Toro Energy Limited

Groundwater Reinjection Study

Lake Maitland Uranium Project
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EXECUTIVE SUMMARY

Toro Energy Limited (“Toro”) is seeking to develop the Wiluna Uranium Project south of Wiluna in Western Australia. In April 2013, Toro was granted environmental approval to construct and operate a uranium mine at the Centipede and Lake Way deposits. Toro is now seeking to expand the approvals to include additional deposits at Millipede and Lake Maitland.

The Lake Maitland deposits are partially beneath the water table and will require dewatering. Toro proposes to reuse as much of the dewatering discharge as possible in the operational water supply, and to reinject the surplus water in the same calcrete formation that is to be dewatered.

Pennington Scott was engaged to investigate the hydrogeological capacity for reinjection at the Lake Maitland project, building on previous hydrogeological investigation work at Lake Maitland by Golder and RPS Aquaterra. The groundwater reinjection investigation included:

- Construction and pump testing of three test production water bores and six monitor bores in the permeable shallow calcrete aquifer and underlying fluvial lacustrine clay and sand sequence;
- An 11 day simultaneous bore pumping and bore reinjection trial; and
- Simulation of injection scenarios in a sub-regional finite element numerical groundwater model, calibrated against the field observations from the trial reinjection program.

The key findings of these investigations were that:

- Injection trials demonstrate that it is possible to inject water into bores in the calcrete aquifer at several litres per second for more than 10 days;
- The calcrete aquifer is very permeable and facilitates a spread of mounding in water levels in response to reinjection.
- Over longer periods, to ensure that the already shallow water table does not daylight at the surface in the low-lying areas, the hydrogeological limitation on reinjection quantity is the soil evaporation capacity in the low-lying playa areas.

A conceptual borefield comprising 24 bores strategically located over the project area was modelled to be able to sustain 1 GL/year of injection over 6 years while limiting water table rise to less than 1 m in the low-lying playa areas. The model was sensitive to assumptions on soil evaporation rates and was based on data from Lake Amadeus (NT) in a similar climate zone. Should soil evaporation be lower, it may be necessary to spread the borefield over a larger area.

Operational constraints for reinjection include:

- Significant spatial hydraulic variability in the calcrete aquifer;
- Potential ephemeral water level mounding due to flood recharge in the lake sediments which may temporarily reduce injection capacity following larger rainfall events; and
- High likelihood of bore clogging over time, posing operational difficulties and costs.

To address these operational factors and soil evaporation uncertainty, a staged development and testing program is required including:
Long-term testing of clogging rates and clogging risk assessment, testing of a range of injection methods, and clogging remediation trials as part of further Definitive Feasibility Study (DFS) investigations;

Investigations to characterise calcrete aquifer spatial variability in the proposed injection areas as part of DFS; and

Development of the injection scheme in stages, with remodelling between stages and adaptive design and management in response to the performance of each stage.
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1. INTRODUCTION

Toro Energy Limited ("Toro") is seeking to develop the Wiluna Uranium Project south of Wiluna in Western Australia. In April 2013, both the Western Australian Minister for Environment and the Federal Minister for Sustainability, Environment, Water, Population and Communities granted Toro environmental approval to construct and operate a uranium mine consisting of two deposits, Centipede and Lake Way, located approximately 30 kilometres (km) south and 15 km south-east of Wiluna respectively. Toro is now seeking to extend the environmental approvals to include mining of two additional deposits, Millipede and Lake Maitland, as well as the construction of a haul road and associated infrastructure.

The Lake Maitland project (hereinafter referred to as “the Project”) was acquired by Toro from Mega Uranium Limited in November 2013, after the assessment for the Centipede and Lake Way deposits was completed. The deposit is located 105 km south-east of Wiluna, and in close proximity to existing infrastructure including roads and an airstrip (Figure 1-1). The proposed 1.3 million tonne per annum (mtpa) Lake Maitland mining operation would be similar to that outlined for the approved Centipede and Lake Way deposits, with free dig truck and shovel excavation from shallow pits less than 15 m deep (Figure 1-2).

The deposits are partially beneath the water table and dewatering strategies have been developed by Toro incorporating previous investigations by Golder (2011a, 2011b and 2011c) and RPS Aquaterra (2010 and 2011). Toro plans to install barriers to minimise dewatering and anticipates dewatering rates to be lower than 4 GL/year (Toro 2014). During routine operation as much water as possible from pit dewatering would be temporarily stored and used as part of the operational water supply. Toro proposes to also develop a reinjection borefield in the same calcrite formation that is to be dewatered, as a contingency surplus water management system. Toro’s water balance assessment indicates that this reinjection contingency capacity may be needed for up to 6 years.

Pennington Scott was engaged by Toro to investigate the hydrogeological potential for reinjection at the Lake Maitland project. The investigation supplements the previous work undertaken by Golder and RPS Aquaterra, and incorporates reinjection trials undertaken in 2014-15 and sub-regional groundwater modelling.

This document presents the results of investigations and assessment for the Lake Maitland groundwater reinjection proposal.
Figure 1-1 Project location
Figure 1-2 Original proposed Project layout after Toro (2014)
1.1 Previous Studies

The investigations described herein build on and supplement the extensive previous hydrogeological work undertaken for the Project. A detailed description of the regional and local hydrogeology of the Lake Maitland region and the mine site is presented in Golder (2011a). Golder also summarised the previous hydrogeological investigations of the site. These include:

- Construction and hydraulic testing of a series of 13 bores and a number of tests pits and costeans in the mine area (RPS Aquaterra 2010);
- Calcrite dewatering and reinjection trials undertaken in 2011 toward the north end of the mining area (Golder 2011a);
- A trial dewatering program including the construction of two trial pits and testing of clay seepage barriers (Golder 2011b); and
- Airborne geophysics, drilling and test pumping to investigate the proposed alluvial aquifer water supply borefield for the project to the north of the mine area, as well as a contingency water supply area to the south (RPS Aquaterra 2011).

Two regional groundwater models were also developed, one model for assessing dewatering requirements (Golder 2011c) and the other for the alluvial aquifer water supply assessment (RPS Aquaterra 2011).

As part of the reinjection investigations, in December 2014 and January 2015, Pennington Scott undertook reinjection trials at Lake Maitland. These included the drilling and hydraulic testing of three test production bores and six monitor bores in the calcrite aquifer, which is the target for reinjection. An 11 day telemetered reinjection test was then undertaken at staged rates ranging from 3 to 7.5 L/s. These reinjection trial data are presented in Pennington Scott (2015a) which is attached as Appendix A of this report.

Also as part of the reinjection investigations, in February 2015 Pennington Scott developed a sub-regional scale numerical groundwater model of the project area, calibrated against regional water table geometry and transient reinjection trial data, to simulate aquifer injection around Lake Maitland. The reinjection modelling report is presented in Pennington Scott (2015b) which is attached as Appendix B of this report.

1.2 Limitations

The primary focus of this study was an investigation of the hydrogeological potential for injection of surplus water from dewatering as input to the Project's environmental approvals process. The study is intended for preliminary planning and environmental approvals purposes only and should not be used for any other purpose. It is not suitable for detailed design or construction.

The study did not include a detailed analysis of injection bore clogging risk, which can be a major operational constraint on reinjection, or other operational factors relating to reinjection. Further investigations and testing, including but not limited to testing and assessment of bore clogging risk and clogging remediation feasibility, are required at the next stage of investigations for a Definitive Feasibility Study (DFS).
2. HYDROGEOLOGICAL SETTING

2.1 Climate

The project area lies within the Australian climatic zone classified as arid with summer rain generally associated with cyclonic activity (Bureau of Meteorology 1984). The climate within this zone is characterised by variable rainfall, hot to extreme temperatures and very dry conditions in summer. Daily temperatures can vary from highs above 40°C in the summer months to subzero night-time lows in winter. The hot desert climate is persistently dry with high annual evaporation creating a large water balance deficit in the area.

Rainfall patterns in the region are erratic and are usually the result of thunderstorms or rain bearing depressions resulting from cyclonic activity in mid to late summer (December through to April). During the winter months, the dry season, occasional light rainfall and mild to warm temperatures are experienced.

The closest Bureau of Meteorology (BoM) weather stations to the Project are Wonganoo Station (BoM Site No. 012108), which has rainfall data from 1928 to present, and Wiluna (BoM Site No. 013012), with generally continuous records from 1988 to present. These weather stations are located some 25 km east and 105 north-west of the Project respectively.

The average annual rainfall at Wonganoo is 224 mm and at Wiluna 250 mm. Wonganoo is considered to be representative of the rainfall at the Project. The average monthly rainfall at Wonganoo is presented in Figure 2-1. The total annual average rainfall varies from 50 to 580 mm.

Evaporation data for the region are limited with long term data only available from Meekatharra (BoM Site No. 007045), located about 270 km to the west of the Project. Here the average annual evaporation is 3,559 mm. The Project is located between the 3,200 and 3,600 mm isohalines on the BoM map of annual average pan evaporation. Evaporation varies seasonally from a monthly maximum of 450 mm in January to a minimum of around 100 mm in June. It greatly exceeds rainfall throughout the year.
Figure 2-1: Monthly rainfall and evaporation statistics at Wiluna, Wonganoo Station and Meekatharra respectively.
2.2 Geology

The geology of the region is covered by Geological Survey of Western Australia 1:250,000 scale geological maps Sir Samuel (Bunting and Williams, 1979) and Wiluna (Elias and Bunting, 1982). The Department of Water (formerly Department of Environment) has also produced a 1:250,000 scale Sir Samuel hydrogeological map sheet (Johnson 2004).

Figure 2-2 shows the surface geology from the Sir Samuel hydrogeological map and Wiluna geological map over the Project area, while Figure 2-3 shows the topographic relief over the same area, derived from 1 second shuttle radar topography mission (SRTM) digital elevation model (Geoscience Australia 2011). The region on the latter figure defined by catchment divides and surface water flow lines is referred to hereinafter as “the Project Catchment” and will also be the groundwater model area.

The Project Catchment lies in the Eastern Goldfields Province of the Archaean Yilgarn Craton and is characterised by granite-greenstone sequences that display a northwest tectonic trend and low to medium metamorphic grade. The basement rocks are generally poorly exposed due to low relief, extensive superficial cover and widespread deep weathering. The area is underlain by granitic and greenstone lithologies of the Yandal Greenstone Belt, however granitic lithologies dominate outcrop in the upper catchment areas.

During the Late Cretaceous and Palaeocene period (56 to 146 Ma), erosion carved channels into the basement rocks, including the Carey channel which drained through the Project. Figure 2-5 shows a schematic cross section through the lithological units buried beneath the Carey palaeodrainage valley at Lake Maitland. Drilling results by RPS Aquaterra (2010) suggest that the buried channel is about 80 to 90 m deep and although the drainage valley in the Project area is several kilometres wide, the actual buried channel is much narrower, and may taper down to less than a few hundred metres width at its base. A conceptual palaeochannel base elevation surface base on these assumptions and the surface extent mapping by Johnson (2004) is shown in Figure 2-4. The palaeochannel has been infilled by a succession comprising several metres of Middle to Late Eocene (34 to 45 Ma) basal quartz sands and gravels overlain by 30 or so metres of apparently homogenous stiff plastic clay of probable fluviatile origin (referred to as the lacustrine clay unit by Golder 2011a). This clay is in turn overlain by a 30 m thick succession of inter-fingering alluvial, colluvial and playa deposits of Pliocene to Miocene age (1.8 to 23 Ma) comprising stringers of braided quartz sand and clay.

The palaeochannel deposits have locally been overprinted by calcareous and ferruginous digenetic replacement. An extensive shallow horizon of calcareous/ferruginous silt and clay through to hard massive calcrete, averaging around 4 m thick, has been intersected in resource drilling holes throughout the Carey drainage valley in the Project area. It outcrops as an extensive calcrete duricrust outcrop in the central drainage immediately west of the proposed mining area and is referred to hereinafter as “the calcrete tongue”.

The surface of the Lake Maitland drainage valley is covered by a 1 to 2 m thick veneer of silty clay evaporates in the central playa areas, with loose gypsiferous silty sand deposits over much of the remaining valley. Gypsiferous sand lunate dunes, several metres high, occur on the southern and eastern margins of the lake, while extensive fine quartz aeolian sandplain deposits cover the eastern margins of the drainage valley.
Figure 2-2 Composite surface geology after DOW Sir Samuel 1:250,000 hydrogeology and GSWA Wiluna 1:250,000 geology over the Project Catchment.
Figure 2-3 Regional topographic relief showing the Project area defined by catchment divides and surface flow lines in the Project Catchment
Figure 2-4 Conceptual base of palaeochannel structure contours in the Project Catchment
2.3 Aquifers

The hydrogeology in the Project Catchment relevant to this reinjection investigation includes six main lithological units, which include:

- an upper gypsiferous silt and playa clay unit;
- calcrete and calcretised/ferruginised silt and clay aquifer;
- surficial sand and clay unit under the calcrete;
- stiff plastic fluvial clay unit;
- basal palaeochannel sand and gravel; and
- surrounding weathered and fractured basement rocks.

Groundwater occurs through the entire sedimentary sequence in the palaeodrainage system and in the flanking and underlying weathered and fractured rocks.
2.4 Recharge / Discharge

Figure 2-6 shows an interpreted regional water table surface within the Project Catchment. The surface is based on regional 5 m contours defined by Golder (2011c) with more detailed 1 m contours in the central lake areas defined by RPS Aquaterra (2010).

Reference to this figure suggests that groundwater flows from high water table elevation on the regional catchment boundaries, where water table mounding is sustained by annual rainfall recharge through relatively low permeability rock, and drains towards a mainly terminal water table sink in the middle of the Lake Maitland playa lake, where groundwater is being continually lost through evaporation.

The water table in the Project area ranges from around 4 m below ground beneath the calcrete tongue to around 1 m below ground in the low-lying playa areas (Figure 2-7).

Recharge rates in the region would typically be expected to be in the order of 0.1% to 1% of rainfall (0.2 to 2.2 mm/year) (Johnson et al. 1999). Calibrated recharge rates in the RPS Aquaterra (2011) model ranged from 0.035 mm/year in weathered bedrock areas to 0.5 mm/year in calcrete. Recharge rates in the Golder (2011c) model were somewhat higher ranging from 0.25 to 2.5 mm/year and averaging 0.75 mm/year.

Evaporative discharge in playa lake systems tends to be significantly lower than potential or pan evaporation, due to evaporation-inhibiting formation of salt encrustation in the sediments. Chen (1992) measured evaporation of 70 mm/year from Lake Amadeus in central Australia in a similar evaporation zone to Lake Maitland, and confirmed similar levels of evaporation in lab experiments. Other Australian studies have measured evaporation rates ranging from 9 to 28 mm/year at Lake Eyre (Ullman 1985) to 90 to 230 mm/year at Lake Frome (Allison and Barnes 1985) using various methods. Similar investigations in the United States have measured 39 to 43 mm of evaporation in a salt lake in Nevada (Deverel et al. 2005) and 88 to 104 mm/year in a salt lake in California (Tyler et al. 1997). The Chen results have been used for the Pennington Scott (2015b) modelling in this investigation as they are considered to be most analogous to the Lake Maitland situation.
Figure 2-6 Regional water table surface after Golder (2011a) and RPS Aquaterra (2010)
Figure 2-7 Depth to water table derived from digital elevation model and water table surfaces
2.5 Hydraulic Parameters

A summary of estimated aquifer parameters for the Carey Palaeodrainage in the Project area based on the previous investigations, model calibrations and values from literature is presented in Table 2-1, with the basis for the estimates described below.

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<th>$K_h/K_v$</th>
<th>Sy</th>
<th>$S_s$</th>
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<tr>
<td></td>
<td></td>
<td>m/day</td>
<td>m/day</td>
<td>%</td>
<td>1/m</td>
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<td>Cenozoic surficial deposits</td>
<td>Shallow gypsiferous sand and clay, carbonate mudstone</td>
<td>1 to 10 (10)</td>
<td>10</td>
<td>3 to 5 (5)</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Calcrete and calcretised/ferruginised silt</td>
<td>1 to 900 (100)</td>
<td>10</td>
<td>5 to 25 (5)</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Sand and Clay</td>
<td>Clay with occasional sand layers</td>
<td>1 to 2 (2)</td>
<td>10</td>
<td>3</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Clay</td>
<td></td>
<td>$10^{-3}$ to $10^{-6}$ (10$^{-4}$)</td>
<td>1</td>
<td>3</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Weathered Profile and Fractured Rock</td>
<td>Predominantly clay profile and fractured bedrock</td>
<td>0.01</td>
<td>10</td>
<td>0.1</td>
<td>$10^{-6}$</td>
</tr>
</tbody>
</table>

Brackets show values adopted by Pennington Scott (2015b) numerical model. Note: where observations are not available, estimates are based on previous investigations, model calibrations and available literature.

RPS Aquaterra (2010) conducted falling head and rising head slug tests on about 12 bores to depths of 12 m and 23 m spread across Lake Maitland. The top 2 to 5 m of each bore was cased and grouted off; which may have inadvertently sealed off much of the permeable calcrete aquifer. Tested permeabilities in these bores ranged from 0.5 m/day to 9.5 m/day, with a median of 3 m/day, albeit that these values may be mostly representative of the clay and sand aquifer underlying the calcrete, with some influence from the calcrete above. The true bulk permeability of the sand and clay aquifer may be around 1 to 2 m/day.

RPS Aquaterra (2010) also conducted six (6) pump out trial dewatering tests from trial pits of 5 m depth into costeans on the lake of depths ranging from 4 to 5.5 m. The dewatering trials are believed to be more representative of the calcrete and produced highly variable hydraulic conductivities ranging between 40 and 900 m/day. Golder (2011) also conducted two trial pit and infiltration trench tests of their own on the calcrete tongue. They back-analysed their results using the SEEPW 2D finite element package to derive permeability values of 0.8 to 8.5 m/day for the shallow gypsiferous silt and clay and carbonate mudstone, 145 to 400 m/day for the calcrete and 0.05 to 3.5 m/day for the sand and clay aquifer underlying the calcrete. Based on these results, RPS Aquaterra (2011) adopted a calcrete hydraulic conductivity of 20 m/day in their numerical modelling for a water supply, and Golder (2011c) adopted a figure of 300 m/day in their dewatering modelling.

Pennington Scott (2015a) pump tested three 24 to 28 m deep production bores screened through the calcrete, plus the sand and clay underlying the calcrete. These tests also demonstrated significant variation in the permeability, thickness and degree of diagenesis in the calcrete aquifer between the three bore sites with the calcrete permeability estimated to be 1.5, 230 and 140 m/day in the three bores. For the purposes of the reinjection modelling, Pennington Scott (2015b) adopted a calcrete
permeability of 100 m/day. The locations of RPS Aquaterra, Golder and Pennington Scott trial pit and test bores at Lake Maitland are shown in Figure 2-8.

Commander et al. (1992) assumed a specific yield of 20% for the palaeochannel sand in the Roe Palaeodrainage near Kalgoorlie, and while this value may be reasonable for the unconsolidated, clay-free sand portion, the bulk specific yield for the palaeochannel deposits will be considerably lower. In 2001 and again in 2007, after considering a number of hydrogeological expert witness statements, the Western Australian Mining Warden found that a bulk specific yield of 3% was appropriate for the bulk palaeochannel sediments, representing an average over sand and clay intervals (WA Wardens Court 2001 and 2007). The specific yield for calcrite will be highly variable, which has been estimated to range from 5% to 25% (Johnson et al. 1999). Where karstic features are most developed the specific yield will be at the higher end of the range, but generally decreases with depth below the water table. Golder (2011), RPS Aquaterra (2010) and Pennington Scott (2015b) have all adopted modelling values of calcrite specific yield towards the lower end of the expected range being 6%, 7.5% and 5% respectively.

Confined aquifer storativity influences the rate of drawdown and extent of the drawdown cone resulting from pumping groundwater from the aquifer while conditions remain confined. As there are no reported values available for Storativity of the palaeochannels over the Yilgarn Craton, generic values for semi-consolidated sedimentary deposits will need to be adopted. Storativity for the palaeochannel aquifer is likely to be multiples of $10^{-4}$ (Kasenow, 2006) with specific storage (Storativity divided by aquifer thickness) of around $10^{-5}$ to $10^{-6}$ m$^{-1}$.

2.6 Groundwater Salinity

Groundwater salinity is controlled by the evaporative discharge process, with regional ground salinity ranging from around 1000 mg/L in the saprolite aquifers in the uplands to hypersaline in the playa discharge zones. Figure 2-9 shows groundwater salinity mapping from Johnson (2004), highlighting the zone of higher salinity water around the Carey palaeodrainage discharge zone. The proposed mine pits are located in the greater than 14,000 mg/L zone.
Figure 2-8 Hydraulic testing undertaken for the Project
Figure 2-9 Groundwater salinity in the project area (Source: DoW 1:250,000 hydrogeological map series)
3. REINJECTION ASSESSMENT

This section discusses the results of the hydrogeological assessment of the reinjection scheme and how groundwater reinjection system might be implemented, optimised and operated at Lake Maitland in terms of:

- Hydrogeological assessment of reinjection at Lake Maitland;
- Operational considerations and constraints on reinjection; and
- Conceptual borefield development plan.

3.1 Hydrogeological Assessment

The primary objectives of this technical assessment are to investigate the hydrogeological potential of the shallow calcrete aquifer to receive injection, and to inform borefield design and layout factors.

The injection trials by both Pennington Scott (2015a) and Golder (2011a) demonstrated that it was possible to inject water into bores in the calcrete aquifer both at the north and the south end of the Project area at several litres per second for up to 11 days. Costean infiltration tests by Golder (2011b) and RPS Aquaterra (2010) also showed that infiltration to the calcrete aquifer was also effective over the short duration of the tests.

Over longer periods, given the shallow depth to the water table in the injected area, injected water will fill up the primary interstitial aquifer porosity causing groundwater to progressively rise in a mound around the injection zone. As the water table rises toward the surface in low-lying areas, evaporation will occur from the water table through the capillary zone. If the rate of reinjection continues to exceed the potential evaporation rate through the capillary zone, the water table will rise until it daylights at surface and pools in the lowest lying areas. Once this occurs, the pooled water would evaporate, at a rate likely to be an order of magnitude higher than from soil evaporation (Tyler et al. 1997).

To minimise environmental impacts, Toro’s strategy for the injection scheme is to ensure that groundwater levels remain below the surface. This requires distributing the groundwater mounding over sufficient area that the injection rate can be accommodated by the soil evaporative capacity.

The assessment of the proposed injection scheme was undertaken using a sub-regional groundwater numerical model calibrated to the field groundwater reinjection trial. The model development and scenarios are described in Pennington Scott (2015b), attached as Appendix B.

The modelling indicated that groundwater reinjection would cause water levels to progressively rise in a mound around the reinjection zone, until the mounding reaches evaporative discharge areas. The mounding will continue to expand until there is sufficient evaporative discharge area to balance the rate of reinjection. The high permeability of the calcrete facilitates a relatively rapid spread of the mounding. The key hydrogeological limitation on injection capacity is the requirement to limit the rise such that the water level remains below the ground surface.

Detailed depth to water mapping in RPS Aquaterra (2010) based on a comprehensive bore census indicates that water levels in the low-lying playa areas around the Project are typically about 1 m below ground. A series of reinjection borefield layouts were trialled in the model to investigate the
volume that could be injected while limiting water level rise in the low-lying playa areas to around 0.5 m over the majority of the impacted low-lying areas, and to less than 1 m in any particular low-lying playa area.

The modelled reinjection borefield with the best outcome in terms of volume and impacts is shown in Figure 3-1. It was modelled to sustain about 1 GL/year of reinjection over 6 years with water levels remaining below the triggers described above. Due to the high permeability of the calcrete, wider bore spacing, in the order of 500 m, was sufficient to spread the mounding effectively, with closer spacing not significantly improving the result. The modelling also indicated that it was best to set the bores back from the low-lying discharge areas (more than 500 m from the lake edge) to facilitate the spreading of the mounding over a larger extent of discharge zone before the 0.5 to 1.0 m trigger was breached. Constructing the bores on higher ground will also improve access for drilling and maintenance.

To obtain further reinjection capacity, the borefield would need to be expanded either to the north or the south to take advantage of further evaporative area in the playa lakes. A rough rule of thumb based on the model results and assumptions is that about 100 ML/year of reinjection per kilometre of lake length could be sustained.

The modelling is most sensitive to the playa soil evaporation rate. In the model, a rate of 70 mm/day was used based on Chen (1992) in a similar climate environment in the Northern Territory. Other studies of salt lake evaporation have given ranges from as low as 9 to 28 mm at Lake Eyre (Ullman 1985) to as high as 90 to 230 mm at Lake Frome in South Australia (Allison and Barnes 1985). Contingency actions, such as expanding the borefield north or south, should be defined in the event soil evaporation loss is lower than anticipated. Likewise, should evaporation be higher than anticipated it may be possible to reduce the extent of the borefield. A staged development strategy would allow the borefield design to be adapted in response to observed changes in water levels.
Figure 3-1 Modelled injection borefield layout (Scenario 4b from Pennington Scott 2015b), showing modelled water level rise over 6 years injecting at 1 GL/year
3.2 Operational Constraints

3.2.1 Hydraulic Variability in the Calcrete Aquifer

The model development assumed the calcrete aquifer would have a constant thickness of 4 metres, and uniform hydraulic permeability of 100 m/day and a specific yield of 5% everywhere. While these parameters are considered generally conservative, it is very likely that there are patches where the calcrete will be less permeable or absent altogether. The actual distribution and efficiency of the calcrete will need to be confirmed during the DFS and the development plan will need to retain the flexibility to refine the borefield as necessary.

3.2.2 Episodic Recharge

While long-term average aquifer recharge rates are expected to be low, recharge may occur episodically in large rainfall events when the low-lying areas over the Lake Maitland region are inundated. To avoid access constraints during large rainfall events, bores should be sited on naturally elevated areas above the main drainage zones.

In addition, the recharge associated with inundation will create ephemeral water level mounding in the aquifer which will, for a period, reduce the possible injection flow rate. Contingency dewater disposal or storage options will be required in these periods.

3.2.3 Bore Clogging

It is almost certain that some form of bore clogging will occur in the bore screens and near well aquifer over time. The primary focus of this investigation was the regional hydrogeological impacts of reinjection and detailed analysis of clogging risk has not been undertaken. Clogging is a major operational constraint that will need to be investigated and addressed in further investigations as part of the project DFS.

Mechanisms of clogging can include:

- physical clogging from entrainment of micro-air bubbles, sediment, or other particulate matter in the reinjection water;
- chemical clogging due to precipitation of minerals due to differences in redox or hydrochemistry between the waste water stream and receiving environment; or
- biological clogging due growth of biofilms, iron-related bacteria, or other microbes in the reinjection bore.

Bacterial infections are a particularly insidious source of clogging that can pose significant operational difficulties for remediation and control.

While clogging risk has not been assessed in detail, the reinjection trials described in Appendix A give some preliminary indications of clogging rates over a 11 day test. As has been observed elsewhere, clogging rates increased non-linearly with flow rate, with clogging increasing sixfold for an approximate doubling in flow rate. While over this short-term test, clogging rates appeared approximately linear with time, longer-term clogging rates are notoriously hard to predict and will only be known following long-term testing and operational experience.
Water quality testing indicates that the levels of iron and manganese, two minerals susceptible to precipitation, are relatively low. Nutrient levels, particularly nitrogen, however, are high which may promote microbial growth. Likewise salinity is very high which contributes to clogging risk.

Accurate characterisation of long-term clogging rates, remediation frequency and feasibility of remediation methods will require long-term testing, operational experience and detailed biochemical analysis. These elements should be incorporated into the next stages of investigation and the borefield development strategy.

Strategies that should be incorporated to minimise clogging include, but are not limited to:

- Ensuring that suspended sediments in the dewatering stream are low through methods such as pumping from dewatering bores rather than sumps, and incorporation of filtration if required;
- Designing piping systems and bore headwork and system to minimise air ingress, aeration of the water and water temperature changes;
- Disinfecting all bores prior to operation and at regular intervals;
- Choosing materials for bore inlets that maximise open area such as PVC vee-wire screens (noting that common grades of stainless steel may not be appropriate due to water quality).

Remediation options that could be considered in an ongoing management strategy include but are not limited to:

- Permanent air lines, or pumps installed in bores for backflushing;
- Treatment with chemicals;
- Provisional for regular bore redevelopment including jetting, airlifting, wire brushing and chemical treatment.

Other non-bore reinjection methods could also be considered, such as costeans, soak wells and infiltration galleries.
4. INJECTION DEVELOPMENT STRATEGY

4.1 Staged Development and Testing

The investigations and analysis described here are primarily focused on the hydrogeological capacity for reinjection for the environmental review process for the Project. These have provided insight into the hydrogeological capacity of the calcrete aquifer to receive excess dewatering water through reinjection and have provided information on a range of factors to be considered in borefield design.

For definitive feasibility assessment and design, it will be important to characterise operational costs operating strategies and maintenance requirements, particularly as these relate to bore clogging. For this purpose, the next stage of investigations for DFS should include:

- Long term injection testing and geochemical analyses to provide more detailed understanding of clogging rates, mechanisms and risks;
- Trials of various bore constructions and other injection methods (costeans, infiltration galleries, trenches, etc.) to determine the most cost-effective injection method in terms clogging risk, capital and operating costs; and
- Trials of various clogging rehabilitation and remediation options such as those described in Section 3.2.3 to assess their feasibility, develop maintenance strategies and quantify maintenance costs.

The DFS should also incorporate investigations to characterise calcrete aquifer variability in the proposed injection areas.

Development of the injection scheme itself should be staged to allow adaptive design and management in response to the conditions encountered. The investigations indicated that, depending on the actual rate of soil evaporation encountered, it may, on the one hand, be possible to reduce the extent of the injection, or on the other hand it may be required to expand it to take advantage of greater playa evaporative area. The performance of the initial borefield stages could be used to recalibrate the model and optimise the borefield layout in later stages.

Likewise, with a staged development approach, experience with clogging, maintenance and remediation in initial stages will help to optimise injection system design and maintenance strategies in later stages.

4.2 Borefield Concept

While the injection scheme design would be refined and adapted during the DFS testing and staged development, a conceptual borefield is shown in Figure 3-1 for preliminary planning. The borefield is based on the model scenarios and includes two bore reinjection lines which the modelling indicates may be capable of injecting up to 1 GL/year. The first line is parallel to the eastern margin of Lake Maitland, set back at least 500 m from the edge of the lake and the second is through the middle of the calcrete tongue to the west of the proposed mining area. This bore layout includes 24 bores with average spacing of about 500 m.

The conceptual borefield incorporates the following features, based on the assessment in Section 3:
• provision for injection head and spreading of the mounding over a wider discharge area by ensuring the natural water table at the reinjection site is at least 2 m below ground surface;

• minimisation of water quality impacts by ensuring the bores are sited where the prevailing groundwater is saline (i.e. within the greater than 14,000 mg/L salinity zone where the mine pits are to be developed);

• minimisation of interference mounding impacts between reinjection sites by ensuring active infiltration sites are located around 500 m apart;

• contingency injection yield to allow for bores that are off-line for remediation and recommissioning;

• siting of the reinjection bores on naturally elevated land away from the main drainage valley to keep the reinjection area trafficable year round.

The investigation results indicate that not every hole drilled into the calcrete will intersect suitable conditions for reinjection in terms of water quality, presence of aquifer materials and sufficient depth to standing water. For this reason the drilling program should allow for exploration/observation bores to be drilled first to confirm suitable aquifer conditions, and the production bores drilled later adjacent to favourable observation holes. The targeting success rate in the calcrete is expected to be in the order of 1 production reinjection bore for every 2 exploration/observation holes drilled.

Indicative bore specifications for this conceptual borefield, based on the investigations to date, are as follows:

• The bores would be drilled using the mud rotary technique in accordance with the (NUDLC 2011) Minimum Bore Construction Requirements and the following protocols;

• The bores would be drilled using mud rotary within 5 m of the most productive exploration holes to a maximum depth of 30 m;

• Chip samples would be collected at one metre intervals and lithologically logged to AS1726-1993 standards (the Australian Standard for Geotechnical Site Investigations).

• Upon completion, the hole will be fully cased with 155 mm i.d. PN12 uPVC, with machine screened liners set opposite the main water bearing zones;

• The top metre of the hole will be cased with blank casing. The hole annulus will be backfilled with 8/16 gravel to within 1 m of surface. The remaining hole annulus will be cement grouted to surface and will include a 200 mm thick concrete plinth;

• The hole will be developed by air for a minimum of 2 hrs or until the discharge runs clear;

• Upon completion of the bore, the hole will be hydraulically pump tested using a combination of steps and constant rate. Baseline water samples will be collected at the end of the pump testing and submitted to a NATA registered laboratory for analysis of major ions and trace metals; and

• All construction materials are to be durable under hypersaline (14,000-250,000 mg/L TDS) and acid (pH 5 to 7) conditions.
Note that the borefield concept and bore specifications described above are intended for preliminary planning only, are subject to the further testing described in Section 4.1 above and are not intended for detailed design and construction.

4.3 Monitoring and Operations

As part of the further DFS investigations, Toro will prepare a detailed Operating Strategy according to Department of Water Operational Policy 5.08 – Use of operating strategies in the water licensing process. Some suggested borefield operating objectives will be to:

- ensure that injected water does not daylight on the land surface;
- spread the reinjection as widely as possible to maximise the volume of water that can be managed through the system;
- minimise inefficient recirculation of water between the reinjection system and active mine dewatering; and
- maintain operational effectiveness of the borefield through a bore rehabilitation program

To achieve the maximum permissible reinjection capacity would require real time monitoring and reinjection control based on a network of water level observation bores both in the reinjection area and across the low lying areas of the lake surface. For this purpose an observation bore should be located adjacent to each reinjection site to monitor the degree of clogging and actual water level conditions without injection water losses. To manage and monitor water level rise in the low-lying playa areas, observation bores should also be located in the lowest lying central lake areas, indicatively at least every kilometre along the lake.

Injection would be best managed with a telemetered monitoring and control system to ensure that the maximum volume of water can be injected without causing unacceptable environmental impacts. The system would continuously monitor water levels in the lake area and around the reinjection borefield and automatically close off reinjection bores as the water table rises close to trigger levels set near the land surface. Trigger levels near the active mine areas could be set to minimise recirculation impacts on pit dewatering, with reinjection bores in the vicinity of active mining areas automatically shut off. The absolute trigger levels for turning off or restarting reinjection points would be determined through long term testing in the staged development program.

The progressive changes in the efficiency of reinjection bores could be continuously monitored by comparing reinjection well losses against the mounding levels in the nearest observation bore, plotted against the volume of water injected at the site. The results would inform maintenance and remediation scheduling.
5. CONCLUSIONS

Toro is seeking to develop the Wiluna Uranium Project south of Wiluna in Western Australia. In April 2013, Toro was granted environmental approval to construct and operate a uranium mine at the Centipede and Lake Way deposits. Toro is now seeking to expand the approvals to include additional deposits at Millipede and Lake Maitland.

The Lake Maitland deposits are partially beneath the water table and will require dewatering. Toro proposes to reuse as much of the dewatering discharge as possible in the operational water supply, and to reinject the surplus water in the same calcrete formation that is to be dewatered.

Pennington Scott was engaged to investigate the hydrogeological capacity for reinjection at the Lake Maitland project, building on previous hydrogeological investigation work at Lake Maitland by Golder and RPS Aquaterra. The groundwater reinjection investigation included:

- Construction and pump testing of three test production water bores and six monitor bores in the permeable shallow calcrete aquifer and underlying fluvial lacustrine clay and sand sequence;
- An 11 day simultaneous bore pumping and bore reinjection trial; and
- Simulation of injection scenarios in a sub-regional finite element numerical groundwater model, calibrated against the field observations from the trial reinjection program.

The key findings of these investigations were that:

- Injection trials demonstrate that it is possible to inject water into bores in the calcrete aquifer at several litres per second for more than 10 days;
- The calcrete aquifer is very permeable and facilitates a spread of mounding in water levels in response to reinjection.
- Over longer periods, to ensure that the already shallow water table does not daylight at the surface in the low-lying areas, the hydrogeological limitation on reinjection quantity is the soil evaporation capacity in the low-lying playa areas.

A conceptual borefield comprising 24 bores strategically located over the project area was modelled to be able to sustain 1 GL/year of injection over 6 years while limiting water table rise to less than 1 m in the low-lying playa areas. The model was sensitive to assumptions on soil evaporation rates and was based on data from Lake Amadeus (NT) in a similar climate zone. Should soil evaporation be lower, it may be necessary to spread the borefield over a larger area.

Operational constraints for reinjection include:

- Significant spatial hydraulic variability in the calcrete aquifer;
- Potential ephemeral water level mounding due to flood recharge in the lake sediments which may temporarily reduce injection capacity following larger rainfall events; and
- High likelihood of bore clogging over time, posing operational difficulties and costs.

To address these operational factors and soil evaporation uncertainty, a staged development and testing program is required including:
• Long-term testing of clogging rates and clogging risk assessment, testing of a range of injection methods, and clogging remediation trials as part of further Definitive Feasibility Study (DFS) investigations;

• Investigations to characterise calcrete aquifer spatial variability in the proposed injection areas as part of DFS; and

• Development of the injection scheme in stages, with remodelling between stages and adaptive design and management in response to the performance of each stage.
6. REFERENCES


Geoscience Australia 2011. 1 second shuttle radar topography mission (SRTM) digital elevation model.


Pennington Scott 2015a Lake Maitland Uranium Project – Bore Completion Report Rev 1 2078
Pennington Scott 2015b Lake Maitland Uranium Project – Reinjection Modelling Report Rev 1 2078


WA Wardens Court. 2007. Murrin Murrin Holdings Pty Ltd and Anor v. St Barbara Mines Ltd [2007] WAMW 4
Appendix A

Bore Completion Report
This report has been prepared on behalf of and for the exclusive use of Toro Energy Limited, and is subject to and issued with the agreement between Toro Energy Limited and Pennington Scott. Pennington Scott accepts no liability or responsibility whatsoever for it in respect of any use or reliance upon this report by any third party.

This report deals with and is based on geoscience data. Geoscience data are by their nature limited measurements, and interpretation of the data is necessarily based on interpolation, extrapolation and/or estimation. All interpretation of geoscience data therefore includes uncertainty. Substantial contingency for this uncertainty should be allowed for in any use of the information presented in this report.

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<td>7 May 15</td>
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1. INTRODUCTION

Toro Energy Limited ("Toro") is seeking to develop the Wiluna Uranium Project south of Wiluna. In April 2013, both the Western Australian Minister for Environment and the Federal Minister for Sustainability, Environment, Water, Population and Communities granted Toro Energy environmental approval to construct and operate a uranium mine consisting of two deposits, Centipede and Lake Way, respectively located approximately 30 kilometres (km) south and 15 km south-east of Wiluna. Toro is now seeking to extend the approvals to include mining of two additional deposits, Millipede and Lake Maitland, as well as the construction of a haul road and associated infrastructure.

The Lake Maitland project (hereinafter referred to as “the Project”) was acquired by Toro from Mega Uranium Limited in November 2013, after the assessment for the Centipede and Lake Way deposits was completed. The uranium mineralisation is hosted in calcrete which are partially beneath the water table. Toro has developed dewatering and water management strategies, which include a proposal to reinject dewatering discharge back into the same calcrete formation that is being mined as a contingency surplus water management option.

Pennington Scott was engaged by Toro to undertake the necessary field investigations and develop a numerical model to investigate the hydrogeological potential for reinjection at Lake Maitland.

The contained factual report documents the bore construction, testing and monitoring results of a groundwater reinjection field trial conducted in the calcrete aquifer from December 2014 to January 2015 as part of the groundwater reinjection study at Lake Maitland.

The 2014/15 field investigation program for the reinjection study included:

- **Test Production Bores**: Three (3) test production bores were drilled and constructed. The holes were cased with 205 mm or 150 mm I.D. PN12 PVC-U with machine slotted liners and/or stainless steel screens adjacent to the water bearing zones;

- **Monitoring Bores**: Six (6) monitoring bores were drilled and cased with 50 mm I.D. PN9 PVC-U and constructed with machine slotted liners adjacent to the water bearing zones;

- **Hydraulic Aquifer Testing**: The test production bores were hydraulically tested during January 2015. Tests included step drawdowns, 24 hour constant rate tests (CRT) and recovery measurements. Observation measurements were taken in the nearest observation bores during each CRT test. In addition, a long-term (11 day) pumping and groundwater reinjection trial was conducted, while the observation bores were monitored during the test.

- **Groundwater Chemistry**: Three (3) production bores were sampled during hydraulic testing. Samples were submitted to a NATA registered chemical laboratory for analysis of major ions, major metals and other laboratory parameters.
2. DRILLING AND BORE CONSTRUCTION

To investigate the potential for groundwater reinjection for the Project, three (3) test production sites were selected at Lake Maitland on the basis that:

- The sites would be in the southern end of the mining lease and in the same lacustrine units as the proposed mining and reinjection activities would occur;
- All sites would be located within 500 m of each other to allow for practical piping between pumping and reinjection bores;
- All bores would be screened in the shallow sediments (less than 30 m depth);
- Bores would be located on existing drill tracks to minimize new disturbance; and
- If practicable, sites to be located close to previous testing and observation bores.

Drilling contractor Kimberley Water Pty Ltd was engaged to undertake all drilling and construction works, while Pennington Scott performed the hydraulic well testing. Bore construction was largely in accordance with the national standard for minimum construction requirements, with all field operations being under the direct supervision of a Pennington Scott hydrogeologist.

Following a heavy rain storm just prior to commencing the lake drilling program, the proposed drill sites were moved away from the edge of the lake due to trafficability issues (see Figure 2-1). The final production sites are marked on Figure 2-3 as sites LKM_1P1, LKM_2P1 and LKM_3P1.

*Figure 2-1  Accessibility issues travelling on the lake surface.*
Table 2-1 contains the summary details of bores constructed for the Project groundwater reinjection study. Completion logs for these bores are included in Appendix A. All construction and testing protocols at each site were as follows:

- **Test Production bores:** A 350 mm (14") diameter mud rotary hole was drilled to nominal depth of 2 m, and cased with 311 mm (12 3/4") I.D. temporary steel surface casing. A pilot hole was then drilled to a nominal depth of 30 m or until recognisable clay basement. On completion of the pilot hole, the hole was lithologically logged to AS1726-1993 (the Australian Standard for Geotechnical Site Investigations) based on chip samples collected every metre. Each hole was then cased with either 205 mm or 150 mm I.D. PN12 PVC-U casing, with a combination of 205 mm I.D. wire wrapped stainless steel screen (1.0 mm aperture), and/or machine slotted PN12 PVC-U liners set opposite the main water bearing interval. A Quick-zip centraliser was used per length of casing. The hole annulus was then backfilled with 1.6 to 3.2 mm graded gravel to 1 m below ground and then cement grouted to 200 mm above surface with a lockable steel monument. The bores were then developed to remove any fines with an air compressor until the discharge ran clear. Figure 2.2 shows the drilling equipment set up on-site during drilling works.

- **Monitoring bores:** A 250 mm diameter mud rotary pilot hole was drilled to nominal depth of 12 m or until recognisable clay basement, which ever occurred first. The hole was then cased to full depth with machine slotted 50 mm I.D. PN9 PVC-U liners set opposite the main water bearing zones. A plastic plug was set 2 m below surface and then the top of the hole was sealed using A and B foam to prevent ingress of wildlife into the annulus of the hole. The casing was then developed with air for a minimum of 20 minutes or until the discharge ran clear.
Figure 2-3 Bore locations at Lake Maitland
### Table 2-1: Summary details of bore installations in January 2015 Toro Energy drilling program

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<th>Northing*</th>
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*GPS coordinates (not surveyed)*

**Measured by tape measure**
3. HYDRAULIC (AQUIFER) TESTING

To develop a thorough appreciation of the hydrogeological system and long-term aquifer performance during reinjection, it is necessary to assess the hydraulic (aquifer) properties of the lake deposits. In particular, the complex distribution of permeability and groundwater storage capacity are the main input parameters used to develop a numerical groundwater model.

There were two phases of aquifer testing at Lake Maitland:

- Three (3) step, constant rate and recovery tests were undertaken separately on the test production bores in during Dec 2014; and
- One 11 day simultaneous step pumping/reinjection trial was undertaken on LKM_3P1 and LKM_2P1 respectively in January 2015.

In each test a submersible electrical pump was installed. During the aquifer tests up to three step-drawdown tests were performed. The information from the step-drawdown tests was used to determine the constant discharge rate for the nominal 24 to 48 hour CRT, which was then followed by a period of recovery measurements. Groundwater level measurements were recorded manually and by automated data loggers during the pumping and recovery phases. Groundwater levels in surrounding observation bores were also monitored throughout the tests. Sections 3.1, 3.2 and 3.3 describe the test results.

Figure 3-1 shows the pumping bore set up. Pump test equipment includes a 4 inch Grundfos SP46-5 submersible pump (capable of delivering up to 16 L/s), 35KVA generator; automated smart pump with real-time telemetered monitoring, 4 inch inline ultrasonic flow meter with automatic flow actuator valve; backup inline helix flow meter; downhole automated water level meter with backup manual dip tube and dip meter.

Figure 3-1: Pumping test setup at Lake Maitland during January 2015 using satellite telemetry pump controller on production bore LKM_3P1
3.1 Step-Drawdown Test Results

Step-drawdown tests were conducted on all test production bores to determine the well efficiency and to select a rate for constant rate testing. Once the pump was installed, a short open flow pump calibration test was performed to find the maximum system flow. This was then divided into three to four incremental step rates.

A conventional continuous step-rate test approach was used, where each step rate was conducted for a period of 40 minutes from the lowest rate. At the end of each step, the rate was increased to the next highest step rate without a break until the final rate was completed. The hole was then left to recover for at least 12 hours before a constant rate test was started.

The step test results were then analysed to determine the well efficiency parameters using the Rorabaugh equation. Test results are displayed in Table 3-1.

<table>
<thead>
<tr>
<th>Bore</th>
<th>Date</th>
<th>Pump Setting (mbtoc)</th>
<th>Step Test Rates (kL/day)</th>
<th>Well Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LKM_1P1</td>
<td>10/01/2015</td>
<td>21.5</td>
<td>130; 216, 302, 432</td>
<td>91, 86, 82, 76</td>
</tr>
<tr>
<td>LKM_2P1</td>
<td>13/01/2015</td>
<td>21.5</td>
<td>432; 864; 1296</td>
<td>60, 43, 33</td>
</tr>
<tr>
<td>LKM_3P1</td>
<td>14/01/2015</td>
<td>21</td>
<td>432; 864; 1296</td>
<td>67, 51, 41</td>
</tr>
</tbody>
</table>

3.2 Constant Rate Aquifer Test (CRT)

3.2.1 Pumping Bores

The 24 hour constant rate pumping tests (CRT) were used to determine near well hydraulic conductivities and likely aquifer boundary and leakage influences. The CRT test rate was chosen by using the results of the step rate test to extrapolate the rate most likely to achieve 80% of the total available drawdown by the end of the CRT. Each CRT test was followed by a period of recovery measurements, nominally 2 hours.

Time-drawdown/recovery plots for all CRT’s conducted during January 2015 at Lake Maitland are presented in Appendix B and summarised in Table 3-2.

These plots generally show an initial high rate of drawdown in the first several minutes due to well loss effects, usually followed by a period of straight-line logarithmic drawdown. The slope of the straight-line response is a function of the abstraction rate and the aquifer transmissivity, which is estimated using methods such as the Cooper-Jacob time-drawdown analysis. The aquifer permeability (hydraulic conductivity) is calculated by dividing the transmissivity by the screened aquifer interval.

The bore transmissivity is a product of the thickness and hydraulic conductivities of all aquifers intersected within the screened interval. In this case, the production bores are screened through both the calcrete aquifer and the low yielding clay and sand deposits beneath the calcrete. The estimated bore transmissivities were 29, 949 and 590 m²/day in LKM_1P1, LKM_2P1 and LKM_3P1 respectively.
The hydraulic conductivity of the lower aquifer is estimated to be between 1 and 2 m/day from previous work conducted by Golder (2011a; 2011b) and RPS Aquaterra (2010 and 2011). Therefore by removing the proportion of bore transmissivity due to the lower aquifer, Table 3-2 shows that the permeability of the calcrite aquifer can be calculated by dividing the remaining transmissivity by the saturated thickness of the calcrite. Assuming the sand and clay aquifer beneath the calcrite has a permeability (hydraulic conductivity) of around 1 to 2 m/day, the remaining 4 m of calcrite aquifer would have permeability of 1.8, 230 and 140 m/day in bores LKM_1P1 to LKM_3P1 respectively.

**Table 3-2 Summary of 24 hour CRT Results from pumped bores, with Cooper-Jacob analysis**

<table>
<thead>
<tr>
<th>Bore</th>
<th>Date</th>
<th>CRT Rate (kL/d)</th>
<th>Duration (mins)</th>
<th>Drawdown at end CRT (m)</th>
<th>Screen length below SWL (m)</th>
<th>Bore Transmissivity (m²/day)</th>
<th>Estimated Transmissivity of underlying clay/sand (m²/day)</th>
<th>Saturated calcrite thickness (m)</th>
<th>Estimated Calcrite hydraulic conductivity (m/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LKM_1P1</td>
<td>11/01/15</td>
<td>276</td>
<td>1440</td>
<td>9.7</td>
<td>26.3</td>
<td>29</td>
<td>22</td>
<td>4</td>
<td>1.8</td>
</tr>
<tr>
<td>LKM_2P1</td>
<td>13/01/15</td>
<td>1296</td>
<td>1440</td>
<td>2.9</td>
<td>22.2</td>
<td>949</td>
<td>18 to 36</td>
<td>4</td>
<td>230</td>
</tr>
<tr>
<td>LKM_3P1</td>
<td>15/01/15</td>
<td>959</td>
<td>1440</td>
<td>11.4</td>
<td>22.4</td>
<td>590</td>
<td>18 to 36</td>
<td>4</td>
<td>140</td>
</tr>
</tbody>
</table>

**Figure 3-2: Example of 24 hour CRT test on pumping bore LKM_1P1**
4. LONG-TERM REINJECTION TRIAL

The long-term (11 day) pump test was undertaken on bore LKM_3P1, with a simultaneous long-term groundwater reinjection test conducted on bore LKM_2P1 within the same calcrete formation.

The reinjection head works included a real-time telemetered ARAD helix and ultrasonic flow meters and downhole pressure transducer, together with manual gate valve, one way air release valve, head works pressure gauge, sealable manual dip tube and 100 m of lay flat hose (Figure 4-1). While the head works was rated to 1800 kPa, the working pressure of the entire reinjection setup was rated to 400 kPa, being the working pressure of the lay flat hose.

For this test, based on the results of the CRT tests, the test was set to maintain a constant pumping/reinjection flow rate of 3 L/s for two days, 6 L/s for two days and then 9 L/s for 7 days. The operator reduced the third test rate to 8 and then to 7.5 L/s after one day due his concern about exceeding the maximum line pressure. The telemetry was programmed to post its measured instantaneous flow rate, back pressure, flow actuator position to an internet site every fifteen minutes, where the test performance was monitored by Pennington Scott in Perth.
In addition to the pumping and reinjection bores, automated water level monitoring was also undertaken in six monitoring bores located about 5, 15 and 50 m away from each of the pumping and reinjection bores. All bores were manually monitored and six existing bores also had continuous monitoring using ‘Keller’ loggers. There was also a Keller logger recording barometric pressure throughout the test.

The monitoring protocol was as follows:

- Automatic water level loggers in the two test bores (LKM_2P1 and LKM_3P1) and four observation holes (LKM_2M3, LKM_2M2, LKM_3M2, and LKM_3M3) were set to record water levels at 15 min intervals throughout the test starting at 3:00pm on 20 January 2015, being the day prior to the start of the test;

- Manual water levels were obtained in test bores LKM_2P1 and LKM_3P1 at the following intervals restarting at each change in rate and at the start of recovery:
  - 1 minute intervals for the first 6 minutes; then
  - 2 minute intervals for the up to 12 minutes; then
  - 3 minute interval for the up to 15 minutes; then
  - 5 minute intervals for the up to 30 minutes; then
  - 10 minute intervals for the up to 120 minutes; then
  - 30 minute intervals for the up to 240 minutes; then
  - 60 minute intervals for the up to 600 minutes; and then
  - 120 minute intervals thereafter.

- Manual water levels were obtained in all six (6) observation bores LKM_2M2, LKM_2M3, LKM_2M4, LKM_3M2, LKM_3M3 and LKM_3M4 at the same intervals starting 20 minutes after each step;

- Flow readings were measured continuously and automatically adjusted to pre-set step rates every 100 litres in production bore LKM_3P1. Flow, EC and pH readings were monitored by the Smartpump and reported by satellite telemetry back to base every 15 minutes.

4.1 Monitoring results

A summary of drawdowns in the monitor bores with respect to the radius from both pumping and reinjection bores is shown in Table 4-1, while groundwater hydrographs and flow measurements in the production and injection bores are summarised in Figure 4-2 and Figure 4-3.

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Bore Status</th>
<th>Radius from pumping bore (m)</th>
<th>Radius from reinjection bore (m)</th>
<th>Drawdown at end of test (m)</th>
<th>Logging method</th>
</tr>
</thead>
<tbody>
<tr>
<td>LKM_2P1</td>
<td>Injection Bore</td>
<td>105</td>
<td>0</td>
<td>-1.71</td>
<td>Keller logger</td>
</tr>
<tr>
<td>LKM_2M2</td>
<td>Monitoring</td>
<td>109</td>
<td>4*</td>
<td>-0.26</td>
<td>VWP</td>
</tr>
<tr>
<td>LKM_2M3</td>
<td>Monitoring</td>
<td>114</td>
<td>16*</td>
<td>-0.34</td>
<td>Keller logger</td>
</tr>
<tr>
<td>LKM_2M4</td>
<td>Monitoring</td>
<td>133</td>
<td>41*</td>
<td>-0.27</td>
<td>Manual dip</td>
</tr>
<tr>
<td>LKM_3P1</td>
<td>Pumping Bore</td>
<td>0</td>
<td>105</td>
<td>2.46</td>
<td>BCM logger</td>
</tr>
<tr>
<td>LKM_3M2</td>
<td>Monitoring</td>
<td>4*</td>
<td>103</td>
<td>0.35</td>
<td>Keller logger</td>
</tr>
<tr>
<td>LKM_3M3</td>
<td>Monitoring</td>
<td>18*</td>
<td>98</td>
<td>0.40</td>
<td>Keller logger</td>
</tr>
<tr>
<td>LKM_3M4</td>
<td>Monitoring</td>
<td>44*</td>
<td>94</td>
<td>-0.02</td>
<td>Manual dip</td>
</tr>
</tbody>
</table>

*Measured with tape measure. All other radii are calculated from GPS coordinates and are therefore approximate.
Figure 4-2: Groundwater hydrographs along pumping line – pumping bore LKM_3P1

Figure 4-3: Groundwater hydrographs along reinjection line – reinjection bore LKM_2P1
4.2 Clogging Assessment

All injection bores are subject to some degree of clogging over time due to the build-up of precipitates, microbial growth and/or physical contaminants such as silt on the bore screens and near well aquifer. The periodic bore remediation approach and frequency of treatments is determined by the nature of the clogging materials (i.e. whether chemical, biological or physical) and the rate of clogging.

The risk of clogging was minimised during the reinjection trials by:

- proper development of both reinjection and pumping bores to ensure minimal fines in the pumping discharge;
- pumping directly from the pumping bore to the reinjection bore to ensure minimal change in redox potential between the pumping and reinjection sites;
- ensuring the pumping and reinjection sites had similar hydro-chemistry;
- inclusion of an air release valve on the reinjection head works to allow escape of air in the pipework; and
- the reinjection column being inserted 5 m below the water table to avoid cascading and minimise turbulence and air entrainment in the bore;

Having taken these precautions, Figure 4-4 shows an assessment of observed clogging in the injection bore LKM_2P1 at increasing flow rates of 3, 6 and 7.5 L/sec during the injection test. Since clogging occurs in the reinjection bore itself, the degree of clogging can be inferred by comparing the head difference between in the reinjection bore and a nearby observation bore, in this case LKM_2M2. The rate of clogging experienced during the test is expressed in metres of additional head loss in the reinjection bore as a function of both time (in days) and flow rate (in L/s). Figure 4-5 takes these results a step further and compares the specific rate of clogging (i.e. m of head loss/ L/s/ day) versus flow rate.

Reference to this figure suggests the reinjection efficiency marginally decreased when the flow rate was doubled from 3 to 6 L/s (i.e. the rate of specific head loss increased from 3 mm/day/L/s to 4 mm/day/L/s), however the efficiency halved (i.e. the rate of specific head loss increased from 4 mm/day/L/s to 8 mm/day/L/s) when the flow rate was increased by another quarter from 6 L/s to 7.5 L/s.
Figure 4-4: Approximation of short term clogging versus flow rate in the injection bore based on the differential head in the injection bore LKM_2P1 less the head in nearby observation bore LKM_2M2.

Figure 4-5: Relationship between the observed rate of clogging during the 11 day test versus the flow rate.
5. WATER QUALITY ANALYSES

Groundwater samples were taken from each test production bore during the constant rate pumping test and sent to the National Measurement Institute, NATA registered laboratory, for chemical analyses. All samples were analysed for major and minor ions, metals and physical parameters. Laboratory results are provided Appendix C and are summarised in Table 5-1.

### Table 5-1: Water quality results for test production bores

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sym</th>
<th>Unit</th>
<th>LOR</th>
<th>LKM 3P1 18-Jan-15</th>
<th>LKM 2P1 19-Jan-15</th>
<th>LKM 1P1 17-Jan-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date sampled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conductivity at 25C</td>
<td>EC</td>
<td>uS/cm</td>
<td>&lt;10</td>
<td>130,000</td>
<td>103,000</td>
<td>143,000</td>
</tr>
<tr>
<td>Total Dissolved Solids (Evap)</td>
<td>TDS</td>
<td>mg/L</td>
<td>&lt;10</td>
<td>122,000</td>
<td>90,100</td>
<td>142,000</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
<td>7.2</td>
<td>7.3</td>
<td>7</td>
</tr>
<tr>
<td>Ion Balance</td>
<td></td>
<td></td>
<td></td>
<td>0.93</td>
<td>0.96</td>
<td>0.95</td>
</tr>
<tr>
<td>TOC as NPOC</td>
<td>TOC</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Major Ions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron - Total</td>
<td>Fe</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>0.19</td>
<td>0.051</td>
<td>0.67</td>
</tr>
<tr>
<td>Sodium - Filterable</td>
<td>Na</td>
<td>mg/L</td>
<td>&lt;10</td>
<td>37,000</td>
<td>27,000</td>
<td>43,000</td>
</tr>
<tr>
<td>Chloride</td>
<td>Cl</td>
<td>mg/L</td>
<td>&lt;10</td>
<td>66,000</td>
<td>47,000</td>
<td>73,000</td>
</tr>
<tr>
<td>Magnesium - Filterable</td>
<td>Mg</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>4,000</td>
<td>2,700</td>
<td>4,700</td>
</tr>
<tr>
<td>Sulphate</td>
<td>SO4</td>
<td>mg/L</td>
<td>&lt;5</td>
<td>16,000</td>
<td>11,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Bicarbonate as CaCO3</td>
<td>HCO</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>100</td>
<td>130</td>
<td>82</td>
</tr>
<tr>
<td>Calcium - Filterable</td>
<td>Ca</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>900</td>
<td>950</td>
<td>840</td>
</tr>
<tr>
<td>Carbonate as CaCO3</td>
<td>CO3</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Fe</td>
<td>mg/L</td>
<td>&lt;0.2</td>
<td>0.36</td>
<td>0.48</td>
<td>0.33</td>
</tr>
<tr>
<td>Nutrients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia as NH3-N</td>
<td>NH3</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Nitrate as NO3-N</td>
<td>NO3</td>
<td>mg/L</td>
<td>&lt;0.2</td>
<td>110</td>
<td>100</td>
<td>130</td>
</tr>
<tr>
<td>Potassium - Filterable</td>
<td>P</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>2,600</td>
<td>2,000</td>
<td>2,900</td>
</tr>
<tr>
<td>Silica as SiO2</td>
<td>SiO2</td>
<td>mg/L</td>
<td>&lt;0.002</td>
<td>19</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>Total Nitrogen (Calc)</td>
<td>N</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>110</td>
<td>100</td>
<td>130</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>P</td>
<td>mg/L</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Trace Metals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium - Total</td>
<td>Al</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>0.24</td>
<td>0.03</td>
<td>0.83</td>
</tr>
<tr>
<td>Arsenic - Total</td>
<td>As</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Barium - Total</td>
<td>Ba</td>
<td>mg/L</td>
<td>&lt;0.001</td>
<td>0.022</td>
<td>0.041</td>
<td>0.021</td>
</tr>
<tr>
<td>Beryllium - Total</td>
<td>Be</td>
<td>mg/L</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Boron - Total</td>
<td>B</td>
<td>mg/L</td>
<td>&lt;0.010</td>
<td>16</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Cadmium - Total</td>
<td>Cd</td>
<td>mg/L</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Chromium - Total</td>
<td>Cr</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Cobalt - Total</td>
<td>Co</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Copper - Total</td>
<td>Cu</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.011</td>
</tr>
<tr>
<td>Lead - Total</td>
<td>Pb</td>
<td>mg/L</td>
<td>&lt;0.001</td>
<td>0.002</td>
<td>0.001</td>
<td>0.013</td>
</tr>
<tr>
<td>Manganese - Total</td>
<td>Mn</td>
<td>mg/L</td>
<td>&lt;0.001</td>
<td>0.098</td>
<td>0.017</td>
<td>0.25</td>
</tr>
<tr>
<td>Molybdenum - Total</td>
<td>Mo</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>0.06</td>
<td>0.059</td>
<td>0.064</td>
</tr>
<tr>
<td>Nickel - Total</td>
<td>Ni</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Selenium - Total</td>
<td>Se</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>0.14</td>
<td>0.12</td>
<td>0.17</td>
</tr>
<tr>
<td>Silver - Total</td>
<td>Ag</td>
<td>mg/L</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tin - Total</td>
<td>Sn</td>
<td>mg/L</td>
<td>&lt;0.010</td>
<td>&lt;0.010</td>
<td>&lt;0.010</td>
<td>0.017</td>
</tr>
<tr>
<td>Uranium - Total</td>
<td>U</td>
<td>mg/L</td>
<td>&lt;0.002</td>
<td>0.09</td>
<td>0.14</td>
<td>0.033</td>
</tr>
<tr>
<td>Zinc - Total</td>
<td>Zn</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>0.018</td>
<td>0.18</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Appendix A

Bore Completion Logs
**Borehole: LKM_1P1**

**Project:** Lake Maitland Uranium Project  
**Zone:** 51 (UTM)  
**Client:** Toro Energy  
**Location:** Lake Maitland

**Total Depth:** 28 m  
**Logged By:** Michael Eaton  
**SWL:** 1.69 m (toc) on 17/01/2015  
**Elevation:** (mAHDL)  
**Checked By:** Don Scott  
**Salinity:** 142000 mg/L on 17/01/2015  
**Logger:** Michael Eaton  

### Lithology

- **Ground Surface**
  - GW sandy fine GRAVEL, well graded, loose, angular, qtz lithic brown.
  - CL sandy CLAY, soft, low plasticity pale cream, with trace SA calcite and SA lithic chips.
  - Calcisiltite granular massive CALCRETE, pale brown, medium strength distinctly weathered.
  - CH CLAY with trace fine gravel, firm, medium plasticity brown.
  - CH CLAY with coarse sand, very stiff, low plasticity brown.
  - SM silty fine SAND, pale brown.
  - CH CLAY with coarse sand, firm, medium plasticity pale reddish brown.
  - CL CLAY with trace coarse sand, very soft, low plasticity pale reddish brown.
  - CH CLAY with coarse sand, soft, high plasticity pale reddish brown.

### Bore Construction

- **Ground Surface**
  - 205 mm Stainless steel screen
  - 205 mm PVC slotted class12 screen
  - 311 mm Steel surface casing
  - 205 mm PVC slotted class12 screen
  - Cement fill
  - Gravel fill

---

**Drilling Company:** Kimberley Water Pty Ltd  
**Drilling Equipment:** RAB - Mud Rotary  
**Drilling Method:** Mud  
**Started:** 5/01/2015  
**Completed:** 5/01/2015

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**Borehole: LKM_2M2**

**Project:** Lake Maitland Uranium Project

**Client:** Toro Energy

**Location:** Lake Maitland

**Zone:** 51 (UTM)

**Elevation:** (mAHDP)

**Total Depth:** 12 m

**Easting:** 310259

**Northing:** 6992275

**SWL:** 2.1 m (toc) on 13/01/2015

**Logged By:** Michael Eaton

**Salinity:** 50280 mg/L on 13/01/2015

**Checked By:** Don Scott

---

**Ground Surface**

- **CH CLAY** with fine sand, soft, medium plasticity brown.
- **SW gravelly coarse SAND** well graded, loose, SA, qtz lithic brown.

**CH CLAY** with coarse sand, medium plasticity brown.

**CH CLAY** with trace coarse sand, soft, medium plasticity brown.

---

**Compiled:**

GPO Box A10 Perth WA 6849

T: +618 9446 7090

www.penningtonscott.com.au

---

**Drilling Company:** Kimberley Water Pty Ltd

**Drilling Equipment:** RAB - Mud Rotary

**Drilling Method:** Mud

**Started:** 4/01/2015

**Completed:** 4/01/2015

---

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Borehole: LKM_2M3

Project: Lake Maitland Uranium Project
Client: Toro Energy
Location: Lake Maitland

Zone: Project: Z1 (UTM)
Easting: 310243
Northing: 6992281
SWL: 2.02 m (toc) on 13/01/2015
Logged By: Michael Eaton
Total Depth: 12 m
Salinity: 46680 mg/L on 13/01/2015
Checked By: Don Scott

SUBSURFACE PROFILE

Lithology

Depth (m)

0
10
20
30
40
50

Ground Surface
SM silty coarse SAND well graded, loose, SR, qtz lithic brown, with trace fine gravel
GW fine GRAVEL with trace clay well graded, loose, SR, qtz lithic dark brown.
GW-GS fine GRAVEL with fine sand well graded, loose, SR, qtz lithic pale brown.
CH CLAY with coarse sand, soft, medium plasticity brown.
CH CLAY with trace med sand, soft, high plasticity brown.
CH sandy CLAY, very soft, high plasticity brown.
SC clayey coarse SAND uniformly graded, medium dense, qtz lithic brown.

Lithology Graphic

Bore Construction

Drilling Company: Kimberley Water Pty Ltd
Drilling Equipment: RAB - Mud Rotary
Drilling Method: Mud

Started: 4/01/2015
Completed: 6/05/2015
Borehole: LKM_2M4

**Project**: Lake Maitland Uranium Project
**Client**: Toro Energy
**Location**: Lake Maitland

**Zone**: 51 (UTM)  **Easting**: 310225  **Total Depth**: 12 m
**Northing**: 6992276  **Logged By**: Michael Eaton

**SWL (toc)**: 1.9 m on 13/01/2015  **Logged By**: Michael Eaton
**Salinity**: 44820 mg/L on 13/01/2015  **Checked By**: Don Scott

**Ground Surface**
- CH sandy CLAY, very soft, high plasticity reddish brown
- GW fine GRAVEL, with trace clay well graded, loose, rounded, qtz lithic brown speckled black
- GW sandy fine GRAVEL, well graded, loose, SR, qtz lithic pale brown, with trace lithic fine gravel, with trace calcrete chips
- CH CLAY with coarse sand, medium plasticity yellowish brown, with trace calcrete chips
- CH CLAY with trace coarse sand, very soft, high plasticity pale brown
- CH CLAY with coarse sand, very soft, medium plasticity pale brown
- SC clayey med SAND, uniformly graded, medium dense, qtz lithic pale brown

**Bore Construction**
- 55.15 mm PVC slotted class 9 screen
- No fill
- Cement fill

**Drilling Company**: Kimberley Water Pty Ltd
**Drilling Equipment**: RAB - Mud Rotary
**Drilling Method**: Mud
**Started**: 4/01/2015
**Completed**: 4/01/2015

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**Borehole: LKM_2P1**

**Project:** Lake Maitland Uranium Project  
**Zone:** 51 (UTM)  
**Client:** Toro Energy  
**Location:** Lake Maitland  
**Easting:** 310260  
**Northing:** 6992276  
**SWL:** 1.89 m (toc) on 19/01/2015  
**Logged By:** Michael Eaton  
**Salinity:** 90100 mg/L on 19/01/2015  
**Checked By:** Don Scott  
**Total Depth:** 24 m  
**Elevation:** (mAHID)  

**SUBSURFACE PROFILE**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Lithology</th>
<th>Bore Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SW gravelly coarse SAND well graded, loose, SR, qtz lithic black speckled brown.</td>
<td>Ground Surface</td>
</tr>
<tr>
<td></td>
<td>GW sandy fine GRAVEL well graded, loose, SR, qtz lithic black speckled brown.</td>
<td>149 mm PVC slotted class12 screen</td>
</tr>
<tr>
<td>10</td>
<td>GW sandy fine GRAVEL well graded, loose, SR, calcareous pale brown, with weakly cemented calcrete</td>
<td>250 mm Steel surface casing</td>
</tr>
<tr>
<td>20</td>
<td>SC clayey coarse SAND well graded, loose, SR, qtz lithic pale brown, with weakly cemented calcrete</td>
<td>Cement fill</td>
</tr>
<tr>
<td></td>
<td>SC clayey coarse SAND well graded, loose, SR, qtz lithic brown, with trace SR fine gravel</td>
<td>Gravel fill</td>
</tr>
<tr>
<td></td>
<td>CH CLAY with trace coarse sand, very soft, high plasticity brown.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>CH CLAY with trace coarse sand, firm, high plasticity brown.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CL CLAY with trace coarse sand, very stiff, low plasticity brown.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH CLAY with coarse sand, soft, high plasticity brown.</td>
<td></td>
</tr>
</tbody>
</table>

**Drilling Company:** Kimberley Water Pty Ltd  
**Drilling Equipment:** RAB - Mud Rotary  
**Drilling Method:** Mud  
**Started:** 4/01/2015  
**Completed:** 6/05/2015  

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### Borehole: LKM_3M2

**Project:** Lake Maitland Uranium Project  
**Zone:** 51 (UTM)  
**Client:** Toro Energy  
**Location:** Lake Maitland  
**Easting:** 310294  
**Northing:** 6992180  
**Total Depth:** 12 m  
**Logged By:** Michael Eaton  
**Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994.**  
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#### Subsurface Profile

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Lithology</th>
<th>Bore Construction</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>Ground Surface</td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>SW coarse SAND with trace clay, well graded, loose, SR, qtz lithic brown.</td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>CH CLAY, soft, medium plasticity brown.</td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>GC clayey fine GRAVEL well graded, loose, SR, qtz lithic pale brown.</td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>CL CLAY, very stiff, low plasticity very pale brown.</td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>CL CLAY with trace coarse sand, stiff, low plasticity brown.</td>
<td></td>
</tr>
<tr>
<td>10-20</td>
<td>No fill</td>
<td></td>
</tr>
</tbody>
</table>

**Drilling Company:** Kimberley Water Pty Ltd  
**Drilling Equipment:** RAB - Mud Rotary  
**Drilling Method:** Mud  
**Started:** 2/01/2015  
**Completed:** 6/05/2015
**Borehole: LKM_3M3**

<table>
<thead>
<tr>
<th>Project: Lake Maitland Uranium Project</th>
<th>Zone: 51 (UTM)</th>
<th>Elevation: (mAHDI)</th>
<th>Total Depth: 12 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client: Toro Energy</td>
<td>Easting: 310281</td>
<td>SWL: 1.77 m (toc) on 15/01/2015</td>
<td>Logged By: Michael Eaton</td>
</tr>
<tr>
<td>Location: Lake Maitland</td>
<td>Northing: 6992176</td>
<td>Salinity: 48060 mg/L on 15/01/2015</td>
<td>Checked By: Don Scott</td>
</tr>
</tbody>
</table>

**SUBSURFACE PROFILE**

- **Ground Surface**
  - GW sandy fine GRAVEL well graded, loose, SR, qtz lithic brown, with trace medium gravel
  - GW-GC fine GRAVEL, with clay well graded, loose, SR, qtz lithic pale brown.
  - CH CLAY with coarse sand, stiff, medium plasticity brown.
  - CH CLAY with coarse sand, very soft, high plasticity.

**Lithology**

**Bore Construction**

- **SWL (toc) 1.77 m**
- **55.15 mm PVC slotted class 9 screen**
- **No fill**
- **Cement fill**

**Drilling Company:** Kimberley Water Pty Ltd
**Drilling Equipment:** RAB - Mud Rotary
**Drilling Method:** Mud

- **Started:** 3/01/2015
- **Completed:** 3/01/2015
- **Compilation:** 6/05/2015
Borehole: LKM_3M4

Project: Lake Maitland Uranium Project
Client: Toro Energy
Location: Lake Maitland

Depth (m) | Lithology Graphic
--- | ---
0 | Ground Surface
| SM silty coarse SAND poorly graded, loose, SR, qtz lithic brown
| MH SILT with trace clay, very soft, medium plasticity brown speckled black, with trace lithic gravel, with trace coarse sand
| CL gravelly CLAY, soft, low plasticity very pale brown speckled white
| CH CLAY with coarse sand, soft, high plasticity brown
| CH CLAY with trace coarse sand, soft, high plasticity brown
| SC clayey coarse SAND gap graded, loose, SR, qtz lithic pale brown

SWL (toc) 1.8 m

Logged to Australian Standard: Geotechnical Site Investigations AS 1726-1993/Amdt 2-1994

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Drilling Company: Kimberley Water Pty Ltd
Drilling Equipment: RAB - Mud Rotary
Drilling Method: Mud

Started: 3/01/2015
Completed: 6/05/2015
**Borehole: LKM_3P1**

**Project:** Lake Maitland Uranium Project  
**Zbne:** S1 (UTM)  
**Elevation:** (mAHDI)  
**Total Depth:** 24 m

**Client:** Toro Energy  
**Easting:** 310302  
**SWL:** 1.89 m (toc) on 18/01/2015  
**Logged By:** Michael Eaton

**Location:** Lake Maitland  
**Northing:** 6992180  
**Salinity:** 122000 mg/L on 18/01/2015  
**Checked By:** Don Scott

---

**SUBSURFACE PROFILE**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Lithology</th>
<th>Bare Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ground Surface: SW coarse SAND with trace fine gravel well graded, loose, SR, qtz lithic dark brown.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SW-SC coarse SAND with clay well graded, loose, SR, qtz lithic dark brown, with trace SA gravel.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>GC clayey fine GRAVEL well graded, loose, SR, calcareous pale cream pale brown, with weakly cemented calcrete.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>CH CLAY with coarse sand, soft, medium plasticity pale brown, with trace medium angular gravel.</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>CH CLAY with coarse sand, very soft, high plasticity brown, with trace fine angular gravel.</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>CH CLAY with trace coarse sand, soft, medium plasticity brown.</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>CH CLAY with trace coarse sand, very soft, medium plasticity pale white mottled very pale brown.</td>
<td></td>
</tr>
</tbody>
</table>

---

**Drilling Company:** Kimberley Water Pty Ltd  
**Started:** 2/01/2015  
**Drilling Equipment:** RAB - Mud Rotary  
**Completed:** 2/01/2015  
**Drilling Method:** Mud  
**Compiled:** 6/05/2015

---

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Appendix B

Hydraulic Test Results
**STEP TEST ANALYSIS**

*LKM_1P1*

**Calculation of well efficiency using Rorbaugh equation**

\[ S = BQ + CQ^2 \]

- \( B = \) y intercept = 1.51E-02
- \( C = \) gradient = 1.12E-05
- \( S = \) drawdown in the bore

**Ew = \( \frac{BQ}{(BQ + CQ^2)} \times 100 \)**

<table>
<thead>
<tr>
<th>Step</th>
<th>( Q ) (kL/day)</th>
<th>( BQ )</th>
<th>( CQ^2 )</th>
<th>Ew (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>130</td>
<td>1.96</td>
<td>0.19</td>
<td>91</td>
</tr>
<tr>
<td>2</td>
<td>216</td>
<td>3.26</td>
<td>0.52</td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td>302</td>
<td>4.57</td>
<td>1.02</td>
<td>82</td>
</tr>
<tr>
<td>4</td>
<td>432</td>
<td>6.53</td>
<td>2.08</td>
<td>76</td>
</tr>
</tbody>
</table>
CONSTANT RATE TEST

LKM_1P1

DRAWDOWN PROJECTED TO 365 DAYS

Date of Test: 11-Jan-15
SWL at start: 1.7 mBTOC
Pump Setting: 21.5 mBTOC
L = Length of Screen = 26.3 m

Available drawdown above pump setting: 19.8 m
Max available drawdown in pump well: m

\[ T = \frac{2.3Q}{4\pi \Delta(h_0 - h)} \]

Q = Test Discharge = 276 kL/day
3.20 L/s
\( \Delta(h_0 - h) \) = Head change per log cycle = 1.75 m
T = Transmissivity = 28.9 m²/day

K = Hydraulic Conductivity = \( \frac{T}{L} \) = 1.10 m/day
STEP TEST ANALYSIS

$LKM_{2P1}$

**s** = step drawdown (m)

**Q** = bore discharge measured in kL/day

**Ew** = apparent well efficiency

**Calculation of well efficiency using Rorabaugh equation**

\[ S = BQ + CQ^2 \]

- **B** = y intercept = 3.87E-04
- **C** = gradient = 5.93E-07
- **S** = drawdown in the bore

**Ew** = \( \frac{BQ}{BQ + CQ^2} \times 100 \)

<table>
<thead>
<tr>
<th>Step</th>
<th>Q (kL/day)</th>
<th>BQ</th>
<th>CQ²</th>
<th>Ew (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>432</td>
<td>0.17</td>
<td>0.11</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>864</td>
<td>0.33</td>
<td>0.44</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td>1296</td>
<td>0.50</td>
<td>1.00</td>
<td>33</td>
</tr>
</tbody>
</table>
CONSTANT RATE TEST

LKM_2P1

DRAWDOWN PROJECTED TO 365 DAYS

Date of Test: 13-Jan-15
SWL at start: 19.7 m BTOC
Pump Setting: 21.5 m BTOC
L = Length of Screen = 22.2 m

Available drawdown above pump setting: 19.7 m
Max available drawdown in pump well: m

\[ T = \frac{2.3Q}{4\pi\Delta(h_0-h)} \]

Q = Test Discharge = 1296 kL/day = 15.00 L/s
\[ \Delta(h_0-h) = \text{Head change per log cycle} = 0.25 \text{ m} \]
T = Transmissivity = 948.8 m²/day

K = Hydraulic Conductivity = \frac{T}{L} = 42.74 m/day
STEP TEST ANALYSIS

**LKM_3P1**

**STEP TESTS**

- **s** = step drawdown (m)
- **Q** = bore discharge measured in kL/day
- **Ew** = apparent well efficiency

Calculation of well efficiency using Rorabaugh equation

\[ S = BQ + CQ^2 \]

\[ B = y \text{ intercept} = 3.26 \times 10^{-3} \]

\[ C = \text{gradient} = 3.64 \times 10^{-6} \]

\[ S = \text{drawdown in the bore} \]

\[ Ew = \frac{BQ}{BQ + CQ^2} \times 100 \]

<table>
<thead>
<tr>
<th>Step</th>
<th>Q (kL/day)</th>
<th>BQ</th>
<th>CQ^2</th>
<th>Ew (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>432</td>
<td>1.41</td>
<td>0.68</td>
<td>67</td>
</tr>
<tr>
<td>2</td>
<td>864</td>
<td>2.82</td>
<td>2.72</td>
<td>51</td>
</tr>
<tr>
<td>3</td>
<td>1296</td>
<td>4.22</td>
<td>6.11</td>
<td>41</td>
</tr>
</tbody>
</table>
CONSTANT RATE TEST

LKM_3P1

DRAWDOWN PROJECTED TO 365 DAYS

Date of Test: 15-Jan-15
SWL at start: 1.6 mBTOC
Pump Setting: 21.0 mBTOC
L = Length of Screen = 22.4 m

Available drawdown above pump setting: 19.4 m
Max available drawdown in pump well: m

\[ T = \frac{2.3Q}{4\pi\Delta(h_0-h)} \]

Q = Test Discharge = 959 kL/day
11.10 L/s
\( \Delta(h_0-h) \) = Head change per log cycle = 0.30 m
T = Transmissivity = 590.0 m²/day

K = Hydraulic Conductivity = \( \frac{T}{L} \) = 26.34 m/day
Appendix C

Laboratory Analyses
# REPORT OF ANALYSIS

Client: PENNINGTON SCOTT  
Suite 5, 149 Herdsman Parade  
Wembley WA 6014  

Job No.: PENN07_W/150127  
Quote No.: QT-02002  

Order No. :  
Date Sampled: 18-JAN-2015  
Date Received: 27-JAN-2015  

Attention: DON SCOTT  
Sampled By: CLIENT  

Project Name:  
Your Client Services Manager: David Lynch  
Phone: (08) 9368 8420  

<table>
<thead>
<tr>
<th>Lab Reg No.</th>
<th>Sample Ref</th>
<th>Sample Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W15/001602</td>
<td>LKM 3P1</td>
<td>WATER 18/01/15</td>
</tr>
<tr>
<td>W15/001603</td>
<td>LKM 2P1</td>
<td>WATER 19/01/15</td>
</tr>
<tr>
<td>W15/001604</td>
<td>LKM 1P1</td>
<td>WATER 17/01/15</td>
</tr>
</tbody>
</table>

## Inorganics

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>W15/001602</th>
<th>W15/001603</th>
<th>W15/001604</th>
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</thead>
<tbody>
<tr>
<td>Ammonia as NH3-N</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Bicarbonate as CaCO3</td>
<td>mg/L</td>
<td>100</td>
<td>130</td>
<td>82</td>
</tr>
<tr>
<td>Calcium - Filterable</td>
<td>mg/L</td>
<td>900</td>
<td>950</td>
<td>840</td>
</tr>
<tr>
<td>Carbonate as CaCO3</td>
<td>mg/L</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>66000</td>
<td>47000</td>
<td>73000</td>
</tr>
<tr>
<td>Conductivity at 25C</td>
<td>uS/cm</td>
<td>130000</td>
<td>103000</td>
<td>143000</td>
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<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>0.36</td>
<td>0.48</td>
<td>0.33</td>
</tr>
<tr>
<td>Ion Balance</td>
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<td>0.93</td>
<td>0.96</td>
<td>0.95</td>
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<tr>
<td>Magnesium - Filterable</td>
<td>mg/L</td>
<td>4000</td>
<td>2700</td>
<td>4700</td>
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<tr>
<td>Nitrate as NO3-N</td>
<td>mg/L</td>
<td>110</td>
<td>100</td>
<td>130</td>
</tr>
<tr>
<td>pH</td>
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<td>7.2</td>
<td>7.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Potassium - Filterable</td>
<td>mg/L</td>
<td>2600</td>
<td>2000</td>
<td>2900</td>
</tr>
<tr>
<td>Silica as SiO2</td>
<td>mg/L</td>
<td>19</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>Sodium - Filterable</td>
<td>mg/L</td>
<td>37000</td>
<td>27000</td>
<td>43000</td>
</tr>
<tr>
<td>Sulfate</td>
<td>mg/L</td>
<td>16000</td>
<td>11000</td>
<td>20000</td>
</tr>
<tr>
<td>TOC as NPOC</td>
<td>mg/L</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Total Dissolved Solids (Evap)</td>
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<td>122000</td>
<td>90100</td>
<td>142000</td>
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<tr>
<td>Total Nitrogen (Calc)</td>
<td>mg/L</td>
<td>110</td>
<td>100</td>
<td>130</td>
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<tr>
<td>Total Phosphorus</td>
<td>mg/L</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.1</td>
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## Trace Elements

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<th>W15/001604</th>
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<tbody>
<tr>
<td>Aluminium - Total</td>
<td>mg/L</td>
<td>0.24</td>
<td>0.030</td>
<td>0.83</td>
</tr>
<tr>
<td>Arsenic - Total</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Barium - Total</td>
<td>mg/L</td>
<td>0.022</td>
<td>0.041</td>
<td>0.021</td>
</tr>
<tr>
<td>Beryllium - Total</td>
<td>mg/L</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Boron - Total</td>
<td>mg/L</td>
<td>16</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Cadmium - Total</td>
<td>mg/L</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Chromium - Total</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Cobalt - Total</td>
<td>mg/L</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Copper - Total</td>
<td>mg/L</td>
<td>0.005</td>
<td>&lt;0.005</td>
<td>0.011</td>
</tr>
</tbody>
</table>

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www.measurement.gov.au
W15/001602 and W15/001604

The conductivity results are above the instrument’s upper calibration range and are therefore indicative only.

David Lynch, Section Manager
Inorganics - WA
Accreditation No. 2474

11-FEB-2015

Unless notified to the contrary, the above samples will be disposed of one month from the reporting date.

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Results relate only to the sample(s) tested.
Appendix B

Reinjection Modelling Report
Toro Energy Limited

Groundwater Reinjection Modelling

Lake Maitland Uranium Project
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1. **INTRODUCTION**

Toro Energy Limited ("Toro") is seeking to develop the Wiluna Uranium Project south of Wiluna. In April 2013, both the Western Australian Minister for Environment and the Federal Minister for Sustainability, Environment, Water, Population and Communities granted Toro Energy environmental approval to construct and operate a uranium mine consisting of two deposits, Centipede and Lake Way, respectively located approximately 30 kilometres (km) south and 15 km south-east of Wiluna. Toro is now seeking to extend the approvals to include mining of two additional deposits, Millipede and Lake Maitland, as well as the construction of a haul road and associated infrastructure.

The Lake Maitland project (hereinafter referred to as "the Project") was acquired by Toro from Mega Uranium Limited in November 2013, after the assessment for the Centipede and Lake Way deposits was completed. The uranium mineralisation is hosted in calcrete which are partially beneath the water table. Toro has developed dewatering and water management strategies, which include a proposal to reinject dewatering discharge back into the same calcrete formation that is being mined as a contingency surplus water management option.

Pennington Scott was engaged by Toro to undertake the necessary field investigations and develop a numerical model to investigate the hydrogeological potential for reinjection at Lake Maitland.

*This document describes the development, calibration, scenario testing and findings of the numerical groundwater model used to simulate groundwater reinjection at Lake Maitland.*

The model incorporates the results of a 2014-15 site investigation consisting of the drilling, hydraulic testing and injection trials of three production bores and six observation bores at Lake Maitland (Pennington Scott 2015b). It also draws on and supplements extensive previous hydrogeological work undertaken for the Project (Golder 2011a; 2011b; RPS Aquaterra 2010), and two previous groundwater models developed for dewatering (Golder 2011c) and water supply RPS Aquaterra 2011) in the Lake Maitland component of the Project.
2. MODEL DEVELOPMENT

The use of the computer model approach provides a powerful tool for the rationalisation of spatial and temporal variability of field conditions at the Project. The modelling process involves simulation of the regional groundwater regime by a system of mathematical equations based on Darcy's Law for groundwater flow. The process requires definition of the following characteristics of the aquifer:

- aquifer geometry and stratigraphy;
- distribution of aquifer hydraulic properties including permeability, specific yield and storage coefficients; and
- regional head distributions or fluxes, including rainfall recharge, evapotranspiration, throughflow, outflow and borefield injection/abstraction.

The sub-regional model for the Lake Maitland groundwater reinjection assessment was constructed using Visual MODFLOW 2011.1 and run using the SURFACT modelling code.

Steady state model calibration was undertaken to achieve an empirical match between spatially distributed recharge and the regional water table geometry. Transient calibration was then undertaken using the results of 2014-15 injection trials (Pennington Scott 2015b).

2.1 Model Extent and Boundaries

The model extent is shown in Figure 2-1. The model boundaries were select to incorporate catchment divides, distant flow lines, or in the case of the central western boundary, a discharge area, to minimise the use of constant head boundaries. All boundaries were set as no-flow boundaries with the exception of the southwestern boundary, at the downstream end of the palaeochannel where a constant head boundary has been set based on the mapped water table surface.

2.2 Model Layers

The aquifer geometry in the model was represented by five layers as shown in Table 2-1. Layers 1 through 4 represent materials within the palaeochannel alluvial system.

Layer 2 is the calcrete aquifer that is the target for groundwater reinjection. This layer comprises ferruginised laterite, calcareous clays with nodular carbonate, decomposed calcrete and massive calcrete and appears to be associated with the water table. The calcrete material is inferred to extend through the reinjection area.

Layer 1 represents sand and gypsiferous clay surficial material that is generally encountered above the calcrete to the ground surface in the palaeochannel area. Layer 3 represents sandy clays and clayey sands, with intercalated carbonate layers that occur below the calcrete up to about 30m depth. Layer 4 represents the palaeochannel lacustrine clay which acts as an aquitard beneath the surficial sands and clays.

Layer 5 represents the lower saprolite (weathered bedrock) outside and beneath the palaeochannel system. Outside of the palaeochannel, Layer 1 is taken to represent upper saprolite.
Figure 2-1 Model extent
The horizontal extent of the palaeochannel system aquifers was defined based on the Sir Samuel 1:250,000 hydrogeology mapsheet (Johnson 2004). A conceptual base of the palaeochannel system was defined as described in Pennington Scott (2015a). The water table elevation was taken from regional water table contours produced in Golder (2011c), and incorporating local water table contours around Lake Maitland from RPS Aquaterra (2010). Ground surface was defined using the regional Shuttle Radar Topography 1 second digital elevation model (DEM) (Geoscience Australia 2011), merged with more detailed 10 m cell size Landgate DEM in the project vicinity (Landgate 2011). The DEM was then generalised to 100 m cell size for model development. Figures showing these surfaces are included in Pennington Scott (2015a).

The model layer geometry was defined with reference to these three surfaces as follows:

- The top of Layer 1 is set to the ground surface.
- The base of Layer 1 (shallow gypsiferous silt and clay inside the alluvial area and upper saprolite outside the alluvial area) is set to 0.1m below the water table surface (to minimise dry cells).
- The base of Layer 3 (palaeochannel clays) is taken as the base of palaeochannel surface.
- Layer 2 (calcrete aquifer) and Layer 3 (surficial sand and clay under calcrete) are given constant thickness of 4m and 20m pinching out at the edge of the palaeovalley.
- Layer 5 (lower saprolite) is given a constant thickness of 10m.

Outside of the palaeochannel, where the palaeochannel formations in layers 2, 3 and 4 are absent their corresponding layers are given a nominal saturated thickness of 0.1m.

A an east-west cross-section of the model layers is shown in Figure 2-2

<table>
<thead>
<tr>
<th>Table 2-1 Model layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>
2.3 Fluxes

2.3.1 Recharge

Recharge was calibrated within a range of 0.2 to 2.2 mm/year (~0.1% to ~1% of rainfall) similar to Golder (2011c) and typical rates reported in Johnson et al. (1999). Calibrated recharge rates were 0.7 mm/year in the alluvial areas and 1.0 mm/year in the saprolite areas.

2.3.2 Evaporation

An upper limit to evaporation was set to 70 mm/year based on the values used in Golder (2011c) derived from testing by Chen (1992) in an Australian salt lake in an area of similar pan evaporation rates (Pennington Scott 2015a). The extinction depth was set to 1 m, on the basis of published curves (Ripple 1972), and comparable to the typical groundwater levels measured in the Project area, as it is assumed that present day groundwater levels are related to evaporation. Between 0 m and 1 m depth, evaporation is scaled linearly by the model.
2.4 Aquifer Parameters

Aquifer parameter ranges for model calibration were defined based on the previous investigations (Pennington Scott 2015b; RPS Aquaterra 2010; Golders 2011a; 2011b) as described in Pennington Scott (2015a). Steady state calibration was then undertaken to the water table surface, and transient calibration to the water level monitoring during the reinjection trials. Aquifer parameters were assumed to be constant for each layer.

Calibrated aquifer parameters are shown in Table 2-2.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Represents</th>
<th>Horizontal Hyd Cond (m/day)</th>
<th>Vertical Hyd Cond (m/day)</th>
<th>Specific Yield (%)</th>
<th>Specific Storage (1/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Surficial sand and clay overlying calcrete aquifer (palaeochannel area)</td>
<td>10</td>
<td>1</td>
<td>5</td>
<td>1e-6</td>
</tr>
<tr>
<td></td>
<td>Upper saprolite (outside palaeochannel area)</td>
<td>0.01</td>
<td>1e-3</td>
<td>1</td>
<td>1e-6</td>
</tr>
<tr>
<td>2</td>
<td>Calcrete aquifer</td>
<td>100</td>
<td>10</td>
<td>5</td>
<td>1e-6</td>
</tr>
<tr>
<td>3</td>
<td>Surficial sand and clay underlying calcrete aquifer</td>
<td>2</td>
<td>0.2</td>
<td>3</td>
<td>1e-6</td>
</tr>
<tr>
<td>4</td>
<td>Fluvial clay</td>
<td>1e-4</td>
<td>1e-4</td>
<td>3</td>
<td>1e-6</td>
</tr>
<tr>
<td>5</td>
<td>Lower saprolite</td>
<td>0.01</td>
<td>1e-3</td>
<td>0.1</td>
<td>1e-6</td>
</tr>
</tbody>
</table>

2.5 Calibration

2.5.1 Steady State Calibration

Steady state calibration consisted of varying the recharge and the hydraulic conductivity in the palaeochannel and saprolite areas to obtain the best match with the water table surface produced from the Golder (2011c) regional water level contours and RPS Aquaterra (2010) local contours. The calibrated steady state head distribution is shown in Figure 2-3 and calibrated versus observed heads at a number of calibration points are shown in Figure 2-4 along with calibration statistics.
Figure 2-3 Calibrated steady state head distribution with calibration points
2.5.2 Transient Calibration

Transient calibration was undertaken to match the observed aquifer response to the injection trials undertaken over 11 days in January 2015 (Pennington Scott 2011b). This test included pumping from one test production bore (LKM_3P1) to another about 100 m away (LKM_2P1), with monitoring at six monitor bores at distances of about 5, 15 and 50 m from each production bore. Details of these bores are shown in Table 2-3, and observed versus modelled water levels are shown in Figure 2-5. The ground levels for the observation bores were taken from the surface elevation in the model cell in which the bore was located. As the model used a 100 m DEM cell size, this is only an approximate elevation, and the comparison is to the changes rather than the absolute heads for calibration.

Transient calibration involved manually adjusting parameters within predefined ranges based on the previous investigations to obtain the best match between modelled and observed water levels in the monitor bores during the reinjection trial. A reasonable replication of the observed water level response in the five of the six injection bores was obtained. Bore LKM_3M4 showed no observed response despite the model predicting about 0.2m of drawdown, which may indicate the bore was not fully developed, or some compartmentalisation of the calcrite aquifer in this area.
Table 2-3 Injection trial bores used in transient calibration

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Easting*</th>
<th>Northing*</th>
<th>Bore Status</th>
<th>Distance from pumping bore** (m)</th>
<th>Distance from reinjection bore** (m)</th>
<th>Drawdown at end of test (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LKM_2P1</td>
<td>310,262</td>
<td>6,992,272</td>
<td>Injection Bore</td>
<td></td>
<td></td>
<td>-1.71</td>
</tr>
<tr>
<td>LKM_2M2</td>
<td>310,258</td>
<td>6,992,274</td>
<td>Monitoring</td>
<td>4</td>
<td></td>
<td>-0.26</td>
</tr>
<tr>
<td>LKM_2M3</td>
<td>310,246</td>
<td>6,992,274</td>
<td>Monitoring</td>
<td>16</td>
<td></td>
<td>-0.34</td>
</tr>
<tr>
<td>LKM_2M4</td>
<td>310,217</td>
<td>6,992,277</td>
<td>Monitoring</td>
<td>41</td>
<td></td>
<td>-0.27</td>
</tr>
<tr>
<td>LKM_3P1</td>
<td>310,303</td>
<td>6,992,175</td>
<td>Pumping Bore</td>
<td></td>
<td></td>
<td>2.46</td>
</tr>
<tr>
<td>LKM_3M2</td>
<td>310,300</td>
<td>6,992,176</td>
<td>Monitoring</td>
<td>4</td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>LKM_3M3</td>
<td>310,285</td>
<td>6,992,177</td>
<td>Monitoring</td>
<td>18</td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>LKM_3M4</td>
<td>310,256</td>
<td>6,992,178</td>
<td>Monitoring</td>
<td>44</td>
<td></td>
<td>-0.02</td>
</tr>
</tbody>
</table>

*GPS coordinates (not surveyed)
**Measured by tape measure

Figure 2-5 Observed vs modelled water levels in transient calibration
3. SIMULATION

Simulations were undertaken of reinjection to the calcrete aquifer. A series of borefield configurations were trialled to attempt to maximise the volume that could be reinjected while limiting water level rise in low-lying areas to around 0.5 m over the majority of the impacted low-lying areas, and to less than 1 m in any particular low-lying playa area. Scenarios assumed that reinjection occurred over a period of six years, which Toro advises is the period during which reinjection may be required. Scenarios were then continued for another 100 years with no reinjection to simulate water level recovery.

Dewatering was not included in the model as Toro intends to use barriers to limit the interaction between the pit dewatering and regional aquifer. Not including dewatering is conservative with respect to modelled water level rise as any dewatering impacts would reduce the water level rise.

Two indicative model scenarios are shown in Figure 3-1 and Figure 3-2 comprising 24 injection bores. The figures show the modelled water level rise over 6 years of groundwater reinjection at 1 GL/year into the borefields with the flow equally distributed among the bores.

Figure 3-3 and Figure 3-4 show sample hydrographs of water level change over 15 years at several points along two sections in the north and south of the mine area for the two scenarios. The hydrographs show most of the rise due to the reinjection occurs in the first few years. Following the cessation of reinjection after six years, about half of the water level recovery back to pre-injection levels occurs in the following two years, followed by a more gradual fall over subsequent years.
Figure 3-1 Modelled water level rise after 6 years of injection at 1 GL/year (Scenario 4a)
Figure 3-2 Modelled water level rise after 6 years of injection at 1 GL/year (Scenario 4b)
Figure 3-3 Modelled hydrographs of water levels from Scenario 4a at a series of points along northing 6,994,855 (top chart) and northing 6,989,655 (bottom chart)
Figure 3-4 Modelled hydrographs of water levels from Scenario 4b at a series of points along northing 6,994,855 (top chart) and northing 6,989,655 (bottom chart)
4. REFERENCES


Geoscience Australia 2011. 1 second shuttle radar topography mission (SRTM) digital elevation model


Pennington Scott. 2015a Lake Maitland Uranium Project – Groundwater Reinjection Study Rev1 2078

Pennington Scott. 2015b. Lake Maitland Uranium Project – Bore Completion Report Rev1 2078

