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Attention: Jared Brook

Dear Jared

Ensham Life of Mine Extension Project
Groundwater Amendment Report

1 Introduction

SLR Consulting Australia Pty Ltd (SLR) was commissioned by AECOM Australia Pty Ltd (AECOM) to undertake the groundwater impact assessment for the Ensham Life of Mine Extension Project. The final report for this assessment was issued in May 2020 (SLR, 2020).

Since finalisation of the technical report, the Ensham LOME Project, referred on 29 May 2020 to the Australian Government Department of Agriculture, Water and Environment (DAWE), submitted as *Environment and Biodiversity Conservation Act 1999* (EPBC Act) referral 2020/8669. On 29 June 2020, the delegate of the Minister for the Environment determined the proposed action to be a controlled action under the Commonwealth EPBC Act.

The controlling provisions are sections:

- 18 and 18A (listed threatened species and communities); and
- 24D and 24E (a water resource, in relation to coal seam gas development and large coal mining development).

The proposed action will be assessed under the bilateral agreement between the Commonwealth and the State of Queensland (section 45 of the EPBC Act) using the EIS prepared under the *Environmental Protection Act 1994* (Qld) (EP Act).

Following their review, DAWE provided the Matters of National Environmental Significance (MNES) Terms of Reference (ToR), in which they identified requirements and recommendations for the MNES chapter of the EIS.

This letter report clarifies where in the groundwater impact assessment these items were addressed. It is an internal document for AECOM's information.

2 Additional information for the Groundwater Impact Assessment

2.1 Climate change considerations

In the ToR Section 5, *DAWE suggested that a climate change scenario should be provided for the predictive numerical groundwater model through the use of the Climate Futures Tool.*

The groundwater impact assessment (SLR, 2020) has not specifically addressed how climate change scenarios will potentially change the impacts on groundwater. This section herein will therefore discuss the potential change of rainfall due to climate change and set these changes into the context of the LOME Project. The Climate Future Tool (CSRIO and BOM, 2020) was interrogated for the cluster East Coast North, which is the relevant sub-cluster for the Ensham Mine. The general rainfall projection for this cluster was summarised as:

"Natural climate variability is projected to remain the major driver of rainfall changes in the next few decades. Models show a range of results, with little change or decrease being more common particularly in winter and spring. Impact assessment in this region should consider the risk of both a drier and wetter climate."

In the Climate Futures Tool, the functionality "Explore projections" was used to quantify the predicted change in annual rainfall. There are four Representative Concentration Pathways (RCPs), which represent different greenhouse gas concentration scenarios. These are (CSIRO and BOM, 2020):

- RCP8.5 - a future with little curbing of emissions, with a CO_2 concentration continuing to rapidly rise, reaching 940 ppm by 2100.
- RCP6.0 – lower emissions, achieved by application of some mitigation strategies and technologies. CO_2 concentration rising less rapidly (than RCP8.5), but still reaching 660 ppm by 2100 and total radiative forcing stabilising shortly after 2100.
- RCP4.5 - CO_2 concentrations are slightly above those of RCP6.0 until after mid-century, but emissions peak earlier (around 2040), and the CO_2 concentration reaches 540 ppm by 2100.
- RCP2.6 - the most ambitious mitigation scenario, with emissions peaking early in the century (around 2020), then rapidly declining. Such a pathway would require early participation from all emitters, including developing countries, as well as the application of technologies for actively removing carbon dioxide from the atmosphere. The CO_2 concentration reaches 440 ppm by 2040 then slowly declines to 420 ppm by 2100).

In the projections explorer, each RCP can be assessed at different points in time (up to 2090). For this assessment, projections change in annual rainfall was assessed for the years 2050 and 2090. The results are presented in **Table 1** and **Table 2** respectively. The percentage value for each RCP indicates the percentage of models which had the corresponding outcome of percent rainfall. For example, in 2050 for RCP 2.6, 38% (11 of 29) models predicted -5 to -15 % rainfall. Based on the annual rainfall comparison tables, most scenarios showed that rainfall was likely to vary from -15% to 5%, indicating little change to slightly drier climate. In 2090, there is a chance of between 28% and 37% that rainfall will decrease by more than 15% for two of the four RCPs.

Table 1 Change in rainfall for different climate scenarios (2050)

% Annual Rainfall Comparison	RCP 2.6 (n=29)	RCP 4.5 (n=68)	RCP 6.0 (n=22)	RCP 8.5 (n=70)
>15% (much wetter)	-	1%	-	3%
5 to 15% (wetter)	24%	15%	14%	16%
-5 to 5 (little change)	31%	54%	50%	31%
-15 to -5 (drier)	38%	22%	32%	33%
> -15% (much drier)	7%	7%	5%	17%

Notes: n refers to the number of models in each of the RCP categories

Table 2 Change in rainfall for different climate scenarios (2090)

% Annual Rainfall Comparison	RCP 2.6 (n=29)	RCP 4.5 (n=68)	RCP 6.0 (n=22)	RCP 8.5 (n=70)
>15% (much wetter)	-	-	9%	6%
5 to 15% (wetter)	14%	15%	23%	13%
-5 to 5 (little change)	34%	29%	27%	21%
-15 to -5 (drier)	24%	40%	23%	23%
> -15% (much drier)	28%	16%	18%	37%

Notes: n refers to the number of models in each of the RCP categories

In the groundwater impact assessment (SLR, 2020), a predictive sensitivity analysis was undertaken for the groundwater recharge as described in Section 6.5 of the report. This predictive sensitivity analysis covered rainfall changes according to the Climate Future Tool projections. The recharge in the model is tied to the rainfall by a calibrated percentage. For the sensitivity analysis, the base case recharge was changed by +/- 20%. With this range, the majority of the predicted rainfall changes from the climate change scenarios provided in **Table 1** and **Table 2** are captured. The impacts for these climate change scenarios were:

- 20% reduction of groundwater recharge: A 4% reduction in mine inflows and no change in Nogoa River baseflow were predicted. No changes in the drawdown extent of the 5m drawdown curve in the target Coal seams were observed.
- 20% increase of groundwater recharge: A 5% increase in mine inflows and no change in Nogoa River baseflow were predicted. No changes in the drawdown extent of the 5m drawdown curve in the target Coal seams were observed.

2.2 Sensitivity analysis: Worst case scenario

DAWE noted in the TOR, Section 5 that *a scenario-based uncertainty or sensitivity analysis, incorporating a ‘worst-case’ scenario of the most sensitive model parameters (e.g. high stream conductance, high hydraulic conductivity of the surrounding alluvium and coal measures) should be provided. This analysis would provide additional confidence about the magnitude and extent of the predicted impacts to the alluvium groundwater levels and Nogoa River baseflows.*

The groundwater impact assessment included a full predictive sensitivity analysis as outlined in Section 6.5 of the report. The ‘worst case’ approach as suggested by DAWE is not deemed suitable to assess the worst-case scenario, as described below.

The predictive sensitivity analysis was based on a calibrated parameter set. In each run, one parameter was changed by an order of magnitude (or by a relevant percentage) in each run. The results for all 17 runs were then presented together and the most sensitive parameters were discussed. By changing only one parameter at a time, it is assumed that the calibrated data set would still match adequately, and the predictions could still be considered a potential outcome. If – as suggested by DAWE – the three parameters are changed at the same time, the model calibration could be far outside of the observed ranges and the prediction based on such a scenario is not meaningful.

As noted earlier, the model calibration is deemed to be conservative on mine inflows. The model simulated average inflows of 3.3 ML/day into underground mining during the calibration period. Observed site inflows ranged from 0.2 to 3.9 ML / day between December 2016 and September 2018 (Section 6.3.5 of the groundwater impact assessment report). This comparison shows that the calibrated model inflows are on the higher side, but within the range of observed the inflows. The inflows into the mine were deemed a conservative estimate. Any potential induced flow from the alluvium and Nogoa River would subsequently also be on the conservative side.

2.3 Uncertainty analysis

This section provides clarification of how uncertainty was assessed in the groundwater impact assessment.

In accordance with the Independent Expert Scientific Committee (IESC) Information Guidelines: *Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* released in December 2018, an uncertainty analysis was conducted to help demonstrate the numerical model is fit for purpose and provide information in a way that allows decision-makers to understand the effects of model uncertainty on the project objectives and impact predictions. Given the low inherent groundwater risk profile of the Project (extension of an already approved underground operation on a site with a long mining history), a Type 1 uncertainty analysis as defined in the IESC Guide was deemed be sufficient for the groundwater impact assessment and was documented in Section 6.5 of the report.

The Type 1 Uncertainty analysis consisted of 17 predictive scenario runs that explored the change in model outputs when changing a set of selected parameters for which the degree of uncertainty was to be quantified. These parameters included recharge, riverbed conductance, selected hydraulic properties and storage properties. These scenarios provided an indication of the range in uncertainty in model outputs such as mine inflow, drawdowns and baseflow effects, but could provide probabilities for the occurrence of impacts.

Further, the IESC Information Guidelines: *Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* also identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- structural / conceptual
- parameterisation
- measurement error
- scenario uncertainties.

These four sources of scientific uncertainty have been qualitatively assessed and were presented in Table 26 in Section 6.7 of the groundwater impact assessment report. Overall, it was considered that the groundwater model is fit for the purpose for addressing the objectives of the Project despite its identified uncertainty.

3 Additional items for clarification

3.1 Peer review

DAWE recommended in the ToR, Section 5 that *models are peer-reviewed by an independent expert, considering the Australian Groundwater Modelling Guidelines and the IESC Explanatory Notes. Recommendations of the peer review should be incorporated into the models. DAWE recommends peer reviewers are engaged early and throughout the groundwater assessment (see above) to ensure it is an iterative process*.

The groundwater impact assessment was reviewed at several stages during its delivery by an independent third-party reviewer (A/Prof Claire Côte, Sustainable Minerals Institute, University of Queensland, Brisbane). The comments and recommendations from the Peer Reviewer were incorporated into the numerical groundwater model and the groundwater impact assessment report (SLR, 2020).

3.2 Assessment scenarios

In the ToR, Section 5, DAWE noted that *it is important for modelling to clearly distinguish between impacts from the proposed project and existing operations. For example, the MNES section must clearly identify the absolute amount of drawdown due to the proposed extension and the total predicted cumulative drawdown values. This must include details on how the estimated contributions to cumulative drawdown have been derived*.

SLR, 2020 discussed the potential of cumulative impacts from surrounding mines (Section 3.3.2) or petroleum activities (Section 3.3.3). It concluded that the mining operations within a 30 km radius were all targeting different coal seams (German Creek Coal Measures or Fairhill Creek Coal Measures) that is separated from the Rangal Coal Measures, specifically the target coal seam Aries and Castor by low permeability aquitards. Mines that are targeting the same coal measures are further than 30km away and cumulative impacts were not expected.

The groundwater impact assessment report Section 6.4 listed the assessed scenarios with their rationale, i.e. how the combination between those scenarios would identify the drawdown due to the proposed extension and the total predicted cumulative drawdown. These were a Null run (no underground mining after September 2018) , the existing operations, and the Project. These three runs were used in combination to assess:

- cumulative impacts: represented by the difference in results predicted for the Null run and results predicted for the existing operation and the Project. For the purpose of this report, “cumulative impacts” refers to the impacts from underground operations compared to a hypothetical case where all underground mining stopped in September 2018. It does not refer to potential impacts from mining operations at other locations.
- incremental impacts: represented by the difference in results predicted for the existing operations and results predicted for the Project.

3.3 Mine inflow estimates

In the ToR, Section 5, *DAWE noted that the groundwater model should be calibrated to the target coal seams, which is critical considering they will be depressurised/dewatered from the proposed action. Insufficient model calibration may systematically underestimate modelled underground mine inflows, alluvium drawdown and Nogoa river baseflows*.

The groundwater model was calibrated to groundwater levels within the coal seams as described in Section 6.3.5 of the groundwater impact assessment report. As the site has current open-cut and underground mining activities, the groundwater level data set used in the calibration is reflecting mining conditions. Nine bores screened in the target coal seam were used in the calibration. The calibration hydrographs were presented in Appendix G of the groundwater impact assessment report.

The model simulated average inflows of 3.3 ML/day into underground mining during the calibration period. Observed site inflows ranged from 0.2 to 3.9 ML / day between December 2016 and September 2018. This comparison shows that the calibrated model inflows are on the higher side, but within the range of observed inflows. The inflows into the mine are hence not systematically underestimated, but a conservative estimate. Any potential induced flow from the alluvium and Nogoa River would subsequently also be on the conservative side.

3.4 MNES report additions

DAWE recommended that the MNES chapter of the EIS also include:

- details of the locations of the sub-cropping coal measures in relation to the alluvium, and confirmation as to whether these have been integrated into the groundwater conceptual model;
- a discussion regarding the degree of hydraulic connectivity between the coal measures, the Nogoa River and the surrounding alluvium, noting (a) the elevated electrical conductivity in the alluvial groundwater and (b) the potential recharge into the alluvium from rainfall and streamflow in localised areas where surficial clays are absent;
- consideration as to whether potential sources of alluvial recharge (e.g. rainfall, streamflow) need to be disaggregated to assist in assessing the potential changes to Nogoa River baseflows during the project operations; and
- given the proximity of the mine to prime agricultural land, the effects of agricultural pumping and discharging on Nogoa River flows and alluvial aquifers should be discussed as part of the groundwater model.

These items were all addressed in the groundwater impact assessment report and further explanation is provided in the following sections herein. AECOM can use this wording to be included in the MNES section if required.

3.4.1 Sub-cropping

The target coal seams outcrop / subcrop over a strike length of about 80 km in north-south direction at the Ensham Mine to the east of the Project Area. To the north of Project Area, the outcrop / subcrop changes direction and is showing east to west. The shape of the outcrop / subcrop can be seen in Figure 11 of the groundwater impact assessment report. The sub-cropping areas were included in both the conceptual model and the numerical model (hydraulic properties in Table 16, and applied recharge rate in Table 17 of the groundwater impact assessment report).

Recharge into the outcropping coal seams was conceptualised as occurring from direct rainfall on the ground surface, infiltrating into the underlying formations through the thin soil cover, weathered profile, as well as through the spoil at site (Section 5.2.3 of the groundwater impact assessment report). The coal measures subcrop in localised zones beneath alluvium associated with the Nogoa River, where the unit is conceptualised to be potentially recharged by downward seepage where there is an absence of clay and silt layers (Section 5.2.3 of the groundwater impact assessment report).

3.4.2 Degree of hydraulic connectivity

DAWE's ToR requirement regarding to the degree of hydraulic connectivity between the coal measures, the Nogoa River and the surrounding alluvium was based on the following items described in the groundwater impact assessment report:

- the high EC observed in the alluvium groundwater; and
- the potential recharge into the alluvium from rainfall and streamflow in localised areas where surficial clays are absent.

With regards to the high EC in the alluvium, this has been conceptualised to be a result of the low connectivity between the Nogoa River and the alluvium. If the Nogoa River was the source of alluvial groundwater, the EC in the alluvium would be expected to be lower, as the constant recharge of fresh river water from the permanent river flow would result in a lower EC in the groundwater. The water quality data analysis in the groundwater impact assessment report (Section 5.4.1.1) concluded that most alluvium bores are responsive to rainfall events indicating that rainfall infiltration is likely the main recharge process occurring in the alluvium. A large recharge event reduces the EC, and prolonged drought will increase the EC over time, when no continuous fresh water source is available.

The potential for recharge in the alluvium was discussed in Section 5.2.1 of the groundwater impact assessment report. The shallow silts and clays were conceptualised to be partially isolating the Nogoa River, limiting leakage from the river into the basal sands and gravels. It is possible that leakage may occur where these clays are absent or where the basal sands are exposed within the river. No evidence of large area with absent clays or exposed sands is available. Based on the water quality data in the alluvium it can be concluded that the degree of separation is present in most areas. This is further illustrated in Figure 14 of the groundwater impact report that shows that there is a disconnect between the surface water level and the groundwater levels. The groundwater occurrence in the alluvium was described highly variable with thin saturated zones of poor-quality water in deeper sections of an otherwise largely unsaturated formation (Section 5.2.1 of the groundwater impact assessment report). If Nogoa River was in close connection to the alluvium, a more continuous groundwater level closer to the River elevation would be expected with freshwater quality.

3.4.3 Sources of recharge

The numerical model disaggregated the two sources of potential alluvium recharge (rainfall and streamflow) by using:

- the Stream boundary condition to simulate potential leakage form from the Nogoa River (Section 6.3.3.6 of the groundwater impact assessment report); and
- the Recharge package to simulate the diffuse areal recharge to the system(Section 6.3.3.3 of the groundwater impact assessment report).

The low hydraulic conductivity in the upper alluvial layer is conceptualised as limiting the water flux between river and alluvium. The areal recharge is applied to the highest active model layer, which mostly is Layer 2 (basal sands).

3.4.4 Effects of agricultural pumping

The effects of agricultural pumping and discharge on the Nogoa River and alluvium could not be quantitatively assessed due to a lack of data. The conceptual understanding from data reviews was presented in Section 5.2.1 and Figure 15 of the groundwater impact assessment report. Two of the upstream alluvial bores (EC01 and EC03) show increasing water levels, when the cumulative rainfall departure indicated drier climatic conditions. Other alluvial bores follow the climatic trend. It was conceptually concluded from this data that irrigation in the area surrounding EC01 and EC03 could potentially result in these localised increased groundwater levels.

4 Closing

This letter provides further explanations for three items raised by DAWE in the MNES ToR (Section 2). Additional wording was provided for AECOM to include into the MNES section if they wish to do so (Section 3).

With the inclusion of the additional context and description on uncertainty, sensitivity and climate change, the groundwater impact assessment addresses the requirements of the DAWE ToR.

Yours sincerely

INES EPARI
Principal Consultant

Checked/
Authorised by: DL

5 References

CSIRO and Bureau of Meteorology, 2020. *Climate Change in Australia website (http://www.climatechangeinaustralia.gov.au/)*, accessed 10 October 2020

SLR, 2020: *Ensham Life Of Mine Extension Project Groundwater Impact Assessment*, Report, May 2020