Our Ref:
HC2013/16

Date:	30 June 2013	
To:	John Ross AGL Energy Limited Level 21, 101 Miller Street North Sydney NSW 2060 Locked Bag 1837 St Leonards NSW 2065	
From:	Dr Noel Merrick	
Re:	**Gloucester Gas Project - Groundwater Peer Review**	

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This report provides a Peer Review of the updated conceptual (hydrogeological) model under Condition 3.9 of the Part 3A approval (MP 08_0154) for the Gloucester Gas Project - Stage 1 GFDA. In a letter from the NSW Department of Planning & Infrastructure to AGL Energy Limited dated 5 March 2013, the Department noted that the Director-General had approved the appointment of Dr Noel Merrick as an appropriately experienced and qualified hydrogeologist for the undertaking of the review. Apart from over 40 years experience as a professional hydrogeologist, geophysicist and groundwater modeller, Dr Merrick has specific experience in the Gloucester Basin, having led the groundwater assessments for two recent open cut coal mine expansions (Duralie, Stratford).

Methodology

The peer review has been undertaken through examination of a written report, following a conceptualisation workshop and two meetings with the developers of the conceptual model.

The updated conceptual model has been documented in a report by Parsons Brinckerhoff (PB):

- Parsons Brinckerhoff, 2013, Hydrogeological Conceptual Model of the Gloucester Basin. Report No. 2162406A PR_7266 prepared for AGL Upstream Investments Pty Ltd. Revision B, Final Report. Authors R. Rollins and S. Brown. Date 28 June 2013. 73p + 2 Appendices.

The terms of reference for the review are articulated in Conditions 3.8 and 3.9 of the Planning Assessment Commission (PAC) Project Approval (22 February 2011) and Condition 16 of the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) Approval (11 February 2013).

The methodology for the review is in accordance with the principles of the Australian Groundwater Modelling Guidelines issued by the National Water Commission (NWC) in June 2012 (Barnett *et al*., 2012[1]) and the Murray Darling Basin Commission Groundwater Flow Modelling Guideline (MDBC, 2001[2]).

Conditions

PAC Condition 3.8:

> *Prior to the commencement of construction of the project, the Proponent shall in consultation with NOW update the conceptual hydrogeological model developed during the assessment stage of the project (referred to in the document listed in condition 1.1d) based on baseline data gathered from (but not necessarily limited to), the pre-construction investigations identified below:*
> *a) seismic surveys of the site to identify geological features of risk;*
> *b) preliminary field sampling of hydraulic conductivity, groundwater levels, groundwater quality and surface water quality based on a packer, pump and slug testing program and surface water sampling; and*
> *c) long-term baseline monitoring (i.e. at least six months) at groundwater and surface water locations determined in consultation with NOW, to ensure representative baseline data on pre-construction conditions (including seasonal variability) in relation to the shallow rock and alluvial beneficial aquifers, deeper coal seam water bearing zones, groundwater users and surface waters.*

PAC Condition 3.9:

> *The updated conceptual hydrogeological model referred to in condition 3.8 shall be submitted for the Director-General's approval, prior to the commencement of construction and shall include:*
> *a) updated assessment of the potential for drawdown and displacement of shallow rock and alluvial beneficial aquifers, considering impacts to nearby registered bore users, based on detailed baseline data gathered from condition 3.8 a) to c);*
> *b) optimal areas for gas well location within the Stage 1 Gas Field Development Area based on minimising the risk of gas migration and of interaction with beneficial aquifers and the outcomes of the updated assessment;*
> *c) recommendations for phased gas well development including indentifying the maximum number of gas wells that would be developed during the first phase of development and associated operational groundwater monitoring strategy consistent with the requirements of condition 4.1; and*
> *d) include an independent peer review by an appropriately experienced and qualified hydrogeologist (who is approved by the Director-General for the purposes of this condition) on the robustness and technical veracity of the model.*

SEWPaC Condition 16:

> *The person taking the action must consult the department on the development of the conceptual hydrogeological model required under Conditions 3.8 and 3.9 of the state approval conditions, and must provide a copy of the model to the department within twenty (20) business days of its finalisation*.

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[1] Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). Australian Groundwater Modelling Guidelines. Waterlines report 82, National Water Commission, Canberra.

[2] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: http://www.mdbc.gov.au/nrm/groundwater/groundwater_guides/

In addition to the regulatory conditions, the evolution of the Gloucester Basin conceptual model since 2010, as documented in three reports cited in PB (2013), was reviewed by Dr Richard Evans (Sinclair Knight Merz) on behalf of the Gloucester Community Consultative Committee. Consideration of his recommendations, as they pertain to an updated conceptual model, is noted in Table 2.3 of the PB (2013) report. Recommendations 13 and 14 sought inclusion in the conceptual model of the hydraulic behaviour of faults and major structural changes related to faults. Recommendation 22 sought consolidation of the conceptual model documentation into a single report.

Checklist

The NWC guide includes a checklist for the assessment of each stage of modelling, including the conceptualisation stage preceding the development of a numerical model. The completed checklist is offered at **Table 1**.

The comments in the checklist provide the foundation for this reviewer's certification of the *robustness and technical veracity of the model*, as required under PAC Condition 3.9(d).

In terms of the conditions:

- Seismic reflection surveys have been conducted and their outputs examined for the identification of fault locations and persistence [PAC Condition 3.8(a)];
- There has been a very extensive field program in accordance with the requirements of PAC Condition 3.8(b), including two field tests of potential effects of faulting on groundwater hydrology;
- There is now more than two years of baseline data in accordance with PAC Condition 3.8(c), with a network of more than 40 monitoring points covering representative lithologies down to a depth of about 350 m; hydraulic conductivity measurements extend to about 900 m depth;
- The report includes a generic discussion on drawdown propagation from CSG activity in accordance with Condition 3.9(a), in Section 6.5.1, with inclusion of a map of registered bores in Figure 5.20, but quantitative assessment is premature;
- There is some discussion on potential subsidence from CSG activity in accordance with Condition 3.9(a), in Section 6.5.2, but consideration of *displacement of shallow rock and alluvial beneficial aquifers* is premature;
- The requested *optimal areas for gas well location* in Condition 3.9(b) are premature, although operational logistics principles are addressed in Section 6.5.3;
- The requested *recommendations for phased gas well development* in Condition 3.9(c) are premature, although operational logistics principles are addressed in Section 6.5.3.

Specific Comments

Apart from the PB field investigation program from 2010 to 2012, the conceptual model is based on 14 prior studies. This reviewer is not aware of the omission of any significant study from examination, apart from the Rocky Hill Project investigations and the associated groundwater assessment which is not yet publicly available.

The geological map in Figure 4.5 (PB, 2013) shows the mapped area of "Quaternary Alluvium". It is likely that much of the mapped area is colluvium, following a detailed TEM survey conducted for the Stratford Extension groundwater assessment.

While Figure 5.1 (PB, 2013) shows the AGL monitoring network centred on AGL-owned properties, there are substantial networks to the south belonging to the Stratford Mine and Rocky Hill Project. Although no monitoring data are shown for these bores, the monitored sites are indicated in Figure 5.20 (PB, 2013).

In Section 5.2 (PB, 2013), an assessment is made of likely baseflow contributions to stream flow. There are many alternative algorithms for baseflow analysis and they can differ substantially in their estimates. It follows that the provided baseflow estimates have an associated uncertainty.

The pre-development regional groundwater level contours in Figure 5.9 are in broad agreement with the inferred levels determined by this reviewer in the Stratford Extension groundwater assessment.

The groundwater hydrographs in Figures 5.10 to 5.18 are compared with daily rainfall. To better illustrate cause-and-effect, the rainfall residual mass curve (in Figure 4.3) could have been overlaid to show that the observed trends are due to climate rather than any other candidate stress. Similarly, this practice would have helped to differentiate potential causative factors during the 29-day flow test (Section 5.3.3.4) and the 3-day pumping test (Section 5.5.2.1) experiments on a strike-slip fault.

Chapter 7 (PB, 2013) introduces the numerical model objectives, target confidence level, model domain, hydrostratigraphic upscaling, boundaries, and processes to be simulated. This reviewer concurs with the model plan as it stands. In particular, the plan is to simulate single-phase (water) rather than dual-phase (water and gas). Given the lack of availability of accessible and computationally efficient dual-phase software, and the focus on environmental impacts, this reviewer agrees with a single-phase approach as it is expected to be conservative in terms of impacts of relevance to the environment and the community.

Conclusion

The updated conceptual model has a very strong scientific basis. This reviewer attests to the *robustness and technical veracity of the model* [PAC Condition 3.9(d)].

The development of the conceptual model has highlighted an uncertainty in the hydraulic role of faults and has confirmed the very wide range in hydraulic properties of host lithologies within the Gloucester Basin.

Yours sincerely

Dr Noel Merrick

Table 1. Peer Review Checklist for the Gloucester Basin Conceptual Model

2. Conceptualisation	*Yes/No*	*Comment*
2.1 Has a literature review been completed, including examination of prior investigations?	Y	14 studies (Table 3.1)
2.2 Is the aquifer system adequately described?	Y	Section 5.3
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Y	Section 4.3
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Y	Entire basin; focus on faulting
2.2.3 aquifer geometry including layer elevations and thicknesses	Y	Provided as sections; detailed elevations and thicknesses deferred to numerical model
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	..	Confinement is discussed for natural and CSG conditions; premature to examine spatially and temporally
2.3 Have data on groundwater stresses been collected and analysed?	Y	
2.3.1 recharge from rainfall, irrigation, floods, lakes	..	Rainfall and residual mass
2.3.2 river or lake stage heights	Y	Stages at 4 gauges
2.3.3 groundwater usage (pumping, returns etc)	..	Mine inflow at Stratford mine; no stock & domestic, but estimate is made
2.3.4 evapotranspiration	Y	BoM map
2.3.5 other?	Y	Aquifer testing; GDE map
2.4 Have groundwater level observations been collected and analysed?	Y	
2.4.1 selection of representative bore hydrographs	Y	6 Sites in alluvium; nested hydrographs at 8 sites
2.4.2 comparison of hydrographs	Y	Alluvial sites compared. Vertical head differences compared at nested sites
2.4.3 effect of stresses on hydrographs	Y	Compared with stream stage and rain (not residual mass)
2.4.4 watertable maps/piezometric surfaces?	Y	One pre-development regional watertable map
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	N/A	
2.5 Have flow observations been collected and analysed?	Y	4 gauges; no flow duration curves or statistics; EC dynamics included
2.5.1 baseflow in rivers	Y	Baseflow separation analysis
2.5.2 discharge in springs	N/A	
2.5.3 location of diffuse discharge areas?	N/A	
2.6 Is the measurement error or data uncertainty reported?		
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N	
2.6.2 spatial variability/heterogeneity of parameters	Y	Hydraulic conductivity variation with lithology and with depth; large ranges
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N	
2.7 Have consistent data units and geometric datum been used?	Y	Metres; Days; ML; MGA; AHD
2.8 Is there a clear description of the conceptual model?	Y	

2.8.1 Is there a graphical representation of the conceptual model?	Y	Pre-development (Figure 6.1). During development (Figure 6.2).
2.8.2 Is the conceptual model based on all available, relevant data?	Y	Extensive analysis
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Y	Section 7.1. Objectives specified in PAC and SEWPaC conditions (for CSG impact assessment) - some unreasonable expectations of a numerical model in SEWPaC conditions. Nominated Class 2 confidence level for numerical model - this is appropriate
2.9.1 Are the relevant processes identified?	Y	Field investigations of potential faulting effects on groundwater hydrology.
2.9.2 Is justification provided for omission or simplification of processes?	Y	None omitted. Faulting will be tested.
2.10 Have alternative conceptual models been investigated?	Y	Faulting in or out