower risk materials placed toward the final outer surface. - A Statement of Reasons drafted by the NTEPA (2014) outlines the justification for the Project progressing to an EIS. That document states that the DME suggested some material in the base layer was considered to be non-benign. Despite the proposed encapsulation some interaction of non-benign material and groundwater may still occur. - MRM waste classification system sees various classifications of waste handled and stored under conditions specific to the classification. - Seepage collection and treatment structures aim to reduce volumes of water entering groundwater or surface water systems. - Design will limit the seepage of water through NOEF to reduce destabilising effects and cartage of contaminants. Consideration of a GSL over CCL aims to reduce seepage of water.

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20	Surface water runoff	- Erosion and subsequent carriage of sediment due to inadequate armouring. - Instability of NOEF structure. - Potential flow of contaminants into adjacent creeks resulting in elevated pollutant loads and TSS. - Potential flow of sediment into adjacent Creeks resulting in elevated TSS and subsequent reduction in light attenuation and aquatic habitat quality. - Potential effect on downstream water quality and exceedance of SSTVs. - Direct effects on aquatic fauna in adjacent Creeks including metal toxicity. Elevated TSS may result in reduced hunting efficiency due to reduced visual acuity and mortality due to clogging of gills with fine particulates.	- NOEF design includes encapsulation of high risk materials to limit oxidation and seepage of oxidation products into groundwater and surface water systems. - NOEF performance objectives include physical stability of structure. - Design of the NOEF (including armouring, slopes compaction and permeability) focus on controlling erosion and sediment loss due to surface runoff. This includes stilling basins to dissipate energy from high flows generated as runoff is directed down steep embankments (see O'Kane 2016). - Installation of numerous drainage channels, sumps and lined (clay, geopolymer or HDPE) dams (referred to as PRODS) to capture runoff. Runoff dams capacities set to have a less than 5% probability of exceedance (spill) over the operating life of the dam. - During NOEF construction exposed areas of reactive rock will generate contaminated surface runoff. This runoff will be diverted into water management dams (PRODS). - NOEF design includes outer layers with low risk materials. As such post-construction runoff is expected to be below SSTVs.	D	3	9 (M)	- TSS in runoff is expected to be elevated for some time following placement of the cover system (O'Kane 2016). Surface water at this time will subsequently be directed into sediment dams to remove sediment by gravity separation. - Ongoing monitoring of surface water runoff. Monitoring and maintenance of surface water management systems as required. - Ongoing monitoring of runoff water quality and surface waters in adjacent Creeks and McArthur River. - Installation of sumps in Barney Creek (mainly BCS2) will ultimately capture potentially impacted groundwater and surface water runoff which has entered Barney Creek. - Compliance with SSTVs at SW11 and surface water quality standards.	D	2	5 (L)	- During construction some water will interact with reactive material. This water will be diverted into PRODS. Once the NOEF is completed and covered with an outer layer of benign materials surface runoff is likely to contain low concentrations of contaminants. - Based on a NOEF design which effectively captures and manages surface water runoff modelling predicts a negligible contribution of the NOEF surface runoff to contaminant levels in Surprise and Barney Creeks. - Barney Creek sumps will capture runoff during low flow periods and limit its entry into the McArthur River. - Large runoff events are associated with wet season rains. Runoff will coincide with high flow events in adjacent Creeks and the McArthur River which will significantly dilute any pollutant or particulate concentration reducing the risk to aquatic fauna. - Post closure NOEF design is based on a moisture store-and-release' and 'barrier' concept which will capture rainwater then progressively dry through evaporation (O'kane 2017). - Extensive surveys of the aquatic fauna of the McArthur River, including during high flow events, indicated that the aquatic fauna present has tolerance of turbid waters. Considering that the duration of a large runoff event is likely to be short it is likely aquatic fauna will persist during limited duration high TSS events.
21	Seepage from NOEF including PAF material giving rise to acid and metalliferous drainage	- NOEF creates groundwater mound affecting flow regime in adjacent Creeks. - Seepage results in contaminant transfer in groundwater with adverse effects on groundwater and surface water quality. - Seepage of metals, sulphates and/or acids can result in direct toxicity to aquatic fauna including listed threatened species. - Adverse impacts on aquatic habitat in adjacent Creeks and downstream including the McArthur River. - Loss of Barney Creek and McArthur River habitat. - Non-compliance with SW11 SSTVs.	- NOEF design includes encapsulation of high risk materials to limit oxidation and seepage of oxidation products into groundwater and surface water systems. - NOEF design aims to manage key risks including generation of acid by encapsulating high risk materials and reducing exposure to oxygen.	C	4	18 (H)	- The NOEF is designed to limit seepage through basal foundation preparation, construction methodologies (including alluvial barriers) and the final cover system (see O'Kane 2017). - Use of a GSL as opposed to CLL to decrease seepage. - Seepage mitigation systems as required to meet MRM's objective. These may include interceptor drains and recovery bores. - Ongoing monitoring of groundwater bores surrounding the NOEF. - Ongoing monitoring of surface water in Barney Creek and downstream. - Installation of sumps in Barney Creek (mainly BCS2) will ultimately capture seepage which had entered Barney Creek.	D	3	9 (M)	- There is significant buffering capacity in the waste rock. As such it is not expected to produce large amounts of acidic mine drainage. - Modelling predicts neutral pH waters will occur in Barney Creek (KCB 2016b). - Post closure outer layer NOEF design is based on a moisture store-and-release' and 'barrier' concept which will capture rainwater then progressively dry through evaporation. A GSL will reduce percolation through the NOEF (ATC Williams 2017). - After rehabilitation of the TSF, seepage from and as a result of the NOEF results in high sulphate concentrations being present in Barney Creek (WRM 2018). This is the main water quality related issues post TSF rehabilitation. Barney Creek sumps will effectively capture runoff and seepage during low flow periods and prevent its entry into the McArthur River. - Modelling predicts that post closure (and after TSF rehabilitation) monthly median sulphate concentrations within Barney Creek downstream of SW06 will continue to increase and will exceed the SW11 SSTVs throughout the year by 2168-2500 reaching concentrations of up to ~4000 mg/kg when creek discharge is at its lowest (WRM 2018).

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											- Modelling predicts that monthly median sulphate concentrations at SW19 will generally only exceed the SSTVs during months of lowest discharge from 2060 onwards (i.e. May to September) (WRM 2018). - *Pristis pristis* has not been captured in Barney Creek during targeted surveying conduced since 2006. Furthermore, Barney Creek does not represent favourable habitat for the species which prefers main channel riverine waters (Thorburn *et al.* 2003). As such the likelihood of occurrence is considered to be very low. - Barney Creek is ephemeral and typically dries out annually. Barney Creek is not considered to be critical habitat for any species in the McArthur River catchment. In the event Barney Creek habitat become unsuitable for sustaining aquatic fauna this is unlikely to have a population level effect on any species. - Capture of seepage in the Barney Creek will prevent waters entering the main channel McArthur River. During peak flow periods water entering the McArthur River from Barney Creek will be highly diluted.
22	Failure of GSL leads to increased seepage through NOEF	- Breakdown of liner over time or puncture by deep-rooted vegetation over time leads to increased seepage. - Seepage results in contaminant transfer in groundwater with adverse effects on groundwater and surface water quality. - Increased seepage leads to water quality in adjacent creeks which differs from modelling outputs affecting the effectiveness of proposed management strategies.	N/A				- Initial cover vegetation establishment will avoid deep-rooted species. - Proposed 5mm GSL incorporates an anti-root barrier layer. - Ongoing monitoring and maintenance of the GSL to maintain performance and functionality. - Ongoing monitoring or groundwater and surface water in adjacent creeks to assess performance of cover layer.	C	3	13 (M)	- Modelling has included an assumed number of defects in the GSL per hectare and permeability rates are expected to be lower than currently modelled results (O'Kane 2017).
23	Surface runoff dams overflow and seepage	- Failure of levee resulting in uncontrolled spill - Overflow of dams during high runoff periods and uncontrolled release into adjacent Barney Creek. - Seepage through levee. - Contamination of surface water and groundwater systems with dam waters containing high metal or sulphate content or of low pH. - Adverse effects on Barney Creek habitat and aquatic fauna and downstream. - Long term effect from groundwater impact including the McArthur River	- Runoff dams system set to have a less than 5% probability of exceedance (spill) over the operating life of the dam.	C	2	8 (M)	- New runoff dams constructed in accordance with relevant Australian National Committee on Large Dams (ANCOLD) Guidelines including ANCOLD's Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure (ANCOLD, 2012). Designed earthquake loading of 1:1,000AEP Max Design Earthquake (MDE) and 1:500 AEP Operating Basis Earthquake (OBE). Crest of spillway above 100 year McArthur River flood level. Spillway design to safely pass a 1:2000 AEP flood event with a 1:10 AEP wind event wave allowance. - Runoff dams lined with low permeability materials such as HDPE lining to limit seepage. - Ongoing biannual monitoring of stability, structure, operation and management during their operational phases. - Ongoing monitoring of dam liner integrity.	D	2	5 (L)	- Based on the design capacities, spill will occur on very large runoff events with a majority of the spill likely to be rainwater. These will coincide with high flow events in adjacent Barney Creek and the McArthur River. As such any spill entering creeks will be highly diluted. - Post-closure runoff dams aim to collect NOEF runoff and due to the low toxicity nature of the outer layer runoff is expected to be benign. - Design criteria, build standards and routine monitoring for the life of the dam means the likelihood of failure of a levee would be low. - Appropriate dam lining and seepage monitoring. - Conceptual seepage recovery systems could be installed as a mitigation measure as required to limit seepage into Barney Creek. - Seepage entering Barney Creek will be captured by BCS2 preventing introduction to the McArthur River.
	Tailings Storage Facility (TSF)										

#	Activity/Aspect and Potential Hazard	Potential Impact	Existing Mitigation and Management	Inherent L	Inherent C	Inherent R	Additional Mitigation and Management	Residual L	Residual C	Residual R	Justification
24	Increased holding capacity creates groundwater mound.	- Increased mass of tailings raises groundwater level/expression leading to altered flow regime of adjacent ephemeral creeks. - Increased release of earth-laden and mine-derived sulphates leading to increase in water electrical conductivity in adjacent ephemeral creeks. - Adverse effect on Surprise Creek aquatic habitat quality through increase in EC. - Alteration of natural flow and drying regimes via alteration of groundwater level. - Adverse effect on fauna distribution and dispersal through exceedance of fauna tolerance.	- Tailings management includes limiting ponding of water on the TSF, improving barrier systems to seepage and groundwater recovery (GHD 2016).	A	2	16 (M)	- Ongoing groundwater and surface water monitoring over operational phases which is continued well after rehabilitation of TSF. - End of mine reprocessing of tailings will see complete removal of tailings, reducing long-term impact and limit risk period. - Rehabilitation and decommissioning of the TSF will see mining landscape left safe and secure for humans and animals in long term (i.e. 100-1000 years) (GHD 2016). Extensive closure objectives are outlined in Section 2.4 of GHD (2016) with environmental values and ecosystems maintained. - Post-closure monitoring undertaken in accordance with GHD (2016).	B	2	12 (M)	- Groundwater monitoring has indicated that ponding of water on TSF has resulted in a water table mound which has interrupted natural groundwater flow and caused prolonged discharge in Surprise Creek. Recent (2015) improvements in TSF surface water management including removal of large water volumes has led to improvements. Sections of Surprise Creek which atypically held water in the late dry season were observed to have dried by October 2016 which was historically the case. - Despite improved management of the TSF to reduce mass, the expansion will lead to significantly larger volumes being stored. As such mounding is still likely to occur.
25	Failure of TSF embankment.	- Uncontrolled release of tailings. - Contamination of Surprise Creek and downstream ecosystems. - Adverse effect on aquatic fauna and habitat.	N/A				- TSF constructed in accordance with relevant Australian National Committee on Large Dams (ANCOLD) Guidelines including ANCOLD's Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure (ANCOLD, 2012). - TSF seismic design criteria include building to 1:1000 AEP Max Design Earthquake (MDE) and 1:500 AEP Operating Basis Earthquake (OBE) criteria. - TSF spillway design flood to 1:100000 AEP (Critical Storm Duration). - Adherence to Critical Operating Parameters (COP's) (GHD 2016). - Tailings characterisation undertaken to understand mass. - Ongoing bi-annual monitoring of stability, structure, operation and management (GHD 2016). - Adherence to Dam Safety Emergency Plan (DSEP).	D	2	5 (L)	- Based on the standard of construction, ongoing inspection and failure controls it is expected that any failure in the TSF embankment would be over a limited area and rapidly repaired.
26	Seepage from TSF influences on-lease groundwater and surface waters	- Contamination of groundwater and surface water including increased metal and sulphate concentrations above SSTVs in water of Barney and Surprise Creeks. - Adverse effects on aquatic habitat and fauna through exceedance of fauna tolerances. - Loss of Surprise and Barney Creek habitats.	- Tailings management includes limiting ponding of water on the TSF, improving barrier systems to seepage and groundwater recovery (GHD 2016). Furthermore, tailings densities will be maximised to reduce permeability of the tailings and thus seepage.	A	2	16 (M)	- Ongoing bi-annual monitoring of stability, structure, operation and management (GHD 2016). - Installation of sumps on Barney Creek to capture surface water reducing risk of tailings. - End of mine reprocessing of tailings and site rehabilitation will reduce long term impact and limit risk period to 2100. - Ongoing monitoring of groundwater and surface water to determine seepage rates and quality.	A	2	16 (M)	- Seepage has historically been a significant issue due to the past extent of water storage on the TSF and the visible expression of seepage to the surface (GHD 2016). Recent (2015) improvements in TSF surface water management including removal of large water volumes has led to improvements. Sections of Surprise Creek which atypically held water in the late dry season were observed to have dried by October 2016 which was historically the case. - During the operational period modelling predicts that Barney Creek Sump 1 (BCS1), located at the confluence of Barney and Surprise Creeks, will collect up to ~40 ML/yr with a majority being identified as seepage from the TSF (WRM 2018). - Modelling predicts median sulphate and zinc concentrations will exceed the SW11 SSTVs within Barney and Surprise Creeks downstream of the TSF at SW22 and SW03 for zinc and SW02, SW24, SW22, SW03, SW19 and SW06

#	Activity/Aspect and Potential Hazard	Potential Impact	Existing Mitigation and Management	Inherent L	Inherent C	Inherent R	Additional Mitigation and Management	Residual L	Residual C	Residual R	Justification
											for Sulphate during the operational period (2018-2047) (peaking in months of lowest flow). - After cessation of mining, reprocessing of tailings and rehabilitation of the TSF impacts associated with the TSF are predicted to decrease. However, elevated median sulphate and zinc concentrations are predicted to persist over a number of centuries or the 1,000 year simulation period during months of lowest flow as a result of naturally occurring mineralised zones and groundwater table recovery. - *Pristis pristis* has not been captured in Surprise or Barney Creeks during targeted surveying conduced since 2006. Furthermore, Surprise and Barney Creeks do not represent favourable habitat for the species which has been recorded as preferring main channel riverine waters (Thorburn *et al.* 2003). As such the likelihood of occurrence is considered to be very low. - The bony fish *Hephaestus* fuliginosus, *Leiopotherapon unicolor*, *Melanotaenia splendida* and *Nematalosa erebi* have been consistently recorded in sulphate-affected reaches of Barney Creek up to 2240 mg/L. Furthermore, *Lates calcarifer* has been recorded from inland waters with sulphate concentrations up 2180 mg/L. Based on these known tolerances, it is likely that some species will persist in Surprise and Barney Creeks when sulphate concentrations are high. - Surprise and Barney Creeks are ephemeral creeks which traditionally dry out annually. These creeks are not considered to be critical habitat for any species in the McArthur River catchment. In the event Surprise and Barney Creek habitats become unsuitable for sustaining aquatic fauna this is unlikely to have a population level effect on any species. - The installation and operation of BCS1 and BCS2 will capture sulphate-affected water. This will restrict flow of sulphate-affected waters into the main channel McArthur River waters. During high flow periods any flow from Barney Creek into the McArthur River will be highly diluted.
27	Seepage from TSF influences off-lease surface waters	- Seepage leads to surface flow in adjacent creeks with subsequent inflow into McArthur River - Increased metal and sulphate concentrations above SSTVs at SW11. - Adverse effects on McArthur River aquatic habitat and fauna through exceedance of fauna tolerances including listed threatened species.	- Tailings management includes limiting ponding of water on the TSF, HDPE lining of the TSF WMD to limit seepage and groundwater recovery (GHD 2016, WRM 2018). Furthermore, tailings densities will be maximised to reduce permeability of the tailings and thus seepage. - Adherence to SW11 SSTVs.	D	1	2 (L)	- Ongoing bi-annual monitoring of stability, structure, operation and management (GHD 2016). - Installation of sumps on Barney Creek to capture surface water reducing risk of tailings reaching McArthur River. - End of mine reprocessing of tailings and site rehabilitation will reduce long term impact and limit risk period to 2100. - Ongoing monitoring of surface water at SW11.	E	1	1 (L)	- Surprise and Barney Creeks are ephemeral creeks which traditionally dry out annually. - The installation and operation of BCS1 and BCS2 will capture sulphate affected water. This will restrict flow of sulphate affected waters into the main channel McArthur River waters. During high flow periods any flow from Barney Creek into the McArthur River will be highly diluted.
28	Water overtopping embankments during large rain events.	- Uncontrolled discharge of tailings. - Entry of tailings into Little Barney Creek. - Adverse on effects on downstream water	N/A				- TSF constructed in accordance with relevant Australian National Committee on Large Dams (ANCOLD) Guidelines including ANCOLD's	D	2	5 (L)	- The frequency of rainfall or storm events large enough to result in a spill from the TSF (and subsequently the PWD) is considered to be low.

#	Activity/Aspect and Potential Hazard	Potential Impact	Existing Mitigation and Management	Inherent L	Inherent C	Inherent R	Additional Mitigation and Management	Residual L	Residual C	Residual R	Justification
		quality and aquatic habitat.					Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure (ANCOLD, 2012). - Adherence to ANCOLD (2012) Extreme Storm Storage and Wet Season Storage Allowance criteria. - Design includes a Process Water Dam (PWD). In the event rainfall leads to a spill, water from the TSF will spill into the PWD.				- If the event is large enough to cause a spill from the PWD water will enter Little Barney Creek. Any release would, however, coincide with local flooding of the Creek meaning dilution of tailings would be high (GHD 2016).

3.0 KEY RISKS, MANAGEMENT AND MONITORING

3.1 Primary Environmental Targets

Table 4 identified specific mitigation and management actions to reduce the potential impact of the project. While most relate to the management of water quality, overarching environmental targets are required in relation to the aquatic fauna present. This is due to the fact MRM has had, and will continue to have, influence on the McArthur River through its physical presence (through its proximity to the McArthur River and tributaries) and mining processes. Furthermore, considering the projected life of the mine and the proposed closure scenario, which includes infrastructure that will become permanent fixtures of the landscape (including the NOEF and Mine Pit Lake), long-term and ongoing targets need to be set to ensure environmental values of the area are maintained.

The aquatic fauna of the McArthur River has been extensively studied and monitored in the past decade to identify what effects MRM has had on the aquatic environment and to determine ways to mitigate or rehabilitate impacted aspects. Consistent with current objectives relating to aquatic fauna, all future MRM operations should be conducted to meet the following objectives:

- MRM activity will result in no reduction in species diversity in the McArthur River;
- MRM activity will result in no measurable change in species abundance outside of natural variation within the McArthur River;
- MRM activity will not decrease river connectivity or migration pathways (including that of *P. pristis*) in the vicinity of the mine or downstream through the creation of physical, thermal or chemical barriers;
- MRM activity will not reduce the overall health or function of aquatic fauna or habitat and will ensure natural tissue metal concentrations in fauna and trophic flows are maintained; and
- MRM will not affect the amenity value of the aquatic fauna resource.

Documentation prepared for the MRM Phase 2 and Phase 3 expansions outlined a number of environmental monitoring programs aimed at assessing these aforementioned objectives. While a number of the aquatic fauna monitoring programs have greatly expanded in years since these previous works, the aquatic fauna monitoring programs currently in place at MRM should continue in order to collect information necessary to identify whether the objectives are being met into the future. Current monitoring of aquatic fauna and water quality both throughout the mine site and downstream should therefore continue throughout the operational mining phase and closure phase until such a point that there is a demonstrated change in the risk associated with the project. The monitoring frequency and the duration of the monitoring program should be revised in the event of any change in the risks associated with the project, and any change to the monitoring program should be determined in consultation with the regulator. Mitigation and management strategies outlined below subsequently build on to the existing programs.

3.2 Risk identification and Mitigation

Major project risks were identified in Section 2.0 and in particular Table 4. The following section summarises these risks into broad categories and provides an expanded description and explanation of the mitigation, management and monitoring applied to reduce these risks.

3.3 Domain 1 - Open Cut: Operation

3.3.1 Reduction in Water Quality

Runoff and direct discharge of waters into Barney Creek, Surprise Creek and the McArthur River have the potential to decrease water quality in the immediate vicinity of the discharge or spill and influence downstream conditions. Discharged and spill waters derived from the Open Cut operation can include accumulated rainwater occurring within the pit and levee walls, process waters from mining operations and runoff from infrastructure (including roads and embankments). In relation to the operation at MRM, these waters have been known to carry various metalliferous contaminants (in particular lead, zinc, cadmium and arsenic), sulphate and particulates which affect the total suspended solid (TSS) loads of receiving waters. An example of the effects of runoff can be seen from the haul road bridge (SW19) where the input of sediment contaminated with lead resulted in increases in bed sediment metals which were subsequently absorbed by fauna (see Section 3.4.4 of Appendix W of the Draft EIS for an expanded discussion).

Throughout the life of the project the effects of runoff and discharge waters should be mitigated and managed in the following ways:

- Implementation and frequent review of site specific management plans which outline water testing and discharge protocols;
- Adherence to Waste Discharge Licences which outline specific water quality targets for both the discharge and at the downstream compliance point at SW11. These conditions should be frequently reviewed and site specific trigger values (SSTVs) adjusted throughout the operational and post-operational periods;

- Determination that waters are of 'low risk' and are not considered to be 'complex solutions' prior to discharge;
- Discharge of waters during high flow periods only to ensure sufficient dilution of potential contaminants;
- Construction of a new 6 ML/d RO Plant will commence from November 2017 to treat poorer quality mine affected water, with its capacity upgraded to 15 ML/d in November 2020. In addition a 2 Module 'lime treatment plant' will be constructed to treat PbOx water and brine from the RO water treatment plant for recycling back through the Mill circuit (WRM 2018).
- Adherence to dust management plans including suppression through the use of water carts on the haul roads to reduce metal contaminated dust entering creeks in close proximity to hauls roads or major work areas;
- Frequent review of roadways and drainage lines to identify potential flow pathways;
- Installation and frequent maintenance of sediment traps such as haul road low points including at SW19;
- Installation of sumps along Barney Creek to capture water during moderate and low flow events and prevent flow into the McArthur River; and
- Annual remediation of SW19 bunding and mechanical excavation of sediments from SW19.

Throughout the life of the Project, the effectiveness of these mitigation and management actions should be determined through monitoring, including:

- Monthly surface water monitoring and reporting of Barney and Surprise Creeks and the McArthur River. Analysis will include a suite of metals (Al, As, Cd, Cu, Fe, Pb, Mn, Hg, Ni and Zn), electrical conductivity (EC) and sulphate as a minimum during the operational phase. Analysis of pH should also be undertaken, as pH can greatly affect bioavailability of metals. Significant changes and exceedances at the compliance point should result in immediate cessation of all discharge and investigation of point source and spill waters. Post closure, the frequency of surface water monitoring may be reviewed and reduced if concentrations of contaminants associated with the mining process are shown to be stable or declining;
- Annual collection and analysis of fluvial sediments from lower sections of Barney Creek, SW11 and sites downstream to determine metal concentrations and inputs from Barney Creek during operation. This sampling should continue post closure until such point that sediment concentrations are seen to stabilise or decrease and are equivalent to reference concentrations; and

- Monitoring of fauna tissues (including SW19 and SW11) to ascertain effects on aquatic biota should be conducted. Monitoring frequency should be based on an adaptive program with sample collection conducted when surface water and fluvial sediment concentrations of analytes of concern are considered to be high.

3.3.2 Drawdown

Inflow of groundwater into the MRM pit is predicted to lead to drawdown of Barney and Surprise Creeks and the McArthur River. While the ephemeral nature of Barney and Surprise Creeks means that drawdown effects on fauna would be low, several late dry season refuge pools exist in the McArthur River adjacent the mine and immediately upstream, for example, Djirrinmini Waterhole. These dry season refugia have been observed to sustain numerous species throughout the dry season including *P. pristis* which is afforded protection under the EPBC Act. Modelling predicts drawdown to be approximately 0.7 m in Djirrinmini Waterhole (KCB 2016a). Considering a majority of Djirrinmini Waterhole would have water depths of less than two metres in the late dry season, water drawdown of 0.7 m has the potential to greatly reduce the available habitat for aquatic fauna. In addition, potential exists for fragmentation of Djirrinmini Waterhole due to the fact shallow sections in the middle of the pool (which can be 0.5 m during the late dry season) may dry completely. Furthermore, a reduced water level may lead to increased water temperatures and light attention throughout these refuge pools which may be less favourable to some species of aquatic fauna.

Throughout the life of the project, the effects of drawdown will be mitigated and managed in the following ways:

- In the long term (post closure), drawdown is predicted to be negligible following flooding of the Mine Pit Lake. Water levels in Djirrinmini Waterhole are predicted to recover within ten years post-mining;
- Supplementary flow may be required to permanent refuge pools adjacent to the Project in the event that drying of the river channel adjacent the pit is atypical of seasonal variation; and
- If large listed aquatic fauna are found to be trapped in dry season refugia affected by drawdown, consideration should be given to their translocation to larger pools in the McArthur River.

Throughout the life of the project the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Water levels should be monitored to assess whether modelled drawdown is accurate throughout the operational phase and until the Mine Pit Lake is flooded. Review of mitigation and management strategies should be undertaken if drawdown is found to be greater than predicted;

- A physical assessment of available refugia should be undertaken in nearby sections of the McArthur River (including Djirrinmini Waterhole) to assess available habitat (refugia) in the late dry season prior to deepening of the pit to provide a basis for comparison and to identify key refugia; and
- Aquatic fauna monitoring should occur to assess whether the potential loss of fauna in refuge pools as a result of drawdown deviates from predictions made in this assessment. Review of mitigation and management strategies should be undertaken if the influence of drawdown is found to be greater than predicted.

3.4 Domain 1 - Open Cut: Closure

3.4.1 Fauna Stranding in the Mine Pit Lake

The Mine Pit Lake will become a permanent major feature of the McArthur River catchment. The proposed design will see annual connection to the McArthur River and, as such, opportunity exists for fauna to enter the Mine Pit Lake. While some opportunity also exists for fauna to exit the Mine Pit Lake, poor water quality and lack of aquatic fauna habitat are major threats to the persistence of any stranded fauna.

Water quality will be influenced by a number of factors including: the presence of non-benign or acidic rock being present on the walls of the pit; placement of non-benign or acidic tailings in the pit during decommissioning of the TSF; discharge of TSF waters into the Mine Pit Lake during decommissioning of the TSF; release of site waters including that from the Barney Creek sumps which includes seepage from the NOEF; and groundwater intrusion. In addition, considering the depth and surface area of the Mine Pit Lake dissolved oxygen levels are expected to be low and limited by depth.

A vast majority of the aquatic fauna species present in the McArthur River are widely distributed throughout the greater Gulf of Carpentaria region. As such, mortality of individuals stranded in the Mine Pit Lake is unlikely to have a population-level effect for most species. However, potential entrapment (or death) of even low numbers of *P. pristis*, which occurs in naturally low abundance, could have a population level effect. This is due to the fact that the species occurs in naturally low abundance (Department of Environment 2015), has a low reproduction rate (Peverell 2009), has demonstrated female philopatry (i.e. females return to their natal river systems to give birth) (Phillips 2011, 2012) and that a low population rate of increase means *P. pristis* is 'particularly vulnerable to excessive mortalities and rapid population declines, after which recovery may take decades' (Musick 2000, Simpfendorfer 2000).

Throughout the life of the project, the effects of water quality and habitat availability in the Mine Pit Lake will be mitigated and managed in the following ways:

- Prior to flooding, benching of the Mine Pit Lake edges should be undertaken. Benching should occur to a depth that takes into account annual water level variations so that extensive vertical pit walls are not exposed and shallow edge waters are always available. These benched areas should be constructed to create varied bathymetry and in sections be embedded with large woody debris and protruding rock to provide aquatic fauna habitat and create areas of varied flow;
- Extensive planting of riparian vegetation should be undertaken prior to connection to the McArthur River to ensure an established flora exists. Riparian vegetation is necessary to provide allochthonous input and physical aquatic habitat in the form of root mats. Riparian vegetation should be maintained until self-generating;
- The period of connectivity between the McArthur River and the Mine Pit Lake is limited to when river stage height is greater than five metres above the channel invert at both the up and downstream levees. As such the window of opportunity for fauna to enter the Mine Pit Lake is limited. Furthermore, output from the Mine Pit Lake to the McArthur River is longer (up to ~40 days per year) than input from the McArthur River to the Mine Pit Lake (~10 days) meaning a greater opportunity exists for fauna to exit.
- An engineered solution should be considered to restrict the entry of large fauna (e.g. *Pristis pristis*) moving into Mine Pit Lake through the upstream and downstream levee. This could include a vertical barrage or a ramp design incorporating vertical batters or gabions. Inlets should, however, also incorporate sluices or fishways on the Mine Pit Lake side to allow fauna to exit the Mine Pit Lake as water levels recede;
- During initial pit dumping and tailings deposition, water with high concentrations of contaminants will be pumped out of the pit to remove contaminant mass and treated (KCB 2017b);
- Rapid filling of the Mine Pit Lake will occur by pumping and water levels will be maintained via inflow from the McArthur River through the levee opening/s. Rapid flooding will reduce the interaction of oxygen with potentially reactive rock;
- The period of connectivity between the McArthur River and the Mine Pit Lake is limited to high flow events. Under a flow-through scenario, inflow from the McArthur River will result in dilution and flushing of the upper layers of Mine Pit Lake waters;

- Quality of site-derived waters (including those from Barney Creek pumps) should be determined prior to them being pumped into the lower layers (greater than 100 m depth) of the Mine Pit Lake. Dewatering to the Mine Pit Lake should cease if introduced waters are seen to have a measurable effect on Mine Pit Lake water quality;
- Adaptive management allows for water treatment methods (for example reverse osmosis) to improve Mine Pit Lake water quality; and
- Ultimate contingency to isolate the Mine Pit Lake from McArthur River should water quality of the Mine Pit Lake be determined to be at risk of causing detrimental and ongoing impact to the McArthur River.

Throughout the life of the project the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Frequent (at least quarterly) ongoing monitoring to determine quality of Mine Pit Lake waters and output water. Analysis will include a suite of metals (Al, As, Cd, Cu, Fe, Pb, Mn, Hg, Ni and Zn), electrical conductivity (EC) and sulphate as a minimum during the operational phase. Analysis of pH should also be undertaken to determine whether changes are occurring as pH can greatly affect bioavailable of metals. The regime should include sampling events prior to the wet season to determine whether there is risk of causing detrimental and ongoing impact to the McArthur River. In such a case isolation of the Mine Pit Lake should be considered. Frequent monitoring is also required to determine the accuracy of predictive modelling used during this project. This will inform whether new modelling should be undertaken and new mitigation measures considered. Surface water monitoring data collected over time will also be used to review the sampling regime, including the frequency of sampling events. For example, if contaminant concentrations are shown to be consistent over time and at levels which are considered to be at a low risk of causing detrimental and ongoing impact to the McArthur River the frequency should be reduced;
- Site water discharge should be analysed prior to discharge into the Mine Pit Lake. This will identify whether there is a risk to Mine Pit Lake waters;
- Depth profiling of Mine Pit Lake waters should be undertaken after the Mine Pit Lake has stabilised to determine water quality at depth and whether a thermocline or chemocline exists. Results from this monitoring should be used to indicate whether risk exists in the event vertical mixing results in higher contaminant concentrations than modelled predictions. If risk is greater than predicted additional mitigation and management actions should be considered to ensure release from the Mine Pit Lake does not adversely affect water quality in the McArthur River ; and

- Monitoring of Mine Pit Lake fauna (species and abundance) should be undertaken (at least in the first five years after connection to the McArthur River) to assess which aquatic fauna species are entering the Mine Pit Lake and whether species are able to persist. This should also include an assessment of which species are capable of exiting the Mine Pit Lake and the effectiveness of the sluices or fishways at providing a pathway for escape. This monitoring will inform whether alterations to the vertical barriers on the inlet ramps may be required to further restrict fauna entering or to sluices (fishways) to increase the opportunity for fauna to exit.

3.4.2 Discharge of Surface and Groundwater from the Mine Pit Lake to the McArthur River

Current modelling predicts that a moderate salinity, neutral pH and low metal (Zn, As and Pb) concentrations can be maintained within Mine Pit Lake (KCB 2017b). Although predicted concentrations within the Mine Pit Lake will be elevated (namely sulphate and zinc) in comparison to those predicted in the McArthur River, they are well below the SSTVs measurable at SW11. Furthermore, currently predicted concentrations are well within the known tolerances of a number of fish species within the catchment.

The current closure scenario will see the uncontrolled release of water from the Mine Pit Lake once the levee wall/s are opened. Currently waters upstream of MRM are of low electrical conductivity (EC) and metal concentration. In the case of sulphate, which is the main local contributor to EC, predicted concentrations in the Mine Pit Lake are considered unlikely to affect the quality of the receiving McArthur River through surface flow out of the levee opening/s. The annual average concentrations of sulphate and zinc are also predicted to decrease with ongoing annual flows from the McArthur River leading to water quality within the Mine Pit Lake improving over time (WRM 2018).

Once flooded, the Mine Pit Lake will contain a large mass of water with significant head pressure. As such seepage from the Mine Pit Lake is likely to occur, which may influence surrounding groundwater and surface waters of the nearby McArthur River.

Throughout the life of the project, the effects of detrimental water quality discharging from the Mine Pit Lake will be mitigated and managed in the following ways:

- Mitigation measures discussed in Section 3.3.1 aim to maintain Mine Pit Lake water quality;
- Acceptable Mine Pit Lake water quality will be demonstrated prior to removal of the downstream and upstream levees and connection with the McArthur River;
- Adherence to SSTVs and WDL conditions at downstream compliance point SW11;
- Engineering of levee opening/s will limit the period of connectivity between the McArthur River and Mine Pit Lake to high flow events. This results in significant dilution

of output water from the Mine Pit Lake. Also, prior to overflowing into the McArthur River, water within the final void will have been diluted due to the inflows experienced during high flow events;

- Installation of groundwater recovery bores between the Mine Pit Lake and the McArthur River to reclaim seepage should a large measureable effect be observed;
- Adaptive management will allow for capability to run a water treatment plant as and when required to manage discharge water quality; and
- Ultimate contingency to isolate Mine Pit Lake from McArthur River should water quality of the Mine Pit Lake be determined to be at risk of causing detrimental and ongoing impact to the McArthur River.

Throughout the life of the project, the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Frequent (at least quarterly) monitoring to determine quality of water within the final void. Analysis will include a suite of metals (Al, As, Cd, Cu, Fe, Pb, Mn, Hg, Ni and Zn), electrical conductivity (EC) and sulphate as a minimum during the operational phase. Analysis of pH should also be undertaken, as pH can greatly affect bioavailable of metals. The regime should include sampling events prior to the wet season to determine whether there is risk of causing detrimental and ongoing impact to the McArthur River. In such a case, isolation of the Mine Pit Lake should be considered. Frequent monitoring is also required to determine the accuracy of predictive modelling used during this project. This will inform whether new modelling should be undertaken and new mitigation measures considered;
- Ongoing monthly monitoring of McArthur River water quality downstream of SW11 and adherence to SSTVs. Should water quality of the Mine Pit Lake be shown to be adversely affecting downstream waters of the McArthur River additional water treatment of Mine Pit Lake should be considered as well as additional measures to slow or cease outflow from the Mine Pit Lake;
- Ongoing annual monitoring of fluvial sediments of the McArthur River at SW11 to determine whether changes in contaminant load are occurring. Should sediment contaminant loads at SW11 be shown to be increasing as a result of the release of water from the Mine Pit Lake additional water treatment of Mine Pit Lake should be considered as well as additional measures to slow or cease outflow from the Mine Pit Lake; and
- Groundwater monitoring from bores surrounding the Mine Pit Lake to determine whether seepage is occurring and the rate of seepage.

3.4.3 Reduction in Water, Sediment and Organic Matter in the McArthur River

Upon connection to the McArthur River via the levee opening/s, water and sediment will be transported into the Mine Pit Lake. Reduced flow in the McArthur River has the potential to reduce available habitat downstream and reduce the window of opportunity for aquatic fauna to migrate and disperse. Sedimentation also has a major influence on river morphology including bank and bed creation. The wet season mobilisation of sediments plays an important role in nutrient cycling in monsoonal rivers. Wet season flow results in the resuspension, redistribution and breakdown of organic matter (detritus), which forms the foundation of all aquatic food webs. Flooding of the Mine Pit Lake, and reduced annual flow of the McArthur River associated with this, has the potential to remove some of these resources from the McArthur River.

Throughout the life of the project, the water, sediment and organic matter loss from the McArthur River will be mitigated and managed in the following ways:

- Initial rapid flooding of the Mine Pit Lake will be undertaken over a number of years by pumping from the McArthur River during wet season when flow exceeds 10 m^3/s. During poor wet seasons, extraction rates will be assessed to ensure sufficient flow remains in the McArthur River. During this time, there will be limited loss of sediment and organic matter from the McArthur River; and
- Engineering of levee opening/s will limit the period of connectivity between the McArthur River and Mine Pit Lake to high flow events when water levels are above five metres from the river invert. This will subsequently limit the period in which water, sediment and organic matter will enter the Mine Pit Lake.

Throughout the life of the project the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Modelling under a flow through scenario predicts a loss of ~12% of total suspended solids (TSS) will occur from the McArthur River measured upstream of the mine (WRM 2018). Monitoring of sediment deposition and accumulation should be undertaken in the years after the Mine Pit Lake is connected to the McArthur River at the levee opening/s. This will confirm the modelled sedimentation rates. If sedimentation rates are found to be vastly higher than predicted, additional engineered solutions aimed at capturing sediment on the inlet should be considered.

3.4.4 Stability of Mine Pit Lake Walls, Inlet and Outlet

High surface water velocities experienced during flood events have the ability to scour and undermine banks and levees which may lead to wall, inlet and outlet failure in the Mine Pit Lake. In consideration of the fact the Mine Pit Lake will become a permanent feature in the

McArthur River catchment, and that the earth levees of the Mine Pit Lake will be subject to natural erosive forces over time (e.g. rainfall runoff and settling), maintaining the integrity of Mine Pit Lake levees, inlet and outlet is vital. This is compounded by the fact that the design of the inlet and outlet ramps plays a major function in controlling water interaction of the Mine Pit Lake and McArthur and thus water quality.

Throughout the life of the project the instability of the Mine Pit Lake levees, inlet and outlet will be mitigated and managed in the following ways:

- Mine Pit Lake levees constructed in accordance with relevant Australian National Committee on Large Dams (ANCOLD, 2012);
- Levee seismic design criteria include building to 1:1000 AEP Max Design Earthquake (MDE) and 1:500 AEP Operating Basis Earthquake (OBE) criteria;
- Ramps designed to withstand flood to 1:100000 AEP (Critical Storm Duration);
- An ongoing inspection program and maintenance schedule should be implemented and considered a key component of the caretaking role. In the event erosion is observed immediate repairs should be undertaken;
- Earth, clay and rock required to maintain and repair Mine Pit Lake levees, inlet and outlet should be stockpiled to ensure a rapid repair can be undertaken;
- Baffling or angling of the inlet ramp should be considered in the design to reduce water velocities on entry to Mine Pit Lake; and
- Ultimate contingency to isolate Mine Pit Lake from McArthur River should the inlet or outlet ramp fail.

Throughout the life of the project the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Monitoring should include frequent inspection through observation. In addition periodic permeability and stability testing of levees and investigations of inlet and outlet stability should be undertaken. These works will also confirm that the inlet and outlet remain at five metres above the river invert to ensure the role of the engineered design is maintained.

3.5 Domain 2 - NOEF

3.5.1 Expansion of NOEF Footprint

The expansion of the NOEF will encroach on the Emu Creek catchment to the north. Despite being a highly ephemeral creek it has been found to provide temporary habitat during the wet season (See Appendix W of the Draft EIS). In addition to the direct loss of some Emu Creek habitat, a potential pathway for the introduction of contaminants also exists which may ultimately enter the McArthur River. A site specific survey of Emu Creek fauna was undertaken to determine the species present and whether the catchment represented critical habitat for any species or potential habitat for listed threatened species. It was determined that a limited loss of the Emu Creek catchment would not affect population viability of any species (See Appendix W of the Draft EIS).

Throughout the life of the project, the loss of Emu Creek habitat and potential water quality effects will be mitigated and managed in the following ways:

- The current NOEF footprint has been minimised by raising the height to avoid extensive expansion to the north and encroachment on Emu Creek. The current design encroaches on a small unnamed tributary of Emu Creek which is highly seasonal and a minor proportion of the catchment; and
- A surface runoff drain will be installed on the northern side of the NOEF to capture surface and groundwater and restrict flow of these waters into Emu Creek. This water will be diverted back to a water management dam.

Throughout the life of the project the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Ongoing monthly monitoring of surface water quality and water level along Emu Creek including at the confluence with the McArthur River. Surface water monitoring in the McArthur River downstream of the confluence should also be undertaken at SW11 to determine adherence to SSTVs.

3.5.2 Effects on Surface and Groundwater

A number of potential pathways exist for waters which have interacted with the NOEF to enter groundwater and surface water. In addition, potential exists for water to seep through the NOEF, including PAF and reactive waste rock, which may ultimately lead to a reduction in groundwater and surface water quality. Indeed, this interaction has the potential to create long-lasting detrimental effects.

The NOEF represents a large catchment area and mass. Consequently, large volumes of surface runoff will occur during rain events. Considering the proximity of Surprise, Barney and Emu Creeks to the NOEF, runoff has the potential to reduce water quality in particular by increasing TSS. The mass of the NOEF also has the potential to cause a groundwater mound which results in rising of the surrounding groundwater level. The subsequent cartage of salts to the surface can influence water electrical conductivities which may exceed fauna tolerances. In addition mounding of groundwater can lead to an alteration of inflow to the creeks in close proximity.

Considering the current design of the NOEF, seepage is most likely to represent the greatest risk to groundwater and subsequently surface water quality. In light of this risk, a GSL as opposed to a CCL will now be included in the cover system to further reduce seepage of water through the NOEF. Current modelling predicts that surface waters in Barney Creek will be high in sulphates and zinc (WRM 2018) which may exceed the tolerance of some fauna. During the operational period this has mainly been attributed to seepage from the TSF. However, post closure and after rehabilitation of the TSF elevated sulphate levels have been directly attributed to the NOEF (WRM 2018). As well as benign material, the NOEF also contains highly reactive and potentially acid forming rock. In consideration of this (and predicted sulphate concentrations) it has been considered vital that interaction of water with these latter waste types is minimised and that any water that has interacted with the NOEF be captured and managed.

Predicted sulphate concentrations (WRM 2018) in Barney Creek, may result in aquatic habitat in the lower part of Barney Creek becoming unfavourable to some aquatic fauna at least for some time each year. This is particularly the case during post-wet periods when flow rates subside resulting in lower dilution and mixing rates and evapoconcentration. While current modelling predicts concentrations of sulphate will decline at some locations after the closure of the TSF and over time, monthly median sulphate concentrations at SW19 will exceed the SSTVs (~2000 mg/kg) during months of lowest discharge from 2060 onwards (i.e. March to September) (WRM 2018). Upon decommissioning of BCS1 (2060) the predicted mean concentration of sulphate is 2929 mg/L. Furthermore, beyond 2060 predicted mean sulphate concentrations at BCS2 (located in Barney Creek near the confluence with the McArthur River) will continue to increase to 3319 mg/L by 2500.

Sampling in Barney Creek has indicated a number of fish species can persist in waters of high electrical conductivity (EC). *Hephaestus fuliginosus*, *Leiopotherapon unicolor*, *Melanotaenia splendida* and *Nematalosa erebi* have been consistently recorded in sulphate affected reaches of Barney Creek up to 2240 mg/L. This implies that not only can these fish species tolerate these concentrations but food for these species (for example, invertebrates, algae or plants) also persists in these environments. In addition *Lates calcarifer* has been recorded from inland waters with sulphate concentrations up 2180 mg/L. Based on this, some resilience exists for aquatic fauna to persist in the lower portion of Barney Creek for some time. At BCS2 within Barney Creek, however, median sulphate concentrations will continue to increase and will exceed the SW11 SSTVs throughout the year by 2168-2500 reaching concentrations of up to ~4000 mg/kg when creek discharge is at its lowest (WRM 2018). This value is beyond the maximum concentrations at which aquatic fauna have been recorded in Barney Creek to date.

The fish species recorded from Barney and Surprise Creek are found throughout the McArthur River catchment and greater Gulf of Carpentaria. Based on this and the fact Barney Creek does not represent critical habitat for any species, it is unlikely the loss of any aquatic habitat will result in a population-level effect. However, capture of affected water from Barney Creek remains an important process to avoid adverse effects on water and habitat quality in the McArthur River.

Throughout the life of the project, influence on surface and water quality will be mitigated and managed in the following ways:

- The design of the NOEF (including armouring, angling compaction and permeability) focuses on achieving physical stability, controlling erosion and sediment loss due to surface runoff. In addition, numerous drainage channels, stilling basins, sediment dams, sumps and lined (HDPE, clay or geopolymer) dams (PRODS) will be constructed to capture runoff and sediment (see O'Kane 2016, WRM 2018). Runoff dam capacities have been set to have a less than 5% probability of exceedance (spill) over the operating life of the dam. As such runoff from the NOEF and entry into adjacent creeks will be limited. Modelling predicts only a very small proportion (less than 1%) of the total mine release volume over the whole operational period will drain to the waterways from mine water storage overflows (WRM 2018);
- During NOEF construction exposed areas of reactive rock will generate contaminated surface runoff. This runoff will be captured and diverted into water management dams (PRODS);
- The outer layers of the NOEF will comprise benign materials. As such any runoff should be benign. In the event runoff from the NOEF reaches adjacent creeks it should be predominantly rainwater which is considered of low risk to aquatic fauna;
- The NOEF is designed to minimise seepage through basal foundation preparation, construction methodologies (including alluvial barriers) and the final cover system. The final cover design is based on a moisture store-and-release' and 'barrier' concept which will capture rainwater then progressively dry through evaporation. A Geo-Synthetic Liner (GSL) will be installed to reduce net percolation through the NOEF (ATC Williams 2017). In addition, a seepage recovery system will include interceptor drains (URS 2006, KCB 2016a) and recovery bores;
- The NOEF design includes encapsulation of high risk materials in the centre to limit oxidation and seepage of oxidation products into groundwater and surface water systems. In consideration of this and the fact encapsulating materials in the NOEF will have limited permeability, percolation of water through the NOEF will be limited;

- Two sumps will be installed in Barney Creek which will ultimately capture potentially impacted groundwater and surface water runoff. This water will be pumped to a water management dam (or ultimately the Mine Pit Lake) to avoid outflow into the McArthur River;
- An ongoing inspection schedule and maintenance program should be designed which will include observation and testing to be conducted on the NOEF to ensure integrity and stability of the outer layers as part of the caretaking role. Erosion and outer layer breakdown of the NOEF will be immediately repaired;
- Compliance with SSTVs at SW11 and surface water quality standards will be adhered to; and
- Recovery bores, trenches and other recovery methods will be installed and maintained around the NOEF to capture NOEF seepage where required.

Throughout the life of the project, the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Ongoing periodic monitoring of NOEF stability and maintenance;
- Ongoing frequent monitoring of groundwater and surface water in proximity to the NOEF and downstream including the McArthur River. The frequency of this monitoring should be monthly during the operational phase to ensure modelling predictions are accurate as the NOEF expands. Monthly monitoring of surface and groundwater should be conducted for an extended period post closure to ensure modelled sulphate concentrations are as predicted and reduce over time. Should sulphate concentrations be higher than predicted additional mitigation and monitoring actions should be considered aimed at reducing sulphate concentration of Barney Creek surface waters. Analysis should include a suite of metals (Al, As, Cd, Cu, Fe, Pb, Mn, Hg, Ni and Zn), electrical conductivity (EC) and sulphate as a minimum during the operational phase. Analysis of pH should also be undertaken to determine whether changes are occurring as pH can greatly affect bioavailable of metals;
- Surface waters should be monitored in the McArthur River below the confluence with Barney Creek to ensure compliance with SSTVs at SW11 and surface water quality standards;
- Frequent monitoring of the composition of sump water should be undertaken to ascertain the maximum concentrations of contaminants. These waters should be analysed for a wide range of analytes to characterise the outflow including metals (Al, As, Cd, Cu, Fe, Pb, Mn, Hg, Ni and Zn), electrical conductivity (EC), sulphate and pH. Should unexpected contamination be detected over time an additional risk assessment should be undertaken to understand potential threats to aquatic fauna and downstream

habitat and water quality. New mitigation measures should subsequently be proposed to deal with unacceptable new risks;

- Monitoring of surface water collected in runoff dams should be undertaken as the NOEF progresses to determine whether the runoff is indeed benign; and
- Ongoing monitoring and maintenance of surface water runoff collection systems and infrastructure. This includes dam liners, levees and spillways. Repair of damaged liners, levees and spillways should be undertaken immediately.

3.5.3 Uncontrolled Release of Water from Runoff Management Dams

The required longevity of the NOEF runoff dams means that periodic and ongoing maintenance will be required. This is due to the fact dam linings (clay, geopolymer or HDPE) may breakdown over time or become compromised resulting in seepage through the levee walls. This seepage can subsequently lead to erosional and destabilising processes that will affect integrity over time. As such, potential exists for stored water to be released. This includes spill during large storm events or as a result of levee failure.

Throughout the life of the project uncontrolled releases from water runoff dams will be mitigated and managed in the following ways:

- Runoff dams will be constructed in accordance with relevant Australian National Committee on Large Dams (ANCOLD) Guidelines including ANCOLD's Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure (ANCOLD, 2012). Designed to an earthquake loading of 1:1,000AEP Max Design Earthquake (MDE) and 1:500 AEP Operating Basis Earthquake (OBE). Crest of spillway above 100 year McArthur River flood level. Spillway design to safely pass a 1:2000 AEP flood event with a 1:10 AEP wind event wave allowance;
- Runoff dams' capacities have been set to have a less than 5% probability of exceedance (spill) over the operating life of the dam;
- Runoff dams will be lined with low permeability liner (clay, geopolymer or HDPE) to limit seepage; and
- An ongoing inspection and maintenance schedule will be initiated which will be a key component of the caretaking role.

Throughout the life of the project the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Ongoing biannual monitoring of stability, structure, operation and management of runoff dams. The frequency of monitoring would reduce once the design is shown to be stable;

- Ongoing monitoring of dam liner integrity; and
- Monitoring of surface water collected in runoff dams should be undertaken as the NOEF progresses to determine whether the runoff is indeed benign.

3.6 Domain 3 - TSF

3.6.1 Groundwater mound

The existing TSF has had the effect of creating a water table mound. As explained by GHD (2016), the mound has interrupted the natural north-west to south-east groundwater flow in the area and caused prolonged discharge into Surprise Creek. Rising groundwater has also resulted in the lifting of sulphate-based metalliferous salts which have also affected electrical conductivities in Surprise Creek. With the subsequent expansion of the TSF, the effect on groundwater is likely to increase until its eventual decommissioning and subsequent rehabilitation of the site.

Throughout the life of the project the influence of groundwater through mounding will be mitigated and managed in the following ways:

- Tailings management includes minimising ponding of water on the TSF (GHD 2016). This will reduce the ultimate mass of the TSF;
- HDPE lining of the TSF WMD to limit seepage; and
- End of mine reprocessing of tailings will reduce long term impacts and limit the risk period. Rehabilitation and decommissioning of the TSF will see a mining landscape left safe and secure for humans and animals in the long term (i.e. 100-1000 years) (GHD 2016). Extensive closure objectives are outlined in Section 2.4 of GHD (2016) with environmental values and ecosystems maintained.

Throughout the life of the project the effectiveness of these mitigation and management actions should be determined through monitoring including:

- Surface water volumes of the TSF should be monitored and managed on an ongoing basis; and
- Post-closure monitoring should be undertaken in accordance with GHD (2016). The detailed post-monitoring program will be used to validate the closure design assumptions and demonstrate successful closure of the TSF.

3.6.2 Uncontrolled Release of Tailings through Spill and Seepage

While management will ensure ponding of water on the surface of the TSF is minimised a number of potential pathways exist through which water and tailings may escape. This includes spill as a result of levee failure or overtopping during large rain events. In addition seepage from the TSF, which has been historically reported, has the potential to affect groundwater and surface water quality and height. Considering the size of the proposed expansion of the TSF, seepage represents the greatest risk in relation to an uncontrolled release.

As discussed in section 3.5.2, modelling predicts that surface waters in Barney Creek will contain high concentrations of sulphates (and zinc) throughout the operational phase and post closure (WRM 2018). These models also predict that a majority of the sulphate will be derived from TSF seepage until its eventual decommissioning. As discussed in Section 3.5.2, highest annual sulphate concentrations (and resulting EC) will be experienced during low flow periods. While Section 3.5.2 also describes fauna that have resilience to these conditions, the recognition that seepage will occur and the nature of the expressed surface water, has resulted in the current Project design incorporating two sumps in Barney Creek. This includes one sump slightly downstream of the confluence with Surprise Creek and the other in the lower part of Barney Creek. While the quality of aquatic habitat will inevitably be degraded in Surprise and Barney Creeks due to the TSF seepage, a primary aim remains the protection of the McArthur River proper. Indeed, if seepage is able to reach the McArthur River this may have long-lasting effects on habitat, water quality and the aquatic fauna present.

Throughout the life of the project the uncontrolled release of tailings will be mitigated and managed in the following ways:

- The TSF will be constructed in accordance with relevant Australian National Committee on Large Dams (ANCOLD) Guidelines including ANCOLD's Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure (ANCOLD, 2012). TSF seismic design criteria will see it built to loading 1:1000 AEP Max Design Earthquake (MDE) and 1:500 AEP Operating Basis Earthquake (OBE). Furthermore, the TSF spillway is designed to flood to 1:100000 AEP (Critical Storm Duration). As such the likelihood of levee failure is considered to be low;
- A Dam Safety Emergency Plan (DSEP) will be drafted and adhered to. In the event of a levee failure, repairs will be immediately undertaken;
- Installation of recovery bores may be undertaken to reduce the volume of seepage reaching groundwater and adjacent Creeks;
- Ongoing bi-annual monitoring of stability, structure, operation and management (GHD 2016);
- Adherence to ANCOLD (2012) Extreme Storm Storage and Wet Season Storage Allowance criteria. The current TSF design includes a Process Water Dam (PWD). In the event rainfall leads to a spill, water from the TSF will spill into the PWD. If the event is large enough to cause a spill from the PWD, water will enter Little Barney Creek. Any

release would, however, coincide with local flooding of the Creek meaning dilution of tailings would be high;

- Tailings management includes minimising ponding of water on the TSF, improving barrier systems to seepage and groundwater recovery (GHD 2016). Furthermore, tailings densities will be maximised to reduce permeability of the tailings and thus seepage;
- Installation of sumps on Barney Creek will capture impacted groundwater and surface water derived from TSF seepage, reducing risk of tailings reaching McArthur River;
- Compliance with SSTVs at SW11 and surface water quality standards will be adhered to; and
- End of mine reprocessing of tailings and site rehabilitation will reduce the long term impact.

Throughout the life of the project, the effectiveness of these mitigation and management actions will be determined through monitoring including:

- Ongoing bi-annual monitoring of TSF stability, structure, operation and management (as per GHD 2016);
- Ongoing monthly monitoring of groundwater and surface water to determine seepage rates and quality until decommissioning. This will include surface water monitoring sites in Surprise Creek above and below the TSF and along Barney Creek. Analysis will include a suite of metals (Al, As, Cd, Cu, Fe, Pb, Mn, Hg, Ni and Zn), electrical conductivity (EC) and sulphate as a minimum during the operational phase. Analysis of pH should also be undertaken to determine whether changes are occurring as pH can greatly affect bioavailable of metals.

3.7 Confirmation of Modelling

The design of the project and this risk assessment relied on the accuracy of predictive modelling outputs. Risk rankings, mitigation and monitoring measures in Sections 2 and 3 are based on the modelling outputs being accurate, with deviation from the modelled predictions ultimately affecting these outputs. As such, results from the routine monitoring outlined above should be constantly compared with model predictions. Indeed, if model predictions are not realised, additional modelling should be undertaken and appropriate mitigation measures reconsidered.

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