Energy in action.

Since 1837

AGL

Surface Water and Groundwater Management Plan for the Waukivory Pilot Program

AGL Upstream Gas | Gloucester Gas Project

Date: 06 May 2015

Table of Contents

Document Revision History

Date	Version	Author	Comment
28 September 2012	V1-5	John Ross	**Version 1** Final for Internal Use at start of the drilling program
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	**Version 2 PUBLISHED** 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	**Version 3** 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	**Version 4.1 PUBLISHED** 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	**Version 4.2** 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	John Ross/James Duggleby	**Version 4.3 PUBLISHED** Revised Final for the Waukivory Pilot REF for the fracture stimulation and pilot testing after SGMP V4.2 approval by OCSG
4 December 2014	V4-4	John Ross/James Duggleby	**Version 4.4** Revised Final for the Waukivory Pilot REF for the fracture stimulation and pilot testing after SGMP V4.3 approval by OCSG and after amendments to EPL 20358 (21 October 2014)
20 March 2015	V4-5	John Ross/James Duggleby	**Version 4.5** Revised Final for the Waukivory Pilot REF for the fracture stimulation and pilot testing after SGMP V4.3 approval by OCSG and after variations to EPL 20358 (18 December 2014 and 11 February 2015)
6 May 2015	V4-6	John Ross	**Version 4.6 PUBLISHED** Revised Final for the Waukivory Pilot REF for the fracture stimulation and pilot testing after modification to the REF approval to pump flowback water to Tiedman East Dam

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

(i) Groundwater Monitoring and Modelling Plan that is referenced under Conditions 12 to 15 of PEL 285.

Glossary

Alluvium	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.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
Aquifer	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.
Aquifer properties	The characteristics of an aquifer that determine its hydraulic behaviour and its response to abstraction.
Aquifer, confined	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Aquifer, semi-confined	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.
Aquifer, unconfined	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.
Aquitard	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.
Australian Height Datum (AHD)	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.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.

Breaker	A chemical that reduces the viscosity of a fluid by breaking long-chain molecules into shorter segments.
Claystone	A non-fissile rock of sedimentary origin composed primarily of clay-sized particles (less than 0.004 mm).
Coal	A sedimentary rock derived from the compaction and consolidation of vegetation or swamp deposits to form a fossilised carbonaceous rock.
Coal seam	A layer of coal within a sedimentary rock sequence.
Coal seam gas (CSG)	Coal seam gas is a form of natural gas (predominantly methane) that is extracted from coal seams.
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeological 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.
Contamination	Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Crosslink gel	A fluid that has a very high viscosity typically in the range of 200-1000 cP.
Depressurisation	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.
Dewatering	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.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.

Drawdown	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.
Electrical Conductivity (EC)	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.
Fracture stimulation	A technique that increases the productivity of a gas well by creating a pathway into the targeted coal seam under high pressure.
Flowback	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.
Flowback water	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.
Fractured rock aquifer	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.
Groundwater	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.
Groundwater system	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.

Hydraulic conductivity	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).
Hydraulic fracturing	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.
Linear gel	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.
microSiemens per centimetre (µS/cm)	A measure of water salinity commonly referred to as EC (see also Electrical Conductivity). Most commonly measured in the field with calibrated field meters.
Monitoring bore	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.
Numerical model	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.
pH	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).
Piezometric surface	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.
Produced water	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.
Proppant	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.
Recharge	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.
Salinity classification	***Fresh water quality –*** water with a salinity <800 µS/cm. ***Marginal water quality –*** water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. ***Brackish quality –*** water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. ***Slightly saline quality –*** water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. ***Moderately saline quality*** – water that is more saline than slightly saline water and generally waters between 10,000 and 20,000 µS/cm. ***Saline quality*** – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 µS/cm. ***Seawater quality*** – water that is generally around 55,000 µS/cm.
Sandstone	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).
Sandstone aquifer	Permeable sandstone that allows percolation of water and other fluids, and is porous enough to store large quantities.
Screen	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.

Sedimentary rock aquifer	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.
Shale	A laminated sediment in which the constituent particles are predominantly of clay size.
Siltstone	A fine-grained rock of sedimentary origin composed mainly of silt-sized particles (0.004 to 0.06 mm).
Source water	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.
Standing water level (SWL)	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.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Water bearing zone	Geological strata that are saturated with groundwater but not of sufficient permeability to be called an aquifer.
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.
Well	Pertaining to a gas exploration well or gas production well.
Zonal isolation	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. Background

1.1. Introduction

AGL Upstream Investments Pty Ltd (AGL) is the holder of Petroleum Exploration Licence (PEL) 285 for the Gloucester Basin (which includes the Waukivory Pilot Project Approval) issued for the Gloucester Gas Project (GGP) coal seam gas exploration activities. PEL 285 was renewed on 6 August 2014.

AGL has prepared this (updated) Surface Water and Groundwater Management Plan (SGMP) to meet the requirements of the Waukivory REF approval and PEL 285 Conditions 12, 13, 14 and 15. The original SGMP was prepared in consultation with the NSW Office of Water (NOW) and was submitted to the NSW Office of Coal Seam Gas (OCSG) for approval by the Minister administering the *Petroleum (Onshore) Act 1991* in October 2014. The original SGMP was also reviewed and endorsed by the Environment Protection Authority (EPA).

1.2. Purpose

The purpose of the SGMP is to describe the surface water and groundwater monitoring activities undertaken in the course of PEL 285 exploration activities and primarily the Waukivory Pilot exploration activities post fracture stimulation. It focuses on the protection of surface water and groundwater resources, and includes risk assessments, investigation and action response triggers, and water management activities to protect water resources.

The plan will be updated whenever new monitoring activities are proposed by AGL and are required under the EPA's environment protection licence (EPL) for the GGP.

1.3. History

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 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 latest EPL 20358 issued for the GGP exploration activities. It includes the information required by the Office of Coal Seam Gas (OCSG), NSW Office of Water (NOW) and the Environment Protection Authority (EPA) under the PEL 285 and EPL conditions. It includes

revisions to the monitoring activities requested by AGL under modifications to the REF and requested by the EPA under recent variations to the EPL.

Version 4.3 is the version that is approved by the OCSG and published on the web-based DIGS database (DRE-OCSG) and the AGL Gloucester website (water studies section) in October 2014.

Version 4.6 (this version) is the SGMP submitted to the OCSG after the approval of the variation related to the onsite storage and management of flowback water prior to its offsite disposal. This SGMP focuses on the Waukivory flowback water management and produced water depressurisation management (as the earlier exploration activities have been completed) and includes water monitoring network changes implemented by AGL and implemented as a result of changes to the EPL.

1.4. Context

The Waukivory Pilot is located within the Stage 1 Gas Field Development Area (GFDA) of the GGP. The GGP is approved under Part 3A of the EP&A Act.

This SGMP (Version 4.6) is applicable to the approved period of the Waukivory Pilot.

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)
- EPL 20358 (current version dated 11 February 2015)
- Variation requests to OCSG related to the storage and management of flowback water prior to its offsite disposal (AGL, 25 February and 15 April 2015).

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 (approved version 4.3) was prepared in consultation with NOW and updates are discussed at regular meetings with 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 but as varied on 21 October 2014, 18 December 2014 and 11 February 2015).

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 plans
- Sections in this report where water management and monitoring plan conditions are addressed.

Table 1.1: Water Management Plan Terminology

Approval Instruments	Approval Reference for water management plan	Addressed in this Report (Section No.)
Waukivory Pilot Project – Fracture Stimulation and Flow Testing (REF EMGA/Mitchell McLennan, 2013a, 2013b, 2014) as modified under 2015 variations.	Enhanced groundwater monitoring program	1.7.1
PEL 285 (renewed in August 2014)	Groundwater Monitoring and Modelling Plan Note 1	1.7.1
EPL 20358 (dated August 2014 but as varied in October and December 2014, and February 2015)	No specific reference although the previous (August) version of the EPL required a Waukivory Surface Water and Groundwater Management Sub Plan	1.7.3
Production Bore Licences (issued in August 2014)	No specific reference but implicitly requires this Surface Water and Groundwater Management Plan for the Waukivory Pilot	1.7.3

Note 1: PEL 285 Condition 16 to 19 for a Produced Water Management Plan are addressed in a separate produced water management plan (AGL, 2015e). .

1.5. Objectives

This SGMP provides 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 flowback water management and produced water management (i.e. depressurisation of the deep coal seams after completion of the fracture stimulation activities). 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 depressurisation 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;
- describe the water quality characteristics of the stored flowback water / produced water in the above ground storage tanks (ASTs), Tiedman East Dam (TED) and Tiedman North Dam (TND);
- 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 investigation and action triggers 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.

1.6. Responsibilities

The AGL Senior Hydrogeologist is responsible for:

- implementation of this SGMP;
- revision of this SGMP and associated reports to reflect changes in applicable approvals, licences and regulations; and
- appointment of technical specialists to undertake periodic monitoring (as required) 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..

The Gloucester Operations Manager is responsible for:

- tracking volumes of flowback water and produced water removed from the pilot wells;
- monitoring the integrity of the water infrastructure, and attending to any remedial measures; and
- disposal of flowback water from TED and adjacent batch tanks.

1.7. Approval and Licensing Conditions

1.7.1. 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 already 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, 2014 and 2015.

In regard to Condition 14:

- Part a) is addressed in Sections 2.3.2 and 3.3.1;
- Part b) is addressed in Sections 6.1, 6.2, 6.3, 6.5 and 6.6;
- Part c) is addressed in Section 2.4;
- Part d) is addressed in Sections 2.4; and
- Part e) is addressed in Section 7.1.

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 various versions of the SGMP. Baseline monitoring programs were initiated in March 2012 and were completed with a baseline sampling event immediately before the fracture stimulation program in October 2014.

1.7.2. REF Variation

On 21 April 2015, AGL applied to vary the REF approval for the Waukivory Pilot to enable the temporary storage of flowback water in the TED, before it is either transported to an EPA licenced facility for treatment and disposal, or treated onsite in accordance with the Stage 1 Extracted Water Management Strategy (EWMS).

This version of the SGMP addresses the proposed variation.

1.7.3. Other Approvals

The other relevant regulatory instruments 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 and was varied on 21 October 2014, 18 December 2014 and 11 February 2015. The original EPL required a revised SGMP; version 4.1 of this SGMP was submitted to EPA on the 3 September 2014 to comply with Condition G2.1. The requirement for a revised SGMP has since been removed from the varied EPL.

The environmental monitoring requirements are described in:

- Condition P1.3 – monitoring locations;
- Condition L3.4 – water concentration limits;
- Condition M1 (multiple) – monitoring records;
- Condition M2 (multiple) – monitoring the concentration of analytes and pollutants at each monitoring location at given frequencies using appropriate sampling methods;
- Condition M3 – testing methods and concentration limits; and
- Condition R4.3 – surface water and groundwater monitoring report (annual return).

The water monitoring location and frequency conditions in the EPL (Conditions P1.3 and M2.2 to M2.6) are covered in Section 6 of this SGMP.

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 of this SGMP.

1.8. Fracture stimulation

Hydraulic fracture stimulation has been used on all 12 completed gas production wells at Gloucester, and this technology was again used in October and November 2014 at the four Waukivory pilot well sites (WK11, WK12, WK13, and WK14).

The additives and treatments were in accordance with the list and volumes described in the original REF (EMGA Mitchell McLennan, 2013a) and the fracture stimulation management plan (AGL, 2014a). Full details of the additives and quantities used are provided in the Fracture Stimulation Completion Reports for each of the wells. The final components of the fracture stimulation fluids did not include the clay stabiliser choline chloride or the bactericide sodium hypochlorite. Summary details are provided in **Table 1.2**.

Table 1.2: Fracture Stimulation Fluid additives – Waukivory Pilot

Main Treatment Program					
Description	Name	WK11	WK12	WK13	WK14
Biocide	Tolcide 75%	√	√	√	√
pH Adjusting Agent	Acetic Acid 60%	√	√	√	√
pH Buffer	Caustic 50 %	√	√	√	√
Crosslinker	BC-140C	√	√	√	√
Gelling Agent	WG-36	√	√	√	√
Gel Breaker	GBW-30	√	√	√	√
Acid Mix					
Description	Name	WK11	WK12	WK13	WK14
Hydrochloric Acid	HCl	√	√	√	√
pH Adjusting agent	Acetic Acid 60%	√	√	√	√
Iron sequestrant	FE-2	√	√	√	√
Corrosion Inhibitor	DA-17004	√	√	√	√
Proppants					
Description	Name	WK11	WK12	WK13	WK14
20/40 Natural Sand		√	√	√	√
100 Mesh		√	√	√	√

Note: Not all additives were used for all zones fractured stimulated in each well. Full details are provided in the fracture stimulation completion reports

Multiple coal seams were fracture stimulated in all four gas wells WK11, WK12, WK13 and WK14. The final fracture stimulation methods and well completions are described in the fracture stimulation completion reports submitted to the OCSG. Details of the fracture stimulation intervals are summarised in **Table 1.3**.

Table 1.3: Fracture stimulation intervals at Waukivory Wells

Zone	Coal seam	Perforation interval (mbgl)	Seam thickness (m)
WK11			
1	Avon	928.7 – 964.25	9.36
2	Glenview	860.5 – 879.2	2.18
3	Bowens Road and Fairbairns Lane	806.6 – 838.0	2.46
4	Fairbairns Lane	709.1 – 741.9	2.06
WK12			
1	Fairbairns Lane	590.4 – 597.0	1.33
2	Roseville (lower)	485.7 – 504.2	3.24
3	Roseville (upper)	406.0 – 424.1	2.93
4	Cloverdale	371.3 – 385.0	2.42
WK13			
1	Triple	934.2 – 946.3	0.91
2	Avon	878.7 – 911.4	10.05
3	Glenview	812.5 – 826.5	2.35
4	Glenview	Not perforated or fracture stimulated	
5	Fairbairns Lane (lower)	694.1 – 738.3	2.75
6	Fairbairns Lane (upper)	612.2 – 628.8	5.93
7	Roseville (lower)	540.2 – 575.1	2.05
8	Roseville (upper)	514.5 – 523.3	2.79
9	Cloverdale	451.4 – 474.0	2.23
10	Bindaboo	404.5 – 408.4	0.75
WK14			
1	Avon	774.5 – 805.8	7.5[(a)]
2	Fairbairns Lane (lower)	532.5 – 542.0	4.23
3[(b)]	Fairbairns Lane (upper)	473.8 – 490.8	3.81
4[(b)]	Roseville	453.3 – 459.7	2.05

(a) Estimated.

(b) WK14 zones 3 and 4 are acid wash intervals. Acid wash of zones 3 and 4 were conducted simultaneously.

2. Geology, Hydrology and Hydrogeology

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^2 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 with three of the four gas wells and the water staging area located on the floodplain. The Tiedman storage dams are all located beyond the floodplain on the highest location on AGL's Tiedman property (at an elevation of approximately 125 mAHD).

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); and
- 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 upthrusted 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;
- shallow fractured rock aquifers;
- deep coal measure interburden confining units;
- deep coal seam water bearing zones.

Only the first two hydrogeological units are known aquifers. The deeper rock types being either very poor aquifers/aquitards (coal seams, conglomerates and sandstones) or confining aquitard/aquiclude layers (mudstones, siltstones 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 **shallow fractured 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 is being reviewed in consultation with NOW and updated based on the results from the Waukivory pilot testing program. The 2013 conceptual model report (PB, 2013a) will be 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 A2** 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.

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.

3. Regulatory 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 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 has been issued for approved exploration activities within PEL 285 and is varied as changes occur to site activities, and as new exploration activities are approved.

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.

3.2. Legislation

3.2.1. Protection of the Environment Operations Act (1997)

The Protection of the Environment Operations Act 1997 (POEO Act) is the key piece of environment protection legislation administered by the EPA. The POEO Act provides a single licensing arrangement to replace the different licences and approvals that existed under separate Acts prior to 1999 relating to air pollution, water pollution, noise pollution and waste management.

Environment Protection Licences (EPLs) are usually issued with conditions. These include requirements to monitor, to provide certification of compliance with a licence, to undertake and comply with a mandatory environmental audit program and pollution studies, reduction programs and financial assurances.

AGL's EPL 20358 for the GGP premises includes air, water, and soil monitoring and reporting for a range of exploration project activities. The licence was issued on 6 August 2014.

3.2.2. 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.

AGL currently holds ten bore licences for this exploration program as at 1 May 2015. Two relate to construction of the gas (test) wells, three apply to the monitoring bores within the immediate 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 perforated, fracture stimulated and flow tested). 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 converted to deep water monitoring bore
20BL173856	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, depressurisation, groundwater monitoring and associated compliance activities.

3.2.3. 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 the four gas wells are fracture stimulated, this CSG activity is considered to be higher risk and hence the AI policy applies. 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 depressurisation, 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 volume 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. The final water production profiles will be confirmed on completion of 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) (µS/cm)	(approx.) Total Dissolved Solids (mg/L)
Alluvium	<2	2,000 – 7,500 (1)	1,500 – 6,000
Fractured rock	<0.5	1,500 – 5,000 (1)	1,000 – 4,250

Note (1) 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 A3**.

The assessed impact to surface water and groundwater resources is assessed to be low. Further information on risk assessments is provided in Section 5 of this SGMP.

3.3.3. Beneficial use

A generalised beneficial use matrix has been designed (in accordance with both yield and water quality characteristics) (see **Table 3.3**). 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 hydrogeological unit or groundwater system.

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 µS/cm (marginal water quality).

The following beneficial use categories can be assigned to each of the groundwater systems at Gloucester (in the broader Waukivory area) (in accordance with **Table 3.3**):

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

The (high yield) beneficial use categories (greater than 5 L/s) are not known to occur in the Waukivory area, and no saline water (greater than 20,000 µS/cm has been detected in the area either.

Table 3.3: 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

3.4. Specific Water Management Approvals

The specific water management approvals required under the Waukivory Pilot REF are provided in Section 1.6 and are summarised as:

- renewal of PEL 285 by the OCSG requires a Groundwater Monitoring and Modelling Plan (Version 4.3 of this SGMP);

- EPL 20358 issued by the EPA for the GGP premises exploration activities requires extensive water monitoring at numerous surface water and groundwater locations (this SGMP); and
- production bore licences (for each of the four gas wells) issued by NOW to fracture stimulate and flow test each of 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 the recently updated PWMP (AGL, 2015e) that has been prepared and approved in parallel with this SGMP. From 30 April 2015, there will be no further reuse of blended produced water under the Tiedman Irrigation Program (TIP). The TIP approval expired on the 30 April 2015.

3.5. Water Monitoring Requirements

Following consultation with NOW and the EPA, and implementation of the EPL 20358, AGL has undertaken the following groundwater monitoring initiatives:

- a formal groundwater monitoring and modelling plan;
- installation of dedicated monitoring bores;
- collection of periodic water level, water quality and volumetric data;
- implemented telemetry of water data and launched its 'Water Portal' for selected water monitoring sites at Waukivory;
- reporting of data and trends; and
- numerical modelling.

There are also specific requirements provided in the AI Policy (NOW, 2012) that 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 for PEL 285 exploration activities (AGL, 2015e).

4. Water Infrastructure

Flowback water is captured in temporary above-ground water storage at each well site and then collectively in a 1.5 ML above ground storage tank (AST) (AST 2) at the WK13 water staging point before being pumped to Tiedman East Dam (TED) for temporary storage. The expected flowback volume is 3 to 3.5 ML. Flowback water will be stored in the TED until a third-party contractor is engaged, or the Stage 1 Gloucester Gas Project commences, at which time the water will be treated via the desalination process outlined in the Extracted Water Management Strategy (EWMS).

If Stage 1 of the GGP has not commenced by 22 February 2016, and lawful offsite disposal of flowback water is still required and not available (or commercially viable) for AGL despite all reasonable and practicable efforts, AGL will seek approval for a mobile containerised water treatment unit to be located at Tiedmans.

Flowback water transitions to produced water once 100% of the fracture stimulation volume is recovered from each well and the produced water quality exceeds 5000 µS/cm. Produced water is then pumped into a 1.5 ML above ground storage tank (AST) (AST 1) at the WK13 water staging point before being pumped to TND for temporary storage. The maximum produced water volumes are expected to be 15 ML, and most likely (depending on length of test etc) to be less than 10 ML.

The major infrastructure associated with transporting and containing water associated with the Waukivory flowback and produced water management process includes:

- dams;
- above ground storage tanks (AST); and
- pipelines.

A description of the dams used as source water and in the management of Waukivory flowback water and produced water (after fracture stimulation) is included in **Table 4.1**. The three 'turkeys nest' dams on Tiedmans are constructed as temporary holding ponds for waters generated from PEL 285 exploration projects. All dams are located beyond the floodplain. They have small footprints and are relatively deep.

TSD and TND were constructed for pilot testing programs associated with the Stratford exploration program while TED was constructed under the TIP REF approval to cater for the temporary storage of produced water from the Waukivory pilot. The dimensions of the TED are as follows:

- Size – approximately 0.9ha being 150m long by 60m wide by 4.4 to 5.7m deep
- Storage capacity – 20.4 ML
- Additional freeboard/capacity – 600mm which equates to an additional 4.3ML of storage

It has never been AGL's intention to store produced water for long periods of time in dams and allow it to evaporate. Along the lower north coast rainfall exceeds evaporation for all months of the year so stored water (with the addition of rainfall) will actually accumulate in surface storages rather than passively evaporate. Consequently the temporary holding ponds have been designed to occupy a relatively small area (all are less than 1ha in size) and are typically 4 to 5 metres deep.

A description of the ASTs used in the management of Waukivory flowback water and produced water (after fracture stimulation) is included in **Table 4.2**.

A description of the pipelines used for source water and in the management of Waukivory flowback water and produced water (after fracture stimulation) is included in **Table 4.3**.

Table 4.1: Dams used for Waukivory flowback water and produced water management

Name	Location	Approved Use	Details	Approved Function	Reference
Pontilands Farm dam	Located on Lot 2 DP 1040412	Irrigation, Industrial and Stock Purposes (freshwater source)	• Large farm dam on unnamed gully leading to the Avon River • Excavated and unlined • 50 ML capacity • 20 ML Water Access Licence • Not in a flood prone area	Natural water source dam for fracture stimulation, workover activities and other industrial uses. Used primarily as source water for the fracture stimulation program but can be used for workover water and other miscellaneous industrial uses at Waukivory if required	Works approval 20CA212873
Tiedmans North Dam	Located on Lot 85 DP979859	Produced water	• Turkeys Nest dam • Single lined - HDPE • 15 year dam and liner life expectancy • 20 ML capacity • 500 mm freeboard before it spills • Not in a flood prone area	Produced water storage dam for PEL 285 exploration activities	REF approval No works approval required because the water that is pumped into this dam is taken from other licenced works
Tiedmans South Dam	Located on Lot 85 DP979859	Freshwater dam for irrigation – water sourced from works approvals 20CA212873 and 20CA204347	• Turkeys Nest dam • Single lined – HDPE • 15 year dam and liner life expectancy • 20 ML capacity • 500 mm freeboard before it spills • Not in a flood prone area	Historically produced water storage dam for PEL 285 exploration activities but mostly the blended water irrigation dam for the Tiedman Irrigation Program. Ongoing will be a freshwater dam	Freshwater dam
Tiedmans East Dam	Located on Lot 85 DP979859	Flowback and/or produced water	• Turkeys Nest dam • Double lined – HDPE – with seepage control and inspection sump • 15+ year dam and liner life expectancy • 20.4 ML capacity • 600 mm freeboard before it spills (extra 4.3 ML capacity) • Not in a flood prone area • Not an evaporation pond	Flowback water and produced water storage dam for PEL 285 exploration activities	REF approval No works approval required because the water that is pumped into this dam is taken from other licenced works

Table 4.2: ASTs used for Waukivory flowback water and produced water management

Name	Location	Approved Use	Details	Function	Reference
AST 1	Waukivory 13 (refer Figure 3)	Source water and produced water	• 1.5 ML AST total capacity; however actual capacity is reduced to 1.1 ML taking into account 500 mm freeboard • open topped • double lined • leak detection system • 500mm freeboard • located in a flood prone area	• AST 1 was used for the storage of freshwater (Pontilands source) during fracture stimulation. • produced water from Waukivory 11, 12, 13 and 14 is pumped to AST 1. • produced water in AST 1 is pumped to the Tiedman East Dam (TED) initially then Tiedman North dam (TND). • AST 1 will remain on site after fracture stimulation as a 'balance' tank for produced water or until such time that the produced water rate is low enough for an alternate (smaller) tank to be located on site.	REF Approval
AST 2	Waukivory 13 (refer Figure 3)	Flowback water	• 1.5 ML AST total capacity; however actual capacity is reduced to 1.1 ML taking into account 500 mm freeboard • open topped • double lined • leak detection system • 500mm freeboard • located in flood prone area	• flowback water from Waukivory 11, 12, 13 and 14 is pumped to AST 2 • flowback water in AST 2 is pumped to TED in the produced water pipeline. • AST 2 will remain on site for the temporary storage of flowback water for approximately 3 to 6 months after the pilot re-commences after suspension • some produced water may also be pumped through this tank as the flowback criteria is 100% of volume injected at each well plus an EC of 5000 µS/cm	REF Approval
Batch tank (BT) 1	Tiedmans	Flowback water and/or produced water prior to off-site treatment	• nominal 50,000 L AST total capacity • closed topped • located in bund with 110% containment • not in flood prone area	• flowback / produced water is decanted from TED into BT1 • sampling, analysis and assessment of water quality in BT 1 is undertaken prior to loading into a tanker for lawful off site treatment and disposal. • BT 1 will remain on site until lawful off site disposal of flowback is complete.	REF Approval (April variation)
BT 2	Tiedmans	Flowback water and/or produced water prior to off-site treatment	• nominal 50,000 L AST total capacity • closed topped • located in bund with 110% containment • not in a flood prone area	• flowback / produced water is decanted from TED into BT2 • sampling, analysis and assessment of water quality in BT 2 is undertaken prior to loading into a tanker for lawful off site treatment and disposal. • BT 2 will remain on site until lawful off site disposal of flowback is complete. • BT1 and BT2 are used alternately.	REF Approval (April variation)

Table 4.3: Water pipelines used for Waukivory flowback water and produced water management

Name	Location	Approved Use	Details	Function	Reference
Source water pipeline	Pontilands dam to AST 1	Source water for the fracture stimulation program and workover water	• poly pipe • underground • hydraulically pressure tested • located in both flood prone and non-flood prone lands.	• water pipeline used for transferring water from Pontilands Dam (freshwater) to the WK13 staging area • this connection to the main transfer pipeline was isolated after the completion of the fracture stimulation program so that flowback water or produced water could not impact the freshwater in Pontilands Dam.	REF approval
Waukivory to Tiedmans flowback and produced water pipeline	AST 1 and AST 2 to TED (flowback water) and TND (produced water)	Main transfer pipeline for transferring flowback water and produced water	• poly pipe • underground • hydraulically pressure tested • located in both flood prone and non-flood prone lands.	• water pipeline used for transferring water from the Waukivory (WK) 13 staging area (either AST 1 or AST 2) to TED (flowback water) or TND (produced water)	REF Approval (April variation)
Waukivory site flowback and produced water pipelines	Waukivory 11, 12, 13 and 14 to AST1 and AST 2 at WK13 staging area	Spur pipelines for transferring flowback water and produced water to the WK13 staging area	• poly pipe • underground • hydraulically pressure tested • located in both flood prone and non-flood prone lands.	• water pipelines from individual wells to the WK 13 staging area	REF Approval
TED to BT 1 and BT 2.	From TED to BT 1 and BT 2	Lawful disposal of flowback water	• poly pipe • above ground • located on non-flood prone lands	• water pipeline to transfer water from TED to BT 1 and BT 2. • this pipeline will remain on site until lawful off site disposal of flowback is complete.	REF Approval (April variation)

5. Risk Assessment

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) and previous versions of this SGMP.

A further risk assessment was completed as part of the most recent variation submitted to the OCSG for improved water management and specifically the transfer of flowback water to TED (Appendix C of EMGA Mitchell McLennan, 2015). This risk assessment is reproduced in **Appendix A4** of this SGMP.

Risks associated with the storage and handling of flowback water and produced water resulting from depressurisation of the wells associated with the Waukivory pilot, are summarised in **Table 5.1**. Unmitigated, these risks have the potential to impact on water resources. They are associated with the storage and handling of flowback water and produced water, and/or are potentially a direct result of depressurisation associated with the pilot testing program. However with mitigation and suitable actions and control measures, these risks are considered low. Proposed control measures are also summarised in Chapter 6 (specifically **Tables 6.3 and 6.4**).

Table 5.1: Summary of risks

Source	Risk	Risk Assessment
Flowback water and produced water	Loss of containment from AST 1 and/or 2 and associated infrastructure (Waukivory 13) may result in soil and/or water contamination.	• The risk of a loss of containment incident from AST 1 and/or 2 and associated infrastructure has been assessed as low. • Control measures include: ○ ASTs are double lined ○ ASTs have a leak detection system ○ 0.5m freeboard ○ regular inspections ○ hydraulic testing of pipelines and connections ○ pump transfer area is bunded ○ volumes are measured ○ emergency response plan

Source	Risk	Risk Assessment
Flowback water and produced water	Loss of containment from TED or BT 1 and/or 2 (Tiedman site) may result in soil and/or water contamination.	• The risk of a loss of containment incident from BT 1 and/or 2 and associated infrastructure has been assessed as low. • Control measures include: o BTs are located in secondary containment o freeboard is maintained o regular inspections o leak testing o transfers are undertaken by operator o pump transfer area is bunded o emergency response plan
Flowback water	Loss of containment during transport to off-site lawful treatment facility, may result in soil and/or water contamination.	• The risk of a loss of containment incident during transport to licenced waste facility has been assessed as low. • Control measures include: o tanker inspections o driver induction o journey management plan o emergency response plan
Flowback water and produced water	Sabotage to infrastructure may result in loss of containment and subsequent soil and/or water contamination.	• The risk of a loss of containment incident from sabotage to infrastructure has been assessed as low. • Control measures include: o security plan o CCTVs o regular inspections o emergency response plan o ASTs double lined o BTs in secondary containment o volumes measured o emergency response plan
Flowback water and produced water	The quality of flowback water or produced water stored in AST 1 and/or 2 or TED, changes resulting in potential risk to human health and if there is a loss of containment, a potential risk to the environment.	• The risk of water quality changes resulting in risks to human health and to the environment has been assessed as low. • Control measures include: o Water monitoring at gas wells o Water monitoring in ASTs and TED o Trigger Action Response Plan (TARP)

Source	Risk	Risk Assessment

Produced Water	Loss of containment from TED and/or TND may result in soil and/or water contamination.	• The risk of a loss of containment incident from TED and/or TND has been assessed as low.
		• Control measures include:
		  ○ TED is double lined and has a leak detection system
		  ○ TND has nearby seepage monitoring bore
		  ○ freeboard is maintained
		  ○ regular inspections
		  ○ volumes are measured
		  ○ emergency response plan

Produced Water	Depressurisation may induce changes to local groundwater pressure and levels or induce changes to surface water levels and flow	• The risk of depressurisation causing changes to local groundwater pressure and levels and changes to surface water levels and flow has been assessed as low.
		• Very small volumes of deep groundwater to be pumped as produced water (i.e. max 15 ML and probably less than 10ML). These volumes are unlikely to deplete shallow aquifers or streams.
		• Control measures include:
		  ○ water monitoring at wells (levels, quality, volume)
		  ○ water monitoring at monitoring bores and gauging sites (levels)

Produced Water	Depressurisation may induce changes to local groundwater quality or induce changes to surface water quality.	• The risk of depressurisation causing changes to local groundwater quality and inducing changes to surface water quality has been assessed as low.
		• Control measures include:
		  ○ water monitoring at wells (levels, quality, volume)
		  ○ water monitoring at monitoring bores and gauging sites (quality, isotopes)

Source	Risk	Risk Assessment

Produced Water	Depressurisation may reduce water levels or affect water quality in nearby private water bores and at pumps on the Avon River	• The risk of depressurisation causing changes to local groundwater pressure and levels and changes to surface water levels and flow has been assessed as low.
		• Very small volumes of deep groundwater to be pumped as produced water (i.e. max 15 ML and probably less than 10ML). These volumes are unlikely to deplete shallow aquifers or streams.
		• Control measures include:
		  ○ water monitoring at wells (levels, quality, volume)
		  ○ water monitoring at monitoring bores and gauging sites (levels)
		• The risk of depressurisation causing changes to local groundwater quality and inducing changes to surface water quality has been assessed as low.
		• Control measures include:
		  ○ water monitoring at wells (levels, quality, volume)
		  ○ water monitoring at monitoring bores and gauging sites (quality, isotopes)

6. Management Plan and Controls

6.1. Groundwater monitoring framework

6.1.1. Objective

The primary objective of the dedicated groundwater network is to monitor and protect the shallowest beneficial aquifers used (and potentially 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).

6.1.2. Background

With the Waukivory Pilot there is an opportunity to collect important groundwater data associated with pilot testing activities. The Waukivory Pilot groundwater monitoring program provides:

- 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 aquifer receptors;
- certainty regarding the effective storage of flowback water in TED and produced water in TED/TND;
- 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;
- 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; and
- monitor flowback water and produced water quality and to monitor the integrity of temporary storages that may impact groundwater resources.

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 µS/cm is reached (and maintained) for the return waters; and
- produced water is deemed to be 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 µS/cm is considered appropriate given that fresh water

(from the Pontilands Dam with a salinity of 265 µS/cm) was the source water for the fracture stimulation program.

6.2. Surface water monitoring framework

6.2.1. Objective

The primary objective of the dedicated surface water network is to monitor and protect the flows and water quality of surface waters flowing in the Avon River and Waukivory Creek that are used for water supply upstream and downstream. From property surveys conducted in 2014 there are no river pump sites known within the immediate vicinity of the Waukivory pilot activities.

6.2.2. Background

With the Waukivory Pilot there is an opportunity to collect important surface water data associated with all the pilot testing activities. The Waukivory Pilot surface water monitoring program provides:

- a better understanding of the surface water flows and water quality in the adjacent streams;
- 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 surface water receptors; and
- certainty regarding the effective storage of flowback water in TED and produced water in TED/TND.

The monitoring network is primarily designed to:

- evaluate the upstream (both Avon River and Waukivory Creek) and downstream (Avon River) water level and water quality attributes and any associated changes; and
- monitor flowback water and produced water quality once brought to the surface, and to monitor the integrity of temporary storages that may impact surface water resources.

6.3. Water data sets

6.3.1. Water Levels

Pilot Wells

Static water levels cannot be obtained in each gas well until after perforating and after the fracture stimulation and flowback programs 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, pressure transducers are installed 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.

The four gas well locations are shown on **Figure 1**.

Monitoring Bores

There are seven groundwater monitoring bores located adjacent to the four gas wells that comprise the Waukivory pilot. These locations are shown on **Figure 1** and summary details of the groundwater monitoring network are provided in **Appendix A5** – Table A5.1.

Three of the four (original) nested monitoring bores that are located within the area of influence of the pilot testing program are 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 monitoring bores on the floodplain, water level and salinity (EC) dataloggers have been installed. Dataloggers will continue indefinitely in all these bores depending on the status and requirements of the broader GGP.

In addition, the deep monitoring location (WKMB05) has been converted to a water monitoring bore after the fracture stimulation of WK13. It has six monitoring intervals 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 or vibrating wire piezometers (VWPs) installed and these will continue indefinitely at the current data collection rate (one reading every 6 hours).

Stream Gauges

Three surface water locations monitor stream levels. A comparison of these water elevations with the water elevations in each of the nearby groundwater monitoring bores will confirm whether the stream is a gaining or losing stream and whether there is any change to baseflows as a result of the pilot testing activities. Water levels are monitored continuously with one reading every 15 minutes. No stream gauging (and the development of rating curves) to assess flow volumes is proposed at this time.

The three monitoring locations are shown on **Figure 1**. Details of the surface water monitoring network are provided in **Appendix A6**.

Further details regarding the water level attributes of the groundwater and surface water monitoring networks are provided in Sections 6.5 and 6.6 respectively.

6.3.2. Water Quality

Water quality samples taken at each of the pilot wells, monitoring bores and stream gauges are for similar analytical suites depending on the pilot testing activity.

AGL has three primary tiers of water quality monitoring, sampling and reporting. The **Comprehensive suite** is used for important sampling events, although other analytes such at BTEX are monitored at selected sites for certain pilot testing activities. 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 **Intermediate suite** is unlikely to be used for this pilot testing program. The analytical suites listed in **Table 6.1** 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 6.1: Field and laboratory analytical suites

Category	Suites			Parameters [Note 1]	
Physical parameters (field)	Basic	Intermediate	Comprehensive	Electrical Conductivity (EC)	Temperature
				Total dissolved solids (TDS)	Redox potential
				pH	Dissolved oxygen
Physical parameters (lab)				EC	TDS
				pH	Temperature
Major ions				*Cations*	*Anions*
				calcium	chloride
				magnesium	carbonate
				sodium	bicarbonate
				potassium	sulphate
Dissolved metals and minor / trace elements				aluminium	lead
				arsenic	manganese
				barium	mercury
				beryllium	molybdenum
				boron	nickel
				bromide	selenium
				cadmium	strontium (dissolved)
				chromium	uranium
				cobalt	vanadium
				copper	zinc
				iron	
Other analytes				Fluoride	Silica
				Total organic carbon	Free and Residual Chlorine
Total Suspended Solids				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 MEA and THPS) were analysed for in fracture stimulation fluids, flowback waters and produced water at each of the gas wells, AST 2 and selected water monitoring sites.

The field parameters for each water sampling event are pH, salinity (EC), redox (eH), dissolved oxygen and temperature.

Further details regarding the water quality attributes of the groundwater and surface water monitoring networks are provided in Sections 6.5 and 6.6 respectively.

6.3.2.1. Sampling and Monitoring Methodology for Fracture Stimulation Additives

In the EPL licence conditions the fracture stimulation additives, are listed with concentration limits for monitoring at the Waukivory (adjacent) monitoring bore locations, private bore locations, surface water monitoring locations, and the four gas wells. These compounds are:

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

The final components of the fracture stimulation fluids used for the Waukivory fracture stimulation program did not include the bactericide sodium hypochlorite. Even though no BTEX compounds were used in the fracture stimulation program they may occur naturally in the coal seams, so these compounds have been included in the key analytical suite.

Standard analysis methods exist for BTEX and sodium hypochlorite. New approved methods were required for THPS and monoethanolamine (MEA). A method to monitor MEAB (as MEA) was prepared and approved by EPA while a new method was developed for THPS and was accepted by the EPA in early December 2014.

Most of the compounds (except THPS) and their elemental constituents occur naturally in the environment (either in surface water or groundwater). AGL reported detections of MEA, THPS and sodium hypochlorite in waters before, during and after the fracture stimulation program. Investigations have concluded and these detections have been assessed as not related to the Waukivory Pilot and consequently a review of the EPL conditions is under way.

AGL is currently monitoring the fracture stimulation additives (and sodium hypochlorite) at the nominated sites in accordance with the monitoring frequencies defined in the EPL.

BTEX is being monitored in accordance with this SGMP.

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. Composite water quality in AST 2 is also monitored.

To address community concerns, concentrations of the fracture stimulation additives were also assessed at the surface water and groundwater monitoring sites during and immediately after the fracture stimulation program but there is no ongoing monitoring for fracture stimulation additives as part of the flowback and produced water pumping phases.

6.3.2.2. Trigger Levels

For the Waukivory pilot activities, trigger levels for BTEX compounds and hydrogen sulphide in flowback water have been developed (**Table 6.2**). These trigger levels are derived from an assessment of the latest site water quality data, exposure pathways and chronic exposure assuming both human health impacts and environmental impacts to exposed flowback water (EnRisks, 2015). The trigger levels are based on extremely conservative assumptions.

Primary Trigger Levels – Protection of Human Health - Vapour Inhalation

Summary: These trigger levels are based on a worker being present 30 metres downwind from AST2 for 8 hours per day for 240 days of the year. Criteria that are protective of exposures by the closest resident (where it is assumed they live in their home 24 hours of the day for 365 days of the year, and the wind always blows from the AST to the home) are higher than calculated for the worker.

Detail: For volatile chemicals that may be present in flowback water there is the potential for these to volatilise from the surface of AST 2 or TED (as neither of these storages are covered) and be present in air in areas where workers are present or subsequently disperse downwind to residential homes. The development of trigger levels relevant to this pathway has focused on AST 2 due to the following:

- flowback water will enter and be stored at AST 2 first, prior to being pumped to the dam. Volatilisation that occurs at AST 2 will lower the concentrations over time resulting in lower concentrations in flowback water that is transferred to the dam; and
- residents are located closer to AST 2 than the dam and hence the potential for exposure to volatiles in the air will be greater.

The assessment of potential vapour inhalation exposures has been undertaken by calculating an air concentration in the workzone close to the AST (30m from the tank) as well as at the closest residential home (490m from the AST) based on the presence of volatile chemicals being present at 1000 µg/L (assumed value for the calculation only). An exposure concentration is then calculated for residents (assumed to be the same as the modelled concentration as it is assumed residents are home all day, every day) and workers (based on them being present 30m from the AST for 8 hours per day for 240 days per year). The exposure concentration is then compared with an appropriate health based guideline (in air). From this comparison a back-calculated water concentration is derived such that the exposure concentration equals the health based guideline.

The above assessment has assumed that flowback water is stored at either the AST or TED for at least 1 year, where long-term chronic exposures may then occur. The calculation does not account for mass loss of volatile chemicals from the water over time, nor degradation of the chemicals in water.

The worst-case concentration is representative of the maximum concentration that may occur under the worst atmospheric dispersion conditions (i.e. when the weather is such that emissions from the tank are not well mixed in ambient air, but may drift downwind to the assessed receptors without much mixing/dilution).

Based on the worst-case 1-hour average concentration, a longer duration average of 1 year has been estimated using a default conversion factor of 0.08 (1-hour to annual average). This has been used to calculate a chronic annual average concentration for evaluating exposures.

The predicted air concentrations at the receptor locations evaluated have then been compared against public health guidelines relevant for long-term chronic exposures (annual average). These health based guidelines are based on the protection of health for all members of the public including infants, children, elderly and those with pre-existing health conditions.

The calculated primary triggers levels for BTEX and hydrogen sulphide are provided in **Table 6.2.**

Primary Trigger Levels – Protection of Human Health - Direct Contact

Summary: These trigger levels are based on a worker coming into direct contact with flowback water for 5 days of the year where they do not follow strict site protocols so they

may have some dermal contact with the water and ingest (drink) 5 mL (1 teaspoon) of water each day.

Detail: There is no mechanism by which the general public could come into direct contact with flowback water in the AST or Tiedmans Dams. Workers, however may come into direct contact with flowback water during the maintenance of the AST or dam infrastructure. Such contact will be incidental only as workers have protocols to follow that outline procedures to follow in the event that they need to work with or come into contact with flowback water. Such measures are expected to effectively eliminate exposures to flowback water, however for the purpose of the EnRisk assessment some incidental contact was assumed.

For the purpose of establishing levels in water that are protective of an incidental contact, a simple approach was adopted where the drinking water guidelines have been modified to more specifically address incidental exposure. This approach is consistent with the approach outlined by the NHMRC (NHMRC 2008) for developing recreational water guidelines based on drinking water guidelines. Drinking water guidelines are derived on the assumption water is ingested at a rate of 2L per day, every day for a lifetime and that intakes of the chemical from drinking water accounts for 10%-20% of the allowable (health based) intake. For evaluating incidental exposures by workers it is assumed that they may incidentally ingest 5 mL per day (1 teaspoon) over 5 separate events during the year or work period.

Based on this approach an incidental direct contact guideline can be calculated that is 29,200 times higher than the drinking water guideline (see **Table 6.2**).

Human health (ingestion) trigger levels have not been considered because flowback water, produced water, local surface water and groundwater are not used as a raw water source for drinking purposes. Even though the Avon River is a minor tributary to the Manning River which (further downstream) is a drinking water catchment, the local and downstream dilution factors are so great that consideration of this exposure pathway is not warranted.

Primary Trigger Levels – Protection of Freshwater Ecosystems

Summary: These triggers are based on an assumption that there is a catastrophic leak from the AST and all of the flowback water spills onto the ground, soaks into the ground and migrates downwards to the underlying alluvial aquifer, mixes and migrates with groundwater and groundwater interacts with and discharges into the closest river/creek located 200m away. The dilution that occurs during all of these processes have been selected to be conservative (i.e. underestimate the level of dilution likely to occur). During this process it is assumed that none of the chemicals in flowback water adsorb to soil (in the dry or wet soil zones) and none of the chemicals biodegrade. It is also assumed that the freshwater ecosystem is exposed to groundwater discharging in the environment for a long period of time (at least a year) which is highly unlikely to occur from a single spill event.

Detail: The scenario considered for developing trigger levels that are based on the protection of aquatic ecosystems is a hypothetical scenario only. The scenario is outlined below:

- a major spill/leak from the AST results in a large quantity of flowback water (up to 1.5ML which is whole contents of the AST including the freeboard volume) flowing over the ground surface near the AST and all of the water then soaking into the ground;
- this water migrates downwards through the overlying soil to the underlying alluvial aquifer and mixes with the aquifer;
- these impacts migrate downgradient in the aquifer; and

- the groundwater then discharges into the aquatic environment in the river.

The above assumes that there is no adsorption and no degradation occurs at all. This is not the case as many chemicals adsorb to soil and readily biodegrade in the environment (in soil and/or groundwater).

Based on these conservative factors, a total dilution factor of 20,000 has been used to determine the primary trigger levels for freshwater ecosystems. These levels are provided in **Table 6.2**.

Adopted Trigger Levels for Review of Flowback Water

Based on these primary triggers levels for human health exposure and the environment, AGL has adopted a two level approach if these key compounds are detected in flowback water. Remedial action will only be triggered if concentrations reach the lowest of the primary trigger levels in **Table 6.2**. Investigation levels will be a conservative 10% of the proposed action levels. The two action levels are:

- **Action level:** being the lesser of the primary trigger levels for impacts to human health (vapour), human health (direct contact) and aquatic ecosystems.
- **Investigation level:** being a conservative 10% of the action level.

Table 6.2: Adopted Thresholds for Dissolved Analytes in Water

		Primary Trigger Levels			AGL Adopted Thresholds for Action	
Analyte	**Units**	**Human Health - Vapour**	**Human Health – Direct contact**	**Aquatic Ecosystems**	**Investigate**	**Action**
Benzene	µg/L	19,000	29,000	19,000,000	1,900	19,000
Toluene	µg/L	55,000,000	23,000,000	3,600,000	360,000	3,600,000
Ethyl Benzene	µg/L	2,900,000	8,800,000	1,600,000	160,000	1,600,000
Xylenes	µg/L	9,600,000	18,000,000	1,500,000	150,000	1,500,000
Hydrogen Sulphide	µg/L	150,000	1,500,000	20,000	2,000	20,000

Key: After EnRisks (2015)

6.3.3. Water Volumes

The final raw water volumes used for the Waukivory Pilot fracture stimulation program were around 3.2 ML with the total injected water volumes approximately 3.6 ML.

Water for Fracture Stimulation and Work overs

Water was sourced from AGL's Pontilands Dam off Fairbairns Lane for the fracture stimulation program. AGL has a water access licence (WAL) and a works and use approval to pump water from this dam and to take water for 'stock, irrigation and industrial' purposes.

Limited work over activities have been completed on the wells to date but small quantities of water are expected to be taken from both the Pontilands Dam and the Tiedman North dam during the pilot testing program.

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 pumped from the ASTs at WK13 to TED for temporary storage and then transported offsite (as flowback water) and pumped to TED/TND (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. The flowback water volume to be pumped and temporarily stored in TED is expected to be 3 to 3.5 ML (given that a volume of 0.42 ML has already been lawfully disposed offsite). Maximum produced water volumes delivered to the Tiedman dams (TED and TND) are expected to be 15 ML, and most likely (depending on length of test) to be less than 10 ML. There is sufficient capacity in each of these dams to temporarily store these volumes.

6.4. Response trigger process

6.4.1. Water level response triggers

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

The adopted trigger is 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, or more than 5 m (outside of the normal range) for deeper (non-coal) monitoring zones. It is expected that at least three months of reliable water level data would be required to have confidence in any unusual water level trend.

Should groundwater water level declines be greater than these triggers at a particular monitoring point, the assessment and notification procedure described in **Table 6.3** would be followed.

AGL's Senior Hydrogeologist is responsible for actioning the required investigations and responses. Note that these actions mostly relate to shallow (beneficial) water resources and aquifers. Aquifers in this SGMP are restricted to the alluvial and shallow fractured rock groundwater systems as deeper zones are deemed to be water bearing zones and are non-aquifers.

For water level trends at monitoring sites, responses are classified as:

No action: if the groundwater level decline is less than 2m outside of the normal seasonal range in an aquifer less than 75 m from surface, or less than 5 m (outside of the normal seasonal range) for deeper (non-coal) monitoring zones

Investigation level: if the groundwater level decline is 1-49% above the adopted trigger

Action level: if the groundwater level decline is more than 50% above the adopted trigger

Table 6.3: Proposed response protocol for water level declines in aquifers – water monitoring sites

Response Level	Actions / Control Measures	Internal Notification		External Notification	
		Who	When (1)	Who	When (2)
Investigation (desktop)	Check water level data set (same site and adjacent sites)	Environment Manager then Operations Manager and Head of Environment	At 3 months		Not required
	Check integrity of the monitoring bore and data logger	Environment Manager then Operations Manager and Head of Environment	At 3 months		Not required
	Check the climatic conditions and expected trends	Environment Manager then Operations Manager and Head of Environment	At 3 months		Not required
Action (desktop and field)	All of the above plus:				
	Check nearby water use (AGL and private users)	Environment Manager then Operations Manager and Head of Environment	At 3 months	NOW and EPA	At 6 months
	Check nearby and recent drilling activities (water, coal and gas programs)	Environment Manager then Operations Manager and Head of Environment	At 3 months	NOW and EPA	At 6 months

	Check flowback/produced water volumes pumped from gas well/s	Environment Manager then Operations Manager and Head of Environment	At 3 months	NOW and EPA	At 6 months
	Check the integrity of the gas well/s as appropriate	Environment Manager then Operations Manager and Head of Environment	At 3 months	NOW and EPA	At 6 months
	If significant event, develop response plan and brief regulators	Environment Manager then Operations Manager and Head of Environment	At 3 months	NOW and EPA	At 3 months

Notes (1) – the internal notification period of 3 months from the Senior Hydrogeologist to Environment Manager then Operations Manager and Head of Environment is required because no definitive trends are possible within a shorter timeframe

(2) – Longer timeframes are proposed for regulators EXCEPT in the case of a significant event

6.4.2. Water quality response actions

Significant water quality variations at the gas wells could also be an indication of connectivity (although water level changes are considered the primary proof). Changed water quality at shallow groundwater and surface water locations could also be an indication of impacts, either from CSG activities or other nearby anthropogenic activities.

However, the more likely exposure pathway for water quality changes is at the open infrastructure sites (i.e. AST1; AST2, TED, BT1, and BT2). The ASTs are the first possible exposure pathway as they are closest to each of the wells generating the flowback water or produced water.

Should concentrations be greater than these triggers at one of the ASTs, the assessment and notification procedure outlined in **Figure 6** and described in **Table 6.4** would be followed.

AGL's Senior Hydrogeologist is responsible for the response action process.

For water quality analytes at infrastructure sites, responses are classified as:

No action: if the dissolved concentration is at or less than the adopted thresholds for action (as shown in **Table 6.2**)

Investigation level: when the dissolved concentration is 10% of the action level which is based on the lesser of the primary trigger levels for human health (vapour), human health (direct contact), and aquatic ecosystems (as shown in **Table 6.2**)

Action level: when the dissolved concentration is at or above the adopted levels for human health (vapour), human health (direct contact), and aquatic ecosystems (as shown in **Table 6.2**)

Table 6.4: Proposed response protocol for water quality exceedances –water infrastructure sites

Response Level	Actions / Control Measures	Internal Notification		External Notification	
		Who	When	Who	When
Investigation (desktop)	Check water quality data set (same site and adjacent sites)	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA and OCSG (info only)	Within 48 hours
	Check integrity of the sampling location and sampling procedures	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA and OCSG (info only)	Within 48 hours
	Check the climatic conditions and expected trends	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA and OCSG (info only)	Within 48 hours
Action (desktop and field)	All of the above plus:				
	Repeat water sampling	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA, OCSG and NOW	Within 24 hours
	Check flowback/produced water volumes pumped from gas well/s	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA, OCSG and NOW	Within 24 hours
	Check the integrity of the gas well/s, tanks, dams, pipes as appropriate	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA, OCSG and NOW	Within 24 hours
	After notification, work with EPA, OCSG and NOW to gather data and determine	Environment Manager then Operations Manager and	On receipt	EPA, OCSG and NOW	Start process within 24 hours

	appropriate response plan	Head of Environment			
	If significantly above the adopted threshold, suspend pumping from gas well (if the exceedance was at a well)	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA, OCSG and NOW	Depends on response plan
	If significantly above the adopted threshold, decant water out of AST or BT and return/pump water to TED (if the exceedance was at a tank)	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA, OCSG and NOW	Within 24 hours
	If dam liner is compromised, pump water to more secure storage, and repair liner	Environment Manager then Operations Manager and Head of Environment	On receipt	EPA, OCSG and NOW	Within 24 hours

6.5. Groundwater monitoring network

The groundwater monitoring network, attributes and frequencies for the flowback water and produced water phases of the pilot testing program are provided in **Table 6.5**. All these locations are dedicated AGL monitoring sites except for monitoring bore GR-P3 and some of the more remote locations (these are part of Gloucester Resources monitoring network). The primary purpose of each of these locations and their constructions details are provided in **Appendix A5**. The monitoring activities completed during the baseline assessment and fracture stimulation programs are provided in earlier versions of this SGMP.

Table 6.5: Groundwater Monitoring Network – Flowback water and Produced water phases

Groundwater Location	Water Levels	Frequency	Listed in EPL	Water Quality	Frequency	Analytical Suite	Listed in EPL
Adjacent Locations							
WKMB01	Yes	Continuous (6 hourly)	Yes	Yes	• one sampling event within 4 weeks of cessation of the pilot	• comprehensive • isotopes	No
WKMB02	Yes	Continuous (6 hourly)	Yes	Yes	• one sampling event within 4 weeks of cessation of the pilot	• comprehensive • isotopes	No
WKMB03	Yes	Continuous (6 hourly)	Yes	Yes	• one sampling event within 4 weeks of cessation of the pilot	• comprehensive • isotopes	No
WKMB05	Yes	Continuous (6 hourly)	Yes	Yes	• one sampling event within 4 weeks of cessation of the pilot	• comprehensive • isotopes	No
WKMB06a/WKMB06b	Yes	Continuous (6 hourly)	No (1)	Yes	• one sampling event within 4 weeks of cessation of the pilot • continuous salinity loggers (6 hourly) at each site	• comprehensive • isotopes (for loggers) • electrical conductivity (EC) • temperature	No
GR-P3	Yes	Continuous (6 hourly)	Yes	Yes	• one sampling event within 4 weeks of cessation of the pilot	• Comprehensive plus isotopes	No
GW080487	No	na	No	No	na	na	No

Key: (1) these may be included in the EPL by the EPA - to be confirmed

Groundwater Location	Water Levels	Frequency	Listed in EPL	Water Quality	Frequency	Analytical Suite	Listed in EPL
Remote Locations							
WMB01	Yes	Continuous (6 hourly)	No	No	na	na	No
WMB02	Yes	Continuous (6 hourly)	No	No	na	na	No
WMB03	Yes	Continuous (6 hourly)	No	No	na	na	No
WMB04	Yes	Continuous (6 hourly)	No	No	na	na	No
PL03	Yes	Continuous (6 hourly)	Yes	No	na	na	No
GR-P1	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P2	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P4	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P5	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P6	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P6A	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P8	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P8A	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P9	Yes	Continuous (6 hourly)	No	No	na	na	No
GR-P9A	Yes	Continuous (6 hourly)	No	No	na	na	No

While baseline and fracture stimulation monitoring was required for the private water supply bore GW080487, no further monitoring is required under the EPL and AGL is not proposing any additional monitoring as part of this SGMP.

6.5.1. Trigger Action Response Plan (TARP)

The groundwater management responses arising from water level and water quality data trends from the groundwater monitoring network will be determined in accordance with the actions and control measures described in **Tables 6.3 and 6.4** (and summarised in **Table 6.6**).

The primary risks are:

- depressurisation may induce changes to local (shallow) groundwater water levels;
- depressurisation may induce changes to local (shallow) groundwater quality; and
- depressurisation may reduce water levels or affect water quality in nearby private water bores.

Responses are provided in **Table 6.6**, although a more detailed TARP may be required depending on the severity of any induced changes that are attributable to CSG activities.

Table 6.6: Groundwater Risks and associated actions

Risk	Response Level	Responses	Responsibility
1. Depressurisation may induce changes to local (shallow) groundwater water levels	Investigation	• check water level data set (same and adjacent sites) • check integrity of monitoring bore and data logger • check the climatic conditions and expected trends	Senior Hydrogeologist (with appropriate instructions to technical consultants)
	Action	• check water level data set (same and adjacent sites) • check integrity of monitoring bore and data logger • check the climatic conditions and expected trends • check nearby water use • check nearby and recent drilling activities (water, coal and gas programs) • check flowback/ produced water volumes pumped from gas well/s • check integrity of gas wells • develop response plan and brief regulators • suspend pumping from gas well/s	Senior Hydrogeologist (with appropriate instructions to technical consultants) Operations Manager

Risk	Response Level	Responses	Responsibility
2. Depressurisation may induce changes to local (shallow) groundwater quality	Investigation	• check water quality data set (same and adjacent sites) • check integrity of the sampling location and sampling procedures • check the climatic conditions and expected trends	Senior Hydrogeologist (with appropriate instructions to technical consultants)
	Action	• check water quality data set (same and adjacent sites) • check integrity of the sampling location and sampling procedures • check the climatic conditions and expected trends • repeat water quality sampling • check flowback/ produced water volumes pumped from gas well/s • check the integrity of the gas well/s, tanks dams and pipes • work with EPA, OCSG and NOW to gather data and determine appropriate response plan • suspend pumping from gas well/s	Senior Hydrogeologist (with appropriate instructions to technical consultants) Operations Manager
3. Depressurisation may reduce water levels or affect water quality in nearby private water bores (NOTE there are no known water bores adjacent)	As for #1 and #2	• Firstly confirm that the water level or water quality impact is real and is attributable to CSG flowback or produced water activities • If confirmed as a probable impact proceed as per Risk 1 and 2 above	Senior Hydrogeologist (with appropriate instructions to technical consultants) and Operations Manager

6.6. Surface water monitoring network

The surface water monitoring network, attributes and frequencies for the flowback water and produced water phases of the pilot testing program are provided in **Table 6.7**. All these locations are dedicated AGL monitoring sites. The primary purpose of each of these locations is provided in **Appendix A6**. The monitoring activities completed during the baseline assessment and fracture stimulation programs are provided in earlier versions of this SGMP.

Table 6.7: Surface Water Monitoring Network – Flowback water and Produced water phases

Surface Water Location	Water levels	Frequency	Listed in EPL	Water Quality	Frequency	Analytical Suite	Listed in EPL
Adjacent Locations							
WKSW01	Yes	Continuous (6 hourly)	No	Yes	• one sampling event within 4 weeks of cessation of the pilot • (EPL) one sampling event every 6 months until the cessation of the pilot testing program	• comprehensive plus fracture stimulation additives (MEA, THPS, sodium hypochlorite)	• Yes
					• continuous salinity logger (every 15 minutes)	• EC • temperature	• No *
WKSW02	Yes	Continuous (6 hourly)	No	Yes	• one sampling event within 4 weeks of cessation of the pilot • (EPL) one sampling event every 6 months until the cessation of the pilot testing program	• comprehensive plus fracture stimulation additives (MEA, THPS, sodium hypochlorite)	• Yes
					• continuous salinity logger (every 15 minutes)	• EC • temperature	• No *
WKSW03	Yes	Continuous (6 hourly)	No	Yes	• one sampling event within 4 weeks of cessation of the pilot • (EPL) one sampling event every 6 months until the cessation of the pilot testing program	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite)	• Yes
					• continuous salinity logger (every 15 minutes)	• EC • temperature	• No *

Key: * the salinity data logger requirement and these parameters are not in the EPL;

6.6.1. Trigger Action Response Plan (TARP)

The surface water management responses arising from water level and water quality data trends from the surface water monitoring network will be determined in accordance with the actions and control measures described in **Tables 6.3 and 6.4** (and summarised in **Table 6.8)**.

The primary risks are:

- depressurisation may induce changes to surface water levels and flow;
- depressurisation may induce changes to surface water quality; and
- depressurisation may reduce water levels or affect water quality at pumps on the Avon River.

Responses are provided in **Table 6.8**, although a more detailed TARP may be required depending on the severity of any induced changes that are attributable to CSG activities.

Table 6.8: Surface Water Risks and associated Control Measures

Risk	Response Level	Control Measures	Responsibility
1. Depressurisation may induce changes to local surface water levels and flows	Investigation	• check water level data set (same and adjacent sites) • check integrity of gauging station and data logger • check the climatic conditions and expected trends	Senior Hydrogeologist (with appropriate instructions to technical consultants)
	Action	• check water level data set (same and adjacent sites) • check integrity of gauging station and data logger • check the climatic conditions and expected trends • check nearby water use • check flowback/ produced water volumes pumped from gas well/s • check integrity of gas wells • develop response plan and brief regulators • suspend pumping from gas well/s	Senior Hydrogeologist (with appropriate instructions to technical consultants) Operations Manager
2. Depressurisation may induce changes to surface water quality	Investigation	• check water quality data set (same and adjacent sites) • check integrity of the sampling location and sampling procedures • check the climatic conditions and expected trends	Senior Hydrogeologist (with appropriate instructions to technical consultants)

Risk	Response Level	Control Measures	Responsibility
	Action	• check water quality data set (same and adjacent sites) • check integrity of the sampling location and sampling procedures • check the climatic conditions and expected trends • repeat water quality sampling • check flowback/ produced water volumes pumped from gas well/s • check the integrity of the gas well/s, tanks dams and pipes • work with EPA, OCSG and NOW to gather data and determine appropriate response plan • suspend pumping from gas well/s	Senior Hydrogeologist (with appropriate instructions to technical consultants) Operations Manager
3. Depressurisation may reduce water levels or affect water quality at pumps sites on the Avon River (NOTE that there are no known pump sites)	As for #1 and #2	• Firstly confirm that the water level or water quality impact is real and is attributable to CSG flowback or produced water activities • If confirmed as a probable impact proceed as per Risk 1 and 2 above	Senior Hydrogeologist (with appropriate instructions to technical consultants) and Operations Manager

6.7. Flowback water monitoring

As proposed in the REF variation to temporarily transfer flowback to TED, the monitoring requirements for flowback water have been expanded. The monitoring network, attributes and frequencies for the flowback water phase of the pilot testing program are provided in **Table 6.9**. The water sampling procedure for the taking of water samples from the gas wells and the AST is provided in AGL, 2015d.

The proposed risks and control measures for the water infrastructure that is used to transfer and store flowback water are provided in Table 5.1 of the Produced Water Management Plan (PWMP) (AGL, 2015e) and are not reproduced in this SGMP. Only the water monitoring locations and the analytical suite are provided in this SGMP.

Table 6.9: Flowback Water Monitoring Network

Flowback Water Location	Water levels	Frequency	Listed in EPL	Water Quality	Frequency	Analytical Suite	Listed in EPL
WK11	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every fortnight for 8 weeks from the commencement of the pilot (i.e. start of the flowback period)	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite) • BTEX daily for the initial 4 weeks.	Yes
WK12	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every fortnight for 8 weeks from the commencement of the pilot (i.e. start of the flowback period)	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite) • BTEX daily for the initial 4 weeks.	Yes
WK13	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every fortnight for 8 weeks from the commencement of the pilot (i.e. start of the flowback period)	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite) • BTEX daily for the initial 4 weeks.	Yes
WK14	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every fortnight for 8 weeks from the commencement of the pilot (i.e. start of the flowback period)	• Comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite) • BTEX daily for the initial 4 weeks.	Yes
AST 2	No	na	No	Yes	• Every fortnight for 8 weeks from the commencement of the pilot (i.e. start of the flowback period)	• Comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite) • BTEX daily for the initial 4 weeks • Hydrogen sulphide daily for the initial 4 weeks.	No (1)

Flowback Water Location	Water levels	Frequency	Listed in EPL	Water Quality	Frequency	Analytical Suite	Listed in EPL
TED	No	na	No	Yes	• Every month for 8 weeks from the commencement of the pilot (start of the flowback period) • Continuous salinity logger (every 15 minutes) *	• Basic suite • BTEX • Electrical conductivity (EC) and temperature	No(1) No
TED Inspection Sump	Yes	Weekly	No	Yes	• Weekly from the commencement of the pilot (i.e. start of the flowback period)	• Field parameters (pH and EC)	No(1)
TED Inspection Sump	Yes	na	No	Yes	• Every month for 8 weeks from the commencement of the pilot (i.e. start of the flowback period)	• Basic suite • BTEX	No(1)
BT 1	No	na	No	Yes	• Batch sampling as required	• Developed in consultation with off site waste facility	No
BT 2	No	na	No	Yes	• Batch sampling as required	• Developed in consultation with off site waste facility	No

Key: * this is the logger that was previously in TSD for the Tiedman Irrigation Program;

(1) these may be included in the EPL by the EPA - to be confirmed

6.8. Produced water monitoring

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.

The monitoring requirements for produced water have been expanded under the April REF variation to temporarily transfer flowback to TED and the decision not to continue with the Tiedman Irrigation Program. The monitoring network, attributes and frequencies for the produced water phase of the pilot testing program is provided in **Table 6.10**. The water sampling procedure for the taking water samples from the gas wells and the AST is provided in AGL, 2015d.

The proposed risks and control measures for the water infrastructure that is used to transfer and store produced water are provided in Table 4.2 of the Produced Water Management Plan (PWMP) (AGL, 2015e) and are not reproduced in this SGMP. Only the water monitoring locations and the analytical suite are provided in this SGMP.

Table 6.10: Produced Water Monitoring Network

Produced Water Location	Water levels	Frequency	Listed in EPL	Water Quality	Frequency	Analytical Suite	Listed in EPL
WK11	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every two months until the cessation of the pilot testing program.	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite).	Yes
WK12	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every two months until the cessation of the pilot testing program.	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite).	Yes
WK13	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every two months until the cessation of the pilot testing program.	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite).	Yes
WK14	Yes	Continuous (6 hourly)	Yes	Yes	• (EPL) Every two months until the cessation of the pilot testing program.	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite).	Yes
AST 1	No	na	No	Yes	• (EPL) Every two months until the cessation of the pilot testing program.	• comprehensive • fracture stimulation additives (MEA, THPS, sodium hypochlorite).	No(1)
TED	No	na	No	Yes	• Every month from the commencement of the pilot (i.e. start of the flowback period) • Continuous salinity logger (every 15 minutes) *	• Basic • BTEX • EC • temperature	No(1) No
TED	No	na	No	Yes	• Quarterly until the cessation of the pilot testing program	• comprehensive	No(1)

Key: * this is the logger that was previously in TSD for the Tiedman Irrigation Program

Produced Water Location	Water levels	Frequency	Listed in EPL	Water Quality	Frequency	Analytical Suite	Listed in EPL
TED Inspection Sump	Yes	Weekly	No	Yes	• Weekly from the commencement of the pilot (i.e. start of the flowback period)	• field parameters (pH and EC)	No(1)
TED Inspection Sump	Yes	na	No	Yes	• Every month for 8 weeks from the commencement of the pilot (i.e. start of the flowback period)	• basic • BTEX	No(1)
TED Inspection Sump	Yes	na	No	Yes	• Quarterly until the cessation of the pilot testing program	• comprehensive	No(1)
TND	No	na	No	Yes	• Quarterly until the cessation of the pilot testing program	• comprehensive	No
TMB04	Yes	Continuous (6 hourly)	Yes	Yes	• Quarterly until the cessation of the pilot testing program (if inflow within 12 hours of purging dry)	• comprehensive	Yes
TMB05	Yes	Continuous (6 hourly)	Yes	Yes	• Quarterly until the cessation of the pilot testing program (if inflow within 12 hours of purging dry	• comprehensive	Yes

Key: * this is the logger that was previously in TSD for the Tiedman Irrigation Program;

(1) these may be included in the EPL by the EPA - to be confirmed

6.9. Water volume monitoring

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 depressurisation activities.

The risks and actions are aligned with those for water level drawdowns. 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.

Investigation approaches would be discussed and agreed with EPA, OCSG and NOW as required.

6.10. Operational Management Responses

Operational management control measures and responses involving the management of flowback water and produced water are dealt with in Sections 4 and 5 of the PWMP (AGL, 2015e). A summary of the important control measures is presented here.

The flowback and produced water dams on Tiedmans (TED and TND) are not located in flood prone areas. Most of the contained water is pumped to the turkey nest dams with only a very small proportion of rainfall directly falling on each of the dams.

The water gathering lines are poly pipe, buried and are located below both flood prone and non-flood prone areas. Pipe has been pressure tested, with joins and pipe sections inspected for leaks. Meters are installed at both ends of the pipeline 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 pipeline route is inspected on a regular basis for any damage, intrusion or wet areas.

The 1.5 ML on-site ASTs at WK13 are open topped, double lined with leak detection in between liners, alarmed, anchored, and are 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 (AST 2) will only be a temporary tank constructed and used for approximately three to six months while flowback of the fracture stimulation water occurs and offsite disposal is required. Pumping to this tank and continuous offsite disposal of fluids to the temporary holding dam TED will ensure that there is at least a 500 mm freeboard maintained at this tank. Water for disposal at the approved offsite facility will be from a load area and smaller ASTs located adjacent to TED. The flowback water tank will be dismantled and taken away after use.

The second 1.5 ML storage tank (AST 1) 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 the produced water flow rate is low enough for either an alternate (smaller) tank to be installed or piped 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 associated pipelines and connections.

Full details regarding the site infrastructure inspections and water management protocols required to manage flowback water and produced water are provided in the PWMP (AGL. 2015e) and the appropriate operating procedures.

7. Records and Reporting

7.1. Records

There are numerous water data sets collected throughout the different phases of pilot testing programs. The Senior Hydrogeologist is responsible for organising the collection, collation, and archival of the different water data sets. For the Waukivory pilot activities:

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

There is 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. This data can be viewed at http://www.agl.com.au/about-agl/how-we-source-energy/natural-gas/water-portal.

Water monitoring data required to be reported under the EPL conditions is available at http://www.agl.com.au/about-agl/how-we-source-energy/monitoring-data .

All interpreted technical reports are available for viewing via the AGL GGP website available at http://www.agl.com.au/gloucester.

7.2. Reporting

Department of Trade and Investment (Division of Resources and Energy) - (Office of Coal Seam Gas)

Quarterly reports will be submitted to the OCSG for all water monitoring points detailed in this SGMP until the Waukivory Pilot Project concludes. The first report (AGL, 2015a) was published on the 27 February 2015. The quarterly reports will include:

- analysis and interpretation of monitoring results including trends; and
- details of any trends requiring specific management and actions to be undertaken.

The first report covers the period from 1 September to 31 December 2014 and includes all baseline data obtained in 2014 prior to the commencement of fracture stimulation activities for the Waukivory Pilot Project. The reporting schedule (showing reports that have been released to date) is provided in **Table 7.1**.

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

Environment Protection Authority

The reporting requirements under the EPL will be published on AGL's website within the nominated timeframes as stipulated in the EPL or in the general reporting requirements for monitoring data. An Annual Return which summarises performance against the EPL requirements is also provided to the EPA in August each year. The reporting schedule (showing reports that have been released to date) is provided in **Table 7.1**.

AGL technical reports

AGL published the first technical report (drilling and completion program) on the Waukivory pilot site in July 2014 (PB, 2014). More in-depth technical data from the 2014 baseline monitoring programs (prior to fracture stimulation) was to be the second technical report. However release of this information coincided with the first quarterly OCSG compliance report so baseline information is included in the OCSG report (PB, 2015).

In addition, data from the pilot testing program will be collated and analysed and the results assessed and written up into a detailed technical report within six months of completion of the pilot test. The investigation results will focus on permeability, water levels, water quality, and environmental/radio-isotope 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 from previous 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.

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 the major sedimentary units, geological and 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.

7.2.1. Summary

The reporting schedule showing reports that have been released to date and those that are proposed is provided in **Table 7.1**.

Table 7.1: Waukivory Pilot data and water technical reporting requirements

Report Type	Regulatory Trigger	Date	Report Reference	Frequency	Responsibility
DRE/OCSG Compliance	REF Approval - for quarter to 31 Dec 14	27 Feb 15	PB, 2015	Quarterly	PB and Senior Hydrogeologist
	REF Approval - for quarter to 31 Mar 15	31 May 15	Not triggered yet	Quarterly	PB and Senior Hydrogeologist

Report Type	Regulatory Trigger	Date	Report Reference	Frequency	Responsibility
	REF Approval - for quarter to 30 Jun 15	31 Aug 15	Not triggered yet	Quarterly	PB and Senior Hydrogeologist
	REF Approval - for quarter to 30 Sep 15	30 Nov 15	Not triggered yet	Quarterly	PB and Senior Hydrogeologist
	REF Approval - for quarter to 31 Dec 15	29 Feb 16	Not triggered yet	Quarterly	PB and Senior Hydrogeologist
EPL Monitoring	EPL 20358	7 Nov14	AGL, 2014c	Within 14 days of data receipt	Senior Hydrogeologist
	EPL 20358	10 Dec 14	AGL, 2014d	Within 14 days of data receipt	Senior Hydrogeologist
	EPL 20358	13 Jan 15	AGL, 2015a	Within 14 days of data receipt	Senior Hydrogeologist
	EPL 20358	20 Jan 15	AGL, 2015b	Within 14 days of data receipt	Senior Hydrogeologist
	EPL 20358	5 Mar 15	AGL, 2015c	Within 14 days of data receipt	Senior Hydrogeologist
	EPL 20358	May to Dec 15	Not triggered yet	At least monthly for subsequent reports	Senior Hydrogeologist
	EPL 20358	Aug 15	Not triggered yet	Annual Report	Senior Hydrogeologist
NOW Compliance	All Gloucester Bore licences	Sep 15	Not triggered yet	Annual Report	Senior Hydrogeologist
	WK Bore Licences	Not defined	(will be the same as AGL completion report)	Data and records of volumes and water quality at completion of the pilot	Senior Hydrogeologist

Report Type	Regulatory Trigger	Date	Report Reference	Frequency	Responsibility
AGL Technical	Drilling and Completion Report (None)	30 Jul 14	PB, 2014	NA	Manager Hydrogeology
	Investigation Report on Completion (None)	May 16	Not triggered yet	Within 6 months of completion	Senior Hydrogeologist

During the ongoing pilot testing program there are two primary reporting processes:

- Public release of all monitoring data is required under the EPL. This data is uploaded within 14 days of receipt. This data is available via the following link: http://www.agl.com.au/about-agl/how-we-source-energy/monitoring-data
- Interpreted technical reports are required under the Waukivory REF approval (SGMP commitment) and are prepared quarterly. The report must be submitted and publicly released within 2 months of the end of the quarterly monitoring period. The first of these reports is available via the following link: http://www.agl.com.au/about-agl/how-we-source-energy/natural-gas/natural-gas-projects/gloucester-gas-project/waukivory-pilot-program

The enhanced monitoring/reporting regime described in the 21 April REF Variation outlined additional commitments and the following monitoring extras:

At the Waukivory site:

- for an initial four week period, daily samples of flowback water will be taken from each well and AST 2. These samples will be analysed for BTEX.

At TED:

- weekly visual check of the liner;
- weekly sample of sump water level and field parameters (ie electrical conductivity);
- monthly (basic as defined in the SGMP) water samples plus BTEX taken from both the dam and the inspection sump during the flowback water pumping period;
- if flowback water is being pumped from AST 2 to TED (ie the contents of TED is 'dynamic') and a third party contractor for lawful offsite disposal of flowback water is available and commercially viable, batches of flowback water will be decanted from the TED into the two enclosed and bunded tanks at Tiedmans for sampling and analysis in advance of lawful offsite disposal.

At TED and the near vicinity:

- characterisation of flowback water prior to lawful offsite disposal to an appropriate destination; and
- quarterly (comprehensive) sampling from the TED during the produced water pumping period; and
- quarterly (comprehensive) sampling of the two seepage monitoring bores (TMB04 and TMB05).

These data will all be included in interpreted quarterly technical reports unless the requirements are also included in the EPL which would mean that the raw data is also included in the EPL 14-day reporting cycle.

Notifications to OCSG

Should offsite lawful disposal of flowback water not be available (or commercially viable) for AGL despite its reasonable efforts, the following trigger/ response mechanisms will be implemented and notifications made to OCSG for the Project:

- **Promptly after each daily sample for first four weeks** – Samples from WK11, 12, 13 and 14 and AST 2 will be taken and analysed for BTEX. BTEX analyses will be provided by the laboratory to AGL within 24 hours (Monday to Friday only excluding public holidays). If requested, an analysis of these results will be promptly provided to OCSG once they have gone through an internal quality control process.
- **Every two weeks -** AGL will provide an updated report to OCSG outlining the reasonable and practicable endeavours to secure a third party contractor for lawful transportation, treatment and disposal of flowback water offsite to a licensed and appropriate facility.
- **Commencement of Stage 1 GGP (up to 22 February 2016) –** If the flowback water has not been transported to an offsite licensed facility for lawful treatment and disposal, then on commencement of Stage 1 GGP, the flowback water will be managed via the approved EWMS.
- **22 February 2016** - If the flowback water has not been transported to an offsite licensed facility for lawful treatment and disposal and Stage 1 GGP has not commenced, AGL commits to a mobile containerised water treatment unit to be located at the Tiedmans site. AGL will apply for all necessary approvals to do so.

8. Review

AGL operates a compliance monitoring system for all its regulatory approvals. Components of this SGMP are uploaded into this system to track and report. In addition, AGL will undertake periodic audits of compliance with the monitoring and reporting commitments in this SGMP.

This SGMP will be valid until the expiry of the Waukivory REF approval and the end of the Waukivory pilot field and reporting program which is likely to be early to mid-2016. There is no formal review date.

Further versions of the plan will be prepared from time to time during 2015 as the work program evolves and there are variations to approvals. Versions will be circulated to regulators, if requested and when there are substantial changes requiring further endorsement from any or all of the three primary regulatory agencies.

10. 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 22 October 2014.

AGL, 2014c, *October 2014 Water Monitoring Report Waukivory Pilot Project: Fracture Stimulation and Flow Test EPL 20358* Report dated 7 November 2014

AGL, 2014d, *November 2014 Water Monitoring Report Waukivory Pilot Project: Fracture Stimulation and Flow Test EPL 20358* Report dated 10 December 2014

AGL, 2015a, *January 2015 Water Monitoring Report Waukivory Pilot Project: Fracture Stimulation and Flow Test EPL 20358* Report dated 13 January 2015

AGL, 2015b, *20 January 2015 Water Monitoring Report including:*

- *Addendum to November 2014 Water Monitoring Report Rev B, 10 December 2014; and*
- *Addendum to January 2015 Water Monitoring Report, 13 January 2015*

Waukivory Pilot Project: Fracture Stimulation and Flow Test EPL 20358 Report dated 20 January 2015

AGL, 2015c, *5 March 2015 Water Monitoring Report Waukivory Pilot Project: Fracture Stimulation and Flow Test EPL 20358* Report dated 5 March 2015

AGL, 2015d, *Procedure for water sampling from pilot gas wells WK11, 12, 13, 14 & above ground flowback water storage tank.* SOP DCS_GN_FM_HSE_020 dated April 2015.

AGL, 2015e, *Produced Water Management Plan for PEL 285 – Gloucester* dated 1 May 2015.

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, *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.

EMGA/Mitchell McLennan, 2015, *Waukivory Pilot Project: Request to vary the approved activity* dated April 2015

EnRisks, 2013, *Flowback Water Trigger Levels – BTEX and H_2S.* Letter report dated 6 May 2015.

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

Parsons Brinckerhoff, 2015, *Waukivory Pilot Project: Surface Water and Groundwater Monitoring Report to 31 December 2014* dated 27 February 2015.

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

Waukivory Gas Wells & Water Monitoring Sites

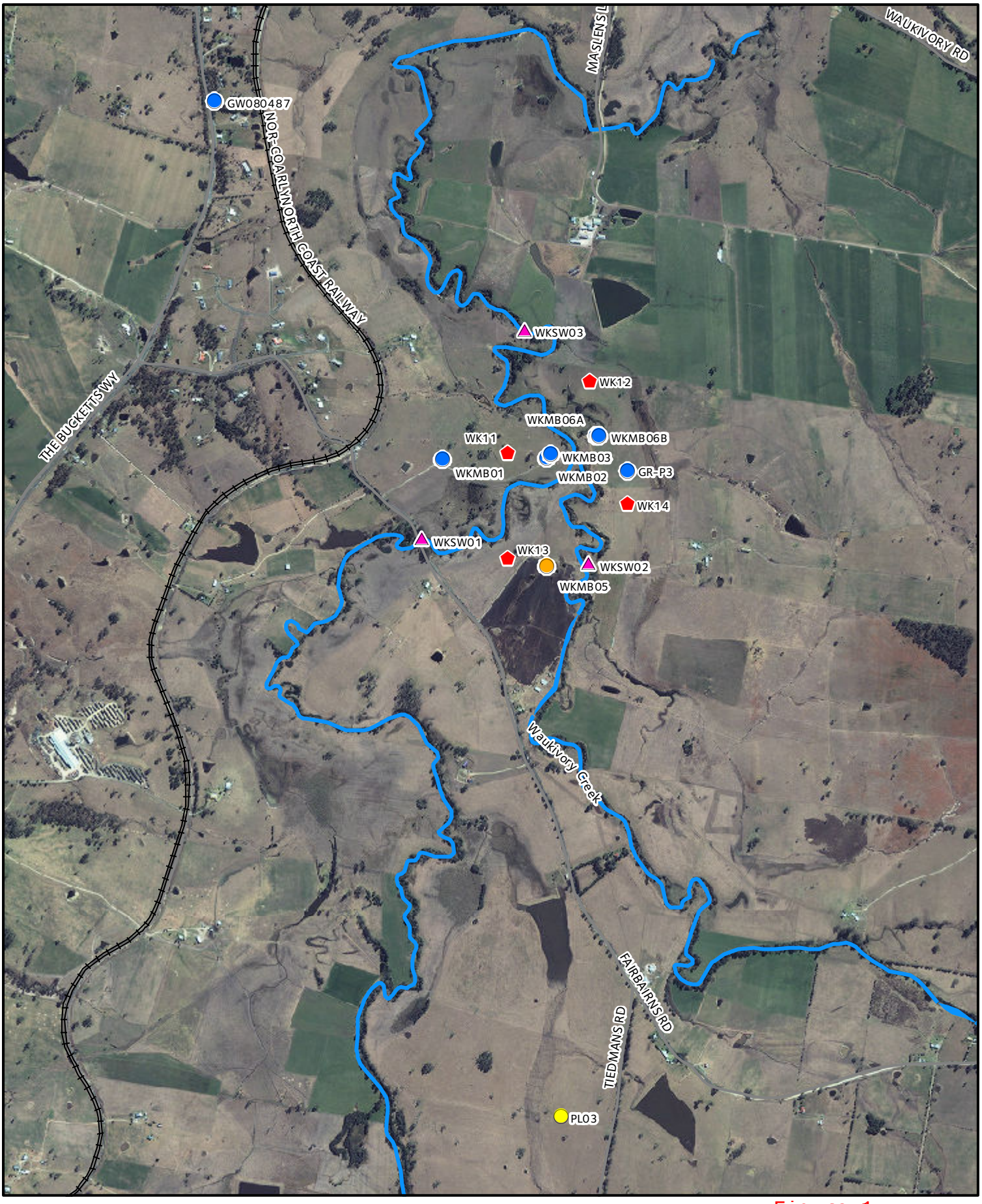


Figure 1

Energy in action.™

AGL

Author:	Upstream Gas
Date:	27-11-2014
Ref:	3191R2

Metres
0 400 800
Scale 1:20,000 @A4

Geocentric Datum of Australia 1994 MGA Zone 56

Legend

- Groundwater monitoring bores
- Surface water monitoring
- Geophone/water monitoring bore
- Vibrating Wire Piezometer
- Waukivory gas well
- Railway Line
- Roads
- Waterbody

N

Sources: AGL Energy Limited, Omnilink PSMA Data, WV2

DRAFT SECTION and LOCATIONS

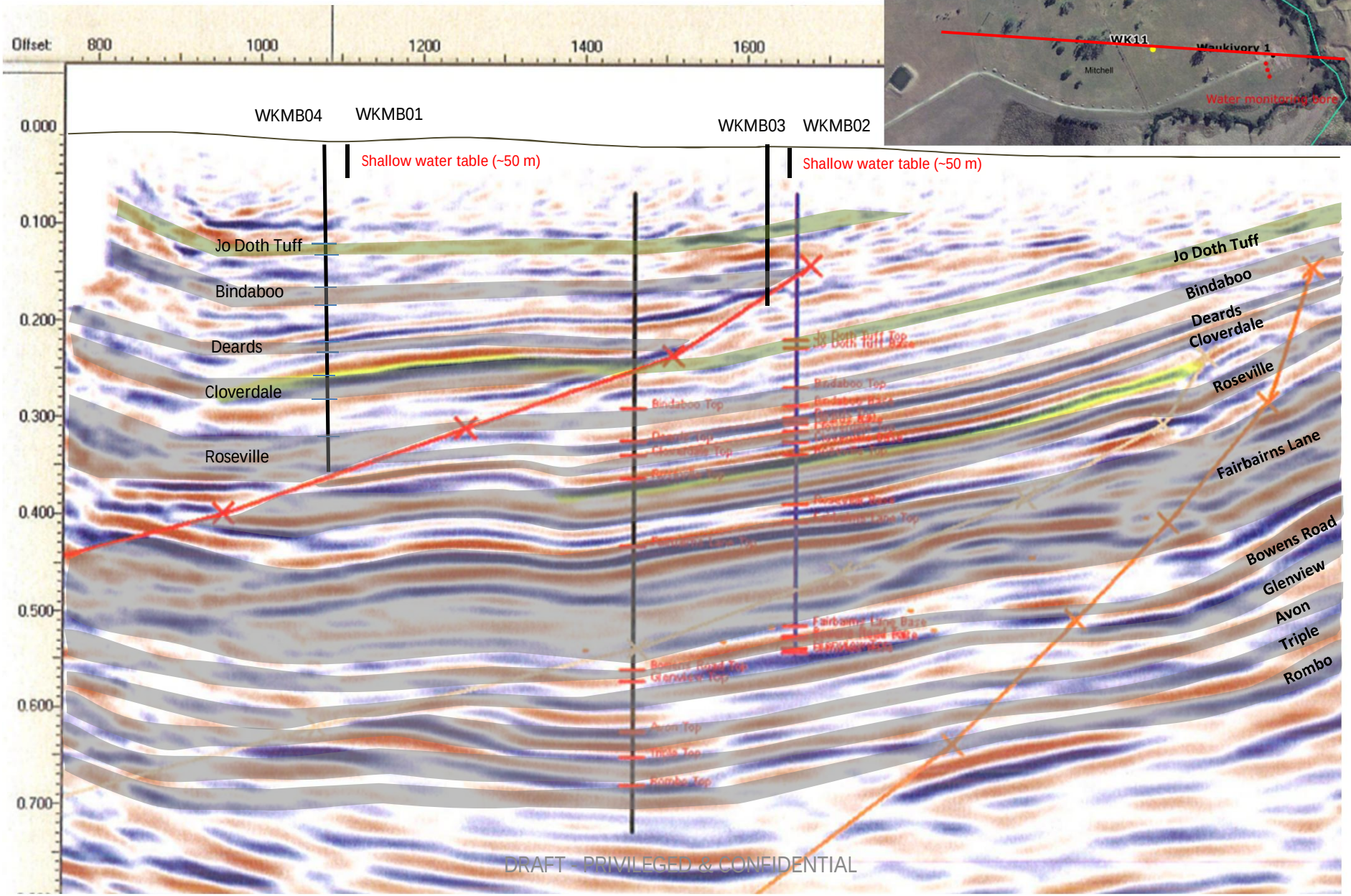
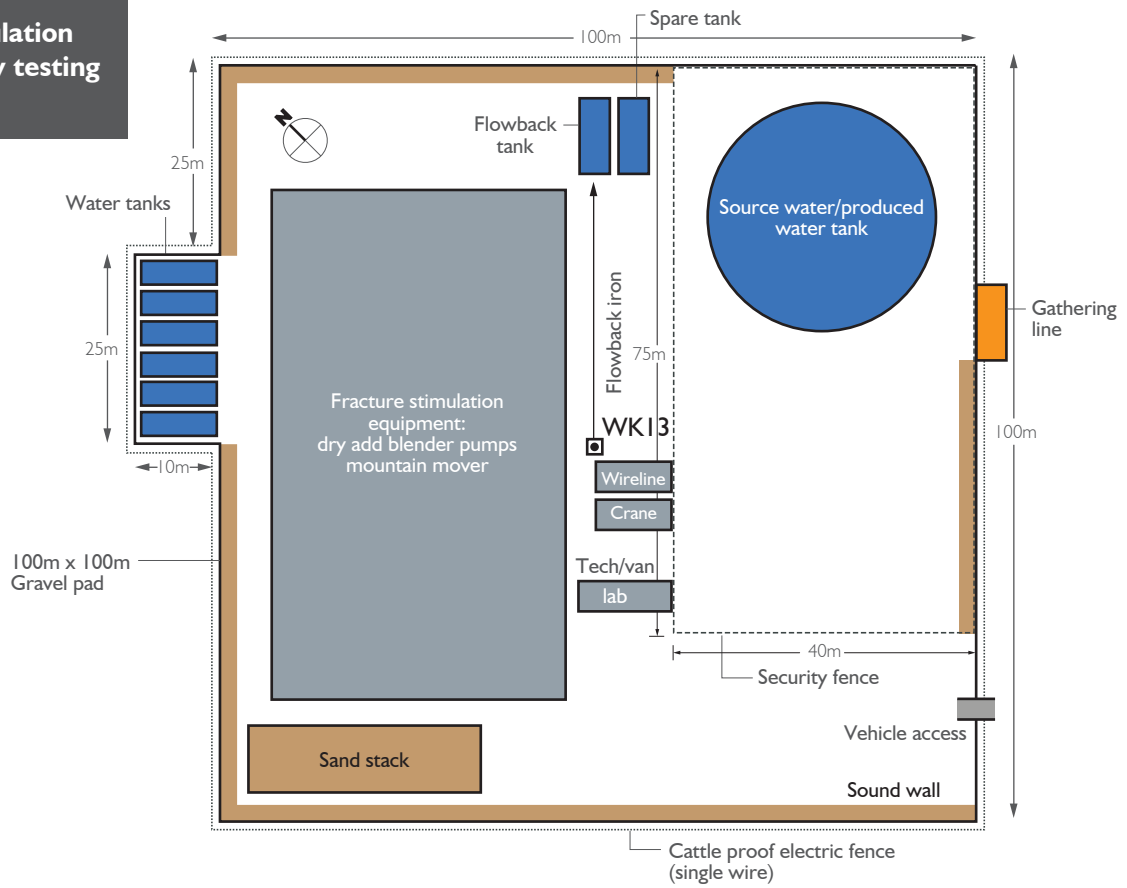
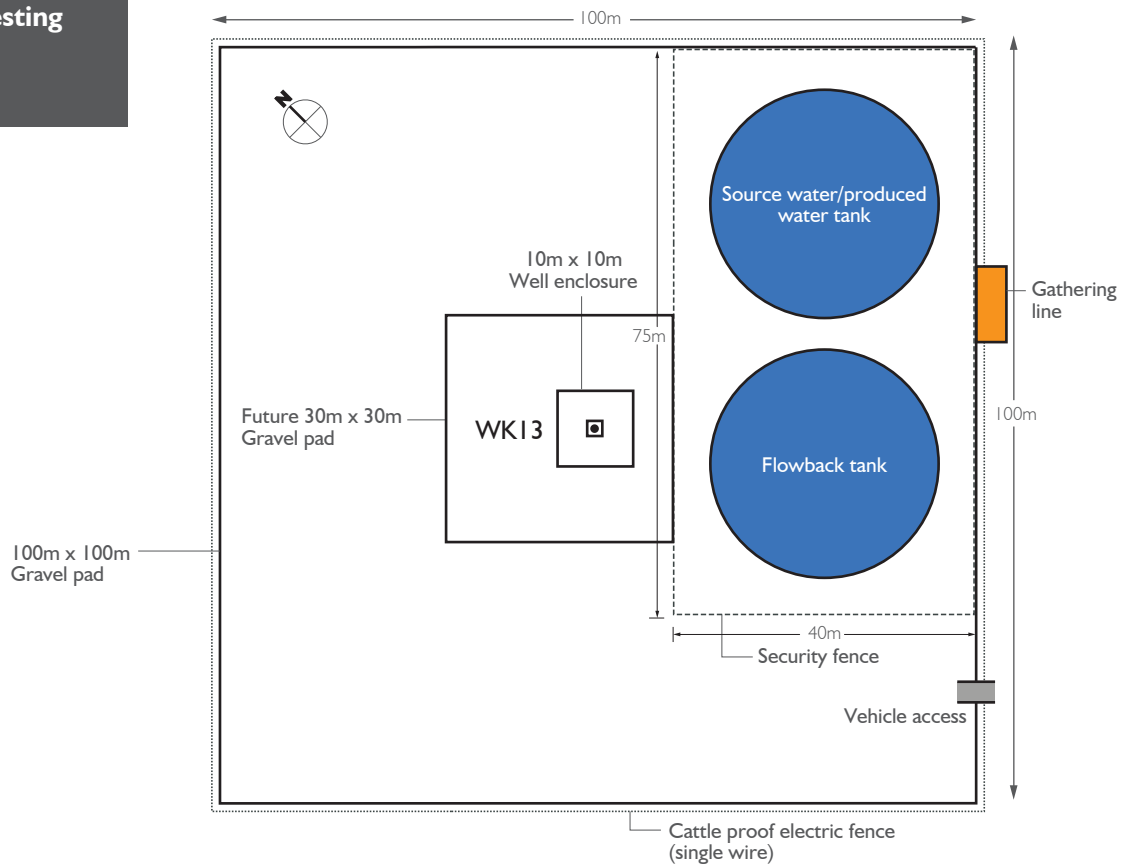


Figure 2

Perforation, fracture stimulation and initial flow testing phase



Production testing phase



EMM
EMGA Mitchell McLennan

WK13 conceptual site layout
Proposed change to the preferred activity
Waukivory Pilot Project

Figure 3

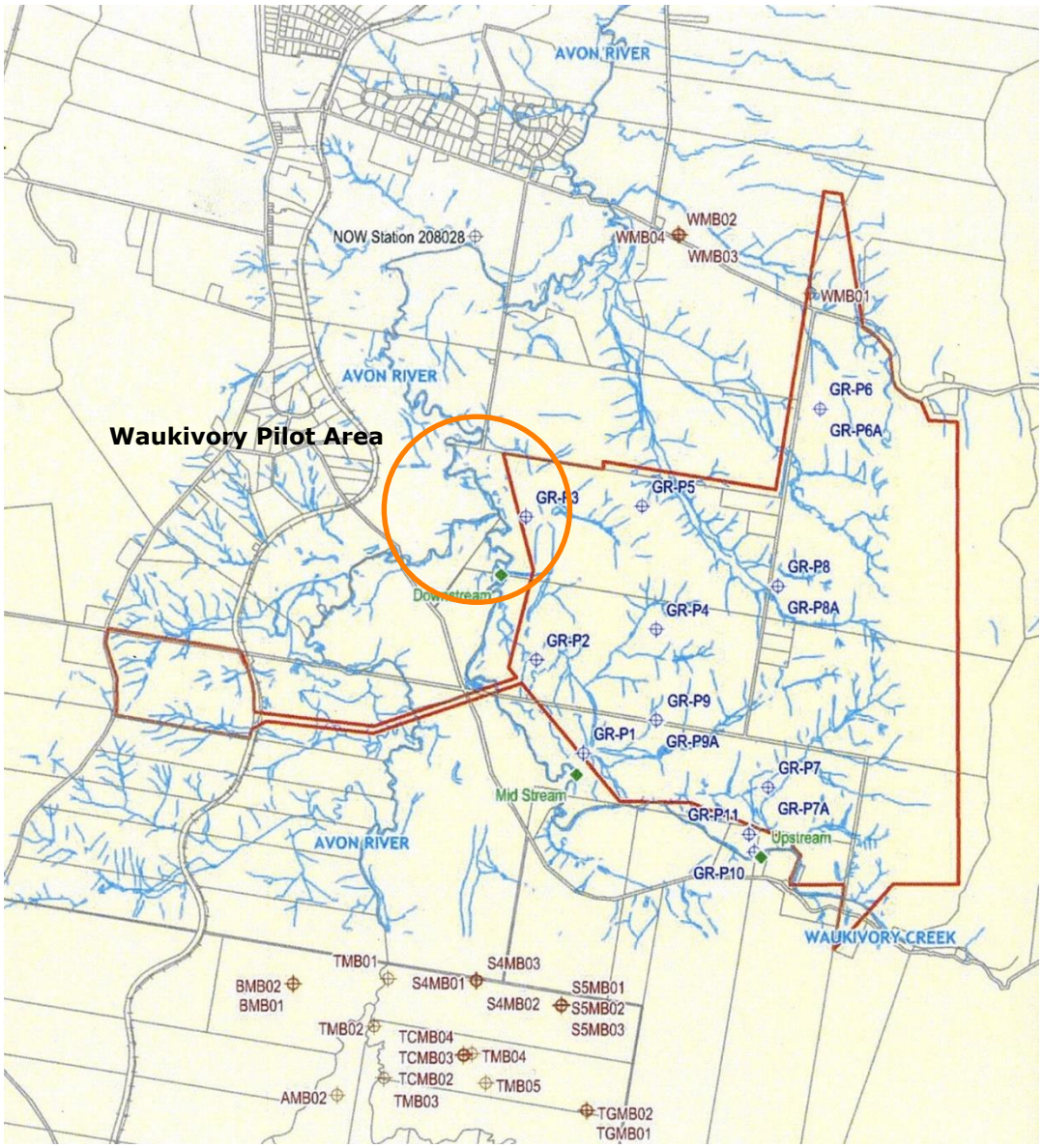


Figure 4: Groundwater Monitoring Bores (AGL and GRL Remote Sites)

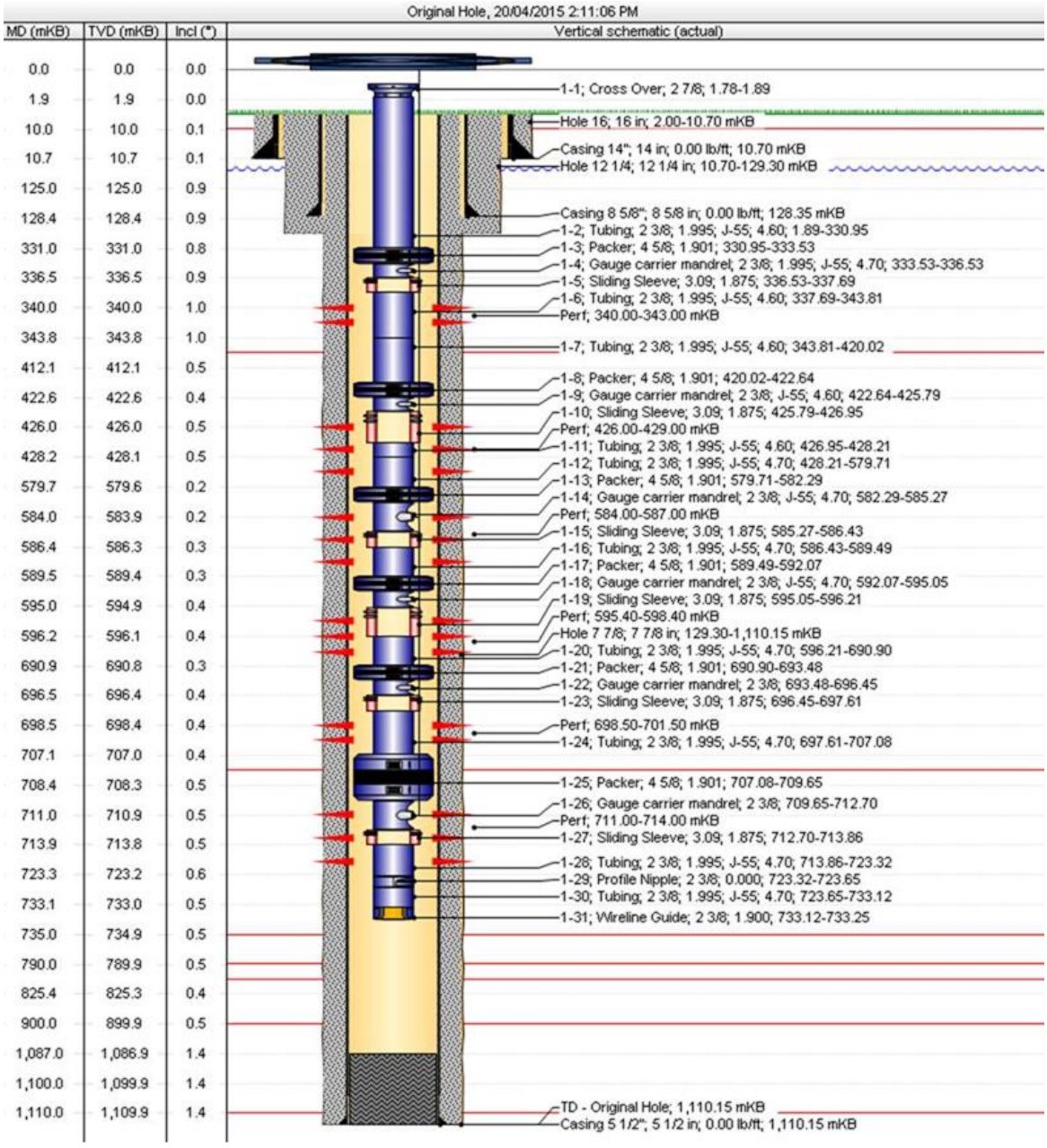
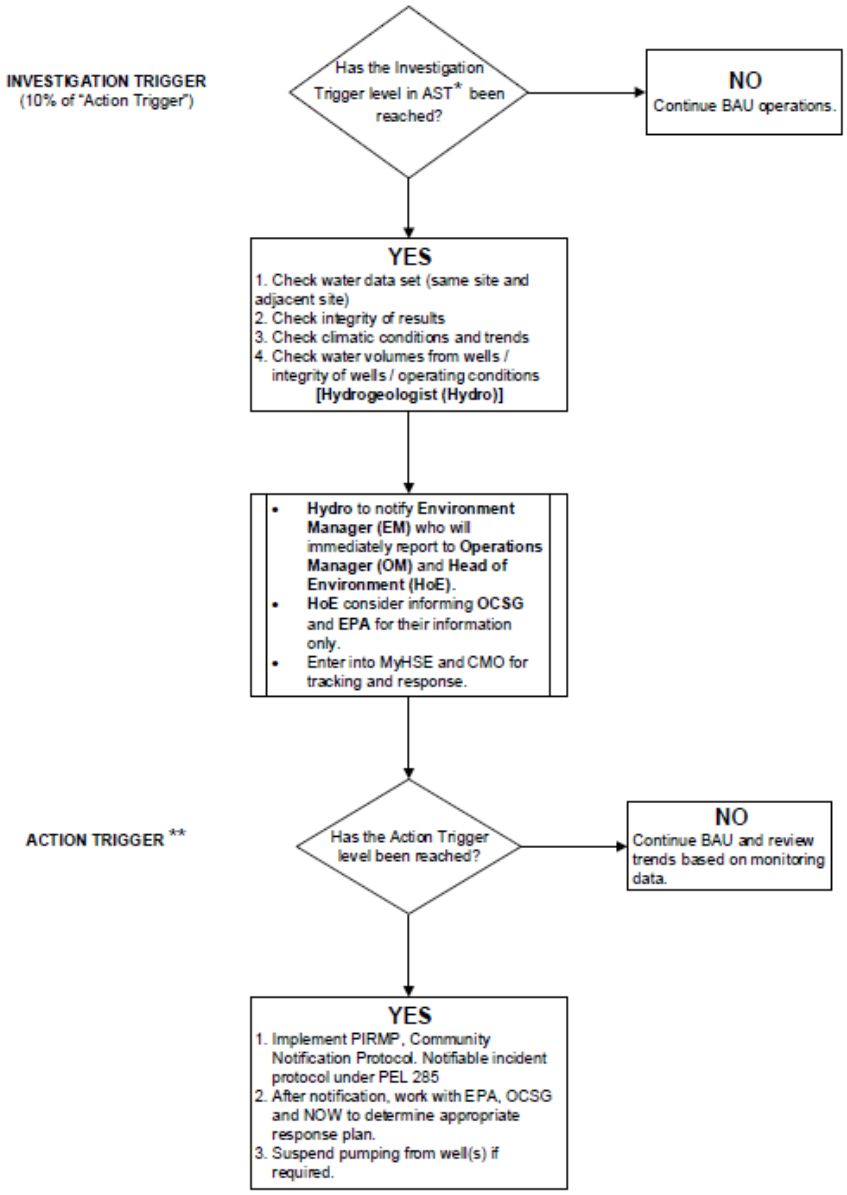


Figure 5: Schematic of the Packer Completion of WKMB05



* "**Investigation Trigger**" in AST is 10% of the "Action Trigger" value (i.e. 10 times lower than "Action Trigger").

** The "**Action Trigger**" is based on an independent risk assessment (EnRisk) of "worst case scenario" exposure from a human health (worker exposure from vapour and/or direct contact) and environmental (aquatic ecosystems on AST spill of 15ML) risk perspective.

Note: See detailed **TARP** for further information

Figure 6: Assessment and notification flow chart – AST infrastructure sites

Appendices

Appendix A1:	Production bore licences
Appendix A2:	Waukivory Pilot REF Addendum – Numerical Modelling (PB)
Appendix A3:	Minimum impact considerations for less productive aquifers
Appendix A4:	Risk Register – Transfer of Flowback Water to TED
Appendix A5:	Waukivory Groundwater Monitoring Network Detail
Appendix A6:	Waukivory Surface Water Monitoring Network Detail

A1 Production Bore Licences

Department of Primary Industries
Office of Water

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

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

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

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

Department of Primary Industries Office of Water

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 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.

(13) PRIOR TO COMMENCING ABANDONMENT OF THE WORK THE HOLDER OF THE LICENCE MUST SUBMIT TO THE NSW OFFICE OF WATER THEIR APPROVAL TO DECOMMISSION THE WORK FROM THE OFFICE OF COAL SEAM GAS.

(14) WITHIN THREE MONTHS OF THE WORK BEING ABANDONED THE HOLDER OF THE MUST SUBMIT TO THE NSW OFFICE OF WATER THE DECOMMISSIONING REPORT.

(15) THE HOLDER OF THE LICENCE MUST MEASURE THE QUANTITY OF WATER INJECTED INTO THE WORK DURING THE COURSE OF THE WAUKIVORY PILOT PROJECT AS APPROVED BY THE OFFICE OF COAL SEAM GAS. THE MEANS OF MEASURING THE QUANTITY OF THIS WATER MUST BE TO THE SATISFACTION OF THE NSW OFFICE OF WATER.

THE HOLDER OF THE LICENCE MUST MAINTAIN A RECORD OF THE ACTUAL VOLUME OF WATER INJECTED INTO THE WORK IN KILOLITRES OR MEGALITRES. THIS INFORMATION IS TO BE PROVIDED TO THE NSW OFFICE OF WATER AT THE COMPLETION OF THE PROJECT OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

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

Department of Primary Industries Office of Water

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 Industrial

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 20BL173600 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.

(13) PRIOR TO COMMENCING ABANDONMENT OF THE WORK THE HOLDER OF THE LICENCE MUST SUBMIT TO THE NSW OFFICE OF WATER THEIR APPROVAL TO DECOMMISSION THE WORK FROM THE OFFICE OF COAL SEAM GAS.

(14) WITHIN THREE MONTHS OF THE WORK BEING ABANDONED THE LICENCE HOLDER MUST SUBMIT TO THE NSW OFFICE OF WATER THE DECOMMISSIONING REPORT.

(15) THE HOLDER OF THE LICENCE MUST MEASURE THE QUANTITY OF WATER INJECTED INTO THE WORK DURING THE COURSE OF THE WAUKIVORY PILOT PROJECT AS APPROVED BY THE OFFICE OF COAL SEAM GAS. THE MEANS OF MEASURING THE QUANTITY OF THIS WATER MUST BE TO THE SATISFACTION OF THE NSW OFFICE OF WATER.

THE HOLDER OF THE LICENCE MUST MAINTAIN A RECORD OF THE ACTUAL VOLUME OF WATER INJECTED INTO THE WORK IN KILOLITRES OR MEGALITRES. THIS INFORMATION IS TO BE PROVIDED TO THE NSW OFFICE OF WATER AT THE COMPLETION OF THE PROJECT OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

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

20BL173601

Department of Primary Industries Office of Water

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

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 Industrial

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 20BL173601 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.

(13) PRIOR TO COMMENCING ABANDONMENT OF THE WORK THE HOLDER OF THE LICENCE MUST SUBMIT TO THE NSW OFFICE OF WATER THEIR APPROVAL TO DECOMMISSION THE WORK FROM THE OFFICE OF COAL SEAM GAS.

(14) WITHIN THREE MONTHS OF THE WORK BEING ABANDONED THE LICENCE HOLDER MUST SUBMIT TO THE NSW OFFICE OF WATER THE DECOMMISSIONING REPORT.

(15) THE HOLDER OF THE LICENCE MUST MEASURE THE QUANTITY OF WATER INJECTED INTO THE WORK DURING THE COURSE OF THE WAUKIVORY PILOT PROJECT AS APPROVED BY THE OFFICE OF COAL SEAM GAS. THE MEANS OF MEASURING THE QUANTITY OF THIS WATER MUST BE TO THE SATISFACTION OF THE NSW OFFICE OF WATER.

THE HOLDER OF THE LICENCE MUST MAINTAIN A RECORD OF THE ACTUAL VOLUME OF WATER INJECTED INTO THE WORK IN KILOLITRES OR MEGALITRES. THIS INFORMATION IS TO BE PROVIDED TO THE NSW OFFICE OF WATER AT THE COMPLETION OF THE PROJECT OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

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

20BL173595

Department of Primary Industries Office of Water

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

LICENSE NUMBER
20BL173595
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 Industrial

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 20BL173595 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 ABANDONEMENT 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.

(13) PRIOR TO COMMENCING ABANDONMENT OF THE WORK THE HOLDER OF THE LICENCE MUST SUBMIT TO THE NSW OFFICE OF WATER THEIR APPROVAL TO DECOMMISSION THE WORK FROM THE OFFICE OF COAL SEAM GAS.

(14) WITHIN THREE MONTHS OF THE WORK BEING ABANDONED THE HOLDER OF THE LICENCE MUST SUBMIT TO THE NSW OFFICE OF WATER THE DECOMMISSIONING REPORT.

(15) THE HOLDER OF THE LICENCE MUST MEASURE THE QUANTITY OF WATER INJECTED INTO THE WORK DURING THE COURSE OF THE WAUKIVORY PILOT PROJECT AS APPROVED BY THE OFFICE OF COAL SEAM GAS. THE MEANS OF MEASURING THE QUANTITY OF THIS WATER MUST BE TO THE SATISFACTION OF THE NSW OFFICE OF WATER.

THE HOLDER OF THE LICENCE MUST MAINTAIN A RECORD OF THE ACTUAL VOLUME OF WATER INJECTED INTO THE WORK IN KILOLITRES OR MEGALITRES. THIS INFORMATION IS TO BE PROVIDED TO THE NSW OFFICE OF WATER AT THE COMPLETION OF THE PROJECT OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

End Of Conditions

A2 Waukivory Pilot REF Addendum – Numerical Modelling (PB)

Parsons Brinckerhoff Australia Pty Limited

ABN 80 078 004 798

Level 27 Ernst & Young Centre
680 George Street, Sydney NSW 2000
GPO Box 5394
Sydney NSW 2001
Australia
Tel: +61 2 9272 5100
Fax: +61 2 9272 5101
Email: sydney@pb.com.au

www.pbworld.com

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

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

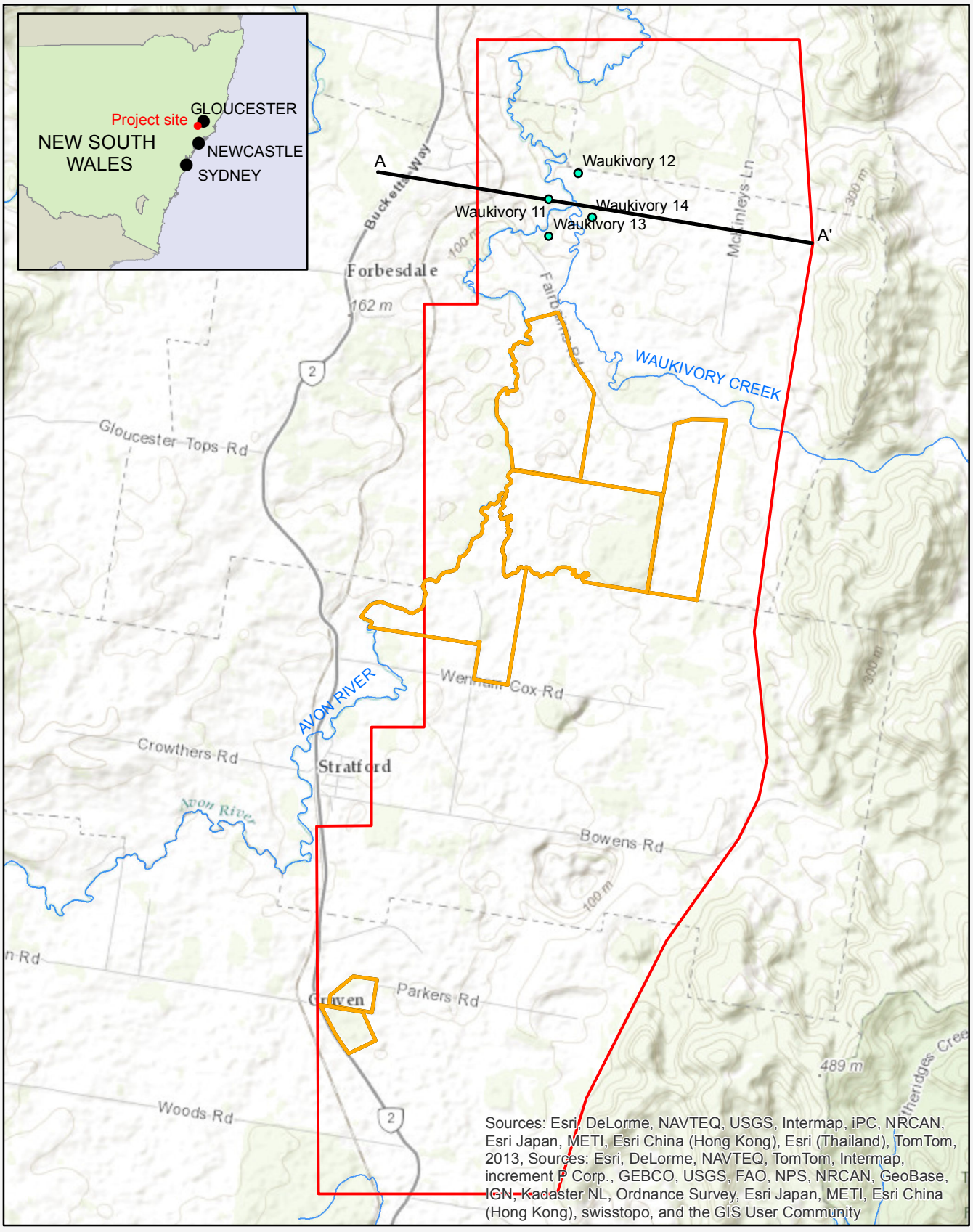
Becky Rollins
Hydrogeologist
Parsons Brinckerhoff

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

PARSONS BRINCKERHOFF

WAUKIVORY PILOT REF
AGL UPSTREAM INVESTMENTS PTY LTD



C:\AGL\GIS\02 Projects\2193335A_GLOUCESTER_REGIONAL_NUMERICAL\Figure 1 Location of Waukivory cross-sectional model.mxd Author: rollinsr 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

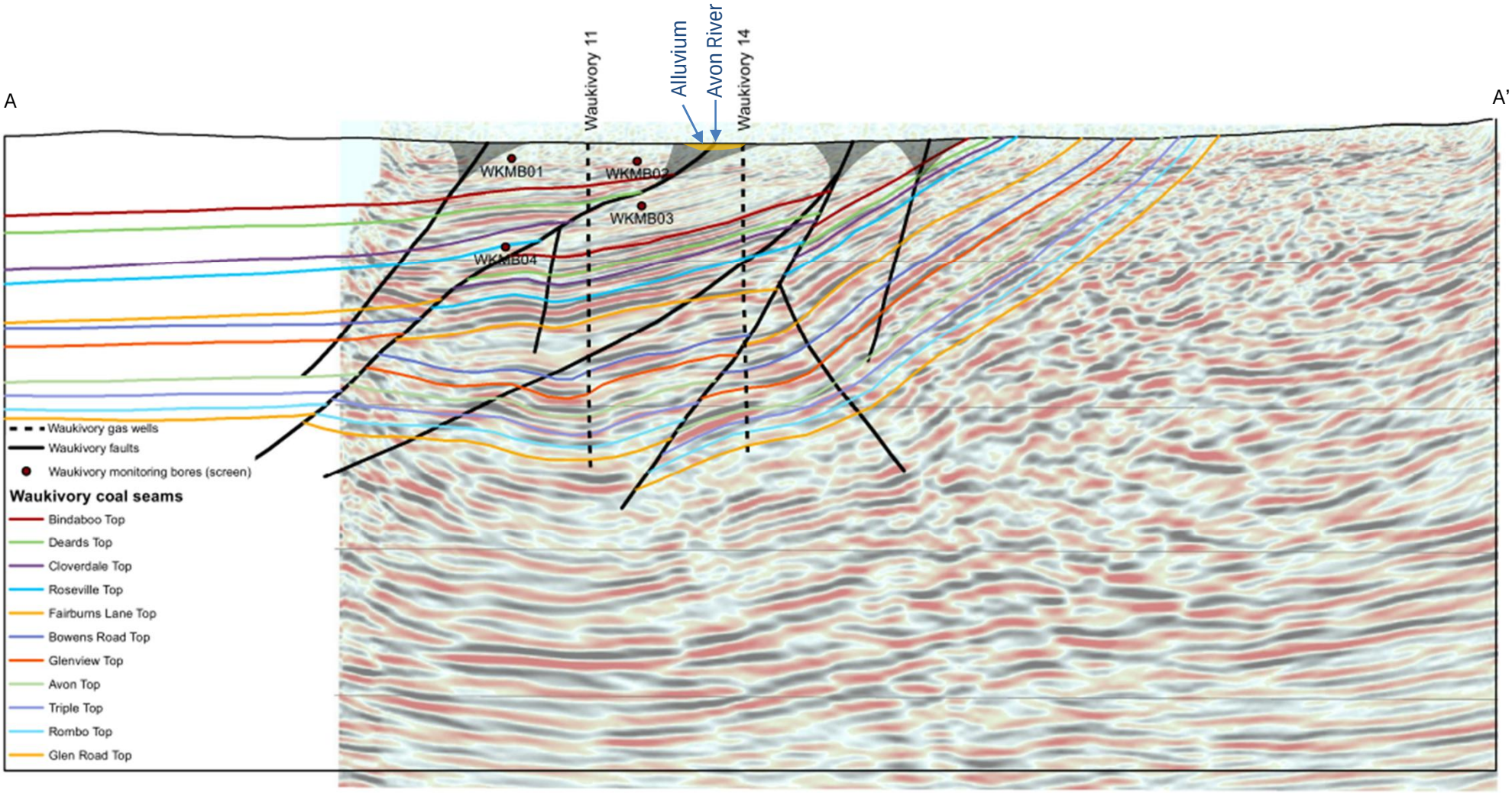
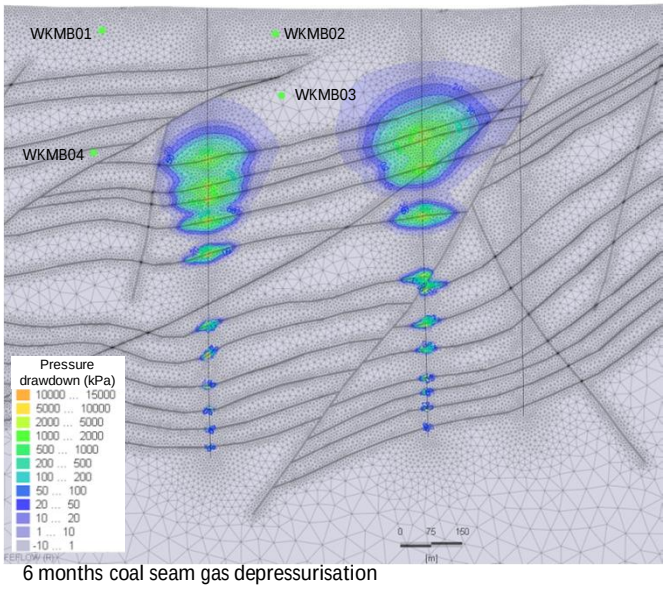
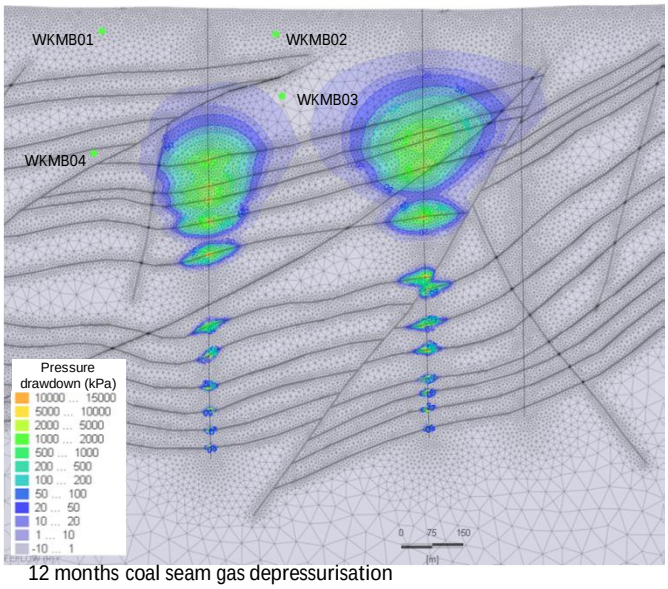


Figure 2 Waukivory interpreted seismic section

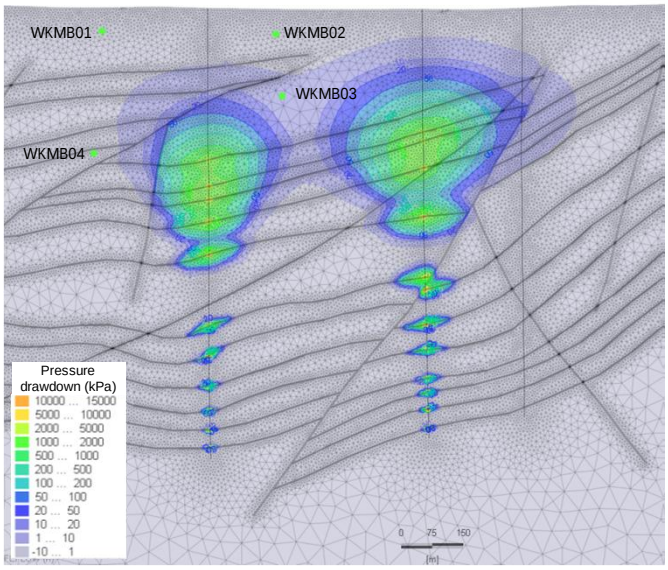
Faults transmissive in shallow rock and barriers at depth



6 months coal seam gas depressurisation



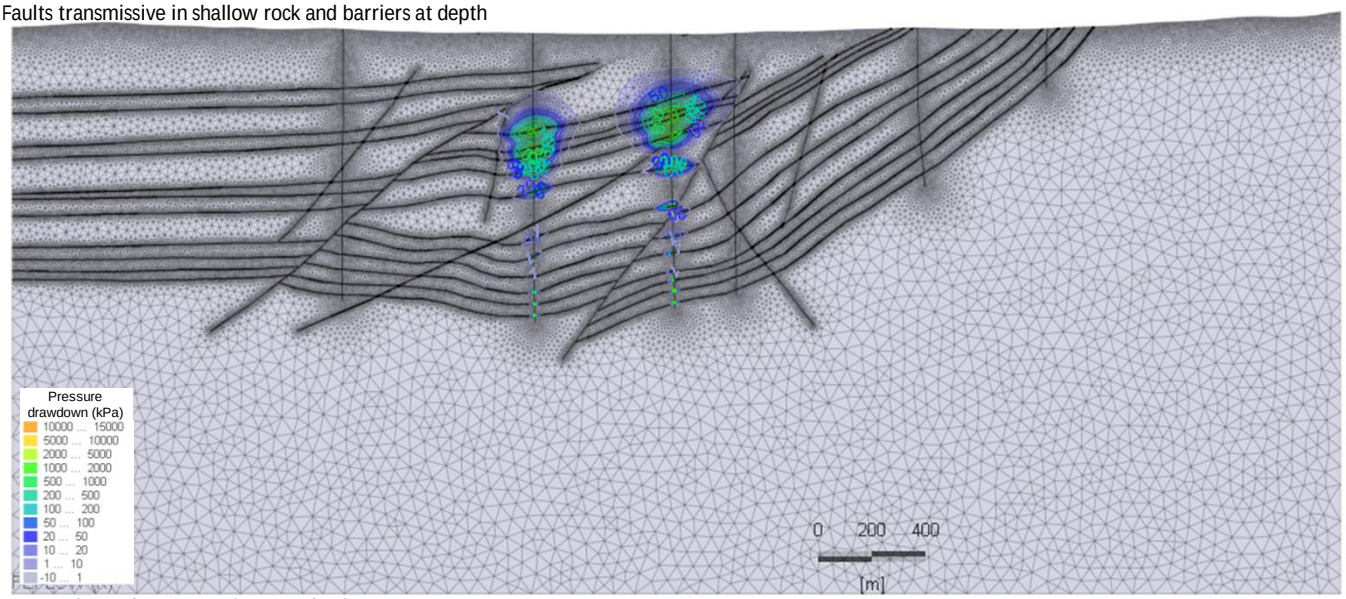
12 months coal seam gas depressurisation



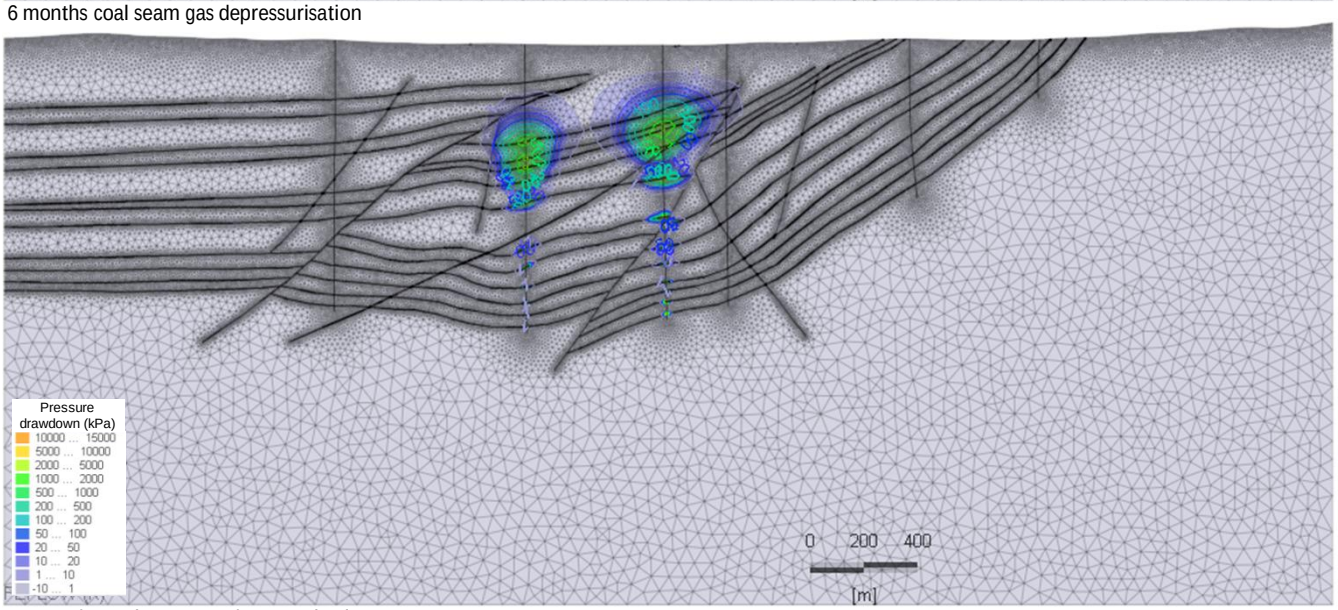
24 months coal seam gas depressurisation

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

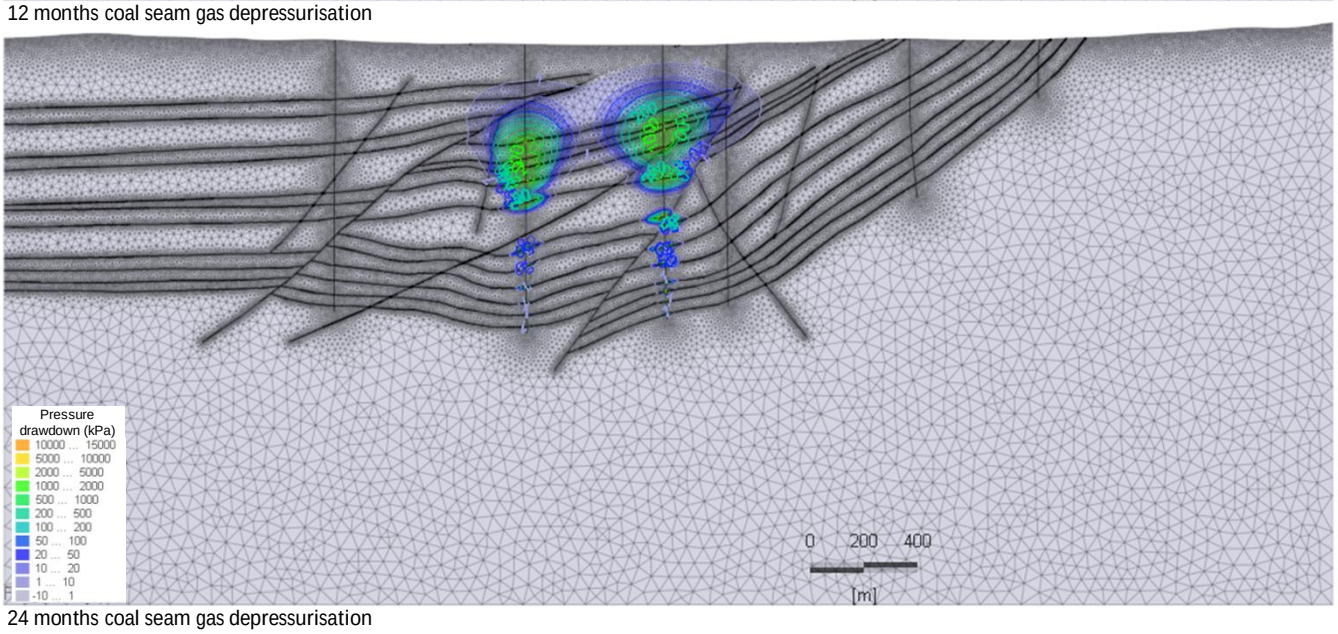
Faults transmissive in shallow rock and barriers at depth



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

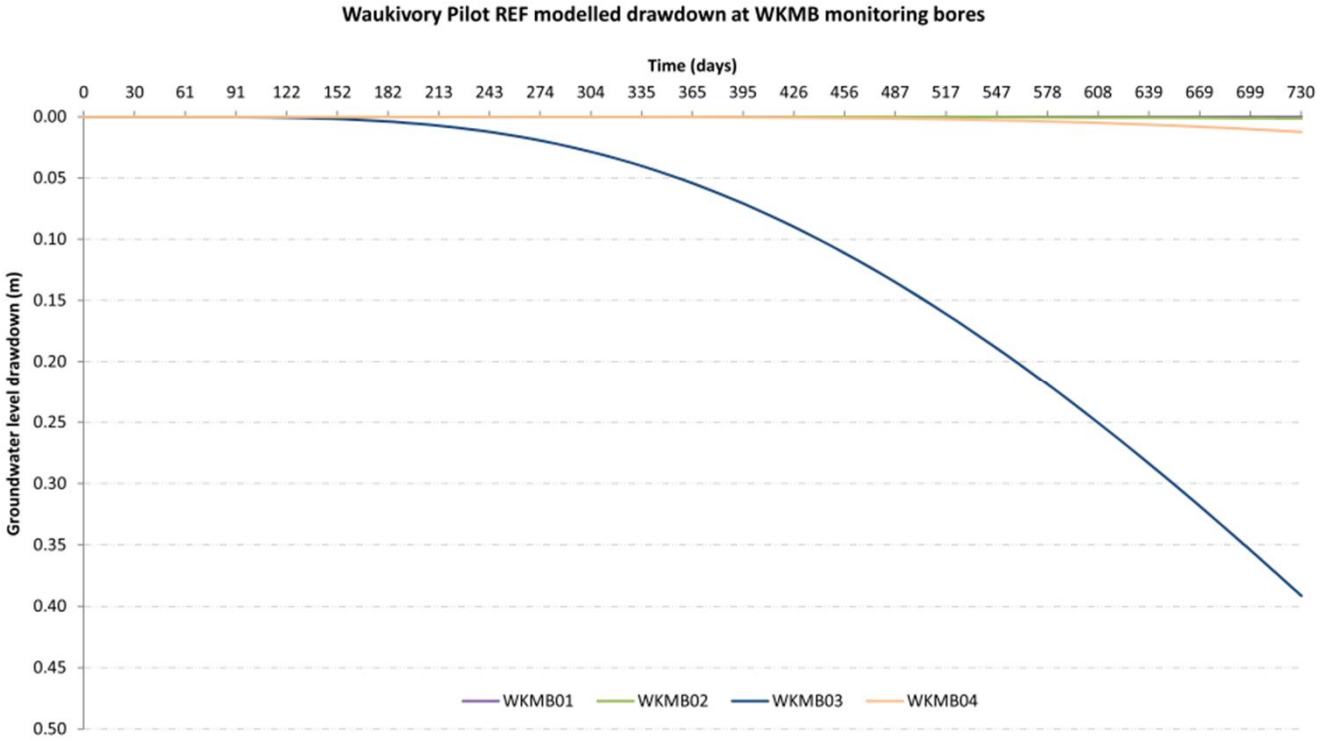


Figure 5 Waukivory Pilot REF drawdown hydrographs

A3 Minimum impact considerations for less productive aquifers

Table A3.1: Minimum impact considerations for the less productive alluvial aquifers

Water component	Minimum impact considerations	Assessment
Water table	1. Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan"(2) variations, 40m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a 2m decline cumulatively at any water supply work unless make good provisions should apply. 2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; 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. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	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. 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. *Fracture Stimulation* Fracture stimulation at depth in the coal seams will not propagate to the near surface alluvial aquifers. *Dewatering* There is negligible 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 A2). Therefore, a decline in the water table level is also unlikely. 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 proposed activity. These bores will be monitored during and after hydraulic fracture stimulation, and during the pilot testing program. In summary, predicted effects are **less than the Level 1 minimal impact considerations**.
Water pressure	Level 1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan"[2] pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work. Level 2. 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.	There is only a 'water table' aquifer in the alluvial aquifers so the Water Pressure criterion has no relevance.
Water quality	Level 1. (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 (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. Redesign of a highly connected[3] surface water source that is defined as a "reliable water supply"[4] is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above. (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".	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. As all gas wells are cased and cemented to full depth, changes in the water quality of beneficial aquifers are unlikely. Activities with potential to contaminate groundwater in beneficial aquifers include the use of chemical additives in fracturing fluids, the storage of produced and

	(d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining 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" Level 2. 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. 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. If condition 1.(c) or (d) are not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that: - there will be negligible river bank or high wall instability risks; - 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 - 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.	flowback water in the holding dam, and reuse of water 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 6). In summary, predicted effects are expected to be **less than the Level 1 minimal impact considerations**.
OVERALL ASSESSMENT		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.

Table A3.2: Minimum impact considerations for less productive porous and fractured rock aquifers

Water component	Minimum impact considerations	Assessment
Water table	Level 1. 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: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2m decline cumulatively at any water supply work. Level 2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; 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. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	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.
Water pressure	Level 1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. Level 2. 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.	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

		separating the shallow fractured rock aquifer from these zones which mostly occur below 150m depth. *Fracture Stimulation* There are inherent difficulties in predicting pressure head decline during hydraulic fracture stimulation. Prior to hydraulic fracture stimulation, a simulator will be run to provide a preliminary model of rock mechanics, fluids, pressures and temperatures. 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. The mini fracture will give a higher degree of confidence that the Level 1 minimum impact threshold for water pressure is not exceeded. In addition, a geophone monitoring bore is in place near WK13 to assess the extent and orientation of fractures in the targeted coal seams. *Dewatering* 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

		the deeper coal seams is unlikely (PB 2012a and PB 2012c). Modelling also suggest negligible impacts to the fractured rock aquifer (refer Appendix A2). Proving this lack of connectivity is one of the primary reasons for the pilot testing program. 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. Water supply bores are very unlikely to be affected given their distance from the gas wells and pilot test program. In summary, predicted effects are **less than the Level 1 minimal impact considerations**.
Water quality	Level 1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. Level 2. 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.	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. 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. 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.

		In summary, predicted effects are **less than the Level 1 minimal impact considerations**.
OVERALL ASSESSMENT		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.

A4 Risk Register – Transfer of Flowback Water to TED

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

RISK REGISTER
Transfer of Flowback water to TED

Risk / Administrative Detail						Raw Risk									
Ref	Category	Source	Due to…	There is a risk that…	Which may result in...	$	BC	Cust	Reg	R&C	E	H&S	Likelihood	Risk Score	Risk Level
1	Environment		PE transfer pipe and connectors may leak, spill or crack	lose containment of flowback and produced water	Significant medium term impact on important environment/habitat OR A repeated event which has occurred previously with short to medium term environmental impact that may extend beyond AGL's operational area						4		2	8	High
2	Environment		flowback water to be stored in TED.	Risk of loss of containment of flowback water in TED	Short to medium term environmental impact that may extend beyond AGL's operational area. OR A repeated event which has occurred previously with small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.				1	1.5	1.5	1.5	2	3	Moderate

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail															
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	Current Controls / Mitigations	Control Effectiveness	$	BC	Cust	Reg	R&C	E	H&S	Likelihood
1	Environment		PE transfer pipe and connectors may leak, spill or crack	lose containment of flowback and produced water	Significant medium term impact on important environment/habitat OR A repeated event which has occurred previously with short to medium term environmental impact that may extend beyond AGL's operational area	1. Meter will be installed on discharge of the transfer pump to measure volume of water pumped to TED . 2. Pump transfer area at WK 13 to be bunded with an impermeable base 3. single hockey stick and foot valve to be shared between ASTs at WK 13, if required. 4. Hydro testing of water gathering line system to be conducted and compliant to Australian standard [AS3500 and AS4654] prior to use. 5.install pressure switch on transfer pump to protect water gathering line from over pressuring. 6. SOP for water transfer to be reviewed to follow best practice and containing any spills. 7. Visual weekly inspection of line between AST2 and Tiedmans - Environ check sheet							4		1
2	Environment		flowback water to be stored in TED.	Risk of loss of containment of flowback water in TED	Short to medium term environmental impact that may extend beyond AGL's operational area. OR A repeated event which has occurred previously with small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.	1. SOP for water transfer to be reviewed to follow best practice and containing any spills. 2. TED has adequate capacity (freeboard) for heavy rain event, estimated only 15% of capacity to be used. 3. TED has double liner and leak detection system. 4. TED is a fully secured fenced site. 5. Daily inspections of the dam liner. 6. Weekly function test of leak detection system.					1	1.5	1.5	1.5	1

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail															
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	Calc. Risk	Risk Level	ALARP?	Escalation	Proposed Controls / Mitigations	$	BC	Cust	Reg	Rep
1	Environment		PE transfer pipe and connectors may leak, spill or crack	lose containment of flowback and produced water	Significant medium term impact on important environment/habitat OR A repeated event which has occurred previously with short to medium term environmental impact that may extend beyond AGL's operational area	4	Moderate	No	General Manager or approved delegate.						
2	Environment		flowback water to be stored in TED.	Risk of loss of containment of flowback water in TED	Short to medium term environmental impact that may extend beyond AGL's operational area. OR A repeated event which has occurred previously with small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.	1.5	High								

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail																	
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	E&C	H&S	Likelihood	Calc. Risk	Risk Level	ALARP?	Action Owner	Implementation Cost	Control Accepted	Name of Approver	Due Date	Status
1	Environment		PE transfer pipe and connectors may leak, spill or crack	lose containment of flowback and produced water	Significant medium term impact on important environment/habitat OR A repeated event which has occurred previously with short to medium term environmental impact that may extend beyond AGL's operational area				0	#N/A							
2	Environment		flowback water to be stored in TED.	Risk of loss of containment of flowback water in TED	Short to medium term environmental impact that may extend beyond AGL's operational area. OR A repeated event which has occurred previously with small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.												

Project / Business Unit:	**UG**
Client:	
Initial Register Development Date:	8/04/2015
Risk Register Owner:	Toni Laurie
Risk Register Builder / Champion / Facilitator:	Doug Ferry
Target Project Completion Date (if relevant):	
Last Review Date:	

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail						Action Tracking		
Ref	**Category**	**Source**	**Due to...**	**There is a risk that...**	**Which may result in...**	**Update**	**Dependency**	**Date Implemented**
1	Environment		PE transfer pipe and connectors may leak, spill or crack	lose containment of flowback and produced water	Significant medium term impact on important environment/habitat OR A repeated event which has occurred previously with short to medium term environmental impact that may extend beyond AGL's operational area			
2	Environment		flowback water to be stored in TED.	Risk of loss of containment of flowback water in TED	Short to medium term environmental impact that may extend beyond AGL's operational area. OR A repeated event which has occurred previously with small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.			

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

RISK REGISTER
Transfer of Flowback water to TED

Risk / Administrative Detail						Raw Risk									
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	$	BC	Cust	Reg	R&C	E	H&S	Likelihood	Risk Score	Risk Level
3	Environment		Transfer of flowback water to enclosed tanks from TED	loss of containment at enclosed tanks	Small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.						1		3	3	Moderate
4	Environment/ Community		Due to illegal and unathourised entry on the site equipment may be sabotaged	Risk of loss of containment of flowback water, delays to operation, intended contamination of flowback water	Short to medium term environmental impact that may extend beyond AGL's operational area. Regional and state and/or online negative publicity for a period approximately a week and social media commentary restricted to interest groups. Localised community complaints		1			1.5	1.5	1	3	4.5	High
5	Business Continuity		Debris in pipeline	blockage of pipeline	Business interruption causes impact to internal or external customers that last up to 5 business days; AND / OR Growth options are delayed for between 3 and 6 months.		1.5						3	4.5	High

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail															
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	Current Controls / Mitigations	Control Effectiveness	$	BC	Cust	Reg	R&C	E	H&S	Likelihood
3	Environment		Transfer of flowback water to enclosed tanks from TED	loss of containment at enclosed tanks	Small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.	1. Inspection report on enclosed tanks 2. Rain water to be vac sucked out of bund in the case of rain event 3. Bunds to have the capacity of 110% of volume of the largest tank 4. dedicated above ground line to enclosed tanks 5. transfer of water is to be supervised by operator -SOP 6. Tanks to be filled to the top of the sight glass only 7. Bunding and impermeable base for connection points 8. demarcated area to define enclosed tanks 9. enclosed tanks located in fully fenced operational area.							1		2
4	Environment/ Community		Due to illegal and unathourised entry on the site equipment may be sabotaged	Risk of loss of containment of flowback water, delays to operation, intended contamination of flowback water	Short to medium term environmental impact that may extend beyond AGL's operational area. Regional and state and/or online negative publicity for a period approximately a week and social media commentary restricted to interest groups. Localised community complaints	1. System access valves to be locked 2. Operational areas fully fences 3. Surveillience of operational areas 4. Mobile security patrols 5. Security Management Plan 6. Use of signage to inform general public that the site is "restricted" 7. Protester Protocols 8. Operational areas require keyed access for vehicles			1			1.5	1.5	1	2
5	Business Continuity		Debris in pipeline	blockage of pipeline	Business interruption causes impact to internal or external customers that last up to 5 business days; AND / OR Growth options are delayed for between 3 and 6 months.	1. Pressure switch to be installed on transfer pump to shut pump down if pressure reaches max working pressure of line. 2. History of pressure is monitored including baseline pressure at various rates. 3. Transfer of water from AST 2 to TED is attended. 4. If pressure increases in pipeline due to obstruction, flush with fresh water at tubulent flow rate, until pressure drops back to baseline pressure			1			1.5	1		2

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail																
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	Calc. Risk	Risk Level	ALARP?	Escalation	Proposed Controls / Mitigations	$	BC	Cust	Reg	Rep
3	Environment		Transfer of flowback water to enclosed tanks from TED	loss of containment at enclosed tanks	Small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.	2	High								
4	Environment/ Community		Due to illegal and unathourised entry on the site equipment may be sabotaged	Risk of loss of containment of flowback water, delays to operation, intended contamination of flowback water	Short to medium term environmental impact that may extend beyond AGL's operational area. Regional and state and/or online negative publicity for a period approximately a week and social media commentary restricted to interest groups. Localised community complaints	3	Moderate		#REF!						
5	Business Continuity		Debris in pipeline	blockage of pipeline	Business interruption causes impact to internal or external customers that last up to 5 business days; AND / OR Growth options are delayed for between 3 and 6 months.	3	Moderate		General Manager or approved delegate.						

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail																	
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	E&C	H&S	Likelihood	Calc. Risk	Risk Level	ALARP?	Action Owner	Implementation Cost	Control Accepted	Name of Approver	Due Date	Status
3	Environment		Transfer of flowback water to enclosed tanks from TED	loss of containment at enclosed tanks	Small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.												
4	Environment/ Community		Due to illegal and unathourised entry on the site equipment may be sabotaged	Risk of loss of containment of flowback water, delays to operation, intended contamination of flowback water	Short to medium term environmental impact that may extend beyond AGL's operational area. Regional and state and/or online negative publicity for a period approximately a week and social media commentary restricted to interest groups. Localised community complaints				0	#N/A							
5	Business Continuity		Debris in pipeline	blockage of pipeline	Business interruption causes impact to internal or external customers that last up to 5 business days; AND / OR Growth options are delayed for between 3 and 6 months.				0	#N/A							

Project / Business Unit: UG
Client:
Initial Register Development Date: 8/04/2015
Risk Register Owner: Toni Laurie
Risk Register Builder / Champion / Facilitator: Doug Ferry
Target Project Completion Date (if relevant):
Last Review Date:

Review Team:

Mike Roy, James Duggelby, Aiden Barnes, Keiren Fetterplace, Brett Haywood, Doug Ferry, Toni Laurie, Gary Hynds, Andrew Adorini , Ben Eastwood

Risk / Administrative Detail						Action Tracking		
Ref	Category	Source	Due to...	There is a risk that...	Which may result in...	Update	Dependency	Date Implemented
3	Environment		Transfer of flowback water to enclosed tanks from TED	loss of containment at enclosed tanks	Small scale and short term environmental impact to localised area of low environmental value and no impact beyond AGL's operational area.			
4	Environment/ Community		Due to illegal and unathourised entry on the site equipment may be sabotaged	Risk of loss of containment of flowback water, delays to operation, intended contamination of flowback water	Short to medium term environmental impact that may extend beyond AGL's operational area. Regional and state and/or online negative publicity for a period approximately a week and social media commentary restricted to interest groups. Localised community complaints			
5	Business Continuity		Debris in pipeline	blockage of pipeline	Business interruption causes impact to internal or external customers that last up to 5 business days; AND / OR Growth options are delayed for between 3 and 6 months.			

A5 Waukivory Groundwater Monitoring Network Detail

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. In late 2014, a new cluster was completed on the floodplain within the area of influence of the pilot wells. These monitoring bores (currently five in total but originally six AGL sites plus one GRL site) 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 and floodplain monitoring bores monitor the upper fractured rock aquifer and shallow thrust fault zone, while the western site monitors the upper fractured rock aquifers. The existing monitoring bore locations are shown on Figure 1 and in cross section on Figure 2, and summary details are provided in Table A5.1.

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 bores on the floodplain target the sub-crop of the shallow thrust fault and 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) is monitored for water levels and water quality trends (as per the close AGL monitoring bores – WKMB01, WKMB02, WKMB03, WKMB06a and WKMB06b).

The WKMB05 monitoring bore is the converted geophone monitoring well located close to WK13. It monitors the deeper groundwater systems (six intervals in the one borehole as per Table A5.1) 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 packer monitoring system is shown in Figure 5. This monitoring location was converted after the fracture stimulation program on WK13 and is 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 A5.1. Summary details of monitoring bores within 3 km of the pilot wells are provided in Table A5.2.

There is ongoing live telemetry for water levels via AGL's Water Portal website from the adjacent AGL monitoring bore network (except for WKMB05 and GR-P3).

Table A5.1: Summary of Adjacent Monitoring Bores – Waukivory Area

Area	Sub – area and Purpose	Monitoring Bores
Waukivory	Within field - 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 Depth – 62 m Screened Interval – 52 to 61 m WKMB03 – Thrust fault Depth – 210 m Screened Interval – 200 to 209 m
Waukivory	West of field - Two bores adjacent to pilot testing program area to monitor shallow groundwater systems (baseline and during pilot)	WKMB01 – Shallow fractured rock Depth – 54 m Screened Interval – 47 to 53 m WKMB04 – Deep coal seam (Roseville CS) Depth – 360 m 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 - Two bores to monitor sub-crop of the fault and overlying alluvium (during pilot)	WKMB06a – Shallow alluvium Depth – 13.4 m Screened Interval – 6.35 to 12.35 m WKMB06b – Thrust fault Depth – 63 m Screened Interval – 52 to 61 m
Waukivory	Within field 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: * - 340 to 343 m Aquitard * - 426 to429 m Cloverdale CS * - 584 to 587 m Aquitard * - 595.4 to 598.4 m Fairbairns Lane CS * - 698.5 to 701.5 m Aquitard * - 711 to 714 m Middle thrust fault
Waukivory	Adjacent (GRL site) to monitor any shallow alluvial impacts (baseline and during pilot)	NOTE - Site monitored by both AGL and GRL GR-P3 – Shallow alluvium Depth – 11.2m Screened Interval – 5 to 9 m

Note: Adjacent sites are those located within 500 m of any pilot well

Table A5.2: 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: WMB01 - Shallow alluvium Depth – 8.5 m Screened Interval – 5 to 8 m WMB02 - Shallow sandstone Depth – 23.0 m Screened Interval – 15 to 21 m WMB03 – Shallow coal seam (Bowens Rd CS) Depth – 36 m Screened Interval – 32 to 34 m WMB04 – Deep sandstone Depth – 80.5 m Screened Interval – 67 to 79 m PL03 – Deep vibrating wire piezometers VWP 3 – 462 m VWP 2 – 496 m 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 GR-P1 – Shallow alluvium Depth – 10.2 m Screened Interval – 5.5 to 8.5 m GR-P2 – Shallow alluvium Depth – 11 m Screened Interval – 4 to 9 m GR-P4 – Fractured rock Depth – 37 m Screened Interval – 32.5 to 35.5 m GR-P5 – Fractured rock Depth – 30 m Screened Interval – 24 to 30 m GR-P6 – Fractured rock Depth – 24 m Screened Interval – 17 to 23 m GR-P6A – Shallow coal seam (Weismantels CS) Depth – 97 m Screened Interval – 89 to 95 m GR-P8 – Fractured rock Depth – 42 m Screened Interval – 29 to 41 m GR-P8A – Shallow coal seam (Avon CS) Depth – 72 m Screened Interval – 62 to 70 m GR-P9 – Fractured rock Depth – 34 m Screened Interval – 24 to 33 m GR-P9A – Shallow coal seam (Cloverdale CS) Depth – 66 m Screened Interval – 59 to 65 m

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

A6 Waukivory Surface Water Monitoring Network Detail

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 A6.1).

The surface water monitoring locations 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 and telemetry commenced in October 2014.

Table A6.1: Summary of Stream Gauges – Waukivory Area

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

There is ongoing live telemetry available via AGL's Water Portal website for water levels and salinity from the AGL stream gauging sites.