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Lake Disappointment Hydrogeology Review

Client:	Reward Minerals Pty Ltd	**Date:**	24/05/2018
Attention:	Greg Cochrane	**From:**	Brian Luinstra
Project No:	REW001	**Revision No:**	0
Project Name:	Lake Disappointment Groundwater Review		
Subject:	Groundwater Studies Regulatory Compliance Review		

1 Objectives

Reward Minerals Pty Ltd ("RWL") engaged SRK to conduct a review of the hydrogeological work completed to support their applications for 5C Licences to take Water for their Lake Disappointment Sulphate of Potash Project (the "Project"). This included a review of available studies completed for the Project, a site visit with regulators, and discussions with RWL. The objective of the exercise was to provide RWL with a technical review, and determine what work may be required in order to meet regulatory requirements.

Prior to completion of this review, preliminary responses to the 5C applications were received by RWL from the Department of Water, Environment and Regulation (DWER) and reviewed by SRK.

1.1 Provided Documents

The following reports were received and used in the review:

- Selroos, J., Walker, D., Ström, A., Gylling, B. and Follin, S. (2002). *Comparison of alternative modelling approaches for groundwater flow in fractured rock*. Journal of Hydrology, 257(1-4), pp.174-188.
- Skrzypek, G., Dogramaci, S., Rouillard, A. and Grierson, P. (2016). *Groundwater seepage controls salinity in a hydrologically terminal basin of semi-arid northwest Australia*. Journal of Hydrology, 542, pp.627-636.
- Lake Disappointment Groundwater Investigation Plan. Memo to Daniel Tenardi (Reward Minerals Pty Ltd) from Dave Morgan (Knight Piésold Consulting), September 2016.
- Lake Disappointment Groundwater Operating Strategy for the Lake Mine. Letter to Daniel Tenardi from Gary Humphreys (DWER), May 2018.
- Response to DWER correspondence document, May 2018.
- Additional information required for a permit/licence under the *Rights in Water and Irrigation Act 1914*. Letter to Mr. Kinnell (Reward Minerals Pty Ltd) from Gary Humphreys, October 2017.
- Groundwater modelling guidelines from National Water Commission – Waterlines.
- Bore logs for Lake Disappointment groundwater modelling report, March 2017.
- Environmental Review document – Lake Disappointment Potash Project. Letter to Dr Michael Ruane (Reward Minerals Pty Ltd) from Peter Tapsell (DWER), March 2018.
- Excel spreadsheet with data from the Cory Bore Field groundwater monitoring.
- Cory Bore Field Groundwater Operating Strategy by Strategic Water Management, January 2018.

- Cory Bore Field H2 assessment. *Hydrogeological Assessment of the Impact of Procesds Water Abstraction from the Cory Bore Field – An H2 Level assessment for 1.5GL/year*. Prepared by Strategic Water Management, September 2017.
- Lake Disappointment groundwater-dependent vegetation spectral data analysis – NDVI, NDWI and ET calculations. Memo to Dan Tenardi & Lisa Chandler (Reward Minerals Pty Ltd) from Phil Whittle (Hydrobiology), August 2017.
- Process Water Review report for Reward Minerals Pty Ltd. Prepared by Global Groundwater, May 2016.
- Public Environmental Review for Lake Disappointment Potash Project – Environmental Scoping Document approval. Letter to Dr Michael Ruane from Tom Hatton (Environmental Protection Authority), October 2016.
- Figures for Lake Disappointment groundwater modelling report, March 2017.
- Lake Disappointment – Salt Dissolution Testing and Brine Runoff Impact. Memo from Dave Morgan to Daniel Tenardi, January 2017.
- Environmental Review Document for Lake Disappointment Potash Project. Prepared by Reward Minerals Pty Ltd, December 2017.
- Environmental Review Document comment table – Lake Disappointment.
- Lake Disappointment Core Porosity Conductivity Measurements and Calculations. Letter to Dan Tenardi from Pendragon Environmental Solutions.
- Acid Sulfate Soils, Hydrology and Hydrogeology, Lake Disappointment. Report by Pendragon Environmental Solutions, August 2014.
- Lake Disappointment Groundwater Operating Strategy. Prepared by Strategic Water Management, March 2018.
- Hydrogeological Assessment to Support a Groundwater Licence Application for the Abstraction of 63GL/year of Mineral Rich Brine. Prepared by Reward Minerals Pt Ltd, May 2017.
- Hydrogeological Assessment of the Impact of Brine Extraction, Lake Disappointment. Prepared by Global Groundwater, March 2017.
- Northern Bore Field Groundwater Operating Strategy, Lake Disappointment Potash Project. Prepared by Strategic Water Management, March 2018.
- Hydrogeological Assessment of the Impact of Process Water Abstraction from the Northern Bore Field – An H2 Level Assessment for 2 GL/year with a Numerical Model. Prepared by Strategic Water Management, September 2017.
- Northern Bore Field Model Parameters document and figures, September 2017.
- Northern Bore Field Bore Completion Reports
- Excel sheets with pump test data
- Lake Disappointment SOP Project: Brine Collection, Evaporation Ponds and Residue Disposal Concept Study. Prepared by Knight Piésold Consulting, December 2016.
- Lake Disappointment – Hydrological Study. Prepared by Knight Piésold Consulting, January 2017.
- Lake Disappointment – Hydrogeological Investigations and associated reports for the Lake/Mine, and Northern Borefield. Letter to Daniel Tenardi from Gary Humphreys, May 2018.
- Lake Disappointment 2017 Flooding Hydrology Calculations. Memo to Daniel Tenardi from Phil Whittle.
- Scoping document requirements – hydrological processes.
- Test pumping data – Lake Disappointment groundwater modelling report, March 2017.

1.2 Regulatory Framework

Groundwater use in Western Australia must be licensed under the *Rights in Water and Irrigation Act 1914* (the Act) by the DWER (with the exceptions of stock and domestic use). Before a Licence to

Take Water is issued to an applicant, DWER undertakes an assessment, including an evaluation of the potential impacts of taking the groundwater. On occasions, the DWER requires additional information in order to make an informed decision on the application. These may include cases where the proposed volume of water to be abstracted is large, the available data for the aquifer is limited, the demand for accessing a particular groundwater resource is high, or the potential impacts on the groundwater system and/or adjacent users as a result of abstraction are considered significant.

The ranking criteria for identifying the level of assessment required for a groundwater abstraction licence application is presented in Table 1 and Table 2. Using these criteria as a guide, the licence applicant may be requested by the DWER to undertake an additional hydrogeological assessment to determine the potential impacts of the proposed abstraction.

Table 1 DWER Assessment Level Criteria – Points Allocation (DoW, 2009)

Volume Requested (kL/yr)	Level of Allocation (Utilisation as Percentage of Sustainable Yield)	Potential for Unacceptable Impacts		Existing Salinity (mg/L)
		Other Users	Groundwater Dependent Ecosystems	
<10,000 (0 points)	0 to <30% (C1) (0 points)	Impacts unlikely (0 points)	Impacts unlikely (0 points)	Fresh <500 (4 points)
10,001-50,000 (2 points)	30 to <70% (C2) (1 point)	Impacts possible (2 points)	Impacts possible (2 points)	Marginal 500-1500 (3 points)
50,001-250,000 (4 points)	70 to <100% (C3) (3 points)	Impacts likely (5 points)	Impacts likely (5 points)	Brackish 1,501-5,000 (2 points)
250,001-500,000 (6 points)	100% and over (C4) (5 points)			Saline 5,001-50,000 (1 point)
500,001-1,000,000 (8 points)	0 to <30% (C1) (0 points)			Hypersaline >50,000 (0 points)
1,000,000-2,500,000 (15 points)				Fresh <500 (4 points)

Table 2 DWER Assessment Level Criteria – Grade Assignment (DoW, 2009)

Number of Points	Assignment	Required Level of Assessment
0-7 points	None (unless other knowledge of risks indicates that H1 is warranted).	None
8-12 points	H1	Desktop hydrogeology assessment sufficient
12-18 points	H2	Basic field hydrogeological assessment, including drilling and test pumping, is required.
>19 points	H3	Detailed field hydrogeological assessment, including drilling, test pumping and groundwater modelling

Due to the volume of proposed water abstraction at the Project for the Northern and Cory Borefields, as well as brine abstraction from Lake Disappointment, the review has been conducted assuming that an H3 level of assessment will be required to support permitting.

1.3 Site Visit

In addition to the review of documents, SRK completed a site visit April 4th-5th combined with representatives from DWER, the Department of Mines, Industry Regulation and Safety (DMIRS) and the Environmental Protection Authority (EPA).

2 Study Review

Although there is a significant amount of cross over between the completed studies and the individual licence applications, this review is structured to match the respective 5C licence applications for the Cory bore field, Northern bore field and Lake Disappointment.

It is the opinion of SRK that the work required to meet the regulatory requirements has been largely completed, however, may not be presented as a cohesive study for the individual applications. There are, however, some first principle issues with some of the field data and the numerical modelling that will need to be addressed, and documentation of the modelling exercise is either not complete or insufficient. Specific issues with the studies will be addressed in the following sections.

2.1 Lake Disappointment Brine Abstraction

It is the opinion of SRK that the work required to meet the regulatory requirements issues relating to abstraction of brine from the lakebed sediments has been completed. The data collection completed for the lake bed has been collected using appropriate methodologies and at an appropriate density to support the 5c licence to take water. It should be noted that this is partially due to the lack of potential impacts, at a conceptual level, to any potential groundwater users or ecosystems from the proposed abstraction.

The numerical groundwater modelling completed in support of the application is overly conservative having assumed no recharge, and has identified maximum potential drawdown impacts on the perimeter of the lake, which are the most likely source of any impacts. The modelling report itself is of poor quality and is not considered compliant with criteria established in the Australian Groundwater Modelling Guidelines (Barnett et al, 2012). It would benefit through the addition of calibration data and figures outlining the model structure. Despite the report, it is acknowledged that this is an area with limited groundwater data availability, and SRK consider the model itself defensible for gaining regulatory approvals.

DWER has highlighted the need to establish threshold groundwater levels, based on the modelling, for the Lake. SRK agree with this recommendation but recommend that any thresholds not be established based on modelling alone. Additional monitoring of water level responses over (preferably) multiple wet and dry seasons and as a minimum incorporating some lake-inundation events would be recommended to establish these thresholds for as conditions of the licence/approval. This monitoring would also be required for operational purposes during brine abstraction.

2.2 Cory Bore Field Abstraction

It is the opinion of SRK that the work required to meet the regulatory requirements issues relating to abstraction of process water from the Cory Bore Field has been largely completed. The data collection completed for the bore field has been collected using appropriate methodologies and at an appropriate density to support the 5c licence to take water.

The numerical groundwater modelling completed in support of the application and the modelling report are not considered compliant with criteria established in the Australian Groundwater Modelling Guidelines (Barnett et al, 2012), nor do they meet typical expectations for a PFS study. The modelling does not incorporate recharge into the model, which is a typical requirement for any model used for the purposes of assessing the sustainability of a bore field and/or potential impacts from groundwater drawdown. This is typically done by assessing drawdown for the proposed life of mine and recovery of water levels once the bore field is decommissioned, which has not been completed. The modelling report itself is inadequate and would benefit through the addition of calibration data and figures outlining the model structure.

2.3 Northern Bore Field Abstraction

It is the opinion of SRK that the work required to meet the regulatory requirements issues relating to abstraction of process water from the Northern Bore Field has been partially completed. The data collection completed for the bore field has been collected using appropriate methodologies and at an

appropriate density to support the 5c licence to take water. The data and analysis from the pumping tests are of good quality, however, not enough information has been collected to address the potential connection between the deeper aquifer and the alluvial aquifer. The alluvial groundwater system may be considered sensitive (potentially for both terrestrial groundwater dependent flora and stygofauna) and has not been adequately characterised. The construction of the production bores with full length screens through both potential groundwater systems, and the lack of monitoring bores specifically targeting the shallow, alluvial system have not allowed for assessment of any connection with the deeper aquifer. Additional field investigations will need to be completed in order to properly characterise the shallow groundwater system, assess any connection with the deeper aquifer and to satisfy the DWER in order to obtain the 5C licence approval.

No formal report was provided for the northern bore field modelling. The numerical groundwater modelling completed in support of the application is not considered compliant with criteria established in the Australian Groundwater Modelling Guidelines (Barnett et al, 2012), nor does it meet typical expectations for a PFS study. The modelling does not incorporate recharge into the model, which is a typical requirement for any model used for the purposes of assessing the sustainability of a bore field and/or potential impacts from groundwater drawdown. This is typically done by assessing drawdown for the proposed life of mine and recovery of water levels once the bore field is decommissioned, which has not been completed.

SRK would highlight to RWL the risk that DWER may not approve of use of the existing production bores due to the construction and associated potential for cross contamination between aquifers. The construction of the production bores with full length screens through multiple groundwater systems is contrary to groundwater best management practices, and it is possible that DWER will ask for all bores constructed as such to be decommissioned prior to issuance of any licences.

2.4 Additional Regulatory Considerations

A Groundwater monitoring plan should include the locations, construction details and monitoring rationales for a network designed to assess the ambient groundwater conditions and to establish a baseline to evaluate potential impacts on the ground system during operations. No groundwater monitoring plan and/or baseline has been presented in the documentation. It is understood that there are significant data collected on site, but not available within the framework of a groundwater monitoring plan. Establishment of a network is essential early in the Project development process in order to develop a baseline that is representative of ambient conditions. The baseline informs development of threshold and trigger values, which will be adopted as conditions within the 5C licences and effectively become constraints on water and/or brine production.

DWER has highlighted the need for a groundwater monitoring plan for each application, which are typically included with the Groundwater Licence Operating Strategy (GLOS) which forms the instrument by which groundwater abstraction is regulated on an ongoing basis.

3 Recommended Forward Works

3.1 Regulatory Consultation

SRK have outlined a high-level forward works intended to address the requirements of DWER for 5C licence approval. It is recommended that RWL initiate discussions with DWER to ensure that any forward works plan will meet their specific requirements prior to commencing any additional work.

3.2 Groundwater Monitoring Network

A groundwater monitoring strategy should be established incorporating existing and new monitoring bores. Existing monitoring bores located near production bores are likely sufficient to monitor water level and quality impacts from drawdown within the bore fields.

SRK recommend development of a groundwater monitoring strategy. This should include, as a minimum, the locations, construction details and rationales for all monitoring bores, as well as a schedule outlining the frequency of sample collection and water level monitoring. The strategy should also include the suites of parameters and desired detection limits for laboratory analysis.

SRK anticipate additional bores will be established for the Project. For budgetary purposes, SRK recommend establishment of three (3) monitoring bores within the shallow alluvial (i.e. Mackay Creek) groundwater system, and up to 6 (six) additional monitoring bores targeting drawdown in Lake Disappointment (3 bores) and along the shoreline of Lake Disappointment (3 bores). Precise locations and target depths should be outlined in the groundwater monitoring strategy.

The groundwater monitoring strategy is required in the GLOS and can be incorporated into those documents once completed.

3.3 Northern Bore Field Supplemental Production Bore Drilling and Hydraulic Testing

The DWER review identified that several of the bores in the Northern bore field were constructed with screens across both the shallow and deeper aquifer systems. As a result, the hydraulic testing completed for the bores, although adequate to assess bore efficiency and develop recommended pumping rates, does not provide adequate information on the source aquifer. SRK therefore recommends that at least one (1) additional production bore and companion monitoring bore be established in the northern bore field area. Ideally, the bore should be established away from existing production bores to limit the potential for cross-aquifer interference from the existing bores (which may act as a conduit between upper and lower groundwater systems) and close enough to monitoring bores established in Mackay Creek to evaluate potential interaction between the deeper aquifer and the Mackay Creek alluvial groundwater system. Logistical, environmental and heritage considerations will constrain the final location of the bore.

Hydraulic testing of the bore should be completed, with a Multi-Rate Test (MRT) and minimum 72 hour Constant Rate Test (CRT) completed. This testing will provide valuable data on the potential connection (or lack of connection) between the groundwater systems, as well as provide the basis for assessing the long-term sustainability of the deeper aquifer.

3.4 Numerical Groundwater Modelling updates

Groundwater models for the Cory and Northern bore fields will need to be updated to meet regulatory requirements. This should include incorporation of recharge into the models, as well as updating hydraulic parameters based on the additional hydraulic testing, particularly for the norther bore field.

Once updated, the models should be recalibrated for both steady-state and transient conditions, and drawdown estimated for the proposed life of project (LOP). This estimate can also be used to assess the sustainability of the bore fields for Project process water supply. The models should also be used to assess post closure water level recovery modelling.

Yours faithfully

SRK Consulting (Australasia) Pty Ltd

Signed by:	**Signed by:**
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