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Review of RTIO Surplus Water Discharge Model

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1. Introduction

This document presents the SKM review of Rio Tinto Iron Ore's (RTIO's) surplus water discharge model. The model has been applied by RTIO for the baseline assessment for Marillana Creek discharge. Based on the scope of work emailed to SKM from RTIO (Annie Featherstone pers.comm. 7/9/10), SKM's proposal dated 14/9/10 and subsequent inception meeting with RTIO on 28/9/10, the purpose of the review is to:

- Provide an overall assessment of the appropriateness of the surplus water discharge model to address concerns in relation to the discharge of water arising from dewatering operations to natural water courses;
- Provide an assessment of the appropriateness of the assumptions on which the model is based; and
- Recommend any refinements that are warranted to enhance the applicability of the model. These recommendations are to be considered in terms of the expected cost/timing of the changes versus the likely outcome/benefit.

SKM has also provided comments where there was potential uncertainty in the interpretation of the information provided by RTIO for the purposes of this review.

1.1. Background context

Hamersley Iron Pty Ltd (Hamersley) is proposing to develop new iron ore mines at the Junction South West (JSW) and Oxbow deposits at Yandicoogina. Hamersley is a fully owned subsidiary of RTIO and already operates mines at the nearby Junction Central (JC) and Junction South East (JSE) deposits. New mines at JSW and Oxbow will enable continuity of production from the overall Yandicoogina operation.

The majority of the Yandicoogina deposits are below the ambient water table and hence the project will require additional dewatering for lowering the water table to enable mining of the new ore deposits (JSW & Oxbow).

Discharge of surplus water from the BHPBIO Yandicoogina mine operation into Marillana Creek began in May 1991. In 1998 RTIO started releasing surplus water into Marillana Creek. Release of surplus water directly into Weeli Wolli Creek began in 2007 with expansion of the JSE mine and development of the Hope Downs 1 operation, located approximately 20 km up gradient of Yandicoogina.

The combined discharges of the various mining projects in the catchment have resulted in continuous stream flow and potential saturated creek bed conditions in the downstream sections of the Marillana and Weeli Wolli Creek systems. Since 2008 the surface water discharge footprint, defined as extent of surface water expression, extends to up to about 8 km below the confluence of the Marillana and Weeli Wolli creeks. The surface wetting front is understood to fluctuate over a distance of several kilometres depending on climatic conditions and surplus water discharge rates.

The subsequent JSW & Oxbow project will contribute disposal volumes of up to 16 GL per year year, with an annual mean of about 10 GL per year over the project life, additional to the volumes discharged from the combined BHPBIO Yandi, Hamersley Yandi and Hope Downs 1 projects into the Marillana and Weeli Wolli creek systems. The cumulative impact of the project was assessed using analytical modelling techniques. The existing discharge footprint from all Yandicoogina operations with an annual average maximum peak discharge of 25 GL per year extends up to 2.5 km beyond the confluence of Marillana Creek and Weeli Wolli creeks. This is predicted to extend up to 13 km from the confluence if existing projects collectively increase their dewatering rates to currently licensed limits.

RTIO surface water modelling has indicated that the project could result in the overall discharge footprint extending up to a further 4 km along the lower reaches of Weeli Wolli Creek (i.e. a total distance of 17 km from the confluence).

2. Material Provided by RTIO for Review

The material provided by RTIO for the review consisted of the following:

- A technical report RTIO (2010) *Baseline hydrology assessment for Marillana Creek discharge*, dated 4 May 2010. This is the principal document for review and contains information about the model's intended purpose, formulation and application to Marillana Creek discharges.
- A copy of the Yandi discharge model Excel spreadsheet, which contains the calculations behind the information presented in Appendix B of the baseline hydrology assessment.
- A technical report RTIO (2009) *Hamersley HMS, Hope Downs 1, Water Management Plan*. This document was used to improve the reviewer's understanding of regional water management issues, but the content was not critically reviewed.
- The Iron Environmental Management System Procedure for RTIO's Water Monitoring.

RTIO modellers were available to contact during the review.

3. Appropriateness of the Surplus Water Discharge Model

Whilst conditions will vary from site to site, the modelling approach taken in RTIO (2010) is considered by SKM to be appropriate for estimating the footprint length and surface water expression arising from discharge of water to local creeks in the Pilbara region. The approach involves undertaking two water balances – the first is on the stream bounded by the atmosphere and the stream bed (to work out the surface water expression), whilst the second is on the stream and surrounding alluvial aquifer, bounded by the atmosphere and the bedrock (to work out the discharge footprint). The water balance equations rely upon a thoughtful consideration of the conditions along the rivers.

The use of Manning's equation to estimate wetted perimeter, top width, velocity and water depth is considered appropriate by SKM and is a standard technique to estimate change in water level and water surface area associated with changes in discharge.

The model operates under steady state conditions. This approach is considered appropriate by SKM for broadly estimating the discharge footprint length. In practice the extent of the discharge footprint will vary according to RTIO's discharge rates, as well as a number of factors beyond RTIO's control, such as climate variability. In the case of Marillana Creek this includes BHPBIO's discharge rate as stated throughout the report (e.g. Section 8.1). The steady state model is considered flexible enough to model alternative discharge conditions and can incorporate alternative input climate data if desired.

The development of a time series model which dynamically responds to seasonal and inter-annual climate variability and changes in operational conditions would be an alternative approach to using a steady state model. Time series models are regularly applied in the modelling of stream hydrology. The main advantage of this alternative approach would be improved understanding of the responsiveness of the receiving waters to changes in discharge or climate over time. If the discharge footprint at a particular site is likely to migrate up and down the river over time and knowledge about this migration is needed to assess potential impacts on the river, then a time series model would be more suitable than a steady state model. This would particularly be the case if (i) seasonal or intermittent wetting of downstream areas is ecologically acceptable, (ii) steady state modelling indicates that the discharge footprint is approaching the desirable limit, and (iii) either discharge volumes or stream losses vary seasonally. However the information requirements for such a model are considerably greater than a steady state model, and could not reliably be constructed or calibrated without historical knowledge of water level and sub-surface moisture upstream and along the receiving waters for a period of several years post-discharge. Such information is not widely available across the Pilbara, is not available prior to completing a predischarge environmental effects statement, and the level of effort required to obtain it is high relative to the minor and uncertain benefits of this alternative approach relative to the current approach. SKM nevertheless recommends it as an alternative approach if improved understanding of movement of the discharge footprint is needed for a particular location.

The appropriateness of any model is best validated using measured observations. Prior to discharges occurring at a site, the model cannot be validated. After discharges have occurred, observing the surface water extent of the discharge footprint will provide a broad indication of the accuracy of the model, as RTIO (2010) has done for the Marillana Creek. For estimation of the sub-surface discharge footprint, tensiometers can be used for shallow alluvial systems and a well can be drilled for deeper alluvial systems, however any such measurement techniques can also be invasive and potentially damage the stream bed. A less invasive approach in the longer term is to observe vegetation change in response to discharge. This can either be undertaken using aerial photography and field survey, or by using a remote sensing technique (e.g. SEBAL) to measure changes in riparian vegetation evapotranspiration prior to and after commencement of the discharges. The model form developed by RTIO is unlikely to require modification after validation in most circumstances. This validation data could however definitely be used to better inform the values for input data and data transposition factors.

Over- parameterisation or under-parameterisation is a common problem in hydrologic models. The model developed by RTIO is not considered by SKM to contain redundant parameters. To further investigate whether a more sophisticated model formulation is required, RTIO could undertake a sensitivity analysis, which would indicate which components of the water balance most heavily influence the magnitude of the estimated discharge footprint. This would then inform whether more sophisticated modelling of each particular aspect of the water balance is warranted. In the case of the Marillana Creek model, in Appendix B of RTIO (2010) for Reach 1, it would appear that the evaporative loss for the reach under Scenario 1 is 0.004 m^3/s, the infiltration is 0.1 m^3/s, the ET loss is 0.006 m^3/s and the recharge (i.e. past the root zone) is 0.04 m^3/s. This implies that the driver for discharging water to the environment in this reach for this scenario is infiltration and subsequent recharge to deeper aquifers and that the loss via evaporation and evapotranspiration is small in comparison. This highlights that any further modification of the model for application at this site is likely to be best served by focussing on the groundwater and surface water interaction terms rather than being overly concerned about refining the representation of evaporation and evapotranspiration.

4. Appropriateness of the Model Assumptions

The model as developed assumes that there are no point source discharges along the reach of the river other than the discharge from mine operations. In the case of Marillana Creek, RTIO (2010) confirms that there is only one spring in the area and that spring is not located on Marillana Creek. The model will be appropriate to apply in its current form in this situation. If this model were to be applied to other areas where springs are located, then careful consideration would need to be given to the hydraulic properties of the spring and how it might interact with the discharged water. The modelling approach taken will depend on how large the spring is and whether there are any natural geological features which influence the movement of water from upstream.

In the model presented in RTIO (2010), no pan factor for evaporation was applied to the input pan evaporation data. RTIO have since advised that this aspect of the model has been revised, and they are now using point potential evapotranspiration data from the Bureau of Meteorology. SKM acknowledges the inherent uncertainty in estimating actual evaporation, even when at-site measurements are taken. Given the open landscape without dense vegetation, point potential evaporation data is considered appropriate to use in this model.

The input on the riparian vegetation width is well explained and referenced to the field observations.

The evapotranspiration (ET) rates adopted by RTIO (2010) draw on the local measurements by Peck et al. (1997) and have been adjusted to account for vegetation types outside of Peck's observations. This approach of making use of the best available local literature to estimate evapotranspiration is considered appropriate.

The use of Manning's roughness coefficients from the United States Geological Survey is considered appropriate and the reach delineation is sufficient to distinguish between different channel geomorphology and riparian vegetation widths.

Recharge rate and surface infiltration rate are likely to vary considerably in the field between reaches and from the published values, however this uncertainty cannot readily be reduced. The use of published literature to estimate recharge and infiltration rates is considered appropriate prior to the commencement of discharges. After discharges have commenced, recharge and surface infiltration rates can be confirmed through calibration of the model to observed data, as discussed previously in Section 3.

5. Conclusions and Recommendations

SKM reviewed RTIO's model that is being used to estimate the discharge footprint associated with mine water discharges in the Pilbara region. Conditions at different locations will vary and may require minor adjustment of model formulation or assumptions, however in general SKM concludes from this analysis that the surplus water discharge model formulation is fit for purpose and the model inputs are appropriately derived. In some local circumstances, alternative model formulations may be required, such as the use of a time series model or more detailed modelling of groundwater and surface water interactions. For this reason, RTIO should assess the conditions at each site rather than automatically applying this model, particularly where conditions vary from those modelled in the example model provided at Marillana Creek.

No hydrologic model formulation can be entirely validated without comparison with field observations. The intent of this surplus water discharge model is for use in estimating discharge footprint prior to the commencement of discharges. SKM concludes that the model is appropriate for this purpose, however we also recommend that the model formulation and assumptions should be verified using field observations post-discharge, where possible. This would provide a greater degree of confidence in the application of the model at new sites and for ongoing estimation of discharge footprint during mine operations at sites already modelled. Possible techniques for verifying discharge footprint estimates are presented in this review and will vary according to local site conditions.

6. References

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