9. Conclusions

Groundwater levels

The shallow alluvial bores showed a slight decrease in water level over the monitoring period reflecting the dry conditions that prevailed during late 2009. The deeper alluvial bores showed slightly rising or constant water levels over the baseline period. The different water level trends in the shallow and deep alluvial aquifers are mostly due to variable recharge characteristics and evapo-transpiration effects, and barometric effects.

During the pumping test on gas well HB02 there were no level changes outside of the expected natural variability of groundwater levels at any of the monitoring locations. Some rainfall recharge and barometric effects are apparent but there were no water level declines in either alluvial or shallow bedrock monitoring bores that are attributable to the depressurisation caused by the pumping test on HB02.

During the recovery phase, groundwater levels recovered to within 8 metres of the original standing water level. This is typical of a low permeability, confined aquifer with limited storage with no drainage (or recharge) from adjacent strata.

The primary water data collected and used in this investigation to prove (or disprove) the connectivity of aquifers suggests there is a strong disconnection between shallow aquifers and deep coal seam aquifers proposed for CSG exploration. There are no trends in the water level monitoring data at any site to suggest there is any drainage or connectivity with deep (coal seam) aquifers.

Aquifer permeability

There is up to five orders of magnitude difference in permeability between the main water resource aquifers in the alluvium and shallow/deep coal seam aquifers. The coal seams are considered to be very poor aquifers and there are lower permeability confining layers located between the upper alluvial aquifers and the coal seams with CSG potential.

Based on the calculated permeabilities for the Blakefield Coal Seam of 0.005 to 0.043 m/day, flow velocities up to 1.6 m/year are possible. Based on likely outcrop and recharge areas about 7kms away to the north, groundwater travel times are estimated to be between 4,500 and 38,000 years.

Groundwater quality

The water quality for the alluvial, shallow bedrock and deeper coal seam aquifers is brackish to slightly saline. Water quality characteristics are typical for this environment and there was little variability across the baseline monitoring period.

Changes in EC, temperature, and methane species were observed in the deep coal seam aquifer during the pumping test on HB02, but had generally returned to baseline conditions during the recovery period (with the exception of methane).

Environmental and radioisotopes were valuable data sets to understand the origin, age and connectivity of different aquifers. The environmental isotopes indicated that all water in all aquifers was sourced from rainfall recharge. Radio isotope results (carbon-14 and tritium) suggest that modern recharge water only occurs in the alluvial aquifers while the groundwater in

the coal seams ranges between 3,000 years BP for the shallow coal seams to more than 20,000 years BP for the deep Blakefield Coal Seam.

These distinct differences in radiocarbon ages and tritium concentrations differentiate the groundwater in the alluvial aquifers, shallow bedrock aquifers and deeper coal seam aquifers. There were slight differences in the radiocarbon ages and tritium results between sampling events in gas well HB02. These are not deemed significant, nor are they corroborated by other sampling results, or indicative of mixing with younger water from overlying aquifers.

Water chemistry was generally comparable between the baseline and recovery periods for the alluvial and shallow bedrock aquifers. There is nothing in the recovery water quality data set to indicate any influence or change generated by the pumping test and depressurisation of the deep coal seam aquifer at the gas well HB02 site.

Aquifer connectivity

The conceptual model developed early in the investigation program is sound and has been reinforced and improved by the results of this water level and water quality investigation.

The alluvium comprises clay, silt, sand and gravel deposited across the floodplain of the Wollombi Valley to depths of between 10 and 20 metres. Porous aquifers occur in the alluvium have high permeability and are unconfined. Recharge to the alluvial aquifer is predominantly from direct surface infiltration from rainfall, the occasional fresh flows along Wollombi Brook, run off from the valley sides and a small contribution from the bedrock aquifers. Groundwater flow is down valley, and natural discharge is likely to permanent pools in streams, evaporation and transpiration by vegetation.

Fractured rock and coal seam aquifers are low permeability and are considered confined because of the very low permeability claystones at various levels above the coal seams. Recharge to the bedrock aquifers is from rainfall and only likely to occur where the bedrock outcrops. This is remote from the Broke area hence deep groundwater has a long residence time and groundwater ages are ten of thousands of years old.

The investigation data supports the original conceptual model and confirms that shallow alluvial and deep fractured rock aquifers are disconnected.

Local water supply implications

Most water supply bores are less than 20 metres deep and target the alluvial groundwater resource. There are minor aquifers in the fractured bedrock, but deeper water bores are unlikely to be drilled to depths greater than 100 metres. Based on this investigation, gas exploration activities are considered to have negligible effect on the local productive alluvial and shallow bedrock groundwater supplies.

10. Recommendations

The following recommendations relate to data collection at the current investigation site to provide continuity with the studies completed in 2009. The recommended data is essentially extended baseline information that will be important to:

- Assess medium term trends when extended exploration gas flow testing is commenced at the site
- More thoroughly assess natural water level and water quality variations
- Provide a reasonable baseline data set for inclusion in any potential future environment assessment

Water level monitoring

Loggers are currently installed in all four monitoring bores at the BM01 site and these have been recording water levels since the pumping test recovery period (November 2009).

Recommendation 1 – PB recommends that the dataloggers continue indefinitely in the four monitoring bores at the BM01 site and be downloaded quarterly.

Water quality sampling

An additional groundwater quality sampling event should be undertaken in early 2010 to complete a full year of monitoring (given there have been several high rainfall events since December 2009).

The following parameters should be analysed:

- Water quality parameters (pH, EC, temperature, Eh, DO, CO_2)
- Major ions
- Dissolved metals
- Methane.

Recommendation 2 – PB recommends that water samples be collected from all nine AGL monitoring bores for the above analytes prior to the middle of March 2010 and prior to any extended flow testing of HB01 and HB02.

Reporting

It is suggested that the additional monitoring data continue to be downloaded and reported to AGL at regular intervals.

11. Acknowledgements

PB would like to thank a number of people and organisations that have contributed monitoring locations and technical assistance for this groundwater project. The assistance of Chris Holmes (Senior Geologist AGL) for his substantial input on the geology and geological structure of the area together with Mike Roy (Head of Gas Operations AGL) for his assistance with the construction and testing of gas wells is very much appreciated.

We would also like to acknowledge the ongoing assistance of Ralph Northey from Xstrata for providing historical water level and piezometer construction data together with access to Xstrata monitoring bores in the immediate area of this groundwater investigation. There were also two landowners at Broke who allowed PB to sample their water supply bores so that these locations could be included as part of the baseline water sampling program.

Finally the role of the BCCC has been important in focusing on important community issues particularly the water supply impacts associated with coal seam gas exploration programs. We would particularly like to recognise the involvement of Bob Kennedy for his substantial assistance in focusing the technical conclusions of the study.