

OMP SUPPLEMENTARY EIS REVIEW

McARTHUR RIVER MINE OVERBURDEN MANAGEMENT PROJECT

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McArthur River Mine Overburden Management Project

Overburden Management Project Supplementary EIS Review



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1. Introduction

ERIAS Group has been engaged by the Northern Territory Government to review the Overburden Management Project Supplementary Environmental Impact Statement (OMP SEIS) prepared by McArthur River Mining and respond to specific questions relating to the following areas:

- ♦ Geochemistry.
- ♦ Groundwater.
- ♦ Surface water.
- ♦ Geotechnical.
- ♦ General.

The draft Overburden Management Project Environmental Impact Statement (OMP EIS) was reviewed by ERIAS Group and the OMP SEIS responds to comments from all stakeholders on the draft OMP EIS.

This report has been prepared following review of the OMP SEIS and addresses the questions outlined by the Northern Territory Environmental Protection Authority in an email dated 21 March 2018.

OVERBURDEN MANAGEMENT PROJECT SUPPLEMENTARY EIS REVIEW
MCARTHUR RIVER MINE OVERBURDEN MANAGEMENT PROJECT

2. Geochemistry

2.1 Background

Geochemistry aspects of the supplementary EIS were reviewed against the findings from ERIAS Group's review of the 2017 Draft EIS (ERIAS Group, 2017a), with focus on the following specific aspects, as requested by the Northern Territory EPA:

- ♦ The likelihood that seepage from the NOEF can be reduced and then managed on the site throughout mining operations and the period over which a significant reduction in the discharge of acid and metalliferous drainage (AMD) and associated metals/metalloids from the NOEF might occur despite the projected growth in size of the NOEF. Provide comment on the expected period required until monitoring of seepage from the NOEF shows the effectiveness (or otherwise) of the AMD containment system and the expected period in which the NOEF will continue to produce AMD. In this respect, outline any additional risks if mining operations cease in the near term in contrast to the management timeframe proposed by MRM.
- ♦ Whether cover trials are likely to provide answers about durability of covers and effectiveness over the expected post-closure timeframe.
- ♦ The probability, based on the design presented in the EIS, that combustion within the NOEF will be prevented in the future and whether this is an important consideration for longevity of the NOEF.
- ♦ Whether the reactive material from the existing dump could conceivably be placed in the pit if the mine expansion did not proceed, and whether this would be a good management option.
- ♦ Whether the tie-in of the new sections of the dump with the existing dump creates a significant weakness in the NOEF design or is likely to affect its performance.
- ♦ Adequacy of the monitoring of the NOEF into the future and the potential for monitoring to adversely affect the integrity of the cover system.

2.2 Summary of Geochemistry Review of 2017 EIS

ERIAS Group's review of the Draft EIS in May 2017 determined that the requirements outlined in the Terms of Reference were largely addressed, but there remained a number of uncertainties and knowledge gaps, particularly in regard to NOEF management. The review found that the geochemical properties of mine materials were well understood, systems of segregation and selective handling of overburden well developed, and the current and future geochemical hazards well defined. However, there were key uncertainties in regard to operational and long-term management of the NOEF, and geochemical modelling predictions of dump seepage quality, pit water quality and down-gradient water quality effects. The key areas of uncertainty were:

- ♦ Given that the northern overburden emplacement facility (NOEF) is a major geochemical hazard for the site, modelled predictions of seepage quality carried out to date should be independently verified.

- ♦ It is doubtful that installation of a contiguous low permeability (1×10^{-9} m/s) compacted clay layer (CCL) over the entire surface of the NOEF is achievable.
- ♦ The integrity of the proposed cover system is obviously critical to long-term performance, but it has not been demonstrated that this can be managed with maintenance and repair for the proposed 1,000-year closure period.
- ♦ The effectiveness of the proposed advection control barriers on the large, heterogeneous and actively convecting system represented by the existing NOEF has not been demonstrated.
- ♦ There is no prediction of differential settlement in the NOEF and its potential impact on the relatively thin infiltration control layer.
- ♦ The above uncertainties suggest that the modelled geochemical impacts from the NOEF may be optimistic, leading to consequent uncertainties concerning the scale and duration of surface water and groundwater collection and treatment requirements.
- ♦ The open pit also represents a major geochemical hazard for the site, and pit void model predictions should also be independently verified.
- ♦ Long term site management strategies and time lines presented in the EIS rely on the validity of GoldSim modelling predictions of AMD impacts on the receiving surface water system, which should be independently verified and take failure modes into account for the two key sources, i.e., the NOEF and open cut.
- ♦ It was not clear from the EIS that there are sufficient resources to collect and treat worst case AMD loadings for the 1000 year period as contingency if other management options are ineffective.

2.3 NOEF Management

The management of the NOEF over the project is outlined in Section 6, with key changes summarised in Table 4-1 (Section 4). There are three key aspects to AMD control of the NOEF:

- ♦ Management of dump seepage during operations.
- ♦ Advection control.
- ♦ Long term seepage management using a cover system.

2.3.1 NOEF Seepage Management During Operations

The approach to operational management of NOEF seepage has not been changed in the Supplementary EIS, with large areas of non-benign materials likely to be exposed to incident rainfall, and no plans for interim covers on exposed surfaces. Interim advection barriers are planned, which may help limit advection, but it is unlikely that oxidation rates and AMD generation rates would significantly reduce until the final cover is installed. However, the installation of the final geosynthetic liner (GSL) cover is planned to be staged (Section 6.5.1.3.3), allowing progressive rehabilitation and infiltration control as the NOEF is constructed, which will help to

reduce loadings. Managing the transport of AMD from the NOEF will continue to rely on collection of seepage and run off in the surrounding PRODs, and treatment/evaporation. McArthur River Mining (MRM, 2018) refers to current dump toe seepage as being circum-neutral pH with high SO₄ and Zn concentrations (Section 3.1.1.1.2) which confirms active oxidation and seepage transport of AMD products will occur during operations.

Toe seepage is currently collected and pumped back to the PRODs, and this would be the primary dump seepage control used during operations. Groundwater NOEF seepage contamination during operations and prior to final cover placement will be controlled by the compacted clay foundation layer in new areas, and the in-situ clay in old areas, and the efficiency of the seepage recovery system to capture all sources from the NOEF.

It is understood that although the in-situ clay below the older dump areas has not been compacted, it is reasonably thick, at 1.5 to 12m (Figure 4.21, ERIAS Group, 2017b), and is expected to direct most seepage into old drainage lines where it can be recovered and pumped. Further investigation would be required to confirm this. It is not clear from the Supplementary EIS if MRM are planning further investigation. This would need to be assessed through monitoring of volumes and AMD loadings recovered against those expected from the water balance, and in the longer term monitoring of loadings reporting to surface drainage and groundwater monitoring.

The clay foundation in new dump areas will be designed to direct seepage to the nearest PROD, using either in-situ low permeability clay materials, or constructing a compacted clay layer (CCL) of 0.25m thick (Section 6.5.1.3.2). It is understood that any in-situ clay foundation would be sloped and profiled to direct drainage to seepage points, and rolled to achieve a maximum saturated hydraulic permeability of 10⁻⁹ m/s, as per Draft EIS Section 3.4.4.3.3.1. Placement of the 0.25m CCL may result in localised increased permeability during operations based on the description provided in Section 6.5.1.3.2. Note that the thinner CCL base would have negligible effect on the performance of the final GSL cover system, which is the key long term seepage control (See Section 2.3.3).

Modelling and groundwater investigations indicate that seepage would report to the lower Barney Creek, where it would be recovered from two collection sumps to help meet surface water quality commitments at SW11 (Section 5.3.2 and 5.3.5). The KCB NOEF flow and water quality modelling report assumes basal seepage (through the in-situ clay and CCL base into the natural groundwater system) of over 20L/s during operations, and suggests that operational seepage effects would stabilise within 50 years after closure (KCB, 2017a). It is difficult to judge based on the information given whether these seepage rates are conservative or not. No updates on exposed dump area are given in the Supplementary EIS, but the staged cover placement proposed and the Draft EIS suggests that the total exposed area of non-benign material at any one time during operations will be a similar order of magnitude to what is exposed currently. Seepage during operations is not expected to have a significant impact on the integrity of the clay base, and as long as the final cover system is successful, the performance of the basal clay is not critical.

2.3.2 NOEF Advection Control

The advection controls described in the Draft EIS are unchanged in the Supplementary EIS, involving placement of compacted alluvium on inter-stage faces that will be exposed for over six

months, with an MS-NAF halo providing further isolation from bulk oxygen flow. PAF materials in the older dump areas were generally end tipped in lifts of approximately 15m, resulting in segregation of coarse and fine materials and creation of chimney structures that encourage rapid convective oxidation and acid generation, and spontaneous combustion in the case of PAF(RE) materials. Control of advection in these older actively convecting PAF dump areas with an external barrier is expected to be challenging given the existing temperature gradients, which would be expected to continue driving the convective oxidation process.

Placement of an alluvium cover over the older end tipped PAF zone is in progress, with temperature monitoring bores used to assess the performance. An update on temperature monitoring was provided in the Supplementary EIS (MRM, 2018), which included additional monitoring holes drilled in 2017. Temperature results show evidence of cooling from the extreme combustion conditions previously measured, but still indicate convective oxidation processes, with average temperatures considered still high at over 70° C. Advection control to date may be helping to limit spontaneous combustion, but is not stopping rapid oxidation rates and AMD generation associated with convection. The report demonstrates an improved understanding of the gas transport processes, and the focus of advection control on the northern batter is appropriate to reduce extreme oxidation rates. However, full control of convection has not been demonstrated, and it should be assumed that the older PAF areas will continue to contribute high AMD loadings into seepage during operations until infiltration is controlled. Note that there are still very high temperature zones, and this could still potentially cause differential settlement, which may affect the integrity of the final cover. The high temperature zones are not expected to directly affect the alluvial advection cover through desiccation effects, but the existing temperature gradient will tend to encourage convective pathways and continued high rates of pyrite oxidation. These advection layers are suitable as an interim measure to control extreme spontaneous combustion, but final control of AMD effects relies on limiting infiltration and transport.

Section 2.3 of the Supplementary EIS mentions that large scale spontaneous combustion had been eliminated since 2014, but this fails to take into account the combustion event in mid 2016, that occurred during recovery of materials from the low grade stockpile on the NOEF. This event resulted in acid leachate reporting to the NOEF SPSPD. The incident highlights the potential for generation of highly acidic leachate from these strongly pyritic PAF materials if advection processes are not controlled.

Successful implementation of the final GSL cover system (see Section 2.3.2 below) would see negligible release of AMD to the environment post closure, and convection should be largely controlled. However, placement of the GSL cover could also affect dissipation of any residual heat from the existing convecting materials resulting in a short term build up of heat, and temperature effects on the GSL would need to be considered. The Supplementary EIS notes that the MS-NAF halo zone will help isolate the GSL from heat, which would need to be confirmed and monitored during construction. Note that MS-NAF is still sulphidic (typical S values range from 1% to 6%S, KCB, 2017b, Table 2-1) and although the 7.5m lifts proposed for the halo zone will help control convective oxidation relative to 15m end tipped lifts, demonstration is again required. It is uncertain if the residual heat would effect successful implementation of the GSL cover system, and this, along with other sensitivities discussed in Section 2.3.3, would need to be evaluated as part of trial work and investigations. The IM is not aware of a precedence for this scale of GSL

cover on an actively convecting waste rock dump, and trials will be the only way of demonstrating likely performance.

Section 6.5.1.3.1 describes the focus on closing off bulk air flow pathways of the older NOEF PAF zones as soon as possible, which would involve continued placement of the MS-NAF halo and compacted alluvium barrier layer, with the entire existing NOEF completely encapsulated with low permeability materials by the end of 2021. The staging plan is provided in Section 6.5.1.3.3, which shows that Stage 2 of the NOEF development is specifically designed to preferentially cover the older area with newly dumped materials, and ultimately by the final cover to provide infiltration control. Placement of the MS-NAF halo and other newly dumped materials will assist control of convection, and also provide a buffer between the hot zones and the GSL. There is still uncertainty as to whether convection will be controlled completely by this method, but the oxidation rates and mobilisation of AMD are likely to be significantly reduced. The older end tipped dump portion represents the greatest potential source of AMD in the NOEF, and these measures are considered the most appropriate approach, short of rehandling and recompacting the older PAF materials. These older dump areas have higher potential differential settlement and temperature effects than other dump areas, and monitoring of potential effects on the Stage 2 GSL should be carried out in addition to the planned continued monitoring of dump temperatures (Section 2.3, and Glencore 2017) to help assess performance.

Currently, PAF is placed in a way that better controls advection, with shorter lifts of 2m used for all PAF materials. This combined with the advection control layer would be expected to perform well during operations to limit convective oxidation and high AMD generation rates. For future dump areas, PAF(RE) materials would be placed in 2m lifts, but other PAF materials (PAF(HC)) would be placed in up to 7.5m lifts (2m base followed by 5.5m tip head). Although the PAF(HC) materials have lower S and are not as reactive as PAF(RE) materials, they still have very high fine grained pyrite contents, with median S values of around 8%S, and would be highly susceptible to convection (if not combustion). ERIAS Group was advised during a site visit in 2017 that even with paddock dumping and compaction, some PAF zones (mixed PAF(RE) and PAF(HC)) on the south west corner of the NOEF were showing spontaneous combustion (ERIAS, 2017b). This was managed through placement of an alluvium cover layer, but the occurrence emphasises the high reactivity of these materials, and supports the need to review the 7.5m option for PAF dumping in the core zone.

2.3.3 NOEF Final Cover System

There has been a major change in the proposed final cover system design, with replacement of a compacted clay layer (CCL) with a geosynthetic liner (GSL) in the final cover (Section 4.2). ERIAS Group raised concerns in the Draft EIS review in achieving the required CCL compaction, and its susceptibility to differential movement, desiccation and erosion. The GSL is considered an improvement on the CCL, with far greater infiltration control, and likely better long-term security. Cover system modelling and design considerations are detailed in OKC 2017a and ICI et al 2017.

Properly constructed GSLs such as HDPE and BGM can be expected to provide high performance infiltration control over the long term, which is supported by numerical modelling presented in OKC 2017a. The results of the cover modelling indicate very low values of net percolation (NP) of less than 5% of rainfall. The numerical model adopted for computing cover performance with respect to surface fluxes, interflow and NP is comprehensive, well defined, and

considered highly credible. Furthermore, the parameters selected for the Soil-Plant-Atmosphere continuum are appropriate and defensible. ERIAS Group also finds the documentation provided for Geosynthetic Liner Design Details (ICI et al 2017) to be comprehensive and appropriate for the purpose of selecting of the most suitable GSL (i.e. HDPE, LLDPE, BGM or EPBM).

Key sensitivities to long term performance of GSLs include:

- ♦ Quality of construction.
- ♦ Isolation from sunlight and weather.
- ♦ Degradation of the GSL.
- ♦ Differential settlement.

ICI et al (2017) clearly outlines the uncertainties and considerations in regard to the above.

The quality of the construction is obviously key to performance of the GSL barriers. Careful installation together with appropriate Quality Assurance/Quality Control will be needed to minimise holes/tears/breaches and hence infiltration. Note that GSL liners such as HDPE have been used for waste rock and low grade dumps at other sites (e.g. Haile Gold Mine, Kelian Gold Mine), but ERIAS Group is not aware of any achieved on the scale planned for the NOEF.

ERIAS Group's review of the Draft EIS recommended that the long-term performance of the selected cover system be evaluated with field scale lysimeters. Such a field trial would have been appropriate to measure infiltration rates for cover systems constructed with a CCL as well as uncovered rock (which is expected to be very high). However, the expected infiltration rates for GSLs are very low since they are a function of flaws and the quality of construction, and are thus difficult to measure in field lysimeters. Therefore, the use of field lysimeters to evaluate GSL performance is not recommended, but constructability trials, such as those described in OKC 2017b, will be essential to successful implementation. It is noted that Appendix H discusses the need for extensive physical, chemical and constructability testing to select the most appropriate GSL, but the trials described in OKC 2017b will only consider BGM, and do not consider testing all the aspects listed. It is unclear if more widespread testing of different GSL options will be part of a future programme.

Keeping the GSL cover isolated from the effects of UV degradation and effects of surface temperature fluctuations and resultant expansion/contraction effects will be key to long-term performance after successful installation. A cover system is outlined in Appendix G, which is designed to protect the GSL from these effects. The continued protection of the GSL relies on maintaining the cover system, and hence erosion and failure of the protection layer are a key consideration.

The installation of a very low permeability GSL has potential impacts on the pore pressure and stability of the overlying cover materials. The modelling report (OKC 2017a) does not appear to evaluate performance of the Base-Case Batter Cover System (i.e. shown in Figure 6-1) in terms of slope stability, and this may represent a fatal flaw. Interflow simulations for various 3 day storm events ranging from a 1-in-50 year to a 1-in-1000 year storm event indicate that saturated conditions are expected to reach the surface of the cover profile. Such events may result in slope

failures seated in the loose alluvium above the soil/geomembrane interface. A simple semi-infinite slope stability analysis indicates that the Factor of Safety may decrease to a value less than unity for a batter slope of 1:3, depending on the interface friction angle available for the geomembrane material. The minimum Factor of Safety value must be well above unity for this case since such a failure could produce a large scale liquefaction flow slide with catastrophic consequences. Further detailed analysis and design modifications must be carried out to ensure adequate slope stability for all batter slopes during extreme events. This appears to be at least partly addressed in Pando (2017), and considered in the trial pad designs (OKC, 2018), but have not been adequately incorporated into the cover design and performance simulations. The design will need to be improved with the use of other materials and improved drainage. It is recommended the geotechnical assessment and cover design be independently reviewed.

In addition to potential mass failure, the GSL cover system will be sensitive to erosion. There have been no updates to erosion modelling and maintenance described in Appendix J (OKC 2016) of the Draft EIS. The inherent assumption in the Supplementary EIS is that costs and resources required to maintain the NOEF cover will be minimal, requiring filling of erosion gullies, weed management etc. (Section 6.4). This assumption would need to be verified during operations with trials and observation of rehabilitated areas. An approach to erosion monitoring is recommended in Section 5.2.1 of OKC 2017b.

In regards to longer term degradation, experience and research by Prof. Kerry Rowe's group is showing that the both HDPE and BCM can have a relatively long service life greater than 500 years (this is also referred to in ICI et al 2017, Section 5.1). However, this timeframe is still uncertain.

Other factors that could affect the cover integrity include differential movement through normal dump settling (as discussed above), or differential movement that is exacerbated by the effects of temperature differentials and local pressure effects in zones of active convection. Appendix E (Pando, 2017) Section 4.3 discusses results of preliminary settlement modelling, which determined the modelled settlement was well within tolerances for the BGM option, which appears to be MRM's preferred option. A more comprehensive settlement assessment is recommended, supported by site observation and settlement monitoring during dump construction.

2.4 Summary and Conclusions

The management of the NOEF described in the Supplementary EIS is designed to control AMD seepage during operations through collection and treatment/evaporation, with long-term control through installation of a high performance infiltration control GSL cover system. The current preferred GSL appears to be BGM.

The presence of the thick in-situ clay below the NOEF suggests that most of the AMD effects on groundwater were due to seepage from the PRODs, rather than directly from the NOEF. With lining of these PRODs, the system of capturing toe seepage, and collection of any basal seepage reporting to the Barney Creek Diversion Channel, is expected to be successful in managing seepage during operations to meet surface water quality commitments at SW11. The staged rehabilitation and successful final cover installation will also help reduce transport of pyrite oxidation products during operations, with the exposed area of non-benign material subject to

seepage likely to be similar to the current NOEF. The older end tipped NOEF zone is undergoing convective oxidation, and is the major source of AMD in the NOEF and a key management concern. McArthur River Mining is prioritising installation of the final cover system over this zone in Stage 2, which is expected to significantly reduce the loadings and liabilities.

Once the GSL cover system is successfully placed over the whole NOEF, further transport of pyrite oxidation products should cease, and the continuation of AMD reporting to drainage will be due to drawdown of seepage within the dump and contaminants already in the groundwater system. Note that the cover system is unlikely to act as a completely sealed oxygen barrier, so that oxidation and accumulation of pyrite oxidation products will continue (via slower diffusion rather than convective rates), but these will not be transported as AMD as long as the final cover functions as designed. Modelling from KCB suggests a decrease in AMD effects in 50 years after successful closure (KCB, 2017), and the proposed adaptive management phase of 70 to 80 years post closure (Section 3.3.3) would cover that period.

Use of the GSL is preferred over the CCL, but there are still a number of uncertainties:

- ♦ Constructability on a large scale.
- ♦ Maintaining protection from sunlight and weather.
- ♦ Life of the GSL.
- ♦ Temperature effects from existing convection and ongoing convection from newly placed materials.
- ♦ Susceptibility to differential settlement.

Despite the above uncertainties, the use of a GSL liner system appears to be the best and most achievable option for final closure of the NOEF. Trials are the only available method of assessing the likely effectiveness of the proposed cover system. The cover trials proposed in OKC 2017b will provide information on constructability of the BGM option, but should include more physical and chemical testing as recommended in Appendix H, and further assess the four different GSL options recommended (HDPE, LLDPE, BGM or EPBM). These trials would provide more information on the adequacy of the proposed 70 to 80 year period of adaptive management. It is noted that the Proactive Monitoring Phase provided in Figure 5-1 (Glencore 2018) does not have a time scale.

The management of PAF(RE) in new dump areas described in the supplementary EIS is expected to be successful in controlling extreme oxidation and combustion. However, ERIAS Group still has concerns with the proposed 7.5m lifts for PAF(HC) materials, which are unlikely to result in spontaneous combustion, but could still cause high convective oxidation rates and generation of AMD. McArthur River Mining currently place all PAF materials (PAF(RE) and PAF(HC)) in 2m lifts, which appears to provide control of convective oxidation. Given the highly pyritic nature of PAF(HC) materials, it is recommended that the PAF(HC) materials also be placed in 2m lifts to minimise AMD loadings and reduce liabilities during all stages of dump construction in case the proposed final cover system is not fully successful.

The construction of the MS-NAF halo around the older end tipped PAF materials in the NOEF and placement of the advection barrier is expected to control the occurrence of spontaneous combustion, but not necessarily convection. The high temperature zones in the older areas are not expected to directly affect the alluvial advection cover through desiccation effects, but the existing temperature gradient will tend to encourage convective pathways and continued high rates of pyrite oxidation. Prioritised placement of the final cover layer over the older PAF areas as part of Stage 2 should greatly reduce any convection by sealing the top surface, and cutting off the air flow path. Placement of the MS-NAF halo and other newly dumped materials over the older PAF areas should also provide a reasonably robust buffer between the hot zones and the GSL cover system. The planned tie in between new and old NOEF areas appears appropriate, but would require monitoring of both settlement and internal dump temperatures to confirm there are no potential long-term issues.

It is not clear to ERIAS Group from the Supplementary EIS exactly what monitoring is planned for the NOEF, apart from ground and surface water quality monitoring, but various documents refer to settlement monitoring, and presumably monitoring bores within the dump will be maintained for monitoring of temperature, water table levels and water quality. The GSL cover system is designed to control infiltration, and sealing any bore contacts with the GSL to prevent water seepage should be straightforward without compromising the cover system. Determining an adequate monitoring program will largely depend on results of trials and materials finally used in the GSL cover system. Relying on groundwater and surface water monitoring alone would not provide feedback in time to modify designs.

If mining were to cease and remediation not carried out, the NOEF would continue to be a source of AMD, and given the very high pyritic contents, would be likely to continue as such for many centuries. The tailings left in the TSF would be an even greater AMD hazard, being classified PAF, albeit with a long lag time, and having very high S greater than 10%S and ultimately producing acid leachate. The waste rock appears to represent a lower (but still significant) AMD hazard, with an overall excess of alkalinity, and likely to produce circum-neutral saline and metalliferous leachate.

From an environmental perspective, cessation of mining would only be a preferred option if sub-aqueous placement of the tailings in the open pit was still carried out, and the existing NOEF was covered with a GSL cover system. Information in the Supplementary EIS suggests that continuation of mine development as far as the proposed Stage 2 NOEF, with some extension of the cover system, could possibly achieve the latter.

Full or partial rehandling of end-tipped PAF materials from the NOEF and placement in the pit is also a possible variation if mining were to cease. The dump reconstruction by AMD type carried out by MRM together with drilling would provide some guide to distribution. However, controls would need to be in place during excavation to prevent rapid oxidation, combustion and generation of acid seepage (as occurred in 2016 with the low grade excavation). The materials would need to be placed in 2m lifts and traffic compacted as is currently carried out. There would be some mobilisation of AMD products when inundated, but this would also occur with the backfilled tailings, and groundwater contamination considerations and management would be the same. Assuming all PAF materials from the NOEF are re-handled, the MS-NAF materials left

behind would still generate salinity and metals/metalloids if a cover system is not installed, but at a much reduced loading, and the impacts of this would need to be assessed in more detail.

2.5 References

- ERIAS Group, 2017a. McArthur River Mine Overburden Management Project, EIS Review Report, May 2017
- ERIAS Group, 2017b. Independent Monitor Environmental Performance Annual Report 2016, October 2017
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- Glencore, 2018. Overburden Management Project Appendix R - Adaptive Management Framework Supplementary Environmental Impact Statement. February 2018. (Appendix R of the OMP Supplementary EIS)
- ICI et al, 2017. Geomembranes for McArthur River Mine Covers. Joint report prepared by I-Corp International, J.P.Giroud and Glencore. (Appendix H of the OMP Supplementary EIS)
- KCB. 2017a. McArthur River Mining Pty Ltd – 2017 MRM EIS Supplementary – NOEF Flow and Water Quality Modeling (Final). December 2017. Klohn Crippen Berger. (Revised NOEF Unsaturated Flow Modelling (TOUGH 2) Report – Appendix K of the OMP Supplementary EIS)
- KCB. 2017b. McArthur River Mine EIS Support, Waste Rock Kinetic Geochemical Testing, Update Report prepared for McArthur River Mining. File ID: 170213R Waste Rock Kinetics.docx. February 2017.
- MRM. 2018. Overburden Management Project Supplementary EIS. McArthur River Mining. Darwin, NT.
- OKC, 2016. NOEF Cover System and Landform Design in Support of the EIS Submission. (Appendix J of the OMP Draft EIS)
- OKC, 2017a. NOEF Geosynthetic Liner Cover System – Preliminary Soil Plant Atmosphere Modelling and Analysis. December 2017. O’Kane Consultants (Appendix G of the OMP Supplementary EIS)
- OKC, 2017b. NOEF Bituminous Geomembrane Cover System – Constructability Test Pads. (Appendix Y of the OMP Supplementary EIS)
- OKC, 2018. NOEF Cover System Trial Design. (Appendix AB of the OMP Supplementary EIS)
- Pando, 2017. Updated Preliminary Geotechnical Assessment NOEF. (Appendix E of the OMP Supplementary EIS)

3. Groundwater

The NT EPA has engaged ERIAS Group to review the hydrogeological component of the Supplementary EIS and provide advice on providing on the following:

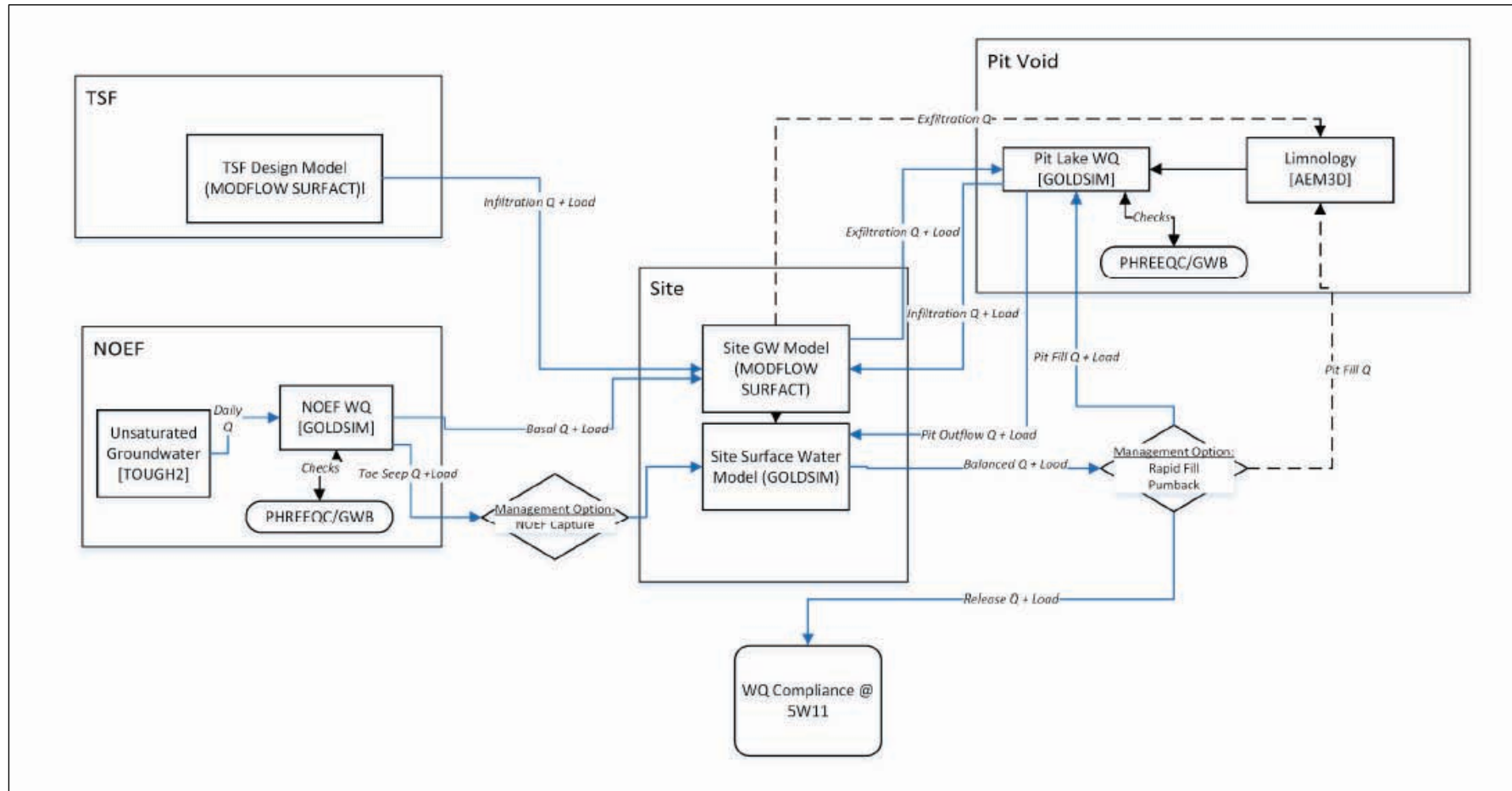
- ♦ The current status of groundwater quality and its impacts on the McArthur River.
- ♦ Whether there is sufficient understanding of groundwater on the site to inform the operator/regulator that contaminated seepage from all domains can be effectively managed during operations and impacts to the McArthur River can be avoided or minimised to acceptable levels into the long-term.
- ♦ The extent of understanding of groundwater connectivity between pit and river and whether pit inflows are likely to increase or decrease with further mining.
- ♦ The approximate rate/volume of discharge of groundwater to the McArthur River, and Barney and Surprise creeks, from the contaminated areas on the mine site.
- ♦ The estimated rate of seepage from the TSF now and over the life of the mine (assuming actions listed in the EIS are carried out) and the likelihood that seepage from the TSF can be reduced and managed until the tailings are treated and re-deposited in the pit.
- ♦ The estimated timeframe before contaminated seepage from the TSF area to Surprise Creek becomes insignificant following removal of the tailings and assuming the site is remediated.
- ♦ If, from a groundwater perspective, MRM leaves the site prior to tailings retreatment, the likelihood of a major failure in the wall of the tailings cells and the expected consequences of this failure on acid, metalliferous and/or saline drainage impacts on groundwater and surface water quality.

3.1 Background

The groundwater component of the Supplementary EIS is generally based on the results from a site-wide groundwater flow and solute transport model developed by Kohn Crippen Berger (KCB, 2017a). The model forms part of a series of models that have been linked via their inputs and outputs to simulate the movement of water and contaminants from source areas to surface water discharge points. The relationship between the various models is shown schematically in Figure 3.1. This approach has enabled the simulation of seepage contamination from the TSF, OEFs, PRODs and other storages operated by MRM, and discharges to the pit, creeks and McArthur River.

OVERBURDEN MANAGEMENT PROJECT SUPPLEMENTARY EIS REVIEW
MCARTHUR RIVER MINE OVERBURDEN MANAGEMENT PROJECT

Figure 3.1 – Schematic of Model Interactions



Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure 2, p5).

The model results provide estimates over the life of mine, during closure and post-closure of the following:

- ♦ Groundwater flow regimes.
- ♦ Contaminant transport within the groundwater system.
- ♦ Contaminant discharge to surface water features.
- ♦ Contaminant discharge to the final pit void lake.

The model is based on the site wide model developed for the Draft EIS, which has been updated to include:

- ♦ Improved linking to other models which form boundary conditions to the groundwater flow and transport model.
- ♦ Revision of the model structure to reflect changes in MRM's conceptual geological and hydrogeological understanding following investigations carried out since the Draft EIS was submitted.
- ♦ Revision of the modelled retardation and source concentrations of contaminants to incorporate the latest geochemical/hydrochemical test data.
- ♦ Changes made to the mine and closure plans since submission of the Draft EIS.

The reliability of the model has also been improved and re-calibrated against recent monitoring data and comparison of model outputs against outputs from alternative methods (e.g., stochastic modelling of contaminant breakthrough using the modified Domenico equation and 1 dimensional modelling using PHREEQC). However, there still remain a number of significant uncertainties in the hydrogeological and geochemical processes that control groundwater flow and contaminant movement across the site, as well as the source inputs from mine related infrastructure (discussed further in Section 3.2).

3.2 General Comments

The work carried out by KCB for the Supplementary EIS is generally considered to be of a high standard, and a significant improvement on the Draft EIS, although, as discussed above, significant uncertainties remain as would be expected given the extent and complexity of the groundwater system. It will therefore be imperative that MRM commit to ongoing model review and recalibration as part of their adaptive management approach. This should include more extensive calibration against measured flows in creeks and the McArthur River.

The remaining key uncertainties include the following:

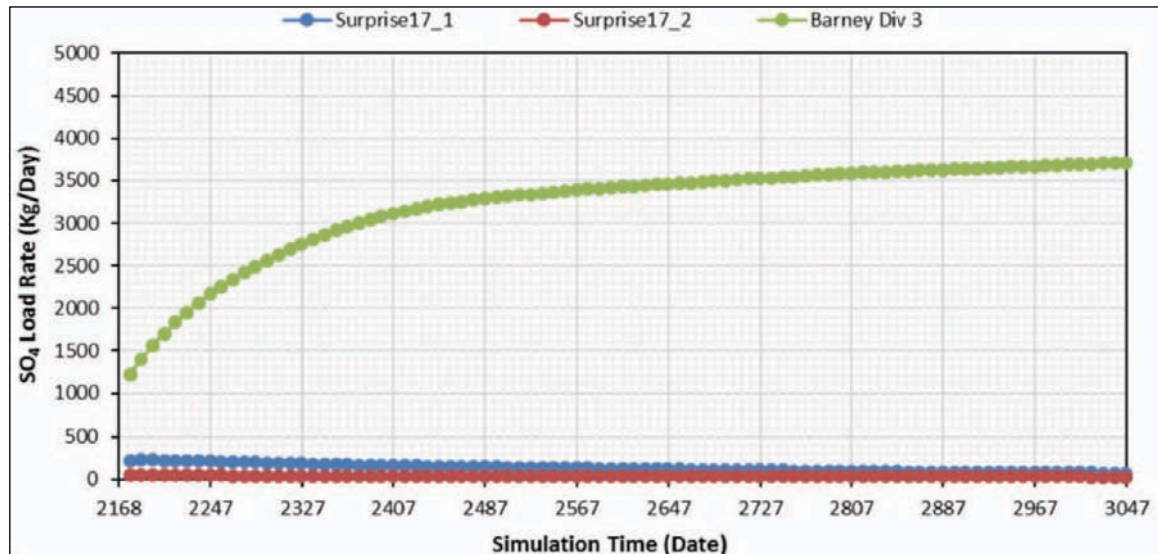
- ♦ Presence and hydraulic properties of fractured rock aquifers, which generally control groundwater flows across the mine site.
- ♦ The effectiveness of the TSF seepage management, e.g., control of seepage discharge to Surprise Creek – the proposed control measure (interception trench) has been

unsuccessfully trialled previously. It is almost certain that the planned trench will reduce the seepage entering Surprise Creek. However, it is also likely that any seepage within any deeper fractured rock systems will migrate under the planned trench.

- ♦ Performance of the NOEF cover and basal CCL, one of the main post closure impacts is from NOEF seepage and underperformance of the NOEF controls will have a major impact on contaminant release to the environment.
- ♦ Long-term groundwater contamination between the NOEF and the Barney Creek diversion, which is going to be used as an interception drain to capture seepage from the dump. Figure 3.2 shows predicted loadings to the diversion, which continue to rise over the 1,000-year simulation period reaching 3,700 kg/day in 3047.
- ♦ The likely presence of a major hydraulic link between the underground workings and either the McArthur River or lower reaches of the Barney Creek, which is evident from the high groundwater inflows to the mine during the wet season. This pathway has not been identified and therefore not realistically simulated in the groundwater model. The presence of this feature is almost certain to affect the predicted impacts on these watercourses.
- ♦ The long-term effectiveness of attenuation in minimising migration of metal contaminants in the groundwater regime, especially as the MODFLOW code was used based on an Equivalent Porous Medium (EPM) approach which may not account for rapid flow pathways and reduced attenuation. There is also uncertainty regarding:
 - The range of partition coefficients tested in the model and whether they are appropriate over the entire model domain, which includes various aquifer and rock types, and weathering states;
 - The appropriateness of using partition coefficients to simulate complex geochemical processes associated with adsorption/desorption of contaminants;
 - The relative proportions of free or unoccupied surface absorption sites within the aquifer media and the total absorbate remaining in solution (i.e. the adoption of the partition coefficient conceptual model assumes the amount of free or unoccupied sites greatly exceeds the absorbate in solution, where this is not the case retardation rates will be greatly reduced);

MRM's approach to managing the migration of non-conservative contaminants (e.g. arsenic, cadmium, lead and zinc) is strongly reliant on the natural retardation provided by the aquifer media. It will be essential for this assumption to be tested as further monitoring data becomes available. This will require an ongoing commitment to monitoring data review and regular and frequent re-calibration of the groundwater flow and contaminant transport model to measured concentrations.

Figure 3.2 – Simulated Long-Term Loadings to the Barney Creek Diversion



Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure 84, p111).

ERIAS Group also notes that MRM has failed, under their adaptive management framework (Glencore, 2018), to clearly state what are the appropriate hydrogeological performance objectives and the relevant performance targets (e.g., trigger values). This deficiency should be addressed as a priority.

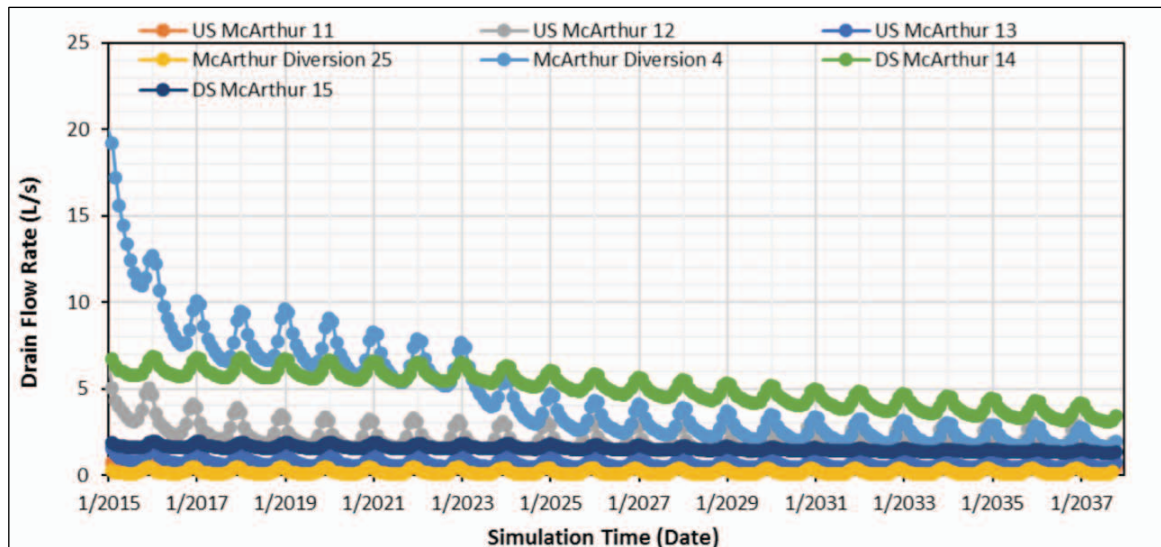
3.3 Current Groundwater Quality and Impacts on the McArthur River

The current groundwater quality and baseflow impacts on the McArthur River have been simulated by KCB using the groundwater flow and solute transport model. The modelling results are discussed below.

- ♦ The simulated baseflows to the McArthur River and the McArthur River diversion are shown in Figure 3.3 and the corresponding river reaches shown in Figure 3.4 (WRM, 2018). The estimated 2018 baseflows upstream and downstream of the diversion are low (less than 5 L/s), with the highest rates occurring during the wet season in response to rainfall recharge. Slightly higher, but still low, baseflows are estimated for the McArthur River diversion. These range from 7 to 10 L/s for McArthur River diversion along reach 4 (next to the ELS) and from 6 to 7 L/s for McArthur River reach 14 km downstream of the diversion.
- ♦ Modelled sulphate loadings (Figure 3.5) are below 100 kg/d for all reaches, apart from the McArthur River diversion reach 4 where loadings of between 250 kg/d (dry season) and 350 kg/day (wet season) are estimated.
- ♦ The simulated 2018 loadings for metals remains low, consistent with natural background metal concentrations in groundwater. Most of the metal loadings are attenuated in the aquifer and therefore do not migrate to the McArthur River.
- ♦ The maximum drawdown at Djirrinmini water hole is predicted to be about 0.7 m.

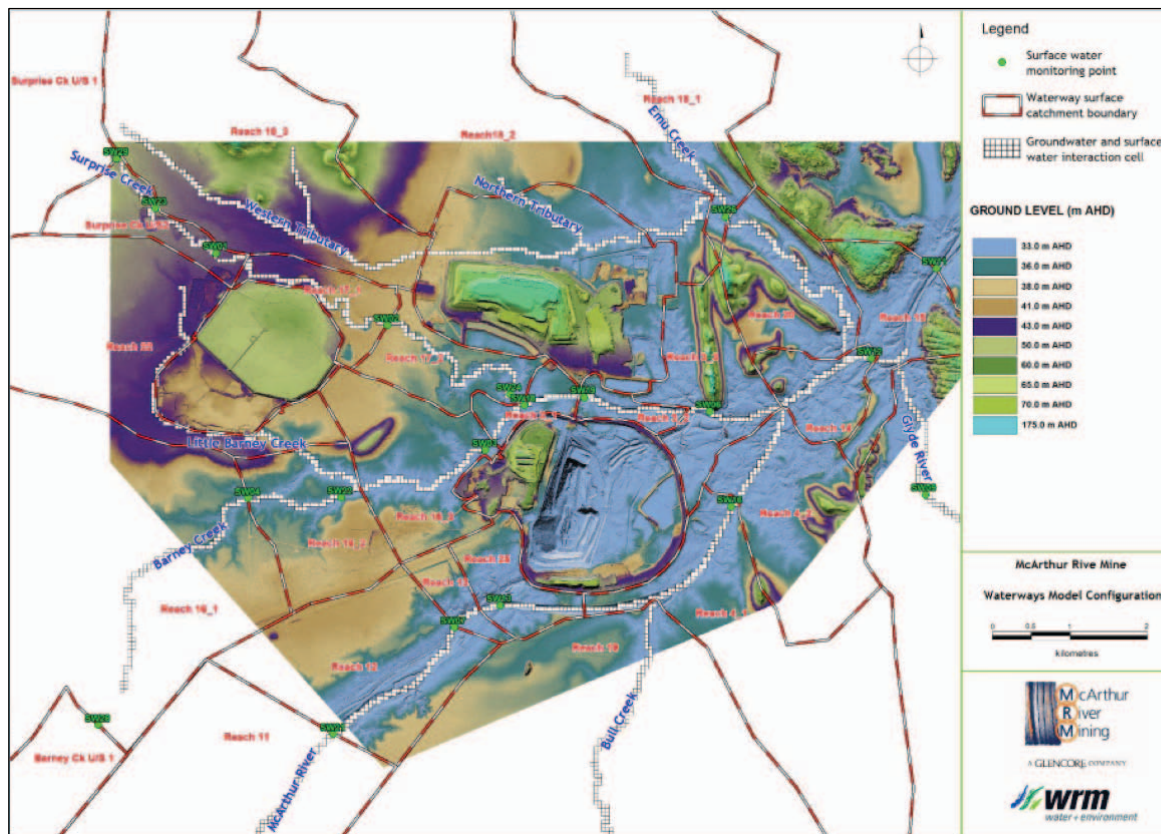
The minimum mean annual flow in the McArthur River, based on data collected from 2009 onwards at the government gauge station immediately upstream of the diversion (station number G9070132), is about 4.5 m³/second. The estimated increase in sulphate concentration in the river water from contaminated baseflow along reach 4, assuming a loading of 350 kg/day and the recorded minimum mean annual flow, is negligible, about 1 mg/L.

Figure 3.3 – Simulated McArthur River Baseflow



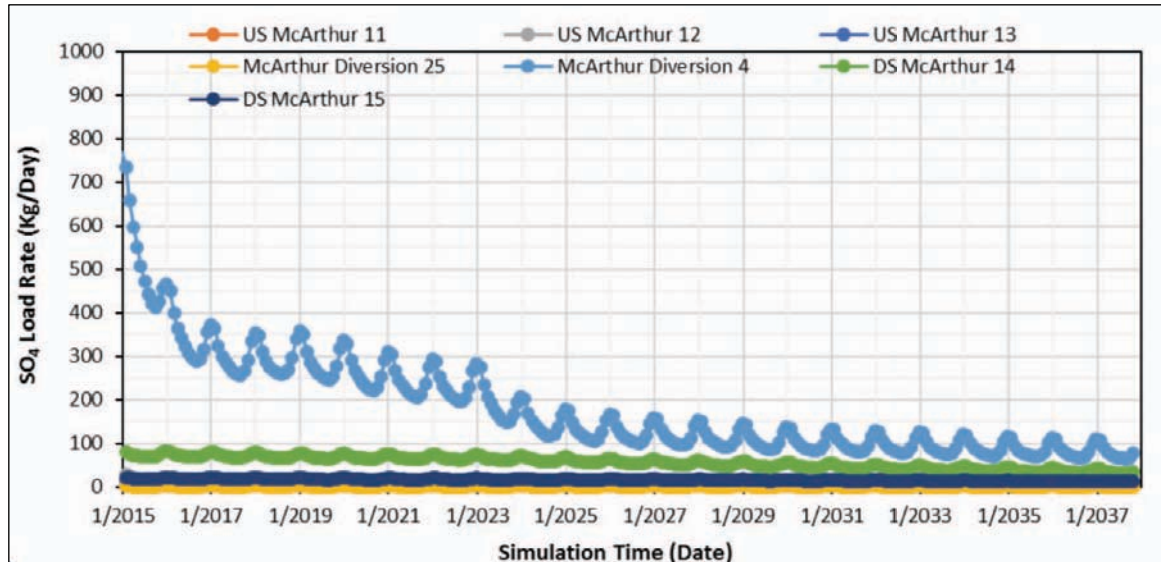
Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure A1-91, p1-46).

Figure 3.4 – Modelled Watercourse Reaches



Source: WRM, 2018 ((Appendix N of the OMP Supplementary EIS, Figure 4.1, p73).

Figure 3.5 – Simulated McArthur River LoM Sulphate Loading

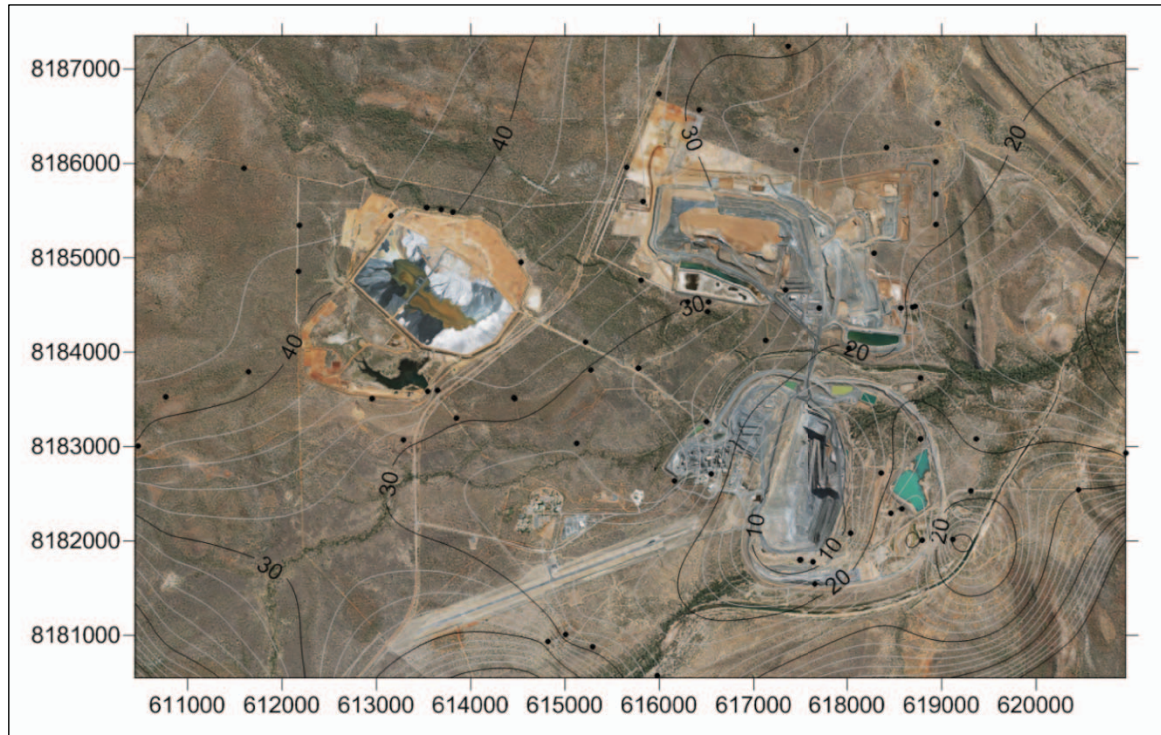


Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure A1-92, p1-46).

The modelling results were compared with the monitoring results presented in the annual groundwater monitoring review for the 2014 to 2016 period (KCB, 2016), which are discussed below.

- ♦ Groundwater level contours for the fresh bedrock for the 2015/2016 wet season (Figure 3.6) indicate groundwater generally flows from west to east across the site towards the McArthur River. However, pit dewatering has locally depressed groundwater levels, resulting in a capture zone around the pit that intercepts the majority of the groundwater flow from the TSF area. Therefore, the main area of concern relates to possible contaminated seepage emanating from the SOEF and ELS in areas closest to the McArthur River and the McArthur River diversion.

Figure 3.6 – Bedrock Groundwater Level Contours 2015/2016 Wet Season

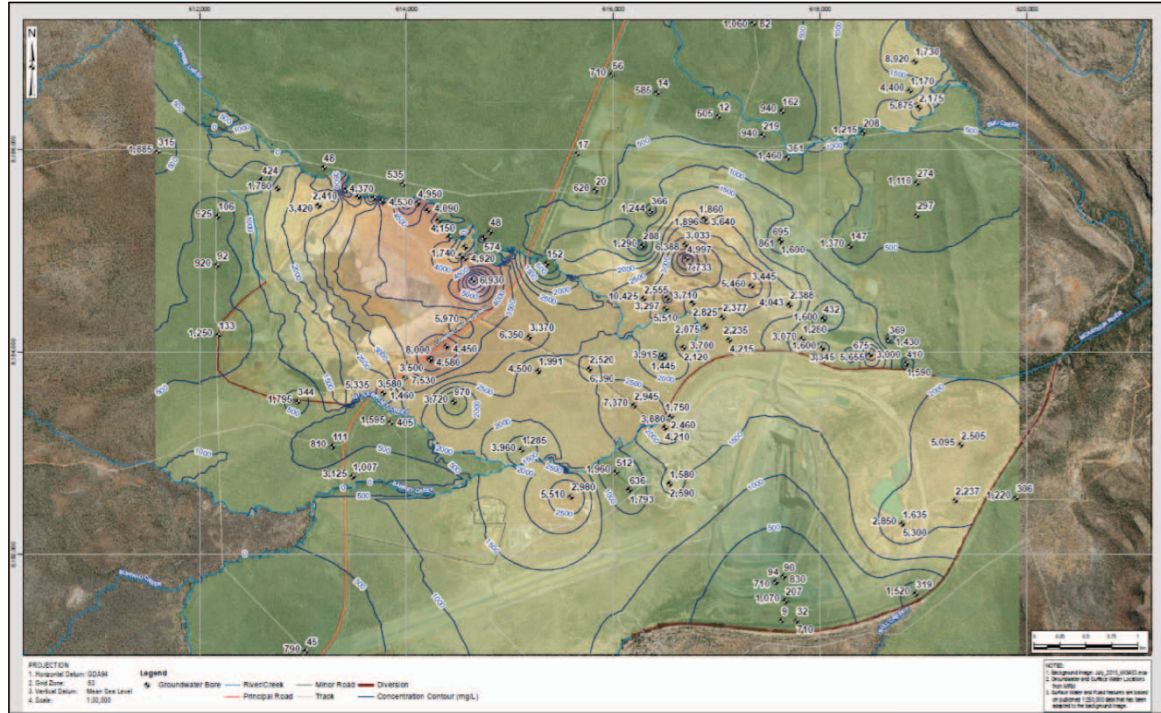


Source: KCB, 2016 (Figure 4-18, page 37).

- ♦ Contours of the recorded sulphate concentrations for the 2014 to 2016 review period are provided in Figure 3.7. The figure shows the following:
 - Elevated sulphate concentrations of up to 5,095 mg/L in the area around the ELS. These are almost certainly the result of seepage from the storage. It is likely the plume extending east of the ELS is migrating towards the McArthur River diversion and that baseflow to the diversion along the associated reach will be contaminated. The western and southern plume extents are expected to report to the pit. ERIAS Group notes that MRM has decommissioned the ELS, therefore sulphate concentrations would be expected to fall as the plume migrates and discharges either into the McArthur River diversion or the mine pit.
 - Isolated high sulphate concentrations, up to 1,070 mg/L, were recorded south of the pit in the area of the SOEF. However, the majority of these high readings are likely to lie in the capture zone developed from pit dewatering and are therefore not expected to report to the nearby McArthur River diversion.
 - High sulphate concentrations (2,980 and 5,510 mg/L) were recorded at monitoring bore GW128 located between the southern end of the TSF and pit. However, the migration direction of the associated plume cannot be reliably assessed from the monitoring data, because of the lack of control points to the south and southeast of the bore.
 - The high sulphate plumes emanating from the NOEF and associated perimeter runoff dams report to Surprise and Barney Creeks and the Barney Creek diversion. These

contaminated flows are managed through containment and pumping, and do not discharge into the McArthur River.

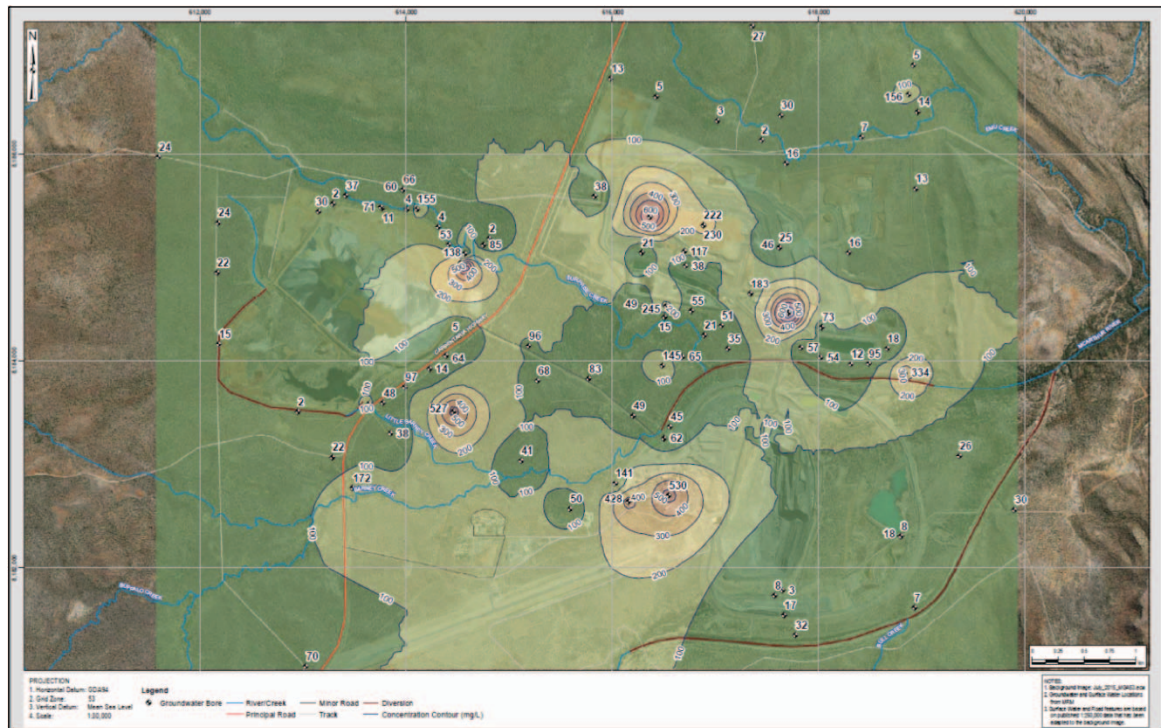
Figure 3.7 – Groundwater Sulphate Concentrations for the 2014-2016 Review Period



Source: KCB, 2016 (Figure 4-30, page 56).

- ◆ Contours of zinc concentrations for the 2014 to 2016 review period are provided in Figure 3.8. The figure shows six areas of elevated zinc concentrations located northeast of the TSF near Surprise Creek, beneath the NOEF, near the SEPROD, southeast of the TSF and in the vicinity of the process plant. There is no indication of groundwater contaminated with zinc reporting the McArthur River or the diversion.

Figure 3.8 – Groundwater Zinc Concentrations for the 2014-2016 Review Period



Source: KCB, 2016 (Figure 4-32, page 58).

In summary, the groundwater flow and contaminant transport modelling results indicate current impacts on the McArthur River are limited to minor increases in the sulphate loading along the diversion as a result of historic seepage from the ELS. Impacts on the river water quality from this source is expected to be negligible. This outcome is supported by recent monitoring data.

3.4 Minimisation of Contaminated Seepage Impacts on McArthur River

The results of the comprehensive modelling carried out by KBC for the Supplementary EIS indicates that contaminant seepage can be effectively managed during operations. These results are considered robust given:

- ♦ The extent of model calibration which includes calibration to measured groundwater levels, sulphate concentrations and concentrations of selected metals;
- ♦ Successful comparison against results from alternative analytical and numerical methods;
- ♦ Successful comparison with the conceptual hydrogeological model.

The main contaminant sources during operations are likely to comprise the TSF, NOEF and associated perimeter runoff dams and other water storages operated by MRM.

The greatest seepage from the TSF is likely to be to the north towards Surprise Creek. Currently the creek acts as an interception trench and contaminated water is managed by recovery at the Barney Creek diversion during low flows. Although not ideal, this limits the risk of unacceptable

impacts on the McArthur River. ERIAS Group notes that MRM are proposing to install a seepage interception trench between TSF Cell 1 and Surprise Creek. This should reduce impacts on the creek although the proportion of seepage recovery is uncertain and it is likely that seepage within any deeper fractured rock systems will migrate under the planned trench.

There is also evidence of seepage from the eastern side of the TSF. This is thought to flow towards the pit. The modelling results suggest most of this seepage will be captured by the drawdown cone around the pit. Although this has yet to be confirmed with monitoring.

Contaminant seepage from the NOEF and associated perimeter runoff dams is currently captured by the Barney Creek diversion. Contaminated water in the diversion is managed to prevent environmental release by containment and pumping during periods when there is insufficient flow for dilution. In the longer term during operations, the drawdown from pit dewatering is expected to extend under the Barney Creek diversion. This is predicted to capture seepage from the NOEF and perimeter runoff dams, which will further minimise the risks to the McArthur River.

3.5 Groundwater Connectivity Between the Pit and McArthur River

The conceptual hydrogeological model, which forms the basis of KCB's groundwater flow and contaminant transport model, identifies flows to the pit from bedrock aquifers (primarily fracture zones related to faults) and the palaeochannel aquifer. The palaeochannel aquifer sub-parallel the original McArthur River channel and is exposed in the southern and eastern pit walls.

The locations and properties of these aquifers have been estimated during previous field investigations. Furthermore, the groundwater flow and contaminant transport model was successfully calibrated to historic pit dewatering rates as part of the work undertaken for the Draft EIS (KCB, 2017b). MRM's understanding of the hydraulic connection between the pit and McArthur river is therefore considered to be reasonable as are the corresponding estimates of future pit inflows (as mining progresses).

However, the majority of the mine dewatering effort (around 140 L/s) is via the original underground workings, most likely from a deep fractured rock pathway linking the underground to either the McArthur River or the lower reaches of Barney Creek. This pathway has not been identified and is simulated in KCB's model with a simple boundary condition that has no basis in reality. This deficiency has been identified as a key uncertainty (Section 3.1).

The groundwater flow and solute transport model predicts that the pit will form a local groundwater sink during and immediately after mining, with groundwater flows directed towards the pit in response to dewatering. This condition is expected to be reversed and the pre-mining west to east groundwater flow regime re-established once the pit is flooded after the completion of tailings re-processing. However, this prediction is dependent on the condition of the final pit void lake.

Under the preferred backflow or through flow closure options, the lake level should be maintained close to the surrounding groundwater level, which will allow groundwater flows to continue through the pit lake towards the McArthur River, although periodic reversals could occur in the dry season if pit lake levels become depressed through evaporative losses. Under this expected west

to east flow regime, the pit lake water will also flow eastward into the McArthur River as seepage via the groundwater system. However, the rate of interaction will be minor compared to any surface water interaction between the pit lake and river.

If MRM elect to close off the pit lake after closure, then it is likely that the pit will continue to act as a local sink, although the drawdown extents would be comparatively localised.

As noted in Section 2.1, the recorded dewatering rates strongly indicate the presence of a major hydraulic link between the underground workings and either the McArthur River or lower reaches of Barney Creek. There is a risk that this could provide a pathway for contaminated water from the deeper parts of the pit void lake to report to McArthur River. The presence of this aquifer and the associated risks have not been determined by MRM as part of the supplementary EIS. It is strongly recommended that this potential hydraulic link be investigated and included in MRM's groundwater flow and contaminant transport, and pit lake models.

3.6 Groundwater Discharge to the McArthur River, and Barney and Surprise Creeks

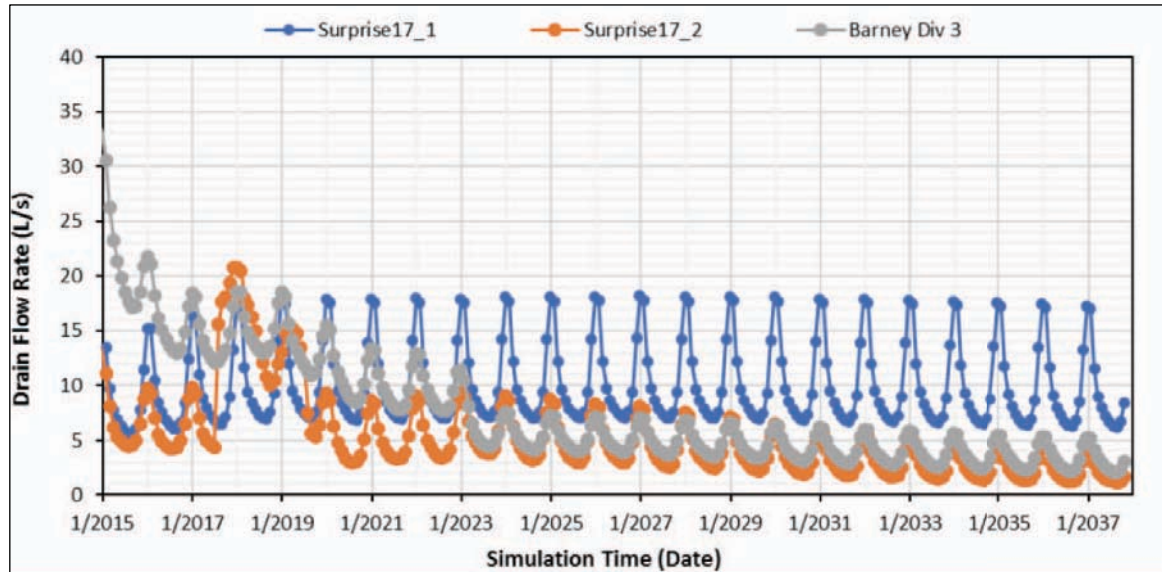
Baseflows to the McArthur River, and Barney and Surprise Creeks have been estimated by KCB using the groundwater flow and contaminant transport model. The baseflows have been discretised for various reaches along each watercourse (see Figure 3.4). The reaches associated with possible contaminated areas are shown in Table 2.1.

Table 2.1 – Contaminated Watercourse Reaches

Contaminant Source	Watercourse	Reach ID
TSF	Surprise Creek	Reach 17_1
NOEF and SPROD	Surprise Creek	Reach 17_2
NOEF and SEPROD	Barney Creek/Barney Creek diversion	Reach 3 (combined 3_1 and 3_2)
TSF	McArthur River (upstream)	Reach 13
Pit	McArthur River/McArthur River Diversion	Reach 25
Pit	McArthur River diversion	Reach 4 (combined 4_1 and 4_2)
Pit	McArthur (downstream)	Reach 14

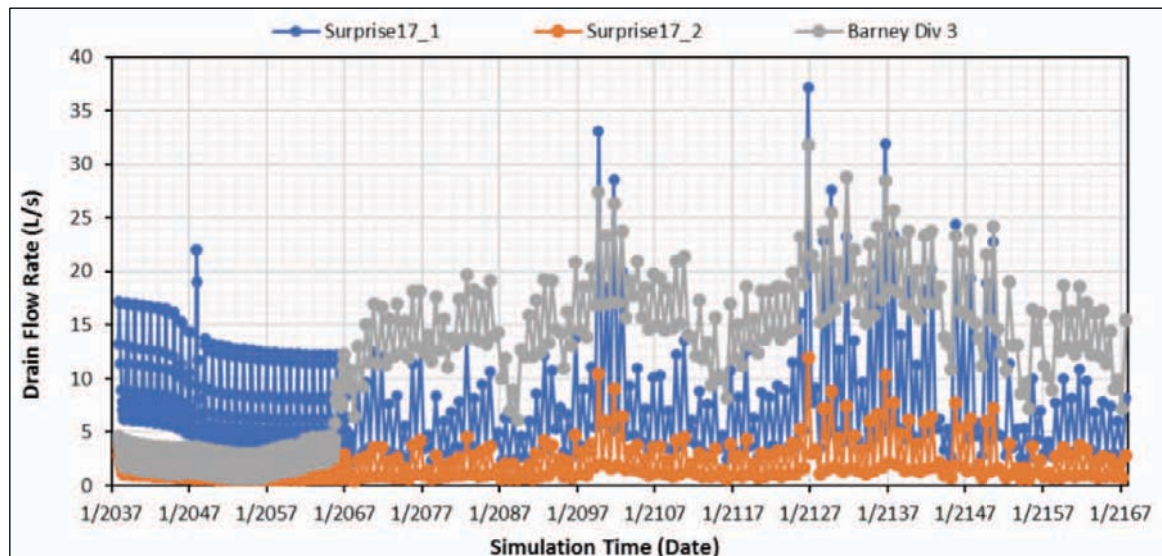
Time series plots showing the predicted baseflows for the reaches along the Surprise Creek and Barney Creek diversion for the life of mine, 100 years into closure and over the 1,000 year (long-term) period are provided in Figures 3.9 to 3.11 respectively. The corresponding hydrographs for the McArthur River and McArthur River diversion are provided in Figure 3.3 and Figures 3.12 and 3.13 respectively.

Figure 3.9 – Simulated Surprise Creek and Barney Creek LoM Baseflows



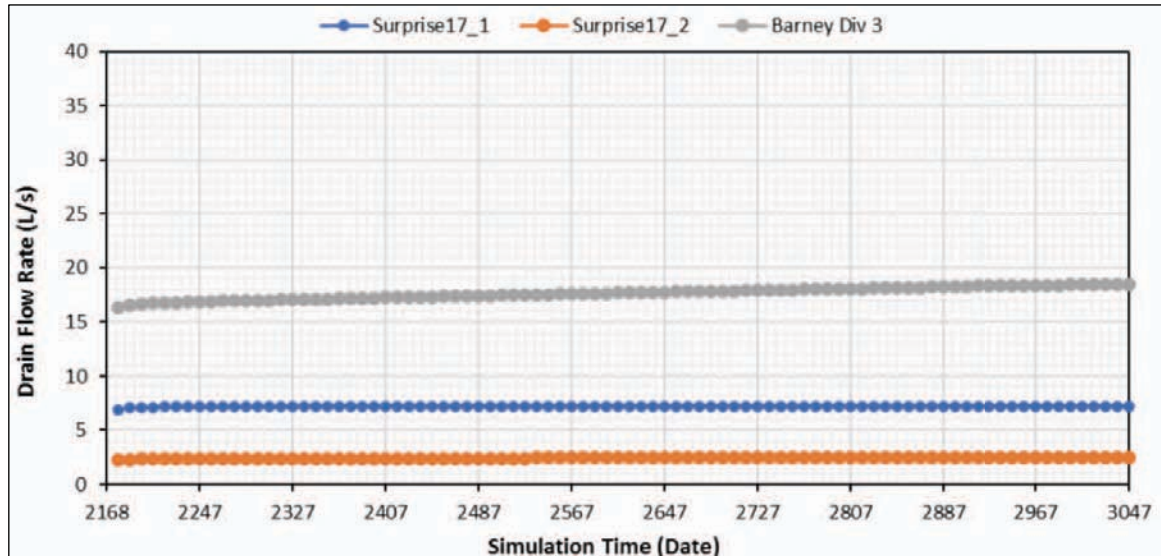
Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure A1-55, p1-28).

Figure 3.10 – Simulated Surprise Creek and Barney Creek Diversion Baseflows 100 Years Post-Closure



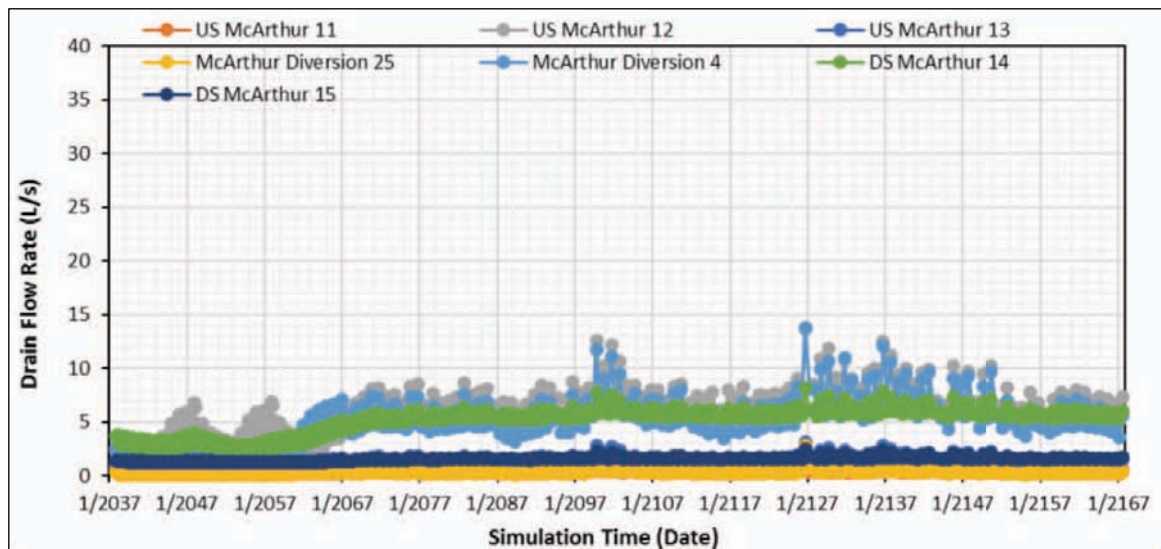
Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure A1-61, p1-31).

Figure 3.11 – Simulated Long-Term Surprise Creek and Barney Creek Diversion Baseflows



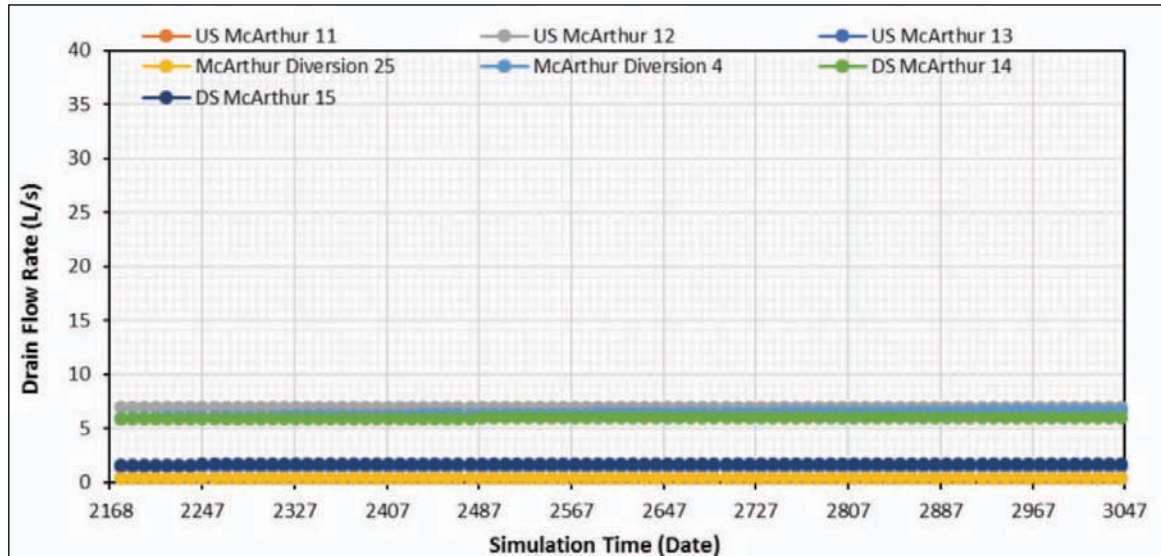
Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure A1-67, p1-34).

Figure 3.12 – Simulated McArthur River Baseflows 100 Years Post-Closure



Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure A1-97, p1-49).

Figure 3.13 – Simulated Long-Term McArthur River Baseflows



Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure A1-103, p1-52).

The figures show the following.

- ♦ Surprise Creek reach 17_1 (adjacent to the TSF):
 - Baseflows remain consistent over the life of mine at between 6 and 18 L/s.
 - Baseflows reduce whilst the tailings are reprocessed and seepage rates decline.
 - Natural (irregular) baseflows are re-established after the TSF is removed.
 - Long-term baseflows remain steady at about 7 to 8 L/s.
- ♦ Surprise Creek reach 17_2 (downstream of the TSF and adjacent to the western end of the NOEF and SPROD):
 - Baseflows decline slightly over the life of mine as the drawdown cone around the pit extends westward, falling from about 6 to 12 L/s to between 1 and 6 L/s in 2037.
 - Baseflows remain between about 1 and 6 L/s whilst the pit is flooded, then recover slightly as the groundwater system rebounds.
 - Average long-term baseflows are around 2 to 3 L/s.
- ♦ Barney Creek/Barney Creek diversion reach 3 (adjacent to the eastern end of the NOEF and SEPROD):
 - A pronounced decline in the baseflows occurs through to 2023 as the drawdown cone around the pit extends westward, falling from about 30 L/s to between 2 and 5 L/s in 2037.
 - Baseflows remain suppressed until the pit is flooded, then recover as the groundwater system rebounds.

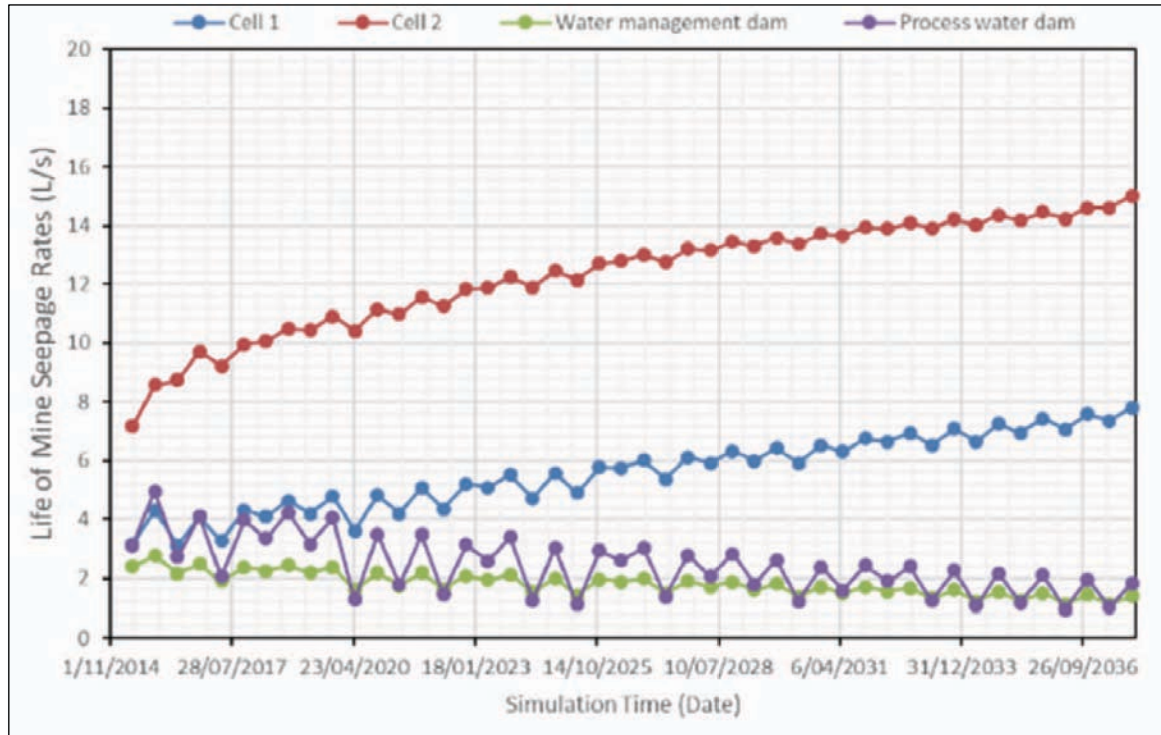
- Baseflows continue to recover in the longer term, increasing to about 19 L/s after 1,000 years.
- ♦ McArthur River reaches 13 and 25 (upstream of the diversion and pit):
 - Baseflows remain constant over the model run period at around or below 2 L/s.
- ♦ McArthur River diversion reach 4 (along the diversion and adjacent to the pit, SOEF and ELS):
 - A pronounced decline in the baseflows occurs through to 2025 as the drawdown cone around the pit extends eastward, falling from about 20 L/s to between 1 and 2 L/s in 2037.
 - Baseflows remain suppressed until the pit is flooded, then recover rapidly as the groundwater system rebounds ranging from about 3 to 8 L/s after 2070.
 - Longer term average baseflow rates are around 6 L/s.
- ♦ McArthur River reach 14 (includes the confluence with Barney Creek, downstream of the diversion):
 - Baseflows gently decline over the life of mine decreasing from about 6 L/s to between 3 and 4 L/s by 2037.
 - Baseflows remain suppressed until the pit is flooded, then recover rapidly as the groundwater system rebounds ranging from about 5 to 6 L/s after 2070.
 - Longer-term average baseflow rates are around 6 L/s.

As discussed in Section 3.3, the modelling results correlate with the conceptual hydrogeological model showing expected responses to changes in stresses.

3.7 TSF Seepage Rates and Seepage Management

Seepage from the TSF was estimated by KCB using a separate groundwater flow and contaminant transport flow model which was last updated as part of the groundwater submission for the Draft EIS. The simulated seepage rates from Cells 1 and 2 over the life of mine are presented as time series plots in Figure 3.14. The figure shows the seepage rates increase over the life of mine from about 4 to 8 L/s at Cell 1 and from 7 to 15 L/s at Cell 2. These increases are due to rising heads as the level of the tailings increases with ongoing deposition.

Figure 3.14 – Simulated TSF Seepage Rates



Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure 33, p61).

The outputs from the TSF model are considered reasonably robust given:

- ♦ The extent of model calibration, which includes generally good calibration to measured groundwater levels at various locations around the TSF.
- ♦ Successful comparison against results from alternative analytical and numerical methods, including models generated during earlier studies.
- ♦ Acceptable model calibration to estimated baseflows in Surprise and Barney Creeks.

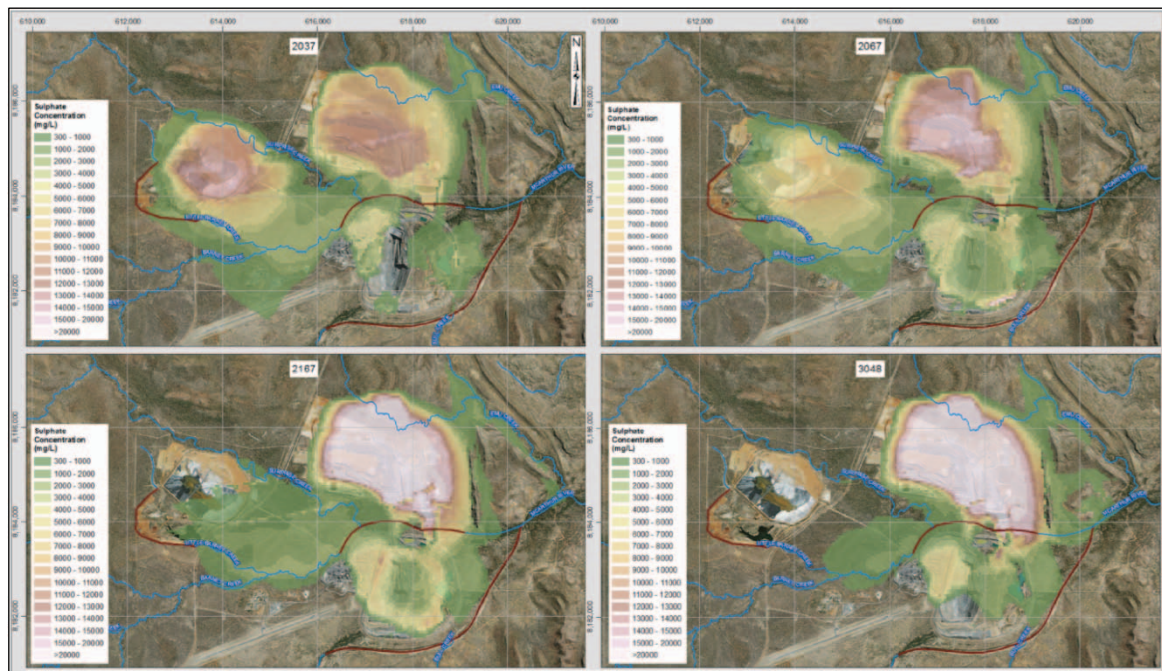
Seepage from the TSF reports to the underlying groundwater system and then flows down-gradient either northwards to Surprise Creek or southeastwards towards Barney Creek and the pit.

The greatest impacts are seen in Surprise Creek, because of the proximity to the northern embankment of Cell 1. The creek acts as an interception trench, which generally prevents further migration of the plume to the north. Contaminated water in Surprise Creek reports to the Barney Creek diversion where it is managed through containment and pumping. Although not ideal, this limits the risk of unacceptable impacts on the McArthur River. ERIAS Group also notes that MRM are proposing to install a seepage interception trench between TSF Cell 1 and Surprise Creek, which should reduce impacts on the creek. Modelling indicates the planned trench will capture the majority of the TSF Cell 1 seepage. However, the use of interception trenches has been trialled previously with only limited success and it is likely that seepage within any deeper fractured rock systems will migrate under the planned Surprise Creek interception trench.

Seepage flowing from the TSF to the southeast has resulted in a sulphate plume that extends as far as Barney Creek, which is evident from the groundwater monitoring results (see Figure 3.7). The majority of this contaminated seepage appears to be captured by the creek, although high sulphate concentrations (2,980 and 5,510 mg/L) have been recorded at monitoring bore GW128, located south of Barney Creek. MRM has postulated that the high sulphate concentrations in the bore are due to natural mineralisation, but this has yet to be confirmed in field investigations.

The groundwater modelling results indicate seepage migrating southeast from the TSF area and underneath Barney Creek during operations and immediately after closure (i.e., before the pit is flooded) will be captured by the drawdown cone around the pit. There is a risk that some seepage from the TSF may report to the McArthur River upstream of the pit. However, the impact from this discharge is likely to be low, given the low baseflow to the upstream McArthur River reaches. Further more, long-term modelled sulphate concentrations (Figure 3.15) show dilution of the plume as it migrates southeast in response to rainfall recharge, which will limit impacts on the baseflow to the McArthur River upstream of the diversion.

Figure 3.15 – Simulated Upper Bedrock Sulphate Concentrations after Closure



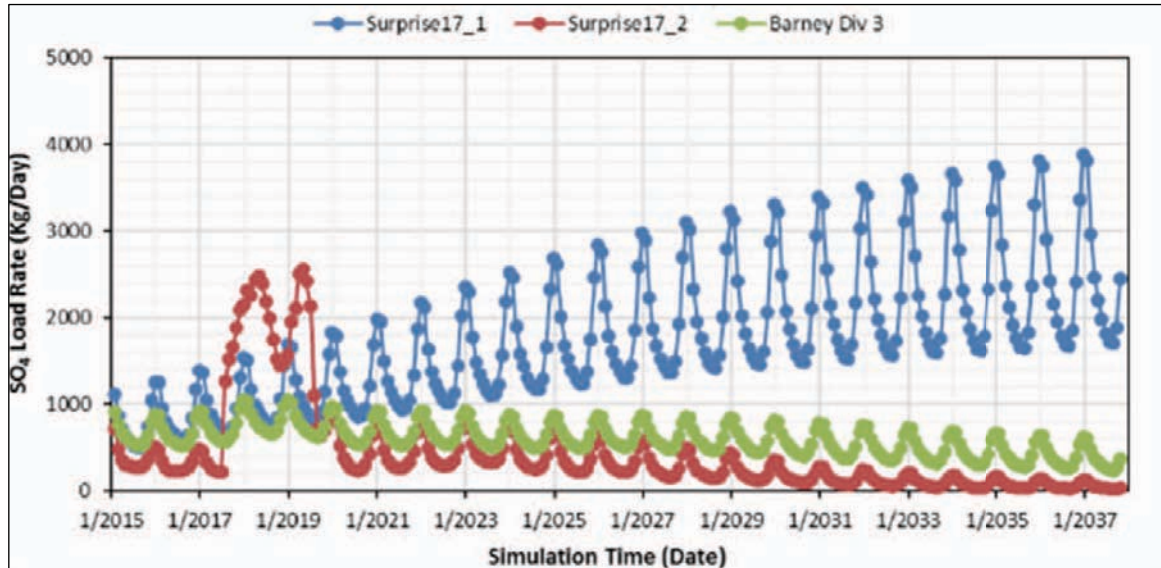
Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure 77, p103).

In summary, the results from the modelling studies completed for the Draft EIS and Supplementary EIS, in conjunction with the groundwater monitoring data, suggest that unacceptable impacts to the McArthur River from the TSF seepage, prior to relocation of the tailings to the pit void, are unlikely. However, more severe impacts to Surprise Creek and Barney Creek are expected to continue over the life of mine, possibly offset at Surprise Creek by installation of an interception trench between the creek and TSF Cell 1.

3.8 TSF Seepage Impacts on Surprise Creek

Impacts of TSF seepage on Surprise Creek were estimated by KCB using the groundwater flow and contaminant transport model. The predicted sulphate loadings to the creek adjacent to TSF Cell 1 (reach 17_1) are shown in Figure 3.16 over the life of mine, and in Figure 3.17 for the closure period.

Figure 3.16 – Simulated Surprise Creek LoM Sulphate Loading



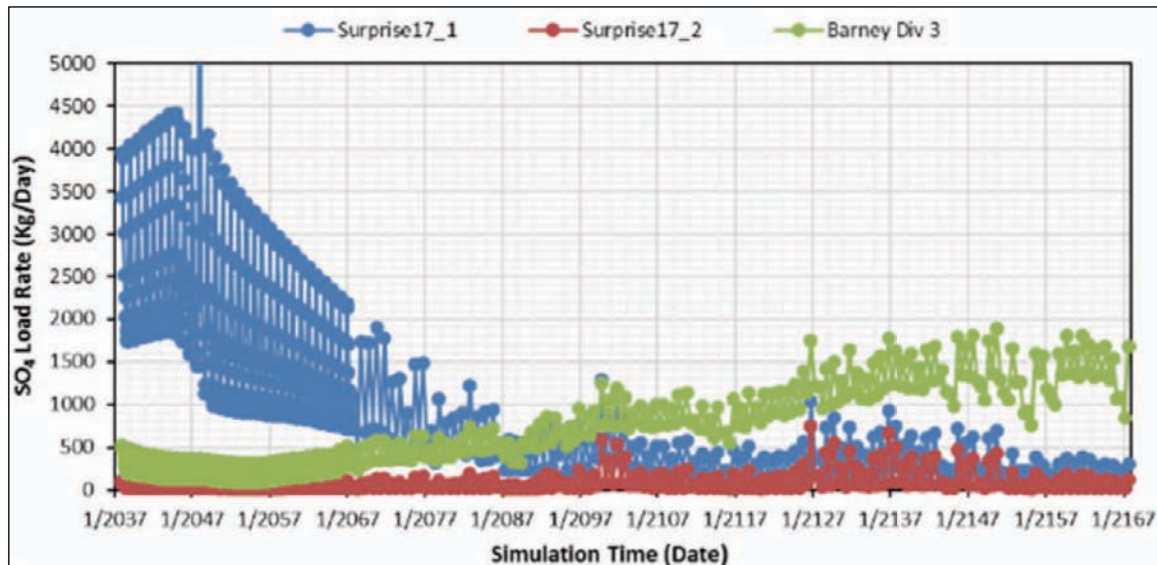
Source: 2017a (Appendix L of the OMP Supplementary EIS, Figure 44, p74).

The figures show the following:

- ♦ Sulphate loadings rise over the life of mine from between 500 and 1,000 kg/d to between 1,700 and 3,900 kg/d in 2038.
- ♦ The rising trend in sulphate loadings continues up until 2044, while tailings are being relocated into the pit void.
- ♦ After 2044, loadings reduce reaching background concentrations after 2087 as the plume migrates to Surprise Creek.

The predicted sulphate loadings after mine closure are shown spatially in Figure 3.15, which shows the sulphate plume migrating away from the TSF footprint with near background concentrations in the Surprise Creek area by 2167.

Figure 3.17 – Simulated Surprise Creek Sulphate Loading 100 Years into Closure



Source: KCB, 2017a (Appendix L of the OMP Supplementary EIS, Figure 83, p110).

Only a slight rise in the baseflow zinc concentrations is predicted over the 1,000-year model run-time, because of attenuation within the aquifer. This rise is not considered significant given general modelling uncertainties.

3.9 Likelihood and Consequence of TSF Embankment Failure

The likelihood of TSF embankment failure is addressed in Section 5 below.

The consequences from failure of the TSF embankment have been briefly assessed as part of the Supplementary EIS (GHD, 2017) and the results summarised in Table 2.2.

Table 2.2 – TSF Failure Consequences

Consequence	Severity
Release of tails and decant water into the WMD	Medium
Overland release of tails and decant water into Surprise, Little Barney and Barney Creeks; and subsequently into the McArthur River	Major
Impacts on population	Major

Additional risks to surface water and groundwater associated with failure of the TSF embankment include the following:

- ♦ Increased exposure and oxidation of tailings previously contained under near saturated conditions (greater than 80%) in the TSF with low oxygen consumption rates. Increased exposure will result in increased rates of saline, acid and metalliferous drainage.
- ♦ Contamination of rainfall and rainfall runoff from exposed tailings, resulting in:
 - Contaminated runoff entering Surprise Creek or Little Barney Creek.

- Infiltration of the contaminated water into the groundwater system.

3.10 References

- GHD. 2017. Tailings Storage Facility Design Development - Life of Mine Plan. Revision 2. Report for McArthur River Mining Pty Ltd. May 2017. (Updated Tailings Storage Facility Life of Mine Plan – Appendix I of the OMP Supplementary EIS)
- Glencore, 2018. Overburden Management Project Appendix R - Adaptive Management Framework Supplementary Environmental Impact Statement. February 2018. (Appendix R of the OMP Supplementary EIS)
- KCB, 2016. MRM Groundwater Report Groundwater Monitoring Report 2014-16. August 2016. Reference D09814A18.
- KCB, 2017a. 2017 MRM EIS Supplementary Updated Groundwater Impact Assessment (Final). December 2017. Reference D09814A25. (Appendix L of the OMP Supplementary EIS)
- KCB, 2017b. 2017 MRM EIS Groundwater Impact Assessment (Final). February 2017. Reference D09814A10. (Appendix T of the Overburden Management Project Draft EIS)
- WRM, 2018. Updated Water Balance and Waterways Modelling for the MRM OMP EIS. 23 February 2018. Reference 0790-38-P5. (Appendix N of the OMP Supplementary EIS)

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4. Surface Water

4.1 Introduction

The NT EPA has engaged ERIAS Group to review information on surface water quality provided in the Supplementary EIS (SEIS) (MRM, 2018) and advice upon the following:

- ♦ Existing environmental condition of the McArthur River in respect of mine-related impacts.
- ♦ Volume and characteristics of Class 5 water, and estimated range of wet and dry season volume of runoff from areas with exposed potentially acid-forming or problematic material.
- ♦ Appropriate parameters for assessing MRM water quality and its impacts on the receiving environment.
- ♦ Use of the underground void as a balancing storage and the feasibility of continuing with this approach as mining goes deeper and the size of the pit increases.
- ♦ Proposed alternative storage facility or alternative options for contaminated water if pit storage is limited and the likelihood that water on the site can be managed through recycling, treatment, evaporation and cautious controlled discharge.
- ♦ Principal sources of total dissolved salt (TDS) in mine discharge, impacts to river water quality as a result and whether the discharge rate of TDS is likely to increase, remain the same or decrease with the proposal.
- ♦ Current quality of sediment transported from the mine site, the level of contamination and how the mine loads compare with catchment loads.
- ♦ Extent to which contaminated soil in surface runoff from dust generated by mining and processing operations, primarily from the TSF, ROM pad, crushing circuit and external concentrate storage area, and direct dust deposition itself, causes poor water quality in the McArthur River.
- ♦ If MRM leaves the site prior to tailings retreatment, the likelihood of a major failure in the wall of the tailings cells and the expected consequences of this failure on acid, metalliferous and/or saline drainage impacts on groundwater and surface water quality.

Comment on these aspects is provided in the following sections.

ERIAS Group notes that MRM's focus in the SEIS (MRM, 2018) has been to provide comments made on the Draft EIS and to incorporate consideration of any changes made since its submission, and improvements and refinements to models used in the assessments. Most of these revised assessment relate to water resources. Detailed MRM responses to NT EPA comments on the Draft EIS are provided in Section 7 of the SEIS (MRM, 2018), supported by reports contained in appendices.

4.2 Existing Condition of the McArthur River

No further description of existing environmental conditions of the McArthur River, based on monitoring program results, is presented in the SEIS (MRM, 2018).

McArthur River Mining (MRM, 2018) has responded to this review comment (Issue No. 194 and Issue No. 196 in Section 7.13) by stating that such information is provided in annual Operational Performance Reports. However, ERIAS Group notes that these reports focus on providing a summary of MRM environmental performance over the preceding year, focused on compliance with licence conditions. It is therefore not apparent that information is available that provides a consolidated summary of environmental monitoring that shows trends in data and interpretation of environmental outcomes.

High-level descriptions of environmental conditions on the mine site are provided in SEIS Section 3.1.1.1 (MRM, 2018), focused on the following three domains:

- ♦ Open Cut.
- ♦ North Overburden Emplacement Facility (NOEF).
- ♦ Tailing Storage Facility (TSF).

However, no description of existing conditions in the downstream receiving environment is provided. The only description of existing conditions in the SEIS (MRM, 2018) is provided in Section 3.1.1.1.2, as follows:

The revised water and sediment management practices around the Barney Creek bridges have improved water and sediment quality in SW19 in successive years since 2013. The established fish metal monitoring program detected elevated lead concentrations in some fish directly underneath the bridge in 2012. In response, there have been modifications to the bridge drains, sediment sumps and roads to reduce loads reporting to the creek.

Lead has been previously reported to be entering sediments at SW19, primarily via surface runoff from the haul road and, to a lesser extent, from haul road traffic generated dust (Indo-Pacific Environmental 2013, 2014, 2015). Whilst elevated lead concentrations were recorded in some of the fauna collected from SW19, these remained within relevant limits. During 2016 the concentrations in *Nematalosa erebi* (Bony Bream) continued to decrease in response to improved sediment and water management.

Modelling of the downstream water quality of the McArthur River (for select parameters) has been undertaken for operational and post-closure periods (Appendix N – Updated Water Balance and Waterways Modelling for the MRM OMP EIS (WRM, 2018)). For the operational period, modelling results are presented from July 2018. No discussion is provided how these modelling results compare to actual observations from monitoring programs for existing conditions, or whether such validation has been undertaken or is planned in the future. ERIAS Group recommends, given the importance of the modelling to predict future impacts on the environment, that such comparisons and calibrations of the model are made, and that assessment of this relationship is specifically described Appendix R – Adaptive Management Framework (Glencore, 2018).

In summary, description of the existing environmental condition of the McArthur River based on information provided by monitoring programs, is not provided in the SEIS.

4.3 Runoff Volumes and Class 5 Water

4.3.1 Volumes

The volumes and characteristics of Class 5 (Poor Quality) water are described in Appendix N – Updated Water Balance and Waterways Modelling for the MRM OMP EIS (WRM, 2018).

Schematics of flow paths are shown in Figure 4.1 (operations; 2018 to 2037), Figure 4.2 (in-pit tailings deposition; 2038 to 2047) and Figure 4.3 (closure; 2047 to 3018).

- ♦ During operations, Class 5 water emanates from the open pit area catchment and the NOEF PRODS (which catch runoff and seepage from the NOEF).
- ♦ During in-pit tailings deposition, Class 5 water emanates from the open cut (36.69 ML/day) and mine water dams.
- ♦ During the closure period, Class 5 water emanates from in-pit tailings consolidation water (which reports to mine pit lake) and seepage from NOEF to Barney Creek sump, which reports to the mine pit lake, and Barney Creek.

ERIAS Group notes that during the closure period the modelling does not appear to consider inputs from the walls of the open cut.

Section 3.3 of Appendix N (WRM, 2018) presents annual average volume outflows for Class 5/Class 6 (Process) water (combined), under dry, median and wet seasonal conditions, from 2018 to 2047. These volumes include Class 5/6 seepage losses and storage overflows.

Class 5/6 water is stored in the following water storages:

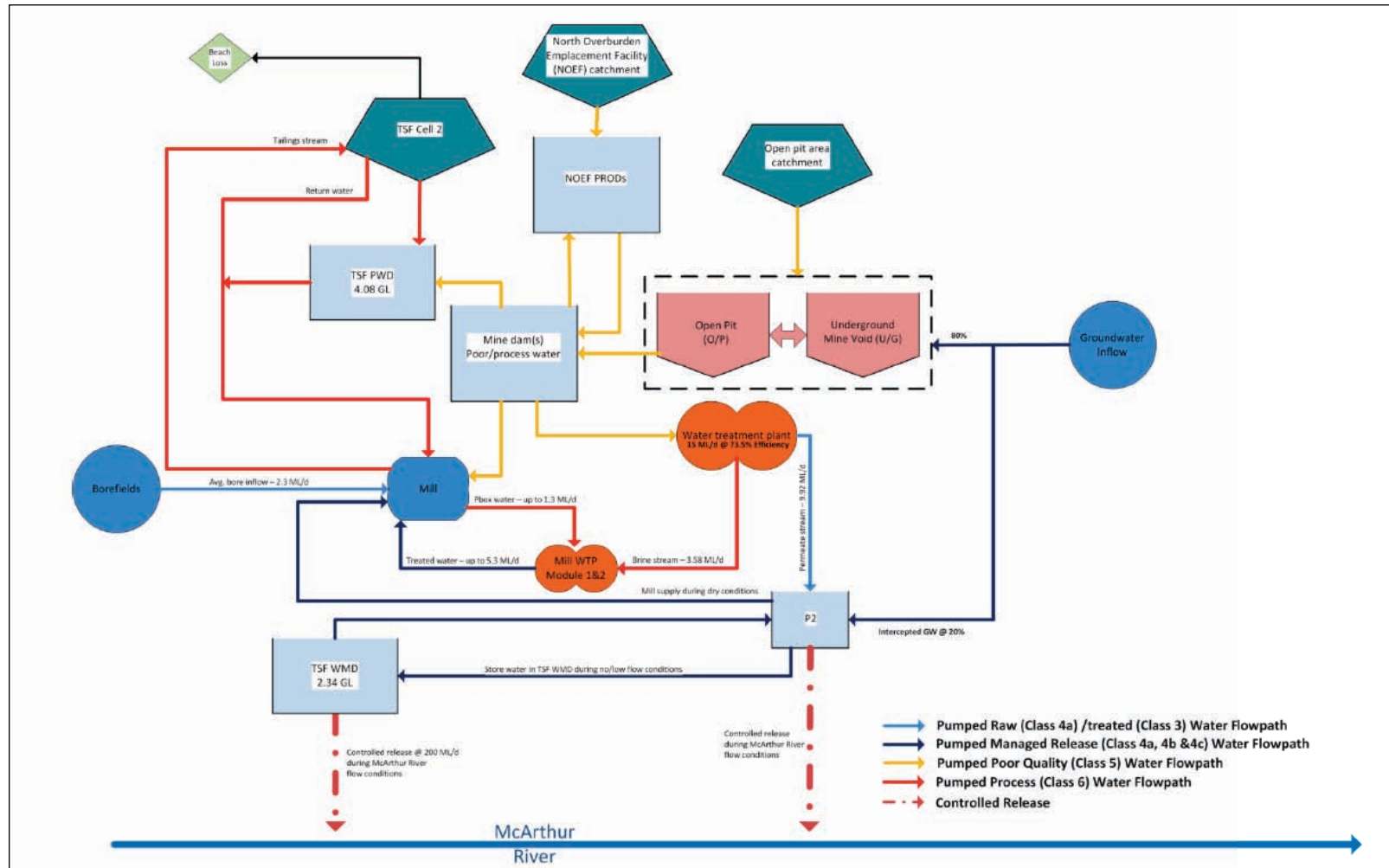
- ♦ NOEF PRODS.
- ♦ TSF PWD (construction scheduled for completion in 2019).
- ♦ Open cut, including underground void.

The modelled volumes of Class 5/6 water stored in the TSF PWD up until 2047 are shown in Figure 4.4. If the capacity of the TSF PWD and NOEF PRODS is exceeded, excess water is stored in the open cut (thereby disrupting mining operations).

Figure 4.5 shows the volume of Class 5/6 water requiring storage in the open pit from 2018 to 2047, and the storage capacity of the open pit underground void. The periods that the underground void storage capacity is expected to be exceeded are shown above the dashed line.

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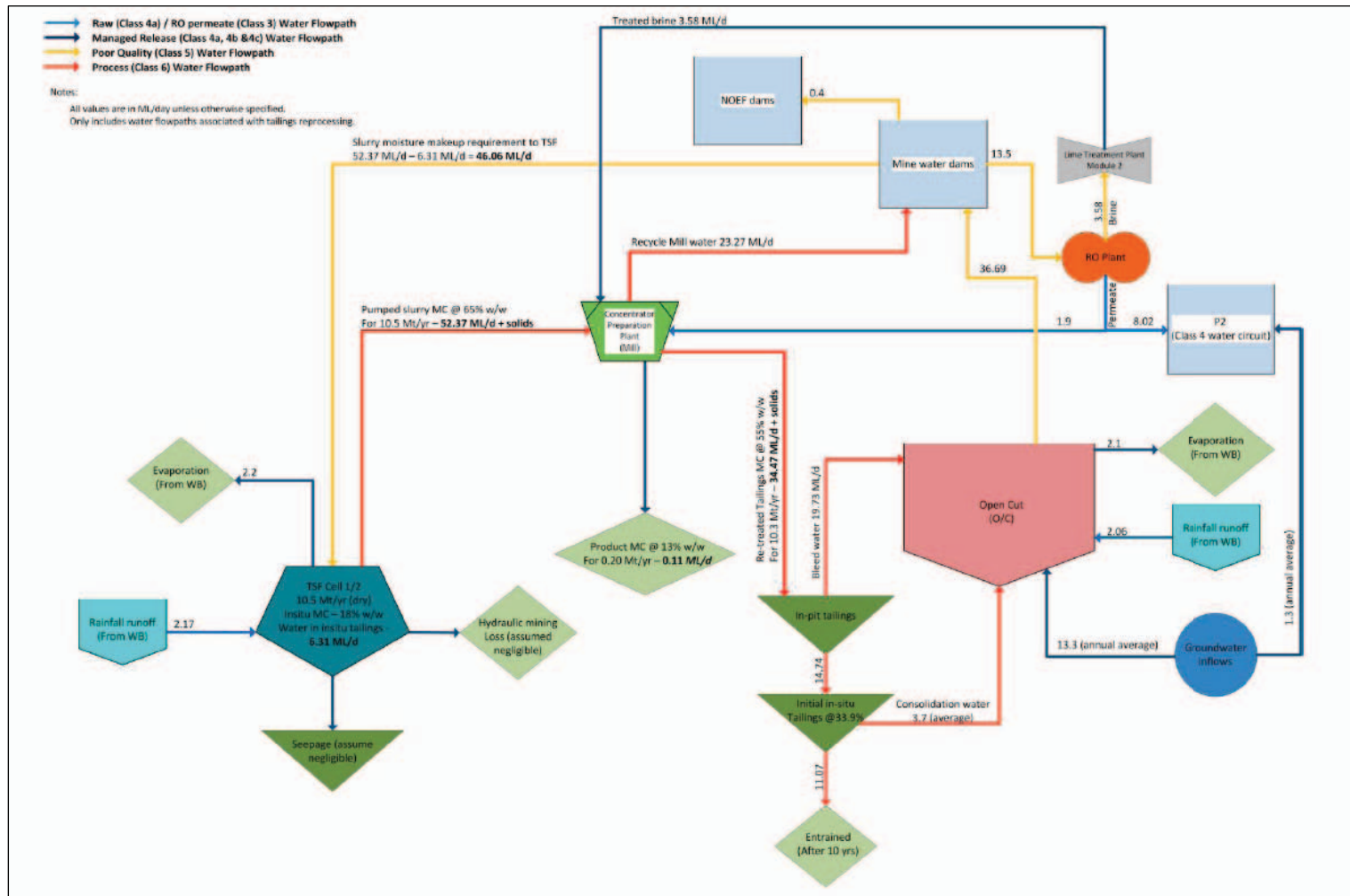
Figure 4.1 – Water Management During Operations (2018 to 2037)



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figure 2.1).

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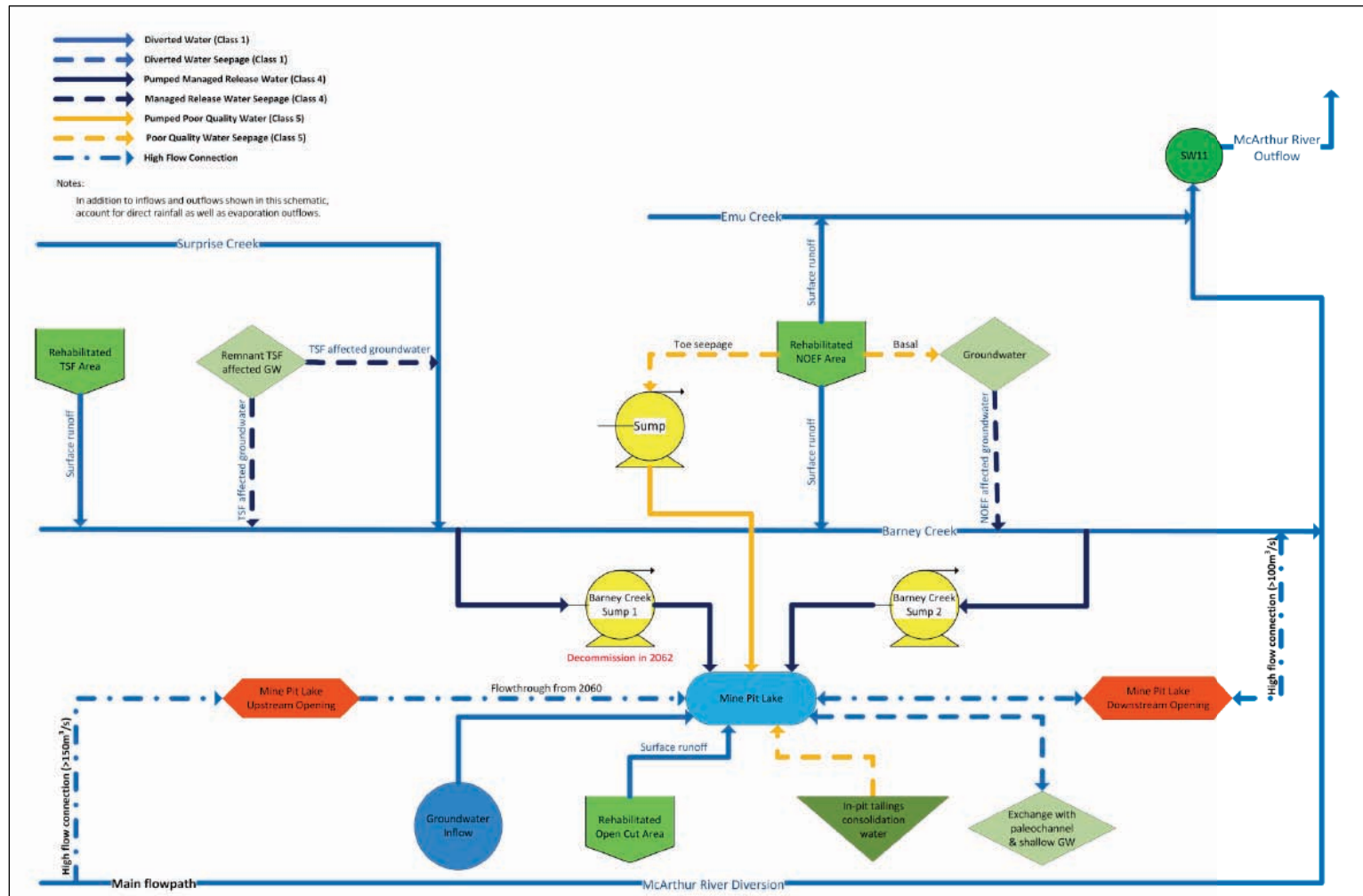
Figure 4.2 – Water Management During In-pit Tailings Deposition (2038 to 2047)



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figure 2.2).

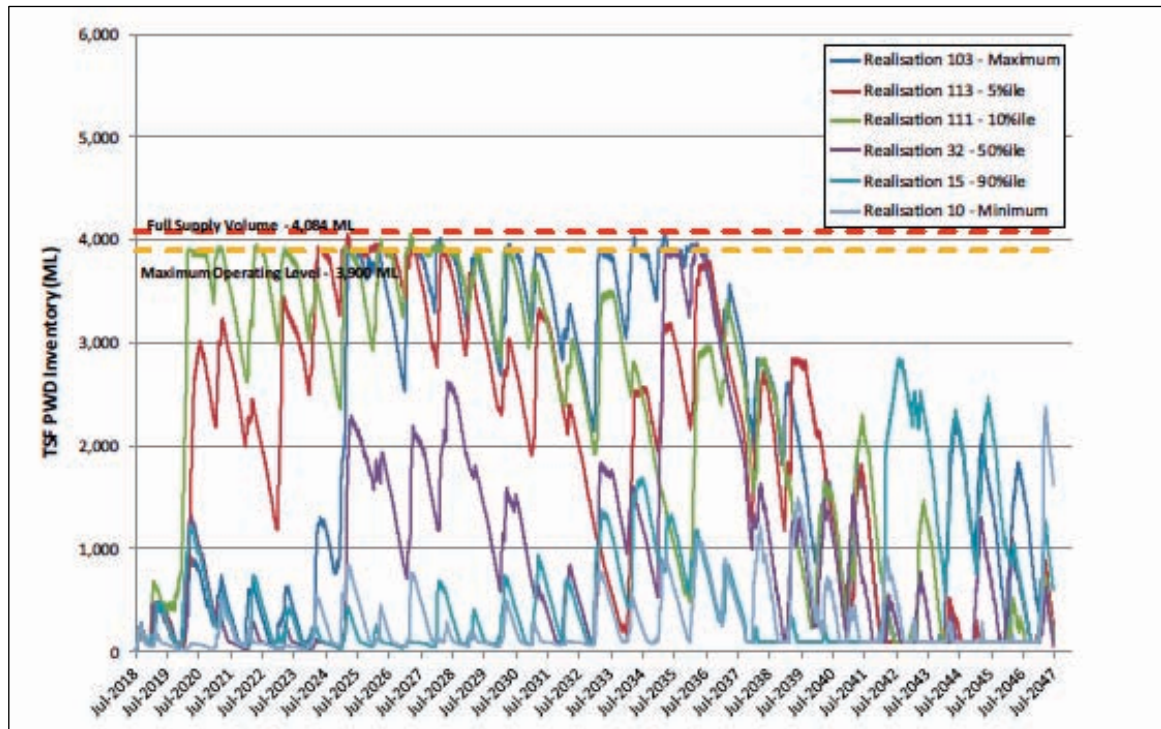
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Figure 4.3 – Water Management Post-closure (2047 to 3018)



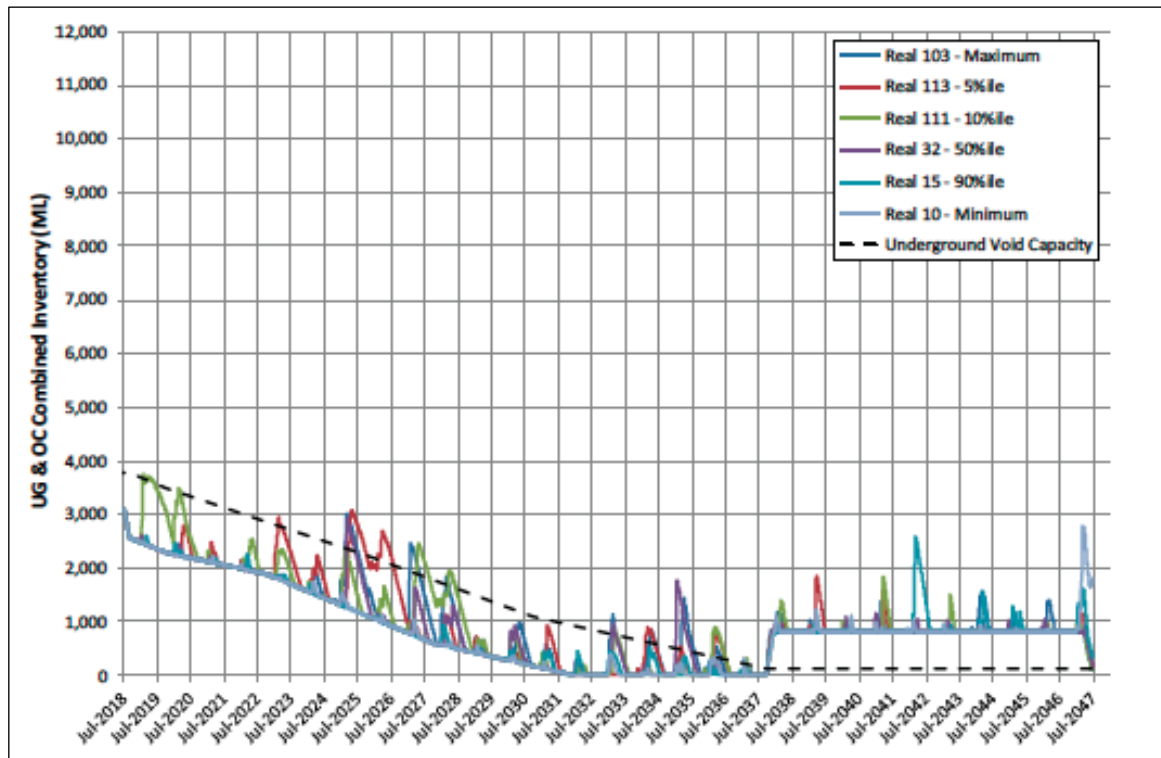
Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figure 2.3).

Figure 4.4 – Water Volumes Stored in TSF PWD



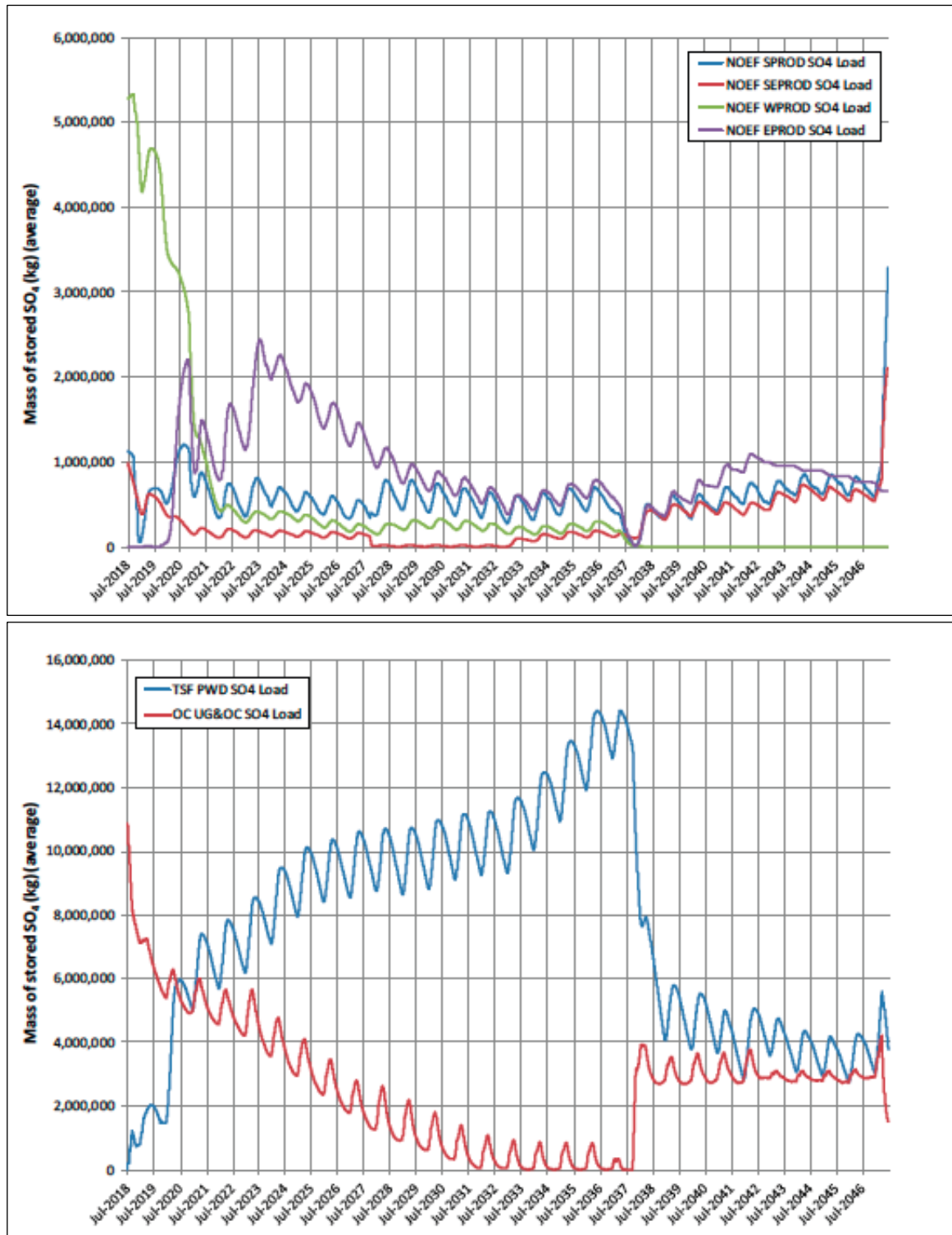
Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figure 3.4).

Figure 4.5 – Water Volumes Stored in Open Cut and Underground



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figure 3.5).

Figure 4.6 – Modelled Stored Loads of Sulphate



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figures 3.16 and 3.17).

4.3.2 Characteristics

Modelled stored loads of contaminants (sulphate, As, Cd, Pb, Zn) in the NOEF PRODs, TSF PWD and open cut from 2018 to 2047 are presented in Section 3.4 of Appendix N (WRM, 2018). The model results for sulphate loads are presented in Figure 4.6. These results are discussed further in Section 4.7 below.

Prior to the commissioning of the TSF PWD in 2019, NOEF WPROD stores significant contaminant loads due to a higher proportion of NOEF toe seepage and open cut water reporting to this dam (through the seepage collection system), with the remainder stored in NOEF SPROD and NOEF SEPROD. Once TSF PWD is constructed, the majority of the contaminant load is stored in the TSF PWD. The mass of contaminants in TSF PWD increases steadily up until the commencement of the in-pit tailing deposition stage in Year 2038 due to the gradual removal of the underground void water storage. Following commencement of in-pit tailing deposition, contaminant loads stored in the Class 5/6 water storages are significantly reduced.

ERIAS Group considers that the modelling provides appropriate information on the expected volumes and characteristics of Class 5 water under various climatic conditions during operations and post-closure, although we are unable to comment on the reliability of the modelling outputs.

4.3.3 Water Treatment

During the operations stage, MRM proposes to construct a two-module 'Lime Treatment Plant' (Mill WTP) to treat PbOx water and brine from the RO water treatment plant to remove salts from the Class 5 and Class 6 water circuit.

All brine generated by the RO plant circuit will be treated through Module 2 of the Mill WTP. The treated water will be recycled back through the Mill circuit, reducing the Mill water demand. Solid residue waste streams from the Mill WTP will report to the final tailings stream. Contaminant loads removed by the Mill WTP modules are therefore modelled as being 'lost' from the water management system. ERIAS Group notes that since the tailings will be ultimately be placed in the open cut that these contaminants in treatment plant residue remain present to be mobilised and released to the downstream environment.

Treatment of water is not proposed to occur post-closure.

4.4 Water Quality Monitoring Parameters

The SEIS does not describe the parameters included in the monitoring program to assess water quality and impacts on the receiving environment.

Waterways modelling assessments are based on sulphate, As, Cd, Pb and Zn as the adopted contaminants of concern (COC). The rationale for these parameters in the selected suite for assessment is described by MRM in response to Issue No. 217 in Section 7.13. It is stated that NT EPA was consulted and agreed upon parameters to be modelled to provide a suitable indication of mine water quality.

McArthur River Mining has also responded to a review comment on the appropriateness of water quality parameters (Issue No. 202 in Section 7.13) by stating that it considers its existing monitoring program is adequate, but that continual review and analysis of results while updating monitoring programs will continue to meet specific and site wide objectives.

The appropriateness of parameters is also raised in Issue No. 236. MRM has responded that parameters for modelling were agreed with NT EPA, and that metals monitored in fish have been selected in agreement with appropriate government department and an adaptive monitoring approach. Within this adaptive management approach, fluvial sediment will be compared from upstream and downstream sites within Barney and Surprise Creek and where there are distinct differences in the suite of parameters currently not analysed they will be included.

Appendix W – Ecotoxicology Forward Work Program (MLC, 2018) presents a framework for development of site-specific guideline values for MRM. These guidelines are recommended by Mine Lakes Consulting to be developed for parameters that exceed ANZECC/ARMCANZ (2000) 'generic' guidelines values, to account for tropical ecosystem characteristics (most ecotoxicology data used to establish generic guidelines values are based on temperate species) and natural enrichment of the catchment. It is also stated (on page 4 of Appendix W) that, commensurate with leading practice framework for future development of water quality management, recommendations are provided for further COC for consideration. However, the only reference to further parameters to be included for assessment of water quality is in Section 5.4.2 of Appendix W. This section indicates that dissolved organic carbon (as a modifier of metal toxicity) and nutrients (important for river ecosystem function) will be considered in water quality assessments and guideline value derivation. Section 5.4.3 of Appendix W also describes consideration of biomagnification and bioaccumulation in development of site-specific guidelines values.

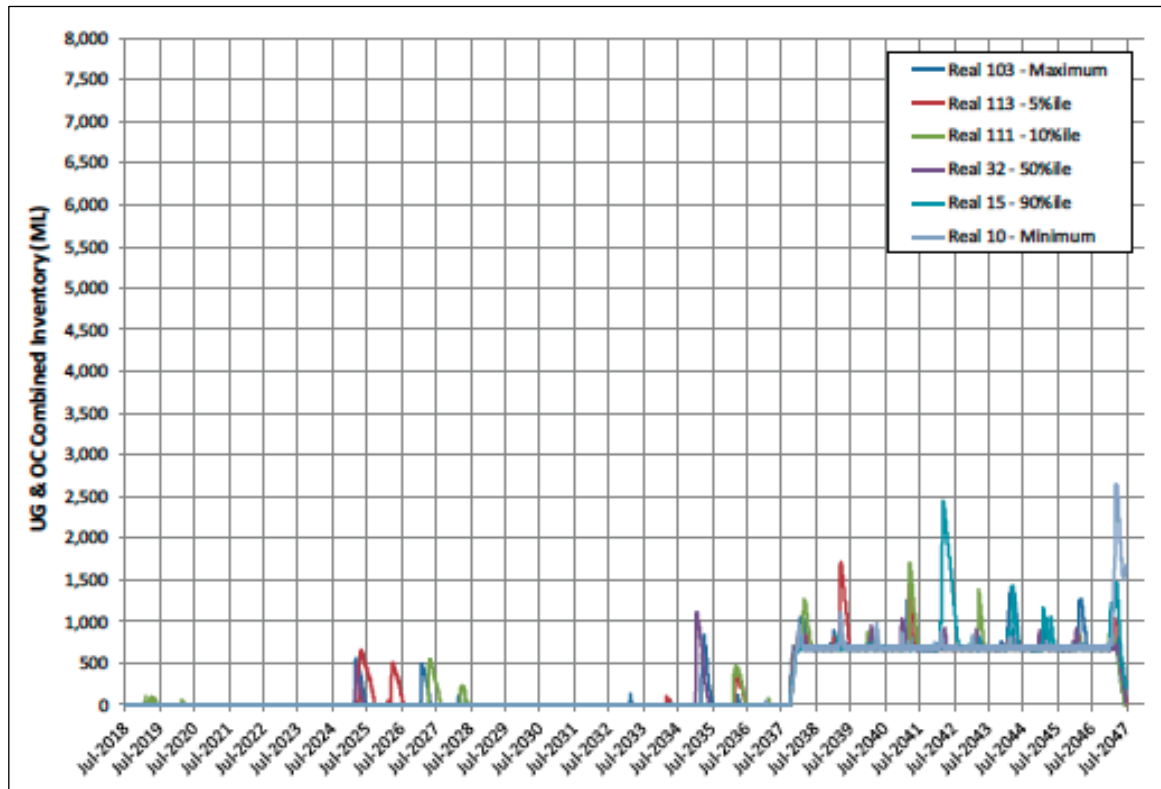
ERIAS Group considers these parameters, while not COC, are valid inclusions for water quality assessment. Additionally, ERIAS Group considers that silver should also be included as a COC, given its presence at high concentrations in the deposit and it is a metal that is known to be toxic to aquatic biota at low concentrations.

ERIAS Group considers that monitoring should be undertaken of total metals, in addition to dissolved metals, to provide information on particulate-associated metals. Monitoring should also include major ions, particularly calcium and magnesium to allow determination of water hardness, and total alkalinity.

4.5 Underground Void Water Storage

Figure 4.5 shows underground void capacity, being about 3,800 ML in 2018 and decreasing in a linear manner to about 100 ML in 2037, when in-pit tailing deposition commences. Figure 4.7 shows excess water required to be stored in the open cut due to the capacity of the underground void being exceeded (under various climatic scenarios).

Figure 4.7 - Water Volumes Stored in Open Cut



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figure 3.6).

The decreasing capacity of the underground void as mining of the open cut progresses is therefore taken into consideration in the water balance modelling. Consideration has been undertaken of the impact on mining operations due to the need to store excess Class 5 water in the pit at times.

4.6 Alternative Contaminated Water Storage or Management

Section 3.3.3 of Appendix N – Updated Water Balance and Waterways Modelling for the MRM OMP EIS (WRM, 2018) states that when the capacity of the TSF PWD is exceeded, excess water is held in the open cut until spare capacity is available in the TSF PWD of the NOEF PRODs.

Section 3.3.5 of Appendix N (WRM, 2018) presents modelling of open cut inundation occurring for more than six months per year (to understand the risk of disruptions to mining operations). No alternatives to storage of contaminated water in the pit are presented. MRM states that it has ore stockpiles that would be processed during this period.

Predicted contaminant loads in water carts, sprinklers and evaporation fans are described in Section 3.4.4 of Appendix N (WRM, 2018). These loads are assumed to be remobilised from the catchment and are captured in rainfall runoff within the water management system modelling.

4.7 Total Dissolved Salt

Sulphate is considered the primary indicator of sulphide oxidation processes and salinity, as described in SEIS (MRM, 2018) Section 7.12, page 7-325.

4.7.1 Operations Mine Discharges

Modelled stored amounts of sulphate in the NOEF PRODs, TSF PWD and the open cut are described in Appendix N (WRM, 2018), Section 3.4.1, and shown in Figure 4.6 above from 2018 to 2047. At the start of the simulation most sulphate is stored within the open cut and NOEF WPROD (which collects the highest amount of NOEF toe storage and water from the open cut). Following completion of construction of the TSF PWD in 2019, most of the sulphate is stored within this dam. The amount of sulphate in the TSF PWD increases until the commencement of in-pit tailing deposition in 2038, due to the decreasing storage capacity of the open cut underground void as mining progresses. From 2038 the amount of sulphate in the TSF PWD reduces as this water is used in the processing of tailings and transferred to the open cut. The Mill Water Treatment Plant (WTP) also treats water during this period and removes sulphate from the site water management system.

Over the whole operational period (2018 to 2047), the modelling shows that about 16,900 t of sulphate (560 t/year), contained in 120 GL of water, will discharge to downstream waterways (Section 4.3.4 of Appendix N (WRM, 2018)). This equates to an average sulphate concentration of 140 mg/L. The majority of this is derived from releases of treated water from the TSF WMD and OP P2 (approximately 87%), with the remaining 13% mainly from rehabilitated area runoff and releases from sediment management structures. Only a very small proportion (less than 1%) of the sulphate release is from mine water storage overflows.

The largest annual sulphate loads in mine water releases are predicted to occur early in the operational period during Stage 1 and Stage 2 (2018 to 2022) prior to the construction of the upgraded 15 ML/d OP WTP and Mill WTP. The sulphate load is mainly derived from TSF WMD managed releases. The predicted annual sulphate loads to the waterways are expected to reduce significantly from 2022 following upgrade of water treatment capacity.

4.7.2 Groundwater

The Waterways Model assumes the operation of two sumps within the Barney Creek diversion to collect groundwater affected by mine-derived seepage (and/or natural mineralised zones), as follows:

- ♦ Barney Creek sump 1 (BCS1) is an existing sump located at the Barney Creek haul road bridge that operates during the operational period and the beginning of the closure period (2018 to 2062).
- ♦ Barney Creek sump 2 (BCS2) is a proposed sump located downstream of the Barney Creek Diversion to intercept NOEF affected groundwater in the future. BCS2 will be operated during the operational and closure periods (2018 to 3018).
- ♦ During the operational period (2018 to 2047), water intercepted by the Barney Creek sumps is pumped to the Class 4 water circuit (via OP P2).
- ♦ During the closure period (2047 to 3018), water collected in the Barney Creek sump is dewatered to the Mine Pit Lake; and is not treated by a water treatment plant.

Updated estimates of groundwater flows and loads delivered to each reach within the Waterways Model were provided by KCB (2017), from their NOEF and site-wide groundwater models

(Appendix K). This included groundwater delivered to the waterways that would be potentially impacted by the following sources:

- ♦ NOEF domain, including residual basal seepage from the NOEF and PRODs that is not intercepted and contained in the site water management system.
- ♦ TSF domain, including residual basal seepage from TSF PWD, TSF WMD and TSF Cell1/2 that is not intercepted and contained in the site water management system.
- ♦ Open cut domain, including residual basal seepage from the WOEF, SOEF, EOEF and mine water dams that is not intercepted and contained in the site water management system.

Estimates of contaminant loads in mine surface water releases are provided in Appendix N (WRM, 2018) Section 4.3.4. However, it is not apparent to ERIAS Group that similar estimates have been provided for mine-derived sulphate loads in groundwater reporting to the downstream environment. The reason for this is not clear, since the EIS and supplementary EIS report that the various groundwater models were used to estimate flows and loads delivered to each reach in the waterways model (as noted above), in which case including loads from groundwater inflows and then discussing the total loads in the surface waterways would seem to be straightforward. If these estimates have been provided, then this should be explicitly acknowledged in the report(s).

4.7.3 Operations Downstream Water Quality

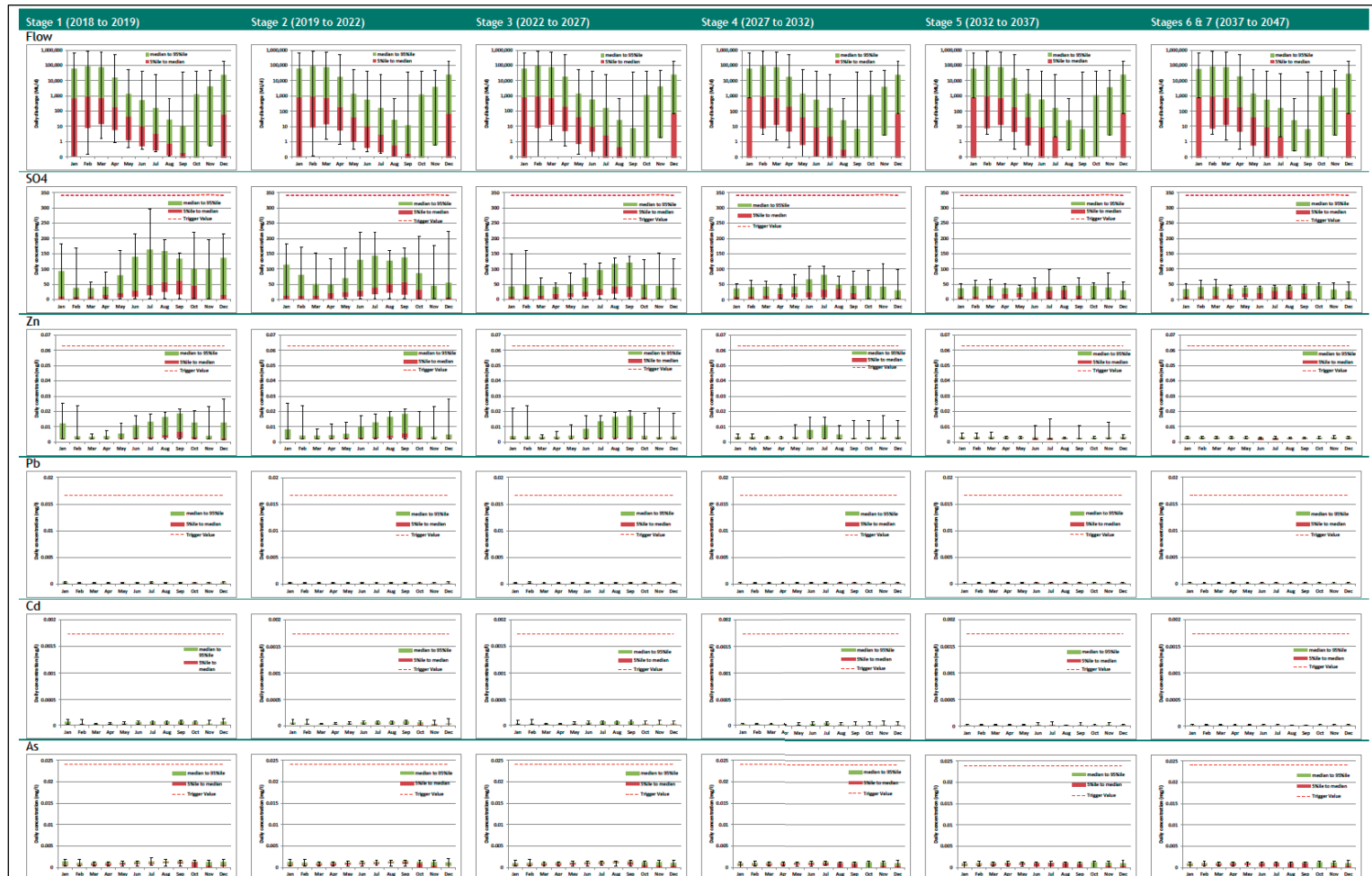
Appendix N (WRM, 2018) Section 4.3 presents results of the Waterways Model which considers contaminant discharges to receiving waters. Results for SW 11 (McArthur River waste discharge licence (WDL) compliance point downstream of the mine) are presented in Figure 4.8. The modelling predicts that sulphate concentrations at SW11 will remain below the WDL trigger values during the operational period of mining. Sulphate concentrations tend to become elevated during the dry season when compared with the adopted background concentrations due to predicted potentially impacted groundwater inflows to Barney Creek and Surprise Creek, originating from TSF seepage which drains to Surprise Creek and Little Barney Creek, and BCS1.

Predicted groundwater impacts associated with the NOEF are stated to be negligible during operations due to groundwater table drawdown associated with open cut dewatering (see page 99 of Appendix N (WRM, 2018)).

Section 4.3.3 of Appendix N (WRM, 2018) presents information on flow volumes and concentrations collected in Barney Creek sumps during the operational period. In this period, the model predicts that BCS1 will collect approximately 25 ML/yr to 44 ML/yr of potentially impacted groundwater. Model results indicate that potentially impacted groundwater may need to be collected from BCS2 at the lower end of the Barney Creek diversion between 2018 and 2027, however this may not be required in the later stages of the operational period as groundwater inflows to Barney Creek reduce due to open cut drawdown of the groundwater table.

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Figure 4.8 – SW11 Modelled Flows and Contaminant Concentrations During Operations (2018 to 2047)



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Table 4.2).

Modelled daily flows and contaminant concentrations at various location in waterways upstream from SW11, i.e., in closer proximity to the mine site, at various stages of the operations period are presented in Appendix N (WRM, 2018) Section 4.5.1. These locations are:

- ♦ SW21 – McArthur River upstream of McArthur River Mine.
- ♦ SW28 – Barney Creek upstream of McArthur River Mine.
- ♦ SW29 – Surprise Creek upstream of McArthur River Mine.
- ♦ SW24 – Surprise Creek upstream of the Barney Creek confluence.
- ♦ SW19 – Barney Creek diversion at the Haul Road crossing.
- ♦ SW06 – Barney Creek south of Barramundi Dreaming (old McArthur River channel).

It is stated in Section 4.3.3 of Appendix N (WRM, 2018) that the predicted annual averaged sulphate concentrations in groundwater dewatered by the Barney Creek sumps into the site water management system will exceed the CoC SW11 trigger values for all stages of the operational period if no additional mitigation measures are implemented (e.g., a NOEF seepage interception trench). No further discussion appears to be provided of implications for downstream water quality if such additional measures are not implemented. It is also not apparent to ERIAS Group that the SEIS proposes implementation of such measures.

It is estimated in Appendix N (WRM, 2018) Section 4.3.4 that approximately 2,500 t/year of sulphate drains to the waterways from background sources including the McArthur River and its tributaries upstream of McArthur River Mine (with the McArthur River contributing about 80% of the background load). This is stated to be about 4.5 times greater than the average annual mine-derived load for sulphate (560 t/year) from surface flows, i.e., excluding groundwater inflows to the waterways. However, it is not apparent that estimates of mine-derived sulphate loads from groundwater have been provided. As noted previously, the reason for this is not clear since the required information would seem to be available from the various groundwater models.

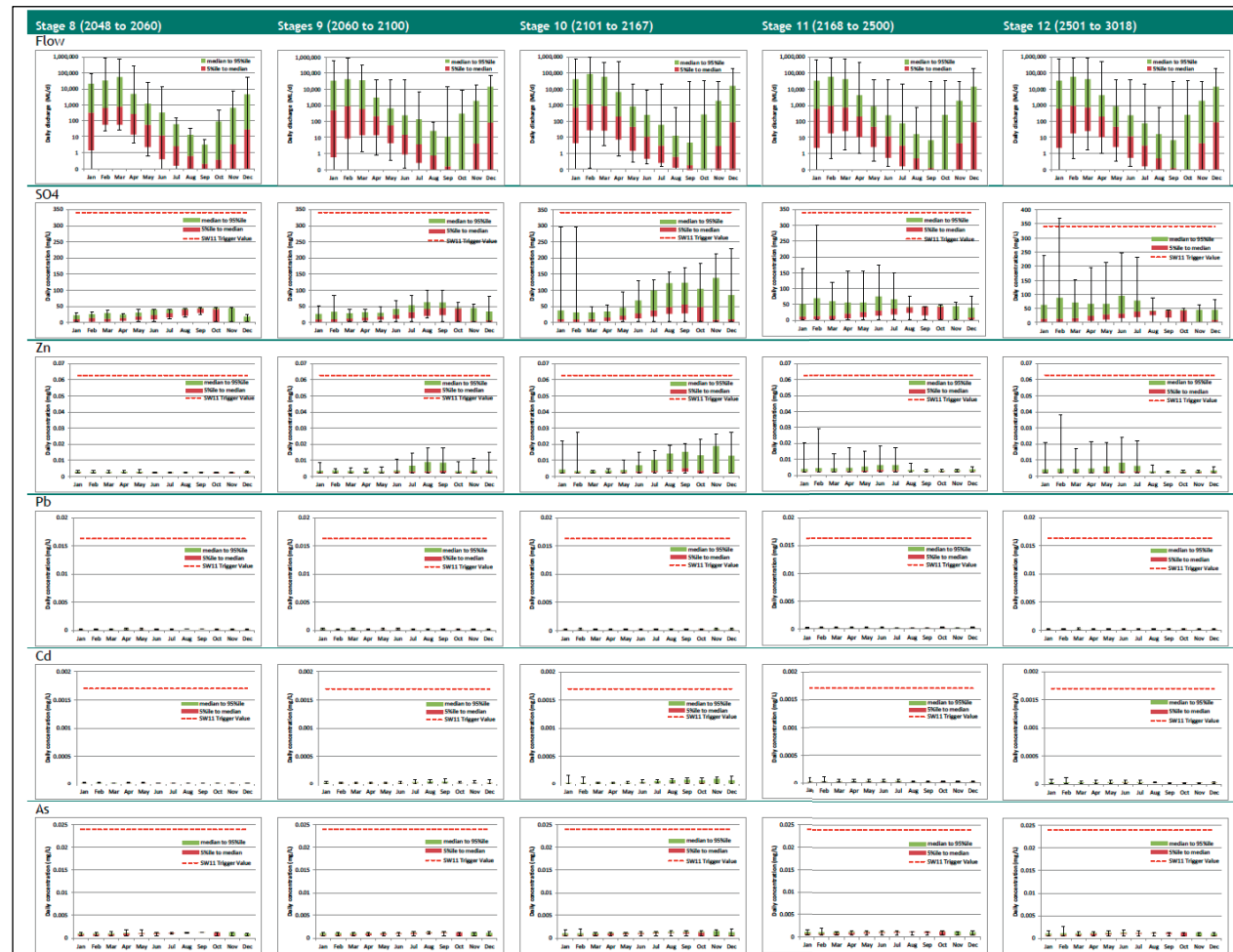
4.7.4 Closure Period Downstream Water Quality

Appendix N (WRM, 2018) Section 4.4 presents modelling results during the closure phase. Modelling results at SW11 (presented in Figure 4.9 for a stratified lake) indicate that, with the proposed Mine Pit Lake opening configuration and Barney Creek collection sumps, predicted sulphate concentrations will remain below the WDL trigger value during the closure assessment period (2047 to 3018).

Sulphate concentrations tend to become elevated when compared with background concentrations during interaction with the Mine Pit Lake and in the dry season due to the influence of groundwater inflows to Barney Creek and Surprise Creek. Sulphate concentrations at SW11 are predicted to peak around August or September when the McArthur River flows drop below 50 ML/d and before the Barney Creek collection sumps are operated. Towards the end of the dry season, predicted SW11 concentrations trend back towards background concentrations due to the operation of the Barney Creek sumps and groundwater inflows to the waterways reduce as the groundwater table lowers over the dry season.

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Figure 4.9 – SW11 Modelled Flows and Contaminant Concentrations During Closure (2047 to 3018) for a Stratified Lake



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Table 4.6).

The predicted annual sulphate load at SW11 in the McArthur River is initially approximately 1.3 to 1.4 times the load from background (upstream) sources between 2047 and 2060 (Figure 4.10). The calculated sulphate loads increase to about 2.2 times and 3.0 times above the background load from 2060 to 2070 mainly due to the initial interaction of the Mine Pit Lake with the receiving environment (for both the stratified and mixed lake cases). From 2080, the calculated annual sulphate load at SW11 is approximately 1.5 to 2.5 times higher than the background load (see Figure 4.10). Most of the annual sulphate load at SW11 occurs mainly during the wet season during outflows from the Mine Pit Lake. During dry periods, very little load passes SW11 due to very low background flow in the river and the collection of affected groundwater in the Barney Creek sumps.

Modelled flows and contaminant concentrations at various mine site locations and SW11 during the closure period are presented in Appendix N (WRM, 2018) Section 4.5.1. Barney Creek diversion is predicted to have elevated sulphate concentrations during the first few decades of closure due to predicted potential upstream groundwater impacts associated with the TSF and natural mineralised zones near the surface. As described above, predicted groundwater impacts associated with the NOEF are negligible during operations due to groundwater table drawdown associated with open cut dewatering. However, elevated sulphate concentrations are predicted to occur during the closure period due to groundwater table recovery when the open cut is filled with water and NOEF seepage migrates to the waterways.

4.8 Suspended and Bed Sediment Contamination

4.8.1 Proposed Further Work Program

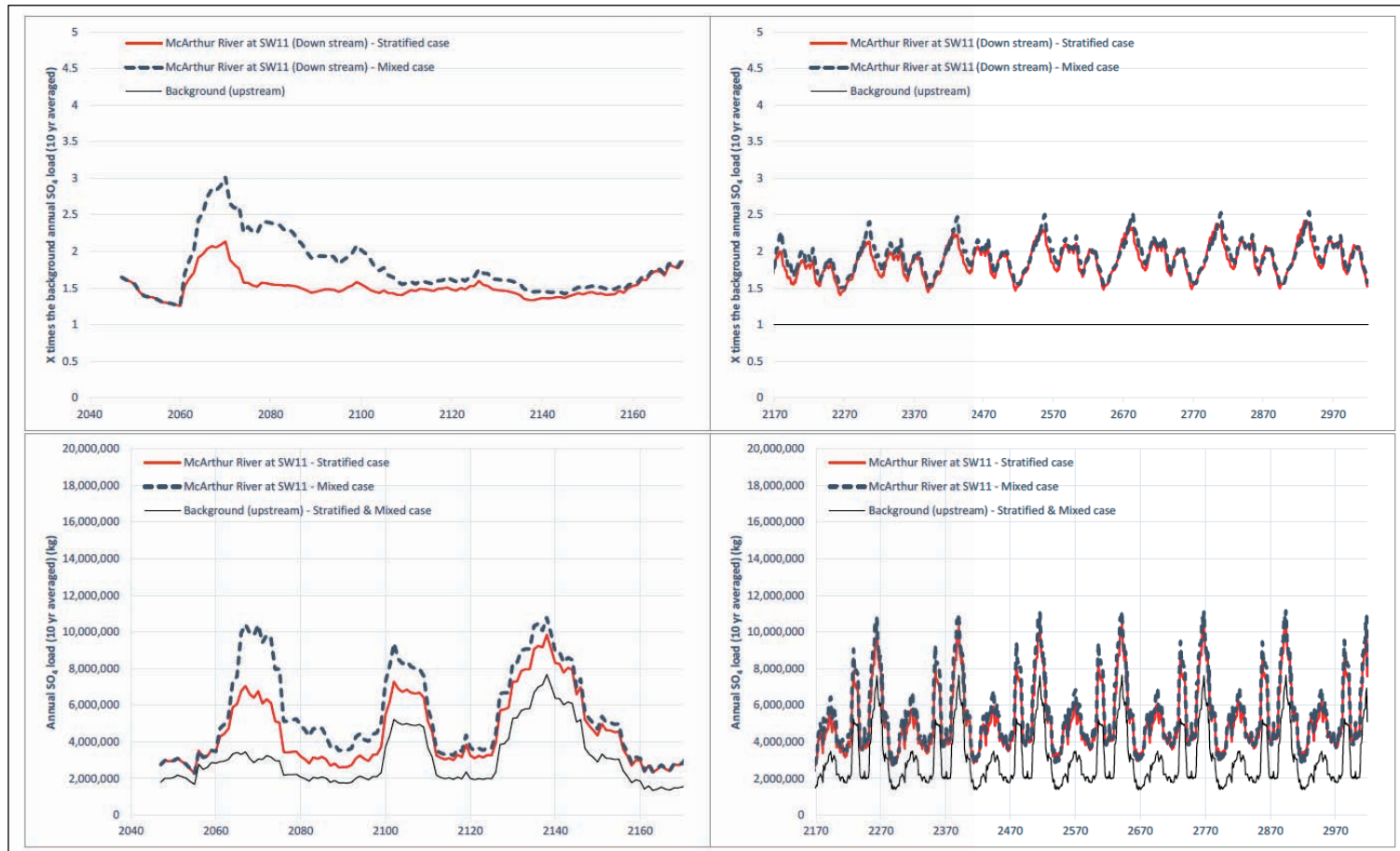
McArthur River Mining (MRM, 2018) has responded to a similar review comment on the need for further information on particulate-associated metals and downstream sedimentation (Issue No. 219 in Section 7.13) by stating that it has scheduled further assessment works for completion in 2018. The assessment is to:

- ♦ Consider sources and pathways of particulate-associated metals and determine impacts on the downstream environment.
- ♦ Undertake geomorphologic and sediment transport assessments of the McArthur River to address potential downstream sedimentation risks.

The work program proposed by Hydrobiology (2017) is described in Appendix Z – McArthur River Geomorphology/Load/Sediment Deposition Forward Work Program. However, little information is provided on the scope of work proposed to assess impacts due to particulate-associated metals. The scope of work is proposed to be prepared by Hydrobiology following completion of a gap analysis.

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Figure 4.10 – Comparison of Background and McArthur River SW11 Sulphate Loads for Closure Period



Source: WRM, 2018 (Appendix N of the OMP Supplementary EIS, Figure 4.8).

4.8.2 Monitoring Program

McArthur River Mining (MRM, 2018) states (on page 7-331) that it has increased the number of surface water monitoring locations that measure particulate-associated metals in surface water flows to assist in further understanding the background and mine-derived particulate-associated metals in the McArthur River system. No information on particulate-associated metals from existing monitoring programs is presented in the SEIS, nor are proposed additions to the monitoring program further described. McArthur River Mining (MRM, 2018) has also committed to install multiple additional stream flow gauging stations and stream flow loggers across the site (page 7-349 and Section 8). Data from these installations will be used to determine load estimates for the different locations.

4.8.3 Existing Assessment

McArthur River Mining (MRM, 2018) describes management measures implemented at the mine site which reduce sediment and particulate-associated contaminants from the mine site entering the downstream environment (page 7-331). It considers the risks due to sedimentation of mine-derived sediment are low due to these measures.

McArthur River Mining (MRM, 2018) also indicates (on page 7-333) that consideration of particulate-associated metal loads for the operational and closure phases of the mine is undertaken in Appendix N (WRM, 2018) (particularly Figure 4.10 to Figure 4.21 and Appendix A of that document). However, it is not apparent to ERIAS Group that this modelling distinguishes particulate-associated metal loads.

4.9 Surface Water Contamination Due to Dust Deposition

In its response to Issue No. 219 (page 7-330), MRM recognises that dust can be a source of particulate-associated contaminants and requires management. An updated Air Quality Management Plan (AQMP) has been finalised that addresses consultation outcomes with the Northern Territory Department of Primary Industry and Resources (DPIR) in relation to the preparation of a Dust Management Plan, the Commonwealth requirement for depositional dust monitoring as well as various commitments made in the Draft EIS.

No information is presented in the SEIS upon the extent to which contaminated dust contributes to the poor water quality of McArthur River, or the intent to further investigate this contribution.

4.10 Impacts on Surface Water in Event of TSF Wall Failure

Appendix R – Adaptive Management Framework (Glencore, 2018) describes performance indicators and monitoring programs to maintain the integrity of the TSF embankment wall/batters and adequately manage surface water (see Table 3-2 pages 21 and 33). Contingency management measures in the event of a TSF embankment failure are yet to be developed.

Appendix I – Updated TSF LOM Plan (GHD, 2017) assesses the consequence of a dam failure. A breach of the TSF embankments has the potential to release tailings and decant water into the WMD, or overland into Surprise Creek, Little Barney Creek or Barney Creek and subsequently into the McArthur River.

Risk assessment of TSF wall failure has been undertaken during operations, but not under the scenario that MRM has left the site prior to tailings retreatment.

Environmental, political and business impacts from a failure are likely to be considerable and the 'severity of damage and loss' is assessed as 'Major'. Based on an assessed 'severity of damage and loss' of 'Major' based on ANCOLD and $PAR \geq 1$ to < 10 , application of ANCOLD (2012) gives a Dam Failure Consequence Category for the TSF of HIGH C.

No specific assessment of consequences on surface water (or groundwater) quality is provided in the SEIS. However, it is ERIAS Group's opinion that impacts on surface water would be major with release of PAF tailing from the TSF to downstream waterways having long-term impacts on water quality due to exposure and oxidation of this material. Impacts to groundwater would not be as significant since a wall failure would remove the water source reporting to the groundwater.

4.11 References

- ANCOLD. 2012. Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure. May. Australian National Committee on Large Dams Incorporated. Hobart, Tasmania.
- ANZECC/ARMCANZ. 2000. Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.
- GHD. 2017. Tailings Storage Facility Design Development - Life of Mine Plan. Revision 2. Report for McArthur River Mining Pty Ltd. May 2017. (Updated Tailings Storage Facility Life of Mine Plan – Appendix I of the OMP Supplementary EIS)
- Glencore. 2018. Overburden Management Project Appendix R - Adaptive Management Framework Supplementary Environmental Impact Statement. February 2018. (Appendix R of the OMP Supplementary EIS)
- Hydrobiology. 2017. McArthur River Mine Geomorphology Investigations – Proposal to McArthur River Mining Pty Ltd. V4-0. December 2017. Auchenflower, Queensland. (McArthur River Geomorphology/Load/Sediment Deposition Forward Work Program – Appendix Z of the OMP Supplementary EIS)
- KCB. 2017. McArthur River Mining Pty Ltd – 2017 MRM EIS Supplementary – NOEF Flow and Water Quality Modeling (Final). December 2017. Kohn Crippen Berger. (Revised NOEF Unsaturated Flow Modelling (TOUGH 2) Report – Appendix K of the OMP Supplementary EIS)
- MLC. 2018. A framework for development of site-specific guideline values for McArthur River Mine. February 2018. Prepared by Mine Lakes Consulting for McArthur River Mining. Joondalup, WA. (Ecotoxicology Forward Work Program – Appendix W of the OMP Supplementary EIS)
- MRM. 2018. Overburden Management Project Supplementary EIS. McArthur River Mining. Darwin, NT.
- WRM. 2018. Updated Water Balance and Waterways Modelling for the MRM OMP EIS. 23 February 2018. Reference 0790-38-P5. (Appendix N of the OMP Supplementary EIS)

5. Geotechnical

5.1 Background

The tailings component of the Supplementary EIS is largely contained within Appendix I (GHD, 2017). This plan has been prepared by GHD and sets out:

- ♦ TSF design including design criteria and standards
- ♦ The TSF life of mine strategy
- ♦ The consequence of failure of the TSF
- ♦ Tailings geochemistry and AMD/NMD Management
- ♦ Relevant investigations undertaken
- ♦ Embankment construction
- ♦ Tailings drying and consolidation modelling
- ♦ Stability calculations
- ♦ Surface and seepage water management
- ♦ Closure
- ♦ Risk assessment; and
- ♦ On going works

In general the LOM Plan provides a relatively comprehensive overview of how tailings are to be managed for the life of mine. Importantly the plan advocates for a reunification of Cell 1 and Cell 2 for the life of tailings disposal operations prior to rehandling and reprocessing the tailings for placement into the final pit void.

5.2 Likelihood and Consequence of TSF Embankment Failure

The TSF has been categorised by GHD 2017 as having an ANCOLD (2012) failure consequence category of High C. This corresponds to a condition whereby a breach of the tailings dam is likely to cause major damage and loss to infrastructure and the environment and may cause the death of 1 to 10 people. A breach and subsequent loss would represent 'failure' in this context and the likelihood of this occurrence would be represented by the probability of failure (PoF). The inverse of the PoF is termed the reliability and calculated simply as $1 - \text{PoF}$.

ANCOLD (2012) recommends balancing risk against cost by adopting key design performance criteria corresponding to the consequence category of the dam. For embankment stability use is made of factor of safety (FoS) analysis. The recommended FoS varies depending on the design event scenario ranging from 1.5 when considering the dam in operation where there is a potential

for loss of containment and under normal operating conditions to 1 to 1.2 when considering a seismic event. PoF is not readily derived from FoS and ANCOLD (2012) recommends that sensitivity and reliability calculations be undertaken to assess the reliability of the structure and therefore the PoF.

GHD 2017 have undertaken a sensitivity analyses of their design but have not extended this to a reliability analysis. Consequently the overall PoF for the TSF embankment is unknown. However, they have adopted key loading events with specific return periods as recommended by ANCOLD (2012) for High C structures. These events are for the TSF in operation and are as follows:

- ♦ A minimum extreme storage allowance during operations for an AEP storm event of 1 in 100 (72 hr event),
- ♦ A minimum flood for spillway design of 1 in 100,000 years (72 hr event),
- ♦ An Operating Basis Earthquake (OBE) with an AEP of 1 in 1,000 years
- ♦ Maximum Design Earthquake (MDE) with an AEP of 1 in 10,000 years during operation,

GHD 2017 notes that the spillway design is preliminary and recommends a more robust quantitative risk assessment specifically for this design component.

An OBE is defined as a design earthquake that would significantly disrupt TSF operations but not result in a breach and loss of tailings or tailings water. A MDE is a design earthquake that would result in such a breach.

ANCOLD (2012) recommends that for closure the embankment should also be designed to sustain a Maximum Credible Earthquake (MCE). The MRM Life of Mine plan for the TSF assumes that all tailings will be relocated to the pit at closure. Consequently GHD 2017 has deemed that this criteria does not apply.

Based on the adopted design criteria and given the existence of a spillway it may be reasonably assumed that the critical event that would cause embankment failure post closure would be the MDE. Therefore the PoF of the TSF post closure is expected to be 1 in 10,000 each year.

Over a lifetime an AEP may be converted to a lifetime exceedance probability (LEP) as follows:

$$LEP = 1 - (1 - AEP)^y \quad \text{where } y \text{ is the lifetime in years}$$

Given a specified closure lifetime of 1,000 years the LEP of failure based on an MDE with an AEP of 1 in 10,000 would be 1 in 10.5. As this MDE would cause failure the lifetime PoF is also 1 in 10.5.

Historical worldwide failure rates of conventional water retention dams have been around 1 in 10,000 generally in line with ISO 2394 (ICOLD 2001). Historical failure rates of tailings dams over the last 100 years, however, are around 1 in 80 (Azam and Li 2010). Converting the 1 in 80 year LEP over 100 years to an AEP gives 1 in 7,950. The equivalent LEP for a 1,000 year lifetime is 1 in 8.5 this also being the PoF. This historical PoF value of 1 in 8.5 is similar to that based on design of 1 in 10.

Based on the above we would expect that the PoF of the TSF at MRM over a 1,000 year closure period is 1 in 10.

Post closure the consequence of failure would be largely similar to the High C assessment made by GHD 2017 in the short term. Over time the risk of direct harm to the population would reduce as the piezometric levels fell and the tailings densified and gained strength. After around 50 years or so the direct risk of harm to the population would be minimal. The environmental consequences would be largely the same as the short terms as once a breach was established tailings would be free to be dispersed throughout the environment due to their relatively high mobility upon rewetting.

5.3 Tailings Disposal Within the Final Pit

ERIAS Group raised a number of issues in the Draft EIS relating to properties used to model tailings consolidation when deposited into the final pit. The Supplementary EIS provides a number of clarifications to these queries most notably a revision of the compressibility parameters A and B.

Compressibility parameters A and B values predict what the final settled density will be. A summary of parameters provided in the Supplementary EIS Appendix P – Revised Tailings Consolidation Report are given in Table 5.1. Included in this table are the tailings dry densities predicted by respective A and B values as derived by ERIAS Group using first principles.

Table 5.1 – Comparison of Compressibility values and associated dry density

Source	Draft EIS (GHD 2016)	Supplementary EIS (GHD 2017 column test)	Supplementary EIS (GHD 2017 Rowe Cell test)
Compressibility parameter $A^{(a)}$	1.5	1.8	1.0
Compressibility parameter $B^{(a)}$	-0.12	-0.488	-0.11
Final Dry Density ^(b) [t/m ³]	1.83	2.85	2.1

a) Values as stated by GHD assumed to be in kPa.

b) Estimated by ERIAS Group from A, B and initial solids content of 45% a particle density of 3.2 t/m³ and an initial height of 220 m.

The densities shown in Table 5.1 indicate that there is a significant variation in predicted final dry densities ranging from 1.83 to 2.85 t/m³. ERIAS Group independently verified the Rowe Cell data published in Appendix P of the Supplementary EIS and derived A and B values similar to the GHD 2017 Rowe Cell values shown in Table 5.1 Therefore ERIAS Group expects the tailings disposed into the final void to have a maximum dry density of 2.1 t/m³.

Appendices B and C of the Supplementary EIS provide estimates of mass and volume of tailings to be placed in the final void as part of mine closure. All three estimates have assumed a dry density of 2.33 t/m³. However, the final dry density is only expected to reach 2.1 t/m³. If confirmed, this discrepancy may have implications for the placement of other material into the final void and the hydrodynamic and geochemical performance of the pit lake. Potential implications include increased turbidity and sediment loading.

5.4 Erosion of Mine Levee Wall at the McArthur River Offtake

No detailed engineering drawings are available regarding the design of the McArthur River offtake. ERIAS Group expects that the issue of erosion can be managed through detailed engineering design of the levee wall breach which is likely to require the use of large rip-rap materials to dissipate energy and reduce scour.

5.5 Estimated Period Until Failure of the Mine Levee

The mine levee wall is around 10m high on average, 20-25m wide at the crest and 100m at the base. KCB 2017 provided some erosion rates for weathered shale which ERIAS Group understands is the bulk of the mine levee wall. The erosion rate for unweathered shale was 50 – 100 mm/year.

Assuming an erosion rate of 100 mm/year this represents a life until complete removal of 1,000 years. However, it is likely that flood events will exacerbate this rate of degradation as the levee is only designed to protect against a 1 in 500 year flood event based on the current 1 in 1000 AEP. ERIAS Group estimates that the design life when considering flood events will likely reduce to around 500 – 750 years. If an erosion rate of 50 mm/year were used time to failure would increase to around 1,000 to 1,500 years.

Over time climate change is expected to increase the severity of a 1 in 1000 AEP event. Data from the Australian Bureau of Meteorology (BoM) shows that wet season rainfall in the vicinity of the TSF has been increasing by about 50 mm per decade on average based on the last 45 years of data. If this trend were to continue this represents in simplistic terms, a reduction in frequency of today's 1 in 1000 AEP storm event to possibly a 1 in 100 year event in 50 to 100 years based on the BoM 2016 IFD curves. This suggests climate change may cause a further reduction in design life of the levy.

5.6 References

- ANCOLD (2012). Guidelines on Tailings Dams - Planning, Design, Construction, Operation and Closure, Australian National Committee on Large Dams.
- Azam, S. and Q. Li (2010), Tailings dam failures: a review of the last one hundred years, *Geotechnical News* 28(4): 50-54.
- GHD. 2017. Tailings Storage Facility Design Development - Life of Mine Plan. Revision 2. Report for McArthur River Mining Pty Ltd. May 2017. (Updated Tailings Storage Facility Life of Mine Plan – Appendix I of the OMP Supplementary EIS)
- ICOLD (2001). Tailings Dams–Risk of Dangerous Occurrences, Lessons Learnt From Practical Experiences (Bulletin 121). Commission Internationale des Grands Barrages, Paris, International Committee on Large Dams/UNEP.
- ISO 2394 General principles on reliability for structures, Second edition, 1998-06-01.
- KCB. 2017. McArthur River Mining Pty Ltd – 2017 MRM EIS Supplementary – NOEF Flow and Water Quality Modeling (Final). December 2017. Kohn Crippen Berger. (Revised NOEF

Unsaturated Flow Modelling (TOUGH 2) Report – Appendix K of the OMP Supplementary EIS)

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6. General

6.1 Project Approved

Should the project proceed the controls that are required to avoid significant environmental impacts off site include:

Geochemistry

- ♦ Address the potential failure mode during extreme storm events of the GSL cover system batter design, and arrange independent review of the geotechnical assessment and cover design.
- ♦ Verify erosion rates during operations with trials and observation of rehabilitated areas to better plan post closure maintenance requirements.
- ♦ Assess temperature effects on the GSL in the context of effects from the existing convecting materials in the NOEF.
- ♦ Carry out the extensive physical, chemical and constructability testing recommended in Appendix H, and include different GSL options to justify selection of the preferred GSL.
- ♦ Monitor dump temperature and settlement during dump construction, with particular focus on the performance of the Stage 2 final cover over the older end tipped and convecting dump portion of the NOEF.
- ♦ Carry out a more comprehensive settlement assessment supported by site observation as per above.
- ♦ Clarify whether the assumptions used for basal seepage in the NOEF Unsaturated Flow Modelling are conservative.
- ♦ Place all PAF(HC) in 2m lifts in the same way as PAF(RE) materials to minimise AMD loadings and reduce liabilities during all stages of dump construction in case the proposed final cover system is not fully successful.
- ♦ Update the areas of exposed non-benign material by years with the current proposed staged cover placement.

Groundwater

- ♦ Annual recalibration of models.
- ♦ Trigger values to be specified for each groundwater monitoring bore as part of the operations adaptive management program.
- ♦ Further investigation into the source of the 140 – 200 lt/sec groundwater infow into the underground workings.

Surface Water

- ♦ Monitoring of sulphate concentrations in particular in Barney Creek and subsequent recalibration of model.

Geotechnical

TSF:

- ♦ Current controls are considered adequate.
- ♦ Regular audits to confirm that TSF conditions are being properly adequately monitored and controls are being used when required in accordance with the operations manual.
- ♦ Careful design, testing and monitoring of the proposed Cell 1 seepage interception trench to ensure high capture efficiency.

NOEF

- ♦ Installation of at least 500 mm compacted clay liner at base.
- ♦ Good compaction of placed waste.
- ♦ Demonstrated (measured) performance against modelling.
- ♦ Installation of a cover cap that had a demonstrated capability to meet design requirements.

6.2 Project Not Approved

Should the project not proceed ERIAS Group expects that there would be a period where the operation would be placed in care and maintenance pending the outcome of negotiations with government. In addition it is understood that closure strategies outlined in the approved 2013 – 2015 Mining Management Plan would need to be revised and an updated closure plan prepared before rehabilitation could commence. This process could take a number of years before any on ground works commenced. Controls that would need to continue include:

Geochemistry

- ♦ Ongoing management of the NOEF to prevent spontaneous combustion.
- ♦ Development of closure plan and in particular for the NOEF, TSF and Open Pit.
- ♦ Placement of compacted clay layers over areas of PAF(RE) and PAF(HC) pending outcome of finalisation of closure plan.

Groundwater

- ♦ Demonstrate a robust solution to preventing unacceptable seepage from the TSF post closure. Ideally this may involve the relocation of tailings to the pit or a long-term cover, with options to mitigate any seepage (e.g. seepage trench, recovery bores).
- ♦ Adequate capping of the NOEF based on the strategies outlined in the draft OMP EIS or OMP SEIS. An alternative may be to evaluate the option of relocating the worst PAF material back into the pit.

- ♦ Suitable management of the pit lake. The approach outlined in the SEIS would appear to be the only viable option.
- ♦ Development of a robust water management system with a focus on rehabilitating areas which contribute the poorest water quality.

Surface water

- ♦ Development of a comprehensive water management plan for care and maintenance.
- ♦ Ongoing water treatment and proactive approach towards discharging the maximum volume of water each wet season.
- ♦ Ongoing surface water monitoring program.

Geotechnical

TSF:

- ♦ Cap the TSF to limit the ingress of surface water. Such features may include sufficient contours to ensure the majority of surface water is shed or a drainage system to collect and divert water laterally. This would require updating the current conceptual capping design to a final design. Alternatively as highlighted above investigate the option of relocation of the tailings to the pit.

NOEF

- ♦ Relocate waste to the pit with appropriate controls. This would require further investigation to ensure that oxidation products are minimised and their migration prevented or severely limited due pit inundation.

6.3 Adaptive Management Framework

A number of questions were raised in ERIAS Group review (ERIAS Group 2017) of the draft OMP EIS regarding adaptive management and particularly the decision making process i.e. the triggers for when action would be taken. ERIAS Group also notes that while MRM has prepared an adaptive management framework (Glencore, 2018), the framework does not clearly state what are the appropriate performance objectives and the relevant performance targets (e.g. trigger values) that MRM are committing to. This deficiency should be addressed as a priority.

6.4 References

Glencore. 2018. Overburden Management Project Appendix R - Adaptive Management Framework Supplementary Environmental Impact Statement. February 2018. (Appendix R of the OMP Supplementary EIS)

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