



Surface Water and Groundwater  
Management Plan for the Waukivory Pilot  
Program – Gloucester Gas Project



Date: 22 October 2014

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## Document Revision History

| Date              | Version | Author         | Comment  |
|-------------------|---------|----------------|--|
| 6 December 2011   | V1-1    | John Ross      | Initial Draft for Internal Review  |
| 16 December 2011  | V1-2    | John Ross      | Second Draft for Internal Review   |
| 8 March 2012      | V1-3    | John Ross      | Final Draft for Internal Review  |
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| 20 December 2012  | V2-1    | John Ross      | Internal Review - Final Draft for Waukivory Pilot REF for the fracture stimulation and pilot testing program for internal review   |
| 12 April 2013     | V2-2    | John Ross      | Internal Review - Revised Final Draft for Waukivory Pilot REF for the fracture stimulation and pilot testing program   |
| 23 September 2013 | V2-3    | John Ross      | <b>Version 2</b> Final for inclusion with Waukivory Pilot REF for the fracture stimulation and pilot testing program   |
| 4 July 2014       | V3-1    | John Ross      | Internal Review - Revised Version 3 for Waukivory Pilot REF for the fracture stimulation and pilot testing program after regulatory feedback on the REF application              |
| 9 July 2014       | V3-2    | John Ross      | <b>Version 3</b> Final for Waukivory Pilot REF for the fracture stimulation and pilot testing program after regulatory feedback on the REF application                           |
| 3 September 2014  | V4-1    | John Ross      | <b>Version 4</b> Final for Waukivory Pilot REF for the fracture stimulation and pilot testing program after REF/PEL and EPL approvals  |
| 16 October 2014   | V4-2    | John Ross      | <b>Version 4</b> Revised Final for Waukivory Pilot REF for the fracture stimulation and pilot testing program after REF/PEL and EPL approvals, and after SGMP V4.1 review by NOW |
| 22 October 2014   | V4-3    | James Duggleby | <b>Version 4</b> Revised Final for the Waukivory Pilot REF for the fracture stimulation and pilot testing after SGMP V4.2 approval by OCSG                                       |

This **Surface Water and Groundwater Management Plan** is the:

- (i) Waukivory Surface Water and Groundwater Management Plan that is referenced under Condition G2.1 of EPL 20358; and
- (ii) Groundwater Monitoring and Modelling Plan that is referenced under Conditions 12 to 15 of PEL 285.



## Glossary

|                                      |  |
|--------------------------------------|--|
| <b>Alluvium</b>                      | Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.  |
| <b>Alluvial aquifer</b>              | Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.  |
| <b>Aquifer</b>                       | Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.  |
| <b>Aquifer properties</b>            | The characteristics of an aquifer that determine its hydraulic behaviour and its response to abstraction.  |
| <b>Aquifer, confined</b>             | An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.   |
| <b>Aquifer, semi-confined</b>        | An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the confining layer – also known as a leaky artesian or leaky confined aquifer. |
| <b>Aquifer, unconfined</b>           | Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.                                   |
| <b>Aquitard</b>                      | A low-permeability unit that can store groundwater and also transmit it slowly from one aquifer to another. Aquitards retard but do not prevent the movement of water to or from an adjacent aquifer.                                  |
| <b>Australian Height Datum (AHD)</b> | The reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of aquifers and water levels in bores.  |
| <b>Bore</b>                          | A structure drilled below the surface to obtain water from an aquifer or series of aquifers.   |



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| <b>Breaker</b>             | A chemical that reduces the viscosity of a fluid by breaking long-chain molecules into shorter segments.   |
| <b>Claystone</b>           | A non-fissile rock of sedimentary origin composed primarily of clay-sized particles (less than 0.004 mm).  |
| <b>Coal</b>                | A sedimentary rock derived from the compaction and consolidation of vegetation or swamp deposits to form a fossilised carbonaceous rock.   |
| <b>Coal seam</b>           | A layer of coal within a sedimentary rock sequence.  |
| <b>Coal seam gas (CSG)</b> | Coal seam gas is a form of natural gas (predominantly methane) that is extracted from coal seams.  |
| <b>Conceptual model</b>    | A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes. |
| <b>Contamination</b>       | Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures.   |
| <b>Crosslink gel</b>       | A fluid that has a very high viscosity typically in the range of 200-1000 cP.  |
| <b>Depressurisation</b>    | The process of reducing the hydrostatic pressure and removing formation water from a targeted coal seam. Depressurisation is required to reduce pressure in the coal so gas can desorb and be produced.  |
| <b>Dewatering</b>          | The process of removing formation water from a targeted coal seam and drawing the water level down within the perforated coal seam horizon so that unconfined conditions prevail.  |
| <b>Discharge</b>           | The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.   |



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| <b>Drawdown</b>                     | A lowering of the water table in an unconfined aquifer or lowering of the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.  |
| <b>Electrical Conductivity (EC)</b> | A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity.   |
| <b>Fracture stimulation</b>         | A technique that increases the productivity of a gas well by creating a pathway into the targeted coal seam under high pressure.   |
| <b>Flowback</b>                     | The process of allowing fluids to flow from a gas well following a treatment, either in preparation for exploration testing, a subsequent phase of treatment / workover, or in preparation for returning the well to production.   |
| <b>Flowback water</b>               | The return to surface of fracture stimulation fluids before transition to natural formation water (groundwater), after which water flowing from the well is termed produced water.   |
| <b>Fractured rock aquifer</b>       | Aquifers that occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary aquifers. |
| <b>Groundwater</b>                  | The water contained in interconnected pores or fractures located below the water table in an unconfined aquifer or located at depth in a confined aquifer or water bearing zone.   |
| <b>Groundwater system</b>           | A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.  |



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| <b>Hydraulic conductivity</b>   | The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water).  |
| <b>Hydraulic fracturing</b>   | A technique that increases the productivity of a gas well by creating a pathway into the targeted coal seam by injecting sand and fluids through the perforated interval directly into the coal seam under high pressure.   |
| <b>Linear gel</b>   | A fluid that has a higher viscosity than water but a lower viscosity than crosslink gel. Typically they have a viscosity between 12 – 20 cP.  |
| <b>microSiemens per centimetre (<math>\mu\text{S}/\text{cm}</math>)</b> | A measure of water salinity commonly referred to as EC (see also Electrical Conductivity). Most commonly measured in the field with calibrated field meters.  |
| <b>Monitoring bore</b>  | A non-pumping bore, is generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter.  |
| <b>Numerical model</b>  | A model of groundwater flow in which groundwater systems are described by numerical equations, with specified parameters and values for different layers and boundary conditions that are solved on a computer.   |
| <b>pH</b>   | The potential of Hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic). |
| <b>Piezometric surface</b>  | The potential level to which water will rise above the water level in an aquifer in a bore that penetrates a confined aquifer; if the potential level is higher than the land surface, the bore will overflow and is referred to as artesian.                                       |
| <b>Produced water</b>   | Water that is taken in the course of a prospecting operation that is part of, or incidental to, that prospecting operation, including water that is   |





encountered within and extracted from boreholes, petroleum wells or excavations.

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| <b>Proppant</b>                | Sand or synthetic high strength particles used with fracturing to fill the fracture space and hold the fracture open during the production life of a well.   |
| <b>Recharge</b>                | The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.   |
| <b>Salinity classification</b> | <p><b><i>Fresh water quality</i></b> – water with a salinity &lt;800 <math>\mu\text{S/cm}</math>.</p> <p><b><i>Marginal water quality</i></b> – water that is more saline than freshwater and generally waters between 800 and 1,600 <math>\mu\text{S/cm}</math>.</p> <p><b><i>Brackish quality</i></b> – water that is more saline than freshwater and generally waters between 1,600 and 4,800 <math>\mu\text{S/cm}</math>.</p> <p><b><i>Slightly saline quality</i></b> – water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 <math>\mu\text{S/cm}</math>.</p> <p><b><i>Moderately saline quality</i></b> – water that is more saline than brackish water and generally waters between 10,000 and 20,000 <math>\mu\text{S/cm}</math>.</p> <p><b><i>Saline quality</i></b> – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 <math>\mu\text{S/cm}</math>.</p> <p><b><i>Seawater quality</i></b> – water that is generally around 55,000 <math>\mu\text{S/cm}</math>.</p> |
| <b>Sandstone</b>               | Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).  |
| <b>Sandstone aquifer</b>       | Permeable sandstone that allows percolation of water and other fluids, and is porous enough to store large quantities.   |
| <b>Screen</b>                  | A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material.  |



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| <b>Sedimentary rock aquifer</b>   | These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest volumes of groundwater. |
| <b>Shale</b>                      | A laminated sediment in which the constituent particles are predominantly of clay size.  |
| <b>Siltstone</b>                  | A fine-grained rock of sedimentary origin composed mainly of silt-sized particles (0.004 to 0.06 mm).  |
| <b>Source water</b>               | In this report, this term is used to define raw water that is used for the fracture stimulation program. The raw water can be either fresh water or brackish produced water.   |
| <b>Standing water level (SWL)</b> | The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.  |
| <b>Stratigraphy</b>               | The depositional order of sedimentary rocks in layers.   |
| <b>Water bearing zone</b>         | Geological strata that are saturated with groundwater but not of sufficient permeability to be called an aquifer.  |
| <b>Water quality</b>              | Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.   |
| <b>Water table</b>                | The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.  |
| <b>Well</b>                       | Pertaining to a gas exploration well or gas production well.   |
| <b>Zonal isolation</b>            | Isolating an interval or unit of rock from surrounding rock types on the basis of its lithology or other features, such as faults or fractures.  |

# 1. Introduction

## 1.1. Context

Version 1 of this Groundwater Management Plan (GMP) was prepared as a condition of the activity approval issued under the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) for the Waukivory exploration drilling program at Gloucester issued by the NSW Department of Trade and Investment, Regional Infrastructure and Services (NSWT&I) – Division of Resources and Energy (DRE - Environmental Sustainability Unit). The initial activity approval for the drilling program, which incorporated the Proposed Exploration Wells – Waukivory REF (Waukivory Drilling REF), was dated 12 October 2011.

Version 2 of this GMP was expanded into a Surface Water and Groundwater Management Plan (SGMP) and included more information for the proposed fracture stimulation and pilot testing program of the four gas wells at the Waukivory site. It was submitted as part of the Review of Environmental Factors (REF) for the Waukivory pilot testing program (Waukivory Pilot) in September 2013 (Waukivory Pilot REF).

Version 3 is the SGMP submitted in support of the Waukivory Pilot REF after review of regulatory feedback, and a further review of the required monitoring network, analytical suites and monitoring frequency.

Version 4 (this version) is the SGMP submitted after the granting of Waukivory Pilot approvals, being the PEL 285 renewal (including the Waukivory Review of Environmental Factors approval) and the new Environment Protection Licence 20358 (EPL) issued for the Gloucester Gas Project (GGP) exploration activities. It includes the information required by the OCSG, NOW and the EPA under the PEL 285 and EPL conditions. It includes late revisions to the SGMP in advance of the Waukivory Pilot.

The SGMP focuses on the Waukivory local area within the Stage 1 Gas Field Development Area (GFDA) of the GGP. The GGP is approved under Part 3A of the EP&A Act.

The exploration area, the pilot wells, groundwater monitoring bores, and surface water monitoring locations are shown on Figure 1. This SGMP should be read together with:

- Proposed Exploration Wells - Waukivory REF (EMGA/Mitchell McLennan, 2011)
- Waukivory Pilot REF (EMGA/Mitchell McLennan, 2013a)
- Addendum to the REF – Preferred Activity Report (EMGA/Mitchell McLennan, 2013b)
- Further Addendum to the REF – Preferred Activity (EMGA/Mitchell McLennan, 2014)
- Waukivory Fracture Stimulation Management Plan (AGL, 2014).

This SGMP also addresses the requirements of the *Code of Practice for Coal Seam Gas – Fracture stimulation activities* (NSWT&I, 2012b) and *Aquifer Interference Policy* requirements (NSWT&I, 2012c).

The SGMP was prepared in consultation with NSW Office of Water (NOW).

The SGMP also complies with the requirements of a Groundwater Monitoring and Modelling Plan (GMMP) (NOW, 2014) as required under the PEL 285 renewal conditions (dated 6 August, 2014) and the requirements under the EPL for the GGP premises (EPL 20358, dated 6 August 2014).

Various approvals issued to AGL refer to various management and monitoring plans relating to water. While the names for these plans vary across these approvals, AGL has prepared this SGMP having regard to the relevant conditions of the approvals relating to water

management and monitoring and, for consistency, will refer to all these plans simply as this SGMP. Relevantly, Table 1.1 lists:

- Approval instruments
- Approval reference for water management and monitoring plan
- Sections in this report where water management and monitoring plan conditions are addressed.

**Table 1.1: Water Management Plan Terminology**

| Approval   | Approval Reference for water management plan   | Addressed in this Report (Section No.) |
|--|--|--|
| Waukivory Pilot Project – Drilling (REF, EMGA/Mitchell McLennan, 2011)   | Groundwater Monitoring Program   | 1.4.1                                  |
| Waukivory Pilot Project – Fracture Stimulation and Flow Testing (REF EMGA/Mitchell McLennan, 2013a, 2013b, 2014) | Enhanced groundwater monitoring program  | 1.4.2                                  |
| PEL 285 (renewed in August 2014)   | Groundwater Monitoring and Modelling Plan <sup>Note 1</sup>  | 1.4.2                                  |
| EPL 20358 (issued in August 2014)  | Waukivory Surface Water and Groundwater Management Sub Plan  | 1.4.3                                  |
| Production Bore Licences (issued in August 2014)   | No specific reference but implicitly requires this Surface Water and Groundwater Management Plan for the Waukivory Pilot | 1.4.3                                  |

Note 1: PEL 285 Condition 16 to 19 for a Produced Water Management Plan are addressed in a separate water management plan (AGL, 2014b). This PWMP is being written concurrently with this plan to comply with the recent PEL 285 renewal.

## 1.2. Objectives

The purpose of this SGMP is to provide a framework which describes how AGL will monitor and assess changes in surface water and the different groundwater systems in the Waukivory local area, particularly within the shallow aquifers and thrust faulting, due to fracture stimulation and dewatering of the deep coal seams. The SGMP focuses on the potential for:

- connectivity of shallow aquifers and the deep water bearing zones; and
- contamination of shallow aquifers and adjacent surface waters.

Consequently, the objectives of this SGMP and associated reports are to:

- describe the water level and water quality monitoring network across the different groundwater systems located beneath the Waukivory Pilot testing area;
- build a database of baseline information (permeability, water levels and water quality for shallow beneficial use aquifers) located beneath the local area;
- identify water level and water quality trends that may suggest connectivity or contamination of aquifers due to fracture stimulation and/or dewatering activities;

- describe the water level and water quality characteristics of the Avon River and Waukivory Creek in the near vicinity of the Waukivory Pilot testing area;
- highlight the results of a risk assessment and adopted controls/mitigation measures;
- provide a monitoring framework for the community and regulators on the groundwater monitoring program to be adopted for the pilot testing program;
- provide water triggers for an action plan should there be unexpected water level or water quality impacts;
- address the data requirements for numerical modelling for the larger Stage 1 GFDA; and
- outline the reporting requirements for the monitoring program associated with the Waukivory Pilot.

### 1.3. Responsibilities

AGL is responsible for:

- implementation of this SGMP; and
- revision of this SGMP and associated reports to reflect changes in applicable approvals, licences and regulations.

The SGMP (Version 4) is written for the period of the Waukivory Pilot and the associated approvals. The fracture stimulation and pilot well monitoring (tracking of injected and produced volumes of water) will be undertaken by AGL Upstream Gas (Operations) staff based at Gloucester.

Periodic monitoring of the water quality from the pilot wells being depressurised, together with water levels from the nested monitoring bore network and the surface water monitoring network, will mostly be carried out by technical specialists appointed by AGL.

### 1.4. Approval Conditions

#### 1.4.1. REF approval for Waukivory Pilot Program - Drilling

The groundwater conditions attaching to the Waukivory Drilling REF (EMGA/Mitchell McLennan, 2011) approval for the construction of the gas wells were:

4. *A NSW Office of Water hydrogeologist should be notified 28 days prior to the commencement of drilling.*

...

7. *A groundwater monitoring program must be developed for the proponent's exploration activities. The monitoring program should lead to the development of a conceptual model of the local groundwater behaviour, both in the target seams and other key aquifers. Prior to moving to production stage, it is expected a numerical hydrogeological model utilising the information gained from this monitoring program, and other available sources will be prepared. This model should quantify predicted impacts on the target aquifers, any other affected aquifers or surface water sources, and any users, including the environment.*

The original GMP (Version 1) relates to the first part of Condition 7 being the monitoring program and the development of a conceptual model.

AGL sought clarification from DRE of the remainder of Condition 7 in November 2011 and was advised that the 'exploration' program includes the drilling, fracture stimulation, and pilot testing of the gas wells, and the preparation of a conceptual model for the local groundwater behaviour was required at the end of the exploration program. The numerical model was required before moving to a production program (i.e. after the exploration program). No numerical model for the Waukivory area was intended to be built at the time.

AGL has since developed a numerical model for the Waukivory Pilot REF Addendum (EMGA/Mitchell McLennan, 2013b) and associated fracture stimulation and flow testing program (PB, 2013c) because of the necessity to demonstrate the likely area of depressurisation and water level declines.

#### **1.4.2. REF for Waukivory Pilot Program – Fracture Stimulation and Flow Testing**

The approval of the Waukivory Fracture Stimulation and Flow Testing Program which was included with the renewal of PEL 285 did not include any new conditions relating to water monitoring or management (apart from what is called up and described in this plan). A discussion of the PEL 285 renewal conditions is provided below.

##### **PEL 285**

PEL 285 expired on 15 April 2012 and was renewed on 6 August 2014. The conditions in the PEL relevant for this SGMP are:

##### ***Groundwater Monitoring and Modelling Plan***

12. *The licence holder must submit a Groundwater Monitoring and Modelling Plan prepared in accordance with the requirements set out in conditions 13 and 14 to the Minister for approval by 3 September 2014.*
13. *The Groundwater Monitoring and Modelling Plan must be prepared in consultation with the NSW Office of Water.*
14. *The Groundwater Monitoring and Modelling Plan must address the following matters to a level of detail commensurate with the scale, timing and potential impact of the proposed prospecting operations:*
  - a) *description of methods for identifying aquifers, aquifer depths, behaviour, containing layers and connectivity with surrounding aquifers or surface water systems;*
  - b) *description of methods for collection of data relevant to the type, quantity and quality of water contained within aquifer systems likely to be encountered during prospecting operations;*
  - c) *a proposal for the future development of a conceptual model of regional groundwater behaviour;*
  - d) *a proposal for the future development of a calibrated computer model of regional groundwater behaviour, to enable the impacts of any proposed production operations to be assessed;*
  - e) *description of how records of all data collected will be maintained;*
  - f) *description of the staging process for implementation of the plan; and*
  - g) *includes any additional requirements prescribed by the Secretary.*
15. *The licence holder must implement and comply with the Groundwater Monitoring and Modelling Plan approved by the Minister under condition 12.*

**Note – Purpose of Groundwater Monitoring and Modelling Plan**

*The Groundwater Monitoring and Modelling Plan is required to ensure:*

- a) there is sufficient groundwater data available to assess future operations against the Aquifer Interference Policy (NSW Office of Water, 2012), as amended or replaced from time to time; and*
- b) baseline data is available prior to submitting an application for any future production operations.*

This SGMP represents the Groundwater Monitoring and Modelling Plan (GMMP) referred to in the PEL and in Condition 12.

In compliance with condition 13 of PEL 285, AGL has discussed the Waukivory monitoring network and program, and consulted with NOW during regular Gloucester update meetings in late 2013 and 2014.

In regard to Condition 14:

- Part a) is addressed in Sections 2.3.2 and 3.3.1;
- Part b) is addressed in Sections 6.2, 6.3, and 6.4;
- Part c) is addressed in Section 2.4;
- Part d) is addressed in Sections 2.4 and 6.8; and
- Part e) is addressed in Section 6.9.

Regarding Part f), as the work program relates only to the Waukivory fracture stimulation and pilot testing program, there is no staging process for the implementation of this plan.

Part g) is not dealt with at this time because there are no additional requirements prescribed by the Secretary.

In regard to Condition 15, AGL will implement and comply with the SGMP. Baseline monitoring programs were initiated in March 2012 and are continuing with a baseline sampling event immediately before the fracture stimulation program.

### **1.4.3. Other Approvals**

The other relevant approvals are EPL 20358 (issued by EPA) and production bore licences 20BL173595, 20BL173599, 20BL173600 and 20BL173601 (issued by NOW). Details are provided below.

#### **EPL 20358**

The EPL 20358 for the GGP premises exploration activities was granted on 6 August 2014. The current EPL conditions relating to the Waukivory Pilot are:

##### ***G2.1 Waukivory Surface Water and Groundwater Management Sub Plan***

*The license must revise the "Surface Water and Groundwater Management Plan for the Waukivory Pilot Program – Gloucester Gas Project, dated 9 July 2014" (SGMP) for the proposal and submit to the EPA for review 1 month prior to the commencement of fracture stimulation activities. The plan must include the additional information below:*

- a) A methodology that clearly defines what constitutes a significant deviation from the trends observed in baseline surface and groundwater parameter ranges at the prescribed surface and groundwater monitoring locations being used to assess potential pollution from fracking activities. This methodology should include the full range of analytes being sampled at surface and groundwater locations monitoring for potential pollution, and should also include salinity.*

b) If produced water from the Tiedman dams will be used as fracking make-up water, the proposed salinity trigger value may not be appropriate and the SGMP will need to be updated to include trigger values that account for the salinity of the makeup water.

c) Some tanks remain open topped and therefore certain risk factors remain. Management triggers in the SGMP should address contingency actions to cease pumping into staging dams if there is a chance of overflow (e.g. due to either pump out failures or high rainfall).

d) Provide further information on intermediate breakdown products of Tetrakis (hydroxymethyl) Phosphonium Sulfate (THPS). These intermediate breakdown products may include, but not be limited to, trishydroxymethyl phosphine (THP) and tris hydroxymethyl phosphine oxide (THPO). Propose analytical methods to be used for licence monitoring of THPS and intermediate breakdown products (prior to full breakdown to elemental constituents).

e) Outline a proposed sampling and monitoring program for the detection of fracture stimulation chemical compounds (including THPS, Choline Chloride, Monoethanolamine Borate and Sodium Hypochlorite and any relevant intermediate breakdown products) to monitor their presence/absence of any fracking chemicals introduced water before being transferred to the Tiedman Irrigation produced water dams.

*This sampling should be included as part of the operational triggers in Section 6.1 of the SGMP that define when the change from flowback water to produced water occurs. The program should include justification for the location and frequency of sampling and the frequency should relate to how the change of flow back water to produced water will be handled.*

In addition, the water monitoring location and frequency conditions in the EPL (Conditions P1.3 and M2.2 to M2.6) are covered in Section 6.

This SGMP represents the Waukivory Surface Water and Groundwater Management Sub Plan (WSGMSP) proposed in the EPL conditions. In regard to Condition G2.1:

- Part a) is addressed in Section 6.3.4;
- Part b) is addressed in Section 6.1;
- Part c) is addressed in Section 6.7;
- Part d) is addressed in Sections 2.5, 6.1, 6.3.3.1; and
- Part e) is addressed in 6.1 and 6.3.3.1.

#### **Bore licences 20BL173595, 20BL173599, 20BL173600 and 20BL173601**

Production bore licences 20BL173595, 20BL173599, 20BL173600 and 20BL173601 were issued by NOW on the 22 August 2014 for each of the four gas wells that comprise the Waukivory Pilot. Licence conditions are extensive so copies of these four bore licences are provided in Appendix A1.

There are no conditions that specifically reference this SGMP, however there are conditions relating to monitoring injected water volumes (Condition 15), monitoring extracted volumes (Condition 7), monitoring water quality (Condition 8) and reporting (Conditions 7, 8, and 15).

The components of the required groundwater monitoring program are outlined in detail in Section 6.



## 2. Background

This chapter provides summary information relating to the landform, surface water, geology and hydrogeology for the Waukivory area. More details are provided in the Phase 1 groundwater investigation report for the Stage 1 GFDA (SRK Consulting, 2010), the Phase 2 groundwater investigation report (PB, 2012a), the revised conceptual model for the Gloucester Basin (PB, 2013a), and the water balance for the same area (PB, 2013b).

### 2.1. Landform

The Gloucester geological basin straddles the Manning River Catchment to the north and the Karuah River Catchment to the south.

The landforms of the locality are guided by the geology of the Stroud Gloucester Syncline and comprise ridges to the east and west, undulating low hills and flat land in the centre where the Avon River flows to the north. The lowest points in the area are on the Avon River floodplain at an elevation of approximately 100 mAHD.

### 2.2. Hydrological Setting

The Waukivory site is within the Manning River Catchment (approximately 8,200 km<sup>2</sup> in size) and the Avon River Sub Catchment. The Avon River originates to the south west of Gloucester and joins the Gloucester River to the north of the township of Gloucester. Waukivory Creek, Dog Trap Creek and Avondale Creek are also located within the Sub Catchment.

The Waukivory Pilot site is located at the confluence of the Avon River and Waukivory Creek.

Both the Avon River and Waukivory Creek are gaining streams in this area i.e. there are diffuse groundwater seepages and discharges to the river/creek. Baseflow accessions from the shallow alluvium are expected in this area based on data from the nearby Waukivory gauging station (PB, 2012b). The Avon River is mostly a permanent stream although during low rainfall periods there is negligible flow and the river can be reduced to a succession of waterholes. Waukivory Creek is more ephemeral.

### 2.3. Geological and Hydrogeological Setting

#### 2.3.1. Geology

The Gloucester Basin is a synclinal structure formed by Permian consolidated sediments. The Permian Rocks display steep dips of up to 90° on the edge of the basin, dipping towards the north south axis, and flattening towards the basin centre. They lay on a basement composed of Early and Late Carboniferous sedimentary and volcanic units that are part of the New England Fold Belt. The geology of the region comprises Quaternary sediments along the valley floor and Permian rocks along the flanks and over most of the catchment. Carboniferous volcanics form the major east and west ridgelines.

The geological strata of the Gloucester Basin (from youngest to oldest) on a local scale can be summarised as:

- Unconsolidated alluvial deposits along the Avon River (Quaternary in age).

- Sedimentary rocks (including substantial coal measures at depth) of the Gloucester Coal Measures (Permian in age)
- Fractured basement rocks of the New England Fold Belt below the sedimentary rocks (Palaeozoic age)

At a local scale, the geology and geological structure at this Waukivory exploration site is complex. The pilot is situated close to the centre of the basin and the strata (including the coal seams) are shallowly dipping at approximately 20° towards the west. A major north-south trending low angle thrust fault (dipping from east to west) with a vertical throw of more than two hundred metres occurs in this area (see Figure 2). The eastern gas wells are located in the stable (footwall) block of this major thrust fault, while the western locations go through the fault but are located in the upthrust block (hanging wall). Subcrop for the shallow western thrust fault is expected to be beneath the Avon River and the shallow alluvium in this area.

### 2.3.2. Hydrogeology

The broader (ridgeline) areas of the Gloucester Basin are underlain by Carboniferous volcanics, the hillsides by a variety of Permian sedimentary rocks while the valley floors are underlain by Quaternary alluvium associated with the Avon River and other minor tributaries.

Groundwater in the Permian rocks is a low value water resource and is rarely used for agricultural and other consumptive uses. Rock permeabilities are generally low, aquifers are mostly bedding and fracture zones, bore yields in rocks and fracture zones are very low and water quality is generally brackish to slightly saline.

Based on the water level, water quality and isotope data from the Phase 2 studies (PB, 2012a and PB, 2012c) and ongoing monitoring, there is a good appreciation of groundwater recharge, discharge and flow processes through the different hydrogeological units of the Gloucester Basin. These units (based on SRK Consulting, 2010) are confirmed as:

- Alluvial aquifers;
- Fractured bedrock aquifers;
- Coal seam water bearing zones;
- Confining units.

Only the first two units are aquifers. The deeper rock types being either very poor aquifers/aquitards (coal seams, siltstones and sandstones) or confining aquitard/aquiclude layers (claystones or indurated sandstones). The deeper units are generally referred to as water bearing zones because of the low permeabilities.

The **alluvium** is relatively shallow (maximum 15m thickness) and in some areas contains an unconfined (sand and gravel) aquifer. Water tables are generally less than 5 m below surface. Groundwater flow processes are relatively simple with rainfall being the predominant recharge source on the floodplain. Flooding occasionally adds additional recharge water to the alluvial water table. Groundwater discharge from the alluvium is to the rivers as baseflow and shallow groundwater is also expected to be transpired by riparian vegetation.

The **bedrock** contains mostly tight siltstone and indurated sandstone rock types with occasional thin semi-confined sedimentary/fractured aquifers (typically to around 75 m depth). Water tables are generally greater than 10 m below surface with deepest levels at elevated sites and in areas of active coal mining. Rainfall is the only recharge source to the bedrock aquifers and recharge does not occur everywhere in the landscape. Recharge mostly occurs in areas of rock outcrop. In areas where there is a weathered (clayey) profile,

brackish to saline water quality suggests there is negligible (vertical) rainfall recharge. Groundwater flow in bedrock aquifers is lateral, either within local fracture zones or individual strata if there are no interconnecting and open fracture zones. Groundwater discharge is via seepage to springs and to the alluvium (and indirectly to creeks and rivers) along the floor of the valley.

The groundwater in the deeper bedrock units is moving very slowly with lateral movement within each rock unit predominating. Confining rock permeabilities are very low, deep coal seam permeabilities are slightly higher (but are still not high enough to be considered aquifers).

Therefore, the only beneficial aquifers in the region are the shallow alluvial groundwater source and shallow semi-confined sedimentary/fractured aquifers to around 75 m depth. Deeper zones are water bearing zones but rarely aquifers.

There are no known groundwater dependent ecosystems (GDEs) (apart from stream baseflow accessions) although there may be some uptake of shallow groundwater (from the alluvium) by native terrestrial vegetation on the floodplain. Diffuse discharge of saline groundwater from bedrock seeps is thought to occur into the alluvium as the stream salinity increases during dry periods. Groundwater discharge is diffuse and discharge does not occur at any one point in the landscape.

## 2.4. Conceptual and Numerical Modelling

The latest review of the conceptual model (PB, 2013a) was completed in advance of the Waukivory Pilot and is not repeated in this SGMP. The conceptual model will be reviewed in consultation with NOW and improved (if required) based on the results from the Waukivory pilot testing program. It is expected that the 2013 conceptual model report (PB, 2013a) will be revised and reissued in 2015.

It is not expected that a 3D numerical model will be prepared specifically for the pilot testing program (although 2D numerical modelling of this local area has been completed for the REF approval and PEL renewal, and is underway as part of the Part 3A approval for the GGP Stage 1). The Waukivory 2D local area model (a cross sectional FEFLOW model) has been developed and has been used to simulate the possible impact of the pilot testing program over a maximum 24 months (PB, 2013c). The (uncalibrated) predictive model results are reported in EMGA MM, 2013b and are summarised in Appendix A4 of this SGMP.

After the pilot testing program, the groundwater level and pressure data from the program will be used to further calibrate and verify the 2D numerical groundwater model. The local model is focused on fault structures, coal seams and aquitards, and is being developed to help design, parameterise and calibrate the regional numerical model required for the Stage 1 GFDA.

AGL believes that the Waukivory Pilot and supporting monitoring network will provide:

- Sufficient water level and pressure data to calibrate the 2D local scale model and inform the broader conceptual model; and
- Enough spatial data to determine whether the depressurisation effects propagate through aquitards and/or are propagated along faults to impact shallow water resources (aquifers in alluvium/rock, and surface water).

The numerical model development, calibration, verification and predictive results will not be part of the Waukivory technical report for this fracture stimulation and flow testing activity but rather will be included in the modelling study reports.

## 2.5. Fracture Stimulation

Hydraulic fracture stimulation has been used on all 12 completed gas production wells at Gloucester, and AGL proposes to continue to use this technology at the four Waukivory pilot well sites.

Hydraulic fracturing consists of pumping a fluid into a steel cased and cemented wellbore to create enough pressure to crack, or fracture, the target rock layer. The fluid contains a “proppant”, such as sand, carried by a viscous guar gel that helps prop the fractures open to allow gas to be produced to surface.

The likely constituents of the well pre-treatment (to be used after perforating each well) and the linear / cross-link gel fluid mix used for all fracture stimulations are described in Table 2.1. Full details are provided in the fracture stimulation management plan (AGL, 2014a).

**Table 2.1: Components of Well Pre-Treatment and Fracture Stimulation Fluids**

**Volumes and Constituents in Proposed Fracture Stimulation Fluid**  
(Based on information provided by AGL's contracted service provider)

| Purpose             | Compound Present  | Well Pre-Treatment <sup>(1)</sup> | Treated Water  | Linear Gel     | Cross-Linked Gel | Indicative Quantity <sup>(2)</sup> |
|---------------------|---|-----------------------------------|----------------|----------------|------------------|------------------------------------|
|                     |   | % volume of compound in fluid     |                |                |                  |                                    |
| Main Fracture Fluid | Water   | 88.12%                            | 99.81%         | 99.65%         | 99.53%           | 4,025,771                          |
| Clean Perforations  | Hydrochloric Acid   | 10.88%                            | -              | -              | -                | 2,067                              |
| Iron Sequesterant   | Citric Acid   | 0.361%                            | -              | -              | -                | 69                                 |
| Corrosion Inhibitor | Ground Coffee Beans   | 0.036%                            | -              | -              | -                | 7                                  |
| pH Adjusting Agent  | Acetic Acid   | 0.60%                             | 0.03%          | 0.03%          | 0.03%            | 1,320                              |
| Bactericide         | THPS<br>Tetrakis(hydroxymethyl)<br>Phosphonium Sulfate <sup>(3)</sup> | -                                 | <0.01%         | <0.01%         | <0.01%           | 302                                |
| Gelling Agent       | Guar Gum  | -                                 | -              | 0.163%         | 0.163%           | 4,916                              |
| Gel Breaker         | Hemicellulase enzyme concentrate                                      | -                                 | -              | <0.01%         | <0.01%           | 60                                 |
| Clay Stabiliser     | Choline Chloride<br>(only used on 2 wells)                            | -                                 | 0.15%          | 0.15%          | 0.15%            | 2,550                              |
| Cross-Linker        | Monoethanolamine borate   | -                                 | -              | -              | 0.108%           | 1,836                              |
| pH Buffer           | Sodium Hydroxide  | -                                 | -              | -              | <0.01%           | 102                                |
| <b>Total</b>        |   | <b>100.00%</b>                    | <b>100.00%</b> | <b>100.00%</b> | <b>100.00%</b>   | <b>4,039,000</b>                   |

|   | Well Pre-Treatment <sup>(1)</sup> | Treated Water | Linear Gel | Cross-Linked Gel | Total Treatment |
|---|-----------------------------------|---------------|------------|------------------|-----------------|
| Indicative Volume of Fluid <sup>(2)</sup> |                                   |               |            |                  |                 |
| Average per well (L)                      | 4,750                             | 252,500       | 327,500    | 425,000          | 1,009,750       |
| Total for all 4 wells (L)                 | 19,000                            | 1,010,000     | 1,310,000  | 1,700,000        | 4,039,000       |

|   | Total Treatment |
|---|-----------------|
| Quantity of Proppant - quartz silica sand |                 |
| Average per well (kg)                     | 110,500         |
| Total for all 4 wells (kg)                | 442,000         |

**Notes:**

<sup>(1)</sup>Well pre-treatment is conducted to clean perforations prior to fracture stimulation.

<sup>(2)</sup>The volumes of each fluid are indicative only and actual volumes cannot be determined until fracture stimulation treatment occurs. This is because during the fracture stimulation treatment AGL monitors the fracture growth using a variety of diagnostic tools. This allows AGL to analyse the fracture geometry and fine-tune the final volumes. In addition, information gained from the initial treatments will enhance design of subsequent treatments.

<sup>(3)</sup>As an alternative to using THPS as a bactericide, AGL may use a mixture of sodium hypochlorite and sodium hydroxide in treated water, linear gel and cross-linked gel recipes at a concentration by volume of 0.015% sodium hypochlorite and 0.001% sodium hydroxide, which will represent a total volume of 605 litres sodium hypochlorite and 40 litres of sodium hydroxide. The HHERA Table 8 has also assessed these compounds in the alternative bactericide.

Fracture stimulation occurs at the coal seam (and only targets the coal seam), hundreds of metres below the surface and below shallow aquifers. Shallow aquifers are protected by four barriers within the well construction: two steel and two cement barriers. The well construction design incorporates numerous contingencies to ensure zonal isolation between coal seams and other formations including aquifers. Zonal isolation is important for gas production, as water migration from any other source (apart from the target coal seams) will hinder gas production, so precautions are taken to avoid connection between different formations. The Waukivory (WK) pilot wells have been constructed to be suitable for fracture stimulation operations, and fracture stimulation target zones comply with the NSW CSG *Codes of Practice for Well Integrity and Fracture Stimulation*.

To check the integrity of well construction and potential impacts associated with targeted fracture stimulation, AGL undertakes geophysical surveys and groundwater monitoring. Groundwater monitoring networks (mostly in shallow aquifers) are installed in reasonable proximity to selected gas wells to assess whether there are water level drawdowns or water quality changes that would indicate connectivity.

Linear gel mixtures are the most likely mixtures to be used for the multiple fracture stimulations at the four gas wells. Cross linked gels may be used for a few of the fracture stimulation intervals however no final decision has been made at this time. If cross linked gels are not used then the cross linker additive *Monoethanolamine Borate* will not be used.

The fluid used during fracture stimulation is recovered from the well through the 'flowback' and dewatering processes. This is done by using a "breaker" to react with the gel, breaking down its viscosity back to water so that the fluid's ability to flow is increased and it can be mobilised back to surface.

The fluid is then captured in temporary above-ground water storage at each well site and then collectively in a larger tank at the site of WK13. AGL will lawfully dispose of flowback water to an appropriate off-site facility from the temporary water storage tank at WK13.

At Waukivory it is planned to fracture stimulate multiple coal seams in all four gas wells WK11, WK12, WK13 and WK14. Further details regarding fracture stimulation are provided in EMGA/Mitchell McLennan, 2013a and the Fracture Stimulation Management Plan (FSMP) (AGL, 2014a).

## 2.6. Water Infrastructure

The major infrastructure associated with water management associated with the Waukivory fracture stimulation and pilot testing program includes:

- Source water dams
  - Pontilands Dam (freshwater)
  - Tiedmans North Dam (brackish produced water)
- Water gathering lines
  - Water pipeline from either the Pontilands Dam (freshwater) or Tiedmans North Dam (produced water) to the WK13 staging area
  - Produced water pipeline from WK13 to the Tiedman East Dam (same line as the water source pipeline)
  - Water distribution and produced water pipelines to and from each gas well (WK11, WK12 and WK14) to and from the WK13 staging area
- On site water tanks for source water

- One 1.5 ML source water/produced water above ground tank at the WK13 staging area
- Six 75,000 litre(L) closed-top tanks to feed water to the blender during fracture stimulation at each well site
- On site tanks for flowback water
  - One 40,000 L open-top flowback tank with diffuser at each well site for immediate storage of flowback water during fracture stimulation and well completion. Once the surface production skid is installed, flowback water will be piped back to the WK13 staging area.
  - One 1.5 ML flowback water, above ground storage facility at the WK13 staging area
- On site tanks for produced water
  - One 1.5 ML source water/produced water, above ground storage facility at the WK13 staging area

The freshwater and produced source water dams are not located in flood prone areas.

The water gathering lines will be poly pipe, buried and are located in both flood prone and non-flood prone lands.

The two 1.5 ML above ground tanks at the WK13 staging area are open-top, anchored and will be within a flood prone area. The tanks will have a freeboard of 500 mm to allow for a heavy rainfall event. The conceptual layout of the infrastructure at WK13 is shown on Figure 3. The 1.5 ML (source water) storage tank will remain on site after fracture stimulation as a 'balance' tank for produced water for the life of the pilot testing program, or until such time that the produced water rate is low enough for either an alternate (smaller) tank to be located on site and/or discharged in the pipeline to the Tiedman East Dam.

The 1.5 ML flowback water tank will be a temporary tank constructed and used for the approximately 3 months that flowback of the fracture stimulation water occurs. Flowback water will be discharged from the tank into road tankers at an adjacent tanker loading area for disposal at an approved offsite facility. The tank will be dismantled and taken away after use.

There will be no in-ground dams or turkeys nest dams constructed for this pilot. Flowback water and produced water pipelines and tank designs have been subject to rigorous risk assessment to identify risks (such as loss of containment of water and level control system failures) and mitigation measures. Further details are provided in EMGA/Mitchell McLennan, 2014.

## 3. Water Management Framework

In NSW, drilling activities that intersect groundwater systems and abstractions from different groundwater sources are managed by the NSW Office of Water (NOW). There are numerous groundwater policies and licensing systems that apply to different areas and different projects. Only those policies and plans that are relevant to the Gloucester Gas Project (GGP) area are discussed in this SGMP.

The access, taking and use of groundwater in NSW is currently managed and implemented by the NOW under two primary legal instruments – the *Water Management Act 2000* (WMAct) and the *Water Act 1912* (WAct).

Monitoring of water quality and water pollution is regulated by the NSW Environment Protection Authority (EPA) under the *Protection of the Environment Operations Act 1997* (NSW). An EPL will be issued for approved exploration activities within PEL 285.

All useful groundwater in the GGP area is located within two groundwater systems – the alluvial sediments associated with the unregulated streams, and the sedimentary/fractured bedrock aquifers. The alluvial sediments are managed under the Lower North Coast Unregulated and Alluvial Water Sources Water Sharing Plan (WSP) and the WMAct, while the deeper sedimentary/fractured rock groundwater systems are currently managed under the WAct.

### 3.1. Groundwater Policies

There are several overarching policies that apply to the development and management of groundwater systems across NSW. These include:

- The **NSW State Groundwater Policy Framework** (Department of Land and Water Conservation (DLWC) 1997). The NSW State Groundwater Policy Framework introduces three policy documents:
  - NSW Groundwater Quality Protection Policy (DLWC, 1998)
  - NSW Groundwater Quantity Management Policy (draft) (DLWC, 2001)
  - NSW Groundwater Dependent Ecosystem Policy (DLWC, 2002).

The NSW State Groundwater Policy Framework aims to slow, halt or reverse degradation in groundwater resources, ensure long-term sustainability of the biophysical characteristics of the groundwater system, maintain the full range of beneficial uses of these resources and maximise the economic benefit to the region and state.

Other policies of interest include:

- NSW Policy for managing access to Buried Groundwater Sources (NOW, 2011)
- NSW Aquifer Interference Policy (NOW, 2012)

The **Buried Groundwater Sources Policy** has been developed to set out a framework for how access to water will be managed in groundwater sources that are fully buried or partly buried (such as deep sedimentary basins).

Fully buried or partly buried groundwater sources have little or no surface expression (outcrop), and therefore have very little or no water available for extraction based on the long-term average annual extraction limit (LTAAEL) (rainfall recharge).

This policy has no application in the Gloucester Basin at this time, and will only be available once the WSP for the Northern Fractured and Porous Rock Groundwater Sources commences and any unassigned water is allocated.

The **Aquifer Interference (AI) Policy** defines aquifer interference activities and describes how these will be managed under the licensing and approvals regime in the WMAct. Under this policy, a water access licence is required when taking water from an aquifer and adjacent water sources that may be impacted by the aquifer interference activity if the volume taken is in excess of three megalitres (ML) per annum. The policy focuses on high risk activities such as mining, CSG, sand and gravel extraction, construction dewatering, aquifer injection activities, and other activities that have the potential to contaminate groundwater or result in unacceptable loss of storage or other structural damage to an aquifer.

Coal seam gas activities have been determined as aquifer interference activities and some additional approval conditions for this Waukivory pilot testing program may be imposed for the fracture stimulation and pilot testing components of the exploration program.

The format of these approvals is yet to be clarified by NOW; however they are expected to apply to any Waukivory REF approval that may be issued and/or the associated production bore licences.

## **3.2. Legislation**

### **3.2.1. Water Act (1912)**

The WAct has been in place since 1912. Since 2003 the WAct has been progressively phased out (repealed) and replaced by the WMAct across NSW as new Water Sharing Plans are gazetted.

AGL's bore licences for the GGP have been issued under the WAct as this is the appropriate water regulation for CSG exploration activity at this time for this water source. New bore licences required for the construction of the pilot wells and monitoring bores have been issued under the WAct.

AGL currently holds eight bore licences for this exploration program as at 22 August 2014. Two relate to construction of the gas (test) wells, two apply to the monitoring bores within the pilot testing area, and four licences relate to the conversion of the gas test wells to gas production wells for the pilot testing program (one licence for each of the four gas wells to be perforated, fracture stimulated and flow tested). There is one application pending for two proposed monitoring bores. Details of the bore licence for the deep vibrating wire piezometers at distance (location PL03) are also referenced because this monitoring site is conditioned in the EPL. Details are provided in Table 3.1.



**Table 3.1: Bore Licences for the Waukivory Pilot Testing Program**

| Licence No.               | Local Well or Bore No.            | Lot and DP | Purpose   |
|---------------------------|-----------------------------------|------------|---|
| 20BL172854                | WK12 and WK14                     | 251/785579 | Gas (test) wells  |
| 20BL173094                | WK11 and WK13                     | 11/841445  | Gas (test) wells  |
| 20BL173038                | WKMB01, WKMB02, WKMB03 and WKMB04 | 11/841445  | Water monitoring bores adjacent to the pilot                        |
| 20BL173596                | WKMB05                            | 26/1112877 | Geophone borehole and then conversion to deep water monitoring bore |
| Pending                   | WKMB06a and WKMB06b               | 251/785579 | Water monitoring bores on the floodplain                            |
| 20BL173274                | PL03                              | 2/1040412  | Deep vibrating wire piezometers located at distance                 |
| 20BL173599 and 20BL173601 | WK12 and WK14                     | 251/785579 | Conversion to gas production wells for pilot testing program        |
| 20BL173595 and 20BL173600 | WK11 and WK13                     | 11/841445  | Conversion to gas production wells for pilot testing program        |

This SGMP and the bore licences listed in Table 3.1 relate to the Waukivory exploration program and drilling, fracturing, dewatering, groundwater monitoring and associated compliance activities.

### 3.2.2. Water Management Act (2000)

There is no WSP for the sedimentary (porous) rocks of the Gloucester Basin at this time and therefore the WMAct currently does not apply to this groundwater source.

### 3.3. Aquifer Interference Approvals

The AI Policy (NOW, 2012) defines exemptions based on the level of risk. The exempt activities are those considered to pose a minimal risk to water sources, their dependent ecosystems and other water users. As all four Waukivory pilot wells are to be fracture stimulated, an AI approval (in the form of explicit conditions on the new bore licences for the pilot testing) is expected.

The policy also requires those new CSG exploration activities where groundwater is taken (irrespective of volume) to have a water access licence or a volumetric bore licence approval.

The pilot testing proposed at Waukivory involves dewatering, and therefore under the policy, new production bore licences are required for this pilot testing program. NOW has issued AGL with a licence for industrial and irrigation purposes for each of the four pilot wells (and each for an annual allocation of 5 ML per annum commencing 1 July). The four bore licences are valid to the 21 August 2015.

The amount of 5 ML for each pilot well is based on the maximum likely extraction from each well during an extended pilot testing program, and includes approximately 1 ML of flowback water recovered immediately after the fracture stimulation program.

Volumes recovered during the pilot testing program may be less than this total volume of 20 ML per annum, but based on the early pilot testing programs at Stratford and recent testing at the Craven06 site, these volumes are considered to be reasonable upper limits. It is not possible to provide a firmer estimate of the water production profiles at this time without completing the Waukivory pilot testing program.

### 3.3.1. Characterisation of the local groundwater systems

'Highly productive groundwater sources' are defined in the AI Policy (NOW, 2012) as having the following properties:

- Total dissolved solids of less than 1,500 mg/L, and
- Water supply works that can yield water at a rate greater than 5 litres per second (L/s).

Table 3.2 provides information on the groundwater productivity of aquifers based on water bore and monitoring bore data in the vicinity of the Waukivory site.

**Table 3.2: Local characteristics for the Waukivory Pilot Testing Program**

| Aquifer        | Yield (L/s) | Electrical Conductivity (EC) ( $\mu\text{S}/\text{cm}$ ) | (approx.) Total Dissolved Solids (mg/L) |
|----------------|-------------|--|---|
| Alluvium       | <2          | 2,000 – 7,500 <sup>(1)</sup>                             | 1,500 – 6,000                           |
| Fractured rock | <0.5        | 3,500 – 5,000 <sup>(1)</sup>                             | 3,000 – 4,250                           |

Note <sup>(1)</sup> values based on nearby monitoring bore data

Both the yields from the alluvial aquifer and the fractured rock aquifer are too low, and the total dissolved solids (TDS) of the groundwater are too high to classify local groundwater systems as a highly productive groundwater source. Therefore, aquifer systems at Waukivory are classified as 'less productive groundwater sources', as defined by the AI Policy (NOW, 2012).

### 3.3.2. Minimum impact considerations

A qualitative aquifer impact assessment was undertaken against the minimal impact considerations for aquifer interference activities, in line with Table 1 of the AI Policy (NOW, 2012).

Alluvial, fractured and porous rock aquifers at Waukivory were assessed. Predicted effects are less than the Level 1 minimal impact considerations for all beneficial aquifers, and across all categories (i.e. water table, water pressure and water quality). The full assessment is provided at Appendix A2.

The assessed impact to surface water and groundwater resources is assessed to be low. More formal risk assessments are provided in Section 5 of this SGMP.

## 3.4. Specific Water Management Approvals

The specific water management approvals required under the Waukivory Pilot REF are provided in Section 1.4 and are summarised as:



- renewal of PEL 285 by the OCSG requires a Groundwater Monitoring and Modelling Plan (this SGMP);
- EPL 20358 issued by the EPA for the GGP premises exploration activities requires a Waukivory Surface Water and Groundwater Management Sub Plan (this SGMP); and
- production bore licences (for each of the four gas wells) issued by NOW required to fracture stimulate and flow test the four gas wells. These bore licences also condition groundwater monitoring.

The renewal of PEL 285 also requires a Produced Water Management Plan (PWMP) for prospecting activities with the potential to generate more than 3 ML per annum of produced water (as a result of cumulative prospecting operations within the exploration licence area).

The PWMP requirements associated with the Waukivory Pilot are addressed under a new plan (AGL, 2014b) that has been prepared in parallel with this SGMP. This PWMP incorporates the requirements of the Tiedman Irrigation Program (TIP). The TIP is a separate exploration approval to the Waukivory Pilot REF approval.

## 4. Drilling and fracture stimulation program

To comply with Condition 4 of the Waukivory Drilling REF approval, NOW was notified that drilling was to commence within 28 days on:

- 7 November 2011 (for the monitoring bore and pilot well drilling programs); and
- 31 August 2012 (for the rescheduled pilot well drilling program)

This chapter is in two parts – Section 4.1 describes the drilling methods used for the pilot well drilling program (and the protection of groundwater), and Sections 4.1 and 4.2 describe the methods proposed for the fracture stimulation program (and associated groundwater monitoring).

### 4.1. Drilling completions and pilot well integrity

The drilling and fracture stimulation program is to complete the four pilot wells as follows:

- drill, case and suspend each of the wells (completed); and
- perforate and fracture stimulate coal seams in all four wells (planned).

The four gas wells were drilled and completed between 2 October and 24 November 2012. The drilling stages consisted of the following:

- **Conductor Casing Section** – The conductor section was drilled through the immediate surface to a typical depth of 10-20 m or until drill resistance was encountered (usually at the base of any alluvium/colluvium but in this case it was at the base of weathered rock). The conductor casing was steel and was cemented in place to provide a seal and prevent washouts of the unconsolidated earth. The conductor casing also provides a seal to prevent washouts during the drilling of the next borehole section, the surface borehole.
- **Surface Casing Section** - Steel surface casing was inserted to 10-15% of the depth of each well and was pressure cemented in accordance with the Code of Practice for Well Integrity (NSWT&I, 2012a). The purpose of this casing is to isolate shallow formations and provide structural support for the pilot well during drilling.
- **Production Casing Section** - Beyond the steel surface casing the rest of the borehole was drilled to the target depth and then fully cased and cemented. The steel casing and cement again isolate shallow aquifers and deeper water bearing zones that were encountered during the drilling process. This ensures that there is no interaction between aquifers and the targeted coal seams, and ensures no cross-contamination between zones.

Once the wells are completed and cased/suspended, the perforation and fracture stimulation programs involve:

#### Perforation

The perforation technique involves correlation of cased borehole logs with open borehole logs and the detonation of shaped explosive charges that penetrate the steel casing, cement and formation establishing the interconnection. Perforation is required to allow communication between the production casing and the target zones. In cased borehole completions, the pilot well is drilled down past the formations desired for production and has a casing or a liner run in, isolating the formation from the wellbore. Perforating usually

involves lowering in perforating guns, which is a string of shaped charges, down to the desired depth and firing them to perforate the casing at the target depth.

#### **Hydraulic fracture stimulation**

Perforations are required to gain access between the production casing and the selected formation. When access to the formation has been established, the formation needs to be stimulated to enhance formation water and gas flow. Hydraulic fracture stimulation involves the injection of a slurry of sand and water at high pressure. This process stimulates the reservoir by providing a highly conductive flow path for gas and water that extends away from the wellbore and into the target seam.

The sand is locked in place by the pressure of the coal formation. The injected water and formation water is allowed to flowback to the well for pumping to the surface. This technique widens cleats and fractures in the coal seams to provide a conductive path for gas to flow freely to the well. As the water is removed, the resulting drop in reservoir pressure enables the gas to begin to desorb from the coal and flow to the wellbore. The wellbore then requires cleaning and maintenance. The tubing, rods and pump required for gas pilot testing are then placed within this casing. Once each gas test well is completed, the surface wellhead equipment is installed.

#### **Best Practice**

Codes of practice have been released for CSG drilling activities in NSW. These two codes apply to well integrity (NSWT&I, 2012a) and fracture stimulation (NSWT&I, 2012b). This drilling and testing program complies with these codes of practice. More details are provided in AGL's Fracture Stimulation Management Plan (AGL, 2014a).

The drilling must also comply with the 'Minimum Construction Requirements for Water Bores in Australia' (NUDLC, 2012). This document outlines consistent and standard information and technical standards for the water bore drilling industry and regulators for constructing, maintaining, rehabilitating and decommissioning water bores in Australia. The document was prepared by the National Uniform Drillers Licensing Committee (NUDLC), which consists of representatives from the drilling industry and each state and territory of Australia.

## **4.2. Monitoring fracture stimulations**

A new monitoring borehole (WKMB05) has been drilled to monitor the fracture stimulation of the WK13 pilot well. It will initially be installed with geophones to monitor hydraulic fracture growth but will then be converted to a water monitoring location with discreet packers and six monitoring/sampling intervals. It is completed to a depth of 1,110 m. The geophone monitoring work is used in conjunction with other monitoring techniques to provide the reservoir engineers with a fracture map of the completion. The WKMB05 well is located at a distance of approximately 160 m east from WK13. This location has been chosen to obtain the best quality fracture monitoring data by optimising the distance from the well for monitoring coal seams (a naturally sound-attenuating rock) and in the direction to provide a side-on view of the hydraulic fracture.

Upon completion of the fracture stimulation program, the fully cased and cemented deep monitoring bore will be perforated and completed with packers so that it can be used as another groundwater monitoring location for intervals below 350 mbgl during the pilot testing program. Two intermediate and deep coal packages are being targeted together with an overlying aquitard for each coal target plus packers against the middle thrust zone and overlying aquitard (i.e. there are six monitoring intervals proposed within WKMB05).



## 5. Risk Assessment

A groundwater impact assessment for the drilling program was completed in November 2012 and included in the previous GMP (version 2) and SGMP (version 3), and has been included in Appendix A3 of this SGMP.

A series of risk assessment workshops were held in December 2012 and January 2013 to identify risks, assess those risks, and determine appropriate risk mitigation measures associated with the fracture stimulation and flowback program for the Waukivory pilot test. Full details are provided in the Risk Assessment Report enclosed in the Fracture Stimulation Management Plan (AGL, 2014a).

Included in this chapter are those risks that may impact on water resources, are associated with the management of fracture stimulation, flowback water activities, and are potentially a direct result of depressurisation associated with the pilot testing program.

Risks associated with the blending and reuse of produced water are not covered in this SGMP as these risks have been previously assessed in the Tiedmans Irrigation Program REF (PB, 2010). The associated irrigation REF approval conditions and the Water Management Plan (AGL, 2012) developed for the irrigation program are outside of the scope and approval requirements of this SGMP.

The risk to water resources (particularly groundwater) potentially increases when each of the wells is fracture stimulated, and the pilot testing program commences. The key (water related) risks, the assessed risk rankings and the controls to mitigate those risks are presented in Table 5.1.

**Table 5.1: Detailed Impact Assessment – Water related risks and controls**

| Fracture Stimulation Impacts on Water Resources  |  |
|--|--|
| Risk   | Control  |
| <p><b>Risk 1</b></p> <p>There is a risk of source water spill during transport to or storage at the site.</p> <p>Consequence: Level 1</p> <p>(Consequence driver: Environment)</p> <p>Likelihood: Unlikely</p> <p>Current Risk Rating: Low</p>   | <ol style="list-style-type: none"> <li>1. The preferred source water is fresh water from the Pontilands Dam and spills would have little to no impact on the environment.</li> <li>2. If an alternative source is used, the water quality may be brackish water. The transportation loading and unloading areas are contained. Spills of brackish water would have minimal impact on soils and surface water.</li> <li>3. Vacuum truck is available together with sufficient bunding.</li> </ol>   |
| <p><b>Risk 2</b></p> <p>There is a risk that the flow back water may be incorrectly transported, captured and/or removed which may result in a spill.</p> <p>Consequence: Level 1</p> <p>(Consequence driver: Environment)</p> <p>Likelihood: Unlikely</p> <p>Current Risk Rating: Low</p> | <ol style="list-style-type: none"> <li>1. Flow back water will be stored in above ground temporary storage tanks.</li> <li>2. Pipes used to transport flow back water to above ground holding facility will be visually inspected</li> <li>3. Visual inspections are conducted on all storage options prior to the transfer of any liquids. Visual inspections are also conducted several times a day during fracture stimulation operations to ensure no overflow or leaks</li> <li>4. Vacuum truck is available together with sufficient bunding.</li> <li>5. Sealed transport tankers are used to remove flowback water from site or holding dams to an approved facility</li> <li>6. Surplus water tanks are available so that if a leak was to occur in a tank the contents of the tank could be pumped into the spare tanks</li> <li>7. Pipes between the individual wells and temporary tank are pressure tested during commissioning before use, and will have a flow meter at either end to ensure all fluid is accounted for</li> <li>8. Wells are monitored during flow back operations</li> <li>9. Environmental Incident Response Plan covers this possibility</li> </ol> |

|   |  |
|---|--|
| <p><b>Risk 3</b></p> <p>The Code requires a qualitative assessment of risk that GFSA may cause connectivity and cross contamination between coal seams and beneficial aquifers. (i.e. exchange of poor water quality between these two sources that may impact water quality characteristics). [Code 7.2(c)(i) and (iv)]</p> <p>Consequence: Level 3</p> <p>(Consequence driver: Environment)</p> <p>Likelihood: Rare</p> <p>Current Risk Rating: Low</p> | <p>Low permeability aquitard layers hundreds of metres thick exist between shallow beneficial aquifers and target coal seams.</p> <p>AGL have developed strategies including:</p> <ol style="list-style-type: none"> <li>1. A Surface Water &amp; Groundwater Management Plan to protect surface water and beneficial aquifers. Baseline assessments suggest that groundwater moves laterally within layers and vertical connectivity is low. A Groundwater Monitoring program has been implemented (since early 2012) and will be used to monitor water levels, pressures and water quality during the fracture stimulation program.</li> <li>2. Pressure monitoring (at individual gas wells) during fracture stimulation.</li> <li>3. Geophone monitoring, measuring direction and height of the fracture in real time on selected wells.</li> <li>4. Temperature log, confirms fracture height after the fracture stimulation of each zone.</li> <li>5. Fracturing execution commences from the deepest zone and progress up the well. This means more information is gathered before approaching the beneficial aquifers.</li> <li>6. Monitoring changes in the flowback chemistry</li> <li>7. Groundwater monitoring programs provide baseline data prior to fracture stimulation programs thereby allowing trends or changes in shallow water chemistry to be identified</li> <li>8. Faulting is mapped through 3D seismic and zones selected for stimulation are away from faults</li> </ol> |
| <p><b>Risk 4</b></p> <p>The Code requires an assessment of the risk that GFSA may induce:</p> <ul style="list-style-type: none"> <li>• changes to groundwater pressure and levels;</li> <li>• changes to surface water levels and flow.</li> </ul> <p>This is generally referred to as surface water/groundwater connectivity [Code 7.2(ii) and (iii)]</p> <p>Consequence: Level 3</p> <p>(Consequence driver: Environment)</p>                           | <p>AGL and the principal contractor have developed strategies including;</p> <ol style="list-style-type: none"> <li>1. A Surface Water &amp; Groundwater Management Plan that protects surface water and beneficial aquifers. A Groundwater Monitoring program has been implemented</li> <li>2. Pressure monitoring during fracture stimulation.</li> <li>3. Geophone monitoring, measuring direction and height of the fracture in real time on selected wells</li> <li>4. Temperature log, confirms fracture height after the operation</li> <li>5. Fracturing execution commences from the deepest zone and progress up the well. This</li> </ol>   |



|   |  |
|---|--|
| <p>Likelihood: Rare</p> <p>Current Risk Rating: Low</p>   | <p>means more information is gathered before approaching the beneficial aquifers</p> <p>6. Monitoring changes in the flowback water chemistry</p> <p>7. Groundwater monitoring programs provide baseline data prior to fracture stimulation programs thereby allowing trends or changes in shallow water chemistry to be identified</p>  |
| <p><b>Management of Flowback Water</b></p>  |  |
| <p><b>Risk</b></p>  | <p><b>Control</b></p>  |
| <p><b>Risk 1</b></p> <p>There is a risk that waste from operations may enter the surrounding environment.</p> <p>Consequence: Level 1<br/>(Consequence driver: Environment)</p> <p>Probability: Possible</p> <p>Current Risk Rating: Low</p>  | <p>1. All contractors on site are subject to AGL pre-qualification and selection process</p> <p>2. The chemical waste contents are dealt comprehensively in the chemical risk assessment report.</p> <p>3. Flowback water will be contained within purpose-designed tanks, together with sufficient bunding, with vacuum truck available.</p> <p>4. Water will be chemically analysed and lawfully disposed of to an appropriate facility.</p>   |
| <p><b>Depressurisation associated with the Pilot Testing Program</b></p>  |  |
| <p><b>Risk</b></p>  | <p><b>Control</b></p>  |
| <p><b>Risk 1</b></p> <p>There is a risk that dewatering associated with the flow test may induce changes to local groundwater pressure and levels or induce changes to surface water levels and flow. This is generally referred to as enhanced natural leakage and is an important risk to be assessed.</p> <p>Consequence: Level 2<br/>(Consequence driver: Environment)</p> <p>Probability: Unlikely</p> <p>Current Risk Rating: Low</p> | <p>AGL has developed strategies including:</p> <p>1. Intensive groundwater monitoring of shallow groundwater monitoring bores (both AGL and GRL locations) to detect water level or pressure changes</p> <p>2. Using the deeper piezometers (formally the geophone monitoring location), to assess deeper water pressure changes in the overlying aquitards and the target coal seams being depressurised.</p> <p>3. Monitoring changes in the produced water chemistry.</p> <p>4. Groundwater monitoring throughout the pilot testing program provides new data to compare against the (natural) baseline data that was collected prior to fracture stimulation and pilot testing programs thereby allowing trends or changes in shallow water levels to be identified.</p> |

|  |  |
|--|--|
| <p><b>Risk 2</b></p> <p>There is a risk that dewatering associated with the flow test may reduce water levels in nearby private water bores and at pumps on the Avon River.</p> <p>Consequence: Level 3<br/>(Consequence driver: Community)</p> <p>Probability: Rare</p> <p>Current Risk Rating: Low</p> | <p>AGL have developed strategies including:</p> <ol style="list-style-type: none"> <li>1. Intensive groundwater monitoring of shallow groundwater monitoring bores (both AGL and GRL locations) to detect water level or pressure changes close to the pilot testing program</li> <li>2. The closest water supply work is an excavation located 600 m away which would not be a risk of water level decline because of low natural connectivity and the dominance of surface water accessions. The closest bore into rock is around 1.5 km distance and would not be within the area of influence of depressurisation</li> <li>3. Property surveys of water supply works on private properties within 2 kms of the pilot have been completed. Apart from the excavation there is just one stock bore within 2 km.</li> </ol> |
|--|--|

There are also more general impact assessment matters of concern to communities and regulators that are summarised in Table 5.2.

**Table 5.2: Commentary on General Impact Assessment Issues**

| General Impact Assessment for Groundwater Systems    |  |
|--|--|
| <b>Level of confidence in predicting the impacts</b> | AGL/AJ Lucas has undertaken fracture stimulation and pilot testing activities as part of the ongoing exploration works associated within their upstream gas projects, particularly the nearby Stratford pilot testing program. The resulting significant level of experience gained from previous projects has resulted in a high level of confidence in accurately predicting any potential associated impacts to groundwater systems from the testing program.   |
| <b>Reversibility of Impacts</b>                      | <p>The potential for shallow (beneficial) aquifer impacts is considered low. Fracture stimulation will only be within the targeted coal seams and similarly the dewatered groundwater will be only derived from the coal seam water bearing zone targets. Drawdown impacts in shallow aquifers are expected to be negligible and no shallow water quality impacts are anticipated given the number of confining layers in the geological sequence. No impacts to surface water resources are expected. Baseline accessions are a small component of surface water flows in this catchment (PB, 2013b) so there would need to be sharp declines in shallow groundwater levels over an extended period for surface water resources to be impacted.</p> <p>The Waukivory pilot is located in an area of thrust faulting. One of these thrust faults sub-crops beneath the alluvial floodplain at the junction of the Avon River and Waukivory Creek. Monitoring is in place (and will be expanded prior to the flow testing program) to assess whether there is any enhanced connectivity associated with this fault features.</p> <p>Given the very small volumes of groundwater likely to be pumped as produced water (i.e. around 15 ML) with an additional 4-5 ML of recovered flowback water, the overall risks are assessed to be low and the reversibility of any impacts is not an issue.</p> |

| General Impact Assessment for Groundwater Systems                              |   |
|--|---|
| <b>Effectiveness of the proposed methods to manage or mitigate the impacts</b> | <p>The proposed methods to manage or mitigate impacts to groundwater have been derived from past project experience. This water management plan and the dedicated monitoring proposed are considered to be sufficient to identify any potential impacts. Management and mitigation measures are not proposed as part of this pilot testing program unless shallow aquifers less than 75 m are definitely impacted by the pilot testing program (see Section 6.8).</p>   |
| <b>Level of public interest</b>  | <p>The IPR reports by Dr Rick Evans (SKM, 2012 and JacobsSKM, 2014) emphasised the importance of the Waukivory pilot testing program to confirm water production rates and the possibility of impacts to shallow aquifers. At this stage the general public are concerned about the program and want assurances that all works are undertaken with minimal impacts to shallow groundwater systems and adjacent surface water systems. The level of impact to groundwater systems from the proposal is considered low however the pilot testing program is necessary to confirm any drawdown or water quality impacts in the different groundwater systems and surface water features.</p> |

## 6. Monitoring Plan and Reporting

The NSW Government (through the EPA and the NOW) requires groundwater monitoring for CSG programs. These requirements include:

- a formal groundwater monitoring and modelling plan;
- installation of dedicated monitoring bores;
- collection of periodic water level, water quality and volumetric data;
- reporting of data and trends; and
- numerical modelling.

Specific requirements are also provided in the AI Policy (NOW, 2012) and include:

- establishing baseline groundwater conditions;
- complying with water access rules;
- assessing the potential for water level, water quality or pressure drawdown impacts on nearby water users and GDEs;
- assessing the potential for increased saline or contaminated water inflows to aquifers and rivers;
- assessing the potential for enhanced hydraulic connection;
- assessing the potential for river bank stability or high wall instability; and
- proposing the method for disposing of extracted water.

Similar requirements are included in the guideline document for developing Groundwater Monitoring and Modelling Plans (NOW, 2014).

This SGMP covers most of the seven requirements of the AI Policy (NOW, 2012); however due to the location of the Waukivory Pilot and the proposed scope of work, there is no requirement for assessing river bank stability. Disposal and reuse of produced water is addressed separately under the PWMP (AGL, 2014b) and the Tiedman Irrigation Program water management plan (AGL, 2012).

### 6.1. Water Monitoring Objectives at Waukivory

The primary objective of the dedicated groundwater network and associated monitoring program is to monitor and protect the shallowest beneficial aquifers used for water supply across the area. These are the Quaternary alluvial aquifers (to maximum 15m depth) and the uppermost Permian sedimentary/fractured rock aquifers (to around 75m depth).

With the Waukivory Pilot there is an opportunity to collect important groundwater data associated with a pilot testing trial where the deep coal seams will be fracture stimulated and depressurised. This groundwater monitoring will provide:

- A better understanding of groundwater flow paths and the connectivity of aquifers and deeper water bearing zones (under actual pilot testing conditions);
- An indication of whether fracture stimulation additives (which are present in extremely low concentrations) can be monitored, and if so, whether there is any risk of migration to shallower aquifers and surface water receptors;

- An improved conceptual model of groundwater flow under production conditions (in an area of both competent rock and thrust faulting); and
- More definitive proof of connectivity (or the lack of connectivity) of coal seam zones with shallow aquifers to better inform the community and regulators.

The monitoring network is primarily designed to:

- Evaluate consolidated rock zones during the pilot testing – assess the vertical permeability of aquitards and the potential for water migration when adjacent coal seams are depressurised; and
- Evaluate thrust fault zones during the pilot testing – assess whether these faults are likely to be barriers, conduits or have no impact on the flow and migration of groundwater.

For the Waukivory Pilot and for this SGMP:

- The flowback water period is deemed to be finished when 100% of the volume of fracture stimulation fluids injected at each well is recovered AND a salinity trigger of 5,000  $\mu\text{S}/\text{cm}$  is reached (and maintained) for the return waters; and
- Produced water is deemed to be all deep groundwater that is pumped to surface after the flowback water trigger is achieved.

The proposed trigger of 100% of the volume of fracture stimulation fluids injected at each well AND a salinity trigger of 5,000  $\mu\text{S}/\text{cm}$  is considered appropriate for both fresh water (from the Pontilands Dam) and brackish water (from the Tiedman Dams) as the source waters for the fracture stimulation program. The water quality of the Tiedman North Dam (TND) where the residual produced water is stored has changed in recent months (minimal rain and high evaporation) so the salinity of the water has increased to around 5,000  $\mu\text{S}/\text{cm}$ . The use of the Pontilands Dam water is the most likely scenario but if the TND water had to be used instead, the proposal is to blend it with a small volume of fresh water to achieve a salinity of around 3,500  $\mu\text{S}/\text{cm}$ . This will provide enough contrast with the expected produced water quality.

The use of fracture stimulation additives as triggers have not been added to the criteria for flowback water and produced water because of the inability to monitor these individual additives in the flowback water. Elemental constituents will be measured instead as proposed in Section 6.3.3.1.

From a water resource and environmental protection perspective, these triggers are considered more than adequate to protect the few local consumptive uses of surface water and groundwater, and the local riverine environment.

## 6.2. Private Water Bores

There are only four registered water bores (one of which is a shallow excavation) located within 5 kms of the proposed exploration program, and there is one water bore (the excavation) within 1 km of the western gas well sites. The two private bores within 2 kms of the western gas wells (together with the excavation) were surveyed in advance of any fracture stimulation and pilot testing program to assess baseline conditions. The 50m deep bore had been abandoned. Both remaining sites were surveyed and sampled in April 2014 however only the bore site was sampled in September 2014 after access was refused to undertake further sampling of the excavation.

Historical and April 2014 details are summarised in Table 6.1.

**Table 6.1: Summary of Private Water Bores – Waukivory Area**

| Bore No.             | Type and Date                  | Depth (m)          | Aquifer Zone (m)                       | Water Level (mbgl)     | Geology   | Distance to closest gas well |
|----------------------|--------------------------------|--------------------|--|------------------------|-----------|------------------------------|
| GW054940<br>(2), (3) | Excavation<br>(1981)<br>(2014) | 4.0<br>~4.0        | 2.5 to 4.0                             | Not known<br>~0.5      | Alluvium  | ~ 600 m<br>to WK13           |
| GW080357<br>(1)      | Bore<br>(2002)                 | 40.5               | 22 to 22.2<br>29 to 29.3<br>37 to 37.2 | 14.0                   | Sandstone | ~ 2.6 km<br>to WK11          |
| GW080487<br>(1), (2) | Bore<br>(2004)<br>(2014)       | 60.0               | 17.0 to<br>18.0                        | 17.0<br>14.42          | Shale     | ~ 1.5 km<br>to WK11          |
| GW200330<br>(3)      | Bore<br>(2006)<br>(2014)       | 50.0<br>Backfilled | Unknown                                | Not known<br>Abandoned | Shale     | ~ 1.8 km<br>to WK13          |

Notes (1): these two bores were water sampled as part of the Phase 1 SRK study in May 2010  
 (2): sampled as part of the Waukivory pilot baseline studies in April 2014  
 (3): this excavation and this bore are reported as 'abandoned and destroyed' in the Rocky Hill mine EIS (GRL, 2013) but recent PB surveys show the excavation does exist

None of the water bores into rock are of use for monitoring purposes during the pilot testing program because of their distance from the pilot well sites. The nearest licensed bore (the excavation which is GW054940) is excavated into alluvium but resembles a farm dam, and is the least likely water source to be affected by depressurising/dewatering because of its shallow depth. The April survey also suggested this site:

- is affected by runoff into and evaporation from the excavation;
- is affected by stock water access; and
- is unlikely to be representative of shallow groundwater in the underlying alluvium.

While no ongoing monitoring of water levels or water quality is considered warranted at any of these private water bore sites, the EPL licence requires monitoring at sites GW054940 and GW080487. The monitoring requirements are:

- water levels and one sampling event before the fracture stimulation program;
- one sampling event within 24 hours of completion of the fracture stimulation program; and
- one sample at week 2 and one sample at week 4 after the completion of the fracture stimulation program.

Ongoing monitoring is dependent on access being granted by the respective landowners.

### 6.3. Monitoring Network, Requirements and Frequency

#### 6.3.1. Monitoring networks

##### Pilot Wells

The pilot wells will be monitored during the fracture stimulation and pilot testing programs.

Fracture stimulation flowback quantities and quality will be monitored and tested at each well. AGL will lawfully dispose of flowback water to an appropriate facility. For the fracture stimulation program, it is proposed to take water samples of the fracture stimulation fluids (as injected and as pumped out as flowback water) and then to take a final water sample once 100% of the volume of fracture stimulation fluids have been removed and a salinity of 5000  $\mu\text{S}/\text{cm}$  is achieved.

Once the water quality is representative of the natural formation water (deep groundwater), the water (referred to as produced water) will be pumped to AGL's Tiedman property, and either stored or blended and reused for irrigation, in accordance with the approved reuse activity (see the Water Management Plan for the Tiedman Irrigation Program).

For the pilot testing program, it is proposed to install pressure transducers in each gas well so as to continuously monitor the drop in hydrostatic head as each of the coal seams is depressurised. In addition it is planned to obtain fortnightly water samples from each gas well so as to track water quality and to submit these water samples for laboratory analysis.

### **Monitoring Bores**

The main groundwater monitoring network is one cluster of monitoring bores within the central area of influence of the pilot testing program, and one cluster immediately to the west of the westernmost pilot wells. A new cluster is proposed on the floodplain within the area of influence of the pilot wells. These monitoring bores (currently five in total but originally six) are conventional monitoring bores (cased with PVC casing/screens and galvanised steel/stainless steel screens) that allow for discreet water level and water quality monitoring. The central monitoring bores will monitor the upper fractured rock aquifer and shallow thrust fault zone, while the western site will monitor the upper fractured rock aquifer. The existing monitoring bore locations are shown on Figure 1 and in cross section on Figure 2, and summary details are provided in Table 6.2.

The locations of the groundwater monitoring bores are sited so they target the shallow beneficial aquifers and potential fault pathways through which shallow groundwater may migrate. The two new proposed bores on the floodplain target the sub-crop of the shallow thrust fault and will monitor the overlying alluvial aquifer.

There are also additional (existing) monitoring bores on Gloucester Resources Ltd (GRL) lands to the east in the coal seam outcrop areas that will be used to assess the extent of drawdowns from this pilot testing program. These bore locations are shown in Figure 4. The closest alluvial monitoring bore (GR-P3) will be monitored for water levels and water quality trends (as per the close AGL monitoring bores – WKMB01, WKMB02 and WKMB03).

The WKMB05 monitoring bore will be the converted geophone monitoring well located close to WK13. It will monitor the deeper groundwater systems (six intervals in the one borehole as per Table 6.2) and is focused on the deep depressurisation trends of the target coal seams and their overlying aquitards, although the deeper packer intervals have been moved higher to monitor the middle thrust zone and an overlying aquitard. The schematic of the proposed packer monitoring system is shown in Figure 5 (note that the intervals quoted on this sketch are not the final adopted design – the intervals in Table 6.2 are the final intervals). The existing bore will be converted by ensuring the hole is overbalanced with a column of freshwater, perforations are completed from bottom-up and the packers are set opposite the target intervals. This monitoring location will be converted after the fracture stimulation program on WK13 and will be fully operational prior to the commencement of the flow testing program.

In addition there is a deep VWP piezometer (PL03) located approximately 1km south of the Waukivory Pilot. Modelling suggests that it is unlikely that depressurisation will extend to this distance.

Those monitoring bores within 500 m of the pilot wells are shown on Figure 1 with their summary details in Table 6.2. Summary details of monitoring bores within 3 km of the pilot wells are provided in Table 6.3.

There will be live telemetry available for water levels from the adjacent AGL monitoring bore network.

**Table 6.2: Summary of Adjacent Monitoring Bores – Waukivory Area**

| Area        | Sub – area and Purpose   | Monitoring Bores   |
|-------------|--|--|
| Waukivory   | Within field -<br>Two bores within the immediate pilot testing program area to monitor fault zone and shallow groundwater system (baseline and during pilot) | WKMB02 – Shallow fractured rock<br>Depth – 62 m<br>Screened Interval – 52 to 61 m<br><br>WKMB03 – Thrust fault<br>Depth – 210 m<br>Screened Interval – 200 to 209 m  |
| Waukivory   | West of field -<br>Two bores adjacent to pilot testing program area to monitor shallow groundwater systems (baseline and during pilot)                       | WKMB01 – Shallow fractured rock<br>Depth – 54 m<br>Screened Interval – 47 to 53 m<br><br>WKMB04 – Deep coal seam (Roseville CS)<br>Depth – 360 m<br>Screened Interval – 335 to 347 m (Note – this site is now abandoned as AGL was unable to convert the bore to a nested VWP location)  |
| Waukivory * | Within field -<br>Two bores to monitor sub-crop of the fault and overlying alluvium (during pilot)   | WKMB06a – Shallow alluvium<br>Depth – max 15 m<br>Screened Interval – tba<br><br>WKMB06b – Thrust fault<br>Depth – max 50m<br>Screened Interval – tba  |
| Waukivory   | Deep water monitoring bore with separate packer intervals to monitor fault, coal seam and aquitard depressurisation at depth (during pilot)                  | WKMB05 – Borehole was completed at 1,110 m depth. Awaiting completion as a water monitoring bore. Likely to have six separate monitoring intervals as follows:<br>* - 340 to 343 m Aquitard<br>* - 426 to 429 m Cloverdale CS<br>* - 584 to 587 m Aquitard<br>* - 595.4 to 598.4 m Fairbairns Lane CS<br>* - 698.5 to 701.5 m Aquitard<br>* - 711 to 714 m Middle thrust fault |
| Waukivory   | Adjacent (GRL sites) to monitor any shallow alluvial impacts (baseline and during pilot)   | NOTE - These are monitored by GRL<br>GR-P3 – Shallow alluvium<br>Depth – 11.2m<br>Screened Interval – 5 to 9 m   |

Note: Adjacent sites are those located within 500 m of any pilot well  
\* - proposed site subject to site access and regulatory approvals



**Table 6.3: Summary of Remote Monitoring Bores – Waukivory Area**

| Area      | Sub – area and Purpose  | Monitoring Bores   |
|-----------|---|--|
| Waukivory | Remote (AGL sites) located ~3kms to the north east and south east of the pilot test area. | Continue to monitor the water levels in:<br>WMB01 - Shallow alluvium<br>Depth – 8.5 m<br>Screened Interval – 5 to 8 m<br>WMB02 - Shallow sandstone<br>Depth – 23.0 m<br>Screened Interval – 15 to 21 m<br>WMB03 – Shallow coal seam (Bowens Rd CS)<br>Depth – 36 m<br>Screened Interval – 32 to 34 m<br>WMB04 – Deep sandstone<br>Depth – 80.5 m<br>Screened Interval – 67 to 79 m<br>PL03 – Deep vibrating wire piezometers<br>VWP #3 – 462 m<br>VWP #2 – 496 m<br>VWP #1 – 681 m (appears inoperable)  |
| Waukivory | Remote (GRL sites) located ~3kms to the east of the pilot test area.                      | NOTE - These are monitored by GRL<br>GR-P1 – Shallow alluvium<br>Depth – 10.2 m<br>Screened Interval – 5.5 to 8.5 m<br>GR-P2 – Shallow alluvium<br>Depth – 11 m<br>Screened Interval – 4 to 9 m<br>GR-P4 – Fractured rock<br>Depth – 37 m<br>Screened Interval – 32.5 to 35.5 m<br>GR-P5 – Fractured rock<br>Depth – 30 m<br>Screened Interval – 24 to 30 m<br>GR-P6 – Fractured rock<br>Depth – 24 m<br>Screened Interval – 17 to 23 m<br>GR-P6A – Shallow coal seam (Weismantels CS)<br>Depth – 97 m<br>Screened Interval – 89 to 95 m<br>GR-P8 – Fractured rock<br>Depth – 42 m<br>Screened Interval – 29 to 41 m<br>GR-P8A – Shallow coal seam (Avon CS)<br>Depth – 72 m<br>Screened Interval – 62 to 70 m<br>GR-P9 – Fractured rock<br>Depth – 34 m<br>Screened Interval – 24 to 33 m<br>GR-P9A – Shallow coal seam (Cloverdale CS)<br>Depth – 66 m<br>Screened Interval – 59 to 65 m |

Note: Remote sites are those located between 500 m and 3 kms of any pilot well

### Stream Gauges

Three surface water gauges and loggers have been installed to monitor the levels and water quality in streams upstream and downstream of the Waukivory Pilot (see Figure 1). The surface water monitoring locations are one upstream on Waukivory Creek; one upstream on Avon River; and one downstream on Avon River (see Table 6.4).

The surface water monitoring locations will each have a water level, temperature and salinity logger installed so that there is continuous data collection. Water sampling (grab samples) to determine natural background conditions commenced in February 2014. Gauging equipment was operational in August 2014.

**Table 6.4: Summary of Stream Gauges – Waukivory Area**

| Area      | Sub – area and Purpose                                      | Stream Gauges   |
|-----------|---|---|
| Waukivory | Within field<br>Upstream and downstream<br>gauging stations | WKSW01 – Avon River upstream<br>WKSW02 – Waukivory Creek upstream<br>WKSW03 – Avon River downstream |

There will be live telemetry available for water levels and salinity from the AGL stream gauging sites.

### 6.3.2. Water Levels

#### Pilot Wells

Static water levels cannot be obtained in each gas well after perforating and the fracture stimulation program due to wellhead safety requirements, downhole bridge plugs, increased formation pressures, and the immediate requirement to recover fracture stimulation fluids. For the pilot testing program, it is proposed to install pressure transducers in each well so as to monitor the drop in hydrostatic head as each of the exposed coal seams is depressurised. These are sensitive instruments that sometimes fail under the changeable pressure conditions that occur within the inner production casing and pump tubing. If the pressure transducers fail during the pilot test, the test will continue without this data. It is expected that the water levels within the targeted coals seams will be close to or within the uppermost perforated intervals.

#### Monitoring Bores

Three of the four nested monitoring bores that are located within the area of influence of the pilot testing program have been equipped with dataloggers to collect baseline information in advance of fracture stimulation and pilot testing programs. This monitoring program commenced in February 2012 and will continue for the life of the Waukivory pilot testing program (including a minimum eight week recovery period after the flow test). For the two new proposed monitoring bores on the floodplain, water level and salinity (EC) dataloggers will be installed immediately upon completion. Dataloggers will continue indefinitely in these bores depending on the status and requirements of the broader GGP.

In addition, the deep monitoring location (WKMB05) will be converted to a water monitoring bore after the fracture stimulation of WK13 and is expected to be operational for the full period of the pilot testing program.

Existing monitoring bores in the broader area to 3 kms have dataloggers installed and these will continue indefinitely at the current data collection rate (one reading every 6 hours).

### Stream Gauges

Three surface water locations will monitor levels and compare these water elevations with the water elevations in each of the nearby groundwater monitoring locations. This will determine whether the stream is a gaining or losing stream and whether there is any change to baseflows. Water levels will be monitored continuously with one reading every 6 hours. No stream gauging (and the development of rating curves) to assess flow volumes is proposed at this time.

### 6.3.3. Water Quality

AGL has three primary tiers of water quality monitoring, sampling and reporting. The **Comprehensive suite** is used for important sampling events. The **Basic suite** is for other sampling events and is mainly used for tracking major salinity / chemistry changes in the CSG produced water (wells and ponds). The **Basic and Intermediate suites** are unlikely to be used for this pilot testing program. The analytical suites listed in Table 6.5 have been adopted for AGL's CSG water sampling programs since August 2010.

In summary, the basic suite assesses field parameters, major ions and dissolved metals; the intermediate suite is the basic suite plus total suspended solids and nutrients; and the comprehensive suite is the intermediate suite plus dissolved gases and hydrocarbons.

**Table 6.5: Laboratory analytical suites**

| Category                                    | Suites         |                       |               | Parameters <sup>Note 1</sup> |                  |
|---|----------------|-----------------------|---------------|------------------------------|------------------|
| Physical parameters (field)                 | Basic          | Intermediate          | Comprehensive | Electrical Conductivity (EC) | Temperature      |
| Physical parameters (lab)                   |                |                       |               | Total dissolved solids (TDS) | Redox potential  |
|   |                |                       |               | pH                           | Dissolved oxygen |
| Major ions                                  |                |                       |               | EC                           | TDS              |
|   | pH             |                       |               |                              |                  |
|   | <i>Cations</i> | <i>Anions</i>         |               |                              |                  |
|   | calcium        | chloride              |               |                              |                  |
|   | magnesium      | carbonate             |               |                              |                  |
| Dissolved metals and minor / trace elements | sodium         | bicarbonate           |               |                              |                  |
|   | potassium      | sulphate              |               |                              |                  |
|   | aluminium      | lead                  |               |                              |                  |
|   | arsenic        | manganese             |               |                              |                  |
|   | barium         | mercury               |               |                              |                  |
|   | beryllium      | molybdenum            |               |                              |                  |
|   | boron          | nickel                |               |                              |                  |
|   | cadmium        | selenium              |               |                              |                  |
|   | chromium       | strontium (dissolved) |               |                              |                  |
|   | cobalt         | uranium               |               |                              |                  |
|   | copper         | vanadium              |               |                              |                  |
| iron  | zinc           |                       |               |                              |                  |

|                        |  |  |  |
|------------------------|--|--|--|
| Other analytes         |  | Fluoride                               | Silica   |
|                        |  | Total organic carbon                   | Free and Residual Chlorine   |
| Total Suspended Solids |  | TSS                                    |  |
| Nutrients              |  | Nitrate                                | Ammonia/Ammonium   |
|                        |  | Nitrite                                | Reactive phosphorus  |
|                        |  | Total Nitrogen as N                    | Total phosphorus   |
| Dissolved gases        |  | Methane                                |  |
| Hydrocarbons #         |  | Phenol compounds                       | Total petroleum hydrocarbons (TPH)/ benzene, toluene, ethyl benzene and xylenes (BTEX) |
|                        |  | Polycyclic aromatic hydrocarbons (PAH) |  |

Note 1: Additional analytes (such as monoethanolamine) will be analysed for fracture stimulation and flowback waters.

The field parameters that will be tested for each water sampling event are pH, EC, Redox, dissolved oxygen and temperature.

### 6.3.3.1. Sampling and Monitoring Methodology for Fracture Stimulation Additives

In the EPL there are four potential fracture stimulation additives that have been listed for monitoring at the Waukivory (adjacent) monitoring bore locations, private bore locations, surface water monitoring locations, and the four gas wells. These are:

- Tetrakis (hydroxymethyl) phosphonium sulphate (THPS);
- Choline Chloride;
- Monoethanolamine Borate; and
- Sodium Hypochlorite.

The 'Method Approved in Writing by the Authority' is by analysis of the chemical compound, or analysis of the elemental constituents of the target compound when the individual chemical compound cannot be identified in waters. The elemental constituents have been listed as:

- Tetrakis (hydroxymethyl) phosphonium sulphate (THPS) – phosphorus and sulphate;
- Choline Chloride – chloride and nitrogen
- Monoethanolamine Borate – boron and nitrogen; and
- Sodium Hypochlorite – free and residual chlorine.

The additives are in minute quantities compared to the volume of source water to be used for the fracture stimulation program (see Table 2.1). AGL has sought advice from our commercial laboratory ALS Environmental on these compounds and their intermediate breakdown products and they have confirmed that there are no known commercial analytical techniques that would allow the identification of these compounds and intermediate breakdown products at this time (see Appendix A5).

While AGL's assessment concluded that the risk of migration of fracture stimulation fluids beyond the target coal seams is negligible, to address community concerns as to whether there is a risk of fracture stimulation fluids migrating to shallow groundwater, surface water and private water bores, AGL proposes to monitor the concentration of the elemental

constituents over at least one pre fracture stimulation sampling event and at least one post fracture stimulation sampling event. In some instances (such as for the monitoring bores and the surface water locations) there will be multiple sampling events to provide a definitive range of water quality characteristics for natural waters at the respective sites.

AGL confirms that for each of the fracture stimulation additives to be tracked that our commercial laboratory is able to analyse and report on low concentrations of:

- phosphorus and sulphate;
- chloride and nitrogen/ammonia/ammonium;
- monoethanolamine, boron and nitrogen; and
- sodium, free and residual chlorine.

This list is an expanded list to that proposed by EPA in the EPL. AGL will undertake the monitoring of these elemental constituents at the nominated sites in accordance with the monitoring frequencies defined in the EPL. The primary locations to assess the removal of fracture stimulation fluids from the target coal seams and the transition from flowback water to produced water are the four gas wells.

The proposed ALS analytical methods and the limit of reporting (LOR) in water are provided in Table 6.6.

**Table 6.6: Proposed Analytical Methods for Elemental Constituents of the likely Fracture Stimulation Additives**

| COMPOUND GROUP                               | ALS METHOD CODE | METHOD REFERENCE               | LOR WATER (µg/L) |
|--|-----------------|--------------------------------|------------------|
| (mono) Ethanolamine                          | EP262           | LC/MS/MS                       | 1                |
| Sulfate - (Turbidimetric) as SO <sub>4</sub> | ED041           | APHA 4500 SO4-E                | 1                |
| Phosphorus Total as P                        | EK067           | APHA 4500 P - F                | 0.01             |
| Chloride - standard                          | ED045           | APHA 4500-Cl <sup>-</sup> -G   | 1                |
| Nitrogen, Total as N                         | EK062           | APHA 4500 Norg/NO <sub>3</sub> | 0.1              |
| ICP/MS: Boron                                | EG020F          | USEPA 6020 ICP/MS              | 0.05             |
| Free Chlorine                                | EK010-1         | In-house                       | 0.2              |
| Total Residual Chlorine                      | EK010-1         | In-house                       | 0.2              |

No additional analytical methods are proposed to satisfy Condition G2.1 d) and e) of the EPL as there are no known commercial analytical techniques.

**Pilot Wells**

For the fracture stimulation and pilot testing program, the following water quality sampling program is proposed for each location (i.e. WK11, WK12, WK13 and WK14):

- Raw (source) waters to be used for fracture stimulation;
- Fracture stimulation fluid mixture (i.e. the raw waters plus the sand and any additives) to be injected into each gas well;
- Flowback water (i.e. return water immediately after the fracture stimulation fluid water volume is pumped back to surface); and
- Produced water (natural groundwater from the coal seam/s after the fracture stimulation fluid water volume is pumped back to surface).

Field parameters will be taken for water samples during fracture stimulation together with enough water sample for the comprehensive suite of analytes as listed in Table 6.5.

Once the pilot testing program is under way, water samples from each gas well will be taken every fortnight for the first eight weeks (the expected flowback period) and then every two months until the cessation of the pilot flow testing. This will include field parameters plus a comprehensive samples for laboratory analysis to check that there are no apparent changes in the produced water chemistry.

Details of the proposed water quality sampling program are shown in Table 6.7.

**Table 6.7: Groundwater monitoring sites, suites and frequencies**

| Fraced Wells                | Baseline         | Fracture Stimulation |             |                  | Pilot Testing<br>(produced water) |       |       |       |
|-----------------------------|------------------|----------------------|-------------|------------------|-----------------------------------|-------|-------|-------|
|                             |                  | Raw water            | Fracc fluid | Flowback water   | Start                             | Mth 2 | Mth 4 | Mth 6 |
| (WK11, WK12, WK13 and WK14) |                  |                      |             |                  |                                   |       |       |       |
| <b>Comprehensive</b>        | X <sup>(1)</sup> | X                    | X           | X <sup>(2)</sup> | X <sup>(3)</sup>                  | X     | X     | X     |

Key: <sup>(1)</sup> unlikely to be able to obtain a comprehensive water sample pre fracture stimulation.

<sup>(2)</sup> multiple samples taken for flow back water –every fortnight for eight weeks

<sup>(3)</sup> essentially eight weeks into the pilot testing phase

### Monitoring Bores

All adjacent monitoring bores (except the GRL site) are equipped with dedicated micro-purge low flow sampling tubing and pumps to obtain discreet water samples at the screened interval within each monitoring bore.

Baseline water quality monitoring data were collected at the four new nested monitoring bore sites in the immediate vicinity of Waukivory pilot test area in 2012/13. Further water sampling occurred in March, June and September 2014.

Bores have been purged and sampled for water quality and isotopes. The initial baseline event in 2012 was a comprehensive event plus isotopes (PB, 2014). Recent sampling in March and June 2014 were also comprehensive events plus isotopes however the recent baseline event (ahead of fracture stimulation) was a comprehensive event.

Environmental isotopes (oxygen-18 and deuterium), tritium, methane isotopes and radio isotopes (carbon 13 and carbon 14) were analysed in addition to the (comprehensive) baseline sampling events in 2012/3. Strontium isotopes were added to the suite for the March and June 2014 events.

AGL recommended no sampling of monitoring bores during the pilot testing program because it is important to maintain a very accurate water level data set (i.e. with no disturbances).

The new EPL licence conditions requires one sample before the fracture stimulation program, one sampling event within 24 hours of the completion of the fracture stimulation program, then one sample at week 2 and another sample at week 4 after the fracture stimulation program.

While this sampling program will be undertaken, it is noted that the important water level data set at these monitoring bore sites may be compromised as a result of the sampling program, and this will need to be carefully monitored. The low flow sampling requires 5 to 10L of water to be purged from the tubing so as to obtain a representative sample from the screened interval. This can result in drawdowns of up to 5m in some monitoring bores which can take several days to recover.

Monitoring bores will be purged and sampled for water quality (comprehensive suite) at each sampling event immediately after the fracture stimulation program. One post pilot testing sampling event is proposed, being a comprehensive event plus isotopes within 4 weeks of the cessation of the test.

It is proposed to install water level, temperature and salinity (EC) loggers in the two proposed monitoring bores to assist with identifying any subtle changes in water quality at this floodplain location.

#### Stream Gauges

The surface water monitoring locations will each have a water level, temperature and salinity (EC) logger installed so that there is continuous data collection.

Water sampling occurred in March, June 2014 (both comprehensive suite plus isotopes) and in September 2014 (comprehensive suite). Water samples under the EPL are required within 24 hours of the fracture stimulation of each well, one sampling event after one week of the fracture stimulation of each well, and one sampling event every 6 months thereafter (until the cessation of the pilot) (comprehensive suite).

One post pilot testing sampling event is proposed, being a comprehensive event plus isotopes within 4 weeks of the cessation of the test.

### 6.3.4. Methodology for assessing water data trends

The following methodology is proposed for tracking key analytes that may be associated with fracture stimulation additives (i.e. sodium, chloride, total phosphorus, total nitrogen, boron, sulphate, monoethanolamine, residual and free chlorine) which are the major elemental components of the fracture stimulation additives). Salinity will also be tracked:

- EWMA (exponentially weighted moving average) approach – this is a weighted average approach which takes account of recent values using a weighting which diminishes over time. The time series of the EWMA value has a similar form to the time series of the target parameter but with the variability muted. The weightings diminish with time controlled by a parameter  $\lambda$  which is chosen with a value between zero and unity (typically values in the range 0.2 to 0.3 are chosen). The smaller the value of  $\lambda$  the larger the influence of earlier values in the weighted average. The initial value for the EWMA statistic has a significant influence on the early form of the EWMA curve. For a value of  $\lambda = 0.2$  the contribution of the initial value is above one third for the first five values in the series.

Consequently apparent trends in the EWMA curve should not be considered significant for the initial portion of the EWMA curve (although there will be at least three baseline events).

The standard deviation of the EWMA values gradually reduces and approaches  $\sqrt{\frac{\lambda}{2-\lambda}}$  times the standard deviation of the underlying measurements as an illustration for  $\lambda = 0.2$  the standard deviation of the EWMA statistic approaches one third of the standard deviation of the individual measurements.

It is proposed to present plots of the variation of the EWMA statistic over time for each of WKMB01, WKMB02, WKMB03, GR-P3, WKSW01, WKSW02, and WKSW03 in the detailed technical report. This approach has the following benefits:

- The value of the EWMA statistic is an estimate of the mean value of the parameter of interest;
- The EWMA statistic provides a smoother representation of the results simplifying the identification of trends over time;
- Results for multiple locations (if required) can be shown on the same plot facilitating comparison between locations;
- As the EWMA statistic is an estimate of the mean, a plot of this value over time has obvious physical meaning;

- The EWMA statistic can be progressively generated, as data is collected and subsequent results, to not affect the results of earlier presentations, so that as a result plots from one period to the next are consistent in their representation of the earlier data; and
- The EWMA statistic can be readily calculated.

For the non key analytes it is just proposed to graph water level and water quality data from each location and talk to the data set and any trends that are evident in the detailed technical report. Piper plots are used to compare all water quality types and trends, and Mann Kendall significance tests will be applied to those sites where there is sufficient data.

## 6.4. Monitoring water volumes

Approximate water volumes of between 0.5 and 2 ML per well (on average 1 ML) and around 4 ML for the whole fracture stimulation program are expected to be required for use during this Waukivory pilot. The quality of the source water does not necessarily have to be fresh but it needs to be consistent in water quality and low in bacterial contaminants.

### Water for Fracture Stimulation

Water will be sourced from licensed water storages located on either of AGL's Pontilands and Tiedman properties (in dams) off Fairbairns Lane. AGL has a water access licence (WAL) and a new works and use approval to pump water from the large dam on the Pontilands property and to take water for 'stock, irrigation and industrial' purposes.

The WAL for the Pontilands Dam is 20 ML per annum (and there is about 50 ML in storage when full) so there is sufficient water available to use this source water for industrial purposes. The water in the Pontilands Dam is fresh water derived from local catchment runoff.

Water in the Tiedman North dam has mostly been derived from the recent pilot testing on the Craven 06 and Waukivory 03 wells, and various Stratford wells that are licensed for industrial and irrigation purposes. As the water in the Tiedman North Dam is licensed for industrial purposes; this produced water is able to be reused for fracture stimulation purposes (if required).

### Water from Pilot Wells

During the flowback and pilot testing program (which is expected to last for at least six months), flowback water and produced water volumes will be metered at each of the pilot well sites. These volumes will be checked against the water volumes that are transported offsite (as flow back water) and delivered via the internal water gathering lines to the Tiedman dams (as produced water).

Pumping rates for each well are unlikely to exceed 0.5 L/s at the start of the test and are likely to diminish to less than 0.05 L/s after six months if the water production profiles observed for the pilot wells at Stratford are repeated here. It is not expected that flowback water and produced water volumes will exceed 5 ML for each well and 20 ML in total for the whole pilot testing program. Produced water volumes delivered to the Tiedman dams are expected to be a maximum of 16 ML.

## 6.5. Response Triggers

Several triggers are proposed, including a change in the beneficial use of an aquifer (note that "aquifer" in this SGMP refers only to the alluvial and shallow fractured rock as deeper zones are deemed to be water bearing zones and are non-aquifers). The other response



triggers relate to water level and water quality trends (for all analytes) where those trends are clearly related to CSG dewatering activities. The primary evidence of aquifer connectivity and potential aquifer contamination (or the lack thereof) are water level drawdowns and water quality changes.

Specific analyte trigger values are not considered useful as an indicator of pollution given the natural variability in both river water and groundwater quality at different locations across the site and at different depths in the geological strata.

Also in regard to the fracture stimulation additives (see Table 2.1), all these compounds readily dissolve and disassociate in water into their elemental constituents. Table 2.1 also shows that the collective percentages of THPS, Choline Chloride, Monoethanolamine Borate and Sodium Hypochlorite and their intermediate breakdown products in the fracture stimulation fluid is very low (<0.3%). It is likely that some of these additives will be omitted from the final fracture stimulation recipe. The elemental constituents are monitored as part of the proposed monitoring program of flow back water and produced waters (see Section 6.3) but the individual fracture stimulation additives (or intermediate breakdown products) will not be identifiable or be able to be quantified in the flowback or produced water samples (see Section 6.3.3).

### 6.5.1. Beneficial Use

A generalised beneficial use matrix has been designed (in accordance with both yield and water quality characteristics) (see Table 6.8). It is based on the salinity classification adopted for this SGMP and is described in detail in the Glossary. Each aquifer/water bearing zone can be assigned one or more beneficial use categories (based on cells within the matrix). Beneficial use categories can vary spatially for each groundwater system. The scale or volume of water required for individual uses may also influence the beneficial use; for example, a small scale farming operation may be able to make use of a water supply bore that has a yield of less than 0.5 L/s, whereas for a large scale farming operation this may not be sufficient. The aquifers in the Waukivory area rarely yield water at a rate greater than 1 L/s and contain poor water quality with salinities greater than 1600  $\mu\text{S}/\text{cm}$ .

The following beneficial use categories can be assigned to each of the groundwater systems at Gloucester (in the Waukivory area) (in accordance with Table 6.8):

- Alluvial aquifers – A2, A3, B2, B3, C2, C3, D2 and D3
- Shallow fractured rock aquifers – C2, C3, D2 and D3
- Deep coal water bearing zones – C3, D3 and E3

Note that none of the (high yield) beneficial use categories (greater than 5 L/s) are known to occur in the Waukivory area.

Should water quality monitoring results indicate alteration of the beneficial use category over time, where it is suspected that the change is the result of CSG dewatering activities, AGL will notify NOW and investigate the likely cause. Where a change in an aquifer's beneficial use category is the result of AGL's activities, mitigation measures will be undertaken in accordance with the measures outlined in Section 6.6.

**Table 6.8: Generalised beneficial use matrix, based on salinity and yield**

|                  |             | Yield (L/s) |        |        |   |
|------------------|-------------|-------------|--------|--------|---|
|                  |             | >5          | 0.5-5  | <0.5   |   |
| Salinity (µS/cm) | 0-800       | D+I+S       | D+I+S  | D+S    | A |
|                  | 801-1600    | D+I+S       | D+I+S  | D+S+In | B |
|                  | 1601-4800   | I+S+In      | I+S+In | S+In   | C |
|                  | 4801-10000  | S+In        | S+In   | In     | D |
|                  | 10001-20000 | In          | In     | In     | E |
|                  | >20000      |             |        |        | F |
|                  |             | 1           | 2      | 3      |   |

Key: D – domestic; I – irrigation; S – stock; In – industry

### 6.5.2. Drawdowns

There are very large drawdowns in the coal seam water bearing zones during pilot testing that are normal for the operation of a CSG wellfield. The key connectivity issue is if there are water level declines in shallow aquifers as a consequence of this depressurisation. Whilst AGL continues to build an understanding of the historical/seasonal variability in the water level drawdowns across the different field areas, if such an event was to occur, AGL would gather all possible water level data from the broader area to understand the geographical extent, possible causes and to decide practical solutions.

The current adopted indicator is if there was a water level decline of more than 2 m (outside of the normal range) in a monitoring bore in an aquifer less than 75 m from surface, and more than 5 m (outside of the normal range) for deeper (non-coal) monitoring zones. Such declines would be sufficient to justify an investigation and management response involving:

- a check of all monitoring bore data;
- a check of nearby water bore use;
- a check of nearby and recent (water bore, coal and gas) drilling activities;
- a check of produced water volumes from the Waukivory gas wells;
- a check of the climatic conditions and expected trends; and
- a check of the integrity of the monitoring bore and datalogger.

If it was confirmed that the water level decline was due to CSG dewatering activities, then the decline would be reported to NOW and a more detailed action plan would be developed and implemented.

If the decline was reported at a private water bore location within the 2 km survey area, then the apparent water level decline would involve:

- a check against the baseline survey results;
- a check of monitoring bore data; and

- possible referral to NOW to assess the validity of the claim and to recommend a course of action.

### 6.5.3. Water Quality

Water quality variations could also be an indication of connectivity. Changed water quality could also be an indication of impacts from different anthropogenic activities. Whilst AGL continues to build an understanding of the historical/seasonal variability in the water quality, if such an event was to occur, AGL would work closely with NOW to gather all possible water quality data from the broader area to best understand the geographical extent, and possible causes.

If water quality, with respect to salinity, at all monitoring sites (including the monitored gas wells) changes over time to a different beneficial use category (Table 6.8) or if water quality, with respect to all other analytes (including heavy metals, salts, hydrocarbons), deviates significantly from the typically observed trend, and if the change is attributable to CSG activities, then this would be sufficient variability to justify an investigation and management response involving:

- repeat basic sampling or an intermediate or comprehensive sampling event;
- a check of produced water volumes from the Waukivory gas wells;
- a check of the integrity of the gas production well.

At gas well sites it is not uncommon to observe a high volume producing well taper to a low volume producing well and to also observe the salinity of the produced water decrease over time. This 'flash evaporation' effect has been observed and researched for low volume wells that are part of AGL's Camden wellfield (PB, 2013d). Such an event as this would not trigger a response as it is not representing a change in formation water quality.

If it was suspected that the change in water quality of beneficial aquifers less than 75 m from surface was due to CSG dewatering activities at depth, then the change in salinity would be reported to NOW/EPA and a more detailed action plan would be developed and implemented.

If the change in water quality was reported at a private water bore location, then the management response would involve:

- repeat sampling and a check against the baseline survey results;
- a check of produced water volumes from the Waukivory gas wells; and
- referral to NOW/EPA in the first instance to assess the validity of the claim and to recommend a course of action.

## 6.6. Water Source Management Responses

Changes in groundwater levels and water quality changes observed in the monitoring network may not be the result of the CSG activities. It is important that identified trends, or impacts identified by AGL or notified to either AGL or to NOW/EPA, be thoroughly investigated in the first instance and a conclusion drawn that the impact is (or possibly is) or is not the result of the CSG activities.

This section details the management responses if a trend or an impact is (or is possibly) associated with the Waukivory fracture stimulation and flow testing activities. The assessment of whether an impact is or is not CSG related, and a more detailed protocol that

describes AGL's water management responses if there is a water level or water quality impact to shallow aquifers is provided in Appendix A6.

### **6.6.1. Water Levels**

If water levels change at dedicated monitoring sites by more than the response trigger (i.e. greater than 2 m outside of the normal range for an aquifer less than 75 m from surface) or if the yield of a water supply bore changes to another beneficial use category (Table 6.8) over time, and if the change is attributable to CSG activities, then NOW would be notified and the following would be considered:

- suspension of dewatering from proximate gas well(s) to assess whether recovery can be achieved; and/or
- other management responses as may be agreed/directed by NOW.

### **6.6.2. Water Quality**

If water quality, with respect to salinity, at dedicated monitoring sites changes over time to a different beneficial use category (Table 6.8) or if water quality, with respect to other analytes, deviates significantly from the typical observed trend, and if the change is attributable to CSG activities, then NOW/EPA would be notified and the following would be considered:

- suspension of dewatering from proximate gas well(s) to assess whether remediation in water quality can be achieved; and/or
- other management responses as may be agreed/directed by NOW (or EPA).

### **6.6.3. Produced Water Volumes**

If the rate of production of water from a pilot well significantly increases over time, or stays relatively static whilst other wells significantly decrease, this would warrant an investigation into the source of the additional produced water. It may or may not be an indication of enhanced hydraulic connectivity with shallower aquifers or surface water as a result of CSG dewatering activities. The investigation program would differ on a case by case basis, but could involve comprehensive water quality and/or isotopic analysis of the produced water and/or nearby (groundwater and/or surface) water sources, and fault or other fluid pathway investigation studies.

## **6.7. Operational Management Responses**

The source water dams are not in flood prone areas. Rainwater fills the Pontilands Dam from catchment runoff. It often overflows freshwater to the Avon River. The brackish water in the Tiedman North dam (a lined turkey's nest dam) cannot overflow to the landscape. There is an adjacent seepage monitoring bore and the dam is currently less than 50% full with more than one metre of freeboard.

The water gathering lines will be poly pipe, buried and are located below both flood prone and non-flood prone areas. Pipe when laid will be pressure tested, with joins and pipe sections inspected for leaks. Meters will be at both ends of the pipeline will help to ensure that the volume of water pumped is the volume of water that is delivered (note there will be always be some slight variations in meter readings depending on the meter itself and the

suspended solid load). The highest risk to the pipeline after commissioning is a break due to vandalism. The pipeline route will be inspected on a regular basis for any damage, intrusion or wet areas.

The 1.5 ML on-site water tanks at WK13 are open topped, double lined with leak detection in between liners, alarmed, anchored, and will be within a flood prone area. A freeboard of 500 mm will be kept in case of heavy rainfall event. Pumping will cease to this tank if heavy rain is predicted or pumps to individual well sites fail, and the tank is full (i.e. the freeboard is already at 500 mm). The conceptual layout of the infrastructure at WK13 is shown on Figure 3. Tanks, internal pipework and footings will be inspected daily to visually assess for any leaks or overflows.

The 1.5 ML flowback water tank will only be a temporary tank constructed and used for approximately three months while flowback of the fracture stimulation water occurs and offsite disposal is required. Pumping to this tank and continuous offsite disposal of fluids will ensure that there is at least a 500 mm freeboard maintained at this tank. If heavy rain is predicted, offsite disposal will be accelerated to ensure there is a greater capacity to store flowback waters. Water for disposal at the approved offsite facility will be from a load area adjacent to this tank. Disposal of flowback water offsite will be at a similar rate to what is being generated to ensure that a large volume is not stored on site. The flowback water tank will be dismantled and taken away after use.

The second 1.5 ML storage tank will remain on site as a balance tank for the produced water for the life of the pilot testing program, or until such time that produced water rate is low enough for either an alternate (smaller) tank or pipe straight back to Tiedmans.

Pipelines within the field area (especially the joins around tanks and valves at individual well sites) will also be periodically inspected to ensure there are no spills or losses from the storage and associated pipelines.

Full details regarding the site infrastructure and water management protocols required to manage flowback water and produced water are provided in the PWMP (AGL. 2014b).

## 6.8. Reporting

Quarterly reports will be submitted to the OCSG for all water monitoring points detailed in this SGMP until the Waukivory Pilot Project concludes. The quarterly reports will include:

- a) Analysis and interpretation of monitoring results including trends; and
- b) Details of any triggers requiring specific management and actions to be undertaken.

The first report will cover the period from 1 September to 31 December 2014 and will include baseline data obtained prior to the commencement of fracture stimulation activities for the Waukivory Pilot Project.

The quarterly reports will be submitted to the OCSG within two months of the end of the reporting period.

Data from the baseline investigation and pilot testing program will be collated and analysed and the results assessed and written up into a detailed technical report which will be submitted to the OCSG within six months of completion of the pilot test. The investigation results will focus on permeability, water levels, water quality, and environmental/radioisotope data and trends. There will be a discussion of the water data obtained from all pilot wells and all adjacent monitoring bores and surface water locations monitored for this pilot testing program. The data from the remote monitoring locations will also be reviewed to determine whether depressurisation effects have propagated greater distances.



The conceptual model developed in the latest site investigation and water balance studies (PB, 2013a and PB, 2013b) will be reviewed and improved (if required) based on the results from this pilot testing program. A revised conceptual model report is proposed for 2015.

It is not expected that a 3D numerical model will be prepared specifically for the pilot testing program (although 2D numerical modelling of this local area is currently underway as part of the GGP Stage 1 approvals).

After the pilot testing program, the groundwater level and pressure data from the program will be used to calibrate and verify the 2D numerical groundwater model. The local model is focused on fault structures and is being developed to help design, parameterise and calibrate the regional numerical model required for the Stage 1 development.

The numerical model development, calibration, verification and predictive results will be separate to the proposed technical report on the surface water and groundwater monitoring results for this Waukivory pilot.

## 6.9. Data archival

There will be numerous data sets collected throughout the pilot testing programs. It is proposed that:

- depressurisation data for individual wells will be archived in spreadsheets maintained by AGL Upstream Gas (Operations);
- water level data from the monitoring bores be continued to be archived with our technical specialists;
- water quality data from the monitoring bores and gas production wells be continued to be archived with our technical specialists;
- water level data from the surface water locations be continued to be archived with our technical specialists;
- water quality data from the surface water locations be continued to be archived with our technical specialists;
- dewatering volumes for individual wells will be tracked and archived in spreadsheets by AGL.

There will be live telemetry of water levels from the AGL monitoring bore network and live telemetry of water levels and salinity from the AGL stream gauging sites. Information will be available for viewing via the AGL GGP website available at <http://www.agl.com.au/gloucester>.

## 7. References

- AGL, 2012, *Water Management Plan for the Tiedmans Irrigation Program – Gloucester* dated May 2012.
- AGL, 2014a, *Fracture Stimulation Management Plan – Gloucester NSW* dated June 2014.
- AGL, 2014b, *Produced Water Management Plan for PEL 285 – Gloucester* dated 14 October 2014.
- Department of Land and Water Conservation (1997). *The NSW State Groundwater Policy Framework Document*.
- Department of Land and Water Conservation (1998). DRAFT *The NSW Groundwater Quantity Management Policy – A Component Policy of the NSW State Groundwater Policy Framework Document*.
- Department of Land and Water Conservation (2001). (Draft) *The NSW Groundwater Quality Protection Policy – A Component Policy of the NSW State Groundwater Policy*.
- Department of Land and Water Conservation (2002). *The NSW State Groundwater Dependent Ecosystems Policy – A Component Policy of the NSW State Groundwater Policy Framework Document*.
- EMGA/Mitchell McLennan, 2011, *Review of Environmental Factors – Proposed Exploration Wells Waukivory* dated March 2011.
- EMGA/Mitchell McLennan, 2013a, *Review of Environmental Factors – Proposed Fracture Stimulation and Flow Testing Waukivory* dated September 2013.
- EMGA/Mitchell McLennan, 2013b, *Addendum to the Review of Environmental Factors – Preferred Activity Report* dated December 2013.
- EMGA/Mitchell McLennan, 2014, *Further Addendum to the Review of Environmental Factors – Preferred Activity* dated June 2014.
- Gloucester Resources Ltd, 2013, *Rocky Hill Coal Project Groundwater Assessment* Prepared by Australian Groundwater and Environmental Consultants dated April 2013.
- JacobSKM, 2014, *Gloucester Water Study Project – Independent Peer Review*. Report to Gloucester Shire Council dated 6 June 2014.
- NOW 2011, *NSW Policy for managing access to Buried Groundwater Sources*. July 2011.
- NOW, 2012, *NSW Aquifer Interference Policy Stage 1* dated September 2012.
- NOW, 2014, *Groundwater Monitoring and Modelling Plans – Information for prospective mining and petroleum activities* dated February 2014.
- NSW Government, 2009, *Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources 2009*. NSW Legislation 2011 No.348 made on 24 July 2009.
- NSWT&I, 2012a, *Code of Practice for Coal Seam Gas – Well Integrity* dated September 2012.
- NSWT&I, 2012b, *Code of Practice for Coal Seam Gas – Fracture Stimulation* activities dated September 2012.
- NSWT&I, 2012c, *Aquifer Interference Policy* requirements dated September 2012
- NUDLC, 2012, *Minimum Construction Requirements for Water Bores in Australia* Edition 3 dated February 2012.



Parsons Brinckerhoff, 2012a, *Phase 2 Groundwater Investigations – Stage 1 Gas Field Development Area Gloucester Gas Project*. Report PR\_5630 dated January 2012.

Parsons Brinckerhoff, 2012b, *Water Balance for the Gloucester Stage 1 GFDA*. Report PR\_1099\_Final dated August 2012.

Parsons Brinckerhoff, 2012c *Gloucester Groundwater and Surface Water Monitoring – Annual Status Report*, Report PR\_1242, dated September 2012.

Parsons Brinckerhoff, 2013a *Hydrogeological Conceptual Model of the Gloucester Basin*, Report PR\_7266 dated June 2013.

Parsons Brinckerhoff, 2013b *Water Balance for the Gloucester Basin*, Report PR\_7296, dated July 2013.

Parsons Brinckerhoff, 2013c *Waukivory Pilot REF – Numerical Modelling* dated December 2013

Parsons Brinckerhoff, 2013d *Water Quality Investigation Camden Gas Project* Report PR\_7196 dated 2 July 2013

Parsons Brinckerhoff, 2014 *Drilling Completion Report: Waukivory Groundwater Monitoring Bores Gloucester Gas Project* Rpt\_7761 RevB dated 30 July 2014

SKM, 2012, *Peer Review of Groundwater Studies – Report to Gloucester Community Consultative Committee* dated May 2012.

SRK Consulting, 2010, *Gloucester Basin Stage 1 Gas Field Development Project: Preliminary Groundwater Assessment and Initial Conceptual Hydrogeological Model*, Report No. AGL002\_Gloucester Basin Hydrogeology Study\_Rev2.



## Figures

- Figure 1: Gas Wells and Groundwater Monitoring Bores (Adjacent Sites)
- Figure 2: Seismic West-East Section with Gas and Monitoring Bore Locations through the Waukivory Area
- Figure 3: WK13 Conceptual Site Layout
- Figure 4: Groundwater Monitoring Bores (AGL and GRL Remote Sites)
- Figure 5: Schematic of the Proposed Packer Completion of WKMB05

# Waukivory Gas Wells & Water Monitoring Sites



Figure 1

Energy in action™



Author: Upstream Gas  
 Date: 16-06-2014  
 Ref: 3191R1

0 250 500  
 Metres  
 Scale 1:12,500 @A4

Geocentric Datum of Australia 1994 MGA Zone 56

Disclaimer: While AGL has taken great care and attention to ensure the accuracy of the data represented on this map, no liability shall be accepted for any errors or omissions. No part of this map may be reproduced without prior permission of AGL.

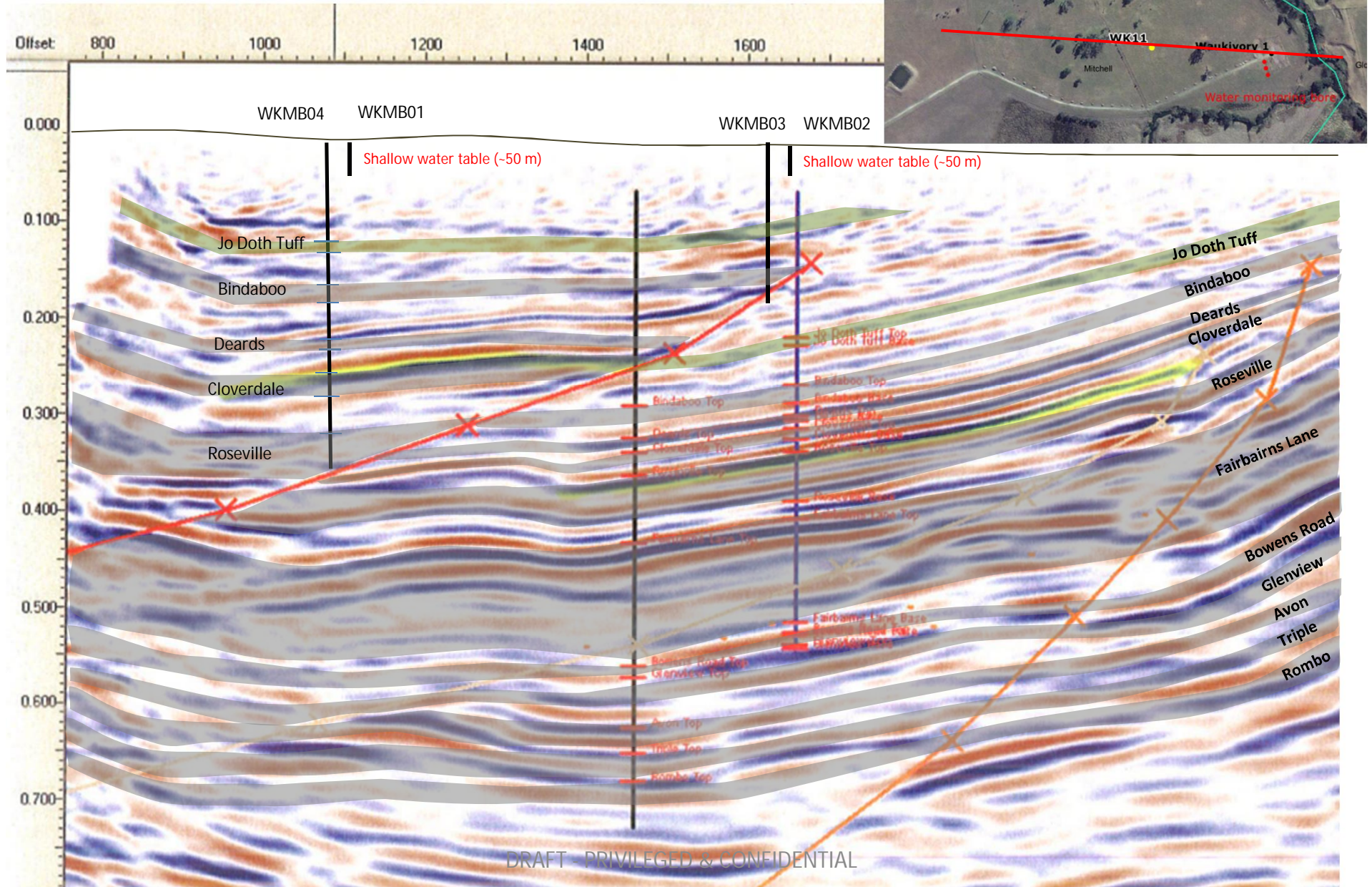
### Legend

- GRL bore
  - ▲ Alluvium
- Surface Monitoring Sites
  - ▲ River
  - ◆ Waukivory gas well
- AGL bore
  - Shallow fractured rock
  - Interburden
- Abandoned Coal seam
- Geophone/ water monitoring bore
- Railway Line
- Roads
- Waterbody



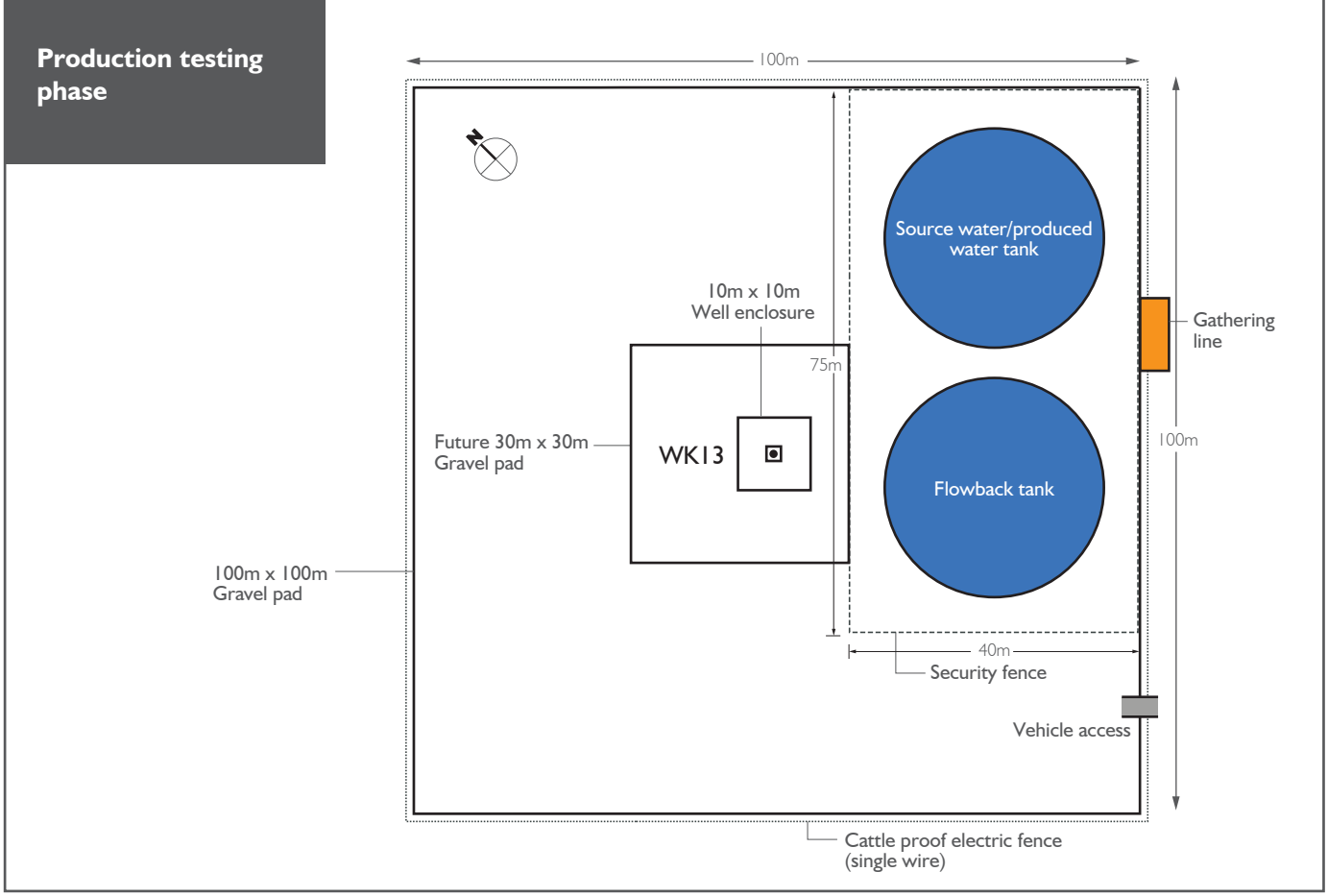
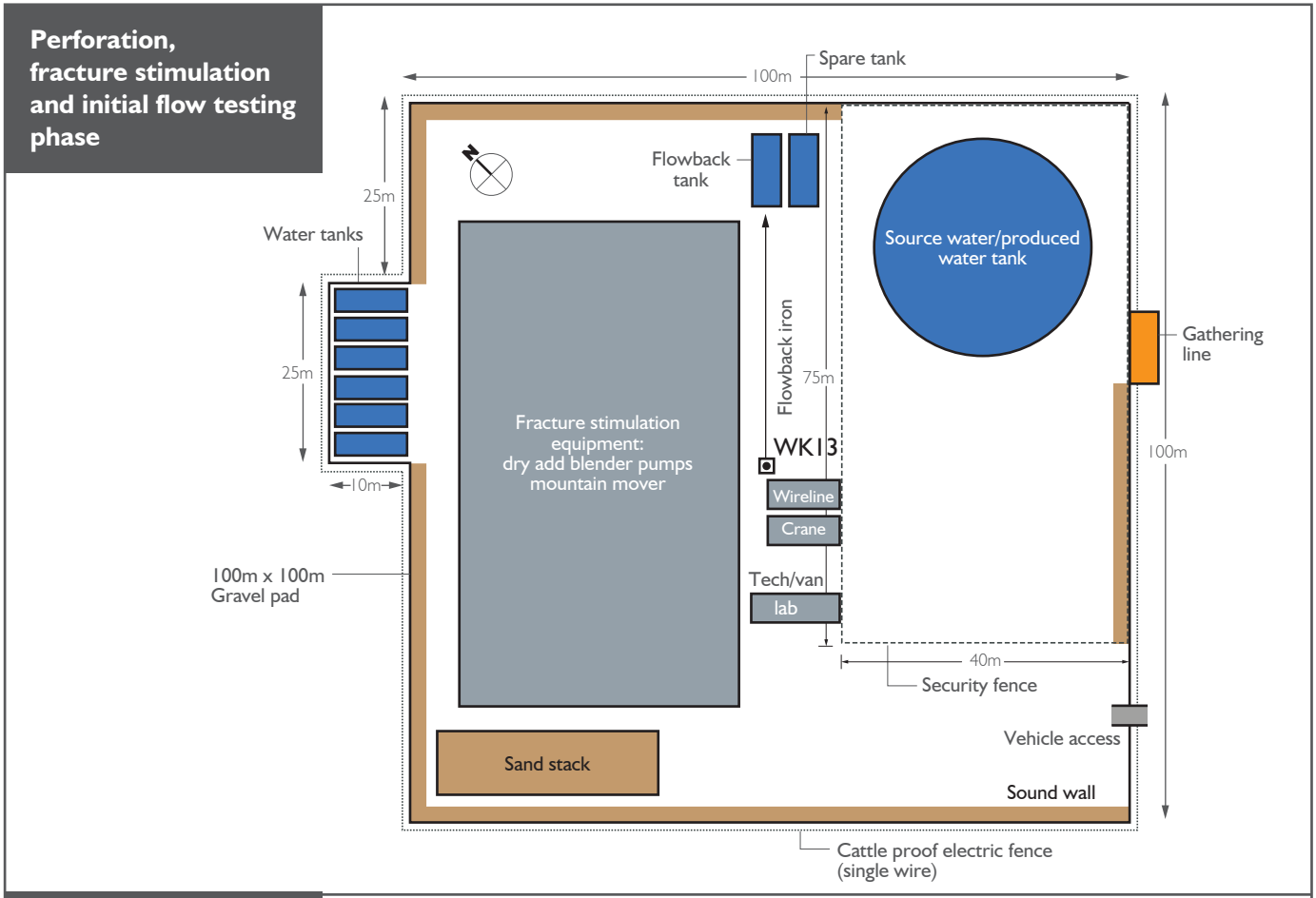
Sources: AGL Energy Limited, Omnilink PSMA Data, SKM

**DRAFT SECTION and LOCATIONS**



DRAFT - PRIVILEGED & CONFIDENTIAL

**Figure 2**



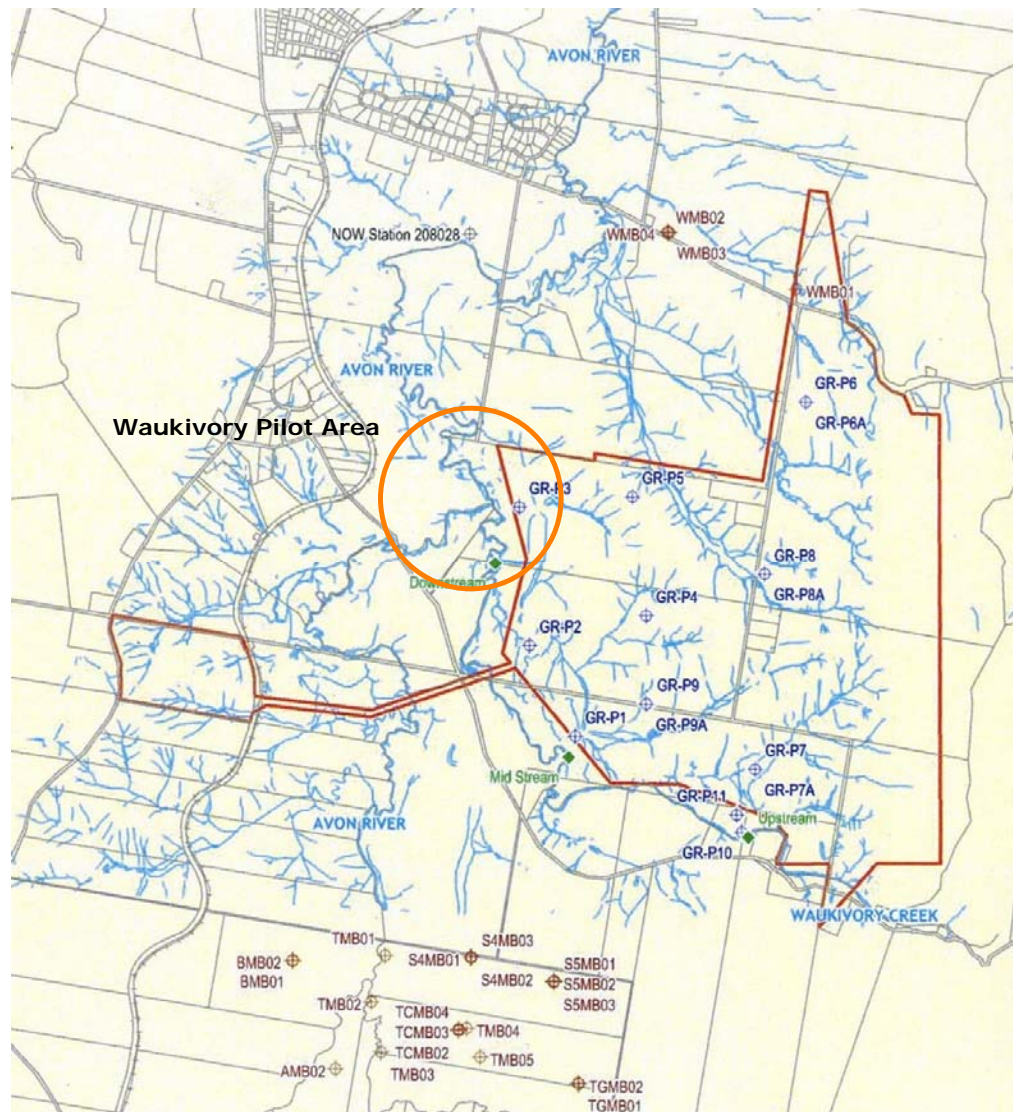
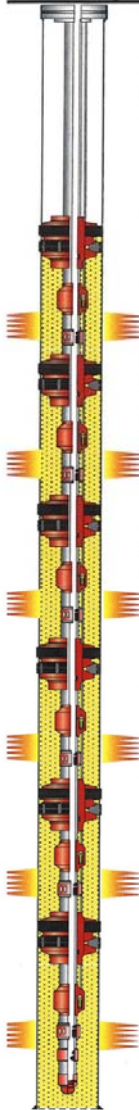


Figure 4: Groundwater Monitoring Bores (AGL and GRL Remote Sites)



**WKMB05\_DHD\_2010830 Multizone\_Proposed  
Micro Seismic Monitoring Well**

Well Name **WKMB05** Date: **30-Aug-14**



| ITEM No.   | DESCRIPTION   | LENGTH (m)                                | CUM (mKB)           |              |            |
|--|---|---|---------------------|--------------|------------|
|  | KB to GL  | 2.72                                      |                     |              |            |
| A  | Surface casing - 8 5/8 24ppf K55  | 125.63                                    | 128.35              |              |            |
| B  | Production casing - 5 1/2in 15.5ppf K55   |   | 1100.00             |              |            |
|  | PBTD tagged at 1087mKB on Groundsearch CBL run 30-12-13<br>note CBL TOC behind 5.5in pipe indicated at 250mKB |   |                     |              |            |
| 1  | KB to GL  | 2.72                                      |                     |              |            |
| 2  | 2-3/8 EUE x 5-1/2 streamflo tubing hanger c/w 2x 1/2NPT ports   | -0.20                                     | 2.52                |              |            |
| 3  | Pup Joint 8ft 2-3/8" 4.7ppf J-55  | 2.44                                      | 4.96                |              |            |
| 4  | Tubing Joints 2-3/8" EUE 4.7ppf J-55 Range 2  | 374.01                                    | 378.97              |              |            |
| 5  | 2-3/8 EUE x 5-1/2" Hydroset II c/w feedthrough  | 2.10                                      | 381.07              |              |            |
| 6  | 2-3/8 EUE gauge carrier mandrel   | 1.20                                      | 382.27              |              |            |
| 7  | 2-3/8 EUE CD6000 sliding sleeve   | 1.22                                      | 383.49              |              |            |
| 8  | Tubing Joints 2-3/8" EUE 4.7ppf J-55 Range 2  | 19.18                                     | 402.67              |              |            |
| 9  | 2-3/8 EUE x 5-1/2" Hydroset II c/w feedthrough  | 2.10                                      | 404.77              |              |            |
| 10   | 2-3/8 EUE gauge carrier mandrel   | 1.20                                      | 405.97              |              |            |
| 11   | 2-3/8 EUE CD6000 sliding sleeve   | 1.22                                      | 407.18              |              |            |
| 12   | Tubing Joints 2-3/8" EUE 4.7ppf J-55 Range 2  | 163.03                                    | 570.21              |              |            |
| 13   | 2-3/8 EUE x 5-1/2" Hydroset II c/w feedthrough  | 2.10                                      | 572.31              |              |            |
| 14   | 2-3/8 EUE gauge carrier mandrel   | 1.20                                      | 573.51              |              |            |
| 15   | 2-3/8 EUE CD6000 sliding sleeve   | 1.22                                      | 574.73              |              |            |
| 16   | Tubing Joints 2-3/8" EUE 4.7ppf J-55 Range 2  | 14.39                                     | 589.11              |              |            |
| 17   | 2-3/8 EUE x 5-1/2" Hydroset II c/w feedthrough  | 2.10                                      | 591.21              |              |            |
| 18   | 2-3/8 EUE gauge carrier mandrel   | 1.20                                      | 592.41              |              |            |
| 19   | 2-3/8 EUE CD6000 sliding sleeve   | 1.22                                      | 593.63              |              |            |
| 20   | Tubing Joints 2-3/8" EUE 4.7ppf J-55 Range 2  | 306.88                                    | 900.51              |              |            |
| 21   | 2-3/8 EUE x 5-1/2" Hydroset II c/w feedthrough  | 2.10                                      | 902.61              |              |            |
| 22   | 2-3/8 EUE gauge carrier mandrel   | 1.20                                      | 903.81              |              |            |
| 23   | 2-3/8 EUE CD6000 sliding sleeve   | 1.22                                      | 905.03              |              |            |
| 24   | Tubing Joints 2-3/8" EUE 4.7ppf J-55 Range 2  | 9.59                                      | 914.62              |              |            |
| 25   | 2-3/8 EUE x 5-1/2" Hydroset II c/w feedthrough  | 2.10                                      | 916.72              |              |            |
| 26   | 2-3/8 EUE gauge carrier mandrel   | 1.20                                      | 917.92              |              |            |
| 27   | 2-3/8 EUE CD6000 sliding sleeve   | 1.22                                      | 919.14              |              |            |
| 28   | Tubing Joints 2-3/8" EUE 4.7ppf J-55 Range 2  | 9.59                                      | 928.73              |              |            |
| 29   | 2-3/8 BXN Nipple  | 0.45                                      | 929.18              |              |            |
|  | Note all dimensions to be treated as indicative   |   |                     |              |            |
| <b>Wellhead Information</b>                                |   |   |                     |              |            |
| A Section - Larkin 8 5/8 STC x 5 1/2in casing bowl 2K      |   |   |                     |              |            |
| B Section - Streamflo 5 1/2 LTC x 7 1/16 5M casing bowl 5K |   |   |                     |              |            |
| <b>FORMATION</b>   |   | <b>PERFORATED INTERVALS:<br/>(m / GL)</b> |                     | <b>GUN:</b>  |            |
|  |   |   |                     | <b>SIZE</b>  | <b>Spf</b> |
|  |   |   |                     | <b>TYPE*</b> |            |
| Deards   | [aquifer]   | proposed perforations<br>392 - 395        |                     |              |            |
| Cloverdale   | [coal seam]   | 426 - 429                                 |                     |              |            |
| Above Fair   | [aquifer]   | 584 - 587                                 |                     |              |            |
| Fairbairns   | [coal seam]   | 595.4 - 598.4                             |                     |              |            |
| Above Avon   | [aquifer]   | 906 - 909                                 |                     |              |            |
| Avon   | [coal seam]   | 932 - 935                                 |                     |              |            |
| <b>REMARKS:</b>  |   |   |                     |              |            |
| ANNULUS FLUID: cement plug displaced with potable water    |   |   |                     |              |            |
| NOT TO SCALE   |   |   | WELLSITE SUPERVISOR |              |            |

Figure 5: Schematic of the Proposed Packer Completion of WKMB05



## Appendices

- Appendix A1: Production bore licences
- Appendix A2: Minimum impact considerations for less productive aquifers
- Appendix A3: Groundwater impact assessment for gas well drilling program
- Appendix A4: Waukivory Pilot REF Addendum – Numerical Modelling (PB)
- Appendix A5: Analysis of Potential Fracture Stimulation Additives (ALS Environmental)
- Appendix A6: Management response protocol – Waukivory Pilot



## **A1 Production Bore Licences**





Department of  
Primary Industries  
Office of Water

AGL Upstream Investments Pty Ltd  
Locked Bag 1837  
St Leonards NSW 2065

Contact: Hannah Grogan  
Phone: 02 4904 2516  
Fax: 02 4904 2503  
Email: [Hannah.grogan@water.nsw.gov.au](mailto:Hannah.grogan@water.nsw.gov.au)  
Our ref: Waukivory Pilot

22 August 2014

Dear Mr John Ross

**Subject: Groundwater licence under Part 5 of the Water Act 1912.**

Please find enclosed licences **20BL173595, 20BL173599, 20BL173600 and 20BL173601.**

Your attention is drawn to the nature and description of the work, terms, limitations and conditions under which the licence is issued.

If you have any further questions in relation to this matter, please do not hesitate to contact our Newcastle office on (02) 4904 2500.

Yours sincerely

A handwritten signature in blue ink, appearing to be 'H C' followed by a long horizontal line.

**Hannah Grogan**  
Water Regulation Officer  
22 August 2014

# NSW Office of Water

Hunter Region  
Po Box 2213  
3/26 Honeysuckle Drive  
Dangar NSW 2309  
Phone: (02 ) 49042500

BORE LICENSE CERTIFICATE  
UNDER SECTION 115 OF THE WATER ACT, 1912

20BL173599

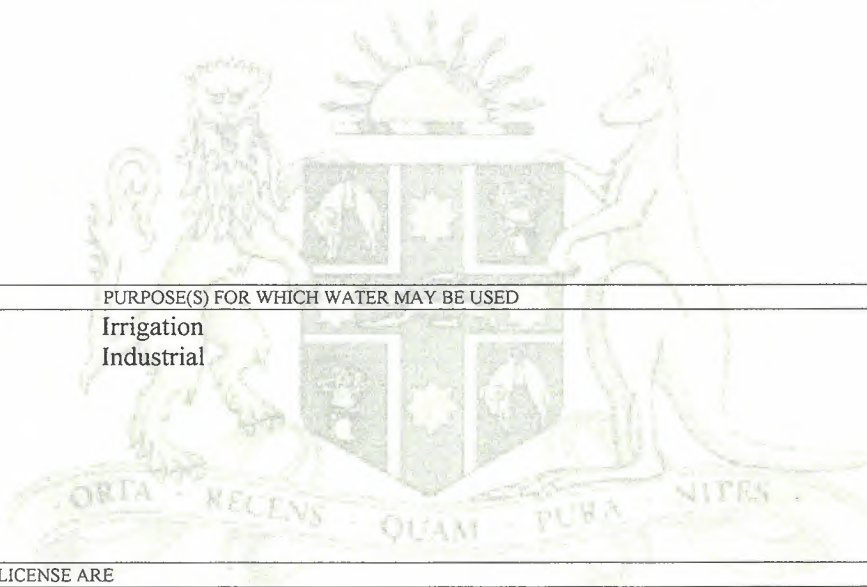


A G L Upstream Investments Pty Ltd  
Locked Bag 1837  
St Leonards NSW 2065

|                         |
|-------------------------|
| LICENSE NUMBER          |
| 20BL173599              |
| DATE LICENSE VALID FROM |
| 22-Aug-2014             |
| DATE LICENSE VALID TO   |
| 21-Aug-2015             |
| FEE                     |
| \$151.00 PAID           |
| ABN 47661556763 GST NIL |

### LOCATION OF WORKS

| Portion(s) or Lot/Section/DP | PARISH     | COUNTY     |
|------------------------------|------------|------------|
| 251//785579                  | Gloucester | Gloucester |



| TYPE OF WORKS              | PURPOSE(S) FOR WHICH WATER MAY BE USED |
|----------------------------|--|
| Well [ Csg - Exploration ] | Irrigation<br>Industrial               |

### CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

**ORIGINAL**

**NSW Office of Water****CONDITIONS STATEMENT REFERRED TO ON  
20BL173599  
ISSUED UNDER PART V OF THE WATER ACT, 1912  
ON 22-Aug-2014**

- (1) THE LICENSEE SHALL ALLOW NSW OFFICE OF WATER OR ANY PERSON AUTHORISED BY IT, FULL AND FREE ACCESS TO THE WORKS, EITHER DURING OR AFTER CONSTRUCTION, FOR THE PURPOSE OF CARRYING OUT INSPECTION OR TEST OF THE WORKS AND ITS FITTINGS AND SHALL CARRY OUT ANY WORK OR ALTERATIONS DEEMED NECESSARY BY THE DEPARTMENT FOR THE PROTECTION AND PROPER MAINTENANCE OF THE WORKS, OR THE CONTROL OF THE WATER EXTRACTED AND FOR THE PROTECTION OF THE QUALITY AND THE PREVENTION FROM POLLUTION OR CONTAMINATION OF SUB-SURFACE WATER.
- (2) WORKS USED FOR THE PURPOSE OF CONVEYING, DISTRIBUTING OR STORING WATER TAKEN BY MEANS OF THE LICENSED WORK SHALL NOT BE CONSTRUCTED OR INSTALLED SO AS TO OBSTRUCT THE REASONABLE PASSAGE OF FLOOD WATERS FLOWING INTO OR FROM A RIVER.
- (3) NSW OFFICE OF WATER SHALL HAVE THE RIGHT DURING THE CURRENCY OF THIS LICENSE TO VARY AT ANY TIME THE VOLUMETRIC ALLOCATION, OR THE RATE AT WHICH THIS ALLOCATION IS TAKEN.
- (4) THE VOLUME OF GROUNDWATER EXTRACTED FROM THE WORKS AUTHORISED BY THIS LICENCE SHALL NOT EXCEED 5 MEGALITRES IN ANY 12 MONTH PERIOD COMMENCING 1ST JULY.
- (5) THE WORKS AUTHORISED BY THIS LICENCE MUST BE OPERATED IN ACCORDANCE WITH THE DEPARTMENT OF TRADE AND INVESTMENT , RESOURCES AND ENERGY - CODE OF PRACTICE FOR FRACTURE STIMULATION ACTIVITIES SO AS TO ENSURE ISOLATION OF AQUIFERS OVERLYING THE TARGET COAL SEAM AND PREVENT THE LOSS OR MIXING OF WATER FROM DIFFERENT GROUNDWATER SOURCES.
- (6) THE LICENSEE MUST INSTALL AN APPLIANCE(S) TO MEASURE THE QUANTITY OF WATER EXTRACTED FROM THE WORKS, TO THE SATISFACTION OF THE NSW OFFICE OF WATER IN RESPECT OF TYPE AND CONSTRUCTION .
- (A) THE APPLIANCE(S) TO CONSIST OF EITHER A METER OR SUCH OTHER MEANS OF MEASUREMENT AS MAY BE APPROVED BY THE NSW OFFICE OF WATER.
- (B) THE APPLIANCE(S) SHALL BE MAINTAINED IN GOOD WORKING ORDER AND CONDITION AND PERIODICALLY TESTED FOR APPROPRIATE FUNCTIONAL PERFORMANCE.
- (C) THE LICENSEE WHEN REQUESTED MUST SUPPLY A TEST CERTIFICATE AS TO THE ACCURACY OF THE APPLIANCE(S) FURNISHED EITHER BY THE MANUFACTURER OR BY SOME PERSON DULY QUALIFIED.
- (7) THE LICENSEE MUST MAINTAIN RECORDS OF THE ACTUAL VOLUME OF GROUNDWATER PUMPED (IN KILOLITRES OR MEGALITRES) AS MEASURED BY THE INSTALLED APPLIANCE(S) AS WELL AS VOLUMES OF WATER TRANSPORTED FROM INDIVIDUAL WELL SITES FOR DISPOSAL OR USE AND PROVIDE THIS INFORMATION TO THE NSW OFFICE OF WATER ON AN AGREED BASIS, AT THE COMPLETION OF THE PROJECT, OR UPON REQUEST FROM THE NSW OFFICE OF WATER.
- (8) THE LICENSEE MUST MAINTAIN RECORDS OF THE RESULTS OF WATER QUALITY TESTING OF SAMPLES FROM ANY EXTRACTION OR MONITORING LOCATIONS AND PROVIDE THIS INFORMATION TO THE NSW OFFICE OF WATER ON AN AGREED BASIS, AT THE COMPLETION OF THE PROJECT, OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

- (9) APPLICATION OF WATER FOR IRRIGATION PURPOSES MUST ONLY BE CARRIED OUT IN ACCORDANCE WITH APPROVAL TO UNDERTAKE PEL 285: TIEDMAN IRRIGATION PROGRAM - MODIFICATION TO APPROVAL, AS APPROVED BY THE OFFICE OF COAL SEAM GAS, DATED 4 JULY 2014.
- (10) WATER ABSTRACTED FROM THE BORE MUST NOT BE USED FOR IRRIGATION PURPOSES AFTER 30 APRIL 2015, UNLESS APPROVED BY OFFICE OF COAL SEAM GAS.
- (11) UNLESS IN ACCORDANCE WITH CONDITION 9 OR CONDITION 10 THE HOLDER OF THE LICENCE SHALL NOT ALLOW ANY WATER EXTRACTED FROM THE BORE TO DISCHARGE INTO OR ONTO:
- ANY LAND
  - ANY RIVER, CREEK OR WATERCOURSE
- (12) IF THE WORK IS TO BE ABANDONED ALL ABANDONMENT AND DECOMMISSIONING WORKS MUST OCCUR IN ACCORDANCE WITH THE DEPARTMENT OF TRADE AND INVESTMENTS RESOURCES AND ENERGY - CODE OF PRACTICE FOR COAL SEAM GAS WELL INTEGRITY (SEPTEMBER 2012). THE HOLDER OF THE LICENCE MUST ENSURE THAT THE OUTCOMES OF WELL ABANDONMENT AS DESCRIBED IN THE ABOVE MENTIONED DOCUMENT ARE MET.
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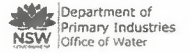
End Of Conditions

# NSW Office of Water

Hunter Region  
 Po Box 2213  
 3/26 Honeysuckle Drive  
 Dangar NSW 2309  
 Phone: (02 )49042500

BORE LICENSE CERTIFICATE  
 UNDER SECTION 115 OF THE WATER ACT, 1912

20BL173600



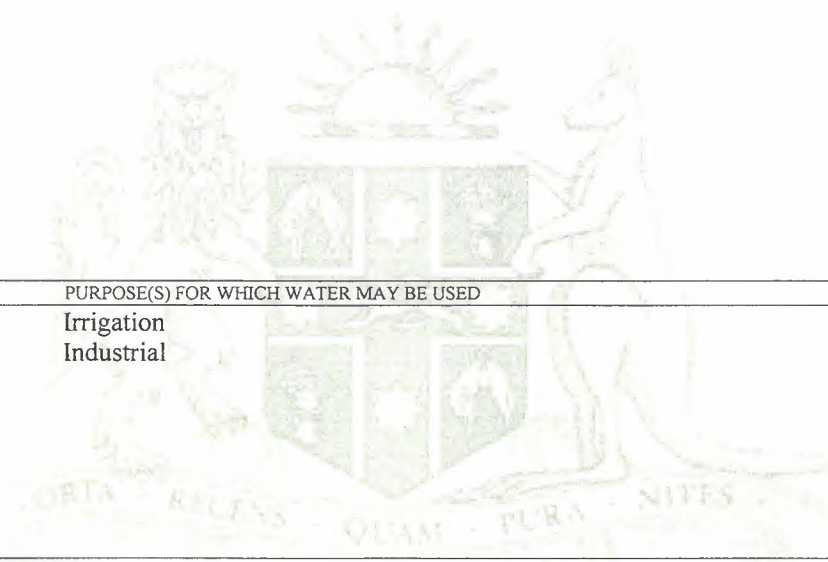
A G L Upstream Investments Pty Ltd  
 Locked Bag 1837  
 St Leonards NSW 2065

|                         |      |
|-------------------------|------|
| LICENSE NUMBER          |      |
| 20BL173600              |      |
| DATE LICENSE VALID FROM |      |
| 22-Aug-2014             |      |
| DATE LICENSE VALID TO   |      |
| 21-Aug-2015             |      |
| FEE                     |      |
| \$151.00                | PAID |

ABN 47661556763 GST NIL

## LOCATION OF WORKS

| Portion(s) or Lot/Section/DP | PARISH     | COUNTY     |
|------------------------------|------------|------------|
| 11//841445                   | Gloucester | Gloucester |



| TYPE OF WORKS              | PURPOSE(S) FOR WHICH WATER MAY BE USED |
|----------------------------|--|
| Well [ Csg - Exploration ] | Irrigation<br>Industrial               |

## CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

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ISSUED UNDER PART V OF THE WATER ACT, 1912  
ON 22-Aug-2014**

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End Of Conditions

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Hunter Region  
 Po Box 2213  
 3/26 Honeysuckle Drive  
 Dangar NSW 2309  
 Phone: ( 02 ) 49042500

BORE LICENSE CERTIFICATE  
 UNDER SECTION 115 OF THE WATER ACT, 1912

**20BL173601**



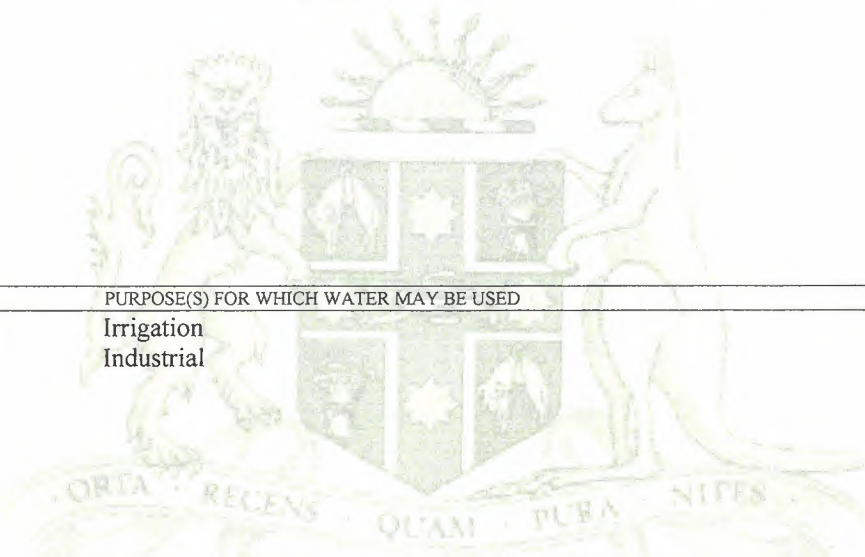
A G L Upstream Investments Pty Ltd  
 Locked Bag 1837  
 St Leonards NSW 2065

|                         |      |
|-------------------------|------|
| LICENSE NUMBER          |      |
| 20BL173601              |      |
| DATE LICENSE VALID FROM |      |
| 22-Aug-2014             |      |
| DATE LICENSE VALID TO   |      |
| 21-Aug-2015             |      |
| FEE                     |      |
| \$151.00                | PAID |

ABN 47661556763 GST NIL

LOCATION OF WORKS

| <u>Portion(s) or Lot/Section/DP</u> | <u>PARISH</u> | <u>COUNTY</u> |
|-------------------------------------|---------------|---------------|
| 251//785579                         | Gloucester    | Gloucester    |



| <u>TYPE OF WORKS</u>       | <u>PURPOSE(S) FOR WHICH WATER MAY BE USED</u> |
|----------------------------|---|
| Well [ Csg - Exploration ] | Irrigation<br>Industrial                      |

CONDITIONS APPLYING TO THIS LICENSE ARE

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**ORIGINAL**



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End Of Conditions

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 Dangar NSW 2309  
 Phone: (02 )49042500

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**20BL173595**

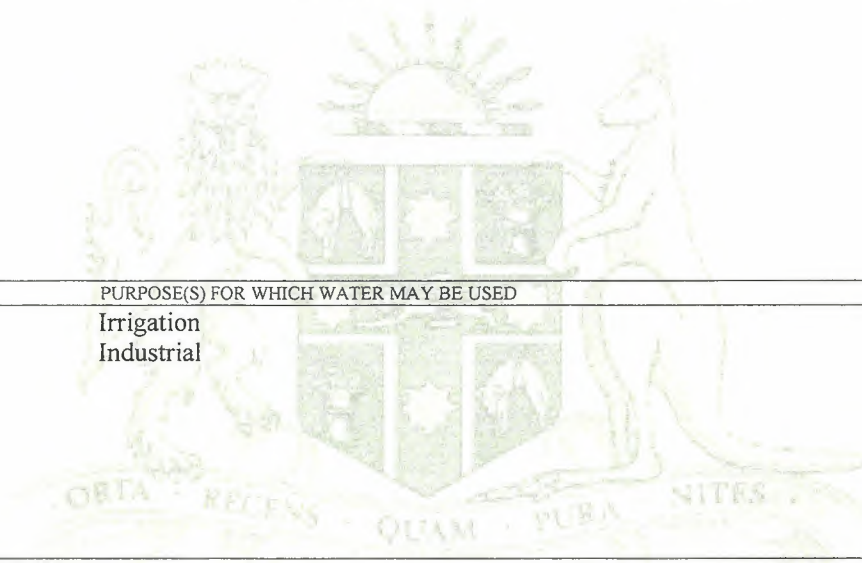


A G L Upstream Investments Pty Ltd  
 Locked Bag 1837  
 St Leonards NSW 2065

|                         |      |
|-------------------------|------|
| LICENSE NUMBER          |      |
| 20BL173595              |      |
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| 22-Aug-2014             |      |
| DATE LICENSE VALID TO   |      |
| 21-Aug-2015             |      |
| FEE                     |      |
| \$151.00                | PAID |
| ABN 47661556763 GST NIL |      |

LOCATION OF WORKS

| Portion(s) or Lot/Section/DP | PARISH     | COUNTY     |
|------------------------------|------------|------------|
| 11//841445                   | Gloucester | Gloucester |



| TYPE OF WORKS              | PURPOSE(S) FOR WHICH WATER MAY BE USED |
|----------------------------|--|
| Well [ Csg - Exploration ] | Irrigation<br>Industrial               |

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End Of Conditions



## A2 Minimum impact considerations for less productive aquifers

Table A2.1 Minimum impact considerations for the less productive alluvial aquifers

| Water component           | Minimum impact considerations  | Assessment   |
|---------------------------|--|--|
| <p><b>Water table</b></p> | <p>1. Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan"<sup>(2)</sup> variations, 40m from any:</p> <p>(a) high priority groundwater dependent ecosystem; or<br/>(b) high priority culturally significant site;</p> <p>listed in the schedule of the relevant water sharing plan; or</p> <p>A maximum of a 2m decline cumulatively at any water supply work unless make good provisions should apply.</p> <p>2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:</p> <p>(a) high priority groundwater dependent ecosystem; or<br/>(b) high priority culturally significant site;</p> <p>Listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.</p> <p>If more than 2m decline cumulatively at any water supply work then make good provisions should apply.</p> | <p>The Avon River alluvium has a maximum thickness of 15 m and contains a shallow unconfined (water table) aquifer. There are no known groundwater dependent ecosystems (GDEs) except for minor baseflow accessions to the Avon River.</p> <p>There are relatively few water supply works nearby. The closest water supply bore is located about 600m across gradient on the neighbouring property (GW054940) and is completed as an excavation in the shallow alluvial aquifer.</p> <p><i>Fracture Stimulation</i></p> <p>Fracture stimulation at depth in the coal seams will not propagate to the near surface alluvial aquifers.</p> <p><i>Dewatering</i></p> <p>There is no potential for the water table in the alluvium to decline during coal seam dewatering due to environmental safeguards including casing and cementing of the gas wells. Modelling also suggest no near surface impacts (refer Appendix A4). Therefore, a decline in the water table level is also unlikely.</p> <p>Water levels will be monitored in the pilot test wells and monitoring bores. Four monitoring bores at the site have collected over 12 months of seasonal data on baseline water levels to inform the design of the</p> |



|                              |   |   |
|------------------------------|---|---|
|                              |   | <p>proposed activity. These bores will be monitored during and after hydraulic fracture stimulation, and during the pilot testing program.</p> <p>In summary, predicted effects are <b>less than the Level 1 minimal impact considerations.</b></p>   |
| <p><b>Water pressure</b></p> | <p>Level 1.<br/>A cumulative pressure head decline of not more than 40% of the “post-water sharing plan”<sup>(2)</sup> pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.</p> <p>Level 2.<br/>If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.</p>  | <p>There is only a ‘water table’ aquifer in the alluvial aquifers so the Water Pressure criterion has no relevance.</p>   |
| <p><b>Water quality</b></p>  | <p>Level 1.<br/>(a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity; and<br/>(b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity.</p> <p>Redesign of a highly connected<sup>(3)</sup> surface water source that is defined as a “reliable water supply”<sup>(4)</sup> is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above.<br/>(c) No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”.<br/>(d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining</p> | <p>The beneficial aquifers at Waukivory and its surrounds are all shallow aquifers that occur in very shallow alluvial sediments or shallow fractured bedrock. The alluvium has a maximum thickness of 15m and contains variable quality water from fresh to moderately saline. As a result no single beneficial use category can be assigned. The alluvial aquifer is expected to be connected to surface water near the Avon River but is known to be poorly connected at the edges of the floodplain.</p> <p>As all gas wells are cased and cemented to full depth, changes in the water quality of beneficial aquifers are unlikely.</p> <p>Activities with potential to contaminate groundwater in beneficial aquifers include the use of chemical additives in fracturing fluids, the storage of produced and flowback water in the holding dam, and reuse of water</p> |



|                                  |  |  |
|----------------------------------|--|--|
|                                  | <p>activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a “reliable water supply”</p> <p>Level 2.<br/>         If condition 1.(a) is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.<br/>         If condition 1.(b) or 1.(d) are not met then appropriate studies are required to demonstrate to the Minister’s satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity.<br/>         If condition 1.(c) or (d) are not met, then appropriate studies are required to demonstrate to the Minister’s satisfaction that:</p> <ul style="list-style-type: none"> <li>- there will be negligible river bank or high wall instability risks;</li> <li>- during the activity’s operation and post-closure, levee banks and landform design should prevent the Probable Maximum Flood from entering the activity’s site; and</li> <li>- low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply.</li> </ul> | <p>for irrigation. Fracture stimulation of coal seams at depth in the gas wells will not impact the shallow alluvial aquifers. Substantial mitigation measures are in place to monitor fracture stimulation and fracture fluids (see Chapter 5).</p> <p>In summary, predicted effects are expected to be <b>less than the Level 1 minimal impact considerations.</b></p>   |
| <p><b>OVERALL ASSESSMENT</b></p> |  | <p>The assessed impact on the (less productive) shallow alluvial aquifers along the floodplain of Avon River as a result of the proposed fracture stimulation and pilot testing programs are assessed to be minimal to negligible based on the baseline water level and water quality monitoring that has been completed to date, and the known conceptual flow model for shallow aquifers, deep aquifers and deeper water bearing zones. Predictive numerical modelling also suggests no impact to alluvial aquifers.</p> |





**Table A2.2 Minimum impact considerations for less productive porous and fractured rock aquifers**

| Water component              | Minimum impact considerations  | Assessment  |
|------------------------------|--|---|
| <p><b>Water table</b></p>    | <p>Level 1.<br/>Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br/>(a) high priority groundwater dependent ecosystem; or<br/>(b) high priority culturally significant site;<br/>listed in the schedule of the relevant water sharing plan.<br/>A maximum of a 2m decline cumulatively at any water supply work.</p> <p>Level 2.<br/>If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br/>(a) high priority groundwater dependent ecosystem; or<br/>(b) high priority culturally significant site;<br/>listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.</p> <p>If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.</p> | <p>There may be a 'water table' in the shallow fractured rock but it is difficult to identify. The aquifers in the rock underlying the site are considered to be semi-confined to confined and are therefore assessed under the 'water pressure' criterion below.</p>   |
| <p><b>Water pressure</b></p> | <p>Level 1.<br/>A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.</p> <p>Level 2.<br/>If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.</p>  | <p>The porous and fractured rocks beneath the alluvium and beneath the Waukivory area contain a few semi-confined aquifers in the uppermost 75m from surface. These are semi-confined to confined aquifers that have low permeability confining layers throughout the sedimentary sequence. Yields to bores are typically low and the water quality is slightly to moderately saline. The deeper bores in rock in the local area are around 60m deep. There are limited beneficial uses for this groundwater (limited to some stock and industrial applications such as dust suppression). The deeper coal seams are confined water bearing zones with more low permeability layers</p> |



|  |  |   |
|--|--|---|
|  |  | <p>separating the shallow fractured rock aquifer from these zones which mostly occur below 150m depth.</p> <p><i>Fracture Stimulation</i></p> <p>There are inherent difficulties in predicting pressure head decline during hydraulic fracture stimulation.</p> <p>Prior to hydraulic fracture stimulation, a simulator will be run to provide a preliminary model of rock mechanics, fluids, pressures and temperatures.</p> <p>Due to the difficulty in predicting changes to the fracture geometry from simulation, a mini fracture will be performed on selected zone prior to the main fracture. A pre-determined volume of the hydraulic fracture stimulation fluid will be pumped into the coal seam without proppant. The pressure decline will be monitored, and these data will be used to inform the main hydraulic fracture stimulation and update the hydraulic fracture model.</p> <p>The mini fracture will give a higher degree of confidence that the Level 1 minimum impact threshold for water pressure is not exceeded.</p> <p>In addition, a geophone monitoring bore is in place near WK13 to assess the extent and orientation of fractures in the targeted coal seams.</p> <p><i>Dewatering</i></p> <p>There is limited potential for the water levels in the shallow fractured rock aquifers to decline during coal seam dewatering due to environmental safeguards including casing and cementing of the gas wells. Additionally, groundwater monitoring data indicates that a vertical connection between the deeper fractured rock aquifers and</p> |
|--|--|---|



|                             |   |   |
|-----------------------------|---|---|
|                             |   | <p>the deeper coal seams is unlikely (PB 2012a and PB 2012c). Modelling also suggest negligible impacts to the fractured rock aquifer (refer Appendix A4). Proving this lack of connectivity is one of the primary reasons for the pilot testing program.</p> <p>Water levels will be monitored in the pilot test wells and monitoring bores. Seven monitoring bores at the site have collected over 15 months of seasonal data on baseline water levels to inform the design of the proposed activity. Four of these bores are in the fractured rock and thrust fault zone and three are in the alluvium. These bores will be monitored during and after hydraulic fracture stimulation, and during the pilot testing program.</p> <p>Water supply bores are very unlikely to be affected given their distance from the gas wells and pilot test program.</p> <p>In summary, predicted effects are <b>less than the Level 1 minimal impact considerations</b>.</p> |
| <p><b>Water quality</b></p> | <p>Level 1.<br/>Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.</p> <p>Level 2.<br/>If condition 1 is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.</p> | <p>The shallow fractured rock aquifer is not considered a beneficial aquifer, or a ‘reliable water supply’ as it has a low yield (generally less than 1 L/s), and has slight salinity (generally above 3000 mg/L TDS). There are very few bores constructed into the rock.</p> <p>The deepest water supply bore known in the local area is 60 m. As all gas wells are cased and cemented to full depth, changes in the water quality of all the shallow beneficial aquifers are unlikely.</p> <p>The only activity with potential to contaminate groundwater in beneficial aquifers is the storage of flowback water. Fracture stimulation of coal seams at depth in the gas wells will not impact the shallow porous and fractured rock aquifers.</p>  |



|                           |  |  |
|---------------------------|--|--|
|                           |  | In summary, predicted effects are <b>less than the Level 1 minimal impact considerations.</b>  |
| <b>OVERALL ASSESSMENT</b> |  | The assessed impact on the (less productive) porous and fractured rock aquifers beneath the Waukivory area as a result of the proposed fracture stimulation and pilot testing programs are assessed to be minimal based on the baseline water level and water quality monitoring that has been completed to date, and the known conceptual flow model for shallow aquifers, deep aquifers and deeper water bearing zones. Predictive numerical modelling also suggests negligible impact to shallow fractured rock aquifers. |

### A3 Groundwater impact assessment (drilling program)

It is considered that, by drilling the pilot wells in accordance with the requirements outlined in Chapter 4, the potential to impact on groundwater systems and local groundwater users is low adverse to negligible. There are no groundwater dependent ecosystems or local groundwater users within the immediate vicinity of the Waukivory pilot wells that could be affected. Impacts are assessed in Table A3.1.

**Table A3.1: Impact Assessment – Waukivory Drilling Program**

| Impact Assessment for Groundwater Systems                                      |   |
|--|---|
| <b>Size, scope and intensity of impacts</b>                                    | <p>The potential impacts on groundwater systems is considered low as the drilling works are for a short duration and undertaken in accordance with the new Well Integrity Code of Practice and national standards.</p> <p>Following the completion of drilling, the exploration hole will be capped and suspended in accordance with the <i>Petroleum and Gas (Production &amp; Safety) Regulation 2004 – Schedule 3</i>.</p>   |
| <b>Level of confidence in predicting the impacts</b>                           | <p>AGL has undertaken core hole and stratigraphic hole drilling activities as part of the on-going exploration works associated within all of their upstream gas projects. The resulting significant level of experience gained from previous projects has resulted in a high level of confidence in accurately predicting any potential associated impacts to groundwater systems from the exploration drilling works.</p>   |
| <b>Reversibility of Impacts</b>  | <p>As the anticipated potential for groundwater impacts is considered low and only water based drilling fluids are used, the reversibility of any impacts is considered to be high.</p>   |
| <b>Mitigation Management Measures</b>  | <p>Mitigation management measures would be pre-emptive and also adaptive to ameliorate any potential for impact. Measures would include:</p> <ul style="list-style-type: none"> <li>• The well will be cased at the surface plus there will be an internal surface casing to ~100m to protect shallow aquifers;</li> <li>• Any drilling fluids/mud will be contained in appropriately sized surface tanks or lined sumps (within the drill compound area);</li> <li>• All sumps will be HDPE lined and banded and have a sufficient capacity in case of heavy rain or additional flow from the holes;</li> <li>• A periodic “pump-out” of the sumps will occur as required to prevent any discharge during wet weather events;</li> <li>• All land disturbed during drilling activities will be restored to pre-operational quality as soon as practical;</li> <li>• Drilling activities will be undertaken in accordance with Australian Government standards, DTIRIS - Minerals Guidelines, Industry best practice and NSW Government standards for well construction. Any additional draft or final Government Codes of Practice.</li> </ul> <p>These mitigation measures are considered to effectively ameliorate all impacts to groundwater and protect its quality.</p> |
| <b>Effectiveness of the proposed methods to manage or mitigate the impacts</b> | <p>The proposed methods to manage or mitigate impacts to groundwater have been derived from past project experience. The drilling process is governed by national standards and industry guidelines. The standards and guidelines outline methods to mitigate potential impacts. Accordingly, the proposed management/mitigation measures proposed are considered to be effective measures as they are enforced through national standards.</p>   |
| <b>Compliance with any relevant policies or plans</b>                          | <p>The drilling methods comply with the national standards, <i>The minimum construction requirements for water bores in Australia</i> (NUDLC, 2012) and industry best practice.</p>   |
| <b>Level of public interest</b>  | <p>The drilling requires a licence pursuant to the <i>Water Act 1912</i> which does not include any allocation to extract groundwater. At the drilling stage it is considered that the general public will maintain an interest in ensuring all works are undertaken with no impacts to groundwater systems. The level of impact to groundwater systems from the proposal is low and predictable with a high level of certainty.</p>  |



| Impact Assessment for Groundwater Systems   |   |
|---|---|
| <b>Is further information required to confidently determine the impact of the activity?</b> | No additional information is required to confirm the predicted level of impact risk to a groundwater system evaluated for the exploration drilling activities.        |
| <b>Categorisation of the extent of impact</b>   | Based on the impact assessment matters listed above the potential for drilling impacts to a groundwater system is determined to be <b>low adverse to negligible</b> . |



## **A4 Waukivory Pilot REF Addendum – Numerical Modelling (PB)**

Parsons Brinckerhoff Australia Pty Limited

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Certified to ISO 9001, ISO 14001, AS/NZS 4801  
A GRI Rating: Sustainability Report 2011

## Memo

**Date** 14 November 2013  
**To** John Ross  
**From** Becky Rollins  
**Ref** 2193335A-DMS-MEM-001 RevA  
**Subject** Waukivory Pilot REF

### Introduction

The Office of Coal Seam Gas (OCSG) review of Waukivory Pilot Testing REF as part of AGL's Gloucester Gas Project has identified the need to assess depressurisation of the alluvium, shallow rock and upper coal measures and also the potential for impacts on groundwater levels at the outcrop areas. In response to this, a numerical cross-sectional model through the Waukivory pilot area in the Stage 1 GFDA was developed using FEFLOW (Figure 1). The model was constructed and parameterised using data from recent groundwater investigations (Parsons Brinckerhoff, 2012a) and in accordance with the hydrogeological conceptual model (Parsons Brinckerhoff, 2013a) and water balance (Parsons Brinckerhoff, 2013b) developed for the Gloucester Basin.

### Model set-up

The Waukivory cross-sectional model is a 5km, roughly east-west section that passes through (or close to) the locations of the Waukivory 11 and 14 gas exploration wells, and the site of the Waukivory groundwater monitoring bores WKMB01, WKMB02, WKMB03 and WKMB04 (Figure 2). The model extends well outside the Stage 1 GFDA to the east and west so that the model boundaries have negligible influence on model predictions, and to a depth of 2000m, below the base of the Permian Coal Measures. The interpreted seismic cross section that forms the basis for the Waukivory model structure is shown in Figure 2.

The cross-sectional model was constructed as a vertical 3D block with a nominal width of 250 m, consisting of six model layers (seven slices). The cross section width allows radial flow to each gas well. Waukivory 11 and 14 gas exploration wells are within 250m of the cross-sectional line, and are therefore included in the model. Waukivory 12 and 13 gas exploration wells are greater than 250m from the cross-sectional line and therefore cannot be accurately represented in the model. However, additional cross-sectional models intersecting Waukivory 12 and 13 would be expected to provide similar results to those presented below.

The eastern and western boundaries were assigned as specified head boundary conditions consistent with observed or interpolated groundwater levels at those locations. Recharge was applied to the model top surface at 1% of rainfall, consistent with estimates of recharge across the shallow fractured rock domains. A specified head boundary condition was assigned to the top most nodes in the location of the Avon River.



Waukivory 11 and 14 gas exploration wells were assumed to be perforated against all major coal seams below 250 m depth, but fully grouted against the interburden units. The Waukivory pilot testing was simulated by applying a specified pressure boundary at nodes where the well intersects relevant coal seams. The pressures at the coal seams were assigned according to the expected down-hole pressures for the duration of the pilot testing (nominally 45 psi or 310 kPa).

Hydraulic conductivity in the shallow rock and deeper coal measures decreases with depth as fractures and pore space (including cleats in coal) close with increasing lithostatic pressure (Parsons Brinckerhoff, 2013a). Hydraulic conductivity was therefore applied to all lithologies and structures with depth functions as follows:

For Interburden:  $K \text{ (m/d)} = 0.03 e^{-0.013 \cdot \text{depth}}$  (to 1000 m), constant  $K \text{ (m/d)} = 10^{-7}$  (below 1000 m)

For Coal seams:  $K \text{ (m/d)} = 0.3 e^{-0.013 \cdot \text{depth}}$  (to 1000 m), constant  $K \text{ (m/d)} = 10^{-6}$  (below 1000 m)

The current conceptual hydrogeological model and a hydrogeological investigation of a strike-slip fault in the northern Gloucester Basin (Parsons Brinckerhoff, 2013c) indicate that faults are weak conduits near the surface and most likely weak barriers at depth. Faults were therefore represented in the model as weak conduits in the top 150m of shallow rock, and as weak barriers with associated depth function in the deeper coal measures. Weak conduit and barrier structures are represented in the model by having a hydraulic conductivity that is one order of magnitude (x10) higher or lower, respectively, than the adjacent interburden. The exact nature of the thrust fault in the area of the Waukivory Pilot is not known and is one of the main reasons for conducting the pilot.

## Model results

The Waukivory pilot testing was simulated over 24 months. The simulated drawdown due to pilot testing is best illustrated in plots showing pressure drawdown (pressure change from steady state pre-development pressure distribution). The results are presented in the following figures:

- Contours of pressure drawdown at 6, 12 and 24 months (focussed on Waukivory 11 and 14) – Figure 3
- Contours of pressure drawdown at 6, 12 and 24 months (full Waukivory model) – Figure 4
- Modelled drawdown hydrographs at the WKMB monitoring bores – Figure 5

The results are presented in relation to groundwater pore pressure in kilopascals (kPa). For reference, one metre of hydrostatic head is equal to ~9.8 kPa; therefore any results expressed as kPa can be converted approximately to metres of head by dividing by 10.

The following conclusions are drawn from the Waukivory pilot testing simulation:

- Pressure drawdown due to gas flow testing forms a steep cone of depression around the perforated zones of the Waukivory gas wells. Hydrostatic pressure increases rapidly with distance away from the wells due to the low permeability of the rock mass (Figures 3 and 4).
- After 24 months of pilot testing, it is predicted that pressure drawdown is unlikely to extend to depths shallower than 70 mbgl (Figure 3). There is no predicted water table drawdown after 24 months of pilot testing (Figure 3).
- Groundwater level drawdown associated with the Waukivory pilot testing is predicted to be ~0.4 m at WKMB03 (screened at 200 to 208 mbgl), and ~0.02 m at WKMB04 (screened at 335 to 347 mbgl) after 24 months of flow testing (Figure 5).

- It is predicted that there will be no measurable groundwater level drawdown associated with the Waukivory pilot testing after 24 months at the WKMB01 (screened at 47 to 53 mbgl) and WKMB02 (screened at 51 to 60 mbgl) monitoring bores (Figure 5).
- The water balance for the Waukivory model implies that each well extracts ~0.75 l/s (0.065 Ml/d) on average over 24 months. It should be noted that this extraction rate is likely to be an over-estimation (and thus prediction of impacts may also be overestimated) because FEFLOW is a single-phase porous groundwater flow model and does not take into account the reduced permeability to water associated with dual phase flow near the gas well.

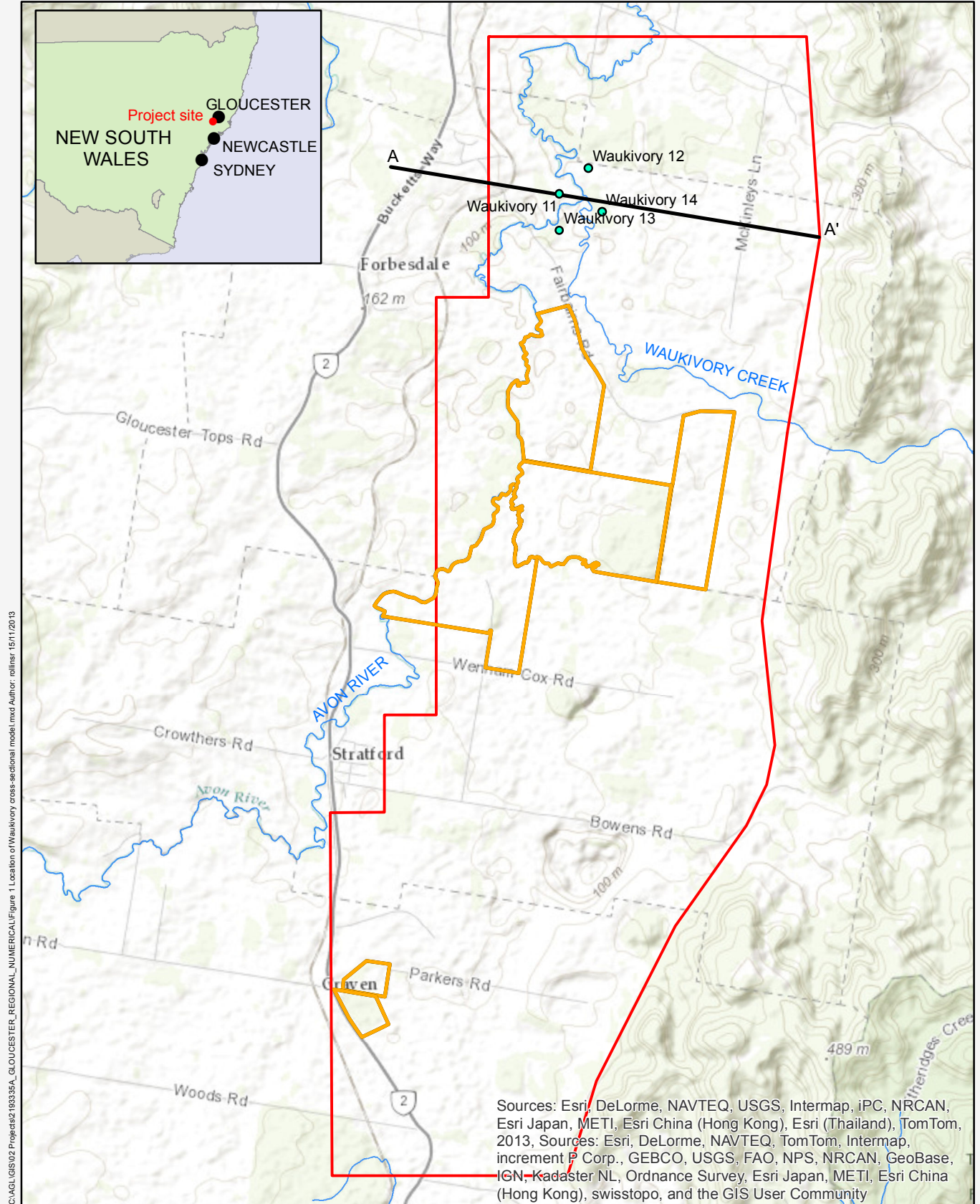
Yours sincerely



**Becky Rollins**  
Hydrogeologist  
Parsons Brinckerhoff

## References

- Parsons Brinckerhoff (2012a) *Phase 2 Groundwater Investigations – Stage 1 Gas Field Development Area, Gloucester Gas Project*, Report PR\_5630, dated January 2012
- Parsons Brinckerhoff (2013a) *Hydrogeological Conceptual Model of the Gloucester Basin*, Report PR\_7266, dated June 2013
- Parsons Brinckerhoff (2013b) *Water Balance for the Gloucester Basin*, Report PR\_7296, dated July 2013
- Parsons Brinckerhoff (2013c) *Hydrogeological Investigation of a Strike-slip Fault in the Northern Gloucester Basin*, Report PR\_5741, dated August 2013



C:\AGL\GIS\02 Projects\2193335A\_GLOUCESTER\_REGIONAL\_NUMERICAL\Figure 1 Location of Waukivory cross-sectional model.mxd Author: collins 15/11/2013

- Rivers and streams
- Waukivory cross-sectional model
- Property Boundaries
- Stage 1 GFDA boundary
- Waukivory gas wells

**Figure 1**  
Location of Waukivory cross-sectional model

N

0 3  
Kilometres

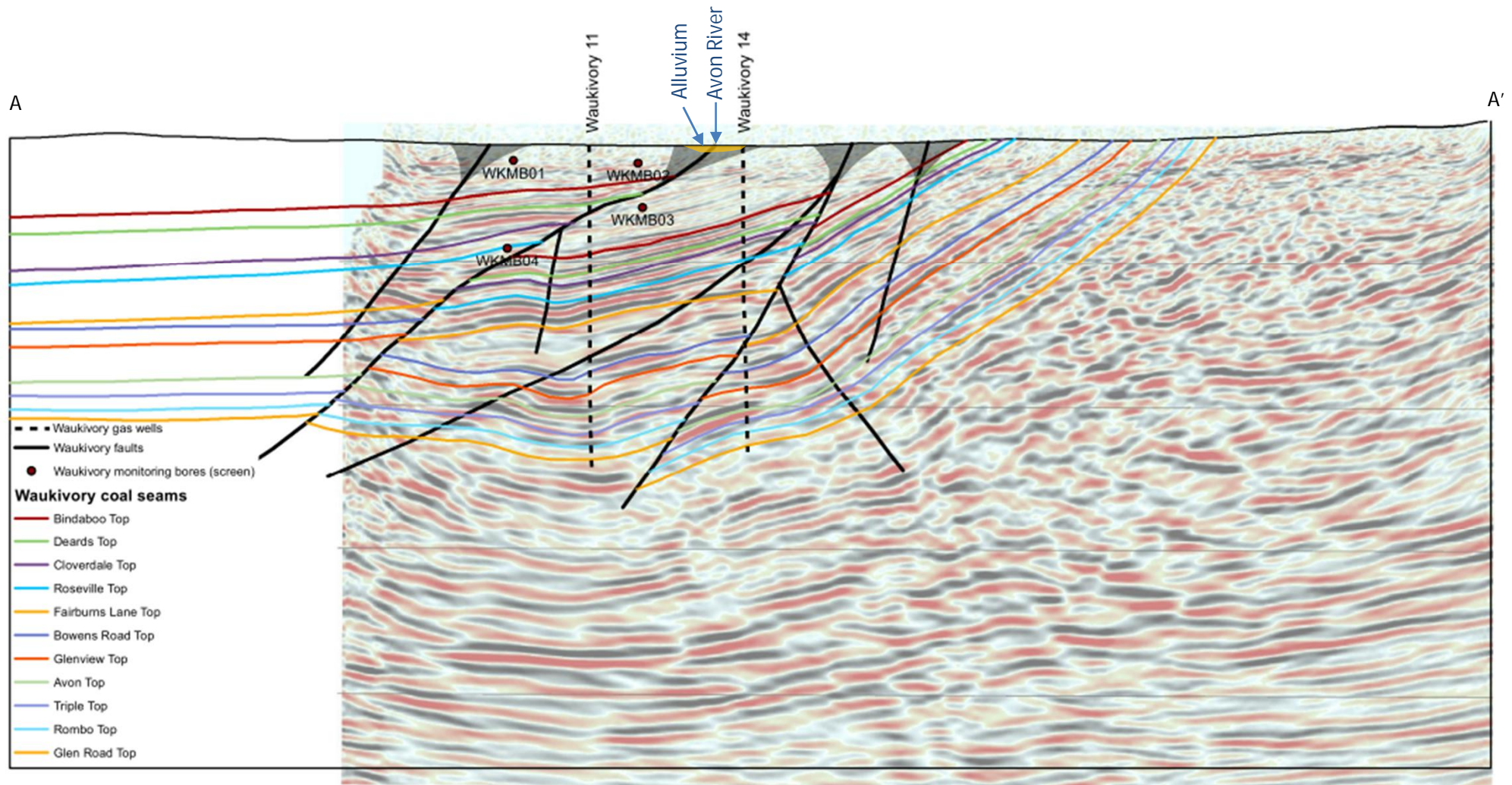
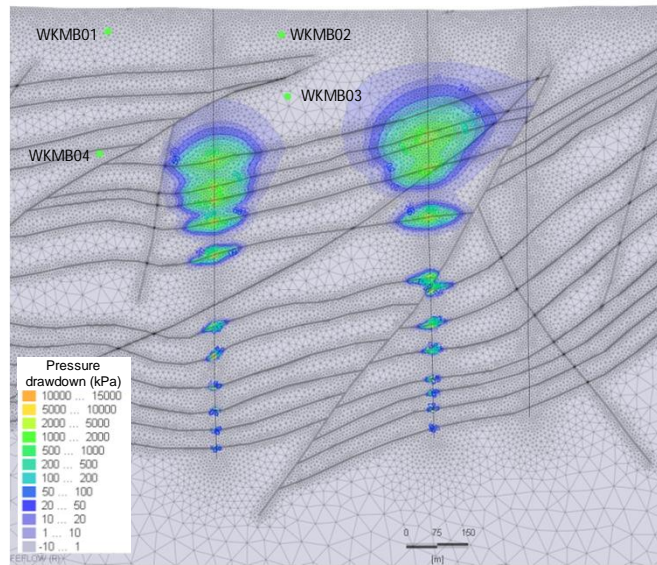
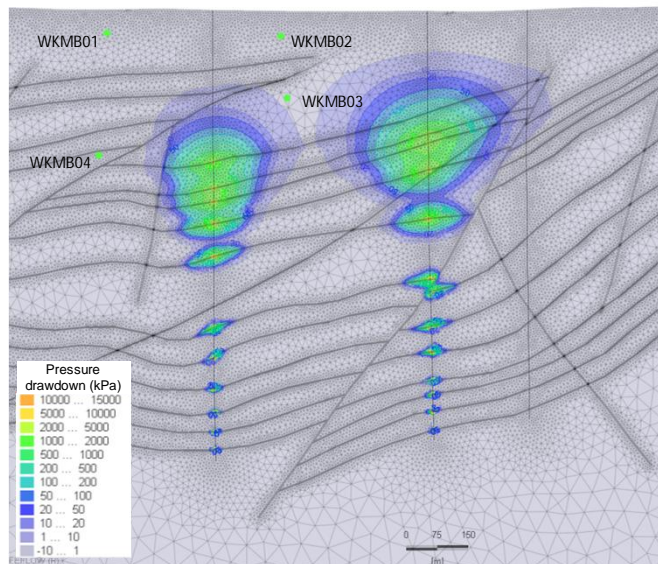


Figure 2 Waukivory interpreted seismic section

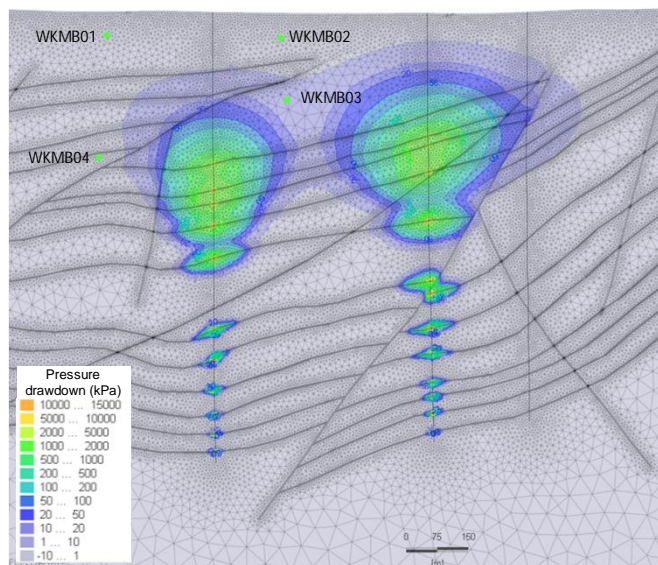
Faults transmissive in shallow rock and barriers at depth



6 months coal seam gas depressurisation



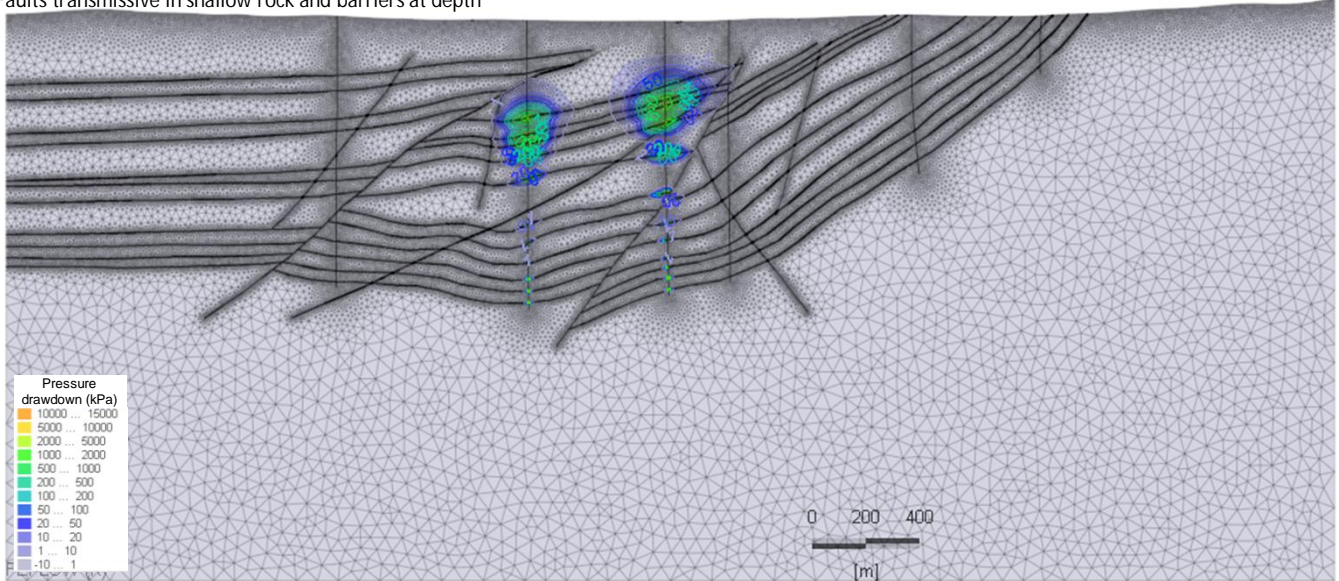
12 months coal seam gas depressurisation



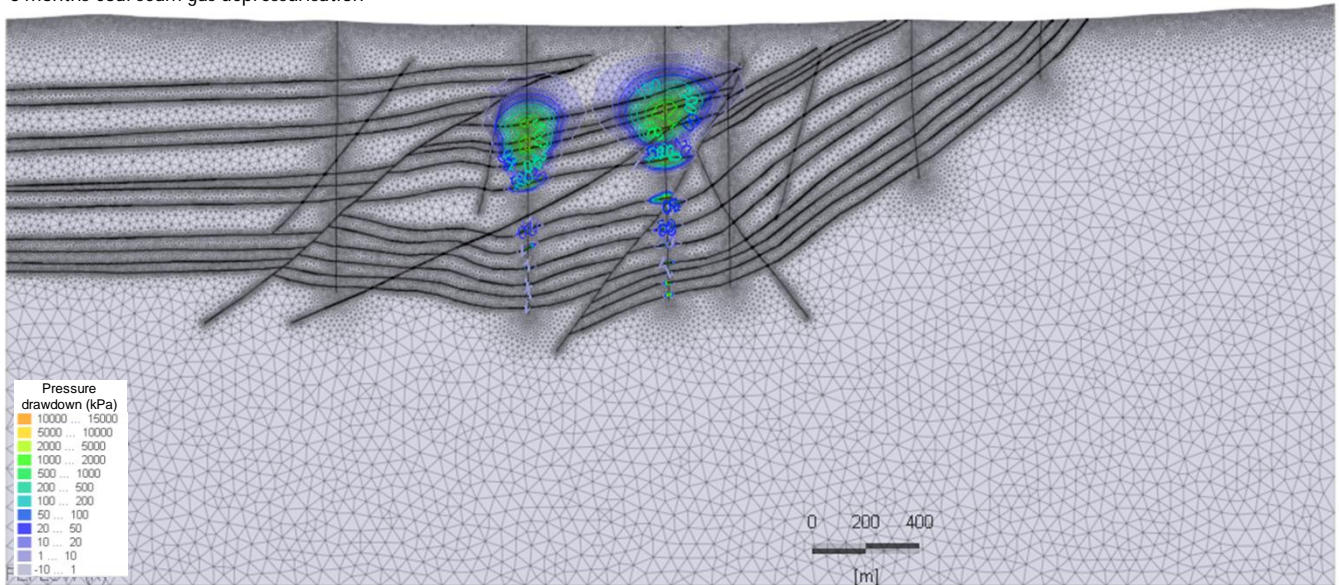
24 months coal seam gas depressurisation

Figure 3 Waukivory pressure drawdown (kPa) after 6, 12 and 24 months of coal seam gas depressurisation

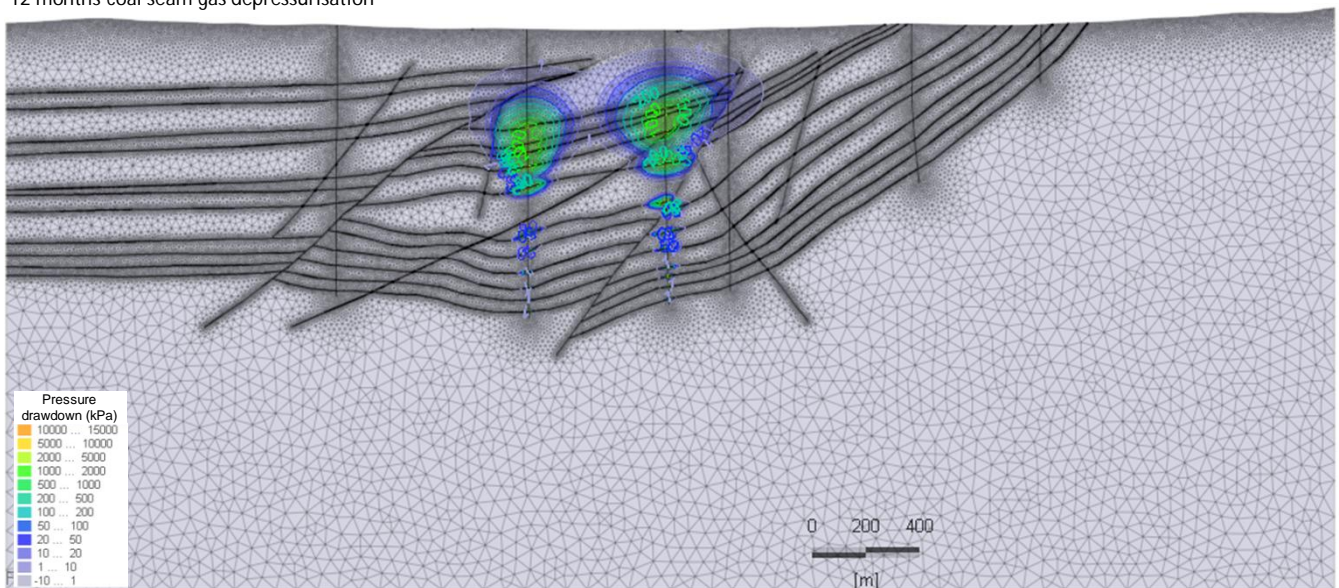
Faults transmissive in shallow rock and barriers at depth



6 months coal seam gas depressurisation



12 months coal seam gas depressurisation



24 months coal seam gas depressurisation

Figure 4 Waukivory pressure drawdown (kPa) after 6, 12 and 24 months of coal seam gas depressurisation

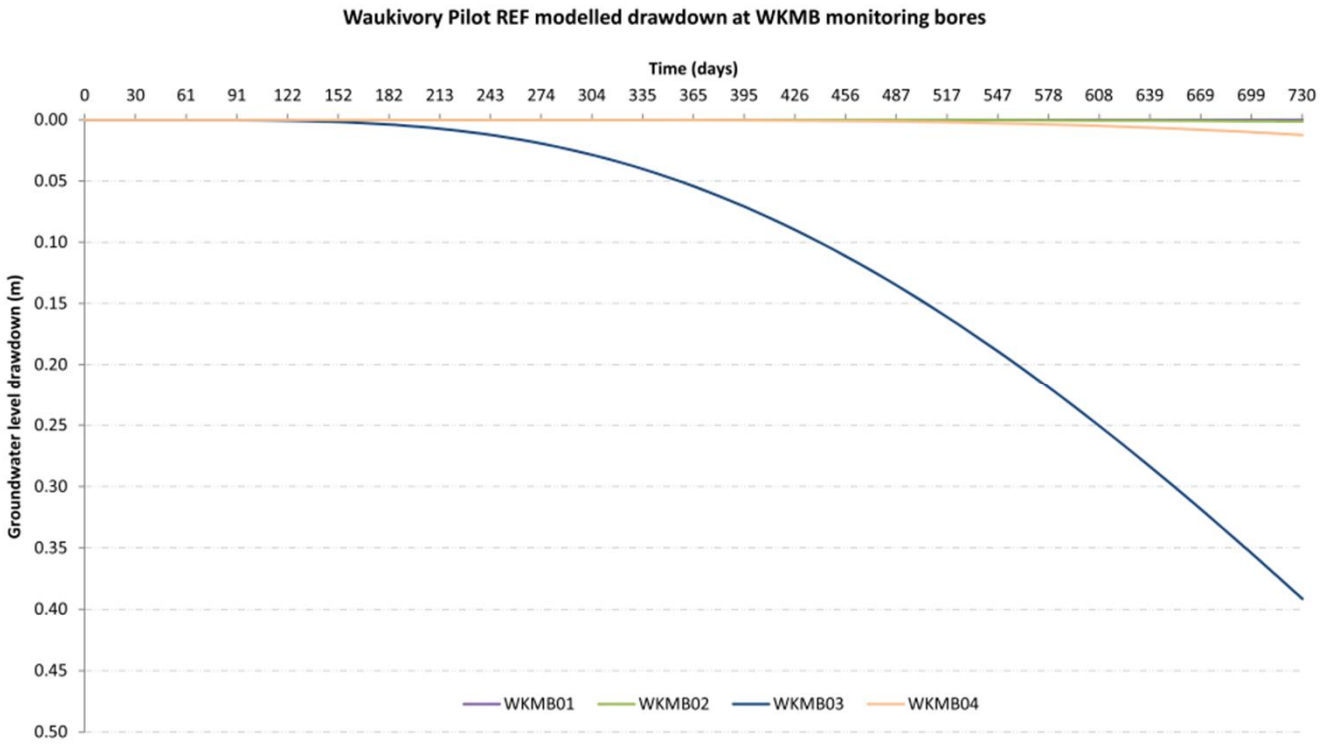


Figure 5 Waukivory Pilot REF drawdown hydrographs



## **A5 Analysis of Potential Fracture Stimulation Additives (ALS)**



1<sup>st</sup> September 2014

**AGL Energy Limited**  
L22, 101 Miller Street  
North Sydney NSW 2060

Dear James,

**RE: ANALYSIS OF POTENTIAL FRACTURE STIMULATION ADDITIVES**

As discussed recently, ALS unfortunately does not currently have capability to test water samples for four potential fracture stimulation additives - Tetrakis (hydroxymethyl) phosphonium sulphate (THPS), Choline Chloride, Monoethanolamine Borate and Sodium Hypochlorite - as chemical compounds. We are also unable to test for the intermediate breakdown products of THPS which may include trishydroxymethyl phosphine (THP) and tris hydroxymethyl phosphine oxide (THPO).

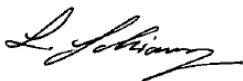
ALS would be able to test for the elemental components of most of these compounds. It has therefore been proposed that ALS would test for the following-

- Phosphorus and sulphate (as indicators for Tetrakis (hydroxymethyl) phosphonium sulphate (THPS))
- chloride and nitrogen/ammonia/ammonium (as indicators for choline chloride)
- Monoethanolamine, boron and nitrogen (as indicators for Monoethanolamine Borate) and
- Sodium, free and residual chlorine (as indicators for Sodium hypochlorite)

There is a possibility that ALS could develop capability for these compounds in the future after consultation with AGL Energy Limited. ALS would have to assess whether the demand for this capability would justify setting up an R&D project specifically for these compounds.

If you require any further information, please feel free to contact me via email ([loren.schiavon@alsglobal.com](mailto:loren.schiavon@alsglobal.com)) or via phone (02) 8784 8555.

Yours Sincerely,



**Loren Schiavon**  
Client Services Coordinator  
ALS Laboratory Group  
**Environmental Division**

## **A6 Management Response Protocol – Waukivory Pilot**

The following management response protocol will be adopted for confirmed or possible changes in water resource trend or impact arising from the operation of the Waukivory pilot.

### **i) Situations that trigger management response – shallow aquifers**

In this context, shallow aquifer/s refers to alluvial aquifers and shallow fractured rock aquifers to around 75m depth.

A situation that triggers a management response would be if water levels change at dedicated shallow aquifer monitoring sites by more than the response trigger (i.e. greater than 2m outside of the normal range for consolidated rock aquifers) or if the yield of a water supply bore changes to another beneficial use category (Table 6.8) over time, and if the change is attributable to CSG activities.

A situation that triggers a management response would be if water quality, with respect to salinity, at dedicated shallow aquifer monitoring sites over time changes to a different beneficial use category (Table 6.8) or if water quality, with respect to other analytes, deviates significantly from the typical observed trend, and if that change is attributable to CSG activities.

To assess whether a water level or water quality impact is attributable to a CSG activity, the following process will be implemented by AGL and each case reviewed/endorsed by NOW and EPA (as appropriate):

- > Review the data set or incident/complaint (if from a private landowner) to identify possible causes
- > Implement additional sampling and monitoring as appropriate
- > Inspect the bore/river site and interview the landowner (if it is a private water supply impact)
- > Assess the trend or impact in terms of local Waukivory operations issues (such as dewatering volumes, performance of individual wells, workovers, timing of events etc)
- > Conclude whether the trend or impact is or is not attributable to a CSG activity
- > Advise NOW/EPA and recommend a course of action if the trend is or is possibly attributable to a CSG activity

The two responses below are based on a trend or impact that is proven or is likely to be attributable to CSG operations.

#### **a) Management response for a situation observed at shallow aquifer monitoring site**

If a situation that triggers a management response is identified at one of the shallow aquifer monitoring sites, the following procedure would be employed, until the situation is rectified.

- 1) Develop a remedial action plan (RAP) for NOW/EPA to endorse. Actions could include:
  - > Perform maintenance on relevant gas well(s) if appropriate, in order to attempt to rectify situation;



**b) Management response for a situation observed at private water supply bore**

If a situation that triggers a management response is identified at a shallow aquifer (private water supply) site, the following procedure would be employed, until the situation is rectified.

- 1) Develop a remedial action plan (RAP) for NOW/EPA to endorse. Actions could include:
  - > Perform maintenance on relevant gas well(s) if appropriate, in order to attempt to rectify situation;
- 2) Determine appropriate alternative water supply arrangement with bore owner if situation cannot be rectified.