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Memo

To	Dylan Asgill Tucker and David Holmes	**Company**	Roy Hill
From	Mark Nicholls, Kathryn Rozlapa and Duncan Storey	**Job No.**	418D
Date	07/02/2022	**Doc No.**	012b
Subject	McPhee Creek Peer Review of Groundwater, Surface Water and Water Balance Modelling for McPhee Creek		

1. EXECUTIVE SUMMARY

AQ2 reviewed water-related reports prepared by GHD to support project environmental approvals for the proposed McPhee Creek project. The reports documented the groundwater study and associated groundwater modelling, surface water impacts modelling and water balance modelling.

The groundwater model is suitable for hydrogeological impact assessment. The groundwater model developed satisfies the requirements of the Australian groundwater modelling guidelines (industry guiding principles). The groundwater model set up and calibration is consistent with the amount of data available at this level of study. The groundwater modelling study, that underpins dewatering estimates and the H3 report, is fit for the purpose of predicting maximum dewatering requirements and the simulation of the hydrogeological impacts of dewatering, excess water disposal and the long-term behaviour of final pit void lakes, to support project environmental approvals.

The predicted dewatering requirements are considered to be consistent with the hydrogeological conditions. The groundwater model has not been used to undertake a detailed dewatering design or develop a dewatering strategy that integrates advanced dewatering with water supply requirements. As such, predicted peak dewatering rates are likely to be a “conservative” worst case. To date only the impact of creek discharge resulting from the peak-rates, has been simulated. Creek discharge, at lower rates, over a longer period of the mine life, that would result from an optimised dewatering strategy has not been simulated.

The surface water model is suitable for hydrological impact assessment. The surface water model has been used to assess the implications of catchment loss on flows and this work is fit for the purpose of supporting project environmental approvals. The surface water model has not been used to assess the infrastructure required to implement a suitable surface water management plan, including flood protection bunds, diversions and sediment control (which would be completed in future assessments and submissions to regulators). As such, the surface water assessment has generally adopted assumptions that would relate to the worst-case environmental impact.

The water balance model has not been described in detail and the model itself has not been reviewed. Some of the inputs to the water balance model may require refinement, and integration with the approaches and assumptions used within the with the ground and surface water models is recommended. The largest input to the water balance model are the dewatering inputs; currently these are based on a worst case dewatering rate and the creek discharge rates do not include site water demands (which means surplus water will be overstated). The closure water balance results appear to have been used in the pit water quality assessment that was completed. AQ2 have not reviewed the pit water quality assessment.

Preliminary modelling has been done to consider the discharge of excess water to three creeks, at the upper end of the expected range (as previously stated). However, additional refinement (of all three models) is required, to include:

- Combination of model outputs to support an integrated water management strategy.
- Optimisation and seasonality of surplus volumes.
- Implications for groundwater level rise and constraints on long term infiltration capacity.
- The extent of the wetting front in each creek taking account of varying discharge and infiltration constraints.
- Consideration of the impact of water quality on the project's water management strategy.
- Input to the assessment of the riparian vegetation in the affected areas and its response to additional surface water and / or rising groundwater levels.

2. INTRODUCTION

The McPhee Creek Project is located approximately 30 km north of Nullagine in the Pilbara region of Western Australia. Atlas Iron completed a Pre-Feasibility Study (PFS) for the project in 2014 which suggested that dewatering of the proposed mine areas would be required. The dewatering would exceed site water demands and an excess water disposal strategy would be required. Excess water disposal to creek lines downstream of the mine area was identified as the preferred disposal option. The PFS was supported by hydrogeological studies completed in 2013 and 2014 by AECOM and SKM (AECOM, 2013 and SKM 2013 and 2014).

As part of further studies for the McPhee Creek project, additional hydrogeological investigations and water management assessments were completed by GHD in 2020 / 2021 to support the project. These studies were designed to assess the potential impacts of the McPhee Creek project on surface and groundwater systems in the area.

3. CURRENT SCOPE OF WORK

Atlas Iron requires independent Peer Review of the groundwater and surface water modelling completed for the McPhee Creek project. The focus of the review is the suitability of the modelling approach used to support project environmental approvals. The review includes:

- The current hydrogeological conceptualisation.
- The representation of the current hydrogeological conceptualisation in the groundwater model.
- Groundwater model set up, model calibration performance and results and treatment of model uncertainty.
- The key assumptions and development of the GoldSim water balance model.
- The surface water model, related to both the extent and impact of creek discharge and flood assessments in the vicinity of the mine development area.

4. APPROACH

The following reports were used to complete the review:

- McPhee Creek Iron Ore Project Water Management Studies H3 Groundwater Report. GHD, October 2011.
- McPhee Creek PFS WMS Update – Surface Water Assessment. GHD, October 2021.
- McPhee Creek Iron Ore Project – Water Management Studies: Water Balance Assessment. GHD, October 2021.

Electronic files were also provided for the groundwater flow model (*McPhee_ck_GW_model_files.zip*) and surface water models (*12548901-MDL_McPhee Discharge Flood Model 20211222.zip*).

No further analyses or model runs have been completed except where outlined in the following sections.

5. H3 REPORT AND GROUNDWATER MODELLING

5.1 Background

The H3 report prepared for the McPhee Creek project provides detail on previous hydrogeological studies (AECOM, 2013 and SKM, 2014) and the most recent hydrogeological studies completed by GHD in 2020/2021 (GHD, 2021a). Recent hydrogeological studies completed by GHD included:

- Hydrogeological drilling of additional test production bores and testing pumping.
- Groundwater modelling to predict dewatering requirements mine closure impacts.
- Integrated groundwater surface water modelled to predict the impacts of the excess water disposal.

The outcomes of the recent water studies completed by GHD are summarised below:

- Hydrogeological investigations included the drilling of eight additional test production bores, with hydraulic testing completed for five bores that further confirmed that the Banded Iron Formation (BIF) sequences of the Paddy Market Formation that host the iron ore deposit form a highly permeable or transmissive unconfined aquifer system. Faulting and secondary faulting is interpreted to result in separate and discrete sub-basins in the southern area of the mine (Avon Pit).
- Packer testing of the Footwall Shale of the Paddy Market Formation and quartzites of the Corboy Formation confirmed lower permeability values in these formations. The aquifer is bounded laterally and at depth by these lower permeability lithologies.
- The aquifer is fresh, with a median TDS value of ~210 mg/L in the mine area. Regionally TDS values have been measured with a median value of ~ 700 mg/L.
- Groundwater recharge (from chloride balance estimates) has been estimated at between 4 and 11 mm per year (up to 3% of annual average rainfall).
- A groundwater model was developed and calibrated to available data and used to predict dewatering requirements for the proposed Avon, Murray, Ord and Nicholson Pits. Dewatering volumes of between 50 and 85 GL were estimated over the life of mine. Drawdown from dewatering was predicted to extend along the aquifer system (north east to south west). Low permeability formations surrounding the aquifer system are predicted to reduce the drawdown impact outside of the main aquifer system. Drawdown is not predicted to extend to pools or areas located downstream of the mine area.
- Predicted dewatering rates are estimated to be in excess of site water demands with the potential for a water deficit later in the mine life if water supply is sourced from dewatering only. An excess water disposal strategy was developed that included the discharge of excess water to three creek lines downstream of the mine area (McPhee Creek, a tributary of McPhee Creek and Lionel Creek). This strategy of using multiple creek lines was developed to restrict the formation of a wetting front associated with creek discharge downstream of discharge areas. Surface water pools have been identified along creek lines downstream of the mine area.
- Post mining, permanent pit lakes are predicted to develop in the Avon and Murray Pits, with a semi-permanent pit lake also predicted to develop in the Ord Pit. Pit lake levels are predicted to recover to an equilibrium level approximately 60 years after the cessation of mining. The equilibrium pit lake levels will be lower than pre-mining groundwater levels with

the Avon and Murray Pits developing into groundwater sinks (i.e., there will be no net outflow from these pit lakes and the pit lakes will be become progressively more saline).

- Drawdown from the pit lakes was predicted to continue to develop across the modelled catchment post mine closure due to the ongoing evaporation from the Avon and Murray Pit lakes.

5.2 Review

Overall, the H3 report (GHD, 2021a) provides a summary of the hydrogeological investigations to date. Our review of the H3 report is outlined below. Our review includes a review of the groundwater model against the modelling review checklist of the Australian Groundwater modelling guidelines (Barnett et al, 2012) and this checklist review is provided in Appendix A. In addition to general comments on the H3 report, some comments are made against the Groundwater modelling guidelines below.

- Some of the information presented in the H3 report is not easy to follow. For example, there is no clear location map showing the bores installed and tested as part of the recent and previous hydrogeological investigations and the figures related to the groundwater model (aquifer parameter zonations, depth to water and predicted drawdowns) are difficult to interpret on the scales presented.
- There is no clear summary of recent hydrogeological testing and comparison to the previous AECOM work.
- The most recent (updated) hydrogeological conceptualisation presented by GHD (2021c) is generally consistent with the conditions identified in earlier investigations (AECOM, 2013) and outlined in Section 5.1 (above). From the information presented the analyses are completed appropriately.
- The aquifer transmissivity values derived from the 2021 drilling and testing of additional bores are generally lower than those derived from the earlier 2013 investigations with the exception of a single bore drilled and tested south of the Murray Pit (bore MCP0152). This bore was tested at a very high rate, with a derived transmissivity up to 3 times higher than all of the other bores (12,000 m^2/d) in the area. We consider this single result anomalous rather than representative as all other aquifer transmissivity values derived from investigations to date were of the order of 500 to 4,000 m^2/d.
- There has been no specific hydrogeological testing (drilling of bores or collection of long term groundwater levels) in the creek areas, proposed for excess water disposal, downstream of the main aquifer areas (Lionel Creek, a branch of McPhee Creek and McPhee Creek).
- The H3 report describes the hydrogeological units represented in the numerical model and shows distributions of aquifer parameters by model layer. There is no description of the thicknesses assigned to model layers to allow an appreciation of the thickness of modelled aquifer units. As the groundwater model is based on the Atlas Iron Leapfrog model, it should include the best possible representation of (hydro)geological units (Appendix A Item 2.2.3).
- The groundwater model is calibrated to hydraulic parameters (aquifer hydraulic conductivity and confined and unconfined aquifer storage) that are at the upper to extreme / maximum end of the measured range (i.e., the model calibration appears to have placed emphasis on the results from bore MCP0152). This would mean that the modelling completed to date may over estimate total dewatering requirements and the extent of drawdown resulting from dewatering. These assumptions may however provide conservatism or an upper estimate (worst case) of the requirements for water reticulation and excess water disposal over the life of mine.
- From the information presented it appears that model parameterisation, as part of automated model calibration (Pilot Points) is only completed in the immediate mine area (Figure 9-6). Model calibration performance is presented for shallow monitoring bores located outside of the main aquifer areas outside of the immediate mine area as average transient residual (i.e., the average difference between measured and modelled water levels over the

calibration data set). In addition to this parameter zones are included for *bedr*, *reg* and *fault* in Table 9-3 (interpreted to be bedrock, regolith and faults). These locations are not shown in Figure 9-6. It is not entirely clear which water level measurements and zones / pilot point locations have been included in the model calibration.

- A water level calibration data is presented that includes three monitoring bores along Lionel Creek (Figure 9-13), however depth to water measurements (prior to mining) are presented for around 20 locations outside of the mine area (Figure 8-4). In particular, initial depth to water measurements are presented in the H3 report for around 10 locations to the south east of the mine area, in the area proposed for excess water disposal, which are not used as part of model calibration or predictions. It is not clear why these points have been omitted from the model calibration data set.
- The model calibration performance was assessed using the simulated match to pumping tests and longer term data. Measured drawdown responses (of less than 5 m) were simulated by the model. A reasonable match to water level magnitude was simulated over the longer term data set (2010 to 2020) despite this data set containing less than 10 data points over the period. Overall, however, the model predicts an increase in water level over the period 2010 to 2020. This is not correlated to long term rainfall or explained in the H3 report. The trend suggests that the model may in fact be filling up due to the balance between inflows (recharge) and outflows (evapotranspiration). The potential for this water level increase may be supported by the long term rainfall statistics presented (GHD, 2021) which suggest that total annual rainfall in the area has increased between 20 to 40 mm per decade since 1970. Water level monitoring data are not available to confirm an increase in water levels cross the catchment over the period 2010 to 2020.
- Model parameter sensitivity was identified as part of the model calibration. The process was used to suggest that assigned aquifer parameters were well informed or not, by the calibration process. Well informed parameters are interpreted to show less uncertainty than parameters that were not well informed. The results of the analysis suggested that:
    - Storage values and recharge are not well informed (subject to uncertainty).
    - Anisotropy (vertical and horizontal) is reasonably well informed (subject to less uncertainty).
    - Horizontal hydraulic conductivity is well informed (less uncertain).

  This assessment is understood to be based on the model calibration performance, using a data set that includes pumping tests (with a duration of 3 days and a measured drawdown of less than 10 m at pumping bores (which will also be complicated by well loss factors) and even less at regional monitoring bores) and an irregular longer term groundwater monitoring data set that extends from 2010 to 2020. It is not clear or discussed if these sensitivities will persist over a longer term calibration data set or over the duration of the model prediction and / or if other model parameters will become important.
- Dewatering was simulated using a "just in time" approach (using drainage boundary conditions), based on dewatering required from 2026 (when mining is expected to reach the pre-mining water table). This approach predicts dewatering rates driven only by the advance of mining rather than a longer term dewatering strategy (that may include advanced dewatering to meet water demands and remove dewatering peaks). Therefore, as reported, predicted dewatering rates that vary considerably over the life of mine.
- Dewatering was also simulated using a number of very high yielding bores that are assumed to be installed to depths of up to 300 m. This approach was designed to predict dewatering requirements over the life of the mine assuming a maximum dewatering early in mine life that declined over the life of mine (rather than the peak inflows using the "just in time" dewatering approach). Horizons of lower BIF, interpreted to extend to the southern side of the proposed pit area were targeted for dewatering bores (Murray Pit). In areas where this aquifer did not extend sufficiently beyond the pit crest to allow the installation of ex-pit dewatering bores, or the aquifer was compartmentalised or formed sub basins, then in-pit bores were proposed (mainly affecting the southern-most Avon pit). These in-pit bores were

also planned to be screened across the lower BIF and if present the intervening chert and overlying upper BIF.

Field investigations have confirmed relatively high transmissivity for the fractured BIF aquifer (notably extending beyond the mineralised zone) which is why ex-pit bores are likely to be successful over most of the deposit. Consequently, this dewatering strategy appears reasonable.

- Model predictions have assessed uncertainty associated with the dewatering approach (constraints around the "just in time" dewatering approach were assessed as well as the simulated period(s) of dewatering (end of entire mine life or end of mining at a particular pit location)). These uncertainties associated with the mining strategy, while valid, do not provide insight into the long term aquifer behaviour if aquifer conditions differ from those simulated.
- The model predicted dewatering requirements from the "just in time" dewatering approach were used to simulate the impacts of excess water disposal using the groundwater model. The predicted peak dewatering and resulting excess discharge requirements represent a worst case in terms of the capacity required to reticulate the water away from the mine area. However, these peak dewatering rates (which do not include any reduction for site water use) may in fact represent a best case in terms of the impacts of disposal (i.e., a lower rate of disposal over the long term may in fact have more impact on the creek systems as total infiltration rates will be different for a short term peak discharge and a lower longer term discharge to creeks). Excess disposal at a lower rate over a longer period has not been simulated using the groundwater model.
- Disposal of excess water that would result from the bore dewatering approach, was not simulated using the groundwater model. Modelling of the impacts of disposal to creeks resulting from bore dewatering was assessed as part of the Surface Water Assessment (GHD, 2021b).
- While some detail is provided on the set up and implementation of the stream flow routing package used to simulate excess water disposal and the predicted stream flows at locations along the simulated creeks, no detail is provided on the aquifer specific yield value adopted for the units underlying the simulated creeks. The modelled storage capacity of this material may be important for the simulation of the impacts of water disposal to creeks. Hydraulic conductivity values are quoted for the creek bed alluvium and the underlying unit as part of the description of the excess disposal, however, it is not clear from the information provided if the creek alluvium is modelled a separate aquifer unit or if these parameters are used to populate the Modflow USG Streamflow Routing package. Information presented in Table 9-3 suggests that the specific yield of the material underlying the modelled creek zones ranges from ~ 4% for regolith and up to ~9% for bedrock. Additionally, no model predicted water balances are provided to allow understanding of the behaviour of simulated creeks used for excess water discharge. The groundwater flow model input and output files provided did not include the simulation of excess water discharge to creek areas.
- Leakage rates out of the modelled creek zones, used for excess water disposal as simulated by the groundwater model, are not discussed in relation to the simulated leakage rates included in the Surface Water Modelling Assessment (GHD, 2021b).
- Predicted water levels shown over the life of mine and over the simulated post mining closure period show the reduction of water levels over the life of mine followed by water level rebound after the cessation of dewatering. Predicted pit void lake water levels are identified as being impacted by the rainfall contribution to pit voids. Two approaches were simulated, that assume that either 30% or 50% of catchment rainfall reports to the pit voids. This represents an estimate of catchment run off that is at the higher end of the range and may over predict the rate of refill of pit void lakes and the final pit void lake levels and provide a conservative (upper estimate) of the final pit void lake water level.
- Evaporation from pit void lakes is assigned at a rate of 2,655 mm per year (80% of long term pan evaporation), higher than the value of 1,600 mm per year assigned to shallow

water table areas. It is possible that these areas would be subject to different evaporative losses, however the reasons for the adoption of two different rates is not explained in the H3 report.

- No model predicted water balances are presented (for dewatering, disposal and mine closure scenarios). It may be implied that all dewatering is derived from aquifer storage and that any excess water disposal will result in an increase in aquifer storage. Of particular interest is how the model simulates the dissipation of creek disposal (i.e., the proportion of excess disposal that is evaporated and the proportion that results in a net increase in storage of the modelled creek system). It is not clear from the information provided how the creek systems respond to water disposal, apart from the model predicted increase in water level, or if the assigned boundary conditions (Evapotranspiration and Streamflow Packages) provide constraints on the results (Appendix A, Items 5.7.1 and 5.7.2).
- Model predictions were completed for a single set of aquifer parameters, despite aquifer parameter sensitivity identified as part of the calibration process (and presumably multiple calibration data sets were derived as part of the calibration process completed). Additionally, no simulations were completed to assess the impact of hydrogeological uncertainty. The aquifer parameters adopted, at the high end of the range for the aquifer area, means that the predicted dewatering is at the higher end of the potential range of dewatering requirements (i.e., a conservative approach to estimating dewatering requirements). The work to date has not assessed the impact on model predictions (dewatering and excess water disposal requirements and the extent of drawdown during operations or as part of mine closure) of a range of aquifer parameters or hydrogeological uncertainty. (Appendix A, Item 6).
- The overall confidence level of the model is stated as Class 2, with elements of Class 3 (Class 3 being the confidence level assigned to a complex simulator model). This description may overstate the predictive reliability or overall confidence in the model predictions. While there may be Class 3 criteria the modelling approach satisfies, the calibration performance to date, (to a data set with limited time series data and limited aquifer stressors) means that there is still significant uncertainty in the model predictions. Notwithstanding, the model and predictive confidence are consistent with similar projects at this level of project implementation.
- The groundwater model developed is suitable for the purpose of predicting dewatering requirements and the simulation of the impacts of dewatering, excess water disposal and the long term behaviour of final pit void lakes. The groundwater model set up and calibration is consistent with the amount of data available at this level of study.
- No assessment or model predictions have been completed on the potential for additional dewatering requirements due to re-circulation associated with the discharge or excess water to McPhee Creek and the McPhee Creek tributary. Additional dewatering due to re-circulation is considered unlikely due to the location of the proposed dewatering discharge (downstream of the mine area) and the nature of the main aquifer, which is bounded by lower permeability material. Based on the hydrogeological understanding, there is no requirement for these simulations to be completed as part of the current assessment.
- The predicted dewatering requirements are considered to be consistent with the hydrogeological conditions. The model has not been used to assess the requirements of detailed dewatering design (simulation of in pit and ex pit bores to facilitate optimised dewatering over the life of mine) that would support the design and implementation of the dewatering and reticulation infrastructure for the project. This kind of assessment is not required for project environmental approvals.
- Elevated groundwater levels are predicted a distance of between 5 and 18 km downstream of the proposed discharge points at the end of 2027 (the year when peak creek discharge is simulated). There is no discussion of the potential for elevated groundwater levels to persist under creek areas past 2027.

- Impacts of the development (groundwater drawdown and excess water disposal) are only discussed in terms of impacts of drawdown on potentially groundwater dependent vegetation or the impact of surface water on permanent pools. The potential risk for the proposed excess creek disposal to alter the amount of water available for vegetation in the creek vadose zones over the life of the mine and any potential impacts on the existing vegetation (for example the impact of elevated groundwater levels under the creek areas used for disposal and the potential for water logging tree-deaths, vegetation recruitment and system adaption to water levels that would not be sustained post mining) is addressed in parallel studies.
- The long term diversion of the catchment headwaters is included in mine closure scenarios. There is no discussion of the impacts of this strategy on the available water just downstream of the mine area.
- Management strategies are proposed for potential groundwater impacts (Table 10-3). Some of the strategies proposed may not be practical (for example limiting the location and timing of dewatering or the artificial supplementation of pool areas impacted by mining / dewatering). While these strategies may mitigate any impacts, the following is noted:
    - A change to the dewatering strategy (location and timing) may not be achievable once mining had commenced.
    - Artificial supplementation of pools / sensitive surface ecosystems would need careful management including the collection of adequate baseline data to achieve the required outcomes.

6. SURFACE WATER ASSESSMENT

6.1 Background

The Surface Water Assessment (GHD, 2021b) details the surface water assessment and conceptual management plan for the proposed McPhee Creek Iron Ore mine site. The McPhee Creek Surface Water Assessment was undertaken with the following stated purposes:

- Undertaking hydrologic and hydraulic modelling to identify and understand flow paths, flood extents, and flood risk.
- Identifying infrastructure to manage surface water risks.
- Assessing changes to catchment areas and resulting impacts on environmental flows and surface water volumes.

The assessment was based on modelling of 1% Annual Exceedance Probability (AEP) and 10% AEP flood events along with two environmental flow events. The flood events selected for modelling are consistent with industry approaches for flood modelling around (operational) mining projects.

The assessment used a hydrologic and hydraulic model to complete a Baseline assessment, then compared the Baseline hydraulic predictions to potential changes to the hydrological behaviour of the downstream environment from model scenarios that included catchment changes due to mine development (including excess water creek discharge), during operations and following mine closure. Predicted changes were quantified at key receptors (downstream seasonal surface water pools and major drainage lines).

The conclusions from the assessment were that changes to the hydrological regime from the proposed mine development would not significantly change the catchment areas for key creeks or downstream surface water pools.

6.2 Review

Our review of the approach and results presented in the Surface Water Assessment report is outlined below. The surface water models were provided with review of some of the model input files completed by AQ2. . Our review comments below are based on our interpretation of the report.

- The Water Management discussion in Section 2.7 mentions that other options for the management of surplus water are being considered other than creek discharge. Although it is understood that creek discharge is being assessed in this report as the only option that impacts surface flows, an overview of the other potential options, or a reference to other reports where these are assessed would provide useful context. The option of Managed Aquifer Recharge (MAR) is mentioned in the H3 report however it is not discussed in detail (Section 9.13.2).
- A comparison between the predictions from previous surface water modelling studies (2012 and 2013) showed flood level discrepancies ranging from between -6.8 m to +3.0 m due to updated terrain data used in the more recent model. These variations are extreme and potentially indicate that the 2012 model results should be discarded and entirely superseded, which should be noted in the 2013 model description presented as part of the recent study.
- The use of local rainfall data supplemented with SILO rainfall data has been used in water balance applications; however, it is not clear whether or how the SILO data were used in the Surface Water Assessment. Application to the water balance should be stated and would be subject to the review findings outlined below. If the SILO precipitation data were not used in the Surface Water Assessment, this should be stated with justification for exclusion, or alternatively the information should not be included in this report if it was not applied.
- Sections 4.5 and 4.6 do not clearly explain the existing environment. In Section 4.5, surface water pools identified in the area are described along with the uncertainty regarding their groundwater dependence. It is therefore not necessarily correct to describe them all as groundwater dependent ecosystems (GDEs) as is done in Section 4.5. Similarly in Section 4.6 mixed terminology is used to describe surface water vegetation and groundwater dependent vegetation (GDV). This leads to confusion throughout the report wherever GDEs and GDVs are mentioned and mapped.
- Section 6.2.1 refers to “1 Equivalent Year” which appears to be a typographic error that should have read “1 Exceedance per Year".
- Section 6.2.2 refers to results from the 5% AEP event. It is not clear if this should in fact be the 10% AEP event, as no results are presented for the 5% AEP event and Section 6.2.1 refers to the 10% AEP event being modelled.
- Section 7.1 outlines the modifications to the Baseline that would be simulated in the Operational model scenario. The Waste Rock Dumps have been removed from the catchment on the assumption that infiltration is promoted, and no runoff is generated. Although this is an acceptable and conservative assumption for modelling of potential maximum changes to downstream water availability, runoff will occur down the waste dump faces which has the potential to cause sedimentation downstream. Sediment control of this runoff should be stated as referenced in later sections. Similarly, Section 7.2.3 and 7.2.4 also assume promoted infiltration on the waste dumps.
- While the impact of reduced catchment areas on flow volumes to the downstream ponds has been assessed, the risk of increased sediment loads from erosion of upstream landforms, which have the potential to settle out in ponds and reduce the storage volume and longevity of the pools, is not considered.
- The distance that a wetting front from creek discharge may extend downstream from the proposed discharge points has been estimated using 2D surface water models. The models adopt assumed infiltration rates into the subsurface, with the extent of the wetting front the point at which the wetted surface area is sufficient to infiltrate the discharge rate. The inherent assumption in this assessment is that there is infinite storage within the underlying subsurface for the infiltration, which may not be realistic. The influence of this assumption on the results (i.e., potential under-estimation of the wetting front propagation distance) is not discussed.
- The surface water model of creek discharge simulates water depths that are less than 0.02 m deep (refer Section 7.4.2). The results rely on an assumed 5 m x 5 m model grid which may

not capture the low flow channel definition for this depth of flow, and therefore simulate a greater flow width (infiltration area) than there would be in practice. Simulated flow depths are likely to be deeper with a smaller grid spacing.

- The impact of dewatering discharge and catchment changes on seasonal flow conditions is discussed in Section 7.4.3. The key observations conclude that dewatering discharge acts as part compensation for loss of runoff due to catchment area reductions. In relation to total flow volume this may be case, but the timing and distribution of the flow is altered.
- The summary section (7.5) concludes that a reduction of catchment area of 10% is not anticipated to significantly impact flows beyond the variability experienced in these ephemeral creeks in pre-mining conditions. However, we note the following:
  - In some flow conditions where the ratio of pool storage volume relative to runoff volumes is highest, longevity of pools may be affected by the stated changes.
  - The fact that the changes to surface flows due to catchment loss are less than the variability in these creeks does not necessarily mean that it is acceptable. It means that the variable flows in the system will all be 10% lower (i.e., low flow conditions will be 10% lower).
- Section 8.2 refers to the collection of runoff from waste dump faces in toe drains and the direction of flow to sediment basins. Sediment ponds may require maintenance until monitoring indicates that vegetation has established sufficiently to reduce sediment loads to pre-mining levels; otherwise, there may be potential for siltation in pools. Reference should be made to the surface water management strategy in Section 10.1 and closure sediment control strategy 10.4.1.
- Pit surface management is described in Section 10.3.2. It is not clear from the report which strategy is proposed for adoption in the Project; the report only clarifies which strategy is assumed for the purpose of conservative impact modelling. For project environmental approvals, this approach appears reasonable, with the proposed surface water management to be documented within future submissions to regulators. Comments on this section include:
  - The report states that “pits are located at the top of the catchment and would receive storm water runoff from the upstream catchments”; this should be clarified that pits are “near” the top of catchments as some localised upstream catchment areas drain to pits; alternatively clarify that there are no significant external catchment areas draining to proposed pit locations.
  - The option to divert catchments around pits is stated as subject to the outcomes of the water balance modelling. The Water Balance Assessment did not outline the strategy for diversion of surface water catchments.
  - In Table 26 it is not clear what runoff coefficients for the external catchments are used. The adopted catchment run off percentage (or factor) of 100% across the pit footprint is considered excessive and therefore the simulated impact of external catchments on the total surface water inflow estimates to the pits will likely be a conservative over estimate.
  - The suggested management strategy of detention ponds upstream of the pits, fitted with a pumping system is unlikely to be practical.
- The Hydrological Modelling methodology is described in Appendix C. The reported flow depths of 0.02 m may warrant the use of increased effective roughness coefficients for flow in shallow conditions. Sensitivity analysis of this parameter is warranted.
- There are inconsistent statements in the report regarding groundwater dependent features. The hydrogeology section within Appendix E suggests that identified pools and heritage sites are predominantly surface water dependent “receptors” based on the depth to groundwater (i.e., where there is significant depth to groundwater, pools are unlikely to be groundwater fed). In the main body of the report, however, it is stated that it is unknown whether

groundwater or surface water dependent ecosystems exist. Consistent definitions and terminology should be used throughout the report.

- The conclusions of the creek wetting front modelling (Appendix E) are provided in Section 9. The wetting front modelling assumptions of unlimited groundwater capacity and steady discharge rate are important and should be clearly communicated in the conclusions.

7. REVIEW OF WATER BALANCE REPORT

7.1 Background

The Water Balance Report (GHD, 2021c) summarises the studies completed by GHD in 2020/2021 (GHD, 2021). The assessment quantifies the volume of water surplus/deficit over the life of the mine, plus how the mine voids are predicted to recover at the cessation of mining.

The outcomes of the assessment completed by GHD are summarised below:

- A lumped mass balance model (i.e., water balance model) was developed for the Project which considered rainfall, evaporation, catchment runoff, dewatering, ore crushing and dust suppression requirements, camp water use and off-site discharge.
- Model results predict the site to have a water surplus during most of the mine life. Surplus water will be required to be discharged off-site. Towards the end of mining, the dewatering rate and mine water demands are similar such that the site is predicted to be close to water neutral during dry years.
- There is uncertainty in the water demands for the project (dust suppression) and how this may influence the neutral water balance toward the end of the mine life. It is noted that any deficit from higher dust suppression demands at the end of the project could be met be operating some of the proposed dewatering bores (which are no longer required to be operated for dewatering purposes) as water supply bores.
- Separate water balances were run to cover the Operational and Closure scenarios. The Operational water balance covered the mine operations period, and the Closure model was run for a longer period covering the pit lake water level recovery.

7.2 Review

Our review of the approach and results presented in the Water Balance Assessment report is outlined below. Note that the GoldSim model itself was not provided for review.

- Some of the information presented in the report is not easy to follow. Our review comments below are based on our interpretation of the report text, in terms of what data was used in the model, the model logic and what the results indicate. In some instances, after reading other reports (such as the Surface Water Assessment report) key assumptions in the Water Balance Assessment report were better understood. In other instances, there appears to be different approaches presented in the different reports which are not consistent.
- The Water Balance Model as described covers the water captured in the Avon, Murray, Nicholson and Ord Pits (as per Table 3-1). It appears that outflow from the pits go to a Raw Water Demand with overflow to McPhee Creek from the Raw Water Dam. Nicholson Pit and Ord Pit also can discharge to sediment ponds.
- It appears that the Water Balance Model has used daily SILO rainfall data for a grid point co-ordinate within the Project area. Comments on this approach are summarised below:
  - o The SILO rainfall data set is extrapolated from nearby rainfall stations, which potentially has the advantage of filling in any missing rainfall data from a single station with nearby records and accounting for spatial climatic trends between the rainfall stations when interpolating rainfall depths. However, in the Pilbara, where rainfall is highly variable spatially and temporarily, there is a risk that the SILO generated dataset:

  - Has a higher number of rain days than a site would experience, as the dataset may include rainfall if any of the nearby rainfall stations records a rainfall depth.
  - Reduces the intensity of large daily rainfall depths. As there are often large differences in daily rainfall recorded across the gauge network the interpolated data set can reduce the peaks of extreme rainfall events.

  It was not possible to determine what the impact of the above potential risks may be on the water balance outcomes based on the results presented. Typically, we would base daily rainfall data sets on the nearest long-term rainfall station, rather than SILO rainfall to avoid the above potential issues, particularly in situations where extreme rainfall events are driving key conclusions in the water balance. Gaps in the data would be patched using SILO. In this case, the Nullagine rainfall station appears to be within 10 km of the Project. This station has a relatively complete data set from 1907 to 1996 (with incomplete data from 1984 to 1988 and 1997 to 2004).

- Annual rainfall data statistics were provided in the report from the SILO data set in the Water Balance Report. A comparison of these to the Nullagine data is provided below (SILO versus Nullagine):
  - Minimum Annual Rainfall Total: 27 mm versus 45 mm (both in 1924).
  - Median Rainfall: 320 mm versus 334 mm.
  - Average Rainfall: 341 mm versus 326 mm (1897 to 2004).

  Maximum Annual Rainfall: 892 mm (2000) versus 693 mm (1942), noting that the rain station at Nullagine was not operational in 2000 so may have missed this large rainfall event. This indicates that from an annual rainfall perspective, the SILO data adopted for the water balance model appears very similar to the Nullagine data. However, the daily SILO rainfall data used in the model should be checked to ensure that it is representative of site conditions (for example, compared against site Intensity Frequency Duration (IFD) data to confirm the expected number of large rainfall events occur in the data set).

- The Surface Water Assessment Report also uses SILO rainfall data and concludes that the average rainfall over the past 20 years is higher than the average rainfall over the past 45 years, which is in turn higher than the average rainfall over the full data set. The average rainfall over the past 20 years appears to be about 20% greater than the full record. Limitations in the Water Balance Model of using the full historic rainfall data set to predict surface inflows during operations and post closure are not discussed in this context.
- No mention of broader climate change predictions is made in the Water Balance Assessment Report. It is assumed that any impacts of climate change have not been considered. This should be noted as a limitation of the modelling completed.

- Water Demand – Overall, the assumed site water demands are not driving any of the environmental impact assessments completed, as the discharge assessment assumes that none of the dewatering produced is used on site. Sections 4.6 and 4.7 of the Water Balance Assessment appear to document the water demand assumptions used in the water balance. From Section 4.7 it appears that the assumed water demands are Crusher, Dust Suppression and Camp use. It is not clear how the data presented in Table 4-3 and the operational mean water use of about 75L/s in Figure 6-1 are related. In particular:
  - Table 4-3 presents water demand inputs with rates of kL/month, and then a unit demand rate of L/ROM. How the kL/month figures relate to the unit demand with a changing ore throughput (shown in Figure 4-6) is unclear. It is not clear which rates of water use are included in the Water Balance Model.
  - There is no discussion on any difference in water demand for Low Grade and High Grade ore, which is presented in Figure 4-6.

- Table 6-1 has an output of Ore Moisture Loss but does not have Crusher Water Use listed. It is unclear if these are the same parameter.
- Figure 6-1 shows a plot with the mean and 90% percentile operational demand from the water balance. There is no mention of uncertainty in the water demands being modelled within the text and therefore it is not clear what the mean and 90% percentile relate to.
- Variation in the mean water demand in Figure 6-1 does not seem to follow changes in the ore production schedule or the rate of processing from Figures 4-6 and 4-7.
- The dust suppression demand (assuming minimum demand of 1,772ML/yr) is the equivalent of about two 110kL capacity water carts being filled each hour on average across the year (as a minimum rate). This assumed dust suppression demand would appear to be reasonable, but the demand is unlikely to be significantly greater than this.
- There appears to be no seasonal variation in water demand considered in the water balance. Given the water balance is run taking into account the impact of seasonal rainfall, the impact of seasonal factors (particularly on dust suppression demand) should be considered, as it would likely mean that a higher rate of surplus water would be generated during the wet season compared with the dry season.
- The Camp water use per person appears appropriate, but there is no documentation included on the assumed size of the camp and the if the camp population changes with time.
- The model does not appear to cover the construction water demands, or any start-up (ramp-up) period.
- The Surface Water Assessment report (GHD, 2021c, Section 10.3) indicates that water collected within the pit would enter the process supply network and be managed through the mine water balance. It is not clear if the "treatment" is only for sediment or for pH. It is also not clear if the collected pit water is proposed to be discharged to the creeks as part of the "mine water balance". This strategy is not discussed in the water balance report, nor is if a large rainfall event were to occur, how long it would take the site water demand to consume the predicted runoff.
- The water demand does not appear to have been taken into account when assessing the dewatering discharge rates to the creek in other assessments (conservative assumption). Hence, uncertainty in the water demands is not impacting the other conservative assessments.

- Storage volumes – Stage versus storage curves for the Avon and Murray Pit were provided for these pits at closure, which look reasonable. It is assumed that these curves were used in the closure water balance to calculate water level recovery based on predicted water volumes at each time step (although not explicitly stated).
  - The Model Methodology section of the report includes a section on "Geometric Approximates" which provides an equation relating depth, area and volume. It is not clear what purpose this equation has in the model operation, the validity of this formula for a pit sump application and what parameter *"P"* is used for the pits.
  - There is some discrepancy in the strategy for management of collected water in pit within the Surface Water Assessment report (GHD, 021b). Section 10 of the Surface Water Assessment indicates that the pit floor sumps will be used to settle out the sediment. Section 10.2 and Figure A8 of the Surface Water Assessment indicates that the water collected on the pit floor will be pumped to a dedicated sediment treatment pond outside each pit prior to on-pumping for discharge to the creek. Figure 3-2 in the Water Balance Report shows a single pond for all pits. Any required detention design criteria for the collection sumps and treatment pond (i.e., detention time) is not explicitly stated, nor is the impact this may have on the ability to remove water from

the pit following a flood event. The details of this strategy can be presented in future submissions to the regulators.

- Evaporation Losses – The report outlines that SILO data was used to generate monthly graphs of evaporation and evapotranspiration. The report indicates that when different sequences of daily rainfall are used in the model, the matching daily evaporation data is also used. In particular:
  - It is not clear what (or if) the evapotranspiration data set that is presented in Figure 4-2 is used for within the model.
  - Any reduction to the evaporation loss due to water being in the pit voids is not discussed.
  - The ponds/water storages which evaporation loss calculations are applied to are not clear. It is assumed losses from pit ponds that form after rainfall events are captured in the model, but how the surface areas which evaporation is applied to are calculated is not presented. Given the same surface areas for "Direct Rainfall onto Storages" and "Evaporation" should be used, it is not clear how the Direct Rainfall onto Storages flux can exceed the Evaporation flux in the results presented in Table 6-1 given average monthly rainfall is likely to be about an order of magnitude less than average evaporation [potentially "Direct Rainfall onto Storages" is actually "Direct Rainfall across Pit Footprints"].
  - It is not clear from the report if the evaporation losses (quantified in Table 6-1 in the mine operational model) include the losses from pit sumps, storage ponds etc. Typically, the evaporative losses from site water storage ponds and pit collection sumps are relatively small compared with the throughflow through the ponds, such that evaporation is unlikely to be a significant component of the mine operation model.
- Groundwater dewatering inputs – These have been taken from the groundwater model. The report for the groundwater model is described elsewhere in this document, but comments related to a lack of uncertainty considered in the groundwater modelling are particularly important when considering the water balance, given groundwater is the largest input flux in the model. Therefore, any uncertainty in the required dewatering rates impacts the certainty of the water balance modelling results.
- Rainfall runoff – an AWBM component within the overall GoldSim water balance model is used to estimate runoff to the pit voids. External catchment areas to the pits that were assumed in the model were documented and have not been reviewed. Comments on the runoff estimation are as follows:
  - AWBM is not a commonly used tool in the Pilbara. It requires a number of parameters to be used, with limited data in the Pilbara to support the adoption of these parameters.
  - More frequently, a simple loss model (proportional loss, initial/continuing loss or initial/proportional loss) is adopted. Within the separate creek wetting front assessment report, an initial loss of 17.3 mm and continuing loss of 6.6 mm/hr were adopted to estimate runoff, which is stated in the report as being consistent with the loss values associated with a 20% AEP event assumed in other assessments (ARR 1998 guidance was for an initial loss of 40 mm and continuing loss of 5 mm/hr from the equivalent storm event). These alternate approaches require rainfall events with the equivalent size of a 50% AEP or larger to occur before any runoff would occur.
  - The average annual yield from the catchment is typically reported as a check that the runoff processes in models are sensible. This data is not presented in the report, so the appropriateness of the runoff generated from the AWBM model cannot be commented on within this review.
- Figure 6-2 provides a plot of the mean cumulative wet weather delays to mining due to runoff flooding of the pit. These appear too large to what would be expected from a typical Pilbara mining operation and would be unlikely to be acceptable to an operation. For example, the mean Murray Pit result is in the order of 180 days of delayed mining due to flooding over an

18-year period (10 days per year). Typically, in the Pilbara for runoff to impact on operations, a large storm event would be required (say in the order of 20% AEP [5yr ARI]). A mean year would expect little to on impacts to the pit. This may indicate the following:

  - o The AWBM runoff model estimates too much rainfall run off in the pits, too frequently. (This could also be related to the notes about daily SILO rainfall data noted above). Typically, where groundwater is being controlled by dewatering bores to lower the groundwater table in advance of mining, there are relatively large rainfall run off losses through the floor of the pit.
  - o Large external catchments around the pit are being captured. The feasibility of diverting these should be considered.
  - o The adopted sump capacity (30ML) and discharge rate (100L/s) is insufficient for the pit. Although it is noted that a stormwater pumping system with a capacity of 100L/s is a typical size for a stormwater pumping system.
  - o The data presented may be poorly explained. Possibly, Figure 6-2 is showing the number of days that water is contained within the pit sump, rather than the days that mining is impacted.

- The Surface Water Assessment report (Section 10.3) also indicates that the decision on diversion of external catchments around the pits would be subject to the outcomes of the water balance assessment. There is no discussion of this in the Water Balance Assessment report.
- Water quality – The GoldSim water balance model is linked to a water quality study, which looks at the potential for acidic water to be generated by the project. There is no linkage from the water quality report back to the water balance report. If acidic runoff or dewatering cannot be discharged to the creek, it should be balanced against the mine demand as there may be a risk of surplus acidic water at the site that cannot be managed.
- Model Runs - The water balance has been run on a Monte Carlo basis to produce statistical results. The only input which changes in each simulation is the climate sequence used (rainfall and evaporation). The model is run for 17-year periods for the mine operational model and for 159-year periods for the post-closure model.
  - o The same climate data set is used, which is 131 years in length spanning from 1889 to 2020. The starting date of the climate sequence that is sampled changes for each model realisation to allow 131 model realisations to be run. If a model realisation reaches the end of the climate data set, it loops back to the beginning of the data set.
  - o The limitation of the above approach is that the same climate sequences are represented across multiple model realisations. For example, each wet season in the climate record is represented in 17 of the operational model realisations, and at least once and potentially twice in each of the post-closure model realisations (albeit in different model years).
  - o Separate synthetic climate sequences may provide a better representation of the climate related uncertainty in the system by accounting for different sequences of rainfall.
- Mine Operation Results are presented in Figure 6-1 and Figure 6-2, with an annual average water balance provided in Table 6-1 for selected years.
  - o Figure 6-1 – when viewed in conjunction with Table 6-1, it is not clear what the data presented in the figure is showing. In particular, it is not clear what mechanism in the model is causing a statistical distribution of results related to the Total Operational Demand (as discussed above).
  - o Pit Availability – as discussed above, the results presented on the potential pit availability for mining due to flooding appears to predict a higher impact of pit flooding on operations than would be expected.

- The Water Balance Assessment does not provide any results on what the range of potential discharge requirements to the creek are when the water demand and surface water management are considered. Without this assessment, it is not clear what the purpose of the Operational Water Balance was.

- Mine Closure Results are presented in Figures 6-3 (Mean Annual Fluxes) and 6-4 (Water Levels).
  - The mean annual water level flux results predict that groundwater and surface water each provide a similar contribution to the inflows to the pit. Once at steady state (about 2070), evaporation losses equal the inflows from groundwater and surface water. Evaporative losses are about an order of magnitude higher compared to Direct Rainfall inputs, as expected. Given the plots show mean annual values across the model iterations, and the realisations cycle through the same climate series it is surprising that there is noticeable variability in catchment runoff values across the model.
  - The groundwater inflow peaks around 2070 and then the inflow appears to decline from that point towards the end of the model period. The Avon Pit water levels are predicted to increase until 2070 and then decline (likely because the groundwater inflow is predicted to decline). Although this could conceivably occur, this behaviour would be unusual in modelling of pit lake recovery. The trend is not highlighted or explained in the model. Murray Pit water levels are not predicted to decline and take a longer period of time to reach steady state.
  - Only the median and $10^{th}/90^{th}$ percentile water level results for pit void lakes are presented. Given the same climate sequence is cycled through all of the model realisations, there would be value in presenting the results from all realisations to show how individual extreme rainfall events and wet periods impact the long-term water levels.
  - As discussed above, the Surface Water Assessment indicates that the SILO rainfall data has a distinct trend of increasing annual rainfall. The average annual rainfall over the last 20 years is noticeably higher than preceding periods. The data from this period only represents 15% of the data record. Given the same rainfall sequences are cycled through each model realisation, the 90^{th} percentile water level is likely to be a closer representation to the pit water levels as a result of recent rainfall results, rather than the median, which will be heavily skewed by the drier conditions in the first half of the data set. In this respect, the result presented is misleading, as the 90^{th} percentile result should not be considered as the water level where there is only a 10% chance of exceedance.
  - The long-term predicted pit water levels are not compared with pit crest levels to discuss the risk of pits overtopping from large rainfall events. For example, what is the freeboard to the pit crest if a PMP event occurred. This may be because of the large amount of free board predicted (long term pit lake water levels are more than 50 m below pre mining water level or ~100 m below the original ground surface).
- No sensitivity or uncertainty model runs are completed on other parameters in the model.
- Limitations of the modelling approach are not documented.

8. SUMMARY

8.1 H3 Report

The hydrogeological conceptualisation for McPhee Creek presented in the H3 report is consistent with previous studies and the results of the most recent testing. The groundwater model for McPhee Creek satisfies the requirements of the Australian groundwater modelling guidelines (industry guiding principles). The groundwater model set up and calibration is consistent with the amount of data available at this level of study and the groundwater model is suitable for hydrogeological impact assessment.

The groundwater model is fit for the purpose of predicting dewatering requirements and the simulation of the regional groundwater impacts of dewatering, excess water disposal and the long term behaviour of final pit void lakes and supporting the project environmental approvals.

A single set of aquifer parameters, that likely represents the upper end of the potential range, has been used to complete predictions of dewatering and to assess excess water disposal requirements. Modelling to date may have predicted dewatering requirements at the upper end of the potential range (a conservative approach). The use of the peak excess water disposal rate may have under estimated the impacts of excess water disposal on creek discharge areas as one large peak discharge may result in less infiltration than a sustained longer term creek discharge at a lower rate.

The model calibration is reasonable given the amount of data available and consistent with a project at this level of development. The length and spatial distribution of the water levels included in the calibration data set and the magnitude of the aquifer stresses compared to the length of time and stresses included in model predictions mean that there is still uncertainty associated with long term model predictions (i.e., over the life of mine and over the mine closure period).

Model uncertainty is associated with the model parameterisation (aquifer parameters assigned to the calibrated model), and with the hydrogeological conceptual model that under pins the groundwater model. Dewatering, and hence disposal requirements may be even greater than simulated, or persist over longer periods than simulated (i.e., as long term high rates of disposal as opposed short peak disposal rates). If the site dewatering and disposal strategies are able to operate without exceeding capacities and licenced limits or triggers this risk may be less significant. Additionally, the hydrogeological and hydrological conditions in the proposed excess water disposal area, along Lionel Creek, McPhee Creek and a branch of McPhee Creek have not been the subject of detail investigations.

Analysis has not been completed as part of predictive modelling to address the uncertainties in model parameterisation and the hydrogeological conceptual model. Additionally, limited analysis of model predicted water budgets was presented to allow review of the groundwater model simulation of the impacts of excess water disposal to creeks.

The completion of future groundwater modelling exercises, which includes the data associated with operational dewatering will be a useful way to quantify model reliability. Operational data (dewatering volumes and the measured groundwater response to dewatering and the response of the creek system to excess dewatering discharge) will provide data to allow assessment of the current hydrogeological conceptualisation and the associated model set up (i.e., the assignment of aquifer parameters and the implementation of the hydrogeological conceptualisation). Model re-calibration may be required to simulate the observed groundwater responses however this process will provide more confidence in future long term model predictions.

8.2 Surface Water Assessment

In general, the flood modelling techniques adopted appear to have been conducted in accordance with current industry standards. The report could benefit from additional disclosures regarding the sensitivity to the adopted assumptions and modelling parameters as well as the extreme uncertainty surrounding those parameters.

The following general points are also made:

- The report focusses on the environmental impact of catchment reduction and creek discharges. The detail on the proposed surface water management strategy/philosophy for the project is limited. In particular, where flood protection, creek diversions etc. are required across the proposed operation.
- The explanations of groundwater dependent ecosystems and groundwater dependent vegetation are unclear. In addition, there is conflicting information presented regarding the potential ground or surface water dependence of these features.

- The assumption that there is unlimited ability for infiltration of creek discharge into the creek subsurface means that the modelling may underpredict creek discharge wetting front extents. Further, the 2D flow model grid resolution is likely to overestimate the creek flow area over which this infinite infiltration is applied. The simulated creek discharge rates are conservatively high given that:
  - They adopt a constant discharge rate (based on the peak dewatering rate).
  - Mine water use is not accounted for when determining the surplus water that is required to be discharged to the creek (i.e., excess water creek discharge estimates are higher than would be expected).
  - The wetting front modelling assumptions of unlimited groundwater capacity and steady discharge rate are important and should be clearly communicated in the conclusions.

Based on the above, it is recommended that the wetting front assessment is refined including a more realistic set of assumptions.

8.3 Water Balance Modelling

- The presentation of input data, description of the model operation and presentation and discussion of model results are difficult to follow and not comprehensive, such that this review is unable to provide confidence in the appropriateness of the water balance completed to address site water management issues.
- The Water Balance Assessment does not appear to have been used by the Surface Water Assessment or the Creek Discharge Assessment, such that any issues with the water balance assessment do not appear to have impacts on these assessments.
- If water demands are considered in the rate of water discharge to the creek, seasonality of these demands should be taken into account.
- We have not reviewed the Pit Water Quality Assessment; however, it is understood that this assessment relied on the Water Balance Assessment results. The potential implications of issues with the Water Balance Assessment on the Water Quality Assessment have not been assessed; however, it is noted that only the climate inputs to the model that are independently quantified in the Water Balance. The groundwater inputs of the Water Balance Assessment are directly taken from the Groundwater Modelling Assessment. Groundwater and surface water inflows to the pits appear to be similar orders of magnitude.
- Based on the data presented, there remain some questions in the water balance with respect to:
  - Runoff simulation using AWBM.
  - Climate sequences used to generate stochastic results; in particular cycling the same climate sequence through the models and the appropriateness of using old climate data which appears significantly drier than more recent climate data.
- The impact of runoff on delays to mining in the assessment appears to be high.
- The Water Balance Assessment does not assist with understanding the water management requirements for site. In particular, it is not clear if runoff collected within the pits is proposed to be discharged with the pit dewatering through the creek discharge systems or if it is all to be contained and consumed. Additionally, it is not clear if external catchments should be diverted around the open cut pits or not.
- No sensitivity on model input parameters has been completed.
- The potential for pits to overtop to the downstream environment has not been discussed. Although it is understood that there is a large freeboard between the recovered pit water level and the pit crest, such that overtopping is unlikely to occur, there is no definitive statement in the report regarding this.

- To provide greater confidence in the dust suppression use on site, the report also contains a recommendation that:

  "Comprehensive record keeping of the number, frequency and volume of dust suppression, and the area it is applied to is maintained during the early part of the mine operations. All meters, including those fitted to standpipes, should be fitted and linked to a telemetry system. Water carts should manually record meter readings at start and stop of each fill up. Further individual water carts should be designated to serve specific areas of the mine. Records once the site moves to extreme water excess are unlikely to be a reliable indicator of the minimum dust suppression requirement that may be required during the latter part of the mine life."

The extensive collection of data over and above the collection of flow meter records at standpipes seems an onerous recommendation that adds little value to the project and is unlikely to be implemented on site.

8.4 Overall Comments

As part of the Peer Review, each of the three reports were reviewed by a different AQ2 team member. As review outcomes were discussed with the team it became clear that in some areas there was limited integration across the reports and that some pieces of information would have provided context for other reports. Data sources and model outputs were not consistently referenced between the reports. For example:

- The flow rates considered for creek discharge assessments did not account for the predicted site surplus water from the water balance assessment, which is considered a conservative approach. The creek discharge assessment used the predicted peak dewatering rate.
- The Water Balance assessment was used as an input to the Pit Water Quality assessment. However, any findings from the water quality assessment did not trigger any further discussion within the Water Balance Assessment on the requirement to contain water within the pit post-closure.
- The Water Balance Assessment findings of impacts to mining due to pit flooding did not appear to feed back to the Surface Water Assessment to investigate the feasibility of diverting upstream catchments around pit voids.
- Different approaches to catchment yields were used in each of the assessments.

9. REFERENCES

AECOM, 2013. McPhee Creek Iron Ore Project Phase 2 Groundwater Investigation.

Atlas, 2021. Water Management Plan McPhee Creek Iron Ore Project. 30/11/2021. 124-EN-PLN-0007 V [1].

GHD, 2021a. Roy Hill McPhee Creek Iron Ore Project Water Management Studies H3 Groundwater Report. Report prepared for Roy Hill Pty Ltd. October 2021.

GHD, 2021b. Roy Hill Iron Ore Pty Ltd McPhee Creek PFS WMS Update Surface Water Assessment. Report prepared for Roy Hill Pty Ltd. October 2011.

GHD, 2021c Roy Hill Iron Ore Pty Ltd McPhee Creek Iron Ore Project – Water Management Studies Water Balance Assessment. Report prepared for Roy Hill Pty Ltd October 2021.

Sinclair Knight Merz, 2013. McPhee Creek Regional Groundwater Model. Model Report and Appendices. Atlas Contract Number C-OPR-0052. Report prepared for Atlas Iron.

Sinclair Knight Merz, 2014. McPhee Groundwater Model. Groundwater Model Update. Document number SOW 124-DEV-HY-SOW-0023. Report prepared for Atlas Iron.

Regards

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Attached:
Appendix A: Model Checklist

Author: KLR / MAN (04/02/22)
Checked: DGS (27/01/22)
Reviewed: DGS (27/01/22)

APPENDIX A

MODEL CHECKLIST

Appendix A

Table A1: Review checklist (after Table 9-2 of Australian Groundwater Modelling Guidelines)

Review Questions	*Yes/No/NA[1]/U[2]/C[3]*	*Comment*
1. Planning		
1.1 Are the project objectives stated?	Yes	
1.2 Are the model objectives stated?	Yes	
1.3 Is it clear how the model will contribute to meeting the project objectives?	Yes	
1.4 Is a groundwater model the best option to address the project and model objectives?	Yes	
1.5 Is the target model confidence-level classification stated and justified?	Yes	The model confidence level may be overstated.
1.6 Are the planned limitations and exclusions of the model stated?	Yes	
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Yes	The current and previous studies are not well integrated.
2.2 Is the aquifer system adequately described?	Yes	The details and descriptions are not always clear and there is no clear link back to previous work.
2.2.1 Hydrostratigraphy including aquifer type (porous, fractured rock...)	Yes	
2.2.2 Lateral extent, boundaries and significant internal features such as faults and regional folds	Yes	
2.2.3 Aquifer geometry including layer elevations and thicknesses	No	Detail not provided in report.
2.2.4 Confined or unconfined flow and the variation of these conditions in space and time?	Yes	
2.3 Have data on groundwater stresses been collected and analysed?		
2.3.1 Recharge from rainfall, irrigation, floods, lakes	Yes	
2.3.2 River or lake stage heights	NA	
2.3.3 Groundwater usage (pumping, returns etc)	Yes	Pumping tests.
2.3.4 Evapotranspiration	Yes	
2.3.5 Other?	NA	
2.4 Have groundwater level observations been collected and analysed?		
2.4.1 Selection of representative bore hydrographs	Yes	
2.4.2 Comparison of hydrographs	Yes	
2.4.3 Effect of stresses on hydrographs	Yes	
2.4.4 Watertable maps/piezometric surfaces?	Yes	Some pre-development water levels are presented but not all are used for the model calibration.

[1]Not applicable
[2] Unknown
[3] Comment

Review Questions	***Yes/No/NA[1]/U[2]/C[3]***	***Comment***
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	NA	
2.5 Have flow observations been collected and analysed?		
2.5.1 Baseflow in rivers	NA	
2.5.2 Discharge in springs	No	Pools are described but they are not simulated by the model.
2.5.3 Location of diffuse discharge areas?	NA	
2.6 Is the measurement error or data uncertainty reported?		
2.6.1 Measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	NA	
2.6.2 Spatial variability/heterogeneity of parameters	Yes	
2.6.3 Interpolation algorithm(s) and uncertainty of gridded data?	NA	
2.7 Have consistent data units and geometric datum been used?	Yes	
2.8 Is there a clear description of the conceptual model?		
2.8.1 Is there a graphical representation of the conceptual model?	Yes	Model derived and graphics not always clear.
2.8.2 Is the conceptual model based on all available, relevant data?	Yes	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Yes	
2.9.1 Are the relevant processes identified?	Yes	
2.9.2 Is justification provided for omission or simplification of processes?	Yes	
2.10 Have alternative conceptual models been investigated?	No	
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Yes	
3.2 Is the choice of numerical method and software appropriate (Table 4-2)?	Yes	
3.2.1 Are the numerical and discretisation methods appropriate?	Yes	
3.2.2 Is the software reputable?	Yes	
3.2.3 Is the software included in the archive or are references to the software provided?	Yes	
3.3 Are the spatial domain and discretisation appropriate?		
3.3.1 1D/2D/3D	Yes	
3.3.2 lateral extent	Yes	
3.3.3 Layer geometry?	Unknown	Aquifer geometry not described with limited detail provided in associated figures.
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Yes	
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	Unknown	Data not provided in report.
3.4 Are the temporal domain and discretisation appropriate?		
3.4.1 Steady state or transient	Yes	
3.4.2 Stress periods	Yes	

Review Questions	*Yes/No/NA[1]/U[2]/C[3]*	*Comment*
3.4.3 Time steps?	Unknown	Detail on time stepping not provided.
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?		
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Unknown	It is unclear if the evapotranspiration and stream cells constrain the disposal predictions.
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Unknown	Refer to comment on boundary conditions (3.5.1).
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Yes	
3.5.4 Are boundaries time-invariant?	No	Stream boundaries are added to some predictions to simulate excess water disposal however there is not enough detail to understand if they are time variant.
3.6 Are the initial conditions appropriate?		
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	C	Based on a steady state calibration.
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	NA	
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	
3.7 Is the numerical solution of the model adequate?		
3.7.1 Solution method/solver	Yes	
3.7.2 Convergence criteria	Yes	
3.7.3 Numerical precision	Yes	
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	Yes	
4.1.1 Groundwater head data	Yes	Mostly but some measured water levels outside of the mine area have not been used for water level calibration.
4.1.2 Flux observations	No	None available.
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	NA	
4.2 Does the calibration methodology conform to best practice?		
4.2.1 Parameterisation	Yes	
4.2.2 Objective function	Yes	
4.2.3 Identifiability of parameters	No	Some zones and associated parameter are not discussed outside of the mine area (bed rock and regolith).
4.2.4 Which methodology is used for model calibration?	Yes	
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 Parameters	Yes	
4.3.2 Boundary conditions	No	
4.3.3 Initial conditions	No	

Review Questions	*Yes/No/NA[1]/U[2]/C[3]*	*Comment*
4.3.4 Stresses	NA	
4.4 Have the calibration results been adequately reported?		
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Yes	
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Yes	Not required.
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Yes	
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?		
4.5.1 Spatially	Yes	
4.5.2 Temporally	Yes	
4.6 Are the calibrated parameters plausible?	C	Model calibrated to higher end of parameter range.
4.7 Are the water volumes and fluxes in the water balance realistic?	U	No water balances assessed or presented to allow assessment.
4.8 Has the model been verified?	No	Verification assumed to be via use of additional data not used during model calibration.
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Yes	
5.2 Is predictive uncertainty acknowledged and addressed?	No	No alternate parameter or parameter combinations or conceptual hydrogeology investigated.
5.3 Are the assumed climatic stresses appropriate?	Yes	
5.4 Is a null scenario defined?	No	Not required.
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Yes	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	No	Pumping stresses and durations are much larger than those included in model calibration.
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	No	
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	No	
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Yes	
5.6 Do the prediction results meet the stated objectives?	Yes	
5.7 Are the components of the predicted mass balance realistic?		
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	U	No predicted water balances are predicted, however, a reduction in predicted pumping rates would be expected in a dewatering scenario.

Review Questions	*Yes/No/NA[1]/U[2]/C[3]*	*Comment*
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	U	No water balance information presented for assessment.
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?	U	No water balance information presented for assessment.
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Yes	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	U	Data not available for assessment.
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	NA	Not required.
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	No	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	No	
6.3 Are the sources of uncertainty discussed?		
6.3.1 Measurement of uncertainty of observations and parameters	No	
6.3.2 Structural or model uncertainty	No	No parameter or hydrogeological uncertainty discussed apart from model calibration.
6.4 Is the approach to estimation of uncertainty described and appropriate?	No	
6.5 Are there useful depictions of uncertainty?	No	
7. Solute transport		
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?	NA	
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	NA	
7.3 Is the choice of numerical method and software appropriate?	NA	
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	NA	
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	NA	
7.6 Are the solver and its parameters appropriate for the problem under consideration?	NA	
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?	NA	
7.8 Has an assessment been made of the need to consider variable density conditions?	NA	
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	NA	
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	NA	
7.11 Is the calibration based on meaningful metrics?	NA	
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	NA	

Review Questions	***Yes/No/NA[1]/U[2]/C[3]***	***Comment***
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	NA	
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	NA	
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?	NA	
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Yes	
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Yes	
8.3 Is the groundwater model coupled with a surface water model?	Yes	Details not described in report.
8.3.1 Is the adopted approach appropriate?	U	Data not presented to allow comparison.
8.3.2 Have appropriate time steps and stress periods been adopted?	Yes	
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	U	Data not presented to allow comparison.