TECHNICAL MEMORANDUM

Review of River Pool-Aquifer Connectivity, Kintyre

Title: Assessment of connectivity between aquifer and river pools at Kintyre
For: Cameco Australia Pty Ltd
Date: 21 September 2012
Ref: 1122 CAM Rev 1

1 Introduction

This memo provides an assessment of the connectivity between river pools on the Yandagooge Creek and the underlying aquifers, as background to the Kintyre Project ERMP. An understanding of this connection is important for determining the potential impact of groundwater drawdowns on the rockholes.

2 Modes of River-Aquifer Connection

Groundwater drawdown only has the potential to impact on water levels in a river pool if the aquifer and pool are hydraulically connected. The two are hydraulically connected if there is continuous saturated material between the riverbed and the water table for at least some part of the year (Figure 1). Where there is an intervening unsaturated zone, the two are not hydraulically connected. Leakage from the river to the aquifer may occur, but the flow is in one direction and water level changes in the aquifer have no influence on the river. Hydraulically connected river-aquifer systems can have a strong connection, where the hydraulic conductivity of the materials between the base of the river and the water table is high, or a weak connection where there are significant impeding layers.

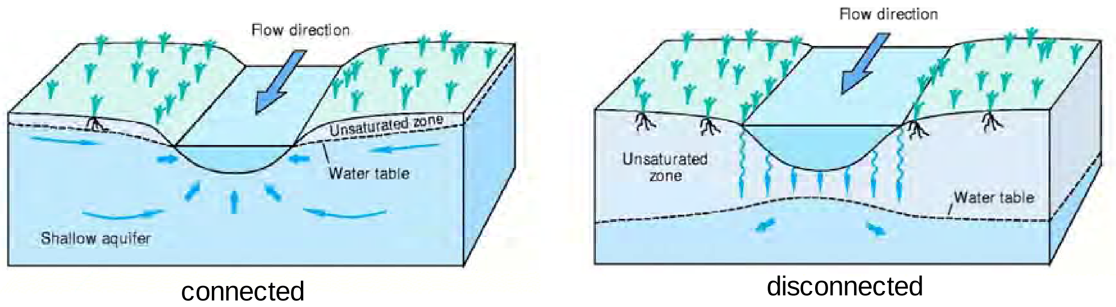

Figure 1 Schematic of connected and disconnected river reaches (adapted from Winter et al. 1998)

3 Surface Hydrology at the Kintyre Project

The Kintyre Project lies within the Coolbro Creek catchment, a sub catchment of the much larger internally draining Sandy Desert Basin. Coolbro Creek dissipates into the desert about 17 km east of the Yandagooge Creek confluence, but during major flood events surface water accumulates within interdunal areas at the creek terminus and flows northward toward Lake Waukarlycarly (MWH 2012).

The Kintyre Project lies within the Yandagooge Creek sub-catchment of the Coolbro Creek catchment (Figure 3), which with a catchment area of 780 km^2 , accounts for more than half the Coolbro Creek catchment of 1,240 km^2. Yandagooge Creek has its headwaters in the Throssell and Watrara Ranges to the west and south, where deeply incised drainages discharge to the broad flat valley. The western and southern branches of Yandagooge Creek converge into a main channel about 4 km north of the Kintyre deposit. The southern branch covers an area of approximately 300 km^2, which is almost twice the southern branch catchment area of around 170 km^2. Stream flow is ephemeral. The creek flows for up to several days following substantial rainfall that is mostly associated with summer cyclonic activity, but remains dry through most of the year. Runoff is generated mainly over the sandstone plateau and quartzite outcrop areas (MWH 2012).

Figure 3 shows the locations of two ephemeral water rockholes in Yandagooge Creek. Pinpi (or Pinbi) Rockhole is closest to Kintyre. It is about 2km to the south, 20m wide and is underlain by moderately weathered schistose bedrock. Another semi-permanent rock hole is Rock Pool, which is located on the plateau flanks 840 m northwest of North Bore, and underlain by Coolbro Sandstone. Both rockholes are about 2.5m deep when full. Figure 2 shows Pinpi rockhole when full after the creek flowed following Cyclone Lau in March 2012 and when dry three months later in July 2012.

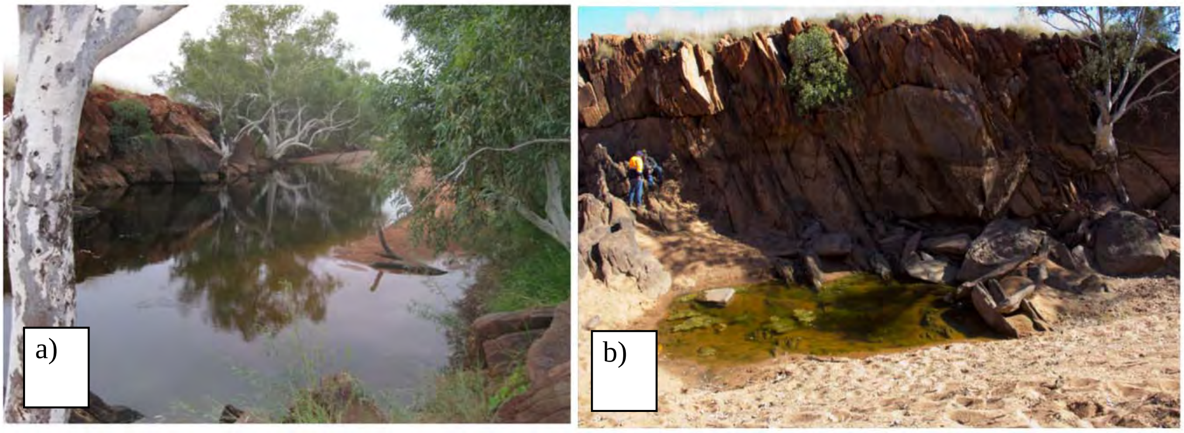

Figure 2: The site at Pinpi Rock rockhole (a) full after Cyclone Lua in March 2012, and (b) almost dry three months later in July 2012.

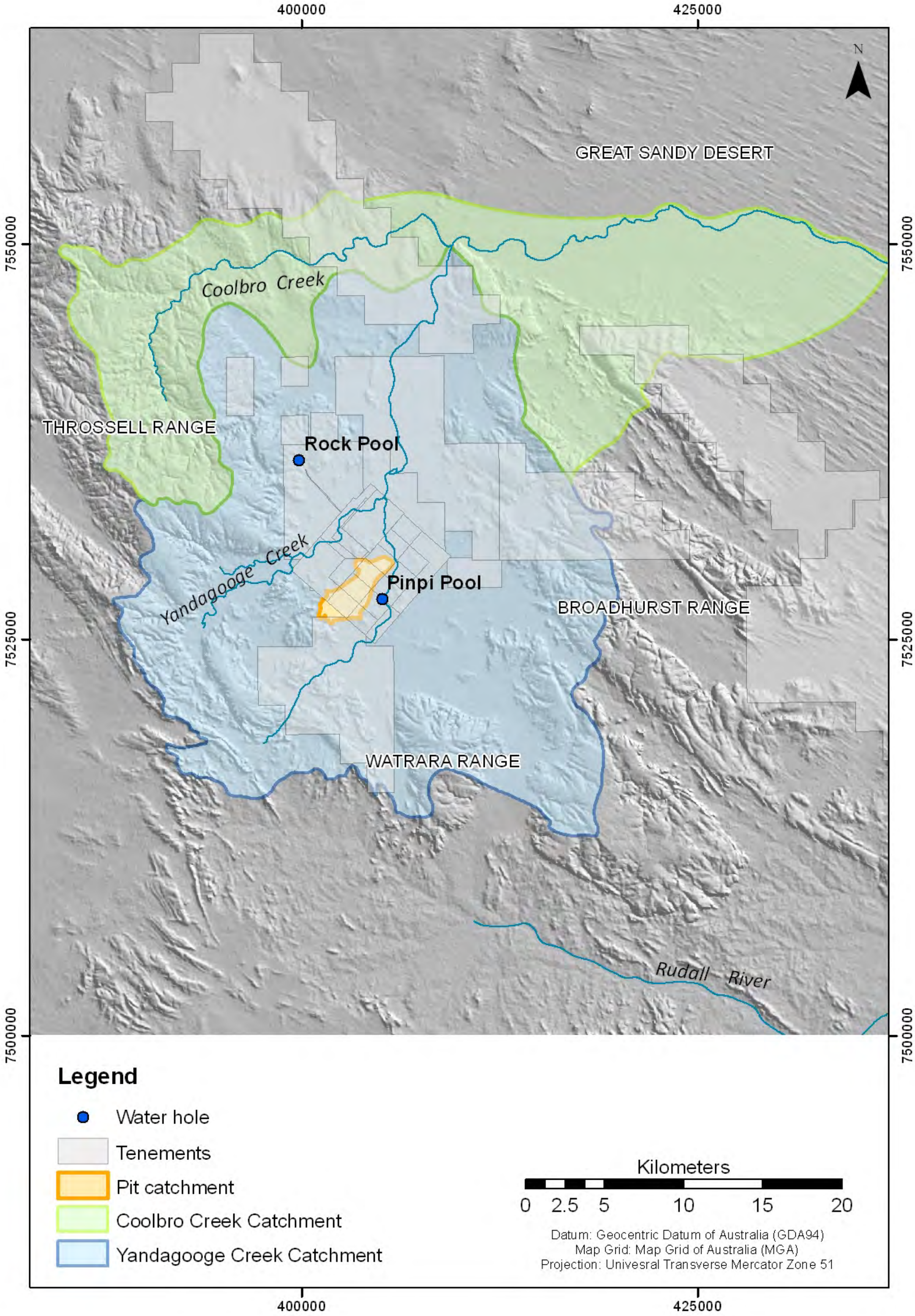

Figure 3: Surface hydrology

4 Evidence of River-Aquifer Connection

4.1 Groundwater Levels

As part of the hydrogeological investigation (Pennington Scott 2012), water table elevations were contoured from all available point monitoring data (Figure 4). These indicate water levels at Rock Pool and Pinpi Rockhole of 358mAHD and 364mAHD respectively. Ground elevations from the high resolution (1 second) digital elevation model indicate ground surface elevations of 388 and 376m respectively giving depth to static water level relative to ground surface of 30m and 12m respectively. As the rockholes are incised about 8m below the ground surface, the depth to water below the riverbed is about 22m and 4m respectively.

Hydrographs from data loggers installed in several bores in the vicinity of the rockholes show a seasonal variability in water levels of 0.1-0.3m, indicating that there is unlikely to be any significant seasonal variation in the depth of groundwater beneath the base of the rockholes.

These results show that it is highly unlikely that there is hydraulic connection between the water table and Rock Rockhole, with a water table depth of more than 20m below the rockhole bed. The results also suggest that there is an unsaturated zone beneath Pinpi Rockhole, albeit less extensive than at Rock Pool. This indicates that the rockhole and water table are not hydraulically connected.

4.2 Response to Streamflow

If the river rockholes were closely hydraulically connected to the aquifer, water levels in the monitor bores should show a relationship to streamflow. Figure 5 shows an example from the Hunter Valley in NSW of a close relationship between river flow and water levels in nearby bores.

While streamflow data are not available for Yandagooge Creek, flows would be expected to have some correlation with rainfall at the nearest meteorological station, Telfer Aero, 66km to the north. Figure 6 shows daily water levels in CWB3S, 1200m from Pinpi Rockhole, and the closest bore with continuous water level data, compared to daily rainfall at Telfer. This chart shows no obvious relationship between rainfall, and presumably streamflow, and water levels in the bore.

Figure 2 shows photos of Pinpi Rockhole in March 2012, when it was about 2.5m deep after the creek flowed following Cyclone Lau, and almost three months later in July 2012. These photos show evidence of significant water level fluctuation in the rockhole in response to streamflow over this period. This water level fluctuation shows no reflection in the nearby groundwater levels, which provides further evidence that the rockhole is not hydraulically connected to the aquifer.

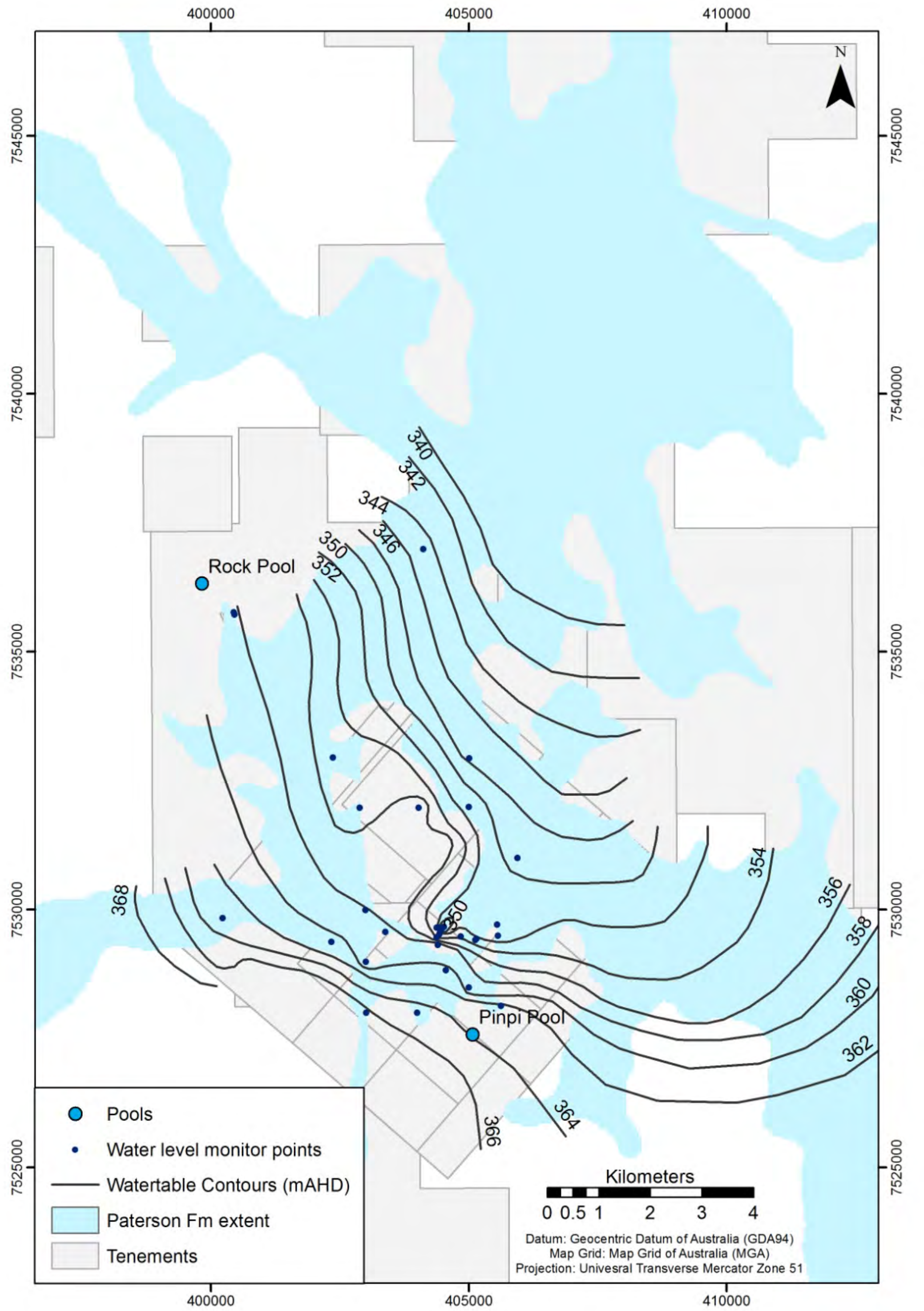

Figure 4 Contoured water table elevations

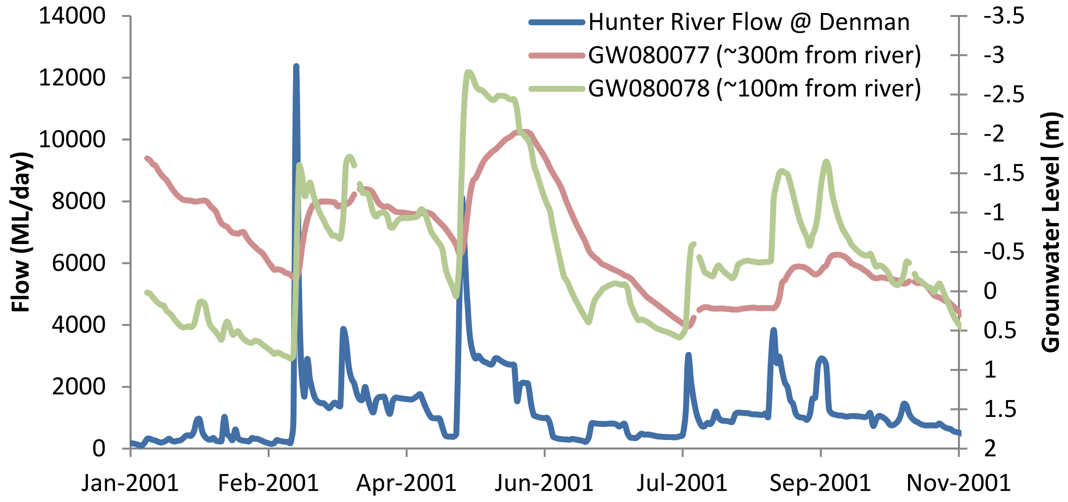

Figure 5 Example of hydraulically connected river and aquifer from the Hunter Valley, NSW

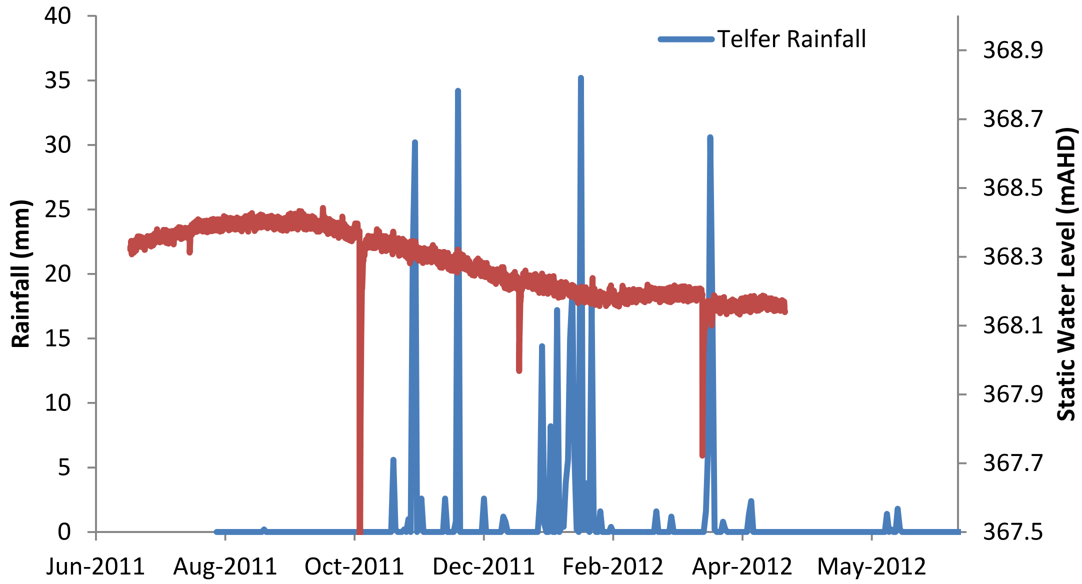

Figure 6 Rainfall at Telfer versus water levels in CWB3S near Pinpi Rockhole showing no evidence of hydraulic connection to the creek

4.3 Water Quality

If the rockholes were a window to the shallow underlying aquifer, their water quality should to some extent reflect the groundwater quality. Dames and Moore (1996) undertook an extensive survey of water quality in river pools throughout the Coolbro and Yandagooge catchments. Ranges of results for key parameters from their survey are shown in Table 1 compared to baseline data for groundwater collected in Pennington Scott (2012). The results , show that the pool water quality is very fresh compared to the groundwater, with water quality parameters in the pools generally orders of magnitude below the values for groundwater. Dames and Moore noted that the pool water quality appeared to reflect surface water quality. These results provide further evidence that the pools are predominantly surface water fed rather than being an expression of groundwater.

Table 1 Comparison of pool and groundwater quality

Parameter	Pool Range	Groundwater Range
TDS (mg/L)	4 - 36	100 - 14,000
Ca	0.6 - 5.1	1 - 520
Mg	0.3 - 1.9	7 -1100
Na	0.2 - 4.4	10 - 4200
K	1.3 - 4.5	4 - 290
HCO3	4.8 - 29.4	52 - 1400
SO4	0.5 - 2.3	5 - 5500
CL	1 - 7	10 - 6,000

Sources: Pool Data (Dames and Moore 1996); Groundwater Data (baseline sampling in Pennington Scott 2012)

5 Conclusions

Review of groundwater level data shows that the pools in Yandagooge Creek are unlikely to be connected to the water table due to the presence of an intervening unsaturated zone between the creek bed and the water table. The lack of hydraulic connection is further evidenced by an absence of any relationship between water level response in the pools and the nearby groundwater monitoring network, and orders of magnitude difference in water qualities.

The evidence indicates that the pools are surface water features that are filled following significant streamflow events, then gradually drain through seepage and evaporation over the subsequent months.

To confirm these findings, in the next stage of the Kintyre Project, Cameco plans to install a shallow monitor bore near Pinpi Rockhole to measure the precise water table elevation and compare to riverbed elevations. Continuous water level loggers will then be installed in both the bore and the rockhole to gather baseline information on water level fluctuations in the two systems, and to assess any relationship. A regular water quality sampling program will also be initiated in the bore and rockhole.

6 References

Dames and Moore. 1996. Summary Report 1998-1992 Kintyre Surface Water Monitoring Program. Prepared for Canning Resources Pty Ltd.

Winter, T.C., Judson, W.H., Franke, O.L., Alley, W.M. 1998. Ground water and surface water a single resource. US Geological Survey Circular 1139. Denver, Colorado.

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Pennington Scott. 2012. Hydrogeological Investigations, Kintyre Joint Venture Project. Prepared for Cameco Australia Pty Ltd.