Stantec

Client Ref: OP-SOW-00870

13 March 2020

Roy Hill Iron Ore Pty Ltd
5 Whitham Road
Perth Airport WA 6105
AUSTRALIA

Attention: **Bobak Willis-Jones**
Superintendent Hydrogeology

Dear Bobak

Re: Peer Review for Roy Hill Life of Mine Groundwater Change Assessment

Introduction

Roy Hill Iron Ore (RHIO) commissioned Stantec to undertake a peer review of the Roy Hill Life of Mine Groundwater Change Assessment (GHD, 2019) undertaken by GHD and reported in January 2019.

Dewatering and process water supply activities commenced at the Roy Hill mine around mid-2015 with managed aquifer recharge (MAR) commencing in November 2018. Knowledge gained from operational-scale activities and further technical works has led to revision of the dewatering, water supply and surplus water disposal plan, and re-assessment of associated groundwater changes. Substantial changes include increased dewatering rates and adoption of managed aquifer recharge as a surplus water disposal strategy. These changes result in a larger footprint of predicted groundwater change and potential environmental impacts. The Environmental Protection Authority (EPA) has specified that the changes warrant re-assessment via a public environmental review (PER).

Stantec understand that the Roy Hill Life of Mine Groundwater Change Assessment document is one component of the various documents prepared in support of the re-assessment and PER process.

This letter report documents Stantec's review of the GHD (2019) report.

Scope of Work

The scope of work was "..*to undertake a technical review of the revised groundwater change assessment and related groundwater management approach GHD (2019) and related documentation*".. (document list provided by RHIO).

The consultant should reference relevant guidelines including but not limited to the Australian groundwater modelling guidelines in performing the review.

The consultant review should address the following:

- *Conformance of the groundwater change assessment methodology with guidelines and industry standards and recommendations for further technical work(s); and*
- *Recommendations for operational management practices to be considered in development of a groundwater management plan.*

Given the brownfields nature of the project, in addition to review of the primary technical document the consultant should allow for discussion with the Principal representative to discover additional information and works relevant to the assessment in ensure available information is adequately considered.

Reviewed Documents

Documents reviewed for the current study were:

- GHD, 2019: Roy Hill Life of Mine Water Management Strategy – Groundwater Change Assessment. Report 61/37437 prepared for Roy Hill Holdings Pty Ltd.
- Managed Recharge, 2018: Roy Hill Remote MAR Project – Phase 1. Report 7-0/18-001 prepared for Roy Hill Iron Ore.
- Ministerial Statement 824.
- Ministerial Statement 829.
- MWH, 2009a: Roy Hill Stage 1 Dewatering and Water Supply Strategy. Report A1046100 prepared for Hancock Prospecting Pty Ltd, dated 30 April 2009.
- MWH, 2009b: Roy Hill Remote Borefield, Preliminary Modelling of Impacts of Abstraction (draft). Report prepared for HPPL, dated September 2009.
- MWH, 2009c: Roy Hill Stage 2 Dewatering Strategy. Prepared for Hancock Prospecting Pty Ltd, dated September 2009.
- MWH, 2009d: Hydrogeological Assessment of the Roy Hill Remote Borefield. Prepared for Hancock Prospecting Pty Ltd, dated November 2009.
- Roy Hill, 2019: 2019 LOMP – Groundwater Modelling Report (Draft).

Relevant Guidelines

Australian groundwater modelling guidelines were used as a basis for reviewing the GHD (2019) numerical groundwater model. The reference for the guideline is:

- Barnett et. al., 2012: *Australian groundwater modelling guidelines*, Waterlines report, National Water Commission, Canberra.

The groundwater modelling guidelines provide detailed information on best practice modelling protocols and procedures, but recognise that all models differ in terms of scale, complexity, method and purpose. The guidelines provide a proforma review checklist designed to prompt the reviewer to consider all aspects of the model in question. However, the detail to which checklist items are addressed is a function of the complexity of the model and its intended purpose, so with a simple model, often not all topic line items are addressed. The completed review checklist for the current study is provided in Attachment A.

A literature search undertaken to identify any guidelines for “groundwater change assessments” was unsuccessful. In the absence of specific, formalised guidelines on groundwater change assessment, a standard industry approach was adopted where required, consistent with any assessment of groundwater impacts due to mining operations (abstraction for dewatering and water supply, and re-injection for excess water disposal or storage).

REPORT REVIEW - Roy Hill Life of Mine Water Management Strategy – Groundwater Change Assessment (GHD, 2019)

The report format does not formally comply with the recommended Australian groundwater modelling guidelines (Barnett et. al., 2012).

The introductory chapter provides the background for the revision of the original Roy Hill Water Management Strategy (RHWMS) (which Stantec has not seen), with the updated Life of Mine (LoM) mining strategy incorporating more dewatering and the adoption of MAR in the RHWMS as the principal excess water disposal strategy.

GHD were requested to carry out an update to the groundwater change assessment of the revised LoM RHWMS and that the objective of the project was to assess groundwater change for the revised LoM RHWMS, with a suitable regional conceptual model needing to be developed and a numerical model constructed for quantitative analysis of groundwater response.

The chapter would benefit from providing details of the environmental performance constraints or threshold criteria for the performance of dewatering and injection operations. Towards the end of the report, a performance constraint of no mounding within 5 metres of the ground surface is stated as being a performance criteria proposed in Willis-Jones (2018), and agreed amongst unspecified parties.

The second chapter in GHD's report describes the RHWMS update and presents a number of operating condition water balances, including the LOM peak operating condition (225 ML/day abstraction) which forms the basis of the subsequent modelling effort to assess likely groundwater level impacts of dewatering and injection to the various disposal options.

The third chapter contains an extensive summary of known hydrogeological information leading into the conceptual model, model development, calibration and predictive modelling. Details of the model are discussed in the next section.

The presentation of the model output (water level change figures, hydrographs) is difficult to analyse due to the small scale of the images. Key vegetation classes and areas of environmental concern could be indicated on the plans to allow rapid assessment of the implications for the environment of the model-generated drawdown/mounding . Additionally and ideally, a figure showing the finite difference grid should be included in the report, although this may require an A3 figure, and key regulatory threshold boundaries such as the 2-m drawdown at 20 years (refer to Ministerial Statements 824 and 829) should be displayed on the plans.

The fourth chapter provides a brief summary of the management approach for the RHWMS and the philosophy behind it, while the Conclusions (fifth) chapter provides the basis for the confidence level for the Class 2 regional model and identifies the preliminary nature of the model being subject to future updates but being satisfactory for the current purpose. The model indicates the proposed MAR areas are suitable to manage surplus water and reiterates the RHWMS planning approach.

MODEL REVIEW

Conceptualisation

The presented hydrogeological conceptualisation is consistent with available information, noting the sparse spatial information on hydraulic properties and geological detail away from the mining area. It is based upon a number of previous models (finite element and finite difference) and incorporates hydrogeological observations acquired from operational experience.

The presence of faults within the Fortescue Valley is recognised as possibly being significant to groundwater flow processes, but that no specific information is available on the character of the faults or their local influence on water table configurations. At this stage, adding such structural elements to the model is not possible and at the coarse discretisation of the model, may not add value – a matter for future evaluation once the model is fully validated.

Available groundwater hydrographs indicate overall water table configuration is insensitive to individual recharge events.

The are no useable surface water flow records to allow considered evaluation of groundwater / surface water interaction, and it is noted that the depth to groundwater is in excess of 20 m in a large proportion of the model domain, such that interaction between the of groundwater and surface water is unlikely in these areas.

A simple groundwater volumetric water balance is presented for the "prevailing conditions" i.e. no contributions of water in response to rainfall events. The water balance assumes all groundwater contributions to the Marsh are removed by evaporation. Rainfall events significant enough to generate substantial surface water flow and flood the Marsh are estimated to occur once in every five years although actual records are not available, with ponding in the Marsh facilitated by the presence of relatively low permeability and silcrete/calcrete hardpans. There is some conceptual confusion indicated as to whether ponded water in the Marsh actually recharges the shallow groundwater system, but it is likely that it does provided those systems are not fully saturated.

Overall the conceptualisation is considered reasonable for the purposes of the model.

Model Design and Construction

The model was constructed in MODFLOW-NWT. The model domain appears sufficiently large enough to avoid boundary effects in the areas of interest, although this should be checked if all areas of environmental concern are displayed within the model domain.

The model consists of 360 rows, 296 columns and 15 layers, and contains 1,109,685 active cells. Uniform element spacing was applied, with element dimensions of 250 m by 250 m.

Boundary Conditions

Boundary conditions are discussed briefly in the text and appear reasonable, however boundary conditions on the model domain periphery are not clearly indicated for the lay person. Specified flux boundaries are reported to be used although it is not specifically stated where. Figure 3-22 poorly shows, due to the scale of the image, 3 mm/year recharge rates applied along the eastern model boundary and possibly along the western boundary, although the Assessment Domain boundary (model domain extent) obscures easy identification of the nature of these boundaries. The boundaries should be explicitly identified and annotated on a plan.

Recharge is only active in parts of the model area and is assumed to be zero in the footprint of the Marsh. Whilst understanding the reasoning for this assumption, it should be demonstrated how sensitive the model is to this assumption, particularly in the areas of environmental concern.

Dewatering in the transient calibration was implemented at locations of existing dewatering bores using actual measured rates for 2014 to 2018 applied on a monthly basis using the WEL package in MODFLOW. Injection was active in 6 locations towards the end of the calibration run.

Calibration

The model hydraulic parameters were based on previous models, so the calibration process in the new model code to some extent validates previous model parameters. While specific model zones (lithologies) differ from the previous models, their properties are very similar and the only real difference is that previous work reported parameter ranges whereas current model zones were given bulk parameters.

Variation in climatic factors (seasonality, large rainfall events etc.) during the evaluated period did not have influence on the observed groundwater levels, according to available hydrographs.

The steady state water table configuration (Figure 3-30) is difficult to compare with the water table configuration on the same figure (presumably pre-mining but not stated – sourced from Simonic et. al., 2015) (Figure 3-7). Individual data points should be displayed on the figure. The steady state calibration groundwater balance (recharge versus evapotranspiration), although erroneously reported in Section 3.5.4, does balance, but this is not surprising given evapotranspiration greatly exceeds recharge.

The transient calibration period includes the start of dewatering and injection operations, and supplied hydrographs show reasonable transient responses, taking into account the coarse discretisation within the model.

The calibration approach and results are considered reasonable for the presumed purpose of the model. Calibration statistics quoted are:

Statistical Measure	Steady State Calibration	Transient Calibration
Residual Mean	0.26 m	0.22 m
Residual Mean Square Error	1.58 m	1.62 m
Scaled Residual Mean Square Error	2.1 %	2.1 %

Sensitivity Analysis

Sensitivity simulations were reportedly monitored during manual calibration (Section 3.5.3) but outcomes are not individually reported. Some notable points identified by GHD are:

- Disparity between RHIO recent models - 20% more-extensive mineralised Marra Mamba Fm (or its hydraulic equivalent) on slopes of the Chichester Range compared to Leapfrog model mapped extents, but effect partly mitigated by introducing a higher permeability zone in the MODFLOW model west of the Zulu area (Christmas Creek Fm?), although the degree of sensitivity is not portrayed.

- Sensitivity simulations of flooded Marsh and flowing Fortescue River scenarios (imposing general head boundaries) did not introduce significant changes to groundwater flow patterns and directions, being limited to the immediate perimeters of the features. These boundaries were subsequently removed from further modelling.
- Water levels in Fortescue Valley are more sensitive (comparison point not provided but presumably the previous bullet point) to hydraulic parameters of alluvial/detrital deposits.
- Better calibration results when hydraulic conductivity of the Fortescue Marsh area (parameter zone 5) was increased. This has previously been considered low hydraulic conductivity hardpan. However, no hydraulic testing has been undertaken on this material to date.
- Recharge rates were not extensively modified during calibration except a zone of higher recharge for outflow areas from the Hamersley Range, and similarly for the alluvial fan of Christmas Creek.

Formal documentation of sensitivity simulations is required and it is recommended that a sensitivity analysis is undertaken on the assumption of no recharge on the Marsh footprint.

Validation

Validation examples are referred to in the text as being presented in Appendix C however the actual Appendix C provides model cross sections. The validation hydrographs appear to be lumped into Appendix E which shows 19 validation points on the Calibration Target Locations figure, but the corresponding hydrographs are not specifically identified amongst the 83 hydrographs presented.

The model should be formally validated using operational data.

Predictive Simulations

Dewatering for predictive simulations was modelled using the MNW2 multi-node well package, following the mining plan for Bravo and Zulu mining areas. The pumping rates applied to MNW2 were from predictive results from RHIO’s FEFLOW model. Summary pumping rates were compiled and aggregated from the FEFLOW model for individual MODFLOW model cells set up as dummy dewatering wells. Injection wells were assigned excess water for disposal.

Six scenarios were simulated for the period from September 2018 to March 2031, with dewatering rates constant and surplus water disposal being moved around the various disposal options (SWIB, Mine Pit Area, RMAR North, RMAR South.

Spatial analysis of the model outputs have been addressed by others, in the context of environmental considerations or regulatory impact constraints, such as ‘no impacts outside of the 20-years, 2 m drawdown boundary’ specified in the Ministerial Statements 824 and 829. Hydrographs for the scenarios modelled have been reviewed against the highest groundwater level constraint of not coming within 5 m of the surface.

Conclusions

The model appears to have been developed according to reasonable standards and procedures for a Class 2 model suitable for coarse examination of regional extents of impacts due to operational dewatering and aquifer re-injection, subject to a formally-documented sensitivity analysis and successful validation using operational site data.

The report documenting the development of the model and explaining its purpose, is suitable for submission to stakeholders.

I trust this letter meets with your immediate requirements, however please contact me if you have any questions.

Yours sincerely

David Thomson

David Thomson
Principal Hydrogeologist, Stantec

Attached: Roy Hill Model Review Checklist

Australian Groundwater Modelling Guidelines - Review Checklist

Review questions	Yes/No	Comments
1. Planning		
1.1 Are the project objectives stated?	Y	Assess groundwater change for the revised LoM RHWMS (more the overarching objective) due to expanded footprint of operations. The report focuses on assessment of groundwater change relating to the dewatering task and surplus water disposal tasks in the RHWMS.
1.2 Are the model objectives stated?	Y	Regional numerical model for quantitative analysis of groundwater response, updating hydrogeological conceptualisation, development of the numerical model, modelling of RHWMS and prediction of water level change.
1.3 Is it clear how the model will contribute to meeting the project objectives?	Y	
1.4 Is a groundwater model the best option to address the project and model objectives?	Y	
1.5 Is the target model confidence-level classification stated and justified?	Y	Class 2, data gaps identified (scattered geological information, heterogeniouty of properties, 30m DTM, lack of surface water flow data generally and unable to directly investigate groundwater and surface water interaction. Regional scale of model emphasised.
1.6 Are the planned limitations and exclusions of the model stated?	N	Not specifically, some asumptions are provided relating to conceptualisation.
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Y	Substantial review of hydrogeological setting
2.2 Is the aquifer system adequately described?	Y	
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Y	
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Y	Faults recognised as an un-evaluated factor but not incorporated into model due lack of any data or information. Signifcance of brines beneath and on perifry of the Marsh, but not modelled specifically.
2.2.3 aquifer geometry including layer elevations and thicknesses	Y	Digital elevation model 1 second (30 m), layers from Leapfrog geological model
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Y	
2.3 Have data on groundwater stresses been collected and analysed?		
2.3.1 recharge from rainfall, irrigation, floods, lakes	Y	Mean annual rainfall and evaporation considered representative for the modelled period
2.3.2 river or lake stage heights	N	Marsh level around 400 m AHD, or slightly below in places
2.3.3 groundwater usage (pumping, returns etc)	Y	
2.3.4 evapotranspiration	Y	
2.3.5 other?		
2.4 Have groundwater level observations been collected and analysed?		83 hydrographs but most data sparse (period 2014 to 2018). Discusses earlier significant recharge events (2011 and 2012 but not shown on hydrographs)
2.4.1 selection of representative bore hydrographs	Y	83 hydrographs but most data sparse (period 2014 to 2018). Discusses earlier significant recharge events (2011 and 2012 but not shown on hydrographs)
2.4.2 comparison of hydrographs	Y	not in detail
2.4.3 effect of stresses on hydrographs	Y	Hydrographs provided (Appendix E). Dewatering and injection, otherwise essentially steady state.
2.4.4 watertable maps/piezometric surfaces?	Y	
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	N	Barometric effects not discussed. Density driven flow not included but explicetly discussed as relevent to the Marsh area only.
2.5 Have flow observations been collected and analysed?		
2.5.1 baseflow in rivers	n/a	No data available
2.5.2 discharge in springs	n/a	Yintas are semi-permanent ponds fed by catchment inflows, but possibly expressions of groundwater table, but not in model.
2.5.3 location of diffuse discharge areas?	Y	
2.6 Is the measurement error or data uncertainty reported?		Data uncertainty discussed
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N	
2.6.2 spatial variability/heterogeneity of parameters	Y	
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N	Not specified for pre-mining water table.
2.7 Have consistent data units and geometric datum been used?	Y	
2.8 Is there a clear description of the conceptual model?	Y	
2.8.1 Is there a graphical representation of the conceptual model?	Y	
2.8.2 Is the conceptual model based on all available, relevant data?	Y	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Y	
2.9.1 Are the relevant processes identified?	Y	
2.9.2 Is justification provided for omission or simplification of processes?	Y	
2.10 Have alternative conceptual models been investigated?	N	Alternative conceptualisation not discussed
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Y	
3.2 Is the choice of numerical method and software appropriate (Table 4-2)?	Y	
3.2.1 Are the numerical and discretisation methods appropriate?	Y	Uniform cells (250 m x 250 m)
3.2.2 Is the software reputable?	Y	
3.2.3 Is the software included in the archive or are references to the software provided?	n/a	no aware of archive status
3.3 Are the spatial domain and discretisation appropriate?	Y	
3.3.1 1D/2D/3D	Y	3D
3.3.2 lateral extent	Y	4,624 km^2
3.3.3 layer geometry?	Y	From Leapfrog geological model

3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Y	Zones not defined specifically in text but included in properties table and layer maps.
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?	Y	Aquitard single layer appropriate for regional model.
3.4 Are the temporal domain and discretisation appropriate?	Y	monthly transient stress period between 2014 and 2018
3.4.1 steady state or transient	Y	both
3.4.2 stress periods	Y	monthly transient stress period between 2014 and 2018
3.4.3 time steps?	Y	monthly
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Y	Requires better presentation of boundary conditions
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Y	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Y	Appropriately distal from areas of interest
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Y/N	Predominantly excluded from marsh footprint, sensitivity required.
3.5.4 Are lateral boundaries time-invariant?	N	
3.6 Are the initial conditions appropriate?	Y	
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?		Not clear but likely interpolation
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	Y	
Review questions		
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	n/a	
3.7 Is the numerical solution of the model adequate?	Y	
3.7.1 Solution method/solver		not specified - MODFLOW-NWT
3.7.2 Convergence criteria	n/a	not specified
3.7.3 Numerical precision	Y	
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	Y	
4.1.1 Groundwater head data	Y	
4.1.2 Flux observations	N	no data
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	N	no data
4.2 Does the calibration methodology conform to best practice?		suitable for regional nature of model and ultimate objective
4.2.1 Parameterisation	Y	
4.2.2 Objective function	Y	
4.2.3 Identifiability of parameters	U	
4.2.4 Which methodology is used for model calibration?		Manual (trial and error)
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 parameters	N	
4.3.2 boundary conditions	N	
4.3.3 initial conditions	N	
4.3.4 stresses	N	
4.4 Have the calibration results been adequately reported?	Y	
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Y	
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Y	
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Y	
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	N	
4.5.2 temporally	Y	
4.6 Are the calibrated parameters plausible?	Y	
4.7 Are the water volumes and fluxes in the water balance realistic?	Y	
4.8 has the model been verified?	Y	Reportedly so but documentation not seen.
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Y	
5.2 Is predictive uncertainty acknowledged and addressed?	Y	
5.3 Are the assumed climatic stresses appropriate?	Y/N	Rainfall removed from marsh, otherwise steady state climate.
5.4 Is a null scenario defined?	U	
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Y	Class 2 model expectations/confidence levels.
Review questions		
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?	Y	
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	U	
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?	U	
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	U	
5.6 Do the prediction results meet the stated objectives?	Y	
5.7 Are the components of the predicted mass balance realistic?	Y	
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	U	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	n/a	
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	

5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Y	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	U	
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	U	out of scope
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	N	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	N	
6.3 Are the sources of uncertainty discussed?	Y	
6.3.1 measurement of uncertainty of observations and parameters	N	
6.3.2 structural or model uncertainty	N	
6.4 Is the approach to estimation of uncertainty described and appropriate?	Y	
6.5 Are there useful depictions of uncertainty?	N	
7. Solute transport		
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?	n/a	
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	n/a	
7.3 Is the choice of numerical method and software appropriate?	n/a	
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	n/a	
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	n/a	
7.6 Are the solver and its parameters appropriate for the problem under consideration?	n/a	
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?	n/a	
7.8 Has an assessment been made of the need to consider variable density conditions?	n/a	
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	n/a	
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	n/a	
7.11 Is the calibration based on meaningful metrics?	n/a	
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	n/a	
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	n/a	
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	n/a	
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?	n/a	
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Y	
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Y	
8.3 Is the groundwater model coupled with a surface water model?	N	
8.3.1 Is the adopted approach appropriate?	Y	
8.3.2 Have appropriate time steps and stress periods been adopted?	Y	
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	n/a	

Notes: U = unknown, n/a = not applicable.

08 April 2020

Bobak Willis-Jones
Superintendent Hydrogeology
Roy Hill Iron Ore Pty Ltd
5 Witham Rd
Perth Airport WA 6105

Our ref: 61 37347

Your ref:

Dear Bobak

Life of Mine Groundwater Change Assessment
Response to Third Party Review

Roy Life of Mine Water Management Strategy – Groundwater Change Assessment (the Report) was prepared for Roy Hill Iron Ore Mine Pty Ltd (RHIO) in January 2019, as part of RHIO's commitment to the EPA for public environmental review (PER) process. This assessment included an update of a regional-scale groundwater flow model which was then used for groundwater impact assessment of mine dewatering and reinjection of excess water into several MAR schemes.

Stantec were commissioned by RHIO to conduct a peer review of the Report in a letter to RHIO dated 13 March 2020 which concluded that the "report documenting the development of the model and explaining its purpose is suitable for submission to stakeholders".

The review also pointed out some areas for clarification which are summarised with addressing response from GHD in the table attached to this letter.

We trust that our response duly addresses the reviewer's comments and consequently we do not envisage changes to the reviewed report. To help characterising and reducing uncertainty in predictive modelling results provided in the report we are evaluating, in collaboration with yourselves, application of a PEST-based sensitivity analysis with linear approach to the key model parameters. This work would inform refinement of the on-going data collection and monitoring program(s).

Kind regards,
GHD Pty Ltd

Milo Simonic
Technical Director Hydrogeology
08 6222 8642

Attachment: Table of responses to peer review comments

Table 1 Response to peer review comments

Item	Review section	Comment	GHD response
1	Conceptualisation	There is some conceptual confusion indicated as to whether ponded water in the Marsh actually recharges the shallow groundwater system, but it is likely that it does provided those systems are not fully saturated.	Recharge mechanisms are discussed in the report and while it is acknowledged that short-term duration high-intensity flooding following the cyclonic events supplements groundwater recharge (e.g. Section 3.3.1, or Groundwater recharge p.43), this is infrequent and shortlived (e.g. Figure 3.21), subsequently removed by evaporation and evapotranspiration. Quantification of recharge volume attributable to a 1:1000 year flooding event is also provided in the last two paragraphs of Section 3.3.
2	Boundary Conditions	Boundary conditions on the model domain periphery are not clearly indicated for the lay person. […] The boundaries should be explicitly identified and annotated on a plan.	All boundaries on the periphery of the model are no flow. No other boundary conditions along the model domain boundary are used in the current model.
3	Boundary Conditions	Recharge is only active in parts of the model area and is assumed to be zero in the footprint of the Marsh. Whilst understanding the reasoning for this assumption, it should be demonstrated how sensitive the model is to this assumption, particularly in the areas of environmental concern	During calibration various conceptual approaches were used: prescribed recharge in the marsh footprint; constant head, general head boundary. Due to episodic occurrence of ponding in the marsh at low frequency the average or prevailing condition in this area is no recharge. That said the discussion of cyclonic events was deemed important to be brought in the conceptualisation. However the recharge input from these events is not likely to influence groundwater flows during the life of mine. The reviewer acknowledged that monitoring data suggest that "groundwater level configuration is insensitive to individual recharge events".
4	Calibration	The steady state water table configuration (Figure	Water levels (dashed lines referred to as conceptual model level) were adopted

Item	Review section	Comment	GHD response
		3-30) is difficult to compare with the water table configuration on the same figure. […] Individual datapoints should be displayed on the figure	from MWH (2015) (not all individual measurement points used in that study are available). These are presented against the computed steady state water levels (full lines) obtained from the numerical model.
5	Calibration	The steady state calibration groundwater balance (recharge versus evapotranspiration), although erroneously reported in Section 3.5.4	Duly noted and acknowledged; the values for conceptual and computed recharge are incorrectly swapped in the paragraph above Table 3-6 when compared with values in Table 3.6 (p. 81).
6	Sensitivity analysis	Sensitivity simulations were reportedly monitored during manual calibration (Section 3.5.3) but outcomes are not individually reported. Formal documentation of sensitivity simulations is required and it is recommended that a sensitivity analysis is undertaken on the assumption of no recharge on the Marsh footprint	The reported model builds on and is considered to be in continuity with previously developed models for the same area with previously reported values. It also uses learnings from the RHIO dewatering model developed in Feflow, therefore sensitivity was discussed in qualitative terms in Section 3.5.3. The second bullet point in this section as well as second paragraph in Section 3.5.5 both make references to testing of inundation applied to Fortescue Marsh and the lack of its response to inundation to monitoring bore hydrographs in the Fortescue Valley.
7	Validation	The model should be formally validated using operational data	The model was operationally validated in that the actual dewatering rates were applied to dewatered pits during calibration and these exerted observed drawdown effects.
8	Checklist 1.6	Are the planned limitations and exclusions of the model stated? Not specifically, some asumptions are provided relating to conceptualisation	Limitations of the model predictions are discussed in the Conclusion section (Section 5), paragraphs 2 to 5 and the reasoning is provided for Class 2 assignment to this model.
9	Checklist 2.4.5	Density driven flow	The aquifer system underneath and near the Fortescue Marsh exhibit groundwater with high salinity and potential density driven flow effects. Due to its distance from the Fortescue Marsh the mining

Item	Review section	Comment	GHD response
			impacts predominantly occur in areas with relatively low salinity where density effects are not important. The majority of hydrographs are from monitoring bores situated in brackish or fresh groundwater. Water level correction in bores with saline groundwater would represent values which would be relatively minor compared to the overall range of water levels. While saline groundwater forms relatively a small part of the model domain it is acknowledged that detailed studies at a local rather than regional scale of the marsh or near marsh processes would benefit from incorporation of density driven flow.
10	Checklist 2.6.1	Measurement error for directly measured quantities	Data were provided by RHIO, no undue errors were assumed for the water level and abstraction rate data. It is understodd that RHIO personnel generally quality checks the data for internal reporting.
11	Checklist 2.10	Alternative conceptualisation	Alternative conceptualisations were examined with respect to representing groundwater surface interaction associated with the Fortescue Marsh and Forescue River and these are discussed in the report in several places. The current model otherwise builds on a succession of previous models (e.g. MWH, 2009[1], MWH, 2010[2], MWH, 2015[3], RHIO, 2018[4]), which were found to be representative of hydrological conditions within and around the mine footprint.
12	Checklist 6.5	Uncertainty (structural and parametric)	Uncertainty analysis has not been systematically applied in this instance of model development. PEST-facilitated

[1] MWH, 2009: Roy Hill Remote Borefield, preliminary modelling of impacts of abstraction. Unpublished technical report prepared for Roy Hill Iron Ore.

[2] MWH, 2010: Roy Hill Iron Ore Mining Project – Bankable Feasibility Study. Mine site water supply, hydrology and dewatering. Unpublished technical report prepared for Roy Hill Iron Ore

[3] MWH, 2015: Roy Hill Iron Ore Mine Dewatering Update. Unpublished report for Roy Hill Iron Ore

[4] Roy Hill Iron Ore, 2018: Hydrogeological assessment for Roy Hill managed aquifer recharge system report. Roy Hill report OP-REP-00510

Item	Review section	Comment	GHD response
			sensitivity/uncertainty analysis is currently being considered.
13	Conceptualisation	There is some conceptual confusion indicated as to whether ponded water in the Marsh actually recharges the shallow groundwater system, but it is likely that it does provided those systems are not fully saturated	Recharge mechanisms are discussed in the report and while it is acknowledged that short-term duration high-intensity flooding following the cyclonic events supplements groundwater recharge (e.g. Section 3.3.1, or Groundwater recharge p.43), this is infrequent and shortlived (e.g. Figure 3.21), subsequently removed by evaporation and evapotranspiration. Quantification of recharge volume attributable to a 1:1000 year flooding event is also provided in the last two paragraphs of Section 3.3.