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MEMORANDUM

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ATTENTION:	Lisa Chandler		
CC:	Andrew Worland		
FROM:	Jon Hall		
DATE:	23rd October 2015	JOB NO: 1134-J8	DOC NO: 030a
SUBJECT:	Response to OEPA and DER Comments on Groundwater Salinity Distributions and Impacts		

Lisa,

We have reviewed available hydrogeological information relevant to the Wiluna Uranium Project and we provide the following response to comments on the project PER (by the OEPA and DER) relating to the pre-mining distribution (vertical and lateral) in areas likely to be impacted by mining and mine water management activities.

1. Conceptual Hydrogeological Model

The conceptual hydrogeological model for the overall Wiluna Uranium Project, and specifically the Millipede and Lake Maitland mining areas is well described in the PER and in a number of technical support documents including:

- Aquaterra, 2007a, 2007b and 2010a
- Golder Associates, 2011a to 2011e and 2015
- Johnson SL, Commander DP and O'Boy CA, 1999
- Pennington Scott, 2015a and 2015b
- RPS Aquaterra, 2011a to 2011c
- RPS, 2014b, 2015a and 2015b

The key components of the conceptual hydrogeological model that influence the magnitude and distribution of salinity in the shallow groundwater (i.e. the groundwater that will be affected in some way by mining and water management activities) are as follows:

- There is a shallow groundwater system within the calcretes, alluvium and playa sediments that occupy the near subsurface within the regional Carey Paleodrainage System and tributary drainages of the main truck paleodrainage.
- Groundwater flows from water table mounds at the catchment boundaries (which are sustained by rainfall recharge to relatively low permeability weathered basement rocks) and drains towards the tributary paleodrainages and the main trunk paleodrainage.
- Groundwater flow through the tributary paleodrainages and weathered basement rocks makes its way the playa sediments, alluvium and calcretes within the trunk paleodrainage system.
- The water table is very shallow in the playas (typically less than 3m depth below surface) and evapotranspiration processes account for a significant proportion of the groundwater inflow. That is the playas are groundwater sinks.
- Groundwater in the shallow aquifers (alluvium) close to catchment boundaries is typically brackish with salinity (TDS) around 1,000 to 4,000mg/L. However, as a result of evapotranspirative concentration of salts, the shallow groundwater in the playas is typically saline to hypersaline and shallow groundwater salinity can exceed 100,000mg/L.

- The shallow aquifers are periodically recharged by comparatively fresh runoff during flood events. However, as a result of the very shallow depth to water table in the main trunk paleodrainage and playas, there is a limit to the volumes of recharge that the shallow aquifers in these area can accept before they are "full". Once the shallow aquifers are full, no further recharge occurs and all flood waters flow down the catchment. This is sometimes referred to as "rejected recharge".
- The periodic recharge by floodwaters can result in a very thin layer of low salinity water temporarily developing over the saline to hypersaline groundwater below. However, such conditions do not persist for long due to the continuing process of evapotranspiration from the water table and mixing with deeper saline groundwater as groundwater flows down gradient.

The main influence of the conceptual hydrogeological model on the distribution of groundwater salinity is that there can be significant lateral variation in salinity between the main paleodrainage and playa system (where groundwater is typically saline to hypersaline) and shallow aquifers associated with tributary paleodrainages and/or weathered basement rocks (where groundwater can be brackish). The transition zones between brackish and saline groundwater extend over several kilometres and reflect a balance between groundwater flow (of lower salinity water) and diffusion of salts from the saline groundwater.

However, there is much less variability in the vertical distribution of groundwater salinity within the shallow aquifers and, while thin layers of low salinity groundwater can develop after flood recharge, these rarely persist.

2. Measured Salinity

2.1 Lateral Variations

Millipede Mine Area

Historical groundwater quality data (as reported in RPS, 2015) show groundwater salinity in the project area ranging from less than 1,000mg/L in the Abercrombie Creek calcrete aquifer to the west of Millipede, and some wells to the north of Abercrombie Creek, up to around 70,000 to 330,000mg/L at the Millipede deposits.

Groundwater salinity in the playa (shallow lacustrine silt) ranges from 27,000 to 240,000mg/L.

Groundwater quality data from a 2011 salinity survey (Outback Ecology Services, 2012) shows salinity (at 2m depth below the water table) within the Millipede mine area ranging from 15,000mg/L at the western (upstream) margin of the mine area to over 130,000mg/L adjacent to Lake Way. Bores sampled as part of this programme are shown on Figure 1.

Lake Maitland

Groundwater quality data from water supply investigations (RPS Aquaterra, 2011c) show shallow groundwater salinity in the tributary paleodrainage system (borefield area) ranges from less than 1,000mg/L near the catchment boundary to around 4,000mg/L at the downstream end of the borefield (which is around 5km to the north of the Lake Maitland mining area).

Downstream of the borefield, shallow groundwater salinity increases markedly to around 40,000mg/L at the northern flank of Lake Maitland to 160,000mg/L at the southern end of the Lake Maitland mining area. Figure 2 shows bores sampled as part of this programme.

2.2 Vertical Variations

Millipede Mine Area

Vertical salinity profiling in a number of bores was undertaken in 2011 (Outback Ecology Services, 2012). The results showed that, in the eastern margin of the mining area adjacent to Lake Way:

- Two bores (S50 and CPSO67) with around 25,000mg/L at top of the water table, increasing to over 40,000mg/L at 1m depth below water table, and then increasing to over 100,000mg/L by 4m depth below water table.
- Two bores (S53 and CPS084) with 60,000 to 70,000mg/L at the top of the water table, increasing over 80,000mg/L at 2m depth below water table.
- One bore (S51) with around 120,000mg/L at the top of the water table increasing to over

150,000mg/L at 9m depth below water table.

In the western part of the mine area, the results showed:

- Two bores (NLW13-1 and NLW15) with 2,000 to 4,000mg/L at the top of the water table, increasing to 7,000 to 10,000mg/L at 2m depth below water table and then increasing to 40,000mg/L below this.
- Two bores (NVCP2 and NVCT01) with 40,000 to 70,000mg/L at the top of the water table, increasing to over 100,000mg/L at 2 to 4m depth below water table.
- One bore (NVCT0174A) with less than 1,000mg/L at the top of the water table, increasing to over 100,000mg/L at 4m depth below water table.

These results clearly show that, while there is some stratification in groundwater salinity, comparatively lower salinity water (where it occurs) is restricted to the top of the water table and that the shallow groundwater is generally saline to hypersaline at and below 1m depth.

Lake Maitland

As part of water supply investigations, three paired shallow and deep monitoring bores were installed (RPS Aquaterra, 2011c). The shallow bores monitor the whole shallow aquifer sequence, while the deep bores monitor the basal sand aquifer (main regional paleochannel aquifer).

Groundwater quality data from the bores at LMMB06 (located on the northern margin of Lake Maitland downstream of the borefield area) show:

- 17,000mg/L in the shallow bore (screened from 12 to 24m depth)
- 43,000mg/L in the deep bore (screened from 67 to 91m depth).

Groundwater quality data from the bores at LMMB07 (located at the downstream end of the Lake Maitland mining area) show:

- 160,000mg/L in the shallow bore (screened from 6 to 18m depth)
- 210,000mg/L in the deep bore (screened from 47 to 74m depth).

These data clearly show an increase in the average salinity between the shallow aquifers and the deeper basal paleochannel aquifers.

3. Impacts of Mining on Salinity Distribution

Mining and mine water management activities have the potential to impact on groundwater salinity distribution in two ways: mine dewatering and excess water re-injection to the shallow aquifer.

3.1 Dewatering

Mining of both orebodies will require some advanced dewatering of the shallow aquifer. Strategies to minimise dewatering requirements have been developed including the installation of low permeability barriers around the mine pits. Whether these low permeability barriers are used or not, there will be some mine inflows and these will generate a “cone of depression” in the water table around the pits. The results of groundwater modelling show that the influence of dewatering only extends for several kilometres from the pits.

The process of groundwater inflow to the pits will have little to no impact on the distribution of shallow groundwater salinity around the pits, as follows:

Lateral Distribution of Salinity

Inflows to the pits will result in the drawing of groundwater towards the pits from surrounding areas. This would include:

- Lower salinity groundwater from inland and upstream tributary areas;
- Similar salinity groundwater from areas immediately adjacent to the mine pits; and
- Higher salinity groundwater from downstream areas within the truck paleodrainage system.

Given that the shallow groundwater in and around the mine areas is already hypersaline, the impact of drawing similar or higher salinity groundwater towards the mine pits will be negligible (i.e no change to beneficial use). The impact of drawing lower salinity water towards the pits will also be negligible and, if anything, might improve shallow groundwater quality at the upstream margins of the mine areas.

In all cases, the transition between saline/hypersaline and brackish groundwater will be gradual and extend over kilometres. There is little to no potential for the development of haloclines.

Vertical Distribution of Salinity

As the pits are very shallow, groundwater flow to the pits will be mostly horizontal flow except in very close proximity to the pit margins where some mixing of groundwater could be expected. As such, groundwater flow towards the pits is not expected to impact on what little vertical distribution of salinity there is.

As the water table recovers following the cessation of mining and dewatering, the minimal vertical layering of salinity (including the occasional very thin layers of low salinity water at the top of the water table) would be re-established following flood events.

3.2 Excess Water Disposal – Aquifer Injection

It is proposed to dispose of excess dewatering production (i.e. the dewatering production that exceeds processing requirements) by aquifer injection to the shallow aquifer system downstream of the Lake Maitland mining area. The current project water balance suggests that aquifer injection of excess water may be required for two years only, although the concept of aquifer injection at rates of up to 1GL/a for 15 years has been investigated (Pennington Scott, 2015). The study concluded than aquifer injection at such rates and over 15 years could be achieved from a borefield comprising some 24 bores spaced at 500m centres, while maintaining water table mounding at least 0.5 to 1m below surface. It was also predicted that the water table mound would extend less than 1km downstream of the injection borefield.

Given that actual excess water disposal requirements will be significantly less than modelled in the Pennington Scott study, the potential impacts would also be significantly less.

However, notwithstanding the above, the potential impacts of aquifer injection on the vertical distribution of shallow groundwater salinity will be minimal. During injection, there will likely be mixing of the injected water with the existing groundwater immediately around the injection bores and within the injection borefield. However, if there is any significant vertical distribution in salinity (i.e. lower salinity groundwater at the water table) downstream of the borefield, the injected higher salinity groundwater will tend to “sink” due to density differences and any such salinity distribution would largely be maintained.

As the water table recovers (declines back to pre-injection levels) following the cessation of aquifer injection, the minimal vertical distribution of salinity that might have been present (including the occasional very thin layers of low salinity water at the top of the water table) would be re-established following recharge events.

4. Summary

The overall conclusion, when taking into account the conceptual hydrogeological model, the existing groundwater quality conditions and the groundwater flow processes that will occur during and after mining, is that mining and mine water management practices will have little to no impact on the distribution of groundwater salinity other than in the immediate mine area and only for the duration of the project. In the immediate mine areas, pre-mining groundwater salinity distributions should be re-established following the first major flood event.

Yours sincerely,
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