APPENDIX F3

Yarra Wurta spring interpretation

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YARRA WURTA SPRING INTERPRETATION

OBJECTIVES AND SCOPE

This technical memorandum has been written to address the uncertainties associated with the potential for impacts on Yarra Wurta Spring as a consequence of the proposed open pit mining at Olympic Dam.

The key discussion on the interpretation of model-predicted water level changes at Yarra Wurta Spring is preceded by memorandum sections aimed at putting the discussion into its appropriate perspective.

Whilst groundwater drawdowns are not expected to extend as far as the spring during the life of the mine, there is a theoretical possibility, centuries after mine closure, that drawdown in groundwater levels may extend as far as the spring. The cause of this drawdown is the final void pit lake from which groundwater would evaporate and which would therefore become a source of groundwater discharge from the Stuart Shelf. Groundwater that would otherwise have discharged to Lake Torrens and the sedimentary sequence beneath that lake would drain into and evaporate from this final void pit lake.

INTRODUCTION

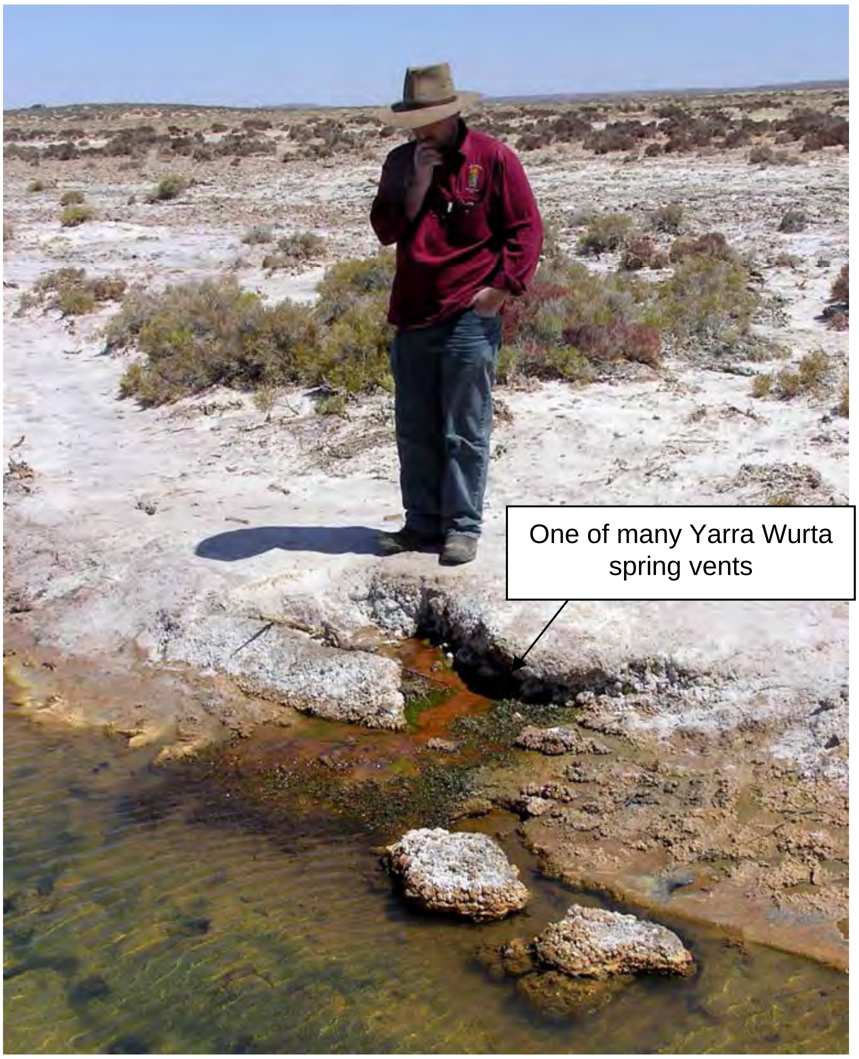
Yarra Wurta Spring is unique on Lake Torrens in the extent of free water around the various small vents and the population of fish that is believed to use the water as a refuge between flooding events.

The uncertainty about the potential for Yarra Wurta Spring to be affected by the mine void discharge is a direct consequence of the difficulty in establishing the source (or sources) of the groundwater that discharges at the spring and the mechanism of discharge. The spring consists of a series of small vents near the north-eastern edge of Lake Torrens, with an associated area of shallow saline water across the lake bed. Two parts of the spring complex are shown in the photographs below, in a small arm of the lake.

The spring's multiple vents and the flat lake bed (that allows the water to spread widely) make direct measurement of the discharge rate practically impossible. The total discharge from vents can be judged to be in the order of 2-10 L/sec, and there may be some diffuse discharge as well. Presumably the local water table is close to the lake surface. If so, only a small discharge would be required to wet a large surface area.

Estimation of the spring discharge rate by assessing the wetted area and applying the likely evaporation rate to that area is prone to large errors. The total evaporation rate from the bed of Lake Torrens has been estimated at only 55 mm/a (Schmid, 1985). Potential evaporation from freshwater would probably be between 2,000 and 3,000 mm/a but the high salinity reduces the rate of evaporation as a consequence of the low water vapour pressure of brines relative to that of fresh water.


Typical spring water area with surrounding salinised land


One of many Yarra Wurta spring vents

HYDROGEOLOGICAL SETTING OF LAKE TORRENS

Lake Torrens is the major hydrological feature of the region within which the Olympic Dam operation is located. Lake Torrens is the terminal lake of a regional-scale, closed surface drainage basin. Its surface has an approximate elevation of 34 m AHD.

Any discussion of Yarra Wurta Spring must understand its location in the Lake Torrens context.

It is not unexpected that springs would be found near the edge of Lake Torrens. The lake is a large playa which we interpret to form a regional sink for groundwater as well as surface water. Probably much more water moves to the lake from the east where the Flinders Ranges drain towards the lake, than from the west. From the west the Stuart Shelf groundwater system discharges mostly to the northern part of the lake.

There is little or no runoff to the northern part of the lake from the Stuart Shelf, the Andamooka Limestone area comprising many small closed depressions. At least some of these closed drainages have dolines that allow surface water to drain to the groundwater system. Small local catchments (both surface water and groundwater) drain from the west towards the southern part of Lake Torrens, where the Tent Hill Formation (and remnants of Bulldog Shale and Algebuckina Sandstone) occur at surface.

The mechanism(s) by which the groundwater systems that flank Lake Torrens discharge to the lake and its underlying sediments are not known in detail. However the topography and groundwater head distribution leave no doubt that the lake is the discharge zone for the aquifers. We are not completely sure whether or not Lake Torrens groundwaters move to the south towards the coast at Spencer Gulf.

Small groundwater discharges have been documented in the Draft EIS along the western margin of the lake and there are a few springs, understood to be broadly similar in morphology to mound springs of the Great Artesian Basin on the bed of the lake (Johns, 1968a and b). Whilst the evolution of the groundwater beneath the lake has not been studied in detail, salt must be accumulating there by evaporation of surface water (from cyclic salt in the rainfall) and the brackish to saline groundwater that drains to the lake.

Lake Torrens is known to be underlain by at least 270 m of sediments of Tertiary age from a drilling and sampling program carried out by the SA Department of Mines (Johns, 1968a). The upper parts of the sedimentary sequence are brine-saturated (some 250,000 mg/L) but at depth (approximately 60m) the groundwater salinity is lower (30,000 – 70,000 mg/L). The underlying saline groundwater has a lower density than the upper brines, leading to potential for hydraulic loading (as salt accumulates in the upper part of the system) to force saline water to surface if there are any structural conduits. This hydraulic loading may be the origin of the springs near the middle of the lake.

ORIGIN OF YARRA WURTA SPRING WATER

The interpretation provided in Appendix K1 of the Draft EIS is as follows:

> *"Hydrogeochemical data and shallow groundwater flow patterns strongly suggest the source of the spring discharge from Yarra Wurta Springs is either the Amberoona Formation of the Adelaide Geosyncline (located to the east; REM, 2007b) or the ALA. The springs are a discharge mechanism for what is likely a local GFS."*

We concur with the first sentence. Whilst we question the interpretation that the springs are <u>likely</u> to be the discharge of "a local GFS", we agree that a local origin is a possible explanation.

Yarra Wurta Spring is located in an area where Andamooka Limestone occurs, and it is within the Torrens Hinge Zone (THZ). The THZ is a broad structural zone that separates the flat-lying sedimentary rocks of the Stuart Shelf from their thicker and folded equivalents in the Adelaide Geosyncline to the east.

Thus Yarra Wurta Spring occurs within the same lithology as the major aquifer of the northern Stuart Shelf but within the major structural zone that occurs beneath Lake Torrens and forms the eastern limit to the Stuart Shelf. The Andamooka Limestone is probably continuous across the THZ from the Stuart Shelf to the Yarra Wurta Spring and there is no reason to postulate structural, hydraulic barriers to groundwater movement. Being near the northern end of the lake, the spring is located in the zone where regional groundwater flow lines converge from west, north and east.

Shallow groundwater movement towards the spring's location at the east of Lake Torrens presumably comes from the east and north east. We do not know the detailed local distribution of heads and salinities.

The low flow rate from the spring vents suggest that, whatever the source, it may be that the spring water is only seen at the surface because the water table is practically at ground surface. The shallow water table is a consequence of Lake Torrens being the lowest part of the landscape and the sink for a more or less closed drainage system.

The chemistry of the groundwater is not definitive with respect to the source of the flow although, as indicated in the Draft EIS, it is consistent with the eastern margin groundwater rather than the Andamooka Limestone Aquifer of the Stuart Shelf.

POTENTIAL IMPACTS AT YARRA WURTA SPRING FROM THE OPEN PIT MINE

General

Predicted groundwater elevations in the revised numerical groundwater model for the Stuart Shelf undertaken by SWS in 2010 (Appendix F4 of the Supplementary EIS) indicates that drawdown at Yarra Wurta Spring is not predicted to increase above 1 m within 500 years post closure (Figure 5.9, Appendix F4 of the Supplementary EIS). Sensitivity analysis carried out shows that in all but one of the sensitivity runs, predicted drawdown at the Yarra Wurta Spring is between less than 1 m to about 2 m at 500 years post closure. One run suggests a potential for a post-closure reduction of groundwater levels at Yarra Wurta Spring by up to about 3 m over a 500-year period.

Regardless of the origin of the groundwater that emerges from the spring vents, if the local water table fell by 3 m, we judge that the extensive areas of shallow water may dry up. In parallel, it is possible that the numerous, small spring vents would cease flowing if the local water table were to fall.

However, it is important to understand the nature of the numerical model to interpret the model-implied risk to Yarra Wurta Spring. The model incorporates hydraulic continuity across from the Stuart Shelf, where the hydrogeology is well-understood regionally, into the Torrens Hinge Zone, where the hydrogeology is not known from any direct investigation. Thus the model allows for direct hydraulic continuity from Olympic Dam to Yarra Wurta Spring with the hydraulic properties of the Andamooka Limestone Aquifer applied across the Torrens Hinge Zone to the spring. This approach is correct, since there is no direct information with which to justify less hydraulic continuity in the model from the Stuart Shelf aquifers to the spring.

The model does not include the sedimentary aquifers within the sequence beneath Lake Torrens, for which no details are available in the northern part of the lake. The model does not allow for the probable buffering effect of the lake groundwater system on predicted drawdowns from the pit void lake at Olympic Dam.

Model uncertainties

The model has inherent uncertainties in its simulation results. The calibration statistics have been described in the latest report by SWS (Appendix F4 of the Supplementary EIS) and are indicated in the tables below.

Table 4.4 Steady state model calibration statistics.

Observation set	Variation in observed data	Mean residual	RMS (m)	SRMS (%)
All observations	102.5	8.2	12.5	12.2
THZ only	56.9	5.1	6.6	9.5
ZAL only	54.8	5.2	7.7	17.0
ZWA only	90.4	16.4	20.1	22.2
ZWC only	14.1	3.8	2.8	19.5

Table 4.5 Time variant model calibration statistics – absolute values.

Observation set	Variation in observed data	Mean residual	RMS (m)	SRMS (%)
All	169	3.7	10.1	6.0
ZAL	39.3	6.3	7.9	20.2
ZWC	147.6	8.8	12.5	8.5

The RMS (Root Mean Square) errors may be, for the purposes of this memorandum, considered as average errors. The tables thus indicate that there is an inherent uncertainty in model simulations of groundwater heads that is greater than the maximum drawdown predicted in the Andamooka Limestone aquifer at Yarra Wurta Spring. The model is not accurate enough to predict small changes in head at the spring. In parallel, it should be borne in mind that the model is not predicting large drawdowns at the spring.

Interpretation of model simulations

Interpretation of the model results needs to consider what is known conceptually, even if this knowledge is not quantitative information. The additional information and inference that should be considered when interpreting the numerical output from the model is as follows.

1) It is likely that the elevation of the water table at the springs is supported by groundwater derived from the north east and generally as a consequence of Lake Torrens position in the regional landscape.

2) It is possible that there is sufficient structural disruption within the Torrens Hinge Zone to impede the development of drawdown across the strike direction of that zone. There is no evidence for such structural dislocation having hydraulic effects.

3) Lake Torrens sedimentary aquifers are extensive and occupy part of the area between Olympic Dam and Yarra Wurta Spring. It is likely that the Lake Torrens sedimentary aquifers have a high storage coefficient and therefore that they might buffer drawdown from the Olympic Dam pit void lake discharge. This buffer might prevent groundwater levels from being lowered at Yarra Wurta Spring or might reduce the amount of the drawdown relative to what is predicted in the model without Lake Torrens sediments.

4) The predicted drawdown of up to 3 m has to be considered in the context of its being predicted centuries into the future. This timeframe carries uncertainties in prediction that are difficult to describe or to quantify.

5) There are no historical data about the behaviour or permanence of Yarra Wurta Spring. However, based on site observations and the geological history of the area, we judge that they are likely to be permanent at a time scale of thousands of years, if not longer. This interpretation suggests that the springs are likely to continue discharging for thousands of years, although we cannot know either whether climate change may affect them or whether they have had in the past intermittent periods without discharge.

6) Lake Torrens floods occasionally, and takes years to dry out after large floods. These floods may be of great importance in the lake's long-term water balance and, being derived largely from the Flinders Ranges, in recharging the aquifers to the east of the lake. The occasional floods may themselves be sufficient to overcome all effects at Yarra Wurta Spring of small drawdown to the west of Lake Torrens.

Worst case impact at Yarra Wurta Spring

The worst case scenario is where the spring dries up. This scenario comes from the model results and a simplified hydrogeological model in which the spring discharge is maintained by the Stuart Shelf groundwater system alone, without any of the other factors (listed above) influencing either the current discharge or the long-term effects of open pit mining at Olympic Dam. This worst case scenario is unlikely to be realistic although it is the most practical and justifiable way of including Yarra Wurta Spring in the regional Stuart Shelf groundwater flow model. This simple model regards the spring vents as being structurally-localised discharges from the Andamooka Limestone Aquifer on the Stuart Shelf.

Even if the water table at the spring were not affected by the long-term effects of the pit void lake, a reduction in head of 3 m in the ALA may stop the surface discharges at the spring vents.

We consider this worst case scenario is extremely unlikely in reality, although the model from which it has been obtained is a correct approach for simulating the regional groundwater system on the Stuart Shelf.

Best case impact at Yarra Wurta Spring

The best case scenario is where there is no effect at the spring. This scenario is much more likely than the worst case, given the potential for some or all of the other factors (listed above) to buffer the springs from the long-term effects of the open pit mine after closure.

Discussion of uncertainties in predicting the long-term impact at Yarra Wurta Spring

There are two different aspects to be discussed, the spring flow mechanism, including the hydrogeological setting and the reliability of model predictions that extend centuries into the future without any transient data for calibration at the point of interest.

a) Spring flow mechanisms and drawdown buffering factors

Every one of the six complicating factors listed above (in the hydrological and hydrogeological setting of Yarra Wurta Spring) and which correctly have not been included in the numerical groundwater model, would be expected to act to reduce the drawdown at the spring relative to the numerical simulations.

b) Predicting drawdowns long into the future

Mathematical models can be used to generate simulations of groundwater heads for hundreds or thousands of years into the future. These results are numerically justifiable but the further into the future the less credible are the simulations and the greater the difficulty in assessing their meaning.

Over 500 years, many factors that influence what we currently observe at Yarra Wurta Spring may change, for example:

- climate
- the extent of groundwater developments on the eastern side of Lake Torrens
- surface water impoundments in the Flinders Ranges (Aroona Dam being the first)
- possible development of Lake Torrens brines as a resource.

Each of these factors, and maybe others, have the potential to affect Yarra Wurta Spring adversely and to overprint any effects from Olympic Dam.

We have no direct knowledge of the behaviour of the spring even over a ten-year period, or since European settlement in that area (some 150 years). We are not aware of long-term traditional knowledge of the spring. The most definite information is that Lake Torrens flooded completely in the 1980s, since which time the fish population at Yarra Wurta Spring must have survived. There is little or no earlier information, so predictions of groundwater level decline from a mathematical model have no direct comparability with the duration of knowledge of the spring's permanence.

Finally, if Yarra Wurta Spring were to diminish in flow or to dry up several centuries into the future, there is no way of knowing now whether it would be possible then to establish whether or not the final void at Olympic Dam were the cause.

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