AGL Upstream Investments Pty Ltd

Drilling Completion Report - Faulkland and Bucketts Way Groundwater Monitoring Bores

Gloucester Gas Project

16 December 2014

PARSONS BRINCKERHOFF

Document information
Client: AGL Upstream Investments Pty Ltd Title: Drilling Completion Report - Faulkland and Bucketts Way Groundwater Monitoring Bores Subtitle: Gloucester Gas Project Document No: 2193324A-WAT-RPT-001 RevD Date: 16 December 2014

Rev	Date	Details
A	01/04/2014	First draft
B	10/10/2014	Second draft
C	17/11/2014	Third draft
D	16/12/2014	Final

Author, Reviewer and Approver details			
Prepared by:	Carolina Sardella	Date: 16/12/2014	Signature: 
Reviewed by:	Stuart Brown, Sean Daykin	Date: 16/12/2014	Signature:  
Approved by:	Andrea Madden	Date: 16/12/2014	Signature: 

Distribution
AGL Upstream Investments Pty Ltd, Parsons Brinckerhoff file, Parsons Brinckerhoff Library

Document owner
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*

Contents

List of tables

List of figures

List of appendices

Glossary

Acidity	Base neutralising capacity.
Alkalinity	Acid neutralising capacity.
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.
Ammonia	A compound of nitrogen and hydrogen (NH_3) that is a common by-product of animal waste and landfills but is also found naturally in reduced environments. Ammonia readily converts to nitrate in soils and streams.
Anion	An ion with a negative charge – usually non-metal ions when disassociated and dissolved in water.
Annulus	The void space between two strings of casing in a water bore or gas well.
Aquatic ecosystem	The stream channel, lake or estuary bed, water, and (or) biotic communities and the habitat features that occur therein.
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 leaky 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.
Artesian water	Groundwater that is under pressure when tapped by a bore and is able to rise above the level at which it is first encountered. It may or may not flow at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is a confined 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.
Baseline sampling	A period of regular water quality and water level measurements that are carried out over a period long enough to determine the natural variability in groundwater conditions.
Bedding plane	In sedimentary or stratified rocks, the division plane which separates the individual layers, beds or strata.
Blowout	The uncontrolled release of formation fluids and gases encountered during borehole drilling.
BoP	Blowout preventer, a large series of valves used to seal, control and monitor blowouts of formation fluids and gasses.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Boundary	A lateral discontinuity or change in the aquifer resulting in a significant change in hydraulic conductivity, storativity or recharge.
Carbon-13 (^{13}C)	A natural, stable isotope of carbon and one of the environmental isotopes. It makes up about 1.109% of all naturally occurring carbon on Earth.
Carbon-14 (^{14}C)	Or radiocarbon is a radioactive isotope of carbon. Its nucleus contains six (6) protons and eight (8) neutrons. Its presence in organic materials is used in radiocarbon dating. It occurs naturally and has a relative abundance up to one part per trillion (0.0000000001%) of all naturally-occurring carbon on Earth. Carbon-14 is one of the most important nuclides in groundwater studies because its half-life of 5,730 years covers a critical time scale of ~500 to 50,000 years, which is ideal for dating regional and intermediate flow systems.
Cation	An ion with a positive charge – usually metal ions when disassociated and dissolved in water.
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.
Concentration	The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample).
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description

	of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.
Confining layer	Low permeability strata that may be saturated and will not allow water to move through it under natural hydraulic gradients.
Contamination	Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Datalogger	A digital recording instrument that is inserted in monitoring and pumping bores to record pressure measurements and water level variations.
Detection limit	The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration.
Deuterium (^{2}H)	Also called heavy hydrogen, a stable isotope of hydrogen with a natural abundance of one atom in 6,500 of hydrogen. The nucleus of deuterium, called a deuteron, contains one proton and one neutron, where a normal hydrogen nucleus has just one proton.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Dissolution	Process of dissolving a substance into a liquid. If the saturation index is less than zero, the mineral is undersaturated with respect to the solution and the mineral might dissolve.
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.
Environmental isotopes	Also known as stable isotopes, they act as 'groundwater signatures' and can be used as natural groundwater tracers.
Falling head test	A hydraulic test on a monitoring bore or piezometer that involves a sudden rise in water level (i.e. a volume of water is quickly added to the water column and the rate of water level decline is measured). Also called a slug test or slug-in test.
Fault	A fracture in rock along which there has been an observable amount of displacement. Faults are rarely single planar units; normally they occur as parallel to sub-parallel sets of planes along which movement has taken place to a greater or lesser extent. Such sets are called fault or fracture zones.
Fluvial	Pertaining to a river or stream.
Formation water	Natural groundwater from deep sedimentary rocks (the term is usually used in the context of deep coal seams).
Fracture	Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions.
Fractured rock aquifer	These 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 rock aquifers.
Global Meteoric Water Line (GMWL)	A line that defines the relationship between oxygen-18 (^{18}O) and deuterium (^{2}H) in fresh surface waters and precipitation from a number of global reference sites.
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
Groundwater age classification	Groundwater ages are commonly referred to as: Modern <100 years Sub-modern 100-1,000 years Old >1,000 years
Groundwater flow	The movement of water through openings in sediment and rock within the zone of saturation.
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 gradient	The change in total hydraulic head with a change in distance in a given direction.
Hydraulic head	A specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between two or more points.
Hydrochemistry	Chemical characterisation of water (both surface water and groundwater).
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrology	The study of the occurrence, distribution, and chemistry of all surface waters.
Igneous rocks	Rocks that have solidified from molten or partly molten material (magma).
Ion	An ion is an atom or molecule where the total number of electrons is not equal to the total number of protons, giving it a net positive or negative electrical charge.
Isotope	One of multiple forms of an element that has a different number of neutrons than other atoms of that element. Some isotopes are unstable or undergo radioactive decay, while others are 'stable isotopes'.
Lithology	The study of rocks and their depositional or formational environment on a large specimen or outcrop scale.

Local Meteoric Water Line (LMWL)	A line that defines the local relationship between oxygen-18 (18O) and deuterium (2H) in fresh surface waters and precipitation. In this report the LMWL used is for the Sydney region.
Major ions	Constituents commonly present in concentrations exceeding 10 milligram per litre. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulphate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate.
Methane (CH_4)	An odourless, colourless, flammable gas, which is the major constituent of natural gas. It is used as a fuel and is an important source of hydrogen and a wide variety of organic compounds.
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.
Oxidising conditions	Conditions in which a species loses electrons and is present in oxidised form.
Oxygen-18 (^{18}O)	A natural, stable isotope of oxygen and one of the environmental isotopes. It makes up about 0.2 % of all naturally-occurring oxygen on Earth.
Percent modern carbon (pMC)	The activity of 14C is expressed as percent modern carbon (pMC) where 100 pMC corresponds to 95 % of the 14C concentration of NBS oxalic acid standard (close to the activity of wood grown in 1890).
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permeable material	Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present.
Permian	The last period of the Palaeozoic era that finished approximately 230 million years before present.
pH	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).
Piezometer	A method by which standing water level or piezometric surface is measured. May take the form of a monitoring bore, vibrating wire piezometer or multilevel packer.
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.

Porosity	The proportion of open space within an aquifer, comprised of intergranular space, pores, vesicles and fractures.
Porosity, primary	The porosity that represents the original pore openings when a rock or sediment formed.
Porosity, secondary	The porosity caused by fractures or weathering in a rock or sediment after it has been formed.
Porous rock	Consolidated sedimentary rock containing voids, pores or other openings (joints, cleats, fractures) which are interconnected in the rock mass and may be capable of storing and transmitting water
Precipitation	(1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral.
Quaternary	The most recent geological period extending from approximately 2.5 million years ago to the present day.
Quality assurance	Evaluation of quality-control data to allow quantitative determination of the quality of chemical data collected during a study. Techniques used to collect, process, and analyse water samples are evaluated.
Radioisotope	Radioisotopes undergo radioactive decay allowing for determination of residence times in aquifers and groundwater systems.
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.
Recharge area	A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones.
Redox potential (ORP or Eh)	The redox potential is a measure (in volts) of the affinity of a substance for electrons – its electronegativity – compared with hydrogen (which is set at 0). Substances more strongly electronegative than (i.e. capable of oxidising) hydrogen have positive redox potentials. Substances less electronegative than (i.e. capable of reducing) hydrogen have negative redox potentials. Also known as oxidation-reduction potential and Eh.
Redox reaction	Redox reactions, or oxidation-reduction reactions, are a family of reactions that are concerned with the transfer of electrons between species, and are mediated by bacterial catalysis. Reduction and oxidation processes exert an important control on the distribution of species like O2, Fe2+, H2S and CH4 etc in groundwater.
Reducing conditions	Conditions in which a species gains electrons and is present in reduced form.
Residence time	The time that groundwater spends in storage before moving to a different part of the hydrological cycle (i.e. it could be argued it is a rate of

	replenishment).
Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).
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 brackish 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).
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 sedimentary rock 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).
Stable isotope	Stable isotopes are atoms of the same element that have different masses due to differences in the number of neutrons they contain. Stable isotopes are not subject to radioactive decay, meaning they do not breakdown over time.
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.
Surface water-groundwater interaction	This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table adjacent to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater through streambeds when the elevation of the water

	table is lower than the water level in the stream.
Total Dissolved Solids (TDS)	A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). See also EC.
Tritium (^{3}H)	A short-lived isotope of hydrogen with a half-life of 12.43 years. It is commonly used to identify the presence of modern recharge. Tritium is produced naturally in small amounts owing to the interaction of cosmic radiation with atmospheric oxygen and nitrogen in the troposphere, and is also produced by thermonuclear explosions.
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 quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists.
Well	Pertaining to a gas exploration well or gas production well.

Abbreviations

AGL	AGL Upstream Investments Pty Ltd
ANSTO	Australian Nuclear Science and Technology Organisation
BoM	Bureau of Meteorology
BTEX	Benzene, toluene, ethyl benzene and xylenes
CDFM	Cumulative deviation from mean
CSG	Coal seam gas
DIC	Dissolved organic carbon
DO	Dissolved oxygen
EC	Electrical conductivity
JSA	Job Safety Analysis
HESP	Health, Environment and Safety Plan
GGP	Gloucester Gas Project
GMWL	Global Meteoric Water Line
GRL	Gloucester Resources Limited
LMWL	Local Meteoric Water Line
LOQ	Limit of quantitation
LOR	Limit of reporting
ORP	Oxidation reduction potential
PAH	Polycyclic aromatic hydrocarbons
PEL	Petroleum Exploration Licence
PPE	Personal Protective Equipment
SMP	Safety Management Plan
SWL	Standing water level
SWMS	Safe Work Methods Statements
TD	Total depth
TDS	Total dissolved solids

TPH	Total recoverable hydrocarbons
VPDB	Vienna PeeDee Belemnite
VSMOW	Vienna Standard Mean Ocean Water

Units

°C	degrees Celsius
L/s	litres per second
km	kilometres
m	metres
mAHD	metres Australian Height Datum
mbgl	metres below ground level
m/day	metres per day
mL	millilitres
mm	millimeters
µS/cm	microSiemens per centimetre
mg/L	milligrams per litre
µg/L	micrograms per litre
mV	millivolt
‰	per mil
pCM	percent modern carbon
TU	tritium unit
yrs BP	years before present

Executive summary

AGL Upstream Investments Pty Ltd (AGL) is proposing to build the Gloucester Gas Project (GGP) which comprises several stages of development; however, only one stage, the Stage 1 Gas Field Development Area (GFDA) is currently approved. A comprehensive groundwater investigation was completed in early 2012 to confirm the hydrogeological conceptual model across the Stage 1 GDFA (Parsons Brinckerhoff 2012). Surface water and groundwater investigations are ongoing pending the commencement of the GGP.

This report relates to the completion of two nested groundwater monitoring sites in June and July 2013 (the Faulkland and the Bucketts Way sites) located beyond the Stage 1 GDFA. The drilling program established one groundwater monitoring bore in the Quaternary alluvium at the Bucketts Way site and three monitoring bores in the shallow and deep sandstone in the Leloma Formation of the Gloucester Coal Measures. Two groundwater monitoring bores were established in the Leloma Formation at the Faulkland site. Following the completion of each monitoring bore, *in situ* pressure transducers (dataloggers) were installed. Hydraulic conductivity and water quality testing was also undertaken at each site.

Baseline groundwater level monitoring results (level and climatic trends) since 2011 across the regional monitoring network indicate that the groundwater level trends in monitoring bores vary depending on the lithology, seasonal climatic trends, proximity to rainfall recharge and proximity to the river. There are few observed water level trends at these new sites given the short period of record:

- Quaternary alluvium: groundwater levels in the monitoring bore at the Bucketts Way location screened in the alluvium did not show a response to the one rainfall event over the short monitoring period.
- Gloucester Coal Measures – Leloma Formation: at both monitoring locations, groundwater levels in the monitoring bores screened in the Leloma Formation have remained stable since monitoring began and show no response to rainfall events.

The initial baseline groundwater quality monitoring suggests that:

- Quaternary alluvium: groundwater is brackish, with slightly acidic pH and slightly reducing conditions. The major ion chemistry is sodium-chloride dominant. Dissolved metal concentrations are typically low; however, several metals occur naturally at concentrations above ANZECC (2000) guideline values. Ammonia and total phosphorus were detected in the alluvial monitoring bore. Concentrations of phenolic compounds, and BTEX were below the laboratory limit of reporting (LOR) and concentrations of total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH) were detected. Isotope data indicate that groundwater is of meteoric origin and is modern.
- Gloucester Coal Measures – Leloma Formation:
  - Faulkland site: groundwater quality is brackish to slightly saline, with neutral pH and reducing conditions. The major ion chemistry indicates sodium is the dominant cation and chloride, bicarbonate and carbonate are the dominant anions. Dissolved metal concentrations are typically low; however, several metals occur naturally at concentrations above ANZECC (2000) guideline values. Ammonia, total phosphorus, and reactive phosphorus were detected above ANZECC (2000) guideline levels in at least one monitoring bore. Concentrations of PAH and benzene, ethyl benzene and xylene were below the laboratory LOR. TPH, toluene and phenolic compounds were detected at low concentrations. Isotope data indicates that groundwater is of meteoric origin and generally classified as old. Methane is of thermogenic origin.
  - Bucketts Way site: groundwater quality is brackish, with slightly acidic to slightly alkaline pH and reducing to strongly reducing conditions. The major ion chemistry is sodium-chloride dominant. Dissolved metal concentrations are typically low; however, copper and zinc occur naturally at concentrations above ANZECC (2000) guideline values in at least one monitoring bore. Ammonia

concentrations were above ANZECC (2000) guideline values in all monitoring bores. Concentrations of TPH, PAH and phenolic compounds were detected in at least one monitoring bore. BTEX concentrations were below the laboratory LOR. Isotope data indicate that groundwater is of meteoric origin and generally classified as old. Methane is of mixed biogenic/thermogenic origin.

It is recommended that monitoring continues at both monitoring locations in accordance with the existing regional monitoring program.

1. Introduction

AGL Upstream Investments Pty Ltd (AGL) is proposing to build the Gloucester Gas Project (GGP) which comprises several stages of development facilitating the extraction of coal seam gas (CSG) from the Gloucester Basin. Concept Plan and Project Approval (Part 3A Approval) for the Stage 1 GFDA was granted on 22 February 2011 under Part 3A of the *Environmental Planning and Assessment Act (1979) (EP&A Act)*. In addition the project received approval under the *Environment Protection and Biodiversity Conservation Act (1999) (EPBC Act)* (EPBC Approval) on 11 February 2013.

AGL also holds Petroleum Exploration Licence (PEL) 285, under the *Petroleum (Onshore) Act 1991*, covering the whole of the Gloucester Basin, approximately 100 km north of Newcastle, NSW. AGL has also applied for a Petroleum Production Lease (PPL) for the Stage 1 area subject of the planning approvals. The Stage 1 GFDA in relation to the PEL boundary is shown in Figure 1.1.

The GGP will involve the dewatering of deep groundwater and the extraction of gas from multiple coal seams within the Gloucester Coal Measures. Target coal seam depths will vary from site to site and are expected to range between 200 and 1,000 metres below ground level (mbgl). The current GGP includes the construction, operation, and decommissioning of not more than 110 coal seam gas wells and associated infrastructure, including gas and water gathering lines, within the Stage 1 GFDA.

This report is the drilling and completion report for two sets of nested monitoring bores located outside of the Stage 1 GFDA in the northern part of the Gloucester Basin.

1.1 Beyond Stage 1 drilling program

The beyond Stage 1 drilling program included the establishment of two nested groundwater monitoring sites (the Faulkland and the Bucketts Way sites) outside of the Stage 1 GDFA (Figure 1.2). The Faulkland site is located near AGL's (now plugged and abandoned) Faulkland 3 CSG well. The Bucketts Way site is located on land owned by Gloucester Resources Limited (GRL).

Installation of a dedicated water monitoring network and the collection of baseline water level and water quality attributes for each of the groundwater systems commenced in mid-2013.

The collection of groundwater quality and level data allows the natural characteristics and variability of the local groundwater systems to be explored and the conceptual understanding of groundwater systems, groundwater flow, and aquifer connectivity across the broader Gloucester Basin to be further developed. This then allows the impacts, if any, from CSG exploration activities on shallow aquifers in the vicinity of AGL's planned CSG exploration and production wells to be ascertained.

The beyond Stage 1 drilling program comprised:

- Establishment of two nested groundwater monitoring sites:
  - Faulkland (FKMB01A and FKMB01B in the Leloma Formation of the Gloucester Coal Measures).
  - Bucketts Way (BWMB01A in the Quaternary alluvium and BWMB01B, BWMB01C and BWMB01D in the Leloma Formation of the Gloucester Coal Measures).
- Installation of in situ pressure transducers (dataloggers) at all groundwater monitoring bores.
- Hydraulic conductivity testing (rising and falling head slug tests) at all groundwater monitoring bores.
- Baseline groundwater quality testing, including: field parameters, major cations and anions, dissolved metals, nutrients, dissolved methane, hydrocarbons and isotopes.

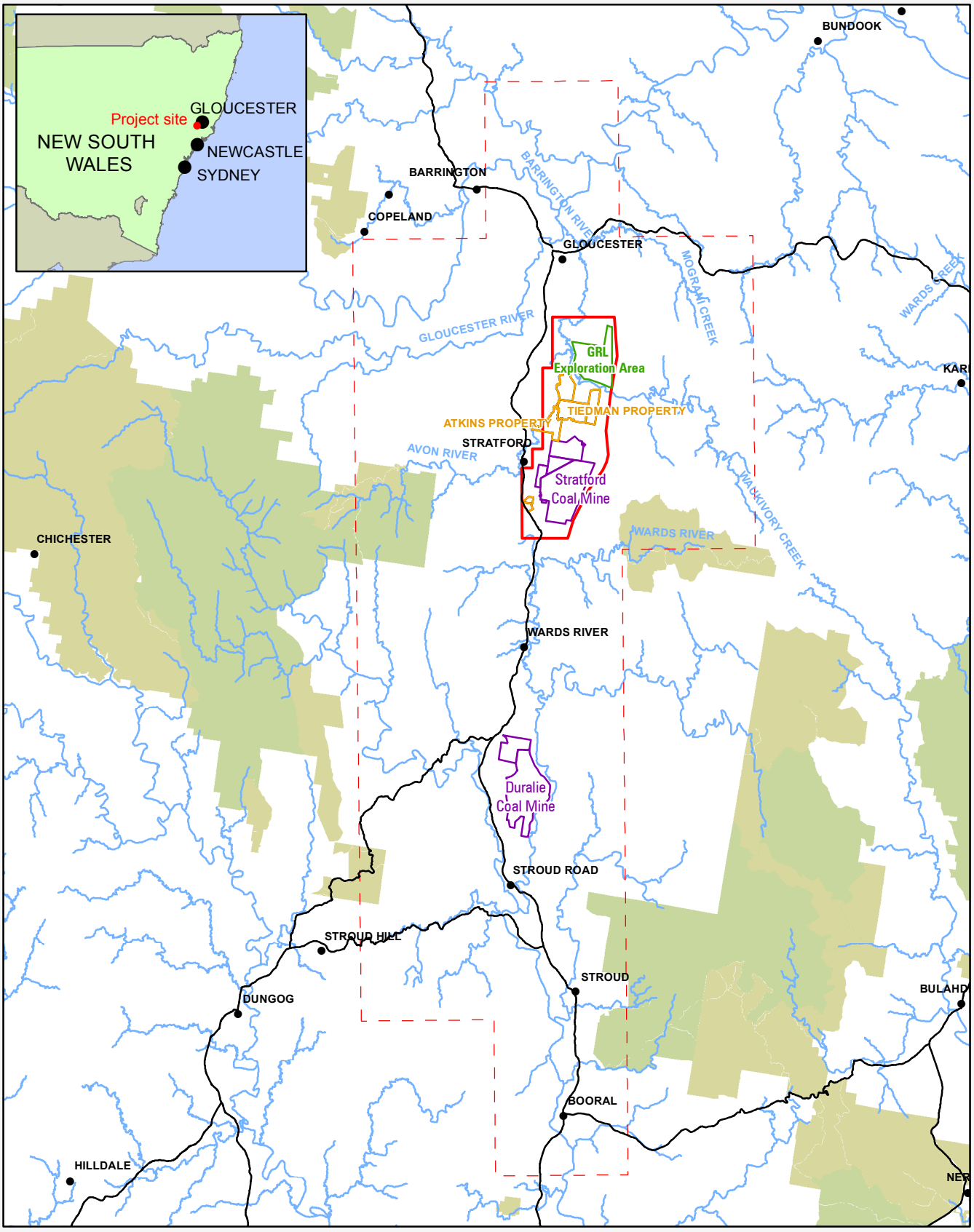
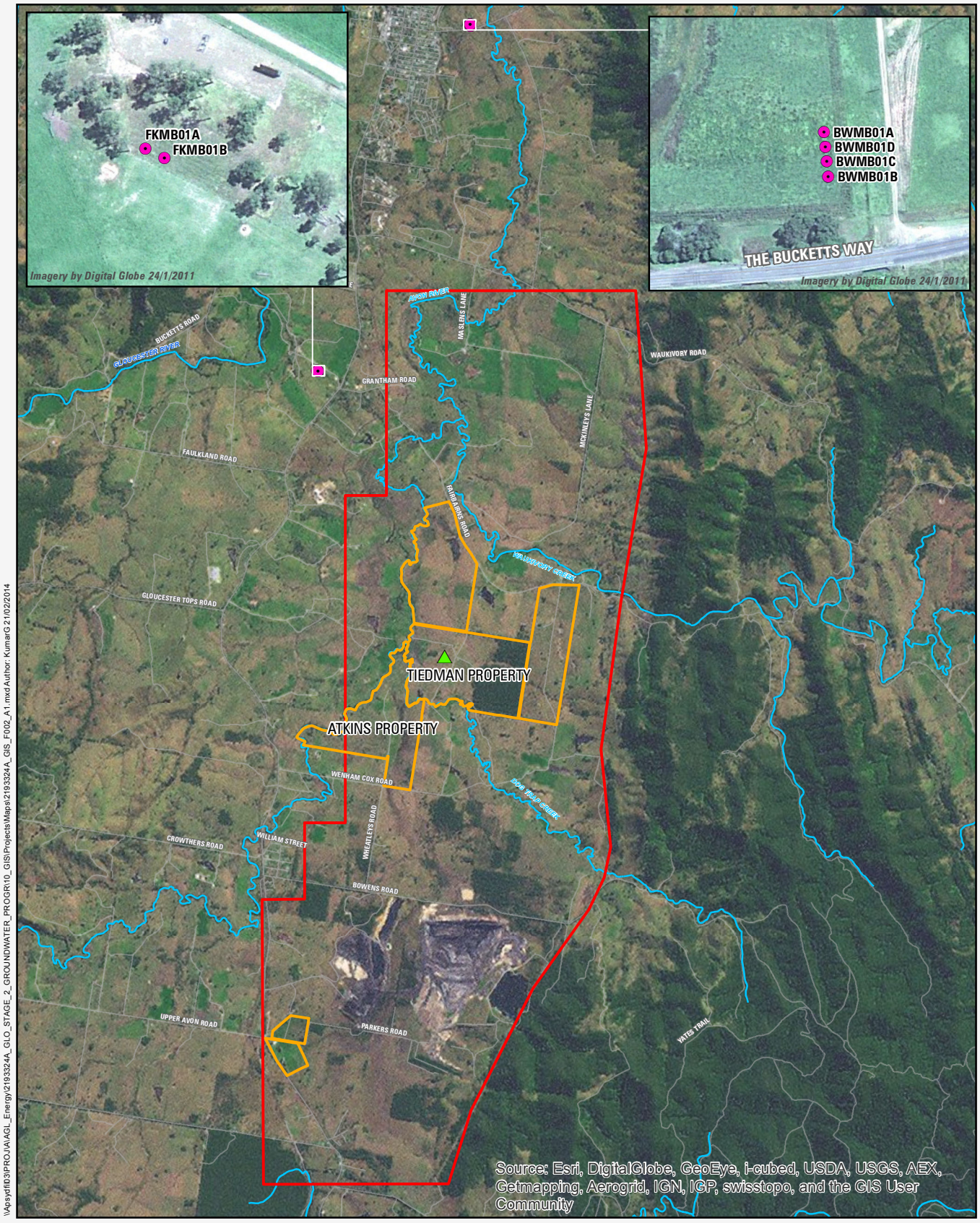


Figure 1.1
Regional Location



\\Apsydfs03\PROJ\AA\AGL_Energy\2193324A_GLO_STAGE_2_GROUNDWATER_PROGR\10_GIS\Projects\Maps\2193324A_GIS_F002_A1.mxd Author: KumarG 21/02/2014

- Groundwater monitoring bore
- AGL weather station
- Rivers and streams
- Roads
- AGL owned properties
- Stage 1 GFDA boundary

N

0 2
Kilometres

Figure 1.2
Locations of the Faulkland and Bucketts Way groundwater monitoring bores

2. Site characterisation

2.1 Site location and topography

The Faulkland site is situated approximately 5 km south of Gloucester, NSW, on the property 4337 Bucketts Way, Forbesdale. Approximately 30 m to the north of the monitoring bore site is the (now plugged and abandoned) CSG well Faulkland 3. The site is an elevated location close to the catchment divide between the Gloucester River to the west and the Avon River to the east with gently undulating hills sloping in both directions.

The Bucketts Way site is located approximately 1.5 km east of Gloucester, on the property Lot 434 Bucketts Way, Gloucester, which is owned by GRL. The site is situated on the floodplain of the Avon River which extends to the east and to the west of the monitoring bores.

2.2 Surface hydrology

The Faulkland site slopes towards the Gloucester River and Sandy Creek approximately 800 m to the west. The Bucketts Way site is located on the floodplain of the Avon River which is the primary catchment and water course within the Stage 1 area. Drainage is to the east and north.

2.3 Land use

The Faulkland site that contains both the groundwater monitoring bores FKMB01A and FKMB01B and the (now plugged and abandoned) CSG well, Faulkland 3, is situated on a dairy property in an enclosed (tree studded) paddock. The Bucketts Way site is used for low intensity cattle grazing.

2.4 Rainfall

There are four Bureau of Meteorology (BoM) weather stations within the Gloucester Basin, and an additional AGL weather station on the Tiedman property at Stratford (Figure 1.2). Average rainfall and the period of monitoring for the BoM stations are presented in Table 2.1.

Table 2.1 BoM stations in the Gloucester Basin (BoM 2014)

BoM station number	Name	Monitoring period	Long term average annual rainfall (mm)[a]
BoM 60015	Gloucester Post Office	1888 to June 2014	982
BoM 60112	Gloucester Hiawatha	1976 to June 2014	981
BoM 60042	Craven (Longview)	1961 to June 2014	1,046
BoM 61071	Stroud Post Office	1889 to June 2014	1,147

(a) Long term average annual rainfall (mm) over the monitoring period.

Long term (1888-2013) cumulative deviation from the annual mean rainfall at Gloucester Post Office (BoM station 60015) is presented in Figure 2.1. Historically, the period between July and September records the lowest monthly rainfall, while the period between January and March typically has the highest monthly rainfall.

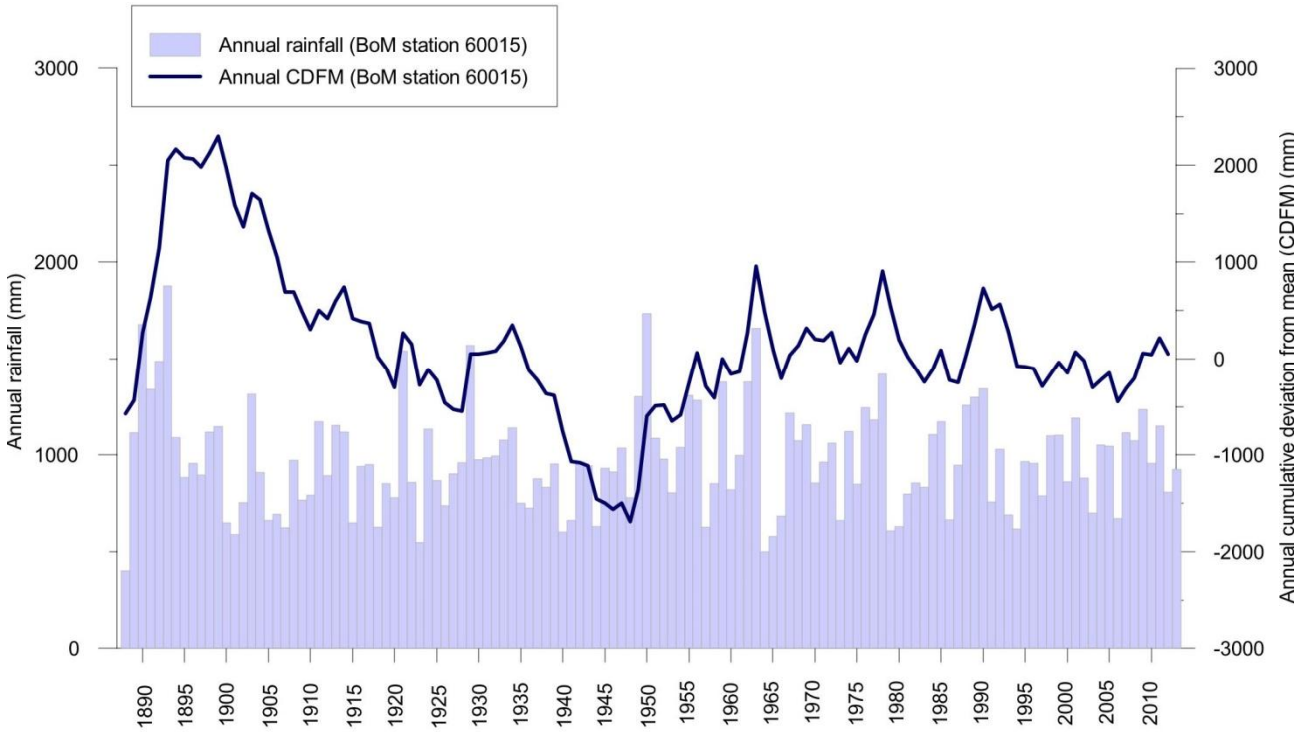


Figure 2.1 Long term annual rainfall and cumulative deviation from annual mean rainfall (CDFM) at Gloucester Post Office (BoM station 060015) (BoM 2014)

Rainfall data collected by AGL since the beginning of the monitoring period is presented in Figure 2.2. The data collected presents the same trends highlighted in the BoM data, with July and September being the driest, and January and March being the wettest periods.

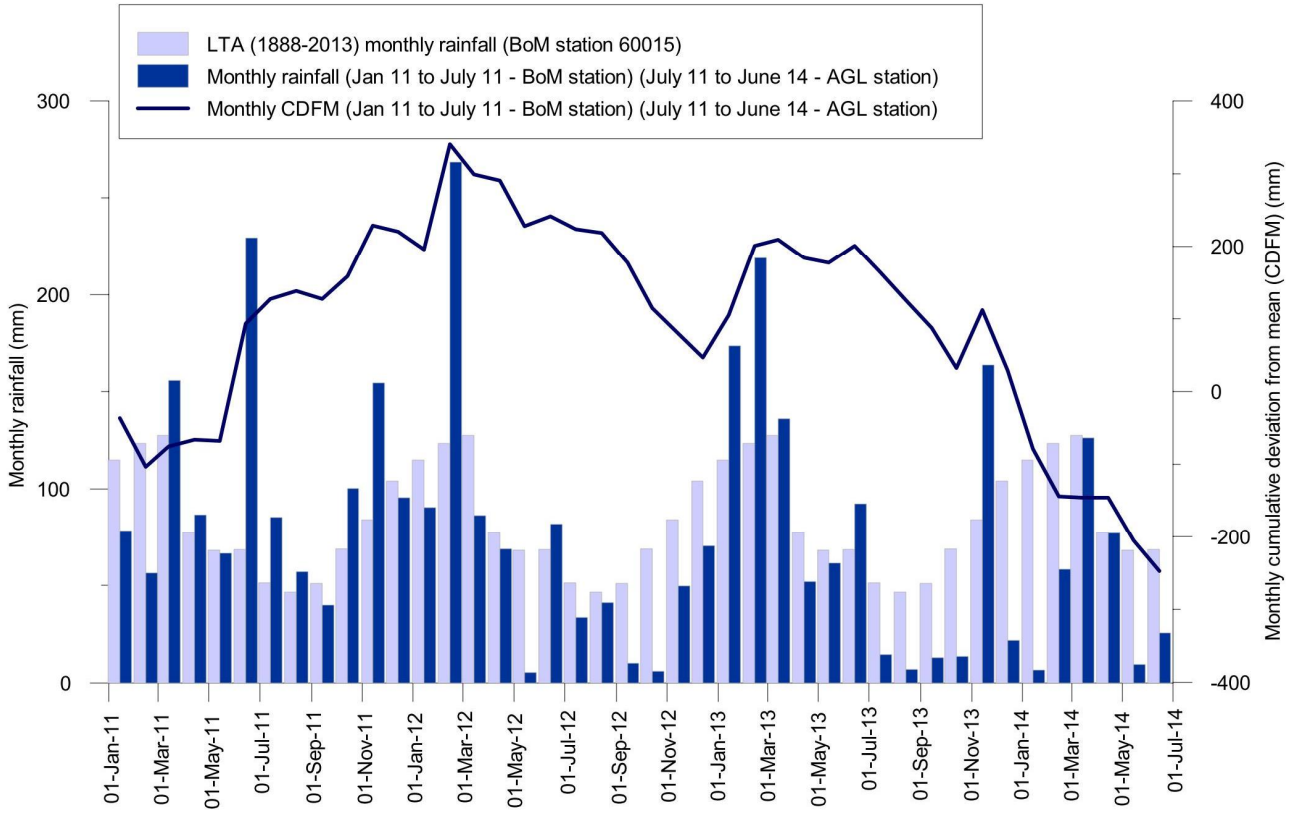


Figure 2.2 Monitoring period monthly rainfall and cumulative deviation from the monthly rainfall at the AGL Gloucester (Tiedman) Station (AGL 2014)

2.5 Geological setting

2.5.1 Regional geology

The Gloucester Basin comprises a thick succession of Permian sedimentary rocks representing deposition in both terrestrial and marine environments during a complex period of subsidence, uplift and relative sea level change (marine transgression and regression).

The Basin is a synclinal intermontane structure formed in part of the New England Fold Belt between a major Permian plate margin and the Sydney-Gunnedah Basin (Lennox 2009). The north-south trending synclinal nature of the Gloucester Basin resulted from the collision between the East Australian and Pacific Plates.

Following a period of extension during the Early Permian, the Gloucester Basin has undergone periods of normal and reverse faulting, with large scale tilting associated with late stage compressional movements towards the end of the Permian (Hughes 1984). Reverse faults dominate present day structure. A comparison with the contemporary horizontal stress field map (Hillis et al. 1998) indicates the Basin is likely to be under compression in an east-west orientation.

The stratigraphy dips steeply (up to 90°) on the flanks of the Basin, dipping towards the north-south trending synclinal Basin axis and flattening toward the centre of the Basin. Early Permian and Carboniferous hard resistive volcanics form the ridgelines of the Basin: the Mograni Range to the east, and the Gloucester and Barrington Tops to the west.

Overlying the Permian stratigraphy is a thin sequence of surficial Quaternary sedimentary deposits and regolith. The Quaternary sediments are non-uniform in thickness, and comprise unconsolidated alluvial

sediments (sand, gravel, silt and clay) along the drainage channels and colluvial deposits across the rest of the plain sourced from the surrounding outcropping Permian deposits.

2.5.2 Stratigraphy of the investigation area

The Gloucester Basin is divided into three major Permian stratigraphic units each representing a distinct depositional setting: the Gloucester Coal Measures, the Dewrang Group, and the Alum Mountain Volcanics. The generalised stratigraphy of the Basin is summarised in Table 2.2. A geological map of the Basin is shown in Figure 2.3.

The CSG development in the Stage 1 GFDA is targeting the intermediate and deep coal seams in the Gloucester Coal Measures generally below depths of 200 m to around 1000 m (Parsons Brinckerhoff 2012).

2.5.3 Structural geology of the investigation area

The tectonic development and structural setting of the Gloucester-Stroud Syncline is discussed by Roberts et al. (1991) based on regional geological mapping and seismic profile interpretation. Subsequent structural interpretations have been carried out by SRK (2005) and Lennox (2009). The following summary is based on those reports.

The Gloucester-Stroud Syncline is the largest structure in the surrounding region, being more than 55 km long and 24 km wide with steeply dipping limbs containing a stratigraphic section up to 8 km thick (Roberts et al. 1991). The syncline has a sinuous axial trace that trends generally northerly (355°) but that swings eastwards (022°) between Stratford and Gloucester. The syncline is doubly plunging, closing at both ends forming a tight canoe-like structure. The axial plane is inclined slightly to the east; bedding in the limbs of the syncline tends to dip steeply toward the axis at more than 60°, with some bedding sub-vertical or slightly overturned.

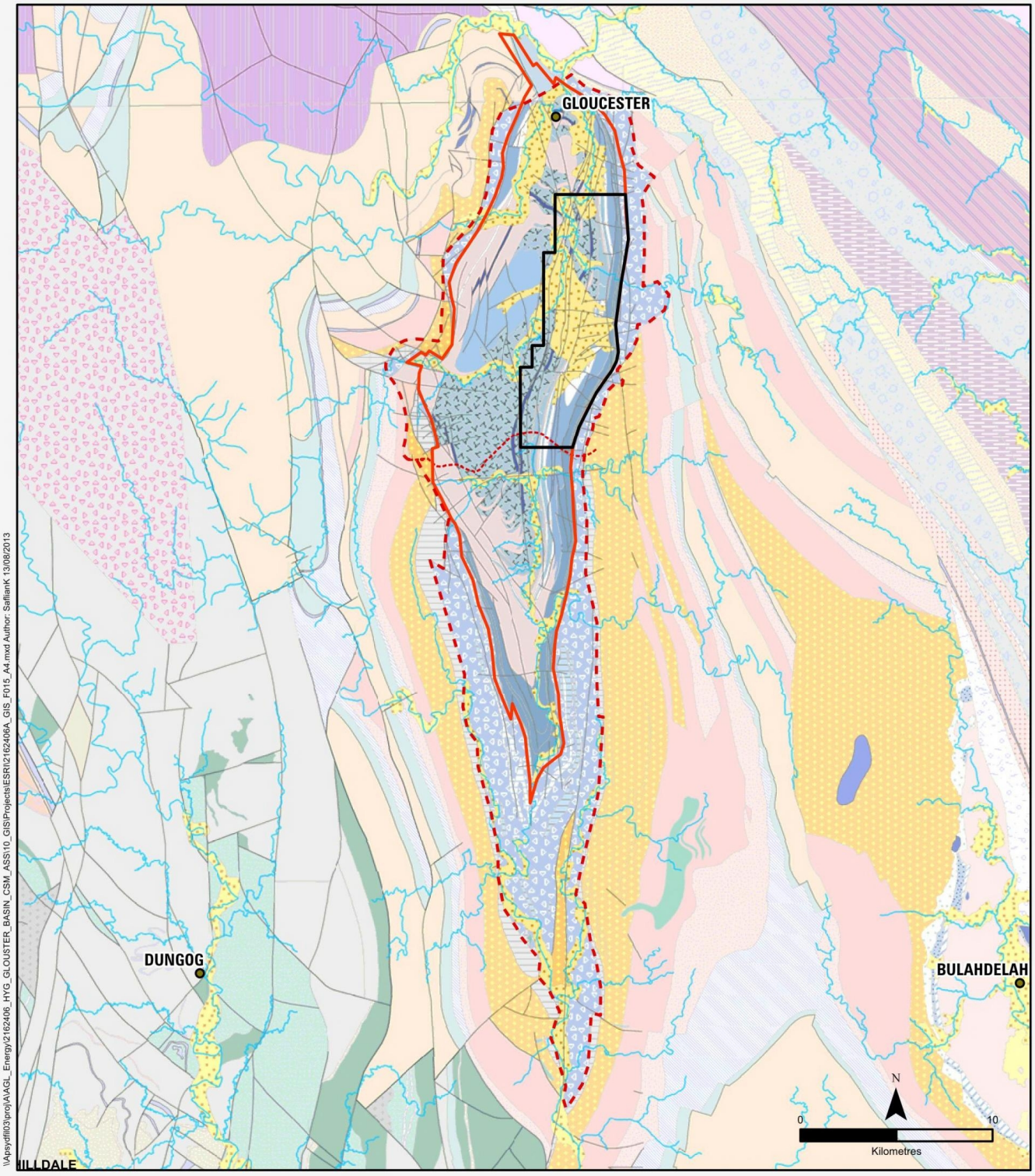
The syncline is a fault bounded trough, active during the Permian. Roberts et al. (1991) identify up to six deformation events that were important in the depositional and structural development of the Basin. SRK (2005) simplified the structural development into two main stages:

- Early – Middle Permian dextral tectonic margin, resulting in reactivation of NNW-striking faults as strike-slip dextral, and formation of NE and EW striking normal faults, particularly around the margins of a circular basement feature (suspected deep intrusion) in the northern part of the Basin. The majority of the coal measures were deposited during this complex phase.
- Late Permian NE shortening during the early stages of the Hunter Bowen Orogeny, resulting in reverse and thrust faulting on NNW faults and some NNE faults.

Combining structural domains with the known distribution of stratigraphy, SRK (2005) divides the Basin into three structure/stratigraphic domains:

1. An eastern domain containing a number of coal seams in the Avon and Craven Sub-Groups.
2. A western domain where the surface mapping indicates sequences of Waukivory Formation and Wards River Conglomerate that mark periods of prograding fluvial systems that have significantly reduced the thickness of coal seams.
3. Major fault zones that separate the eastern and western domains.

In addition, SRK (2005) identifies a possible basement structure or intrusion overlapping with the northern part of the Basin that appears to have influenced the structural development of the Basin. The margin of that structure coincides with arcuate and east-west faulting in the mid part of the Basin (e.g. west of Stratford) and may account for the contrasting deformation styles in the Carboniferous basement rocks to the north and south of this approximate line.



Alum Mountain Volcanics boundary
Permian Coal Measures boundary
Stage 1 GFDA boundary
Rivers and streams

Gloucester Basin Geology

- Qa Quaternary Alluvium
- G Unnamed microgranite

Permian Geology

- Plc Crowthers Rd Conglomerate
- Pll Leloma Formation
- Pllj Jo Doth Tuff Member
- Plo Jilleon Formation
- Plw Wards River Conglomerate
- Pla Wards River Conglomerate
- Plgx Gloucester Coal Measures
- Plh Wenham Formation
- Plp Speldon Formation
- Plt Dog Trap Creek Formation
- Pli Waukivory Creek Formation
- Pldy Mammy Johnsons Formation
- Plde Weismantels Formation
- Pldd Duralie Road Formation
- Pea Alum Mountain Volcanics
- Pear Unnamed Rhyolite Member
- Peat Unnamed Welded Tuff Member
- Peac Unnamed Basal Sequence

Carboniferous geology

- Clo1 Johnsons Creek Conglomerate
- Clkm McInnes Formation
- Clr Booral Formation
- Fault

Figure 2.3
Regional geology

Table 2.2 Stratigraphy of the Gloucester Basin

Period	Group	Sub-group	Formation	Approx. thickness (m)	Coal seam	Depositional environment	Tectonic events
Upper Permian	Gloucester Coal Measures	Craven	Crowthers Road Conglomerate	350		Marine regression, progradation of alluvial fans	Uplift to west of Gloucester Basin
			Leloma	585	Linden		
					Jo Doth		
					Bindaboo		
					Deards		
			Jilleon	175	Cloverdale		
					Roseville		
					Tereel/Fairbairns		
			Wards River Conglomerate	Variable			
			Wenham	23.9	Bowens Road		
					Bowens Road Lower		
		Speldon Formation				Marine transgression but also some progradation of alluvial fans in the west related to uplift	Extension (normal fault development) and regional subsidence. Uplift to west of Basin
		Avon	Dog Trap Creek	126	Glenview		
			Waukivory Creek	326	Avon		
					Triple		
					Rombo		
					Glen Road		
					Valley View		
					Parkers Road		
	Dewrang	Mammy Johnsons		300	Mammy Johnsons	Marine transgression, regression and further marine transgression	Extension (normal fault development) and regional subsidence
		Weismantel		20	Weismantel		
		Duralie Road		250			
Lower Permian	Alum Mountain Volcanics				Clareval	Arc-related rift	
					Basal		

Modified from AECOM (2009) and SRK (2005).

2.6 Hydrogeological setting

Four broad hydrogeological units have been identified within the Gloucester Basin (Table 2.3). The permeability and groundwater flow characteristics of rocks within the Gloucester Basin are controlled by several factors including lithology, depth, and the degree of fracturing and faulting. In this sense hydrogeological units and flow systems do not always correspond with defined geological boundaries.

Table 2.3 Four key hydrogeological units

Unit	Aquifer type	Formation name	General lithology	Hydraulic characteristics
Alluvium	Semi-confined, clay capped, porous, granular	Quaternary alluvium	Clay/mixed gravels	Heterogeneous, highly variable permeability associated with varying lithology
Shallow Rock (<150 m)	Semi-confined, fractured rock	Upper Permian Coal Measures, Alum Mountain Volcanics	Interbedded sandstone/siltstone with bedding plane fractures	Heterogeneous, high and low permeability domains associated with fault zones and fracturing
Interburden	Confined, fractured rock	Upper Permian Coal Measures	Interbedded indurated sandstone/siltstone and claystone	Low permeability associated with sparse fractures, permeability decreases with depth
Coal Seams	Confined, fractured rock	Upper Permian Coal Measures	Coal/shale	Low permeability associated with cleating and fractures in coal seams, permeability decreases with depth

The four hydrogeological units are summarised as follows (Parsons Brinckerhoff 2012):

1. **Alluvial deposits** adjacent to major creeks and rivers comprising unconsolidated sand, gravel and clay. These deposits are typically 12 to 15 m thick. These systems are heterogeneous but generally permeable with rapid recharge, through-flow and discharge associated with interactions with streams, and to a lesser extent with the underlying less permeable shallow rock. Hydraulic conductivity measurements range from 0.3 to 300 m per day (m/d), averaging around 10 m/d.
2. **Shallow fractured rock** comprising variably weathered and fractured Permian rocks extending to approximately 150 m below the surface, across all sub-cropping Permian units. The shallow rock zone is highly heterogeneous with relatively impermeable domains separated by more permeable domains, but on the whole it is more permeable that the deeper coal measures. The higher permeability domains are due to a higher density of fracturing associated with an irregular weathering profile and the near-surface expression of faulting. Shallow aquifers observed during drilling occur within 75 m of surface. Groundwater flow within this zone is more strongly controlled by weathering and fracturing than the attitude of geological strata. Hydraulic conductivity of the shallow rock ranges from 10 m/d to 1 x 10^{-6} m/d at a depth of 150 m, but is typically in the order of 10^{-3} to 10^{-4} m/d.
3. **Deep Coal Measures interburden**. Sandstone and siltstone units that form the interburden to coal seams are indurated and typically of very low permeability, forming aquitards and confining layers. The permeability of the interburden decreases with depth such that, at the maximum depth of CSG exploration, is likely to be in the order of 10^{-5} to 10^{-7} m/d, or less.
4. **Deep coal seams** tend to be slightly more permeable than the interburden and commonly form weak water bearing zones. Permeability and storage are provided by small fractures and cleats in the coal. As with the interburden, drill-stem tests clearly show that the permeability of coal seams generally

decreases with depth. At the maximum depth of CSG exploration, the permeability of the coal seams is very low (10^{-4} to 10^{-6} m/d), but may be an order of magnitude higher than the interburden.

The Alum Mountain Volcanics underlie the Permian Coal Measures, and form the impermeable base of the Gloucester Basin. The Alum Mountain Volcanics outcrop in the eastern and western boundaries of the Basin, forming the elevated topography of the Gloucester and Barrington Tops to the west, and the Mograni Range to the east.

3. Drilling program

Parsons Brinckerhoff was the Principal Contractor for the entire site investigation program and provided all project management services and managed all subcontractors. A drilling specification and program was developed for the two sites (Parsons Brinckerhoff 2013a).

The objective of the drilling program was to target the alluvium at the Bucketts Way site and the Leloma Formation at both the Bucketts Way and Faulkland sites. The Bucketts Way site was installed to assess whether there was natural upward flow in this portion of the Basin and to assess the degree of interaction between groundwater in the alluvium and groundwater in the underlying shallow fractured rock. The Faulkland site was located at an elevated position on the catchment divide to determine the depth to groundwater and whether there is downward flow indicative of a potential groundwater recharge zone at the divide.

Objectives were achieved by establishing nested monitoring bores so that the groundwater systems at different depths could be characterised. Establishing nested monitoring bores also provides a network capable of assessing temporal trends and any vertical connectivity during both natural climatic cycles and during any future pilot testing or production programs.

Parsons Brinckerhoff supplied all the required technical services including geological, hydrogeological and surveying services. The subcontractors engaged to complete the site investigation program were:

- Highland Drilling (all drilling and bore completions)
- Water N Tipper Hire Pty Ltd (all fresh water deliveries)
- Mid Coast Liquid Waste Pty Ltd (all offsite water and mud disposal)
- CalCo Surveyors Pty Ltd (all surveying services).

3.1 Health, safety and environment

Onsite health, safety and environment issues were managed through a health, environment safety plan (HESP) (Parsons Brinckerhoff 2013b), construction and environment management plan (CEMP) (Parsons Brinckerhoff 2013c), and safety management plan (SMP) (Parsons Brinckerhoff 2013d); these documents were prepared in advance of the drilling program and were reviewed and approved by AGL's safety team. Highland Drilling (nominated drilling contractors for the works) provided safe work method statements (SWMS) (Highland Drilling 2013a) and job safety analyses (JSA) (Highland Drilling 2013b) covering works relating to the drilling and construction of the boreholes, these documents were also reviewed and approved by AGL.

All Highland Drilling and Parsons Brinckerhoff staff and any site visitors were required to undergo a drill site induction during which they were given an overview of the commitments included in the HESP, SMP, and CEMP and how these applied to their specific duties.

3.1.1 Health, Environment and Safety Plan

Prior to the commencement of the field based phase of the project, Parsons Brinckerhoff developed a comprehensive site specific HESP for the supervision of drilling work and groundwater monitoring activities at the Gloucester sites: *Health, Environment and Safety Plan (HESP) AGL – Gloucester Groundwater Investigations* (Parsons Brinckerhoff 2013b). This plan detailed the planned field tasks and the associated risk, and introduced risk mitigation measures to manage the risks. Measures include: risk elimination, substitution and implementation of controls, and training and use of personal protective equipment (PPE).

3.1.2 Safety Management Plan

The installation of the monitoring bores was conducted in accordance with the SMP which was developed by Parsons Brinckerhoff in collaboration with Highland Drilling and approved by AGL (Parsons Brinckerhoff 2012c). The SMP should be read in conjunction with the following AGL and Highland Drilling documents which together cover the health, safety and environmental working procedures for AGL's GGP:

- Gloucester Gas Project Health and Safety Management Plan (AGL 2013a)
- Gloucester Gas Project Emergency Response Procedure (AGL 2013b)
- Upstream Gas Golden Rules (AGL 2010)
- Standard Work Method Statement – Gloucester drilling task (Highland Drilling 2013a)
- Job Safety Analysis – Gloucester drilling (Highland Drilling 2013b).

All fieldwork undertaken at the Gloucester drill sites was covered under the aforementioned documents including exploratory drilling and subsequent testing, and groundwater monitoring and sampling. These documents aim to ensure that the health, safety and welfare of Parsons Brinckerhoff employees and subcontractors are upheld through systematically identifying and documenting hazards, and assessing and controlling the associated risks.

Prior to the commencement of the field program, a desktop risk assessment for the drilling and construction of each borehole was undertaken, as per the requirements of the SMP. Taking into consideration the borehole depth and the likely strata to be drilled through (i.e. faults and/or producing coal seams) the bores were assessed to have a high, medium or low risk of intersecting gas. The risk rating determines the construction method and level of well control required i.e. the practices used to prevent and/or manage the influx of formation fluids/gas in the borehole (blowouts) and this is often via the use of a Blowout Preventer (BoP) and drill muds.

All monitoring bores at both locations were assessed to be low risk. Consequently drilling was mostly carried out underbalanced using air rotary drilling methods.

3.1.3 Construction and Environment Management Plan

All site operations were undertaken in accordance with the environmental management systems as detailed in a site specific CEMP.

A detailed water management plan was a critical part of the CEMP detailing the stringent measures implemented to ensure compliance to zero discharge of produced (drilling) waters to adjacent land and surface water receivers. In summary:

- All water utilised during the drilling process was supplied by AGL through Water N Tipper Hire Pty Ltd and stored in above ground storage tanks onsite prior to use.
- All groundwater produced during the drilling operations was contained in above ground storage tanks. If the capacity of the tanks reached 80%, work on that bore ceased until excess water in the tanks could be tankered offsite.
- All cuttings produced during drilling were also contained in above ground tanks and were dried and used for internal farm track maintenance on AGL's Tiedman property.
- All groundwater produced during the drilling was collected by Mid Coast Liquid Waste Pty Ltd and transported to AGL's Tiedman property, where water from the exploration programs is currently stored in specific (lined) dams.

Run-off waters from rainfall events were diverted from the drilling areas (where required) by the construction of diversion bunds on the up-gradient side of the site. Water from the drill pads and any access tracks

constructed was diverted away by sand bag bunds, silt fencing and other control structures so as to direct water onto adjacent grassed areas and not erode the drill pads, fire trail and track areas.

3.1.4 Wellsite Permit to Work System

The internationally recognised Wellsite Permit to Work System (www.wellsite.org.au) was utilised for the GGP groundwater drilling program. The system provides the means to manage field safety aspects in a systematic, formalised and auditable manner for non-routine tasks which are not covered in the health and safety plan and JSAs. As a standardised work planning mechanism, the Permit to Work System was used to issue hot work, cold work and pressure work permits, ensuring the individual undertakes a documented work plan and assessment of the risks.

3.2 Groundwater monitoring bore drilling and construction

Between June and July 2013, two groundwater monitoring bores were drilled and constructed at the Faulkland site. In October 2013 four groundwater monitoring bores were drilled and constructed on the Bucketts Way site. AGL submitted a Category 1 notification together with the required Site Disturbance Notices to the Division of Resources and Energy (DRE) under the reconnaissance drilling program requirements of PEL 285. Test (monitoring bore) licences under the Water Act 1912 were obtained by AGL prior to the monitoring bore drilling program as summarised in Table 3.1 and shown in Appendix A.

The drilling and completion of the groundwater monitoring bores was carried out in accordance with the NSW Office of Water (NOW) bore licence conditions and followed a detailed design and specification compliant with the *National Uniform Drillers Licencing Committee (NUDLC) 2012, Minimum Construction Requirements for Water Bores in Australia, Edition 3*.

Table 3.1 Monitoring bore licences

NOW Licence No.	No. of locations	Local bore ID		Site location (property)	Lot	DP	Bore type
20BL173512	2 bores	FKMB01A	FKMB01B	Faulkland	1	877783	Monitoring
20BL173447	4 bores	BWMB01A BWMB01B	BWMB01C BWMB01D	GRL site: Bucketts Way	430	192505	Monitoring

The drilling of all bores was undertaken by Highland Drilling, using a rotary drilling rig under the supervision of a Parsons Brinckerhoff hydrogeologist. The target depth of all boreholes was confirmed by the supervising Parsons Brinckerhoff hydrogeologist. Geological bore logs are included in Appendix B.

Table 3.2 summarises the bore construction details.

Table 3.2 Bore construction details

Monitoring bore	Borehole diameter (mm)	Predominant drill bit	BoP and muds	Ground elevation (mAHD)	Depth of surface casing (mbgl)	Total depth (mbgl)	Screened interval (mbgl)	Screened interval (mAHD)	Screened formation	Hydro-stratigraphic units	Construction details
FKMB01A	139	Air hammer	N/A	139.97	5.0	54.0	44.0 – 53.0	96.6 – 87.6	Leloma	Sandstone	50 mm uPVC casing and screen
FKMB01B	139	Air hammer	N/A	140.13	5.0	150.2	140.2 – 149.2	0.5 – -8.5	Leloma	Sandstone	50 mm galvanised steel casing and screen
BWMB01A	205	Blade	N/A	88.53	3.0	11.6	6.5 – 9.5	82.6 – 79.6	Alluvium	Gravel	50 mm uPVC casing and screen
BWMB01B	153	Casing advance/Tubex	N/A	88.68	13.2	21.0	14.0 – 20.0	75.1 – 69.1	Leloma	Sandstone	50 mm uPVC casing and screen
BWMB01C	139	Air hammer	N/A	88.61	16.2	81.4	67.4 – 79.4	21.8 – 9.8	Leloma	Sandstone	50 mm uPVC casing and screen
BWMB01D	139	Air hammer	N/A	88.59	5.0	162.6	149.6 – 161.6	-60.5 – -72.5	Leloma	Sandstone/siltstone	50 mm galvanised steel casing and screen

mAHD = metres Australian Height Datum.
mbgl= metres below ground level.

3.2.1 Quaternary alluvial monitoring bore

The alluvial monitoring bore drilled at the Bucketts Way site (BWMB01A) was intended to target the deep alluvium and was initially drilled with a 205 mm blade bit. Large alluvial gravels that fined with depth were encountered from 6 m onwards causing the bore to collapse and preventing further drilling and installation. As a result, the bore was converted to a shallow alluvial bore and screened in the gravel from 6.5 to 9.5 mbgl.

Across the Avon River floodplain in the northern portion of the Gloucester Basin, the depth of alluvium encountered during drilling ranged from 5 to 18 mbgl. There was little groundwater inflow while drilling through the alluvium (some minor seeps of less than 0.1 litres per second (L/s)), likely due to the long dry period prior to drilling.

3.2.2 Permian Gloucester Coal Measures bores

Five monitoring bores were installed into the Leloma Formation in the Craven sub group of the Gloucester Coal Measures at the Faulkland (two monitoring bores) and Bucketts Way sites (three monitoring bores). These bores target the first fractured rock zone within the uppermost 50 m and the second major fracture within the next 100 m (to approximately 150 mbgl).

At the Faulkland site the weathered profile was encountered at 5 mbgl, and fresh Leloma Formation at 18 mbgl. At FKMB01A the Leloma Formation comprised of predominately tight siltstones and fine to medium grained sandstone. The shallow screened section was completed in the sandstone (44.0 – 53.0 mbgl) which had the highest groundwater inflow at 0.1 L/s. At the deeper bore (FKMB01B) more fine to medium grained sandstone was encountered with layers of siltstone throughout. The screen was placed in the fine to medium grained sandstone (140.2 – 149.2 mbgl) with an inflow of <0.1 L/s. The highest groundwater inflow of 0.2 L/s was recorded in a fracture zone between 84 – 90 mbgl.

The geology encountered during the drilling of the Bucketts Way bores was similar to that at the Faulkland site with alternating layers of siltstone and sandstone, with the addition of numerous minor coal seams. BWMB01B was drilled with a 153 mm winged air hammer using the Tubex casing advance technique to prevent the alluvial gravels from collapsing. BWMB01B was screened (from 14 to 20 mbgl) into the top of the weathered sandstone. BWMB01C was completed in medium grained sandstone (screened 67.4 – 79.4 mbgl) with a peak (airlift) groundwater inflow at 78 mbgl of 7.6 L/s. The deepest bore (BWMB01D) was screened across siltstone and sandstone (screened 149.6 – 161.6 mbgl) with the peak (airlift) inflow of 16.2 L/s at 156 mbgl in the fine grained sandstone.

3.2.3 Airlifting

Airlift development was continuous during drilling and the air rotary boreholes were further developed after the construction of each monitoring bore until the groundwater was free of sediment and the water quality field parameters stabilised.

3.2.4 Logging

A detailed geological log of the lithology recorded at 1 m intervals was produced, and instantaneous water flow recorded at the end of each drill rod (every 6 m) where applicable. Water quality field parameters measured (using a calibrated hand-held water quality meter) were: temperature, electrical conductivity, pH, dissolved oxygen and oxidation reduction potential (redox). These parameters are shown on the geological bore logs provided for each monitoring bore in Appendix B.

3.2.5 Borehole construction

Following the drilling of the bores to the target depth/formation, a Parsons Brinckerhoff hydrogeologist finalised the specifications and design of the groundwater monitoring bore installations.

The alluvial monitoring bore (BWMB01A) and the shallow fractured rock monitoring bores (FKMB01A, BWMB01B and BWMB01C) were installed with 50 mm internal diameter, Class 18 uPVC screwed casing and screen (0.5 mm aperture machine slotted) with a 1 – 2 m sump and end plug.

Deep fractured rock monitoring bores FKMB01B and BWMB01D were installed with 50 mm internal diameter, galvanised steel, screwed casing and stainless steel screen (1 mm aperture slots) with a 1 m galvanised steel sump and end cap.

The screen length at each bore targeted the most productive water bearing zone. A washed and graded (3 – 5 mm) gravel filter pack was installed in the annulus around the screen and extended 1 – 5 m above the screened section in all bores.

Coated bentonite pellets were then installed above the gravel pack. At the alluvial monitoring bore a 0.7 m thick plug of bentonite was installed above the gravel pack, while for FKMB01A, FKMB01B, BWMB01B, BWMB01C and BWMB01D a 3 to 5 m thick plug of bentonite was installed above the gravel pack. A cement grout mix was then tremmied in a controlled manner back to surface. The bentonite seal and cement grout ensure hydraulic isolation of the screened section preventing any flow of groundwater through the annulus of the bore column. Following the construction of each bore, the site was reinstated and a lockable steel monument installed around the bores, surrounded at its base by a concrete slab.

3.2.6 Survey

Registered surveyors CalCo Surveyors Pty Ltd surveyed the location and height of all the groundwater monitoring bores under the supervision of Parsons Brinckerhoff. All bores were surveyed to MGA, a grid coordinate system based on the Universal Transverse Mercator projection and the Geocentric Datum of Australia 1994. The bores were also surveyed for surface elevation to Australian Height Datum (AHD) (Table 3.3).

Table 3.3 Monitoring bore survey coordinates and elevations

Monitoring bore	Easting	Northing	Ground level elevation (mAHD)	Top of casing level elevation (mAHD)
FKMB01A	400584.36	6453225.96	139.97	140.61
FKMB01B	400594.73	6453220.69	140.13	140.68
BWMB01A	402829.65	6458307.06	88.53	89.09
BWMB01B	402831.92	6458282.83	88.68	89.13
BWMB01C	402831.05	6458291.15	88.61	89.16
BWMB01D	402830.38	6458299.11	88.59	89.13

mAHD = metres Australian Height Datum.
mbgl = metres below ground level.

4. Permeability testing

Falling and rising head ('slug') tests were conducted at all monitoring bores to estimate the horizontal hydraulic conductivity of each of the screened intervals. Hydraulic conductivity is the permeability of the formation with respect to the porous flow of water.

A falling head test is achieved by introducing a volume of water or solid 'slug' to displace the water column within the monitoring bore causing the water level to instantaneously rise and flow from the bore into the aquifer via the screen. A rising head test is the opposite, where a volume of water (or a solid slug) is instantaneously removed from the groundwater monitoring bore, causing the water level to fall, drawing water into the bore from the aquifer. The time it takes for the water level in the bore to recover to pre-test levels is related to the permeability of the host formation. Rising and falling head tests sometimes produce slightly different results and therefore each bore is tested three times (falling, rising, then falling again).

At the commencement of the test, the standing water level (SWL) was measured from a fixed reference point at the top of casing and the datalogger programmed between 0.125 second to 1 second intervals to measure rapid changes in water level within the bore.

Test data were processed and analysed using the appropriate Bouwer and Rice (Bouwer 1989), or Hvorslev (1951) method with AQTESOLV Version 4.5. Results are presented as estimates of hydraulic conductivity (as m/day) in Table 4.1 and Figure 4.1. The AQTESOLV reports are included in Appendix C.

The permeability values are consistent with previous hydraulic conductivity values at the Waukivory site (Parsons Brinckerhoff 2014b).

Table 4.1 Hydraulic conductivity results from slug tests

Monitoring bore	Screened section (mbgl)	Lithology	Formation	No. of tests	Hydraulic conductivity range (m/day)	Mean Hydraulic conductivity (m/day)
FKMB01A	44.0 – 53.0	Sandstone	Leloma	2	0.0005 – 0.0009	0.00065
FKMB01B	140.2 – 149.2	Sandstone	Leloma	1	0.0003	0.0003
BWMB01A	6.5 – 9.5	Gravel	Alluvium	3	7.32 – 17.54	10.85
BWMB01B	14.0 – 20.0	Sandstone	Leloma	4	8.23 – 15.63[a]	12.17
BWMB01C	67.4 – 79.4	Sandstone	Leloma	4	9.99 – 14.13[a]	11.46
BWMB01D	149.6 – 161.6	Sandstone/siltstone	Leloma	4	0.166 – 0.187	0.178

(a) High result which may represent a zone of fracturing and/or be affected by the long screened interval and the sizable gravel pack (BWMB01C).

mbgl = metres below ground level.

All analysis conducted with the Hvorselv method except for BWMB01A where the Bower – Rice method was applied.

Permeability	Permeable				Semi-Permeable				Impermeable				
Aquifer	Good						Poor		None				
Unconsolidated Sediments	Well Sorted Gravel		Well Sorted Sand or Sand & Gravel			Very Fine Sand, Silt, Loess, Loam		Layered Clay		Unweathered Clay			
Consolidated Rocks	Highly Fractured Rocks				Oil Reservoir Rocks			Fresh Sandstone		Fresh Limestone, Dolomite		Fresh Granite	
κ (cm^2)	0.001	0.0001	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}	10^{-15}
κ (millidarcy)	10^{+8}	10^{+7}	10^{+6}	10^{+5}	10000	1000	100	10	1	0.1	0.01	0.001	0.0001
K (cm/s)	10^{2}	10	10^{0}=1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
K (m/d)	86400	8640	864	86.4	8.64	0.864	0.0864	0.00864	0.000864	8.64E-05	8.64E-06	8.64E-07	8.64E-08

Alluvium
Leloma Formation - Faulkland monitoring bores
Leloma Formation - Bucketts Way monitoring bores

κ = permeability
K = hydraulic conductivity

Figure 4.1 Aquifer permeability summary

5. Groundwater levels

This section presents the initial baseline groundwater level monitoring results. Hydrographs showing groundwater levels and rainfall from the start of monitoring until early June 2014 are presented in Figure 5.1 and Figure 5.2. Individual hydrographs for each monitoring bore are included in Appendix D.

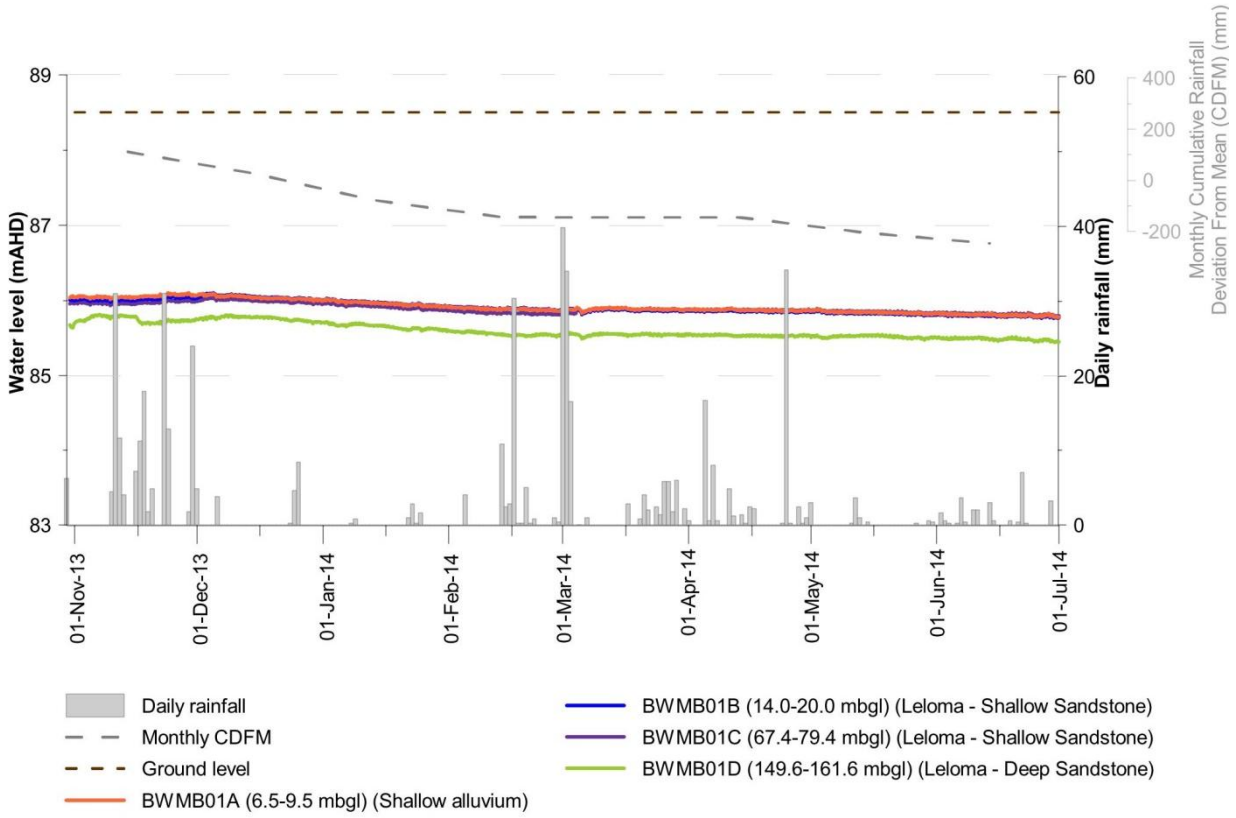


Figure 5.1 Groundwater levels at the Bucketts Way site

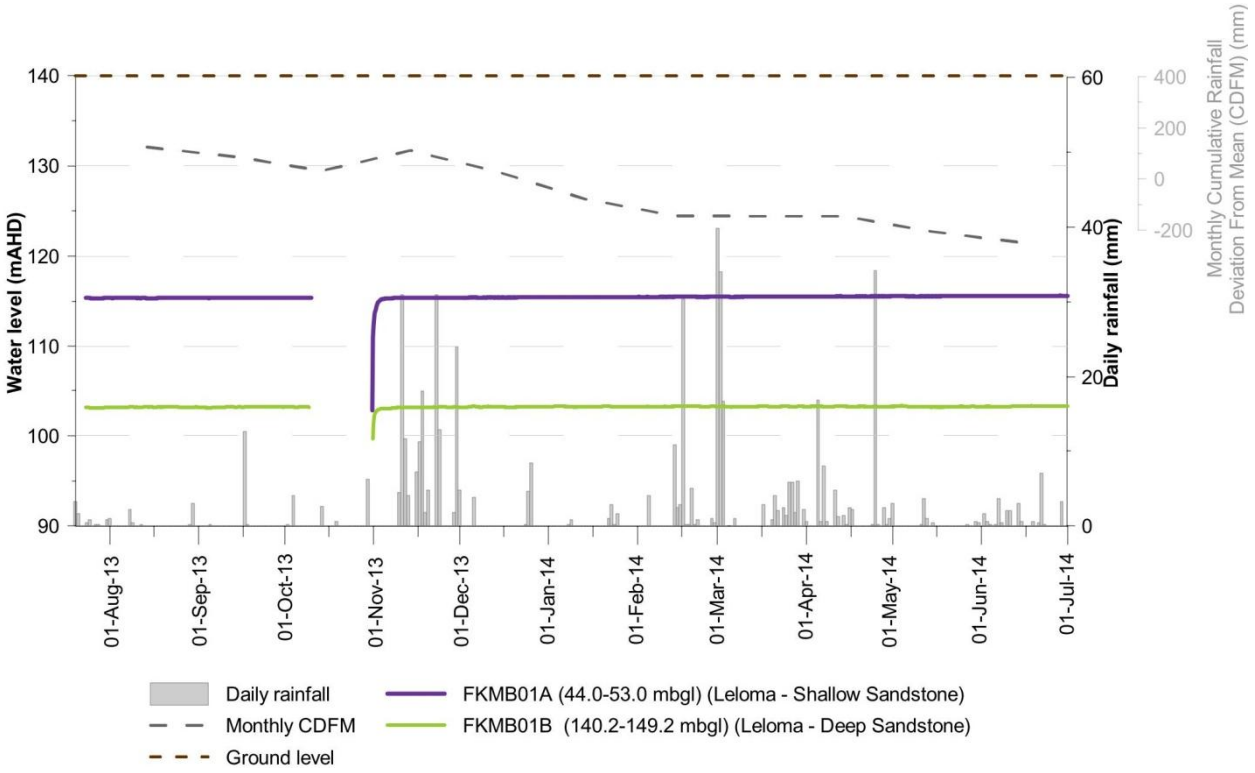


Figure 5.2 Groundwater levels at the Faulkland site

Following the completion of each monitoring bore, *in situ* pressure transducers (dataloggers) were suspended from a galvanised steel wire in the water column and programmed to record a groundwater level measurement every six hours. To verify the level recorded by the dataloggers, manual measurements are recorded quarterly using an electronic dip meter.

A barometric logger installed above the water table at monitoring bore WKMB02 (part of the original Stage 1 groundwater monitoring network) records changes in atmospheric pressure. Data from this logger are used to correct for the effects of changing barometric pressure and barometric efficiency on groundwater levels. Initial manual groundwater level measurements following bore installation are presented in Table 5.1.

Table 5.1 Initial manual groundwater levels

Bore ID	Date	Screened formation	Ground elevation (mAHD)	Groundwater level (mbgl)	Groundwater level (mAHD)
FKMB01A	10/10/2013	Leloma	139.97	24.6	115.3
FKMB01B	9/10/2013	Leloma	140.13	36.9	103.2
BWMB01A	29/10/2013	Alluvium	88.53	2.5	86.0
BWMB01B	29/10/2013	Leloma	88.68	2.6	86.1
BWMB01C	29/10/2013	Leloma	88.61	2.6	86.0
BWMB01D	29/10/2013	Leloma	88.59	2.8	85.8

mbgl = metres below top of casing.
mAHD = metres Australian Height Datum.

5.1 Quaternary alluvium

Groundwater levels at BWMB01A (shallow alluvium) have been monitored since October 2013. This site is located close to the Avon River. Groundwater levels show no direct response to rainfall events over the short monitoring period (Figure 5.1) however this was a relatively dry period (except for November 2013 and March 2014). Groundwater levels showed a slight rise (0.1 m) in November 2013, followed by a slight decrease (0.3 m) until June 2014.

The data suggests that water levels in the alluvium, underlying weathered zone and shallow fractured rock are in equilibrium.

5.2 Permian Gloucester Coal Measures – Leloma Formation

5.2.1 Faulkland site

Groundwater levels in the Leloma Formation of the Gloucester Coal Measures have been monitored at FKMB01A and FKMB01B since July 2013 (Figure 5.2). Groundwater levels have shown a slight rise (~0.3 m) from July 2013 to June 2014. No data was recorded in the second half of October 2013 due to datalogger failure.

Groundwater levels in the shallow sandstone are higher than groundwater levels in the deeper sandstone (Figure 5.2), suggesting the potential for downward (vertical) flow.

5.2.2 Bucketts Way site

Groundwater levels in the Leloma Formation of the Gloucester Coal Measures have been monitored at BWMB01B, BWMB01C and BWMB01D since October 2013 (Figure 5.1). BWMB01B and BWMB01C showed a slight rise (0.1 m) in groundwater level in November 2013, followed by an overall decrease (~0.2 m) in groundwater level until June 2014. BWMB01D showed a slight rise (0.1 m) and subsequent fall in groundwater level in November 2013, after which, the groundwater level responded in a comparable manner to BWMB01B and BWMB01C.

Groundwater levels in the Gloucester Coal Measures were similar to those in the alluvium suggesting that there is no significant vertical gradient between the alluvium and the Leloma Formation at the Bucketts Way site.

6. Groundwater quality

6.1 Groundwater quality monitoring

Groundwater sampling was undertaken between 30 and 31 October 2013 after the completion of the new monitoring bore sites. This initial section describes the sampling methodology and techniques.

6.1.1 Sampling techniques

Two methods were used to obtain groundwater quality samples from the monitoring bores. The methods were selected based on the permeability of the screened formation of each monitoring bore which was determined during hydraulic conductivity testing. Higher yielding monitoring bores were purged and sampled using a submersible pump. Lower yielding monitoring bores were sampled using a low flow pump, in summary:

- Submersible pumps were used in monitoring bores: BWMB01A, BWMB01B and BWMB01C.
- A micro-purge™ low flow sampling pump was used in monitoring bores: FKMB01A, FKMB01B and BWMB01D.

Where applicable, submersible pumps were used to purge a minimum of three well volumes from the monitoring bores prior to sampling to allow a representative groundwater sample to be collected. If purged until dry the monitoring bore was allowed to recharge and this water was collected for analysis. Field water quality parameters were measured during and following purging to monitor water quality changes and to indicate representative groundwater suitable for sampling and analysis.

For lower yielding monitoring bores and selected deeper bores with high purge volumes, a micro-purge™ low flow sampling system was deployed. The micro-purge™ system allows groundwater to be drawn into the pump intake directly from the screened portion of the aquifer, eliminating the need to purge relatively large volumes of groundwater from these monitoring bores. Water quality parameters were monitored during the micro-purge™ pumping to ensure that a representative groundwater sample was collected.

Physio-chemical parameters (pH, electrical conductivity (EC), temperature, total dissolved solids (TDS), dissolved oxygen (DO) and oxidation reduction potential (ORP)) were measured during and following purging using a calibrated hand-held water quality meter.

6.1.2 Chemical analysis of water

Groundwater samples collected in the field were analysed for a broad chemical suite designed specifically to assess the chemical characteristics of the different aquifers and water bearing zones at the monitoring sites. Table 6.1 details the groundwater analytical suite.

Table 6.1 Groundwater analytical suite

Category	Parameters	
Field parameters	Electrical conductivity (EC) Temperature Dissolved oxygen (DO)	pH Oxidation redox potential (ORP) Total dissolved solids (TDS)
General parameters	EC	TDS

Category	Parameters	
	Total suspended solids	
Major ions	Calcium Magnesium Sodium Potassium	Chloride Bicarbonate Sulphate Fluoride Silica
Metals and minor/trace elements	Aluminium Arsenic Barium Beryllium Boron Bromine Cadmium Cobalt Copper Iron	Lead Manganese Molybdenum Nickel Selenium Strontium Uranium Vanadium Zinc
Nutrients	Ammonia Phosphorus (total) Phosphorus (reactive)	Nitrite Nitrate Total organic carbon (TOC)
Hydrocarbons	Phenol compounds Polycyclic aromatic hydrocarbons (PAH)	Total petroleum hydrocarbons (TPH) Benzene, toluene, ethyl benzene and xylenes (BTEX) Oil and grease
Dissolved gases	Methane Ethene Ethane Propene	Propane Butene Butane
Isotopes	Oxygen-18 (^{18}O) Deuterium (^{2}H) Tritium (^{3}H) Radiocarbon (^{14}C)	Carbon-13 dissolved organic carbon ($^{13}C_{DIC}$) Carbon-13 methane ($^{13}C\text{-}CH_4$) and deuterium methane ($^{2}H\text{-}CH_4$)

Groundwater samples for laboratory analysis were collected in sample bottles specified by the laboratory, with appropriate preservation when required. Samples undergoing dissolved metal analysis were filtered through 0.45 µm filters in the field prior to collection.

The samples were sent to the following laboratories under appropriate chain-of-custody protocols (documentation and laboratory results are provided in the Appendices):

- Australian Laboratory Service (ALS) Environmental Pty Ltd, Smithfield, Sydney – chemistry analysis. NATA certified laboratory (Appendix F).
- GNS Stable Isotope Laboratory, Lower Hutt, New Zealand – oxygen-18 and deuterium analysis (Appendix G).
- Rafter Radiocarbon Laboratory, Lower Hutt, New Zealand – carbon-14 analysis (Appendix H).

- Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights – tritium (Appendix I).
- UC Davis Stable Isotope Facility, Davis, California, USA – carbon-13 ($^{13}C_{DIC}$) and methane isotope analysis ($^{13}C\text{-}CH_4$ and $^{2}H\text{-}CH_4$) (Appendix J).

6.1.3 Quality assurance

A full outline laboratory QA/QC procedures is provided in Appendix K.

6.1.3.1 Field QA/QC

The field sampling procedures conformed to Parsons Brinckerhoff's Quality Assurance/Quality Control protocols to prevent cross-contamination and preserve sample integrity. The following QA/QC procedures were applied:

- one duplicate sample was collected as a control for chemical analysis
- samples were collected in appropriate bottles with appropriate preservation solutions
- samples were delivered to the laboratories within the specified holding times
- unstable parameters were analysed in the field (field parameters).

6.1.3.2 Laboratory QA/QC

The laboratories conduct their own internal QA/QC program to assess the repeatability of the analytical procedures and instrument accuracy. These programs include analysis of laboratory sample duplicates, spike samples, certified reference standards, surrogate standards/spikes and laboratory blanks.

6.2 Groundwater quality results

This chapter presents the baseline water quality monitoring results. The results have been compared against the ANZECC (2000) guidelines 95% species protection for freshwater ecosystems (south-east Australia – lowland rivers) because the rivers are the ultimate receiving waters for groundwater discharge. However these water guidelines are often naturally exceeded in catchments with rocks deposited in marine environments, hence they are only guidelines and not strict criteria that should be used to evaluate individual results.

Groundwater quality monitoring was undertaken between 30 and 31 October 2013. Full water quality results are presented in Appendix E.

A piper diagram is a graphical representation of the chemistry of a water sample and can be used to graphically show the relative concentrations of major ions (Ca^{2+}, Mg^{2+}, $Na^{+}+K^{+}$, Cl^{-}, $HCO_3^{-}+CO_3^{2-}$ and SO_4^{2-}). The piper plot for all Faulkland and Bucketts Way groundwater monitoring bores is presented in Figure 6.1.

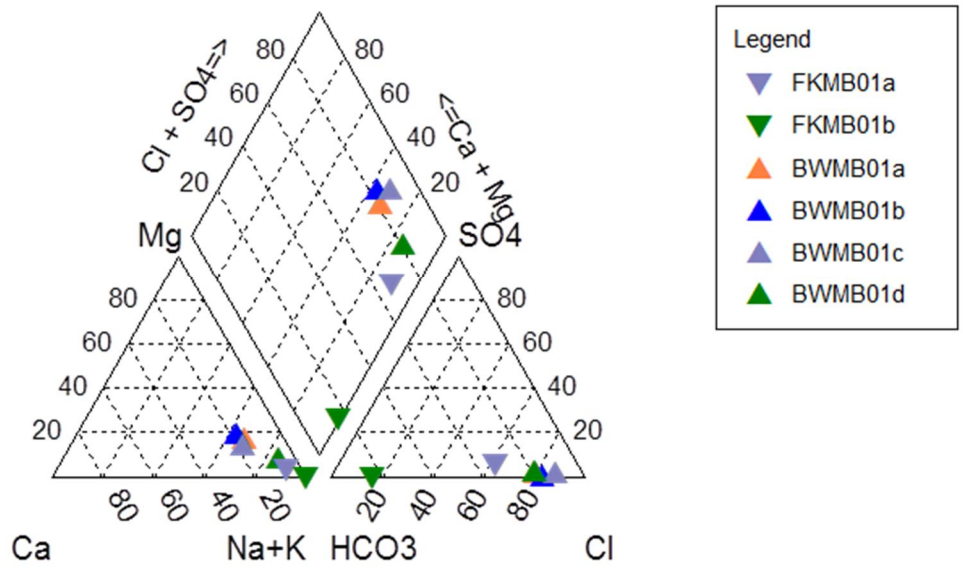


Figure 6.1 Piper diagram for Faulkland and Bucketts Way monitoring bores

6.3 Faulkland monitoring bores

Both monitoring bores are completed in the Permian Leloma Formation. A summary of water quality results for the Faulkland monitoring bores is provided in Table 6.2. Full water quality results are presented in Appendix E.

Table 6.2 Water quality summary for the Faulkland monitoring bores

Parameters	Units	ANZECC (2000) guidelines[a]	FKMB01A	FKMB01B
Field parameters				
pH (field)	pH units	6.5 – 8.0[b]	7.20	**10.38**
EC (field)	µS/cm	125-2,200[b]	**5,334**	**3,820**
EC (lab)			**5,400**	**3,940**
Temperature	°C	-	29.22	26.56
DO	% sat	80 - 110%[b]	**31.0**	**21.9**
TDS (field)	mg/L	-	2,880	2,407
TDS (lab)			2,930	2,080
Redox potential	mg/L	-	-122.3	-81.3
Major ions				
Calcium	mg/L	-	53	<1
Magnesium	mg/L	-	21	1
Sodium	mg/L	-	920	887
Potassium	mg/L	-	10	6
Chloride	mg/L	-	1,070	472

Parameters	Units	ANZECC (2000) guidelines[a]	FKMB01A	FKMB01B
Sulphate	mg/L	-	143	2
Total alkalinity as $CaCO_3$	mg/L	-	784	1,350
Dissolved metals and metalloids				
Aluminium	mg/L	0.055 (pH>6.5)	0.02	**0.09**
Arsenic	mg/L	0.013 (AsV), 0.024 (AsIII)	0.004	<0.001
Barium	mg/L	-	0.671	0.138
Beryllium	mg/L	ID	<0.001	<0.001
Cadmium	mg/L	0.0002	<0.0001	<0.0001
Cobalt	mg/L	ID	<0.001	<0.001
Copper	mg/L	0.0014	**0.002**	<0.001
Lead	mg/L	0.0034	<0.001	<0.001
Manganese	mg/L	1.9	0.238	<0.001
Molybdenum	mg/L	ID	0.003	0.007
Nickel	mg/L	0.011	0.004	<0.001
Selenium	mg/L	0.011 (total)	<0.01	<0.01
Strontium	mg/L	-	12.600	0.816
Uranium	mg/L	ID	0.003	<0.001
Vanadium	mg/L	ID	<0.01	<0.01
Zinc	mg/L	0.008	**0.046**	**0.048**
Boron	mg/L	0.37	0.08	0.11
Iron	mg/L	ID	0.50	0.10
Bromine	mg/L	ID	3.9	1.6
Nutrients				
Ammonia as N	mg/L	0.02[a]	**0.82**	**1.74**
Nitrite as N	mg/L	0.02[b]	<0.01	<0.01
Nitrate as N	mg/L	0.70	0.01	<0.01
Total phosphorus as P	mg/L	0.05[b]	**0.06**	**0.08**
Reactive phosphorus as P	mg/L	0.02[b]	<0.01	**0.10**
Total organic carbon	mg/L	1	27	41
Dissolved gases				
Methane	µg/L	-	2,190	9,920
Phenolic compounds				
Phenol	µg/L	320	<1.0	5.3

Parameters	Units	ANZECC (2000) guidelines[a]	FKMB01A	FKMB01B
Polycyclic aromatic hydrocarbons	µg/L	**-**	<LORs	<LORs
BTEX				
Benzene	µg/L	950	<1	<1
Toluene	µg/L	-	30	3
Ethyl benzene	µg/L	-	<2	<2
Xylenes	µg/L	-	<2	<2
Total petroleum hydrocarbons				
C_6-C_9	µg/L	-	60	<20
C_{10}-C_{14}	µg/L		<50	<50
C_{15}-C_{28}	µg/L		<100	<100
C_{29}-C_{36}	µg/L		<50	<50

(a) ANZECC (2000) guidelines for the protection of freshwater aquatic ecosystems: 95% protection levels (trigger values).
(b) ANZECC (2000) guidelines for the protection of freshwater aquatic ecosystems: trigger values for lowland rivers in south-east Australia.

BOLD - value outside of the ANZECC (2000) guideline trigger values.
ID - insufficient data for trigger value to be established.
LOR - laboratory limit of reporting.

6.3.1 Field parameters

The groundwater salinity (EC) at the Faulkland monitoring site ranges from brackish to slightly saline. EC values were above the ANZECC (2000) guideline values. The pH conditions were neutral at FKMB01A and alkaline at FKMB01B. Redox conditions were reducing.

The pH at FKMB01B is uncommonly high for natural aquifers and indicates the monitoring bore has been compromised by contamination with alkaline grout used to seal the annular space during well completion (Bartos and Ogle 2002). A high pH affects groundwater chemistry, thereby making this bore currently unsuitable for baseline characterisation.

6.3.2 Major ion chemistry

The water types for the Faulkland monitoring bores are presented in Table 6.3 and are displayed on the Piper diagram in Figure 6.1. Groundwater at FKMB01A is dominated by sodium, chloride and bicarbonate. Groundwater at FKMB01B is dominated by sodium, carbonate and chloride.

Table 6.3 Major ion chemistry for the Faulkland monitoring bores

Location	Water type
FKMB01A	Na-Cl-HCO_3
FKMB01B	Na-HCO_3-Cl

6.3.3 Dissolved metals

Dissolved metal concentrations for the Faulkland monitoring bores were typically low. Beryllium, cadmium, cobalt, lead, selenium and vanadium were below the laboratory limit of reporting (LOR). The following dissolved metals were detected:

- Aluminium was detected at both monitoring bores and was above the ANZECC (2000) guideline value (0.055 mg/L) at FKMB01B.
- Copper was detected at FKMB01A and was above the ANZECC (2000) guideline value (0.0014 mg/L).
- Zinc concentrations were detected above the ANZECC (2000) guideline value (0.008 mg/L) at both monitoring bores.
- Arsenic, manganese and nickel concentrations were detected at FKMB01A only and were below the ANZECC (2000) guidelines.
- Barium, bromine, iron, molybdenum and strontium were detected at both monitoring bores. Uranium was detected at FKMB01A.

The dissolved metal concentrations are considered natural and not unusual for natural groundwater in the Leloma Formation.

6.3.4 Nutrients

Ammonia (as N) and total phosphorus (as P) concentrations were above the ANZECC (2000) guideline values at both monitoring bores. Nitrate (as N) and nitrite (as N) were equal to or below the laboratory LOR. Reactive phosphorus was detected at FKMB01A only and was above the ANZECC (2000) guideline value. Total organic carbon concentrations were 27 mg/L and 41 mg/L in FKMB01A and FKMB01B, respectively.

6.3.5 Hydrocarbons

Concentrations of total petroleum hydrocarbons (TPH) were below the laboratory LOR at both monitoring bores, except for C_6-C_9 fractions which were detected at FKMB01A.

Polycyclic aromatic hydrocarbons were below the laboratory LOR at both monitoring bores. Phenolic compounds were below the laboratory LOR, with the exception of phenol at FKMB01B. BTEX compounds were below the laboratory LOR, with the exception of toluene which was detected at both monitoring bores at low concentrations.

6.3.6 Dissolved gases

Dissolved methane was detected at FKMB01A (2,190 µg/L) and at FKMB01B (9,920 µg/L).

6.3.7 Isotopes

6.3.7.1 Stable isotopes of water

Stable isotope ($\delta^{18}O$ and $\delta^{2}H$) values are compared to the Global Meteoric Water Line (GMWL) ($\delta^{2}H = 8.13\ \delta^{18}O + 10.8$) (Rozanski et al. 1993) in Figure 6.2. The GMWL (as shown on Figure 6.2) provides an important key to the interpretation of oxygen-18 and deuterium data. It is a line that defines the relationship between oxygen-18 (^{18}O) and deuterium (^{2}H) in fresh surface waters and precipitation from a number of global reference sites. Water with an isotopic composition that lies on the meteoric water line is

assumed to have originated from the atmosphere and to be unaffected by other isotopic processes. The isotopic values for the groundwater samples are also compared to the Local Meteoric Water Line ($\delta^2H = 8.3\ \delta^{18}O + 16.3$) (Crosbie et al. 2012). This line defines the relationship between ^{18}O and ^{2}H for rainfall in the Sydney region.

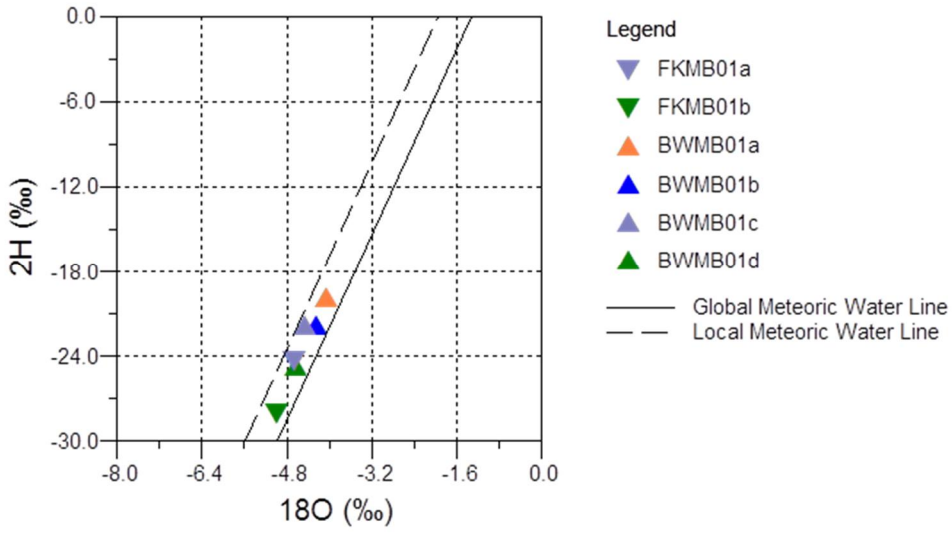


Figure 6.2 Deuterium versus oxygen-18 for Faulkland and Bucketts Way monitoring bores

Stable isotope ($\delta^{18}O$ and $\delta^{2}H$) results for the Faulkland monitoring bores are presented in Table 6.4.

Table 6.4 Stable isotope results for the Faulkland monitoring bores

Bore	Oxygen-18 (‰)	Deuterium (‰)
FKMB01A	-4.65	-4.99
FKMB01B	-24.26	-27.95

Both samples plot along the GMWL and LMWL indicating groundwater is of meteoric (rainfall) origin (Figure 6.2). These isotope results are consistent with previous monitoring rounds in the GGP area in 2012 (Parsons Brinckerhoff 2012) and 2013 (Parsons Brinckerhoff 2013f).

6.3.7.2 Radiogenic isotopes

Tritium and radiocarbon results are presented in Table 6.5. Carbon-13 of dissolved inorganic carbon ($\delta^{13}C$-DIC) is also presented in Table 6.5.

Table 6.5 $\delta^{13}C$-DIC, radiocarbon and tritium results for the Faulkland monitoring bores

Bore	$\delta^{13}C$ (‰)	$a^{14}C$ (pMC)	^{14}C age[a] (yrs BP)	^{14}C age[b] (yrs BP)	Tritium (TU)
FKMB01A	-14.75	70.14±0.16	2,787±19	2,200 (old)	0.033±0.025[c]
FKMB01B	-2.53	44.11±0.12	6,513±22	6,050 (old)	0.067±0.025[c]

(a) Uncorrected radiocarbon age.
(b) Corrected radiocarbon age.
(c) This result is below the Minimum Detectable Activity (MDA) and Limit of Quantification (Quant Limit) and therefore has an unacceptable level of uncertainty. Hence the data should only be used as an indicator of true concentration.

Carbon-14 activities ($a^{14}C$) for the Faulkland monitoring bores were 70.14±0.16 pMC and 44.11±0.12 pMC for FKMB01A and FKMB01B, respectively. The ^{14}C activities correspond to apparent (uncorrected) ages of 2,787±19 yrs BP for FKMB01A and 6,513±22 yrs BP for FKMB01B. Radiocarbon ages have been corrected to account for potential dilution by processes such as carbonate dissolution, sulphate reduction and methanogenesis (as defined in Clark and Fritz (1997)). Groundwater age increased with depth from 2,200 yrs BP at FKMB01A to 6,050 yrs BP in FKMB01B. Tritium was below the minimum detectable activity indicating that no modern water is present in the groundwater at these monitoring bores.

6.3.7.3 Carbon and hydrogen isotopes of methane ($\delta^{13}C$-CH_4 and $\delta^{2}H$-CH_4)

Compound specific isotopes of dissolved methane (carbon-13 ($\delta^{13}C$-CH_4) and deuterium ($\delta^{2}H$-CH_4)) were analysed in all groundwater monitoring bores. Dissolved methane concentrations and isotope results are presented in Table 6.6, and isotope results are compared to data collected by AGL from coal seams during exploration in the GGP area. Background theory on carbon and hydrogen isotopes is presented in EMGAMM (2014), and the evolution of methane in waters for the GGP is presented in Parsons Brinckerhoff (2014a).

Table 6.6 Dissolved methane concentrations and isotope results for the Faulkland monitoring bores

Bore	CH_4 (µg/L)	$\delta^{2}H_{CH4}$ (‰)	$\delta^{13}C_{CH4}$ (‰)
FKMB01A	2,190	-146.9[a]	-41.02[a]
FKMB01B	9,920	-221.7	-42.24

(d) Below limit of quantitation.

The limit of quantitation (LOQ) is the lowest concentration or quantity of a target variable that can be reported with a specified degree of confidence; therefore sample FKMB01A with $\delta^{2}H$-CH_4 results below the LOQ cannot be interpreted with a degree of confidence; however values do suggest a thermogenic origin.

The results for FKMB01B indicate the methane is early mature thermogenic methane (Figure 6.3).

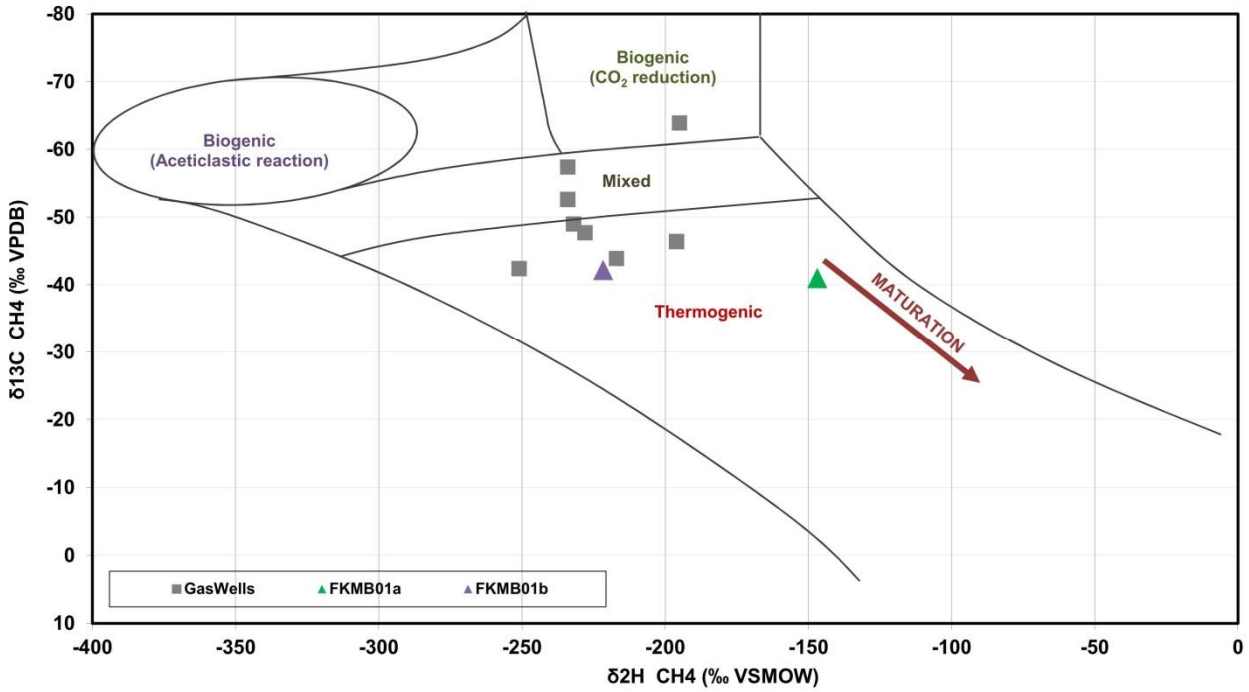


Figure 6.3 $^{13}C\text{-}CH_4$ versus $^{2}H\text{-}CH_4$ for FKMB01A and FKMB01B

6.4 Bucketts Way monitoring bores

A summary of water quality results for the Bucketts Way monitoring bores is provided in Table 6.7. Full water quality results are presented in Appendix E.

Table 6.7 Water quality summary for the Bucketts Way monitoring bores

Parameters		ANZECC (2000) guidelines[a]	BWMB01A	BWMB01B	BWMB01C	BWMB01D
Field parameters						
pH (field)	pH units	6.5 – 8.0[b]	6.52	6.55	**8.76**	**8.47**
EC (field)	µS/cm	125-2,200[b]	**3,779**	**4,490**	**3,440**	**3,295**
EC (lab)			**3,900**	**4,650**	**3,320**	**3,490**
Temperature	°C	-	22.20	20.27	19.70	19.96
DO	% sat	80 - 110%[b]	**9.3**	**31.2**	**7.0**	**25.5**
TDS (field)	mg/L	-	2,457	2,919	1,810	2,135
TDS (lab)			1,970	2,420	1,750	1,940
Redox potential	mg/L	-	-33.8	-71.4	-158.7	-181.0
Major ions						
Calcium	mg/L	-	98	132	92	41
Magnesium	mg/L	-	66	88	43	30
Sodium	mg/L	-	488	540	388	602

Parameters		ANZECC (2000) guidelines[a]	BWMB01A	BWMB01B	BWMB01C	BWMB01D
Potassium	mg/L	-	4	5	17	12
Chloride	mg/L	-	927	1,130	828	792
Sulphate	mg/L	-	22	4	15	30
Total alkalinity as $CaCO_3$	mg/L	-	297	309	142	264
Dissolved metals and metalloids						
Aluminium	mg/L	0.055 (pH>6.5)	**0.32**	0.05	0.02	<0.01
Arsenic	mg/L	0.013 (AsV), 0.024 (AsIII)	**0.028**	0.001	0.003	0.003
Barium	mg/L	-	1.250	3.610	3.170	2.630
Beryllium	mg/L	ID	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0002	0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	ID	0.006	0.002	<0.001	<0.001
Copper	mg/L	0.0014	**0.006**	**0.002**	**0.002**	<0.001
Lead	mg/L	0.0034	0.002	<0.001	<0.001	<0.001
Manganese	mg/L	1.9	0.501	0.418	0.030	0.054
Molybdenum	mg/L	ID	0.002	0.001	0.007	0.017
Nickel	mg/L	0.011	0.005	0.002	0.002	<0.001
Selenium	mg/L	0.011 (total)	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	-	2.12	3.00	3.37	1.77
Uranium	mg/L	ID	0.001	0.001	<0.001	<0.001
Vanadium	mg/L	ID	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.008	**0.114**	**0.167**	**0.026**	**0.570**
Boron	mg/L	0.37	<0.05	<0.05	<0.05	<0.05
Iron	mg/L	ID	1.7	14.3	0.06	<0.05
Bromine	mg/L	ID	2.1	2.8	1.9	2
Nutrients						
Ammonia as N	mg/L	0.02[a]	**0.24**	**0.58**	**3.22**	**1.74**
Nitrite as N	mg/L	0.02[b]	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.70	<0.01	<0.01	<0.01	<0.01
Total phosphorus as P	mg/L	0.05[b]	**0.59**	**0.06**	<0.01	<0.01
Reactive phosphorus as P	mg/L	0.02[b]	<0.01	<0.01	<0.01	<0.01

Parameters		ANZECC (2000) guidelines[a]	BWMB01A	BWMB01B	BWMB01C	BWMB01D
Total organic carbon	mg/L	1	11	17	1	13
Dissolved gases						
Methane	µg/L	-	<10	264	5,080	2,660
Phenolic compounds						
Phenol	µg/L	320	<1.0	<1.0	<1.0	1.2
Polycyclic aromatic hydrocarbons						
Naphthalene	µg/L	16	1.8	3.6	3.8	<1.0
Acenaphthene	µg/L	-	4.2	5.2	14.8	<1.0
Fluorene	µg/L	-	2.6	3.8	11.2	<1.0
Phenanthrene	µg/L	ID	2.9	5.2	13.8	<1.0
Anthracene	µg/L	ID	<1.0	<1.0	2.0	<1.0
Fluoranthene	µg/L	ID	<1.0	<1.0	1.9	<1.0
Pyrene	µg/L	-	<1.0	<1.0	1.0	<1.0
BTEX	µg/L	-	<LORs	<LORs	<LORs	<LORs
Total petroleum hydrocarbons						
C_6-C_9	µg/L	-	<20	<20	<20	<20
C_{10}-C_{14}	µg/L	-	120	90	820	<50
C_{15}-C_{28}	µg/L	-	<100	<100	150	<100
C_{29}-C_{36}	µg/L	-	90	<50	<50	<50

(a) ANZECC (2000) guidelines for the protection of freshwater aquatic ecosystems: 95% protection levels (trigger values).

(b) ANZECC (2000) guidelines for the protection of freshwater aquatic ecosystems: trigger values for lowland rivers in south-east Australia.

BOLD - value outside of the ANZECC (2000) guideline trigger values.

ID - insufficient data for trigger value to be established.

LOR – Laboratory limit of reporting.

6.4.1 Quaternary alluvium

6.4.1.1 Field parameters

Alluvial groundwater salinity at the Bucketts Way site was brackish, with an EC value of 3,779 µS/cm. Electrical conductivity values exceeded the ANZECC (2000) guideline value (125 – 2,200 µS/cm). The pH conditions in the alluvial monitoring bore was slightly acidic and was within the ANZECC (2000) guideline (6.5 – 8.0). Redox conditions were slightly reducing.

The brackish nature of the groundwater is attributable to evaporative concentration due to the shallow water table, together with some salinity influence from the underlying rock groundwater systems.

6.4.1.2 Major ion chemistry

The Bucketts Way alluvial monitoring bore is sodium and chloride dominant (Figure 6.1).

6.4.1.3 Dissolved metals

Dissolved metal concentrations for the alluvial monitoring bore were typically low. Beryllium, boron, selenium and vanadium were below the laboratory LOR. The major findings of dissolved metal analysis were as follows:

- Aluminium, arsenic, copper and zinc were detected and concentrations exceeded the ANZECC (2000) guideline values.
- Cadmium, lead, manganese and nickel were detected and did not exceed the ANZECC (2000) guideline values.
- Barium, cobalt, iron, molybdenum, strontium and uranium were detected at relatively low concentrations.

The dissolved metal concentrations are considered natural and not unusual for these alluvial deposits.

6.4.1.4 Nutrients

Nitrite, nitrate and reactive phosphorus were not detected in the alluvial monitoring bore. Ammonia and total phosphorus concentrations were above the ANZECC (2000) guideline values. Total organic carbon concentrations were 11 mg/L.

6.4.1.5 Hydrocarbons

Total petroleum hydrocarbons (C_{10}-C_{14} fraction at 120 µg/L and C_{29}-C_{36} fraction at 90 µg/L) and polycyclic aromatic hydrocarbons were detected in the alluvial monitoring bore..

Phenolic compounds and BTEX were below the laboratory LOR.

6.4.1.6 Dissolved gases

No dissolved gases were detected in the alluvial monitoring bore.

6.4.1.7 Isotopes

Stable isotopes of water

Stable isotope results for the alluvial monitoring bore are presented in Table 6.8.

Table 6.8 Stable isotope results for the Bucketts Way alluvial monitoring bore

Bore	Oxygen-18 (‰)	Deuterium (‰)
BWMB01A	-4.04	-19.89

The sample plots along the GMWL and LMWL indicating groundwater is of meteoric (rainfall) origin (Figure 6.2). These isotope results are consistent with previous monitoring rounds in the GGP area in 2012 (Parsons Brinckerhoff 2012) and in 2013 (Parsons Brinckerhoff 2013f).

Radiogenic isotopes

Tritium and radiocarbon results are presented in Table 6.9. Carbon-13 of dissolved inorganic carbon (δ^{13}C-DIC) is also presented in Table 6.9.

Table 6.9 δ^{13}C-DIC, radiocarbon and tritium results for the Bucketts Way alluvial monitoring bore

Bore	δ^{13}C (‰)	a^{14}C (pMC)	^{14}C age[a] (yrs BP)	^{14}C age[b] (yrs BP)	Tritium (TU)
BWMB01A	-12.98	81.53±0.17	1,578±17	modern	0.400±0.033

(a) Uncorrected radiocarbon age.
(b) Corrected radiocarbon age.

Carbon-14 activities (a^{14}C) for the Bucketts Way alluvial monitoring bore was 81.53±0.17 pMC. Three correction methods are applied (Fontes-Garnier (1979); revised Fontes-Garnier; Tamers (1975) and Ingerson and Pearson (1964)) to apparent radiocarbon data to account for potential dilution of ^{14}C signature by incorporation of inactive carbon. The three models showed good agreement for corrected radiocarbon ages. The corrected radiocarbon ages indicate that groundwater in the alluvium is modern (<50 years BP). This finding is supported by the presence of detectable tritium in the monitoring bore. Tritium in rainfall across Australia currently averages 2 to 3 TU; based on these values the age of water in the alluvium is about 60 years old.

Carbon and hydrogen isotopes of methane (δ^{13}C-CH_4 and δ^{2}H-CH_4)

Compound specific isotopes of dissolved methane (carbon-13 (δ^{13}C-CH_4) and deuterium (δ^{2}H-CH_4)) were analysed in the alluvial groundwater monitoring bore. Dissolved methane concentrations and isotope results are presented in Table 6.10 and are compared to AGL isotope data collected during exploration.

Table 6.10 Dissolved methane concentrations and isotope results for the Bucketts Way alluvial monitoring bore

Bore	CH_4 (µg/L)	$\delta^{2}H_{CH4}$ (‰)	$\delta^{13}C_{CH4}$ (‰)
BWMB01A	<10	-67.9[a]	-29.82[a]

(a) Below LOQ.

The LOQ is the lowest concentration or quantity of a target variable that can be reported with a specific degree of confidence; therefore samples with results below the LOQ have not been interpreted.

6.4.2 Permian Gloucester Coal Measures – Leloma Formation

6.4.2.1 Field parameters

Groundwater salinity in the Bucketts Way monitoring bores screened in the Leloma Formation was brackish. EC values ranged from 3,295 µS/cm at BWMB01D to 4,490 µS/cm at BWMB01B, and exceeded the ANZECC (2000) guideline value (125 – 2,200 µS/cm) at all monitoring bores. The pH conditions in the Leloma Formation monitoring bores were slightly acidic to slightly alkaline and pH values were above the ANZECC (2000) guideline values (6.5 - 8.0) at BWMB01C and BWMB01D. Redox conditions were reducing to strongly reducing.

It is uncertain why the deeper groundwater in the fractured rock has an overall lower salinity than the shallow groundwater alluvium, however is likely to be related to evaporative concentration effects as discussed in Section 6.4.1.1.

6.4.2.2 Major ion chemistry

Table 6.11 summarises the major ion chemistry of the Bucketts Way monitoring bores screened in the Leloma Formation. Sodium was the dominant cation and chloride was the dominant anion in the monitoring bores (Figure 6.1).

Table 6.11 Major ion chemistry for the Bucketts Way Leloma Formation monitoring bores

Location	Water type
BWMB01B	Na-Cl
BWMB01C	Na-Cl
BWMB01D	Na-Cl

6.4.2.3 Dissolved metals

Dissolved metal concentrations for the Bucketts Way rock monitoring bores are typically low. Beryllium, boron, cadmium, lead, selenium, uranium and vanadium were all below the laboratory LOR. The major findings of dissolved metal analysis were as follows:

- Aluminium was detected at BWMB01B and BWMB01C although did not exceeded the ANZECC (2000) guideline value (0.055 mg/L).
- Arsenic and manganese were detected at all monitoring bores and nickel was detected at BWMB01B and BWMB01C. Concentrations did not exceed the ANZECC (2000) guideline values.
- Copper concentrations at BWMB01B and BWMB01C were above the ANZECC (2000) guideline value (0.0014 mg/L).
- Zinc concentrations were above the ANZECC (2000) guideline value (0.008 mg/L) at all monitoring bores.
- Barium, molybdenum and strontium were detected at all monitoring bores. Iron was detected at BWMB01B and BWMB01C and cobalt was detected at BWMB01B only.

The dissolved metal concentrations are considered natural and not unusual for groundwater in the Leloma Formation.

6.4.2.4 Nutrients

Ammonia concentrations were above the ANZECC (2000) guideline value (0.02 mg/L) at all monitoring bores. Nitrite and nitrate were not detected and total phosphorus and reactive phosphorus were detected at BWMB01B, with total phosphorus exceeding the ANZECC (2000) guideline value. Total organic carbon concentrations ranged from 1 mg/L at BWMB01C to 17 mg/L at BWMB01B.

6.4.2.5 Hydrocarbons

Total petroleum hydrocarbons (TPH) were detected at BWMB01B (C_{10}-C_{14} fraction was 90 µg/L) and at BWMB01C (C_{10}-C_{14} fraction was 820 µg/L and C_{15}-C_{28} fraction was 150 µg/L). Polycyclic aromatic hydrocarbons were detected at BWMB01B and BWMB01C and phenol was detected at BWMB01D (1.2 µg/L). BTEX concentrations were below the laboratory LOR.

Hydrocarbons in these types of formations can be naturally occurring (Volk et al., 2011) and have been detected in sedimentary rocks in the Gloucester Basin during early exploration programs (Thornton 1982; Hunt et al. 1983).

6.4.2.6 Dissolved gases

Dissolved methane was detected at BWMB01B (264 µg/L), BWMB01C (5,080 µg/L) and BWMB01D (2,660 µg/L).

6.4.2.7 Isotopes

Stable isotopes of water

Stable isotope results for the Bucketts Way Leloma Formation monitoring bores are presented in Table 6.12.

Table 6.12 Stable isotope results for the Bucketts Way Leloma Formation monitoring bores

Bore	Oxygen-18 (‰)	Deuterium (‰)
BWMB01B	-4.24	-21.85
BWMB01C	-4.47	-23.60
BWMB01D	-4.62	-24.76

The samples plot along the GMWL and LMWL indicating groundwater is of meteoric (rainfall) origin (Figure 6.2). These isotope results are consistent with previous monitoring rounds in the GGP area in 2012 (Parsons Brinckerhoff 2012) and in 2013 (Parsons Brinckerhoff 2013f).

Radiogenic isotopes

Tritium and radiocarbon results are presented in Table 6.13. Carbon-13 of dissolved inorganic carbon (δ^{13}C-DIC) is also presented in Table 6.13.

Table 6.13 δ^{13}C-DIC, radiocarbon and tritium results for the Bucketts Way Leloma Formation monitoring bores

Bore	δ^{13}C (‰)	a^{14}C (pMC)	^{14}C age[a] (yrs BP)	^{14}C age[b] (yrs BP)	Tritium (TU)
BWMB01B	-13.72	78.85±0.16	1,864±17	modern	0.250±0.033
BWMB01C	-13.30	49.39±0.13	5,605±21	3,500 (old)	0.133±0.025[c]
BWMB01D	0.59	26.82±0.10	10,508±30	10,300 (old)	0.075±0.025[^]

(b) Uncorrected radiocarbon age.
(c) Corrected radiocarbon age
(d) This result is below the Minimum Detectable Activity (MDA) and Limit of Quantification (Quant Limit) and therefore has an unacceptable level of uncertainty. Hence the data should only be used as an indicator of true concentration.

Carbon-14 activities (a^{14}C) for the Bucketts Way monitoring bores screened in the Leloma Formation decreased with depth from 78.85±0.16 pMC at BWMB01B to 26.82±0.10 pMC at BWMB01D. The ^{14}C activities correspond to apparent (uncorrected) ages of respectively 1,864±17 years BP and 10,508±30 years BP. Radiocarbon ages have been corrected to account for potential dilution by processes such as carbonate dissolution, sulphate reduction and methanogenesis (as defined in Clark and Fritz (1997)). Corrected ages increase with depth from modern at BWMB01B to 10,300 years at BWMB01D. Tritium was detected in the shallowest monitoring bore (BWMB01B), supporting the corrected radiocarbon age and was below the minimum detectable activity at BWMB01C and BWMB01D indicating no modern water is present.

Carbon and hydrogen isotopes of methane (δ^{13}C-CH_4 and δ^{2}H-CH_4)

Compound specific isotopes of dissolved methane (carbon-13 (δ^{13}C-CH_4) and deuterium (δ^{2}H-CH_4)) were analysed in the Bucketts Way groundwater monitoring bores screened in the Leloma Formation. Dissolved methane concentrations and isotope results are presented in Table 6.14 and are compared to AGL isotope data collected during exploration.

Table 6.14 Dissolved methane concentrations and isotope results for the Bucketts Way Leloma Formation monitoring bores

Bore	CH_4 (µg/L)	δ^2H_{CH4} (‰)	$\delta^{13}C_{CH4}$ (‰)
BWMB01B	264	-163.9[a]	-34.62[a]
BWMB01C	5,080	-199.3	-63.51
BWMB01D	2,660	-210.8	-57.75

(a) Below LOQ.

The isotope results indicate that methane at BWMB01C is of biogenic origin and BWMB01D is of mixed biogenic/thermogenic origin and is similar to some gas samples collected by AGL from depths ranging from 200 to 1,100 m (Parsons Brinckerhoff 2014a) (Figure 6.4). The isotope results at BWMB01B were below the LOQ, therefore results have not been interpreted.

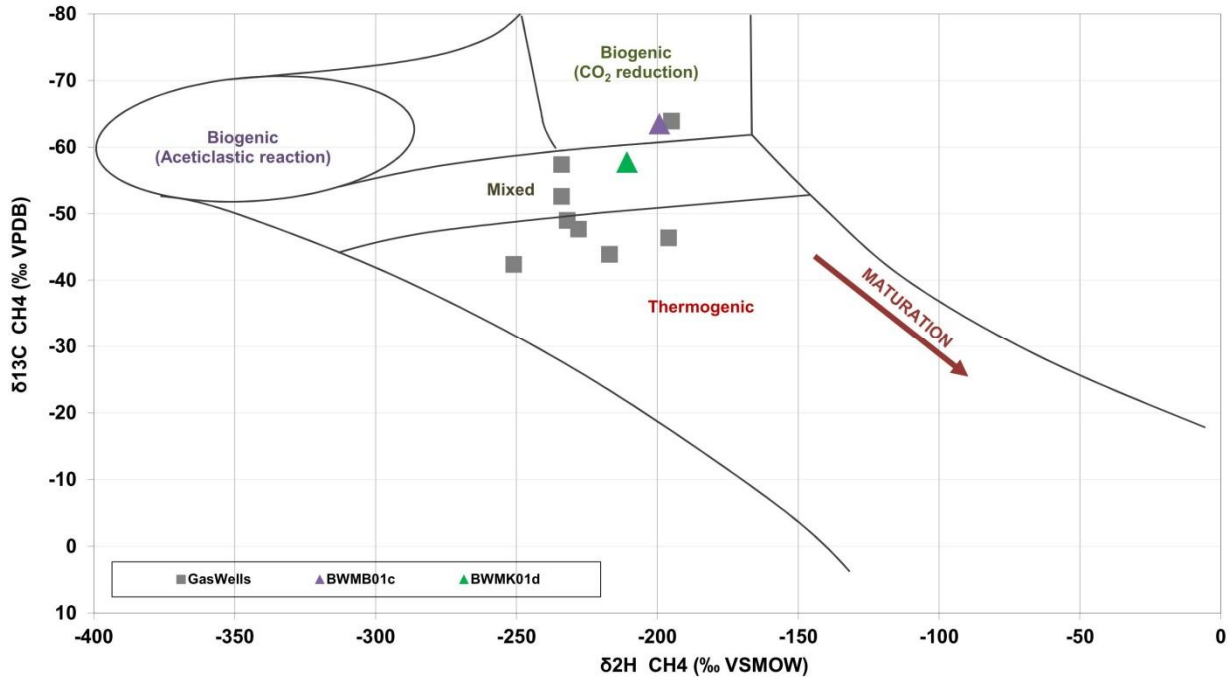


Figure 6.4 ^{13}C-CH_4 versus ^{2}H-CH_4 for BWMB01C and BWMB01D

7. Conclusions

Water level and water quality data obtained from this drilling program generally support the hydrogeological conceptual model updated in the annual monitoring report for the GGP (Parsons Brinckerhoff 2013e).

The conclusions from the current investigations are discussed below.

7.1 Faulkland monitoring bores

- Groundwater levels in the Leloma Formation at this site have remained stable since monitoring began and show no response to rainfall events. The groundwater levels in the shallow sandstone are higher than groundwater levels in the deep sandstone, suggesting the potential for downward flow.
- Groundwater quality in the Leloma Formation at this site is brackish to slightly saline, with neutral pH and reducing conditions. The major ion chemistry indicates sodium is the dominant cation and chloride and bicarbonate, carbonate are the dominant anions.
- The pH at FKMB01B is high and indicates the monitoring bore has been compromised by contamination with alkaline grout used to seal the annular space during well completion. A high pH affects groundwater chemistry, thereby making the results obtained from this bore unsuitable for baseline characterisation.
- Dissolved metals concentrations were typically low, however minor exceedances of the ANZECC (2000) guidelines were observed in at least one monitoring bore for aluminium, copper and zinc.
- Ammonia, total phosphorus and reactive phosphorus were detected in at least one monitoring bore above ANZECC (2000) guidelines.
- Dissolved methane concentrations were detected in both monitoring bores.
- TPH (C_6-C_9), phenol and toluene were present at low concentrations.
- Isotope data indicates that groundwater in the Leloma Formation is of meteoric origin and generally classified as old. Methane is of thermogenic origin.

7.2 Bucketts Way monitoring bores

7.2.1 Quaternary alluvium

- Groundwater levels in the monitoring bore screened in the alluvium do not show a response to rainfall events over the short monitoring period.
- Levels in the alluvium and shallow fractured rock are in equilibrium and do not suggest vertical flow.
- Groundwater in the alluvium is brackish, with slightly acidic pH and slightly reducing conditions. The major ion chemistry was sodium-chloride dominant.
- The alluvial groundwater has typically low dissolved metal concentrations; however, minor exceedances of the ANZECC (2000) guidelines were observed for aluminium, arsenic and copper.
- Ammonia and total phosphorus were detected in the alluvial monitoring bore.
- Total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAH) were detected. Phenolic and BTEX compounds were not detected in alluvial monitoring bore.

- Isotope data indicates that groundwater is of meteoric origin and is modern.

7.2.2 Leloma Formation

- Groundwater levels in the Leloma Formation at this site are shallow and comparable to the alluvial groundwater level. There is no response to rainfall which is comparable to those at the Faulkland site.
- Groundwater quality in the Leloma Formation at this site is brackish with slightly acidic to slightly alkaline pH and reducing to strongly reducing conditions. The major ion chemistry is sodium-chloride dominant.
- Dissolved metals concentrations are typically low, however minor exceedances of the ANZECC (2000) guidelines were observed in at least one monitoring bore for copper and zinc.
- Ammonia concentrations were above ANZECC (2000) guideline values in all monitoring bores and total phosphorus was above the ANZECC (2000) guideline value in one monitoring bore.
- BTEX compounds were not detected in the fractured rock monitoring bores.
- TPH, PAH and phenolic compounds were detected in at least one monitoring bore.
- Dissolved methane concentrations in the fractured rock were comparable to those encountered at the Faulkland site.
- Isotope data indicates that groundwater in the Leloma Formation is of meteoric origin and is several thousand years old. Methane is of mixed biogenic/thermogenic origin.

8. Recommendations

The following recommendations are made regarding these additions to the monitoring network and ongoing GGP groundwater monitoring:

- Electronic and manual groundwater level monitoring should continue to monitor and further understand the different groundwater systems and the hydrogeological environment over different seasonal conditions.
- Groundwater quality monitoring should be included in the regional water quality monitoring program to provide a more definitive baseline characterisation of the natural groundwater systems at the Faulkland and Bucketts Way sites.
- The results from the groundwater level monitoring should be incorporated into the GGP annual monitoring reports.

9. Statement of limitations

9.1 Scope of services

This report has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client (AGL) and Parsons Brinckerhoff (scope of services). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

9.2 Reliance on data

In preparing the report, Parsons Brinckerhoff has relied upon data, surveys, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, Parsons Brinckerhoff has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Parsons Brinckerhoff will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Parsons Brinckerhoff.

9.3 Environmental conclusions

In accordance with the scope of services, Parsons Brinckerhoff has relied upon the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants or emissions.

Within the limitations imposed by the scope of services, the monitoring, testing, sampling and preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, expressed or implied, is made.

9.4 Report for benefit of client

The report has been prepared for the benefit of the client (and no other party). Parsons Brinckerhoff assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of Parsons Brinckerhoff or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Parties other than the client should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

9.5 Other limitations

Parsons Brinckerhoff will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

10. References

- AECOM (2009) Gloucester Gas Project Environmental Assessment, report prepared for AGL, dated November 2009.
- AGL Energy Ltd (2010) Upstream Gas Golden Rules.
- AGL Energy Ltd (2013a) Gloucester Gas Project Health and Safety Management Plan, DCS_GN_HSE_MP_003.
- AGL Energy Ltd (2013b) Gloucester Gas Project Emergency Response Procedure, DCS_GN_HSE_MP_004.
- AGL Energy Ltd (2014) Weather: Daily Summary Data, data provided by AGL in February 2014.
- ANZECC (2000) Chapter 3 Aquatic Ecosystems, in Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.
- Bartos, TT and Ogle KM (2002) 'Water Quality and Environmental Isotopic Analyses of Ground-Water Samples Collected from the Wasatch and Fort Union Formations in Areas of Coalbed Methane Development-Implications to Recharge and Ground-Water Flow, Eastern Powder River Basin, Wyoming', Water-Resources Investigations Report 02-4045, United States Geological Survey and United States Department of the Interior, Wyoming, USA.
- Bouwer, H. (1989) The Bouwer and Rice slug test, Ground Water, vol. 27, no. 3, pp. 304-309.
- Bureau of Meteorology, Climate Data Online, available at http://www.bom.gov.au/climate/data/, accessed February 2014.
- Clark I.D. and Fritz P. (1997) Environmental isotopes in hydrogeology, CRC Press/Lewis Publishers, Boca Raton, Florida, 328 pp.
- Crosbie R.S., Morrow D., Cresswell R.G., Leaney F.W., Lamontagne S. and Lefournour M. (2012) New insights into the chemical and isotopic composition of rainfall across Australia. CSIRO Water for a Healthy Country Flagship, Australia.
- EMGAMM (2014) A review of the use of isotopes for coal seam gas investigations, report J13084RP1, dated March 2014, EMGAMM, Sydney.
- Fontes J-Ch. and Garnier J-M. (1979) Determination of the initial 14C activity of total dissolved carbon: A review of existing models and a new approach, Water Resources Research, 15:399–413.
- Highland Drilling (2013a) Safe work method statement & risk assessment: Gloucester groundwater project, dated June 2013.
- Highland Drilling (2013b) Job safety analysis: Broke groundwater project, construction of monitoring bores, dated June 2013.
- Hillis R. R., Meyer J. J. and Reynolds S. D. (1998) The Australian Stress Map. Exploration geophysics (1998):420 – 427.
- Hughes, W.W., Wilcox, R.D. and Wilcock, S.W. (1984) Regional exploration of the Gloucester Basin, Report prepared for Esso Australia Ltd.
- Hunt, J. W. (1989) Permian coals of eastern Australia: geological control of petrographic variation, International Journal of Coal Geology, 12, 589-634.
- Hvorslev M. J. (1951) Time lag and soil permeability in groundwater observations. U.S. Army Corps of Engineers Water-way Experimentation Station, Bulletin 36.

- Ingerson E. and Pearson Jr. F.J. (1964) Estimation of age and rate of motion of groundwater of the 14C-method. Recent researches in the fields of Atmosphere, Hydrosphere, and Nuclear Geochemistry, Sugawara Festival Volume, Maruzen Co., Tokyo.
- Lennox, M. (2009) Stroud Gloucester Trough: Review of the Geology and Coal Development, Ashley Resources, Sydney, dated January 2009.
- National Uniform Drillers Licencing Committee (NUDLC) (2012) Minimum Construction Requirements for Water Bores in Australia, Edition 3.
- Parsons Brinckerhoff (2012) Phase 2 Groundwater Investigations – Stage 1 Gas Field Development Area, Gloucester Gas Project, PR_5630, dated January 2012, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2013a) GGP Groundwater drilling program for areas beyond Stage 1 GFDA, 2193324A-UGE-MEM-7281, dated June 2013, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2013b) Health, Environment & Safety Plan: Gloucester Gas Project, Groundwater Investigations, 2193324AOH_5603_RevA, dated June 2013, Parsons Brinckerhoff Sydney.
- Parsons Brinckerhoff (2013c) Construction & Environment Management Plan: Gloucester Gas Project, Additional Monitoring Bores, Groundwater Investigations, 2193324A PR_7277, dated June 2013, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2013d) Safety Management Plan: Gloucester Gas Project, Groundwater Investigations, 2193324A-UGE-RPT-7278, dated June 2013, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2013e) Gloucester Groundwater and Surface Water Monitoring – Annual Status Report, 2162406E-RES-RPT-7423 RevA, dated October 2013, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2013f) Hydrogeological Investigation of a Strike-slip Fault in the Northern Gloucester Basin, 2192406B PR_5741 RevC, dated August 2013, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2014a) 2013 Flow Testing of Craven06 and Waukivory 03 Gas Wells, 2162406C-WAT-RPT-7642 RevB, dated February 2014, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2014b) Drilling completion report: Waukivory groundwater monitoring bores. 2162406C-WAT-RPT-7761 RevB, dated July 2014, Parsons Brinckerhoff, Sydney.
- Parsons Brinckerhoff (2014c*) (in preparation*) 2014 Groundwater and Surface Water Monitoring Status Report – Gloucester Gas Project, 2201007A-RES-RPT-001 RevC, Parsons Brinckerhoff, Sydney.
- Roberts, J., Engel, B., Chapman, J. (1991) Geology of the Camberwell, Dungog, and Bulahdelah 1:100 000 Geological Sheets 9133, 9233, 9333*,* New South Wales Geological Survey, Sydney.
- Rozanski K., Araguas-Araguas L. and Gonfiantini R. (1993) Isotopic patterns in modern global precipitation, in Continental Isotope Indicators of Climate. American Geophysical Union Monograph, cited by Clark and Fritz, 1997.
- SRK Consulting (2005) Gloucester Basin Geological Review*,* SRK Project Number GBA001.
- Tamers M.A. (1975) The validity of radiocarbon dates on groundwater, Geophysical Survey, 2:217–239.
- Thornton, R.C.N. (1982) Oil occurrence in Esso stratigraphic corehole C7029, Gloucester Basin. Esso Australia Limited, 69pp.
- Volk H., Pinetown, K., Johnston, C. and McLean, W. (2011) A desktop study of the occurrence of Total Petroleum Hydrocarbon (TPH) and partially water-soluble organic compounds in Permian coals and associated coal seam groundwater. CSIRO Petroleum & Geothermal Research Portfolio Open File Report EP-13-09-11-11.
- Waterra (2011) Waterra 3 Part Well Slugs User Guide, Waterra (UK) Ltd www.waterrauk.com, accessed August 2011.

Appendix A

Bore licences

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

20BL173512

Department of Primary Industries Office of Water

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

LICENSE NUMBER
20BL173512
DATE LICENSE VALID FROM
10-May-2013
DATE LICENSE VALID TO
PERPETUITY
FEE
$0.00

ABN 47661556763 GST NIL

LOCATION OF WORKS

Portion(s) or Lot/Section/DP	PARISH	COUNTY
1//877783	Gloucester	Gloucester

TYPE OF WORKS	PURPOSE(S) FOR WHICH WATER MAY BE USED
Bore	Monitoring Bore

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 20BL173512 ISSUED UNDER PART V OF THE WATER ACT, 1912 ON 10-May-2013

(1) THE LICENCE SHALL LAPSE IF THE WORK IS NOT COMMENCED AND COMPLETED WITHIN ONE YEAR OF THE DATE OF ISSUE OF THE LICENCE.

(2) 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.

(3) WATER SHALL NOT BE PUMPED FROM THE BORE AUTHORISED BY THIS LICENSE FOR ANY PURPOSE OTHER THAN GROUNDWATER INVESTIGATION.

(4) THE WORK SHOULD BE CONSTRUCTED TO SEAL OFF WATER FROM ANY AQUIFER OTHER THAN THE TARGET AQUIFER BY:
(A) INSERTING THE APPROPRIATE LENGTH OF CASING TO A DEPTH IMMEDIATELY ABOVE THE TARGET AQUIFER
(B) CEMENTING BETWEEN THE CASING(S) AND THE WALLS OF THE BORE HOLE FROM THE BOTTOM OF THE CASING TO GROUND LEVEL.

(5) THE LICENSEE SHALL NOTIFY NSW OFFICE OF WATER IF A FLOWING SUPPLY OF WATER IS OBTAINED. THE BORE SHALL THEN BE LINED WITH CASING AND CEMENTED AND A SUITABLE CLOSING GEAR SHALL BE ATTACHED TO THE BOREHEAD AS SPECIFIED BY NSW OFFICE OF WATER.

(6) IF A WORK IS ABANDONED AT ANY TIME THE LICENSEE SHALL NOTIFY NSW OFFICE OF WATER THAT THE WORK HAS BEEN ABANDONED AND SEAL OFF THE AQUIFER IN ACCORDANCE WITH THE MINIMUM CONSTRUCTION REQUIREMENTS FOR WATER BORES IN AUSTRALIA.

(7) THE LICENCE HOLDER MUST, WITHIN 2 MONTHS OF COMPLETION OF THE CONSTRUCTION OF THE WORK, OR WITHIN 2 MONTHS AFTER THE ISSUE OF THE APPROVAL IF THE WORK IS EXISTING, SUBMIT TO THE DEPARTMENT THE FOLLOWING:
(I) THE COMPLETED APPROVED FORM (FORM A),
(II) DETAILS OF THE LOCATION OF THE WORK ON A COPY OF THE LOT AND DEPOSITED PLAN, THE WORKS GPS REFERENCE, AND THE RESPECTIVE DISTANCE(S) OF THE WORK FROM THE PROPERTY BOUNDARIES,
(III) IF THE MINISTER HAS REQUESTED ANY WATER ANALYSIS AND/OR PUMPING TESTS TO BE CARRIED OUT, DETAILS OF THE WATER ANALYSIS AND/OR PUMPING TESTS AS REQUIRED BY THE MINISTER,

(8) IF, DURING THE CONSTRUCTION OF THE WORK, SALINE OR CONTAMINATED WATER IS ENCOUNTERED ABOVE THE PRODUCTION AQUIFER, THE LICENCE HOLDER MUST:
(I) NOTIFY THE DEPARTMENT,
(II) ENSURE THAT SUCH WATER IS SEALED OFF BY:
(1) INSERTING CASING TO A DEPTH SUFFICIENT TO EXCLUDE THE SALINE OR CONTAMINATED WATER FROM THE WORK,
(2) IF SPECIFIED BY THE MINISTER, PLACING AN IMPERMEABLE SEAL BETWEEN THE CASING(S) AND THE WALLS OF THE WORK FROM THE BOTTOM OF THE CASING TO GROUND LEVEL AS SPECIFIED BY THE MINISTER,
(III) IF THE MINISTER HAS SPECIFIED ANY OTHER REQUIREMENTS, COMPLY WITH THE REQUIREMENTS (IF ANY) SPECIFIED BY THE MINISTER,

(9) 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;

(10) THE LICENCE HOLDER SHALL NOT DISTURB THE HABITAT OF ANY NATIVE FLORA AND/OR FAUNA.

(11) THE LICENCE HOLDER IS NOT AUTHORISED BY THIS LICENCE TO REMOVE OR CLEAR ANY NATIVE VEGETATION OR TREES AS DESCRIBED WITHIN THE NATIVE VEGETATION CONSERVATION ACT 1997 OR NATIVE VEGETATION ACT 2003. ANY VEGETATION REMOVAL WILL REQUIRE SEPARATE WRITTEN APPROVAL FROM NSW OFFICE OF WATER.

(12) BORE DRILLING/CONSTRUCTION MUST OCCUR IN ACCORDANCE WITH THE MINIMUM CONSTRUCTION REQUIREMENTS FOR WATER BORES IN AUSTRALIA.

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

20BL173447

Department of Primary Industries Office of Water

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

LICENSE NUMBER
20BL173447
DATE LICENSE VALID FROM
10-May-2013
DATE LICENSE VALID TO
PERPETUITY
FEE
$0.00

ABN 47661556763 GST NIL

LOCATION OF WORKS

Portion(s) or Lot/Section/DP	PARISH	COUNTY
430//192505	Gloucester	Gloucester

TYPE OF WORKS	PURPOSE(S) FOR WHICH WATER MAY BE USED
Bore	Monitoring Bore

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 20BL173447 ISSUED UNDER PART V OF THE WATER ACT, 1912 ON 10-May-2013

(1) THE LICENCE SHALL LAPSE IF THE WORK IS NOT COMMENCED AND COMPLETED WITHIN ONE YEAR OF THE DATE OF ISSUE OF THE LICENCE.

(2) 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.

(3) WATER SHALL NOT BE PUMPED FROM THE BORE AUTHORISED BY THIS LICENSE FOR ANY PURPOSE OTHER THAN GROUNDWATER INVESTIGATION.

(4) THE WORK SHOULD BE CONSTRUCTED TO SEAL OFF WATER FROM ANY AQUIFER OTHER THAN THE TARGET AQUIFER BY:
(A) INSERTING THE APPROPRIATE LENGTH OF CASING TO A DEPTH IMMEDIATELY ABOVE THE TARGET AQUIFER
(B) CEMENTING BETWEEN THE CASING(S) AND THE WALLS OF THE BORE HOLE FROM THE BOTTOM OF THE CASING TO GROUND LEVEL.

(5) THE LICENSEE SHALL NOTIFY NSW OFFICE OF WATER IF A FLOWING SUPPLY OF WATER IS OBTAINED. THE BORE SHALL THEN BE LINED WITH CASING AND CEMENTED AND A SUITABLE CLOSING GEAR SHALL BE ATTACHED TO THE BOREHEAD AS SPECIFIED BY NSW OFFICE OF WATER.

(6) IF A WORK IS ABANDONED AT ANY TIME THE LICENSEE SHALL NOTIFY NSW OFFICE OF WATER THAT THE WORK HAS BEEN ABANDONED AND SEAL OFF THE AQUIFER IN ACCORDANCE WITH THE MINIMUM CONSTRUCTION REQUIREMENTS FOR WATER BORES IN AUSTRALIA.

(7) THE LICENCE HOLDER MUST, WITHIN 2 MONTHS OF COMPLETION OF THE CONSTRUCTION OF THE WORK, OR WITHIN 2 MONTHS AFTER THE ISSUE OF THE APPROVAL IF THE WORK IS EXISTING, SUBMIT TO THE DEPARTMENT THE FOLLOWING:
(I) THE COMPLETED APPROVED FORM (FORM A),
(II) DETAILS OF THE LOCATION OF THE WORK ON A COPY OF THE LOT AND DEPOSITED PLAN, THE WORKS GPS REFERENCE, AND THE RESPECTIVE DISTANCE(S) OF THE WORK FROM THE PROPERTY BOUNDARIES,
(III) IF THE MINISTER HAS REQUESTED ANY WATER ANALYSIS AND/OR PUMPING TESTS TO BE CARRIED OUT, DETAILS OF THE WATER ANALYSIS AND/OR PUMPING TESTS AS REQUIRED BY THE MINISTER,

(8) IF, DURING THE CONSTRUCTION OF THE WORK, SALINE OR CONTAMINATED WATER IS ENCOUNTERED ABOVE THE PRODUCTION AQUIFER, THE LICENCE HOLDER MUST:
(I) NOTIFY THE DEPARTMENT,
(II) ENSURE THAT SUCH WATER IS SEALED OFF BY:
(1) INSERTING CASING TO A DEPTH SUFFICIENT TO EXCLUDE THE SALINE OR CONTAMINATED WATER FROM THE WORK,
(2) IF SPECIFIED BY THE MINISTER, PLACING AN IMPERMEABLE SEAL BETWEEN THE CASING(S) AND THE WALLS OF THE WORK FROM THE BOTTOM OF THE CASING TO GROUND LEVEL AS SPECIFIED BY THE MINISTER,
(III) IF THE MINISTER HAS SPECIFIED ANY OTHER REQUIREMENTS, COMPLY WITH THE REQUIREMENTS (IF ANY) SPECIFIED BY THE MINISTER,

(9) 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;

(10) THE LICENCE HOLDER SHALL NOT DISTURB THE HABITAT OF ANY NATIVE FLORA AND/OR FAUNA.

(11) THE LICENCE HOLDER IS NOT AUTHORISED BY THIS LICENCE TO REMOVE OR CLEAR ANY NATIVE VEGETATION OR TREES AS DESCRIBED WITHIN THE NATIVE VEGETATION CONSERVATION ACT 1997 OR NATIVE VEGETATION ACT 2003. ANY VEGETATION REMOVAL WILL REQUIRE SEPARATE WRITTEN APPROVAL FROM NSW OFFICE OF WATER.

(12) BORE DRILLING/CONSTRUCTION MUST OCCUR IN ACCORDANCE WITH THE MINIMUM CONSTRUCTION REQUIREMENTS FOR WATER BORES IN AUSTRALIA.

End Of Conditions

Appendix B

Bore logs

BORE COMPLETION REPORT - FKMB01a

Project: AGL Gloucester Gas Project
Location: Faulkland 3
Easting: 400584.357 **Northing:** 6453225.964
TOC elevation: 140.6 mAHD (PVC casing)
Grid system: MGA 94 Zone 56 **Stick-up height:** 0.64 m

Drilling contractor: Highland Drilling
Driller: I. Palk **Rig:** Rig 12
Drilling method: Rotary Air

Bore diameter	205.0 mm	0	- 5.0	m	**Bit:** Blade
Bore diameter:	139.0 mm	5.0	54.0	m	**Bit:** DHH

Purpose of bore: Groundwater monitoring bore
Screened Fmn: Leloma
Logged by: A. McFarlane
Start date: 28/6/13 **Compl. date:** 2/7/13
Total drilled depth: 54.0 m

Static WL: 119.37 mAHD 20.6 mBTOC
WL date: 3/7/13

Plain casing: 0-44m: 50mm PVC Class 18
Screen: 44.0-53.0m: 50mm PVC Class 18 (0.5mm slot)
Sump: 53.0-54.0m: 50mm PVC Class 18
Cement grout: 0-35.5m: 0.4m3
Gravel backfill: NA
Bentonite seal: 35.5-42.5m
Gravel pack: 42.5-54.0m: 5mm washed gravel
Bentonite plug: NA

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY GRAPHIC LOG	LITHOLOGY	WATER QUALITY
Steel headworks and monument	-1			
	0		GRAVEL clayey, yellowish brownish grey, coarse, up to 20mm (FILL)	
6 inch steel surface casing	1			
	2		GRANEL yellowish brown, clayey, sandy, cobbles <40mm	
	3			
	4			
	5		CLAYSTONE purplish greyish brown, clayey	
	6			
	7			
	8			
	9			
	10		CLAYSTONE grey, clay	
	11			
	12			
	13		SILTSTONE light grey	
	14			
	15			
	16		SILTSTONE grey	
	17			
Cement grout	18		SANDSTONE fine grained, grey, minor carbonaceous material	
	19			
	20			
	21			
50mm blank PN18 U-PVC casing (threaded)	22		SANDSTONE very fine grained , light grey	
	23			
	24			

PARSONS BRINCKERHOFF

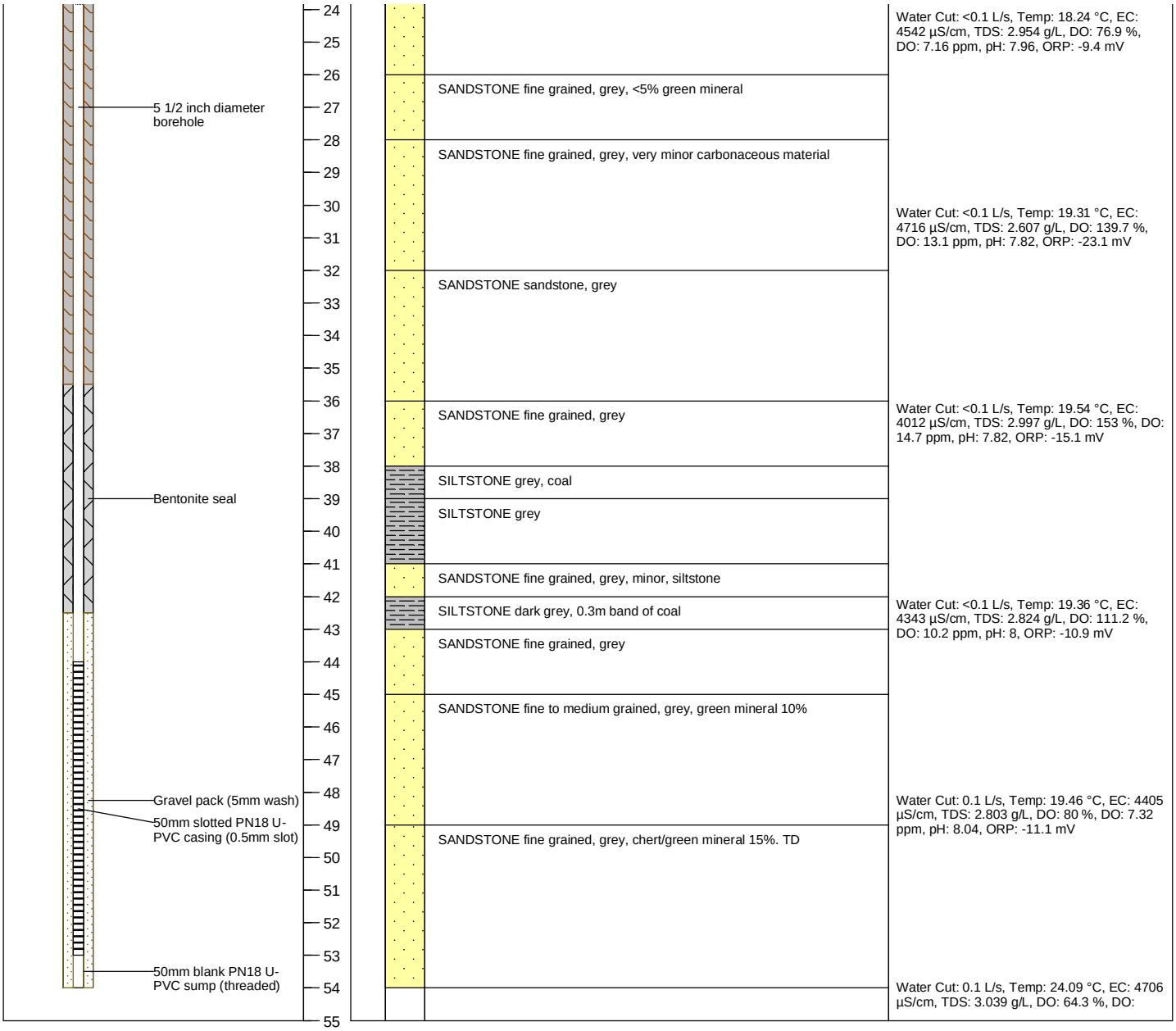
Drawing No.:	FKMB01a - Bore Construction		
Revision:	A	Date Drawn:	5/2/14
Drawn By: K. Maher		Checked By:	
Project No.	2193324A		

AGL

AGL Upstream Investments Pty Ltd
FKMB01a

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - FKMB01a



PARSONS BRINCKERHOFF

Drawing No.: FKMB01a - Bore Construction	
Revision: A	Date Drawn: 5/2/14
Drawn By: K. Maher	Checked By:
Project No. 2193324A	

AGL

AGL Upstream Investments Pty Ltd

FKMB01a

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - FKMB01b

Project: AGL Gloucester Gas Project
Location: Faulkland 3
Easting: 400594.7 **Northing:** 6453220.7
TOC elevation: 140.7 mAHD (PVC casing)
Grid system: MGA 94 Zone 56 **Stick-up height:** 0.55 m

Drilling contractor: Highland Drilling
Driller: I. Palk **Rig:** Rig 12
Drilling method: Rotary Air

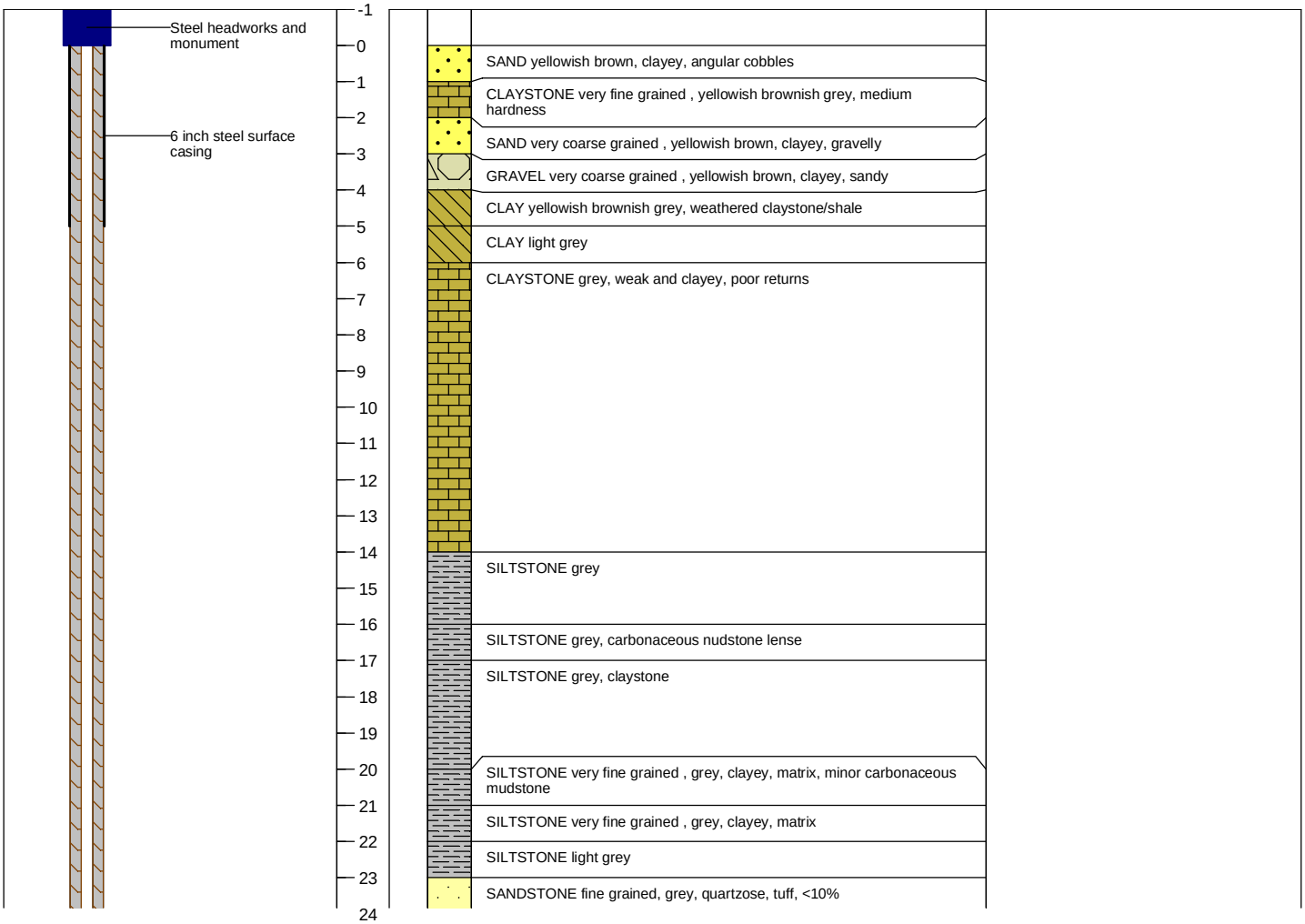
Bore diameter:	205.0 mm	0	- 5.0 m	**Bit:** Blade
Borehole diameter:	139.0 mm	5.0	- 150.2 m	**Bit:** DHH

Purpose of bore: Groundwater monitoring bore
Screened Fmn: Leloma
Logged by: A. McFarlane
Start date: 26/6/13 **Compl. date:** 1/7/13
Total drilled depth: 150.2 m

Static WL: 103.2 mAHD 36.8 mBTOC
WL date: 2/7/13

Plain casing: 0-140.2m: 50mm PVC Class 18
Screen: 140.2-149.2m: 50mm PVC Class 18 (0.5mm slot)
Sump: 149.2-150.2m: 50mm PVC Class 18
Cement grout: 0-131.5m: 1.6m3
Gravel backfill: NA
Bentonite seal: 131.5-135.4m
Gravel pack: 135.4-150.2m: 5mm washed gravel
Bentonite plug: NA

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY GRAPHIC LOG	LITHOLOGY	WATER QUALITY



PARSONS BRINCKERHOFF

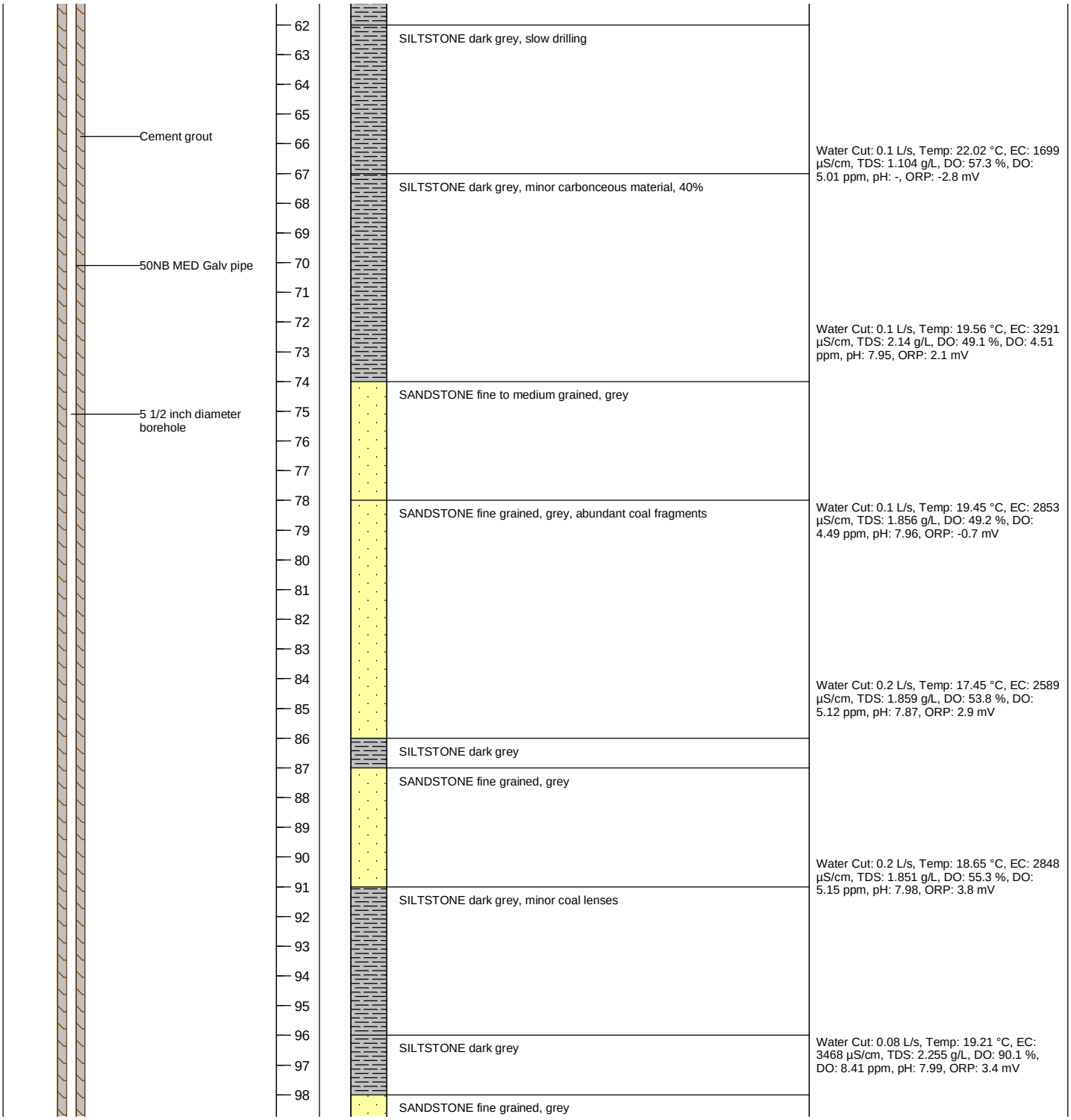
Drawing No.:	FKMB01b - Bore Construction		
Revision:	A	Date Drawn:	5/2/14
Drawn By:	K. Maher	Checked By:	J. Duggleby
Project No.	2193324A		

AGL

AGL Upstream Investments Pty Ltd
FKMB01b

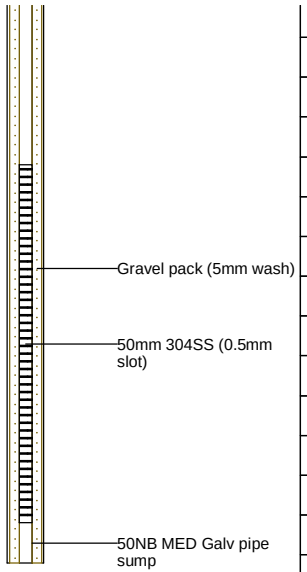
Drilling Completion Report FKMB & BWMB

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY	GRAPHIC LOG	LITHOLOGY	WATER QUALITY
	24				
	25			SANDSTONE fine grained, grey, minoe carbonaceous material	
	26				
	27				
	28				
	29			SILTSTONE dark grey	
	30				
	31			MUDSTONE dark grey	
	32			SANDSTONE fine grained, grey, minor coal and siltstone bands	
	33				
	34				
	35				
	36			SANDSTONE fine grained, grey	Water Cut: 0.1 L/s, Temp: 16.29 °C, EC: 3053 µS/cm, TDS: 1.983 g/L, DO: 45.5 %, DO: 4.43 ppm, pH: -, ORP: 40.9 mV
	37				
	38				
	39				
	40				
	41				
	42				
	43				
	44				
	45				
	46				
	47				
	48			SANDSTONE fine to medium grained, grey	Water Cut: 0.1 L/s, Temp: 17.99 °C, EC: 3558 µS/cm, TDS: 2.304 g/L, DO: 69.8 %, DO: 6.52 ppm, pH: -, ORP: 68 mV
	49			SANDSTONE fine to medium grained, light grey, claystone/tuff, 20%, green mineral (chlorite?), 10%, possible fracture at 52m	
	50				
	51				
	52				
	53				
	54			SANDSTONE greyish green, chert and green/grey mineral (dolerite?), minor tuff (possible intrusion?)	Water Cut: 0.1 L/s, Temp: 21.53 °C, EC: 1838 µS/cm, TDS: 1.194 g/L, DO: 63.3 %, DO: 5.65 ppm, pH: -, ORP: 18.9 mV
	55				
	56			SILTSTONE dark grey	
	57				
	58				
	59				
	60			SILTSTONE grey, weathered tuuf band, fine to medium grained sandstone	Water Cut: 0.1 L/s, Temp: 16.95 °C, EC: 3211 µS/cm, TDS: 2.089 g/L, DO: 57.8 %, DO: 5.57 ppm, pH: -, ORP: 0.9 mV
	61				


BORE CONSTRUCTION
DEPTH (m)
STRATIGRAPHY
GRAPHIC LOG
LITHOLOGY
WATER QUALITY
Cement grout
50NB MED Galv pipe
5 1/2 inch diameter borehole
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
SILTSTONE dark grey, slow drilling
SILTSTONE dark grey, minor carbonceous material, 40%
SANDSTONE fine to medium grained, grey
SANDSTONE fine grained, grey, abundant coal fragments
SILTSTONE dark grey
SANDSTONE fine grained, grey
SILTSTONE dark grey, minor coal lenses
SILTSTONE dark grey
SANDSTONE fine grained, grey
Water Cut: 0.1 L/s, Temp: 22.02 °C, EC: 1699 µS/cm, TDS: 1.104 g/L, DO: 57.3 %, DO: 5.01 ppm, pH: -, ORP: -2.8 mV
Water Cut: 0.1 L/s, Temp: 19.56 °C, EC: 3291 µS/cm, TDS: 2.14 g/L, DO: 49.1 %, DO: 4.51 ppm, pH: 7.95, ORP: 2.1 mV
Water Cut: 0.1 L/s, Temp: 19.45 °C, EC: 2853 µS/cm, TDS: 1.856 g/L, DO: 49.2 %, DO: 4.49 ppm, pH: 7.96, ORP: -0.7 mV
Water Cut: 0.2 L/s, Temp: 17.45 °C, EC: 2589 µS/cm, TDS: 1.859 g/L, DO: 53.8 %, DO: 5.12 ppm, pH: 7.87, ORP: 2.9 mV
Water Cut: 0.2 L/s, Temp: 18.65 °C, EC: 2848 µS/cm, TDS: 1.851 g/L, DO: 55.3 %, DO: 5.15 ppm, pH: 7.98, ORP: 3.8 mV
Water Cut: 0.08 L/s, Temp: 19.21 °C, EC: 3468 µS/cm, TDS: 2.255 g/L, DO: 90.1 %, DO: 8.41 ppm, pH: 7.99, ORP: 3.4 mV

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY	GRAPHIC LOG	LITHOLOGY	WATER QUALITY
	99				
	100				
	101				
	102				Water Cut: 0.01 L/s, Temp: 22.97 °C, EC: 1823 µS/cm, TDS: 1.185 g/L, DO: 88.1 %, DO: 7.63 ppm, pH: 8.05, ORP: -7.2 mV
	103				
	104				
	105			SANDSTONE fine grained, grey, minor limonite staining	
	106			SANDSTONE fine very fine grained, grey, clayey matrix, almost siltstone	
	107				
	108			SANDSTONE fine grained, grey, minor carbonaceous material	Water Cut: 0.08 L/s, Temp: 20.91 °C, EC: 2503 µS/cm, TDS: 1.627 g/L, DO: 48.5 %, DO: 4.32 ppm, pH: 8.11, ORP: -0.9 mV
	109				
	110				
	111				
	112				
	113				
	114				Water Cut: 0.08 L/s, Temp: 30.32 °C, EC: 2963 µS/cm, TDS: 1.926 g/L, DO: 58.4 %, DO: 5.28 ppm, pH: 8.1, ORP: 5.5 mV
	115				
	116				
	117				
	118				
	119				
	120				
	121				Water Cut: 0.08 L/s, Temp: 20.61 °C, EC: 2878 µS/cm, TDS: 1.872 g/L, DO: 98.2 %, DO: 9.11 ppm, pH: 8.09, ORP: 4.5 mV
	122				
	123				
	124				
	125				
	126				
	127			SANDSTONE fine grained, grey, carbonaceous material, 10%	Water Cut: 0.08 L/s, Temp: 18.93 °C, EC: 3152 µS/cm, TDS: 2.049 g/L, DO: 69 %, DO: - ppm, pH: 8.08, ORP: 10.8 mV
	128				
	129				
	130				
	131				
	132				
Bentonite seal	133			SANDSTONE fine grained, grey, siltstone/carbonaceous mudstone, 25%	Water Cut: 0.08 L/s, Temp: 21.73 °C, EC: 2642 µS/cm, TDS: 1.717 g/L, DO: 46.4 %, DO: 6.21 ppm, pH: 8.11, ORP: 6.1 mV
	134				
	135				
	136				

BORE COMPLETION REPORT - FKMB01b

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY	GRAPHIC LOG	LITHOLOGY	WATER QUALITY
	136				
	137				
	138				
	139				Water Cut: 0.08 L/s, Temp: 18.97 °C, EC: 2756 µS/cm, TDS: 1.792 g/L, DO: 59.5 %, DO: 4.27 ppm, pH: 8.13, ORP: 9.3 mV
	140				
	141				
	142			SANDSTONE fine to medium grained, light grey	
Gravel pack (5mm wash)	143			SANDSTONE fine to medium grained, light grey, 10% chert, possible fracture	
	144				
50mm 304SS (0.5mm slot)	145			SANDSTONE fine to medium grained, grey, TD	Water Cut: 0.08 L/s, Temp: 21.6 °C, EC: 2922 µS/cm, TDS: 1.9 g/L, DO: 97.6 %, DO: 7.25 ppm, pH: 8.1, ORP: 8.3 mV
	146				
	147				
	148				
	149				
50NB MED Galv pipe sump	150				Water Cut: 0.12 L/s, Temp: 24.3 °C, EC: 2580
	151				

PARSONS BRINCKERHOFF

Drawing No.: FKMB01b - Bore Construction	
Revision: A	Date Drawn: 5/2/14
Drawn By: K. Maher	Checked By: J. Duggleby
Project No. 2193324A	

AGL

AGL Upstream Investments Pty Ltd

FKMB01b

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - BWMB01a

Project: AGL Gloucester Gas Project
Location: Bucketts Way 01
Easting: 402829.6 **Northing:** 6458307.1
TOC elevation: 89.09 mAHD (PVC casing)
Grid system: MGA 94 Zone 56 **Stick-up height:** 0.56

Drilling contractor: Highland Drilling
Driller: B. Delamont **Rig:** HD 20
Drilling method: Air Rotary

Bore diameter: 205 mm 0 - 18.0 m **Bit:** Blade
Bore diameter: NA **Bit:** NA

Purpose of bore: Groundwater monitoring bore
Screened Fmn: Shallow Alluvium
Logged by: K. Maher
Start date: 1/10/13 **Compl. date:** 1/10/13
Total drilled depth: 18.00 m

Static WL: 86.06 mAHD 3.025 mBTOC
WL date: 17/10/13

Plain casing: 0-6.5m: 50mm PVC Class 18
Screen: 6.5-9.5m: 50mm PVC Class 18 (0.5mm slot)
Sump: 9.5-11.63m: 50mm PVC Class 18
Cement grout: 0-2.71m: 0.034m3
Gravel backfill: NA
Bentonite seal: 2.71-3.5m
Gravel pack: 3.5-11.43m: 5mm washed gravel
Bentonite plug: 11.43-11.63m

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY / GRAPHIC LOG	LITHOLOGY	WATER QUALITY
Steel headworks and monument	-1			
	0		SOIL brown,	
Cement grout	1		CLAY grey, medium brownish, very dry	
6 inch steel surface casing	2			
Bentonite seal	3		CLAY yellowish brown, slight moisture	
50mm blank PVC Class 18 casing (threaded)	4		CLAY medium brown,	
	5		CLAY medium cream, cobbles up to ~4cm	
	6		GRAVEL brown,	Water Cut: - L/s, Temp: 27.18 °C, EC: 1885 µS/cm, TDS: 1.226 g/L, DO: 48 %, DO: 3.83 ppm, pH: 6.87, ORP: 189.9 mV
Gravel pack (5mm wash)	7			
50mm slotted PVC Class 18 casing (0.5mm slot)	8			
5 1/2 inch diameter borehole	9			
	10			
50mm blank PVC Class 18 sump (threaded)	11			
Bentonite plug	12			Water Cut: 1.25 L/s, Temp: 20.52 °C, EC: 1346 µS/cm, TDS: 0.847 g/L, DO: 110.1 %, DO: 9.33 ppm, pH: 7.26, ORP: 101.5 mV
	13		GRAVEL finer, brownish orangey grey,	
	14			
	15			
	16			
	17			
	18			

PARSONS BRINCKERHOFF

Drawing No.:	BWMB01a - Bore Construction		
Revision:	A	Date Drawn:	5/2/14
Drawn By: K. Maher		Checked By:	J. Duggleby
Project No.	2193324A		

AGL

AGL Upstream Investments Pty Ltd
BWMB01a

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - BWMB01b

Project: AGL Gloucester Gas Project
Location: Bucketts Way 01
Easting: 402831.9 **Northing:** 6458282.8
TOC elevation: 89.13 m (PVC casing)
Grid system: MGA 94 Zone 56 **Stick-up height:** 0.45 m

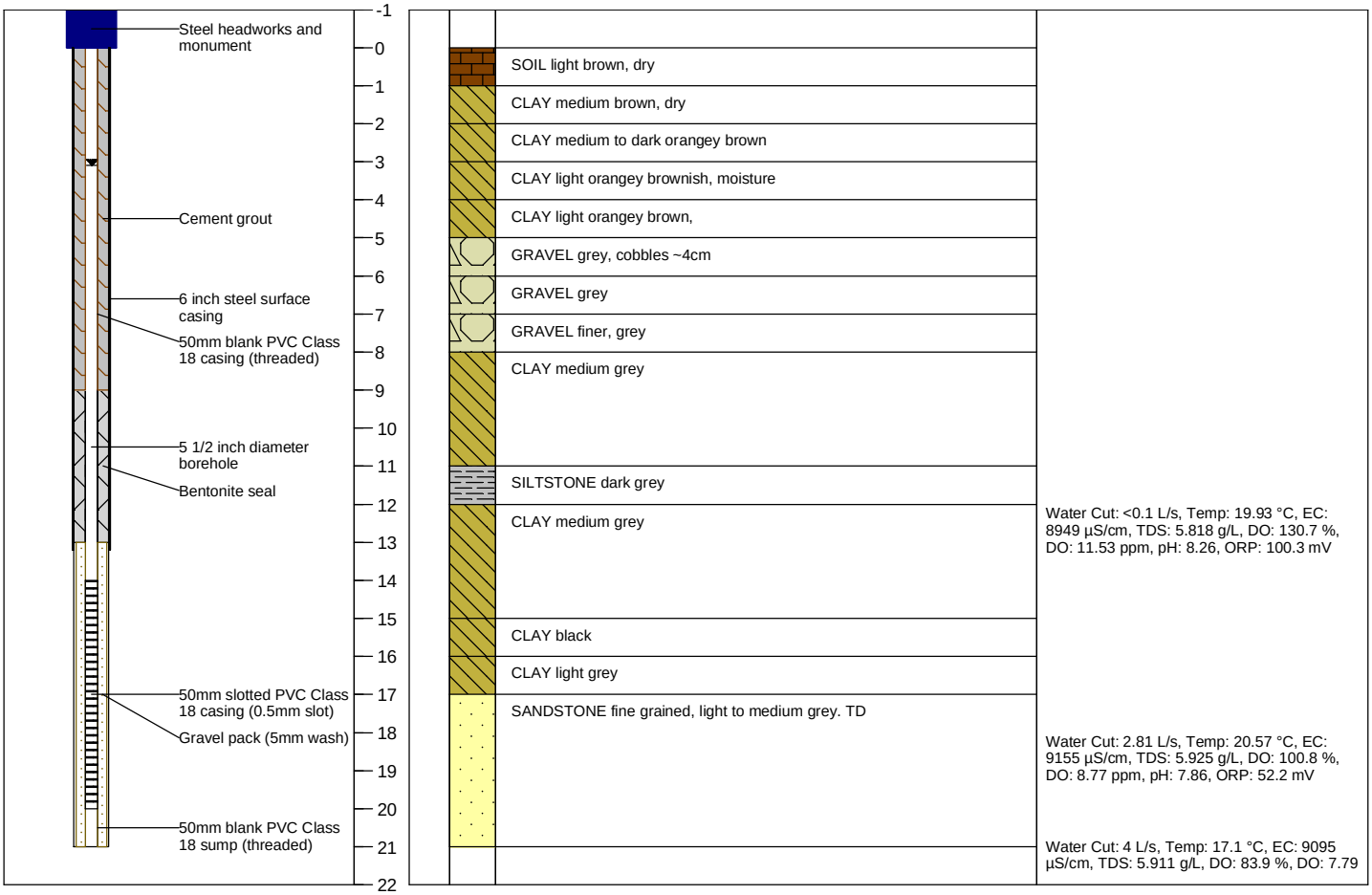
Drilling contractor: Highland Drilling
Driller: B. Delamont **Rig:** Rig 20
Drilling method: Air Rotary

Bore diameter:	153	mm	0	- 21	m	**Bit:** Tubex
Bore diameter:	NA			-		**Bit:** NA

Purpose of bore: Groundwater monitoring bore
Screened Fmn:
Logged by: K. Maher
Start date: 15/10/13 **Compl. date:** 16/10/13
Total drilled depth: 21 m

Static WL: 86.04 mAHD 3.09 mBTOC
WL date: 17/10/13

Plain casing: 0-14m: 50mm PVC Class 18
Screen: 14-20m: 50mm PVC Class 18 (0.5mm slot)
Sump: 20-21m: 50mm PVC Class 18
Cement grout: 0-9m: 0.113m3
Gravel backfill: NA
Bentonite seal: 9-13m
Gravel pack: 13-21m: 5mm washed gravel
Bentonite plug: NA



PARSONS BRINCKERHOFF

Drawing No.:	BWMB01b - Bore Construction		
Revision:	A	Date Drawn:	5/2/14
Drawn By: K. Maher		Checked By:	J. Duggleby
Project No.	2193324A		

AGL

AGL Upstream Investments Pty Ltd
BWMB01b

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - BWMB01c

Project: AGL Gloucester Gas Project
Location: Bucketts Way 01
Easting: 402831.1 **Northing:** 6458291.2
TOC elevation: 89.16 mAHD (PVC casing)
Grid system: MGA 94 Zone 56 **Stick-up height:** 0.55 m

Drilling contractor: Highland Drilling
Driller: B. Delamont **Rig:** Rig 20
Drilling method: Air Rotary

Bore diameter:	153 mm	0 - 5.0 m	**Bit:**	Tubex
Borehole diameter:	139.0 mm	5.0 - 81.4 m	**Bit:**	DHH

Purpose of bore: Groundwater monitoring bore
Screened Fmn:
Logged by: K. Maher
Start date: 11/10/13 **Compl. date:** 14/10/13
Total drilled depth: 81.4 m

Static WL: 86.69 mAHD 2.47 mBTOC
WL date: 17/10/13

Plain casing: 0-59.4m: 50mm PVC Class 18
Screen: 67.4-79.4m: 50mm PVC Class 18 (0.5mm slot)
Sump: 79.4-81.4m: 50mm PVC Class 18
Cement grout: 0-131.5m: 2.0m3
Gravel backfill: NA
Bentonite seal: 59.4-64.4m
Gravel pack: 64.4-79.9m: 5mm washed gravel
Bentonite plug: 79.9-81.4m

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY GRAPHIC LOG	LITHOLOGY	WATER QUALITY
Steel headworks and monument 6 inch surface casing	-1 to 24		SOIL light to medium brown CLAY light to medium greyish brown CLAY greyish brownish orange CLAY brownish yellowish orange CLAY brownish yellowish orange GRAVEL light to medium brownish yellow, pebbles up to ~3cm CLAY dark grey SILTSTONE dark grey SANDSTONE fine grained, light to medium grey SANDSTONE fine grained, medium grey CLAY black SILTSTONE dark grey	Water Cut: <0.1 L/s, Temp: 26.93 °C, EC: 11967 µS/cm, TDS: 7.78 g/L, DO: 71.3 %, DO: 5.42 ppm, pH: 7.65, ORP: 76.4 mV

PARSONS BRINCKERHOFF

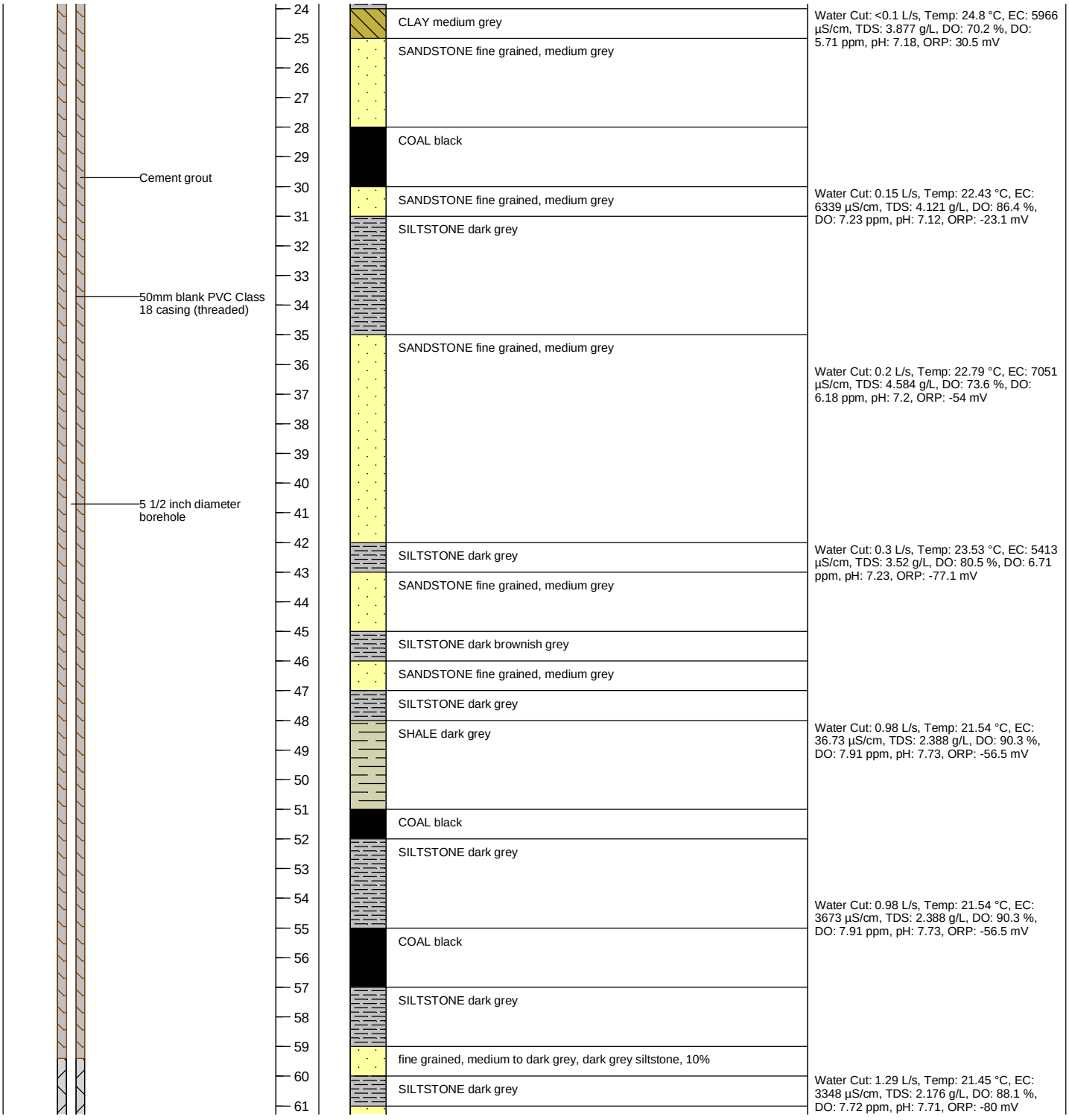
Drawing No.:	BWMB01c - Bore Construction		
Revision:	A	Date Drawn:	5/2/14
Drawn By: K. Maher		Checked By:	J. Duggleby
Project No.	2193324A		

AGL

AGL Upstream Investments Pty Ltd
BWMB01c

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - BWMB01c



PARSONS BRINCKERHOFF

Drawing No.: BWMB01c - Bore Construction	
Revision: A	Date Drawn: 5/2/14
Drawn By: K. Maher	Checked By: J. Duggleby
Project No. 2193324A	

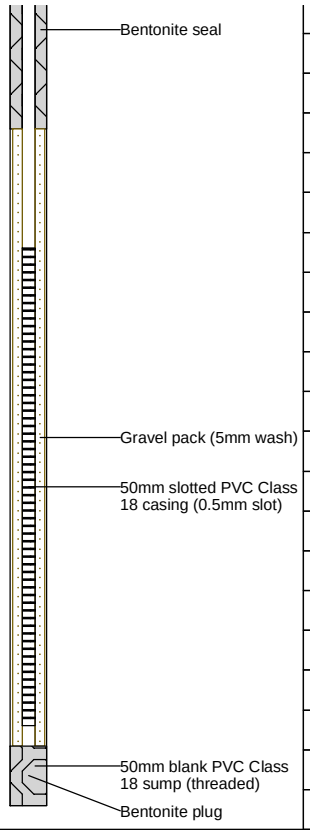
AGL

AGL Upstream Investments Pty Ltd

BWMB01c

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - BWMB01c

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY	GRAPHIC LOG	LITHOLOGY	WATER QUALITY
	62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82			SANDSTONE fine grained, medium grey SILTSTONE dark grey SANDSTONE medium grained , medium grey SANDSTONE fine grained, medium to dark grey SANDSTONE fine grained, medium grey SANDSTONE medium grained , medium grey, altered, speckled SANDSTONE medium grained , medium grey SILTSTONE, dark grey, TD	Water Cut: 2.96 L/s, Temp: 19.36 °C, EC: 5295 µS/cm, TDS: 3.441 g/L, DO: 94 %, DO: 8.45 ppm, pH: 7.72, ORP: 97.6 mV Water Cut: 6.06 L/s, Temp: 19.46 °C, EC: 6248 µS/cm, TDS: 4.662 g/L, DO: 84.8 %, DO: 7.63 ppm, pH: 7.84, ORP: -47.7 mV Water Cut: 7.57 L/s, Temp: 20.01 °C, EC: 6408 µS/cm, TDS: 4.165 g/L, DO: 98.2 %, DO: 8.69 ppm, pH: 7.92, ORP: -61.8 mV Water Cut: 9.701 L/s, Temp: 20.06 °C, EC:

PARSONS BRINCKERHOFF

Drawing No.: BWMB01c - Bore Construction	
Revision: A	Date Drawn: 5/2/14
Drawn By: K. Maher	Checked By: J. Duggleby
Project No. 2193324A	

AGL

AGL Upstream Investments Pty Ltd
BWMB01c

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - BWMB01d

Project: AGL Gloucester Gas Project
Location: Bucketts Ways 01
Easting: 402830.4 **Northing:** 6458299.1
TOC elevation: 89.13 mAHD (Gal casing)
Grid system: MGA 94 Zone 56 **Stick-up height:** 0.54 m

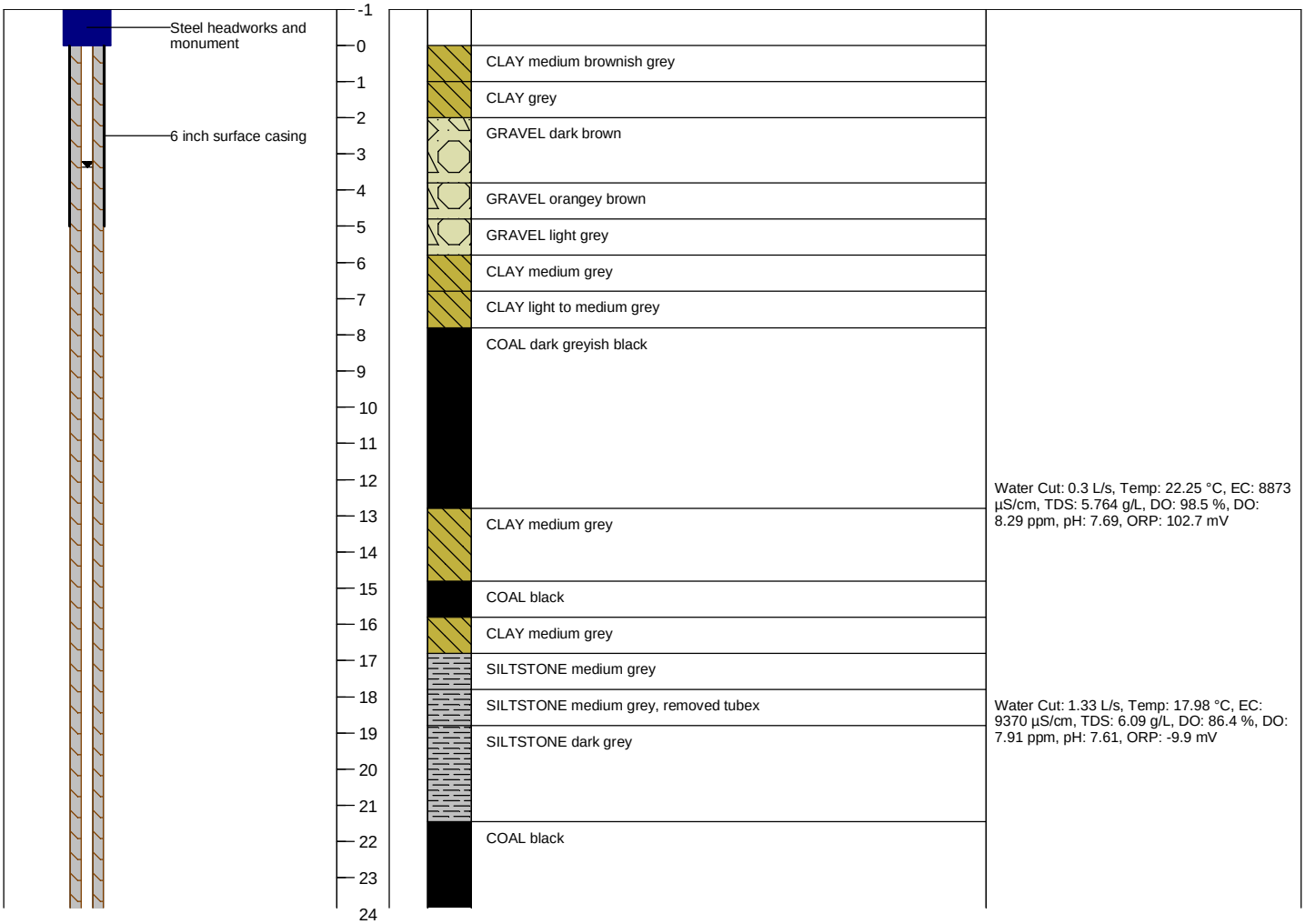
Drilling contractor: Highland Drilling
Driller: B. Delamont **Rig:** Rig 20
Drilling method: Air Rotary

Bore diameter:	153	mm	0	- 5.0 m	**Bit:** Tubex
Bore diameter:	139	mm	5.0	- 162.6 m	**Bit:** DHH

Purpose of bore: Groundwater monitoring bore
Screened Fmn:
Logged by: K. Maher
Start date: 4/10/13 **Compl. date:** 9/10/13
Total drilled depth: 162.6 m

Static WL: 85.76 mAHD 3.37 mBTOC
WL date: 2/7/13

Plain casing: 0-140.2m: 50NB MED Gal pipe
Screen: 149.6-161.6m: 50mm 304SS (1mm slot)
Sump: 161.6-162.6: 50NB MED Gal pipe sump
Cement grout: 0-149.6m: 1.88m3
Gravel backfill: NA
Bentonite seal: 141.6-146.6m
Gravel pack: 146.6-162.6-m: 5mm washed gravel
Bentonite plug: NA



PARSONS BRINCKERHOFF

Drawing No.:	BWMB01d - Bore Construction		
Revision:	A	Date Drawn:	5/2/14
Drawn By:	K. Maher	Checked By:	J. Duggleby
Project No.	2193324A		

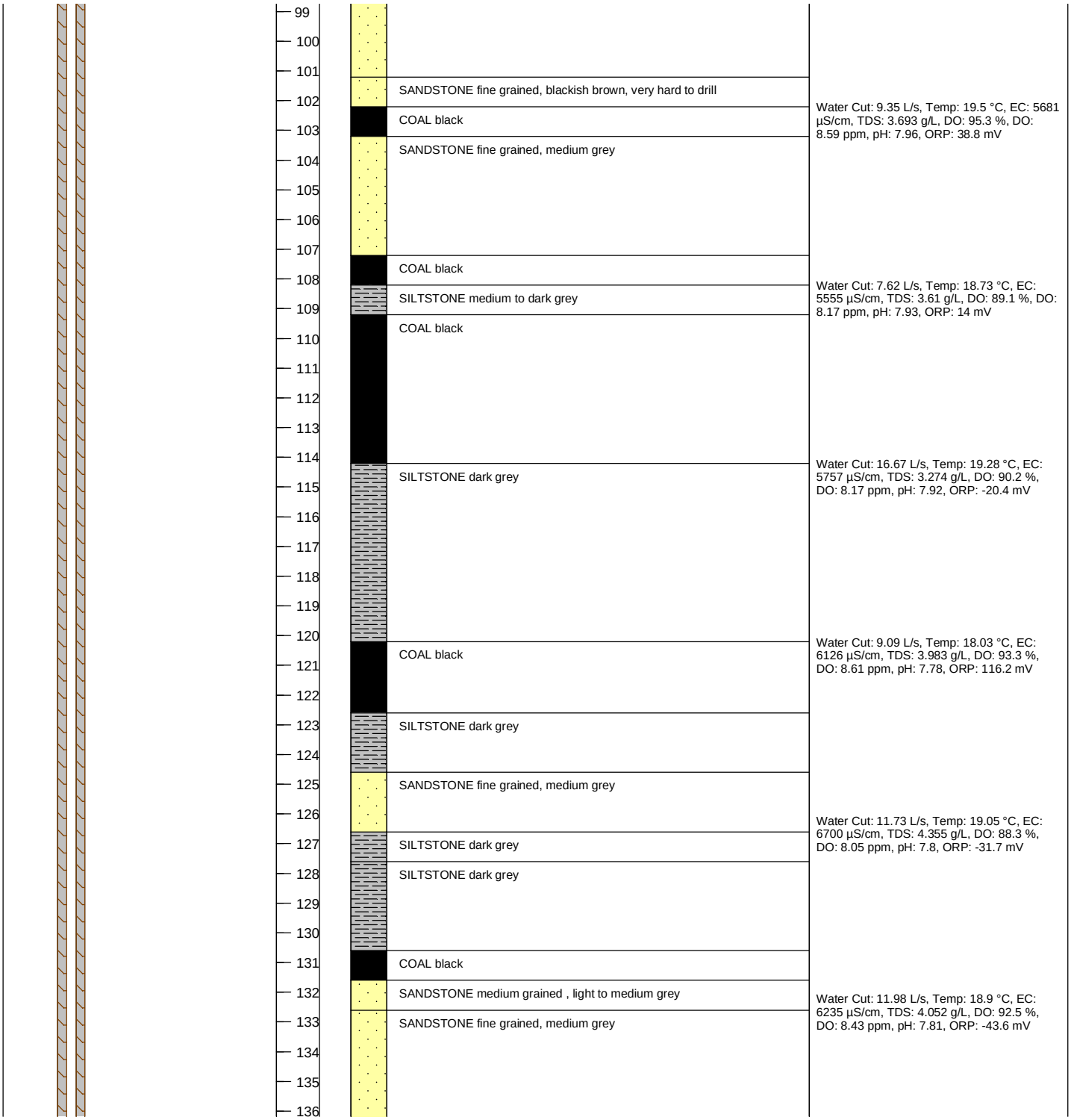
AGL

AGL Upstream Investments Pty Ltd
BWMB01d

Drilling Completion Report FKMB & BWMB

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY	GRAPHIC LOG	LITHOLOGY	WATER QUALITY
	24				Water Cut: 3.33 L/s, Temp: 18.65 °C, EC: 8621 µS/cm, TDS: 5.606 g/L, DO: 89.6 %, DO: 8.16 ppm, pH: 7.6, ORP: -44 mV
	25			SILTSTONE medium grey	
	26				
	27			SILTSTONE dark grey	
	28				
	29				
	30			SILTSTONE dark grey	Water Cut: 3.33 L/s, Temp: 18.54 °C, EC: 8557 µS/cm, TDS: 5.561 g/L, DO: 92.5 %, DO: 8.42 ppm, pH: 7.62, ORP: -74.5 mV
	31				
	32				
	33				
	34				
	35				
	36				Water Cut: 5 L/s, Temp: 18.65 °C, EC: 7396 µS/cm, TDS: 4.829 g/L, DO: 87.1 %, DO: 7.99 ppm, pH: 7.61, ORP: -87.2 mV
	37				
	38				
	39				
	40				
	41				
	42				Water Cut: 5 L/s, Temp: 17.97 °C, EC: 6953 µS/cm, TDS: 4.521 g/L, DO: 103.1 %, DO: 9.43 ppm, pH: 7.79, ORP: -52.4 mV
	43				
	44				
	45				
	46				
	47				
	48				Water Cut: 5.71 L/s, Temp: 18.48 °C, EC: 6889 µS/cm, TDS: 4.478 g/L, DO: 86.6 %, DO: 7.95 ppm, pH: 7.78, ORP: -60 mV
	49				
	50				
	51				
	52				
	53				
	54				Water Cut: 6.25 L/s, Temp: 18.9 °C, EC: 6846 µS/cm, TDS: 4.45 g/L, DO: 97.6 %, DO: 8.87 ppm, pH: 7.72, ORP: -93.2 mV
	55				
	56				
	57				
	58				
	59				
	60				Water Cut: 6.67 L/s, Temp: 19.92 °C, EC: 6879 µS/cm, TDS: 4.46 g/L, DO: 93.6 %, DO: 8.73 ppm, pH: 7.74, ORP: -74.2 mV
	61				

BORE CONSTRUCTION	DEPTH (m)	STRATIGRAPHY	GRAPHIC LOG	LITHOLOGY	WATER QUALITY
Cement grout	62–71			SANDSTONE fine to medium grained, medium to dark grey	
	66–71			SILTSTONE dark grey	Water Cut: 8.62 L/s, Temp: 18.2 °C, EC: 7760 µS/cm, TDS: 5.003 g/L, DO: 115.9 %, DO: 10.43 ppm, pH: 7.64, ORP: -84.8 mV
50mm 50NB MED Galv pipe	72–84			SANDSTONE medium grained , medium grey	Water Cut: 13.89 L/s, Temp: 17.72 °C, EC: 7369 µS/cm, TDS: 4.79 g/L, DO: 83.5 %, DO: 7.76 ppm, pH: 7.78, ORP: -18.4 mV
5 1/2 inch diameter borehole	78				Water Cut: 10 L/s, Temp: 19.51 °C, EC: 6928 µS/cm, TDS: 4.502 g/L, DO: 122.9 %, DO: 10.83 ppm, pH: 7.7, ORP: -41.4 mV
	84–85			COAL black	Water Cut: 10 L/s, Temp: 19.57 °C, EC: 7143 µS/cm, TDS: 4.644 g/L, DO: 92.7 %, DO: 8.3 ppm, pH: 7.73, ORP: -36.6 mV
	85–89			SANDSTONE fine grained, medium grey	
	89–90			COAL black	
	90–96			SANDSTONE fine grained, medium grey	Water Cut: 10 L/s, Temp: 20.45 °C, EC: 6536 µS/cm, TDS: 4.249 g/L, DO: 73.7 %, DO: 6.51 ppm, pH: 7.88, ORP: 27.8 mV
	96–98				Water Cut: 11.17 L/s, Temp: 20.14 °C, EC: 6443 µS/cm, TDS: 4.188 g/L, DO: 84.8 %, DO: 7.49 ppm, pH: 7.92, ORP: -10.2 mV



PARSONS BRINCKERHOFF

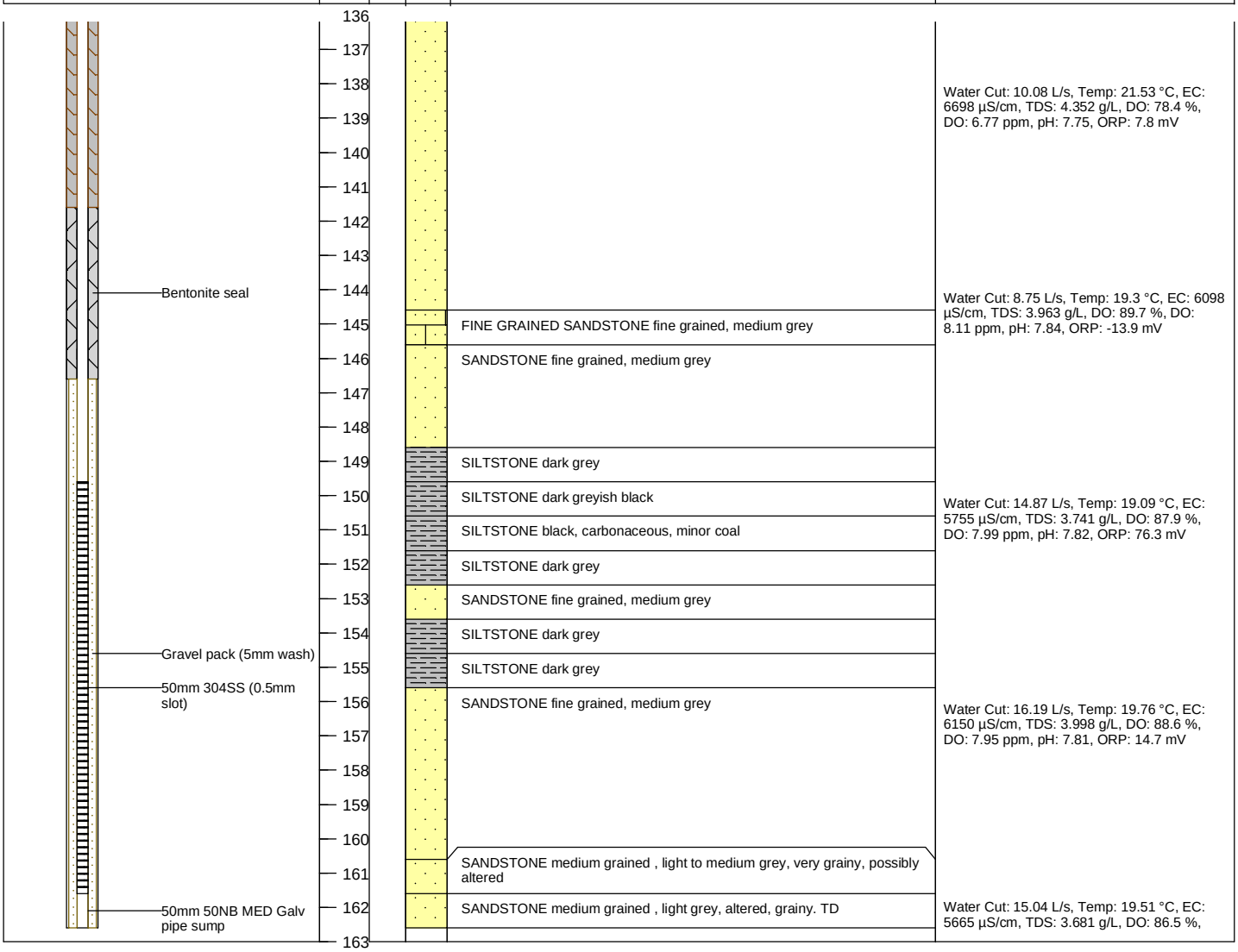
Drawing No.: BWMB01d - Bore Construction	
Revision: A	Date Drawn: 5/2/14
Drawn By: K. Maher	Checked By: J. Duggleby
Project No. 2193324A	

AGL

AGL Upstream Investments Pty Ltd
BWMB01d

Drilling Completion Report FKMB & BWMB

BORE COMPLETION REPORT - BWMB01d



PARSONS BRINCKERHOFF

Drawing No.: BWMB01d - Bore Construction	
Revision: A	Date Drawn: 5/2/14
Drawn By: K. Maher	Checked By: J. Duggleby
Project No. 2193324A	

AGL

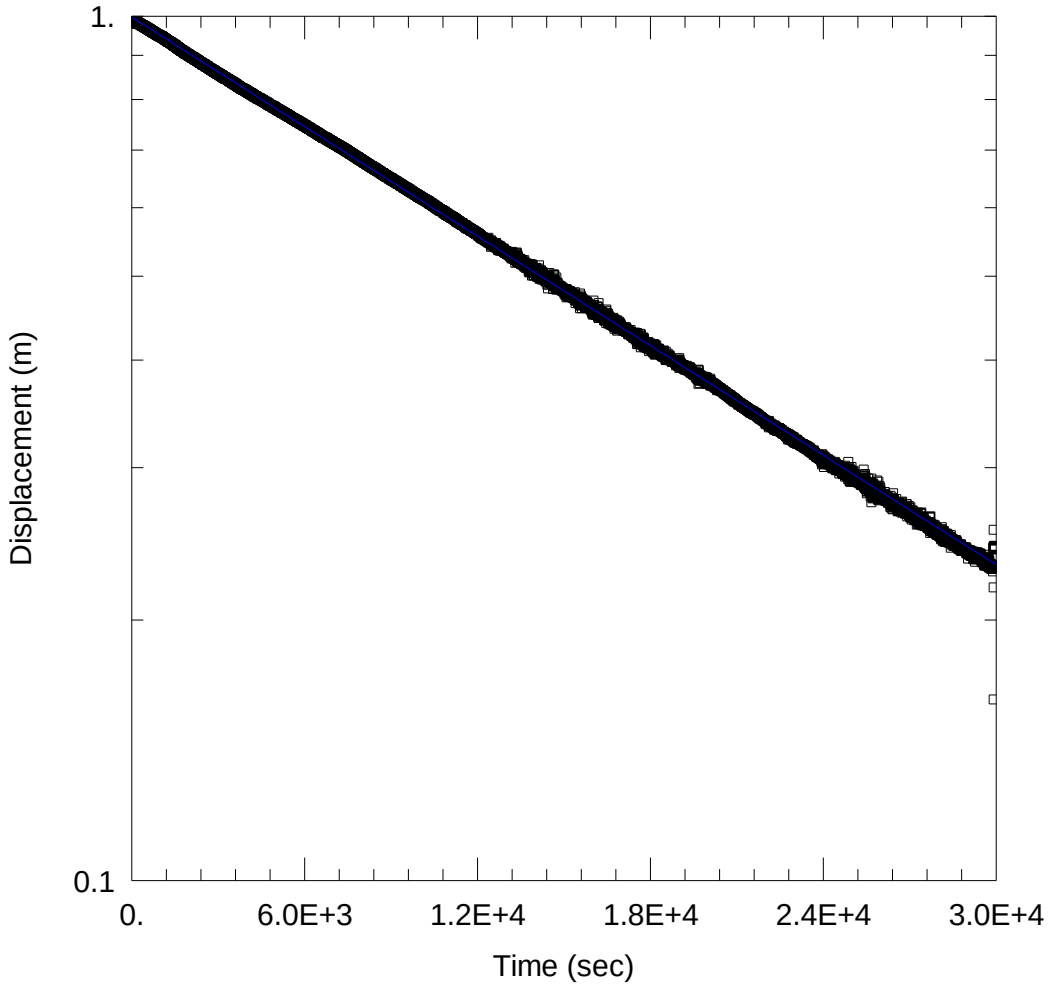
AGL Upstream Investments Pty Ltd

BWMB01d

Drilling Completion Report FKMB & BWMB

Appendix C

Hydraulic conductivity reports



WELL TEST ANALYSIS

Data Set: \...\FKMB01A_fh1.aqt
Date: 02/05/14 Time: 12:30:30

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Gloucester
Test Well: FKMB01B
Test Date: 9/10/2013

AQUIFER DATA

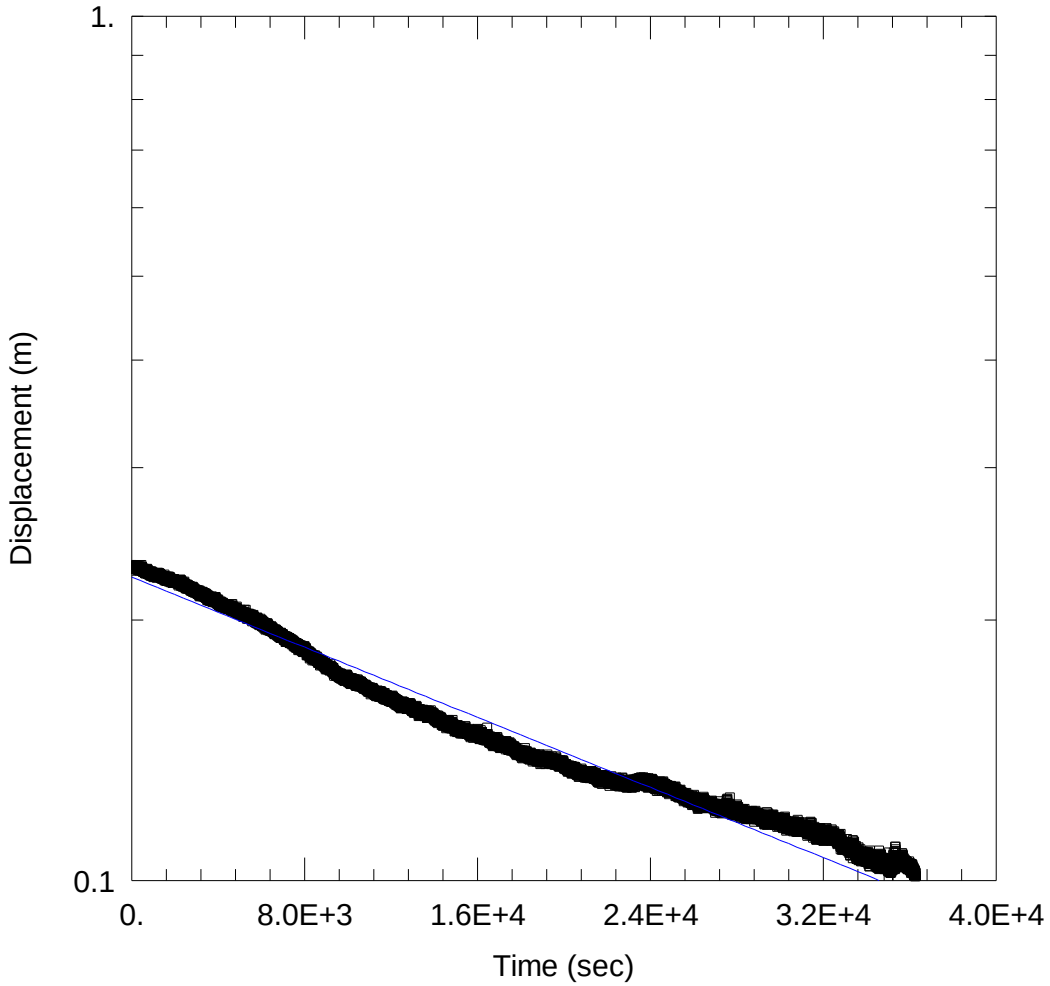
Saturated Thickness: 12. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (FKMB01B)

Initial Displacement: 0.9913 m
Total Well Penetration Depth: 11. m
Casing Radius: 0.05 m
Static Water Column Height: 112. m
Screen Length: 9. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 0.00303 m/day
y0 = 0.997 m



WELL TEST ANALYSIS

Data Set: \...\FKMB01A_rh1.aqt
Date: 02/05/14 Time: 12:42:11

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Gloucester
Test Well: FKMB01B
Test Date: 9/10/2013

AQUIFER DATA

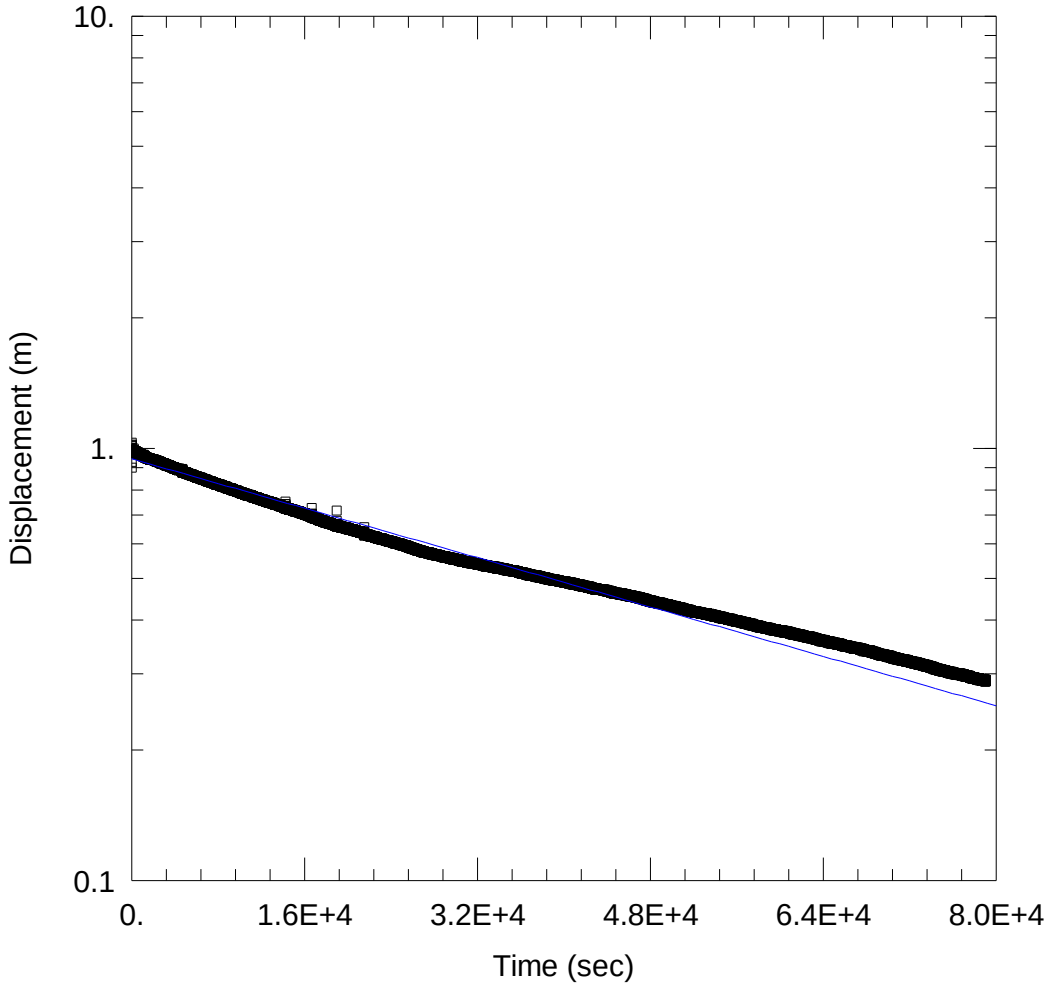
Saturated Thickness: 12. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (FKMB01B)

Initial Displacement: 0.2318 m
Total Well Penetration Depth: 11. m
Casing Radius: 0.05 m
Static Water Column Height: 112. m
Screen Length: 9. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 0.001455 m/day
y0 = 0.2243 m



WELL TEST ANALYSIS

Data Set: \...\FKMB01B.aqt
Date: 02/05/14 Time: 12:01:36

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Gloucester
Test Well: FKMB01B
Test Date: 9/10/2013

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

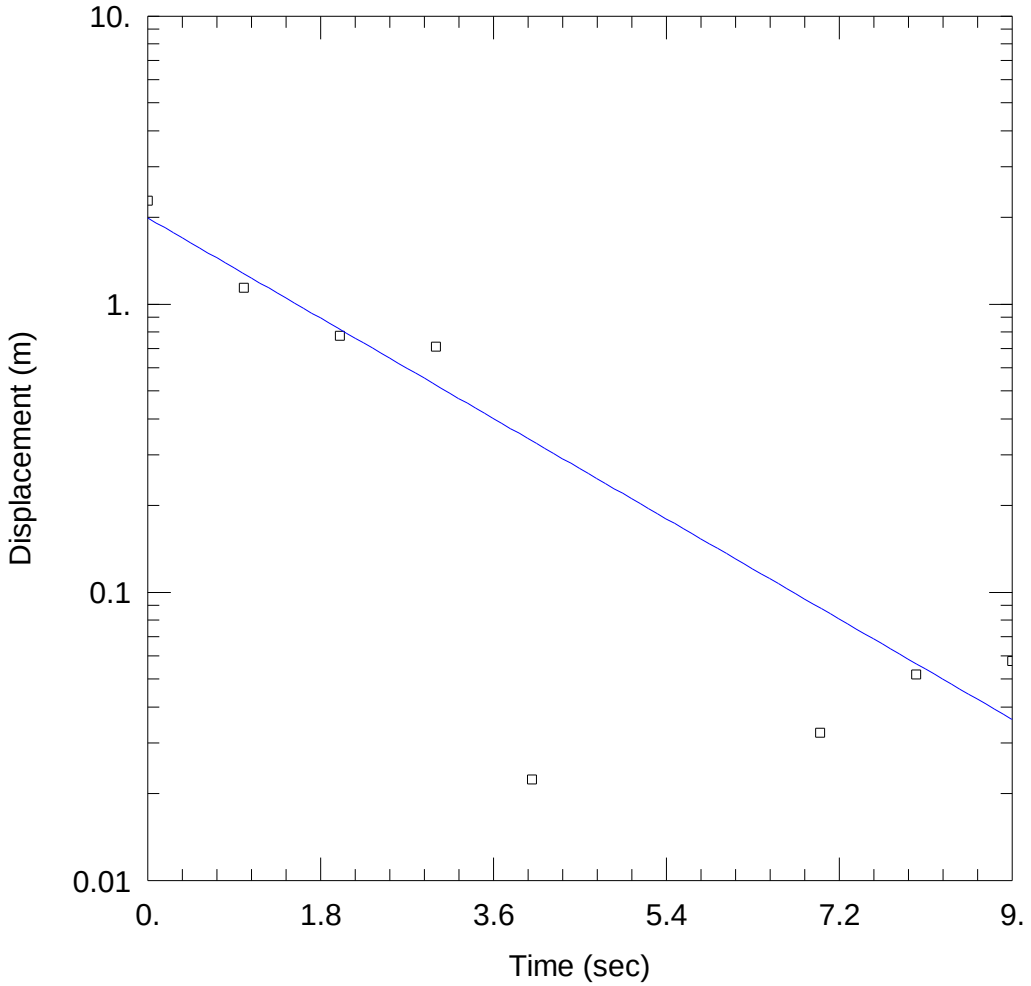
WELL DATA (FKMB01B)

Initial Displacement: 1.002 m
Total Well Penetration Depth: 49. m
Casing Radius: 0.05 m
Static Water Column Height: 112. m
Screen Length: 9. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev

K = 0.001025 m/day y0 = 0.9449 m



WELL TEST ANALYSIS

Data Set: \...\01A_fh1.aqt
Date: 02/04/14 Time: 15:02:01

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01A
Test Date: 29/10/2013

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

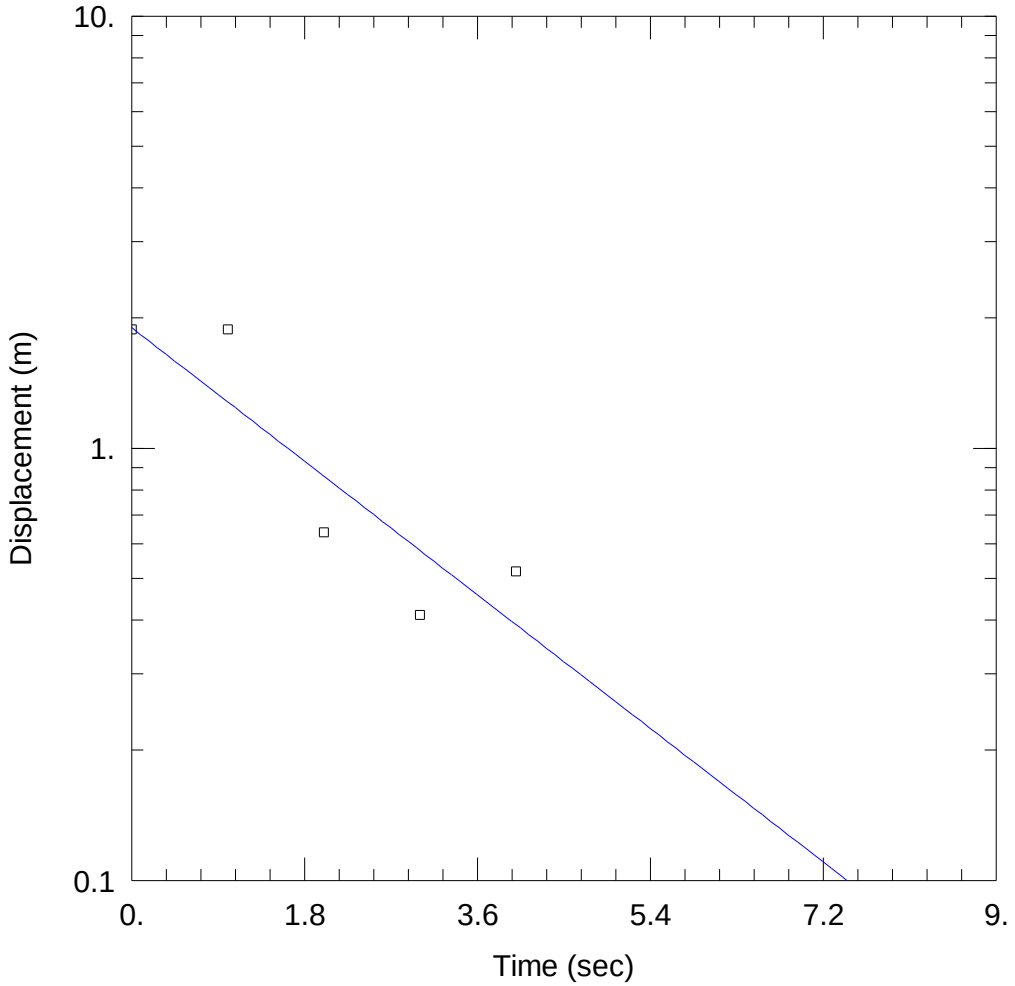
WELL DATA (BWMB01A)

Initial Displacement: 2.28 m Static Water Column Height: 8.6 m
Total Well Penetration Depth: 6.5 m Screen Length: 3. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 48.79 m/day y0 = 1.993 m



WELL TEST ANALYSIS

Data Set: \...\01A_rh1.aqt
Date: 02/04/14 Time: 15:03:33

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01A
Test Date: 29/10/2013

AQUIFER DATA

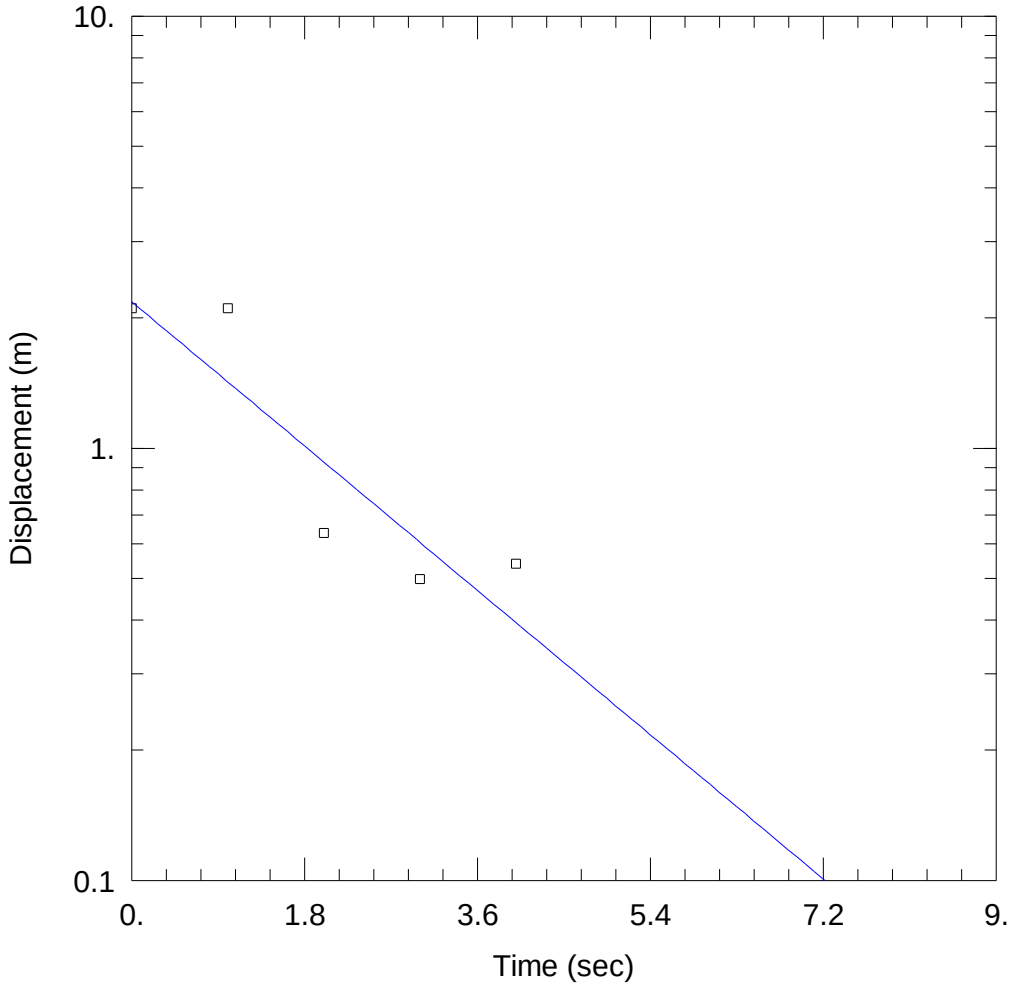
Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01A)

Initial Displacement: 1.886 m Static Water Column Height: 8.6 m
Total Well Penetration Depth: 6.5 m Screen Length: 3. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 43.3 m/day y0 = 1.9 m



WELL TEST ANALYSIS

Data Set: \...\01A_fh2.aqt
Date: 02/04/14 Time: 15:03:02

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01A
Test Date: 29/10/2013

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

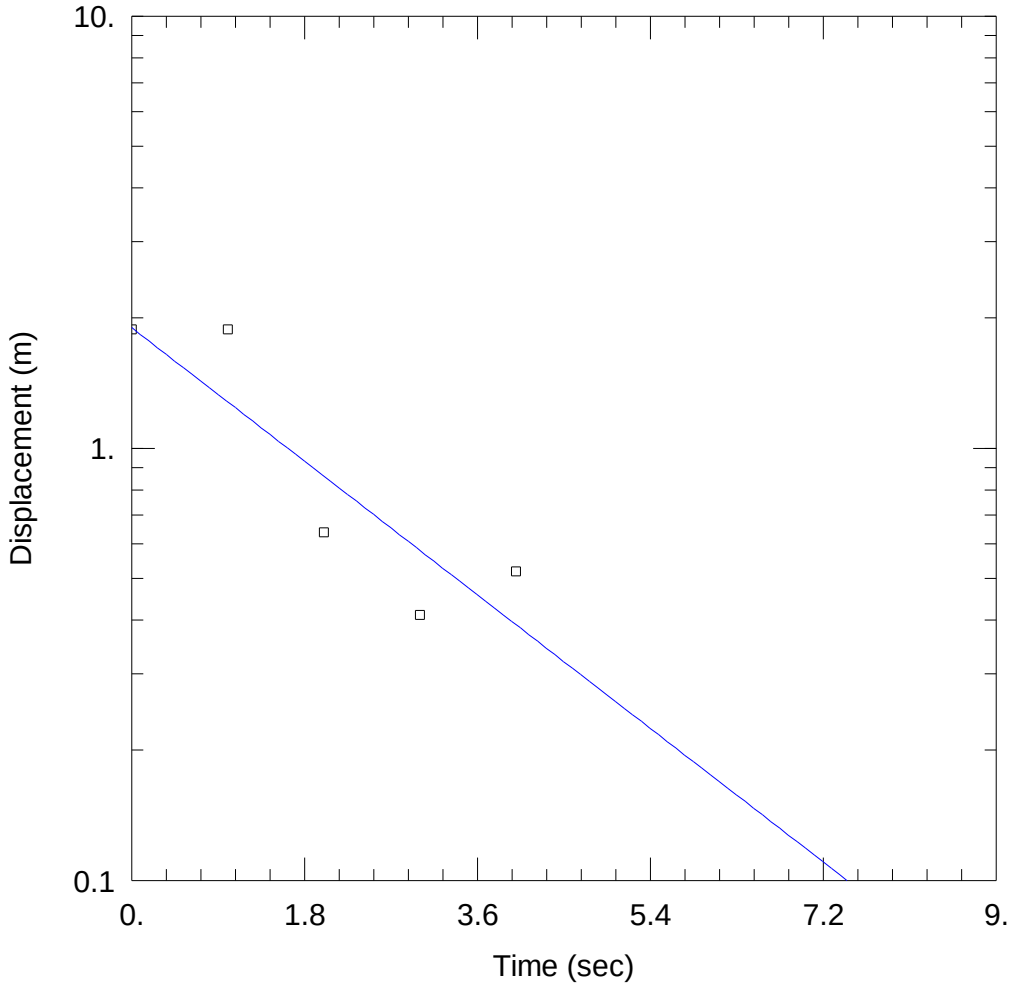
WELL DATA (BWMB01A)

Initial Displacement: 2.106 m
Total Well Penetration Depth: 6.5 m
Casing Radius: 0.05 m
Static Water Column Height: 8.6 m
Screen Length: 3. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 46.8 m/day y0 = 2.182 m



WELL TEST ANALYSIS

Data Set: \...\01A_fh3.aqt
Date: 02/04/14 Time: 15:03:23

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01A
Test Date: 29/10/2013

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

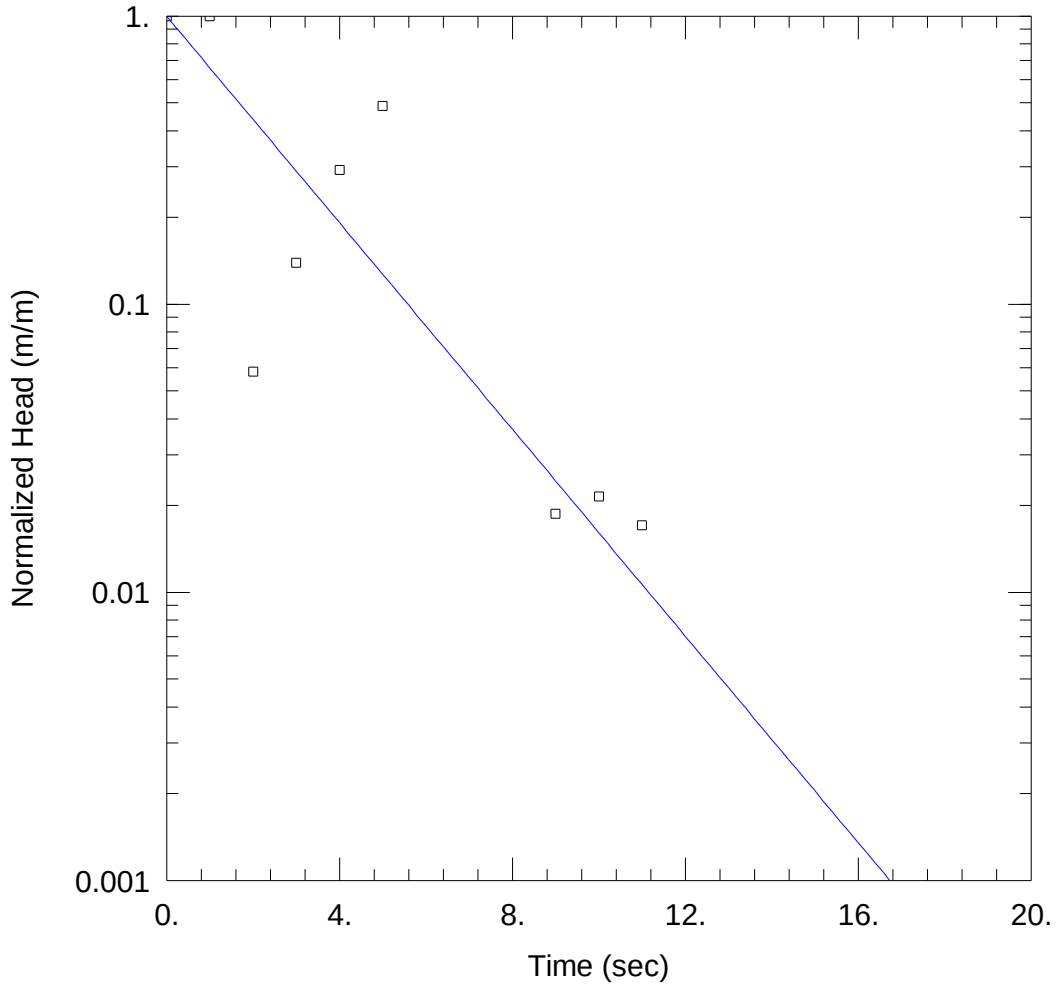
WELL DATA (BWMB01A)

Initial Displacement: 1.886 m
Static Water Column Height: 8.6 m
Total Well Penetration Depth: 6.5 m
Screen Length: 3. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 43.3 m/day
y0 = 1.9 m



WELL TEST ANALYSIS

Data Set: \...\01A_rh3.aqt
Date: 02/04/14 Time: 15:03:47

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01A
Test Date: 29/10/2013

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

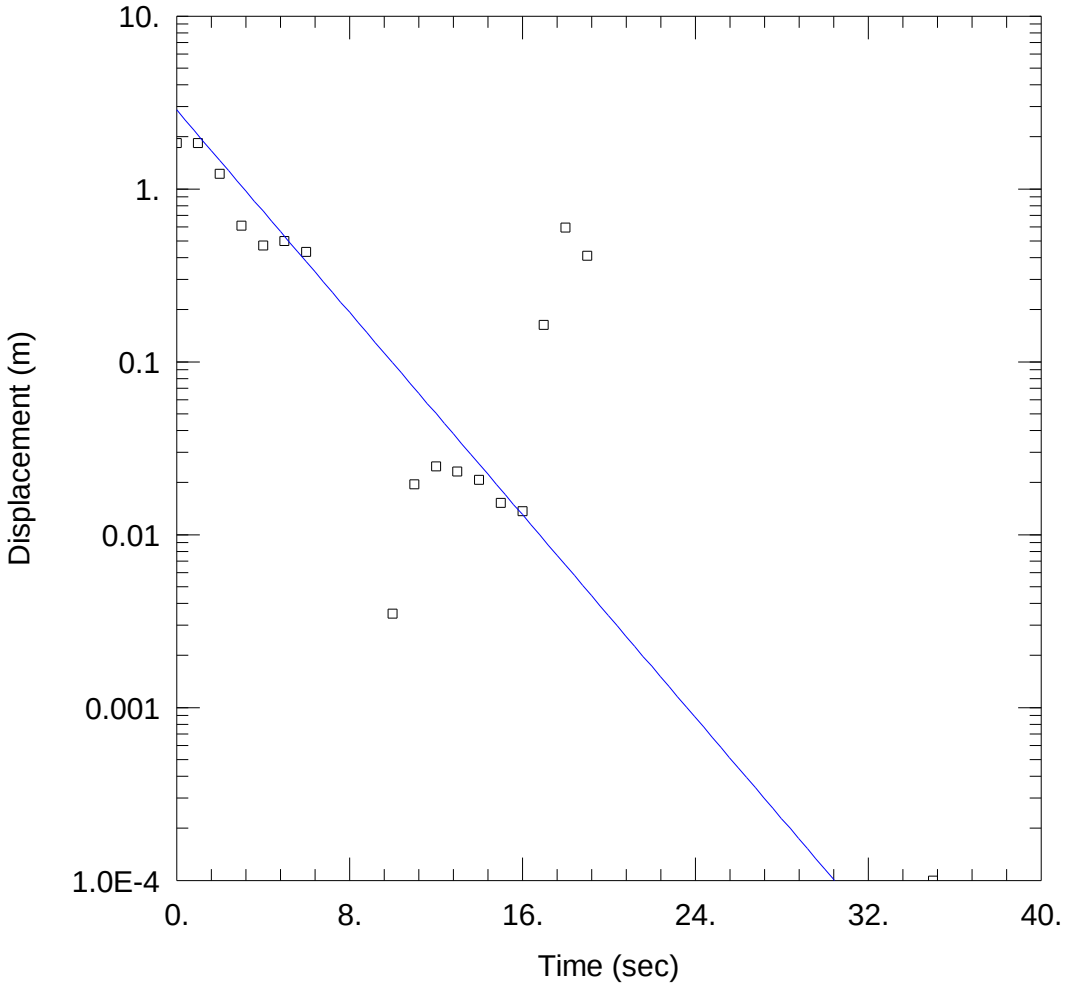
WELL DATA (BWMB01A)

Initial Displacement: 1.333 m
Static Water Column Height: 8.6 m
Total Well Penetration Depth: 6.5 m
Screen Length: 3. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 45.23 m/day
y0 = 1.33 m



WELL TEST ANALYSIS

Data Set: \...\01B_fh1.aqt
Date: 02/04/14 Time: 15:04:05

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

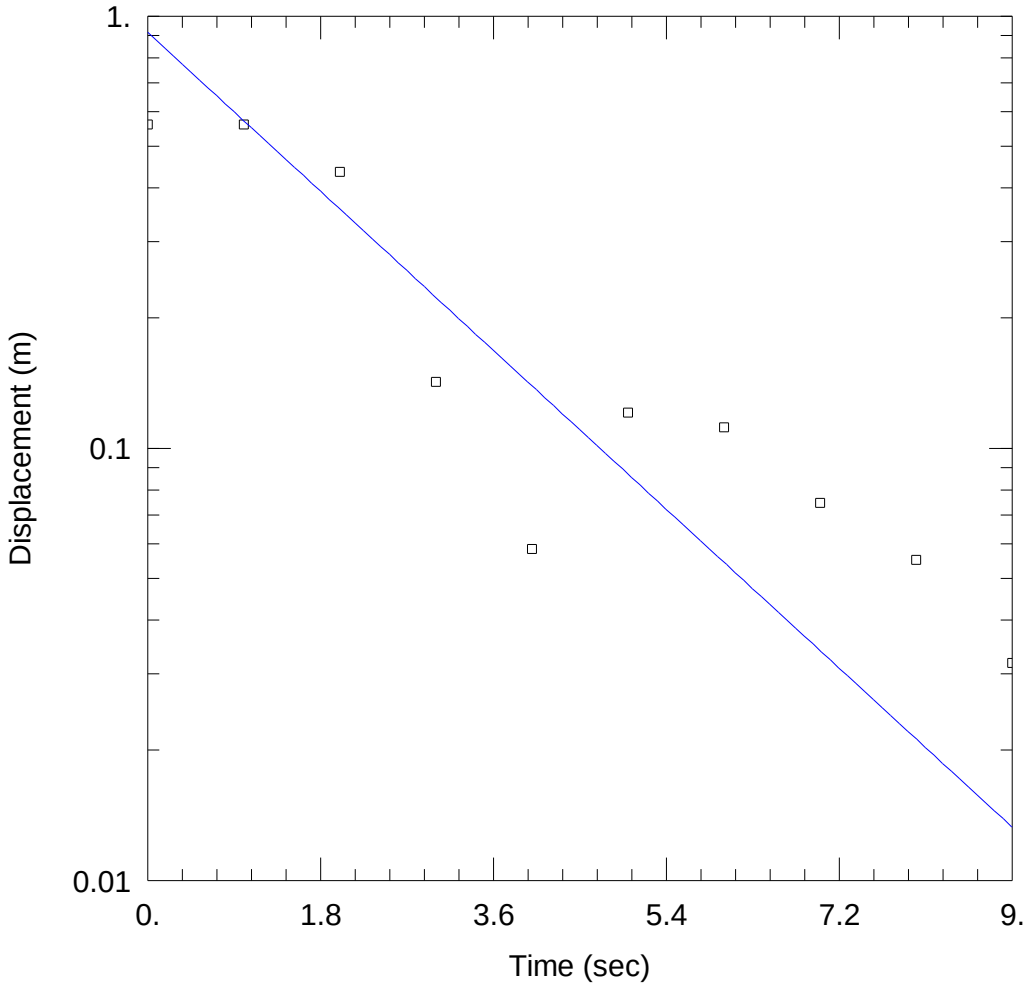
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 1.834 m
Static Water Column Height: 17. m
Total Well Penetration Depth: 17. m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 29.03 m/day
y0 = 2.858 m



WELL TEST ANALYSIS

Data Set: \...\01B_rh1.aqt
Date: 02/04/14 Time: 15:08:53

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

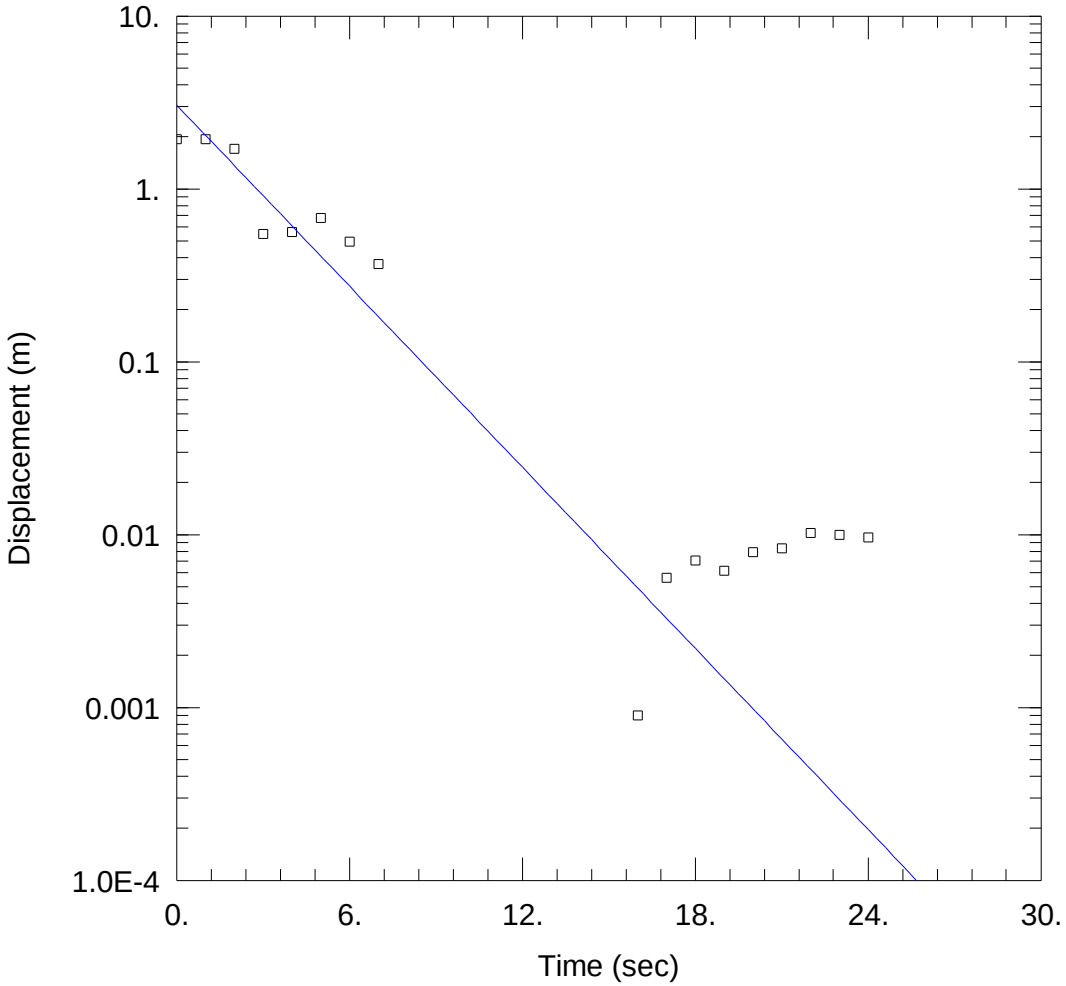
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 0.5609 m
Static Water Column Height: 17. m
Total Well Penetration Depth: 17. m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 40.53 m/day
y0 = 0.9165 m



WELL TEST ANALYSIS

Data Set: \...\01B_fh2.aqt
Date: 02/04/14 Time: 15:04:15

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

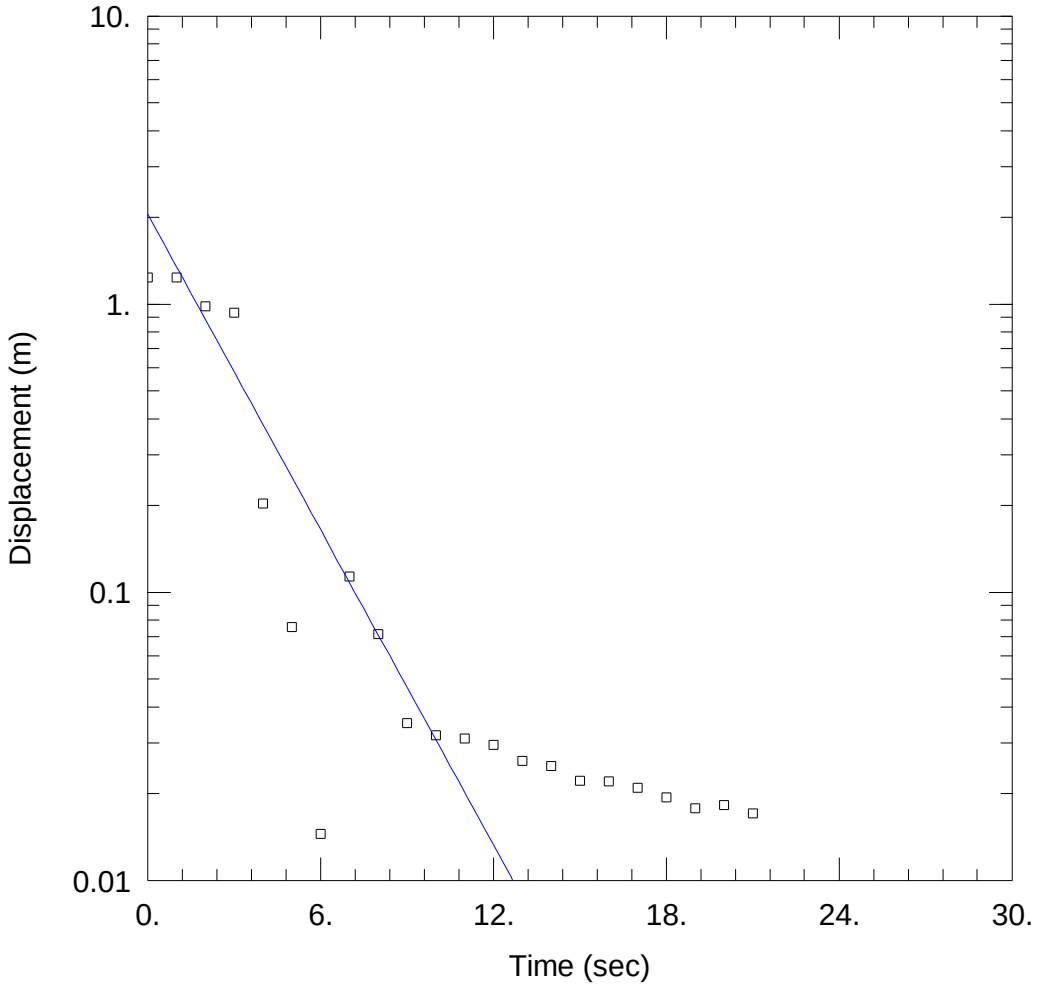
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 1.939 m
Static Water Column Height: 17. m
Total Well Penetration Depth: 17. m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 34.65 m/day
y0 = 3.055 m



WELL TEST ANALYSIS

Data Set: \...\01B_rh2.aqt
Date: 02/04/14 Time: 15:09:09

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

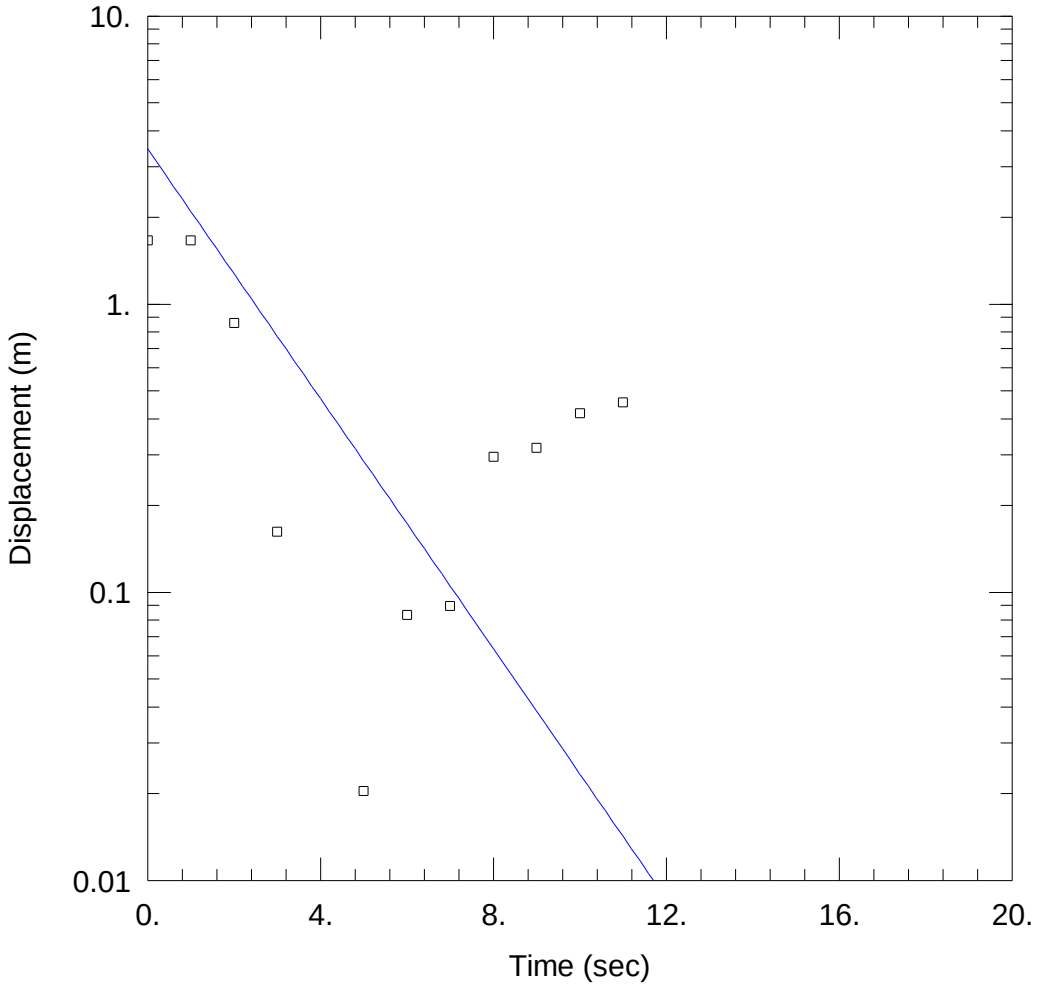
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 1.236 m
Total Well Penetration Depth: 17. m
Casing Radius: 0.05 m
Static Water Column Height: 17. m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 36.19 m/day
y0 = 2.054 m



WELL TEST ANALYSIS

Data Set: \...\01B_fh3.aqt
Date: 02/04/14 Time: 15:04:35

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

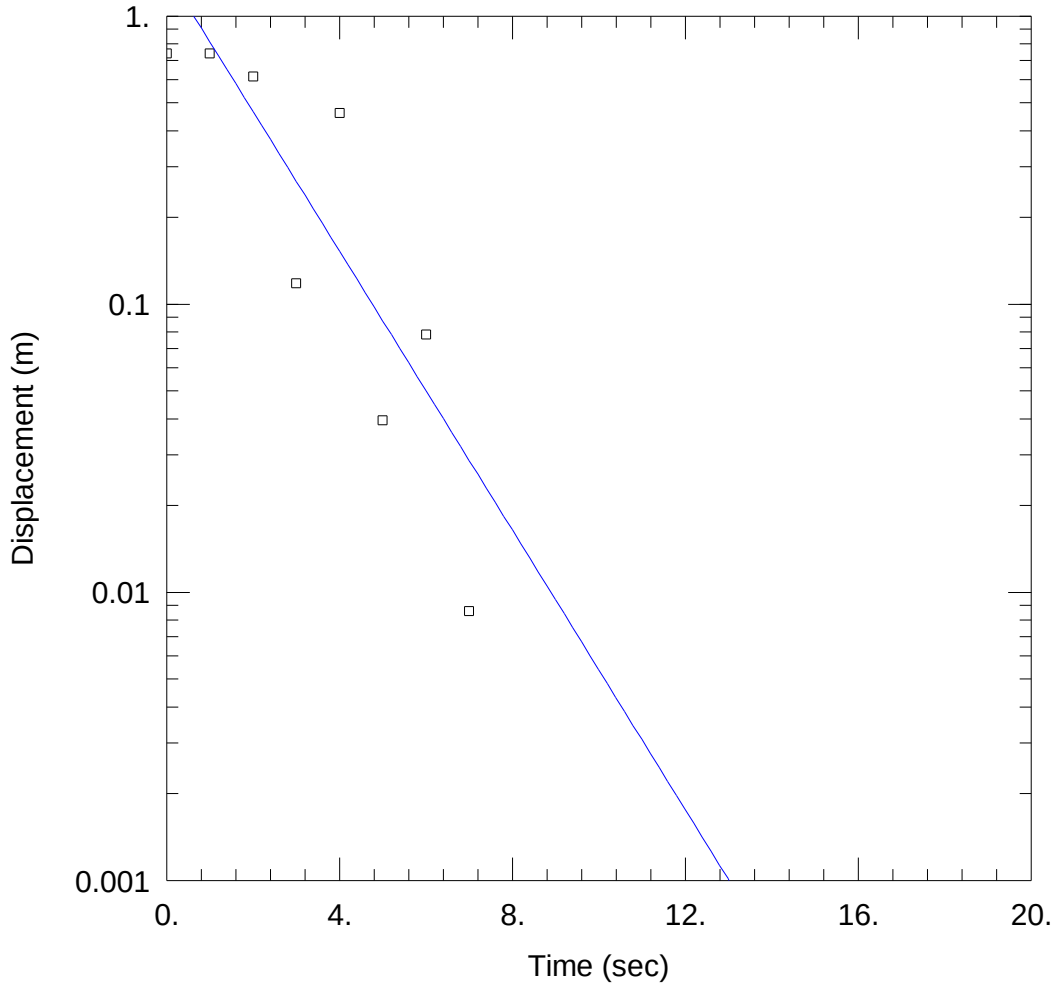
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 1.663 m
Total Well Penetration Depth: 17. m
Casing Radius: 0.05 m
Static Water Column Height: 17. m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 43.02 m/day
y0 = 3.459 m



WELL TEST ANALYSIS

Data Set: \...\01B_rh3.aqt
Date: 02/04/14 Time: 15:09:22

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

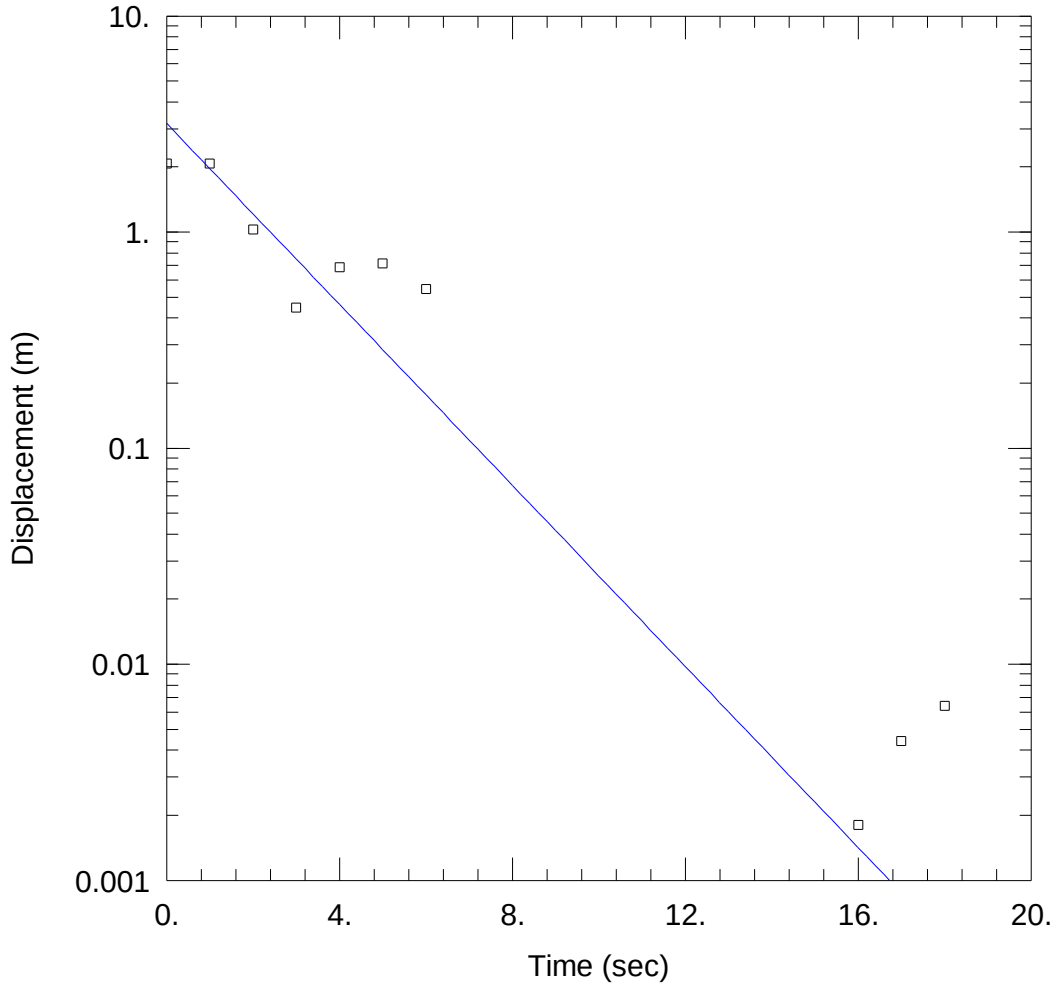
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 0.7402 m Static Water Column Height: 17. m
Total Well Penetration Depth: 17. m Screen Length: 6. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev
K = 48.05 m/day y0 = 1.422 m



WELL TEST ANALYSIS

Data Set: \...\01B_fh4.aqt
Date: 02/04/14 Time: 15:07:52

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

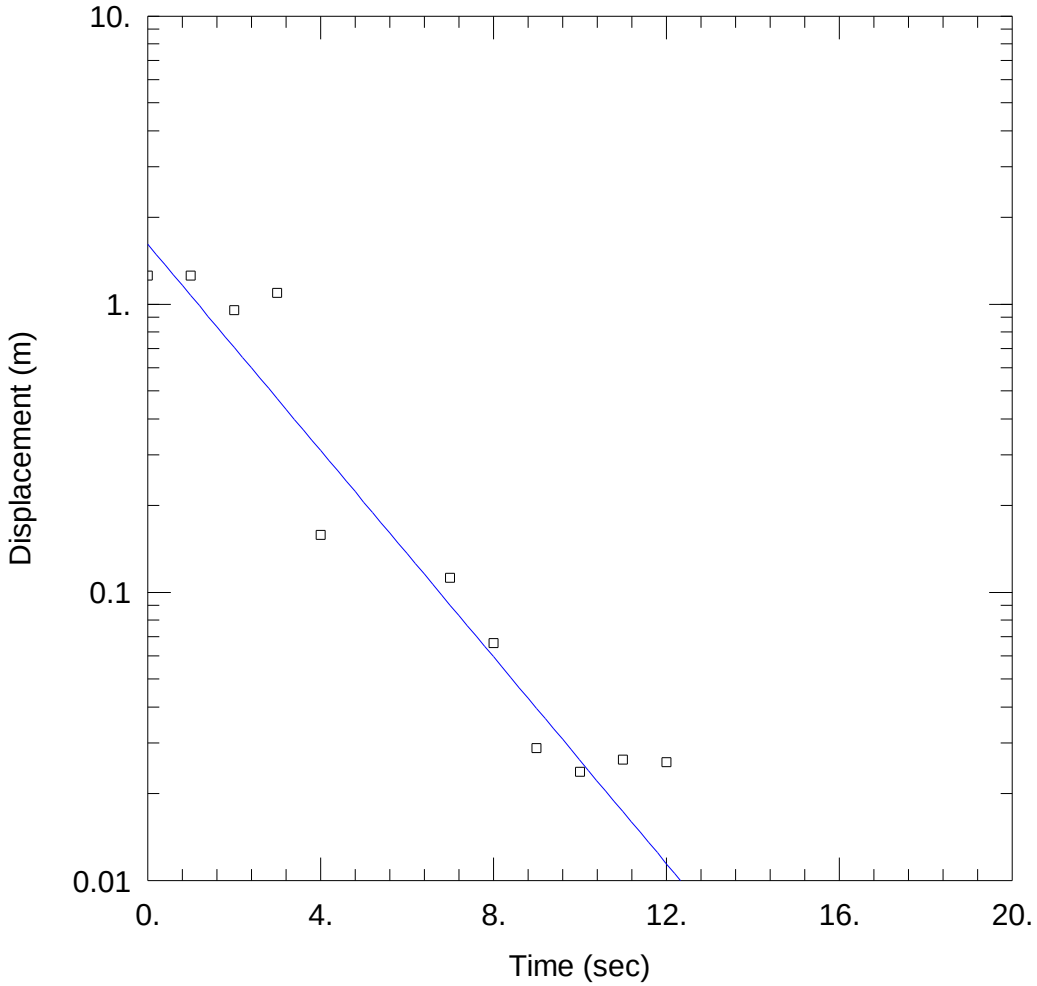
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 2.08 m
Static Water Column Height: 17. m
Total Well Penetration Depth: 17. m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 41.53 m/day
y0 = 3.181 m



WELL TEST ANALYSIS

Data Set: \...\01B_rh4.aqt
Date: 02/04/14 Time: 15:09:33

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

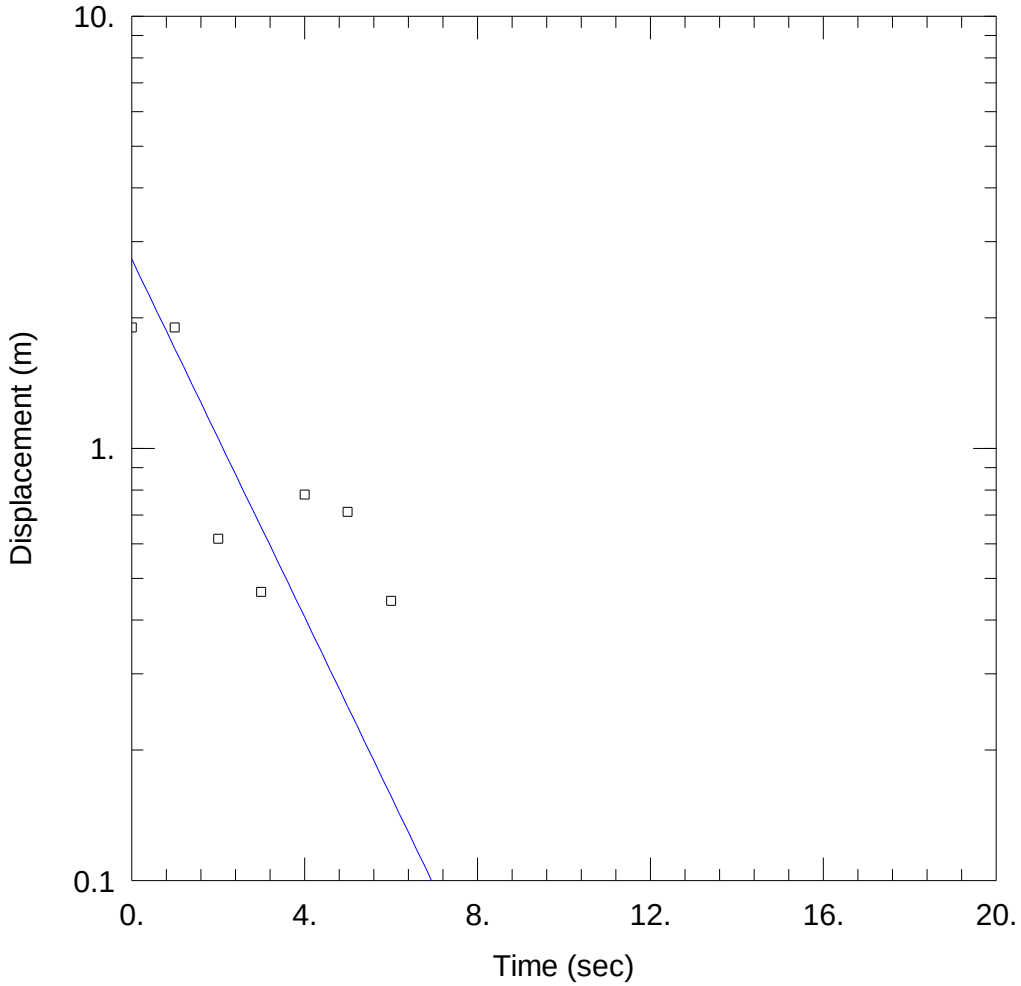
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 1.253 m
Total Well Penetration Depth: 17. m
Casing Radius: 0.05 m
Static Water Column Height: 17. m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 35.52 m/day
y0 = 1.615 m



WELL TEST ANALYSIS

Data Set: \...\01B_fh5.aqt
Date: 02/04/14 Time: 15:08:08

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

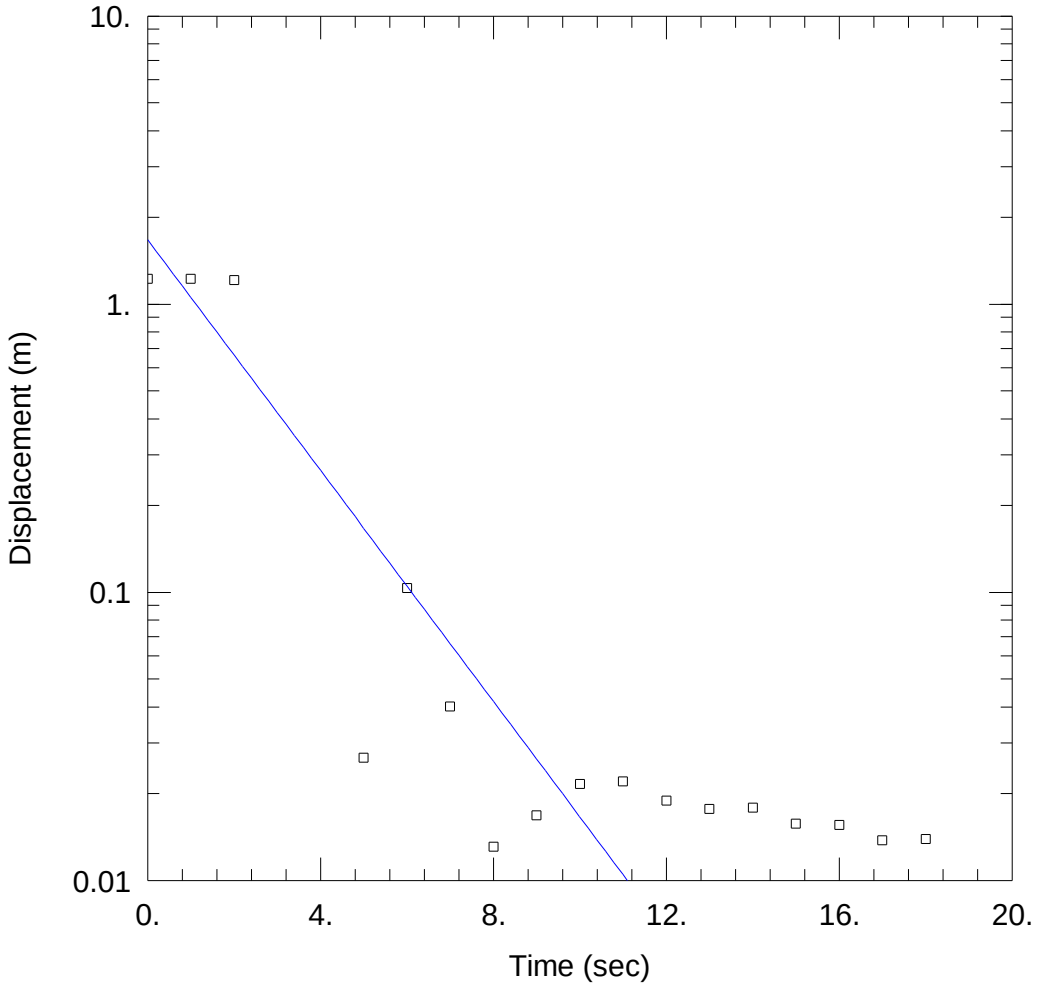
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 1.899 m
Total Well Penetration Depth: 17. m
Casing Radius: 0.05 m
Static Water Column Height: 17. m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 41.1 m/day
y0 = 2.74 m



WELL TEST ANALYSIS

Data Set: \...\01B_rh5.aqt
Date: 02/04/14 Time: 15:09:51

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

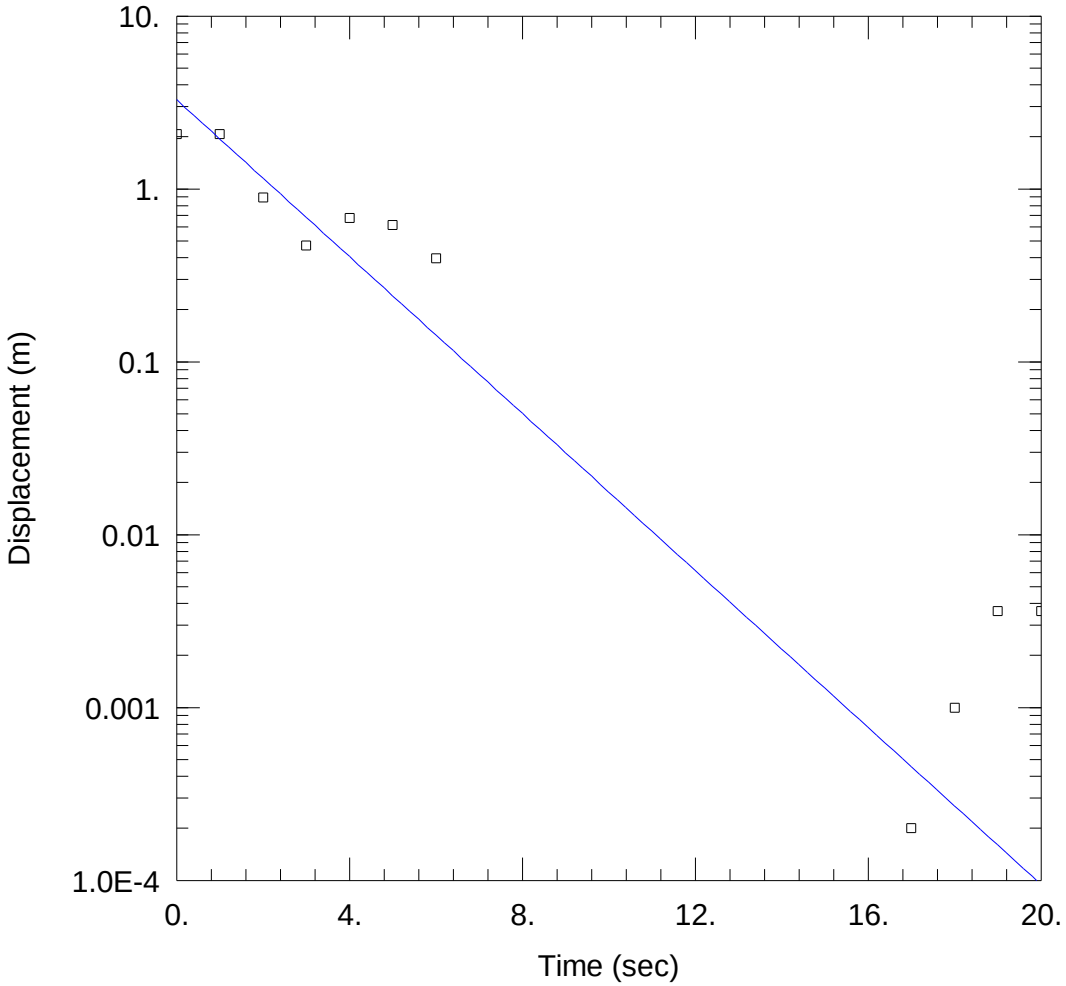
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 1.222 m
Total Well Penetration Depth: 17. m
Casing Radius: 0.05 m
Static Water Column Height: 17. m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 39.74 m/day
y0 = 1.674 m



WELL TEST ANALYSIS

Data Set: \...\01B_fh6.aqt
Date: 02/04/14 Time: 15:08:33

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

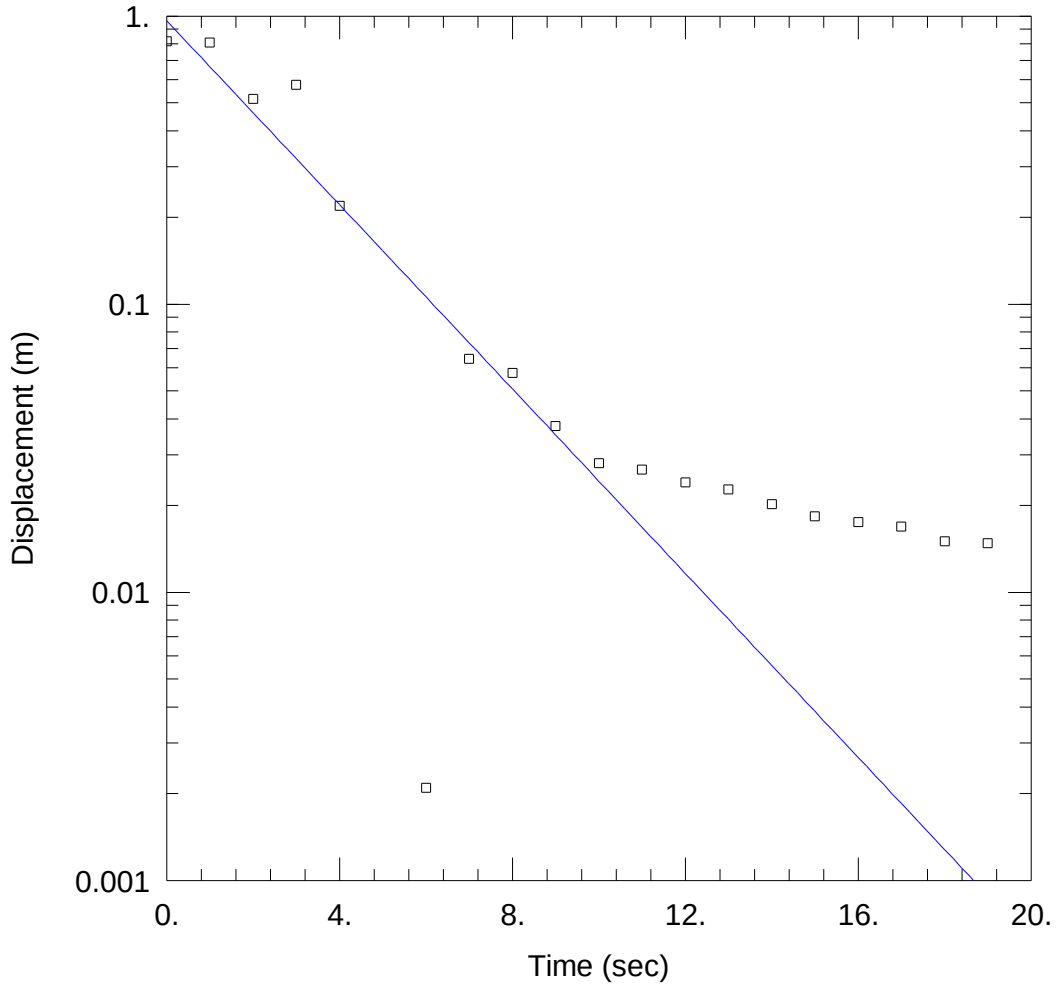
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 2.07 m
Static Water Column Height: 17. m
Total Well Penetration Depth: 17. m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 45.01 m/day
y0 = 3.274 m



WELL TEST ANALYSIS

Data Set: \...\01B_rh6.aqt
Date: 02/04/14 Time: 15:10:05

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01B
Test Date: 29/10/2013

AQUIFER DATA

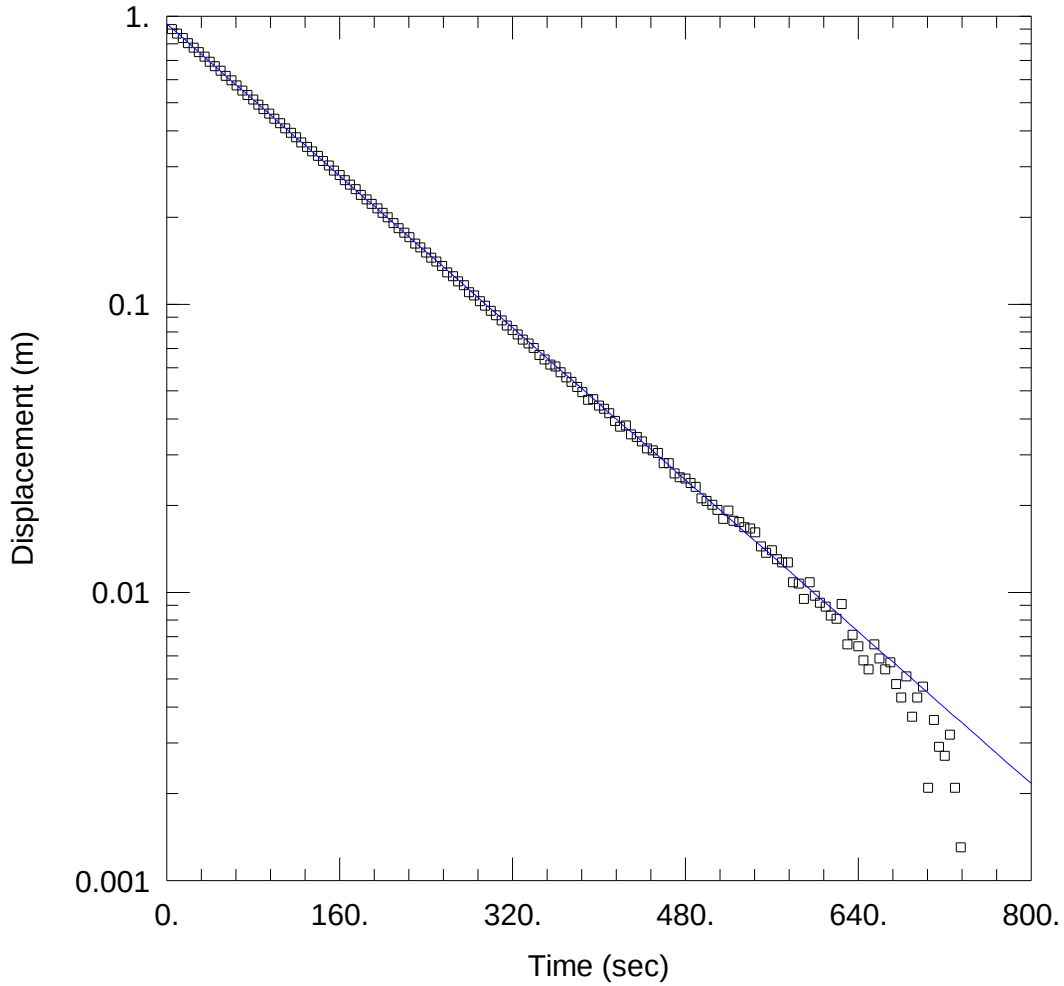
Saturated Thickness: 18. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01B)

Initial Displacement: 0.8167 m
Static Water Column Height: 17. m
Total Well Penetration Depth: 17. m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 31.7 m/day
y0 = 0.9636 m



WELL TEST ANALYSIS

Data Set: \...\01D_fh1.aqt
Date: 02/04/14 Time: 15:10:20

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01D
Test Date: 29/10/2013

AQUIFER DATA

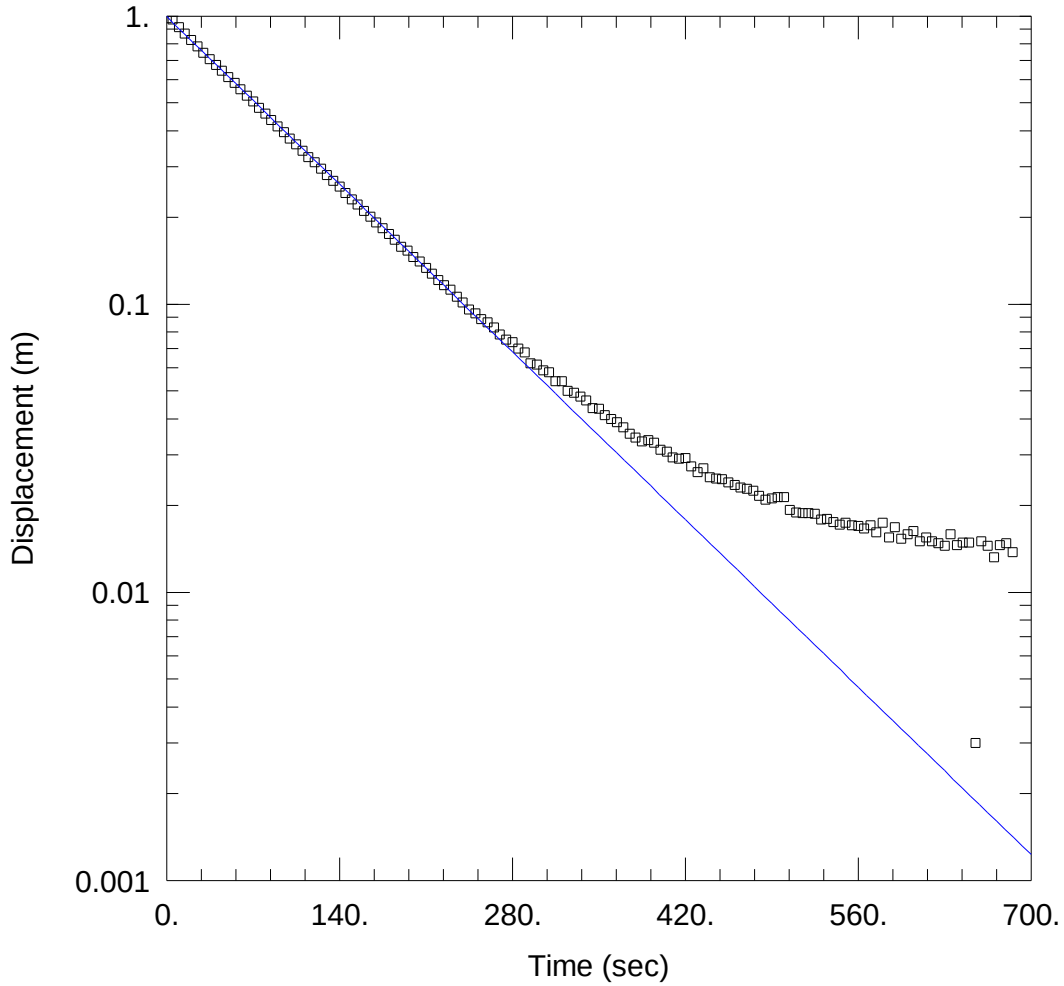
Saturated Thickness: 160. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01D)

Initial Displacement: 1.206 m Static Water Column Height: 158.5 m
Total Well Penetration Depth: 157.5 m Screen Length: 12. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev
K = 0.3744 m/day y0 = 0.94 m



WELL TEST ANALYSIS

Data Set: \...\01D_rh1.aqt
Date: 02/04/14 Time: 15:10:34

PROJECT INFORMATION

Company: Parsons Brinckerhoff
Client: AGL
Project: 2193324A
Location: Bucketts Way
Test Well: BWMB01D
Test Date: 29/10/2013

AQUIFER DATA

Saturated Thickness: 160. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BWMB01D)

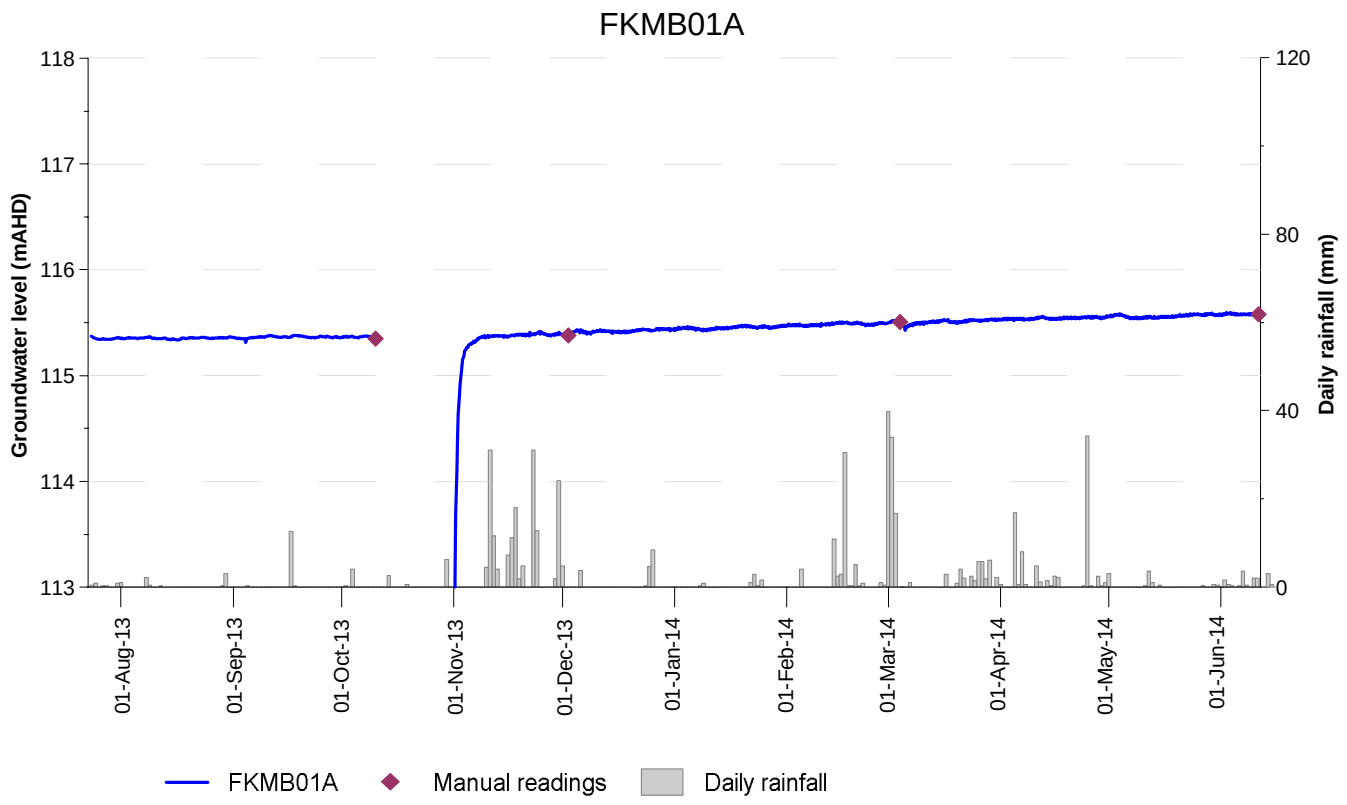
Initial Displacement: 0.9808 m Static Water Column Height: 158.5 m
Total Well Penetration Depth: 157.5 m Screen Length: 12. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev
K = 0.4719 m/day y0 = 0.995 m

Appendix D

Hydrographs



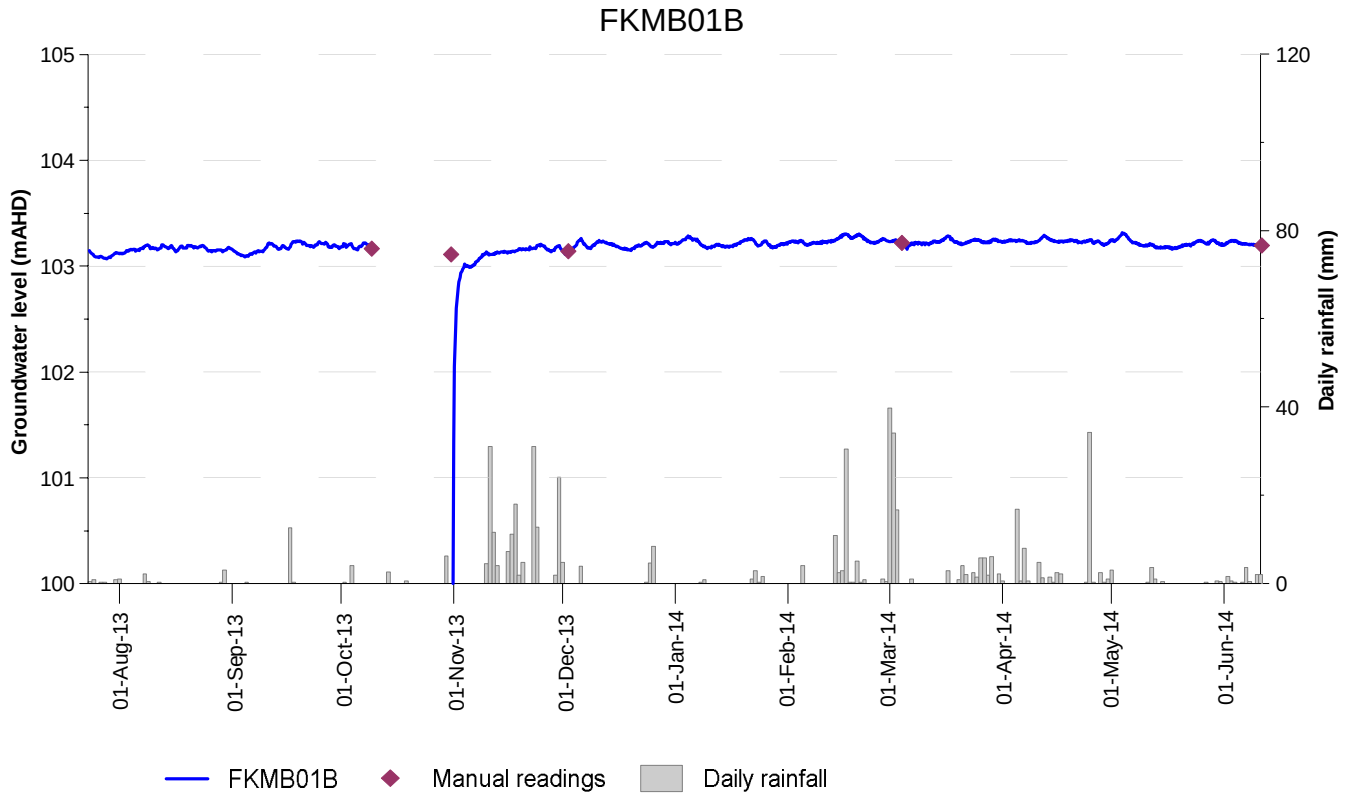


Figure D.1: FKMB01A and FKMB01B monitoring bores

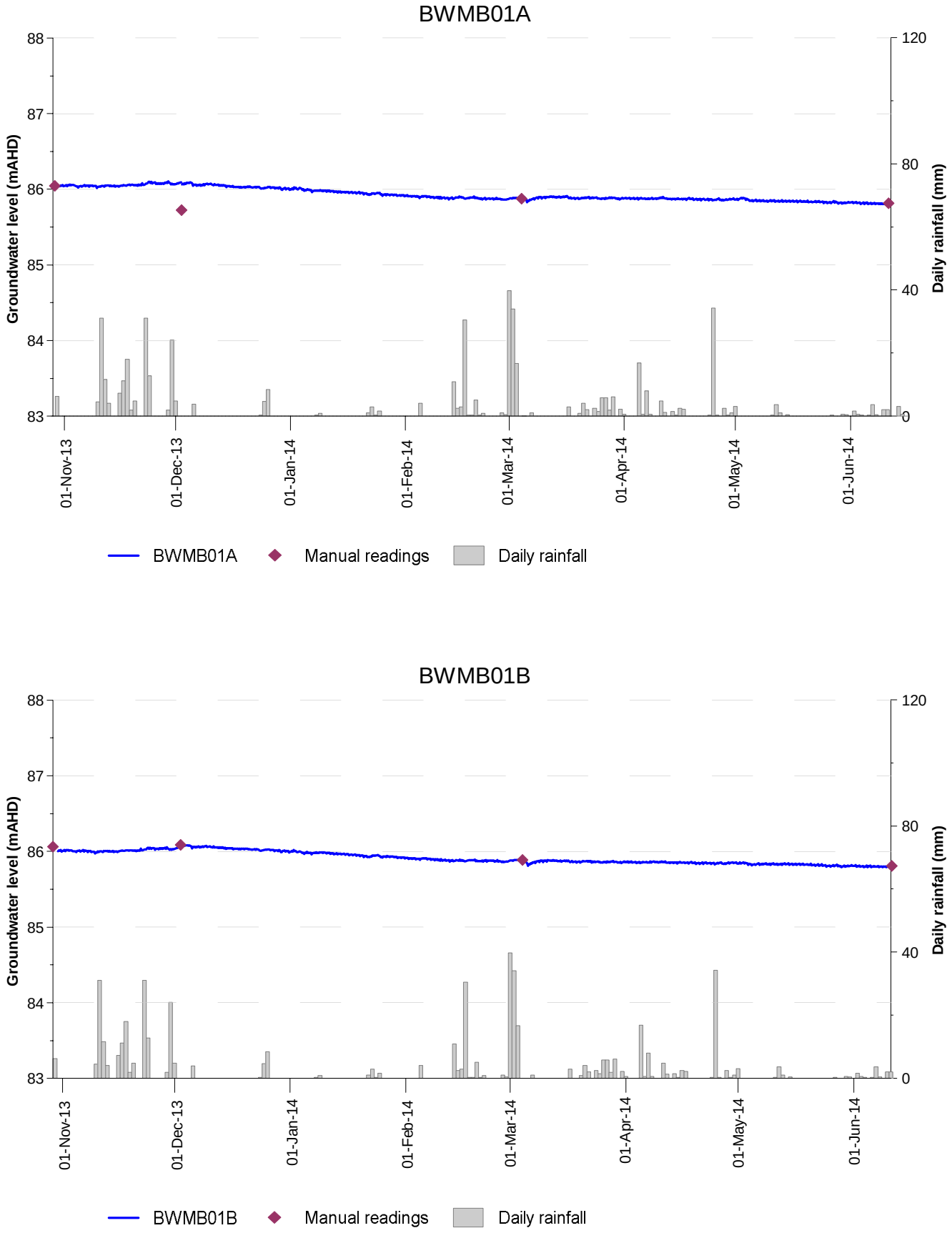
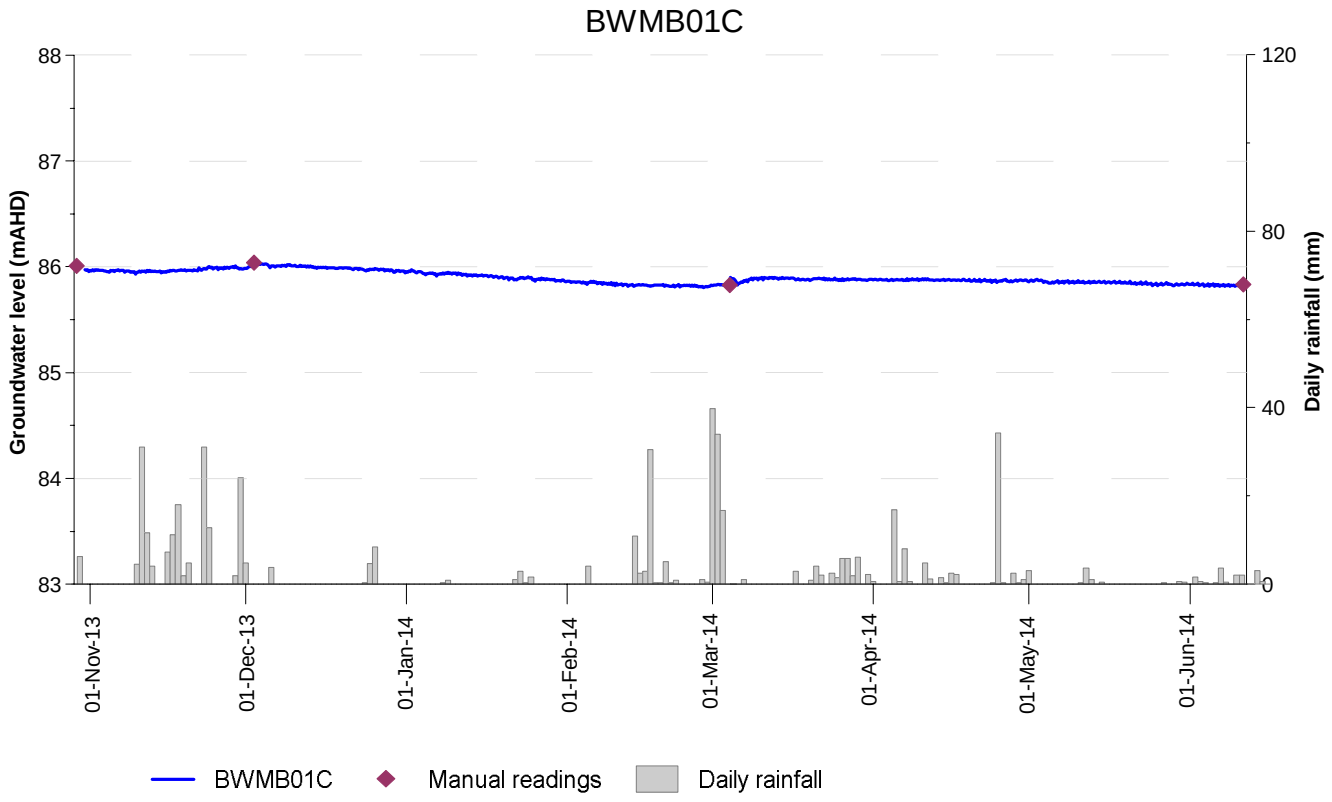


Figure D.2: BWMB01A and BWMB01B monitoring bores



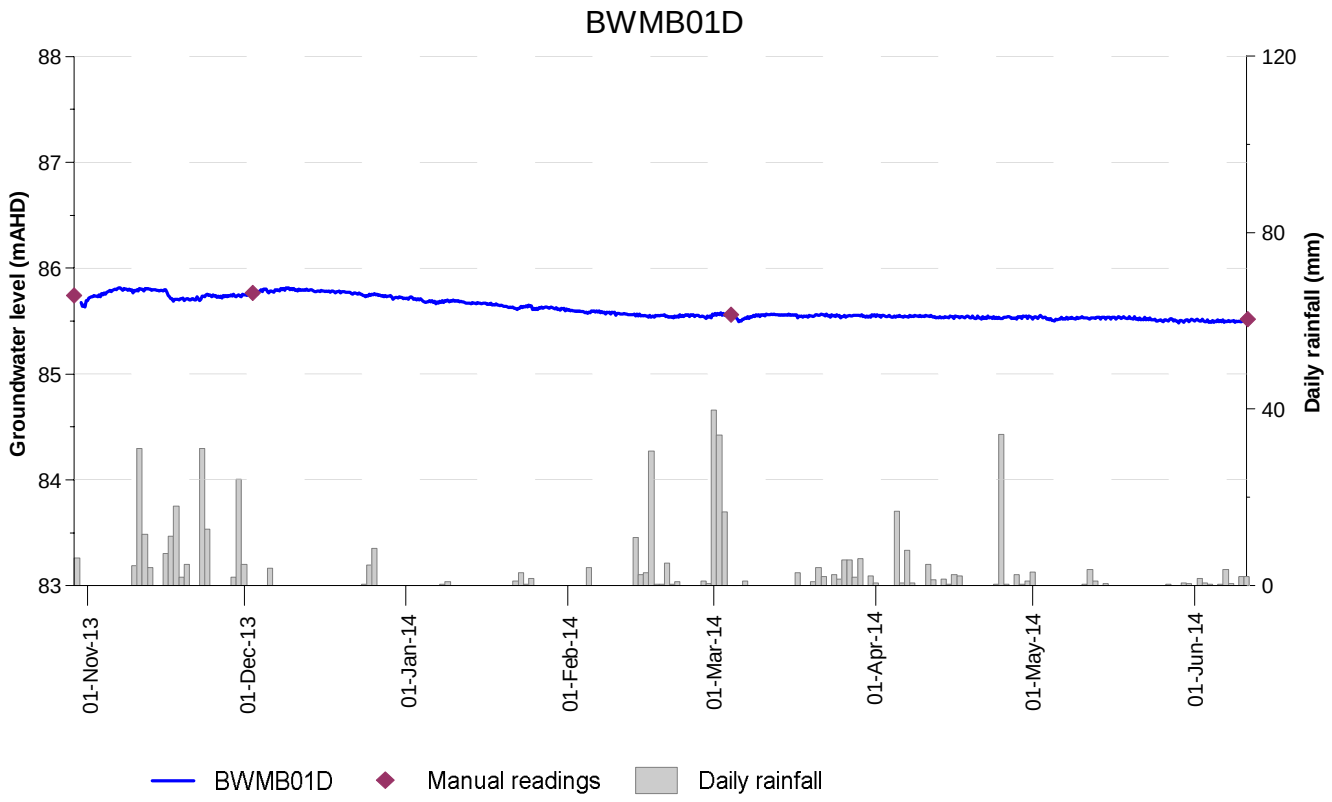


Figure D.3: BWMB01C and BWMB01D monitoring bores

Appendix E

Water quality summary tables

Summary Table E.1: Groundwater quality results

Analyte	Units	LOR	ANZECC 2000 Guidelines	FKMB01A	FKMB01B	BWMB01A	BWMB01B	BWMB01C	BWMB01D
Sample date				31/10/2013	31/10/2013	30/10/2013	30/10/2013	30/10/2013	30/10/2013
Project area				Gloucester	Gloucester	Gloucester	Gloucester	Gloucester	Gloucester
Sceen depth (mbgl)				44.0-53.0	140.2-149.2	6.5-9.5	14.0-20.0	67.4-79.4	149.6-161.6
Aquifer				Leloma Formation - Shallow sandstone	Leloma Formation - Deep sandstone	Shallow alluvium	Deep alluvium	Leloma Formation - Shallow sandstone	Leloma Formation - Deep sandstone
Water level	mbTOC			23.28	37.57	3.045	3.39	3.15	3.38
General parameters									
pH	pH units	0.01	6.5-8.0*	7.20	**10.38**	6.52	6.55	**8.76**	**8.47**
Conductivity (field)	µS/cm	1	125 - 2200*	**5,334**	**3,820**	**3,779**	**4,490**	**3,440**	**3,295**
Conductivity (lab)				**5,400**	**3,940**	**3,900**	**4,650**	**3,320**	**3,490**
Temperature	°C	0.1	-	29.22	26.56	22.20	20.27	19.70	19.96
Dissolved oxygen	% sat	0.1	85-110 %* saturation	**31.0**	**21.9**	**9.3**	**31.2**	**7.0**	**25.5**
Total dissolved solids (field)	mg/L	1	-	2,880	2,407	2,457	2,919	1,810	2,135
Total dissolved solids (lab)				2,930	2,080	1,970	2,420	1,750	1,940
Redox	mV	0.1	-	-122.3	-81.3	-33.8	-71.4	-158.7	-181.0
Laboratory analytes									
Hydroxide alkalinity as $CaCO_3$	mg/L	1	-	<1	<1	<1	<1	<1	<1
Carbonate alkalinity as $CaCO_3$	mg/L	1	-	<1	1,180	<1	<1	<1	<1
Bicarbonate alkalinity as $CaCO_3$	mg/L	1	-	784	170	297	309	142	264
Total alkalinity as $CaCO_3$	mg/L	1	-	784	1,350	297	309	142	264
Sulfate as SO_4^{2-}	mg/L	1	-	143	2	22	4	15	30
Chloride	mg/L	1	-	1,070	472	927	1,130	828	792
Calcium	mg/L	1	-	53	<1	98	132	92	41
Magnesium	mg/L	1	-	21	1	66	88	43	30
Sodium	mg/L	1	-	920	887	488	540	388	602
Potassium	mg/L	1	-	10	6	4	5	17	12
Silica	mg/L	0.1	-	20.9	10.2	29.1	34.2	11.4	13.6
Fluoride	mg/L	0.1	-	0.3	0.8	0.2	0.1	<0.1	0.4
Ions									
Total Anions	meq/L	0.01	-	48.80	40.30	32.50	38.10	26.50	28.20
Total Cations	meq/L	0.01	-	44.60	38.80	31.60	37.40	25.40	31.00
Ionic Balance	%	0.01	-	4.50	1.96	1.40	0.91	2.05	4.65
Dissolved metals									
Aluminium	mg/L	0.01	0.055	0.02	**0.09**	**0.32**	0.05	0.02	<0.01
Arsenic	mg/L	0.001	0.013 (As V)	0.004	<0.001	**0.028**	0.001	0.003	0.003
Barium	mg/L	0.001	-	0.671	0.138	1.250	3.610	3.170	2.630
Beryllium	mg/L	0.001	ID	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	ID	<0.001	<0.001	0.006	0.002	<0.001	<0.001
Copper	mg/L	0.001	0.0014	**0.002**	<0.001	**0.006**	**0.002**	**0.002**	<0.001
Lead	mg/L	0.001	0.0034	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	1.9	0.238	<0.001	0.501	0.418	0.030	0.054
Molybdenum	mg/L	0.001	ID	0.003	0.007	0.002	0.001	0.002	0.017
Nickel	mg/L	0.001	0.011	0.004	<0.001	0.005	0.002	0.002	<0.001
Selenium	mg/L	0.01	0.011 (total)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	0.001	-	12.600	0.816	2.120	3.000	3.370	1.770
Uranium	mg/L	0.001	ID	0.003	<0.001	0.001	0.001	<0.001	<0.001
Vanadium	mg/L	0.01	ID	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.005	0.008	**0.046**	**0.048**	**0.114**	**0.167**	**0.026**	**0.570**
Boron	mg/L	0.05	0.37	0.08	0.11	<0.05	<0.05	<0.05	<0.05
Iron	mg/L	0.05	ID	0.5	0.1	1.7	14.3	0.06	<0.05
Bromine	mg/L	0.1	ID	3.9	1.6	2.1	2.8	1.9	2
Nutrients									
Ammonia as N	mg/L	0.01	0.02*	**0.82**	**1.74**	**0.24**	**0.58**	**3.22**	**1.74**
Nitrite as N	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.70	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	mg/L	0.01	0.04*	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Phosphorous	mg/L	0.01	0.05*	**0.06**	**0.08**	**0.59**	**0.06**	<0.01	<0.01
Reactive Phosphorous	mg/L	0.01	0.02*	<0.01	**0.10**	<0.01	<0.01	<0.01	<0.01
Total Organic Carbon	mg/L	1	-	27	41	11	17	1	13
Dissolved gases									
Methane	µg/L	10	-	2,190	9,920	<10	264	5,080	2,660
Ethene	µg/L	10	-	<10	<10	<10	<10	<10	<10
Ethane	µg/L	10	-	<10	<10	<10	<10	<10	<10
Propene	µg/L	10	-	<10	<10	<10	<10	<10	<10
Propane	µg/L	10	-	<10	<10	<10	<10	<10	<10
Butane	µg/L	10	-	<10	<10	<10	<10	<10	<10
Butene	µg/L	10	-	<10	<10	<10	<10	<10	<10
Phenolic compounds									
Phenol	µg/L	1	320	<1.0	5.3	<1.0	<1.0	<1.0	1.2
2-Chlorophenol	µg/L	1	490	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2-Methylphenol	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
3-&4-Methylphenol	µg/L	2	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
2-Nitrophenol	µg/L	1	ID	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dimethylphenol	µg/L	1	ID	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dichlorophenol	µg/L	1	160	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2.6-Dichlorophenol	µg/L	1	ID	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
4-Chloro-3-Methylphenol	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2.4.6-Trichlorophenol	µg/L	1	20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2.4.5-Trichlorophenol	µg/L	1	ID	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Pentachlorophenol	µg/L	2	ID	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Polycyclic aromatic hydrocarbons									
Naphthalene	µg/L	1	16	<1.0	<1.0	1.8	3.6	3.8	<1.0
Acenaphthylene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	µg/L	1	-	<1.0	<1.0	4.2	5.2	14.8	<1.0
Fluorene	µg/L	1	-	<1.0	<1.0	2.6	3.8	11.2	<1.0
Phenanthrene	µg/L	1	ID	<1.0	<1.0	2.9	5.2	13.8	<1.0
Anthracene	µg/L	1	ID	<1.0	<1.0	<1.0	<1.0	2	<1.0
Fluoranthene	µg/L	1	ID	<1.0	<1.0	<1.0	<1.0	1.9	<1.0
Pyrene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	1	<1.0
Benz(a)anthracene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b)fluoranthene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	µg/L	0.5	ID	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	µg/L	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total petroleum hydrocarbons									
C_6-C_9 fraction	µg/L	20	ID	60	<20	<20	<20	<20	<20
C_{10}-C_{14} fraction	µg/L	50	ID	<50	<50	120	90	820	<50
C_{15}-C_{28} fraction	µg/L	100	ID	<100	<100	<100	<100	150	<100
C_{29}-C_{36} fraction	µg/L	50	ID	<50	<50	90	<50	<50	<50
C_{10}-C_{36} fraction (sum)	µg/L	50	-	<50	<50	210	90	970	<50
Total recoverable hydrocarbons									
C_6-C_{10} fraction	µg/L	20	-	60	<20	<20	<20	<20	<20
C_6-C_{10} fraction minus BTEX (F1)	µg/L	20	-	30	<20	<20	<20	<20	<20
>C_{10}-C_{16} fraction	µg/L	100	-	<100	<100	120	100	840	<100
>C_{16}-C_{34} fraction	µg/L	100	-	<100	<100	<100	<100	100	<100
>C_{34}-C_{40} fraction	µg/L	100	-	<100	<100	<100	<100	<100	<100
>C_{10}-C_{40} fraction (sum)	µg/L	100	-	<100	<100	120	100	940	<100
Aromatic hydrocarbons									
Benzene	µg/L	1	950	<1	<1	<1	<1	<1	<1
Toluene	µg/L	2	ID	30	3	<2	<2	<2	<2
Ethyl Benzene	µg/L	2	ID	<2	<2	<2	<2	<2	<2
m&p-Xylenes	µg/L	2	ID	<2	<2	<2	<2	<2	<2
o-Xylenes	µg/L	2	350	<2	<2	<2	<2	<2	<2
Total xylenes	µg/L	2	-	<2	<2	<2	<2	<2	<2
Sum of BTEX	µg/L	1	-	30	3	<1	<1	<1	<1
Naphthalene	µg/L	5	16	<5	<5	<5	5	17	<5
Isotopes									
Oxygen-18	‰	0.01	-	-4.65	-4.99	-4.04	-4.24	-4.47	-4.62
Deuterium	‰	0.1	-	-24.26	-27.95	-19.89	-21.85	-23.60	-24.76
Carbon-13	‰	0.1	-	-14.75	-2.53	-11.98	-12.48	-13.59	-1.83
Radiocarbon	pMC	0.1	-	70.14±0.16	44.11±0.12	81.53±0.17	78.85±0.16	49.39±0.13	26.82±0.10
Radiocarbon Age (uncorrected)	yrs BP	1	-	2,787±19	6,513±22	1,578±17	1,864±17	5,605±21	10,508±30
Radiocarbon age (corrected)	yrs BP	1	-	2,200	6,050	modern	modern	3,500	10,300
Tritium	TU	0.01	-	0.033±0.025^	0.067±0.025^	0.400±0.033	0.250±0.033	0.133±0.025^	0.075±0.025^
13C in Methane	VPDB		-	-41.02^	-42.24	-29.82^	-34.62^	-63.51	-57.75
2H in Methane	VSMOW		-	-146.9^	-221.7	-67.9^	-163.9^	-199.3	-210.8
13C of Dissolved Inorganic Carbon	VPDB		-	-14.59	0.89	-12.98	-13.72	-13.30	0.59

Bold - exceeds guideline limits ID - Insufficient data

Guideline values

ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems.

* ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems, South-East Australia, low lying river ecosystems

^ This result is below the Minimum Detectable Activity (MDA) and Limit of Quantification (Quant Limit) and therefore has an unacceptable level of uncertainty. Hence the data should only be used as an indicator of true concentration.

na - not analysed

PARSONS BRINCKERHOFF

Appendix F

ALS results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1323682**	Page	: 1 of 13
Client	: **PARSONS BRINCKERHOFF AUST P/L**	Laboratory	: Environmental Division Sydney
Contact	: MR JAMES DUGGLEBY	Contact	: Client Services
Address	: GPO BOX 5394 SYDNEY NSW, AUSTRALIA 2001	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: jduggleby@pb.com.au	E-mail	: sydney@alsglobal.com
Telephone	: +61 02 9272 5100	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 9272 5101	Facsimile	: +61-2-8784 8500
Project	: 2193324A	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 01-NOV-2013
Sampler	: CR/AMcF	Issue Date	: 07-NOV-2013
Site	: ----		
		No. of samples received	: 7
Quote number	: EN/008/13	No. of samples analysed	: 7

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG020/ED093: Results for samples ES1323682 - #004 and #007 has been confirmed by reanalysis.**
- **EG020: Bromine quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.**

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Ashesh Patel	Inorganic Chemist	Sydney Inorganics
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics
Edwandy Fadjar	Organic Coordinator	Sydney Organics
Hoa Nguyen	Senior Inorganic Chemist	Sydney Inorganics
Pabi Subba	Senior Organic Chemist	Sydney Organics
Raymond Commodor	Instrument Chemist	Sydney Inorganics
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	FKMB01B	FKMB01A	BWMB01C	BWMB01D	BWMB01B
				Client sampling date / time	31-OCT-2013 11:45	31-OCT-2013 13:30	30-OCT-2013 10:10	30-OCT-2013 10:20	30-OCT-2013 14:00
					ES1323682-001	ES1323682-002	ES1323682-003	ES1323682-004	ES1323682-005
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		**3940**	**5400**	**3320**	**3490**	**4650**
EA015: Total Dissolved Solids									
Total Dissolved Solids @180°C	----	10	mg/L		**2080**	**2930**	**1750**	**1940**	**2420**
EA025: Suspended Solids									
Suspended Solids (SS)	----	5	mg/L		**110**	**174**	**14**	**8**	**124**
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		**1180**	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**170**	**784**	**142**	**264**	**309**
Total Alkalinity as CaCO3	----	1	mg/L		**1350**	**784**	**142**	**264**	**309**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**2**	**143**	**15**	**30**	**4**
ED045G: Chloride Discrete analyser									
Chloride	16887-00-6	1	mg/L		**472**	**1070**	**828**	**792**	**1130**
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		<1	**53**	**92**	**41**	**132**
Magnesium	7439-95-4	1	mg/L		**1**	**21**	**43**	**30**	**88**
Sodium	7440-23-5	1	mg/L		**887**	**920**	**388**	**602**	**540**
Potassium	7440-09-7	1	mg/L		**6**	**10**	**17**	**12**	**5**
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.09**	**0.02**	**0.02**	<0.01	**0.05**
Arsenic	7440-38-2	0.001	mg/L		<0.001	**0.004**	**0.003**	**0.003**	**0.001**
Beryllium	7440-41-7	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L		**0.138**	**0.671**	**3.17**	**2.63**	**3.61**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	**0.002**
Copper	7440-50-8	0.001	mg/L		<0.001	**0.002**	**0.002**	<0.001	**0.002**
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		<0.001	**0.238**	**0.030**	**0.054**	**0.418**
Molybdenum	7439-98-7	0.001	mg/L		**0.007**	**0.003**	**0.007**	**0.017**	**0.001**
Nickel	7440-02-0	0.001	mg/L		<0.001	**0.004**	**0.002**	<0.001	**0.002**
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	7440-24-6	0.001	mg/L		**0.816**	**12.6**	**3.37**	**1.77**	**3.00**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	Client sample ID: FKMB01B	FKMB01A	BWMB01C	BWMB01D	BWMB01B
				Client sampling date / time: 31-OCT-2013 11:45	31-OCT-2013 13:30	30-OCT-2013 10:10	30-OCT-2013 10:20	30-OCT-2013 14:00
				ES1323682-001	ES1323682-002	ES1323682-003	ES1323682-004	ES1323682-005
EG020F: Dissolved Metals by ICP-MS - Continued								
Uranium	7440-61-1	0.001	mg/L	<0.001	**0.003**	<0.001	<0.001	**0.001**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	**0.048**	**0.046**	**0.026**	**0.570**	**0.167**
Boron	7440-42-8	0.05	mg/L	**0.11**	**0.08**	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**0.10**	**0.50**	**0.06**	<0.05	**14.3**
Bromine	7726-95-6	0.1	mg/L	**1.6**	**3.9**	**1.9**	**2.0**	**2.8**
EG052G: Silica by Discrete Analyser								
Reactive Silica	----	0.10	mg/L	**10.2**	**20.9**	**11.4**	**13.6**	**34.2**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.8**	**0.3**	<0.1	**0.4**	**0.1**
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**1.74**	**0.82**	**3.22**	**1.74**	**0.58**
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	**0.01**	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	**0.01**	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**2.1**	**1.1**	**3.3**	**2.0**	**0.6**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**2.1**	**1.1**	**3.3**	**2.0**	**0.6**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.08**	**0.06**	<0.01	<0.01	**0.06**
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	**0.10**	<0.01	<0.01	<0.01	<0.01
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**40.3**	**48.8**	**26.5**	**28.2**	**38.1**
Total Cations	----	0.01	meq/L	**38.8**	**44.6**	**25.4**	**31.0**	**37.4**
Ionic Balance	----	0.01	%	**1.96**	**4.50**	**2.05**	**4.65**	**0.91**
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**41**	**27**	**1**	**13**	**17**
EP020: Oil and Grease (O&G)								

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	FKMB01B	FKMB01A	BWMB01C	BWMB01D	BWMB01B
				Client sampling date / time	31-OCT-2013 11:45	31-OCT-2013 13:30	30-OCT-2013 10:10	30-OCT-2013 10:20	30-OCT-2013 14:00
					ES1323682-001	ES1323682-002	ES1323682-003	ES1323682-004	ES1323682-005
EP020: Oil and Grease (O&G) - Continued									
Oil & Grease	----	5	mg/L		<5	<5	<5	<5	<5
EP033: C1 - C4 Hydrocarbon Gases									
Methane	74-82-8	10	µg/L		**9920**	**2190**	**5080**	**2660**	**264**
Ethene	74-85-1	10	µg/L		<10	<10	<10	<10	<10
Ethane	74-84-0	10	µg/L		<10	<10	<10	<10	<10
Propene	115-07-1	10	µg/L		<10	<10	<10	<10	<10
Propane	74-98-6	10	µg/L		<10	<10	<10	<10	<10
Butene	25167-67-3	10	µg/L		<10	<10	<10	<10	<10
Butane	106-97-8	10	µg/L		<10	<10	<10	<10	<10
EP075(SIM)A: Phenolic Compounds									
Phenol	108-95-2	1.0	µg/L		**5.3**	<1.0	<1.0	**1.2**	<1.0
2-Chlorophenol	95-57-8	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
2-Methylphenol	95-48-7	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
3- & 4-Methylphenol	1319-77-3	2.0	µg/L		<2.0	<2.0	<2.0	<2.0	<2.0
2-Nitrophenol	88-75-5	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dimethylphenol	105-67-9	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dichlorophenol	120-83-2	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
2.6-Dichlorophenol	87-65-0	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
4-Chloro-3-methylphenol	59-50-7	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Pentachlorophenol	87-86-5	2.0	µg/L		<2.0	<2.0	<2.0	<2.0	<2.0
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons									
Naphthalene	91-20-3	1.0	µg/L		<1.0	<1.0	**3.8**	<1.0	**3.6**
Acenaphthylene	208-96-8	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L		<1.0	<1.0	**14.8**	<1.0	**5.2**
Fluorene	86-73-7	1.0	µg/L		<1.0	<1.0	**11.2**	<1.0	**3.8**
Phenanthrene	85-01-8	1.0	µg/L		<1.0	<1.0	**13.8**	<1.0	**5.2**
Anthracene	120-12-7	1.0	µg/L		<1.0	<1.0	**2.0**	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L		<1.0	<1.0	**1.9**	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L		<1.0	<1.0	**1.0**	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	FKMB01B	FKMB01A	BWMB01C	BWMB01D	BWMB01B
				Client sampling date / time	31-OCT-2013 11:45	31-OCT-2013 13:30	30-OCT-2013 10:10	30-OCT-2013 10:20	30-OCT-2013 14:00
					ES1323682-001	ES1323682-002	ES1323682-003	ES1323682-004	ES1323682-005
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued									
Benzo(b)fluoranthene	205-99-2	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L		<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L		<0.5	<0.5	**48.5**	<0.5	**17.8**
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L		<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		<20	**60**	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L		<50	<50	**820**	<50	**90**
C15 - C28 Fraction	----	100	µg/L		<100	<100	**150**	<100	<100
C29 - C36 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L		<50	<50	**970**	<50	**90**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013									
C6 - C10 Fraction	C6_C10	20	µg/L		<20	**60**	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L		<20	**30**	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L		<100	<100	**840**	<100	**100**
>C16 - C34 Fraction	----	100	µg/L		<100	<100	**100**	<100	<100
>C34 - C40 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L		<100	<100	**940**	<100	**100**
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L		<100	<100	**820**	<100	<100
EP080: BTEXN									
Benzene	71-43-2	1	µg/L		<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L		**3**	**30**	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L		<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L		<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L		<2	<2	<2	<2	<2
^ **Total Xylenes**	1330-20-7	2	µg/L		<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L		**3**	**30**	<1	<1	<1
Naphthalene	91-20-3	5	µg/L		<5	<5	**17**	<5	**5**
EP075(SIM)S: Phenolic Compound Surrogates									

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	FKMB01B	FKMB01A	BWMB01C	BWMB01D	BWMB01B
				Client sampling date / time	31-OCT-2013 11:45	31-OCT-2013 13:30	30-OCT-2013 10:10	30-OCT-2013 10:20	30-OCT-2013 14:00
					ES1323682-001	ES1323682-002	ES1323682-003	ES1323682-004	ES1323682-005
EP075(SIM)S: Phenolic Compound Surrogates - Continued									
Phenol-d6	13127-88-3	0.1	%		**28.3**	**36.3**	**38.8**	**38.5**	**33.4**
2-Chlorophenol-D4	93951-73-6	0.1	%		**62.3**	**74.7**	**77.6**	**78.1**	**77.1**
2.4.6-Tribromophenol	118-79-6	0.1	%		**82.0**	**85.2**	**83.9**	**89.9**	**78.3**
EP075(SIM)T: PAH Surrogates									
2-Fluorobiphenyl	321-60-8	0.1	%		**66.8**	**61.5**	**58.1**	**61.7**	**56.8**
Anthracene-d10	1719-06-8	0.1	%		**72.5**	**75.3**	**76.5**	**80.7**	**70.0**
4-Terphenyl-d14	1718-51-0	0.1	%		**68.8**	**71.3**	**71.8**	**75.0**	**67.5**
EP080S: TPH(V)/BTEX Surrogates									
1.2-Dichloroethane-D4	17060-07-0	0.1	%		**119**	**86.3**	**90.3**	**80.9**	**85.2**
Toluene-D8	2037-26-5	0.1	%		**124**	**89.3**	**89.1**	**81.1**	**92.2**
4-Bromofluorobenzene	460-00-4	0.1	%		**100**	**85.8**	**92.8**	**93.3**	**101**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	BWMB01A	QA	----	----	----
				Client sampling date / time	30-OCT-2013 15:00	30-OCT-2013 15:00	----	----	----
Compound	CAS Number	LOR	Unit		ES1323682-006	ES1323682-007	----	----	----
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		3900	3570	----	----	----
EA015: Total Dissolved Solids									
Total Dissolved Solids @180°C	----	10	mg/L		1970	1950	----	----	----
EA025: Suspended Solids									
Suspended Solids (SS)	----	5	mg/L		3700	94	----	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		297	326	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L		297	326	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		22	20	----	----	----
ED045G: Chloride Discrete analyser									
Chloride	16887-00-6	1	mg/L		927	793	----	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		98	56	----	----	----
Magnesium	7439-95-4	1	mg/L		66	32	----	----	----
Sodium	7440-23-5	1	mg/L		488	611	----	----	----
Potassium	7440-09-7	1	mg/L		4	11	----	----	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		0.32	0.18	----	----	----
Arsenic	7440-38-2	0.001	mg/L		0.028	0.003	----	----	----
Beryllium	7440-41-7	0.001	mg/L		<0.001	<0.001	----	----	----
Barium	7440-39-3	0.001	mg/L		1.25	3.00	----	----	----
Cadmium	7440-43-9	0.0001	mg/L		0.0001	<0.0001	----	----	----
Cobalt	7440-48-4	0.001	mg/L		0.006	0.002	----	----	----
Copper	7440-50-8	0.001	mg/L		0.006	0.001	----	----	----
Lead	7439-92-1	0.001	mg/L		0.002	<0.001	----	----	----
Manganese	7439-96-5	0.001	mg/L		0.501	0.115	----	----	----
Molybdenum	7439-98-7	0.001	mg/L		0.002	0.011	----	----	----
Nickel	7440-02-0	0.001	mg/L		0.005	0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	----	----	----
Strontium	7440-24-6	0.001	mg/L		2.12	1.99	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	BWMB01A	QA	----	----	----
				Client sampling date / time	30-OCT-2013 15:00	30-OCT-2013 15:00	----	----	----
Compound	CAS Number	LOR	Unit		ES1323682-006	ES1323682-007	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Uranium	7440-61-1	0.001	mg/L		**0.001**	<0.001	----	----	----
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L		**0.114**	**3.88**	----	----	----
Boron	7440-42-8	0.05	mg/L		<0.05	**0.06**	----	----	----
Iron	7439-89-6	0.05	mg/L		**1.70**	**0.52**	----	----	----
Bromine	7726-95-6	0.1	mg/L		**2.1**	**2.0**	----	----	----
EG052G: Silica by Discrete Analyser									
Reactive Silica	----	0.10	mg/L		**29.1**	**16.3**	----	----	----
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.2**	**0.3**	----	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.24**	**1.71**	----	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	----	0.01	mg/L		<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		<0.01	<0.01	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**2.5**	**1.9**	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**2.5**	**1.9**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.59**	<0.01	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	----	----	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**32.5**	**29.3**	----	----	----
Total Cations	----	0.01	meq/L		**31.6**	**32.3**	----	----	----
Ionic Balance	----	0.01	%		**1.40**	**4.83**	----	----	----
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**11**	**15**	----	----	----
EP020: Oil and Grease (O&G)									

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	BWMB01A	QA	----	----	----
				Client sampling date / time	30-OCT-2013 15:00	30-OCT-2013 15:00	----	----	----
Compound	CAS Number	LOR	Unit		ES1323682-006	ES1323682-007	----	----	----
EP020: Oil and Grease (O&G) - Continued									
Oil & Grease	----	5	mg/L		<5	----	----	----	----
EP033: C1 - C4 Hydrocarbon Gases									
Methane	74-82-8	10	µg/L		<10	**7060**	----	----	----
Ethene	74-85-1	10	µg/L		<10	<10	----	----	----
Ethane	74-84-0	10	µg/L		<10	<10	----	----	----
Propene	115-07-1	10	µg/L		<10	<10	----	----	----
Propane	74-98-6	10	µg/L		<10	<10	----	----	----
Butene	25167-67-3	10	µg/L		<10	<10	----	----	----
Butane	106-97-8	10	µg/L		<10	<10	----	----	----
EP075(SIM)A: Phenolic Compounds									
Phenol	108-95-2	1.0	µg/L		<1.0	<1.0	----	----	----
2-Chlorophenol	95-57-8	1.0	µg/L		<1.0	<1.0	----	----	----
2-Methylphenol	95-48-7	1.0	µg/L		<1.0	<1.0	----	----	----
3- & 4-Methylphenol	1319-77-3	2.0	µg/L		<2.0	<2.0	----	----	----
2-Nitrophenol	88-75-5	1.0	µg/L		<1.0	<1.0	----	----	----
2.4-Dimethylphenol	105-67-9	1.0	µg/L		<1.0	<1.0	----	----	----
2.4-Dichlorophenol	120-83-2	1.0	µg/L		<1.0	<1.0	----	----	----
2.6-Dichlorophenol	87-65-0	1.0	µg/L		<1.0	<1.0	----	----	----
4-Chloro-3-methylphenol	59-50-7	1.0	µg/L		<1.0	<1.0	----	----	----
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L		<1.0	<1.0	----	----	----
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L		<1.0	<1.0	----	----	----
Pentachlorophenol	87-86-5	2.0	µg/L		<2.0	<2.0	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons									
Naphthalene	91-20-3	1.0	µg/L		**1.8**	**5.8**	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L		<1.0	<1.0	----	----	----
Acenaphthene	83-32-9	1.0	µg/L		**4.2**	**6.2**	----	----	----
Fluorene	86-73-7	1.0	µg/L		**2.6**	**4.8**	----	----	----
Phenanthrene	85-01-8	1.0	µg/L		**2.9**	**6.7**	----	----	----
Anthracene	120-12-7	1.0	µg/L		<1.0	<1.0	----	----	----
Fluoranthene	206-44-0	1.0	µg/L		<1.0	<1.0	----	----	----
Pyrene	129-00-0	1.0	µg/L		<1.0	<1.0	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L		<1.0	<1.0	----	----	----
Chrysene	218-01-9	1.0	µg/L		<1.0	<1.0	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	BWMB01A	QA	----	----	----
				Client sampling date / time	30-OCT-2013 15:00	30-OCT-2013 15:00	----	----	----
					ES1323682-006	ES1323682-007	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued									
Benzo(b)fluoranthene	205-99-2	1.0	µg/L		<1.0	<1.0	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L		<1.0	<1.0	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L		<0.5	<0.5	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L		<1.0	<1.0	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L		<1.0	<1.0	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L		<1.0	<1.0	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L		**11.5**	**23.5**	----	----	----
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L		<0.5	<0.5	----	----	----
EP080/071: Total Petroleum Hydrocarbons									
C6 - C9 Fraction	----	20	µg/L		<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L		**120**	**130**	----	----	----
C15 - C28 Fraction	----	100	µg/L		<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L		**90**	**90**	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L		**210**	**220**	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013									
C6 - C10 Fraction	C6_C10	20	µg/L		<20	<20	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L		<20	<20	----	----	----
>C10 - C16 Fraction	>C10_C16	100	µg/L		**120**	**140**	----	----	----
>C16 - C34 Fraction	----	100	µg/L		<100	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L		<100	<100	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L		**120**	**140**	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L		**120**	**140**	----	----	----
EP080: BTEXN									
Benzene	71-43-2	1	µg/L		<1	<1	----	----	----
Toluene	108-88-3	2	µg/L		<2	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L		<2	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L		<2	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L		<2	<2	----	----	----
^ **Total Xylenes**	1330-20-7	2	µg/L		<2	<2	----	----	----
^ **Sum of BTEX**	----	1	µg/L		<1	<1	----	----	----
Naphthalene	91-20-3	5	µg/L		<5	**5**	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates									

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BWMB01A	QA	----	----	----
			Client sampling date / time	30-OCT-2013 15:00	30-OCT-2013 15:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1323682-006	ES1323682-007	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates - Continued								
Phenol-d6	13127-88-3	0.1	%	40.1	38.0	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	81.4	77.3	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	88.4	84.0	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	63.2	71.7	----	----	----
Anthracene-d10	1719-06-8	0.1	%	79.5	75.4	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	75.1	71.7	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	97.0	78.6	----	----	----
Toluene-D8	2037-26-5	0.1	%	90.2	85.2	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	104	93.8	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10.0	44
2-Chlorophenol-D4	93951-73-6	14	94
2.4.6-Tribromophenol	118-79-6	17	125
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	20	104
Anthracene-d10	1719-06-8	27.4	113
4-Terphenyl-d14	1718-51-0	32	112
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

Appendix G

GNS Stable Isotope Laboratory results

STABLE ISOTOPE RESULTS

National Isotope Centre
30 Gracefield Road
Lower Hutt 5010
PO Box 31 312
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4657
www.gns.cri.nz

Parsons Brinckerhoff
Level 27, 680 George St
World Square, Sydney
NSW 2001
Australia

Project Title	2193324A	**Invoice**	**Parsons Brinckerhoff**
SIL Order No.:		**Attn:**	**Ellen Kwantes**
Client Ref.:			**Level 27, 680 George St**
Date Received:	7/11/2013		**World Square, Sydney**
Date Measured:			**NSW 2001**
Approved By:			**Australia**
Date Reported:	2/12/2013		

Sample Type: **water (H & O)**

SIL ID	External ID	δD Value	δ18O Value	Analysis Type	Overseas or NZ	State or Province	Country Code	Collection Date/Time (Start)	Other Info
W-1302893	FKMB01A	-24.3	-4.65	D, O18	OS	New South Wales	AS	31/10/2013	Groundwater
W-1302894	FKMB01B	-28.0	-4.99	D, O18	OS	New South Wales	AS	31/10/2013	Groundwater
W-1302895	BWMB01A	-19.9	-4.04	D, O18	OS	New South Wales	AS	30/10/2013	Groundwater
W-1302896	BWMB01B	-21.9	-4.24	D, O18	OS	New South Wales	AS	30/10/2013	Groundwater
W-1302897	BWMB01C	-23.6	-4.47	D, O18	OS	New South Wales	AS	30/10/2013	Groundwater
W-1302898	BWMB01D	-24.8	-4.62	D, O18	OS	New South Wales	AS	31/10/2013	Groundwater

Appendix H

Rafter Radiocarbon Laboratory results

Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 55386
R 40404/1
Job No: 197156
Measured: 20/12/2013
TW No: 2909
Date issued: 23 Dec 2013

Sample ID	FKMB01A
Description	Groundwater
Fraction dated	Groundwater
Submitter	Ellen Kwantes Parsons Brinckerhoff

Conventional Radiocarbon Age (years BP)	**2787**	±	**19**	
$\delta^{13}C$ and Source of measurement	-14.8	±	0.2	C13
Fraction modern	0.7069	±	0.0016	
$\Delta^{14}C$ (‰) and collection date	-298.6	±	1.6	31 Oct 2013

Measurement Comment:

Sample Treatment Details

Sample was submitted in: frosted white plastic Nalgene bottle with a small amount of brown sediment at the bottom. No head space. Sample colour: colourless. Odour Description: odourless. CO2 was generated by phosphoric acid evolution, and carbonate content was 174.6mgC/kgH2O, total dissolved inorganic carbon (TDIC) 14.6mmol/kgH2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach, Radiocarbon 19:355-363 (1977) and $\Delta^{14}C$ is decay corrected to the collection date given, and not reported if no collection date was supplied. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25 permil, defined by Donahue, D. J., T. Linick, and A. T. Jull, *Radiocarbon*, *32* (2):135-142 (1990). $\delta^{13}C$ was obtained from the source indicated. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error component based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

National Isotope Centre, GNS Science
PO Box 31-312 Lower Hutt, New Zealand Fax +64 4 570 4657 Phone +64 4 570 4644
Email radiocarbon@gns.cri.nz Website www.RafterRadiocarbon.co.nz

Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 55387
R 40404/2
Job No: 197157
Measured: 20/12/2013
TW No: 2909
Date issued: 23 Dec 2013

Sample ID	FKMB01B
Description	Groundwater
Fraction dated	Groundwater
Submitter	Ellen Kwantes Parsons Brinckerhoff

Conventional Radiocarbon Age (years BP)	**6513**	±	**22**	
$\delta^{13}C$ and Source of measurement	-2.5	±	0.2	C13
Fraction modern	0.4445	±	0.0012	
$\Delta^{14}C$ (‰) and collection date	-558.9	±	1.2	31 Oct 2013

Measurement Comment:

Sample Treatment Details

Sample was submitted in: nalgene bottle with small air bubble and dark brown sediment. Water colourless with faint H2S odour with no head space. Sulphur test was Positive. Odour Description: H2S confirmed with test strip. Will need to recombust gas. CO2 was generated by phosphoric acid evolution, and carbonate content was 176.1mgC/kgH2O, total dissolved inorganic carbon (TDIC) 14.7mmol/kgH2O. CO2 was combusted with silver wire to remove Sulphur. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach, Radiocarbon 19:355-363 (1977) and $\Delta^{14}C$ is decay corrected to the collection date given, and not reported if no collection date was supplied. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25 permil, defined by Donahue, D. J., T. Linick, and A. T. Jull, *Radiocarbon*, *32* (2):135-142 (1990). $\delta^{13}C$ was obtained from the source indicated. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error component based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

National Isotope Centre, GNS Science
PO Box 31-312 Lower Hutt, New Zealand Fax +64 4 570 4657 Phone +64 4 570 4644
Email radiocarbon@gns.cri.nz Website www.RafterRadiocarbon.co.nz

Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 55388
R 40404/3
Job No: 197158
Measured: 20/12/2013
TW No: 2909
Date issued: 23 Dec 2013

Sample ID	BWMB01A
Description	Groundwater
Fraction dated	Groundwater
Submitter	Ellen Kwantes Parsons Brinckerhoff

Conventional Radiocarbon Age (years BP)	**1578**	±	**17**	
$\delta^{13}C$ and Source of measurement	-12.0	±	0.2	C13
Fraction modern	0.8216	±	0.0017	
$\Delta^{14}C$ (‰) and collection date	-184.7	±	1.7	30 Oct 2013

Measurement Comment:

Sample Treatment Details

Sample was submitted in: nalgene bottle with thick layer of brown sediment present. No sulphur odour, no head space. Sample colour: colourless. CO2 was generated by phosphoric acid evolution, and carbonate content was 82mgC/kgH2O, total dissolved inorganic carbon (TDIC) 6.8mmol/kgH2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach, Radiocarbon 19:355-363 (1977) and $\Delta^{14}C$ is decay corrected to the collection date given, and not reported if no collection date was supplied. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25 permil, defined by Donahue, D. J., T. Linick, and A. T. Jull, *Radiocarbon*, *32* (2):135-142 (1990). $\delta^{13}C$ was obtained from the source indicated. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error component based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

National Isotope Centre, GNS Science
PO Box 31-312 Lower Hutt, New Zealand Fax +64 4 570 4657 Phone +64 4 570 4644
Email radiocarbon@gns.cri.nz Website www.RafterRadiocarbon.co.nz

Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 55389
R 40404/4
Job No: 197159
Measured: 20/12/2013
TW No: 2909
Date issued: 23 Dec 2013

Sample ID	BWMB01B
Description	Groundwater
Fraction dated	Groundwater
Submitter	Ellen Kwantes Parsons Brinckerhoff

Conventional Radiocarbon Age (years BP)	**1846**	±	**17**	
$\delta^{13}C$ and Source of measurement	-12.5	±	0.2	C13
Fraction modern	0.7947	±	0.0016	
$\Delta^{14}C$ (‰) and collection date	-211.5	±	1.6	30 Oct 2013

Measurement Comment:

Sample Treatment Details

Sample was submitted in: nalgene bottle with orangey coloured precipitate or sediment. No head space. Sample colour: colourless. Odour Description: no sulphur odour. CO2 was generated by phosphoric acid evolution, and carbonate content was 87.1mgC/kgH2O, total dissolved inorganic carbon (TDIC) 7.3mmol/kgH2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach, Radiocarbon 19:355-363 (1977) and $\Delta^{14}C$ is decay corrected to the collection date given, and not reported if no collection date was supplied. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25 permil, defined by Donahue, D. J., T. Linick, and A. T. Jull, *Radiocarbon*, *32* (2):135-142 (1990). $\delta^{13}C$ was obtained from the source indicated. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error component based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

National Isotope Centre, GNS Science
PO Box 31-312 Lower Hutt, New Zealand Fax +64 4 570 4657 Phone +64 4 570 4644
Email radiocarbon@gns.cri.nz Website www.RafterRadiocarbon.co.nz

Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 55390
R 40404/5
Job No: 197160
Measured: 20/12/2013
TW No: 2909
Date issued: 23 Dec 2013

Sample ID	BWMB01C
Description	Groundwater
Fraction dated	Groundwater
Submitter	Ellen Kwantes Parsons Brinckerhoff

Conventional Radiocarbon Age (years BP)	**5605**	±	**21**	
$\delta^{13}C$ and Source of measurement	-13.6	±	0.2	C13
Fraction modern	0.4977	±	0.0013	
$\Delta^{14}C$ (‰) and collection date	-506.1	±	1.3	30 Oct 2013

Measurement Comment:

Sample Treatment Details

Sample was submitted in: nalgene bottle with slight debris on bottom of bottle with no head space. Sample colour: colourless. Odour Description: no odour. CO2 was generated by phosphoric acid evolution, and carbonate content was 31.8mgC/kgH2O, total dissolved inorganic carbon (TDIC) 2.7mmol/kgH2O. The low yield meant that insufficient CO2 was obtained for further processing, and therefore the process was repeated and CO2 from both was combined to get 0.96mg C. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach, Radiocarbon 19:355-363 (1977) and $\Delta^{14}C$ is decay corrected to the collection date given, and not reported if no collection date was supplied. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25 permil, defined by Donahue, D. J., T. Linick, and A. T. Jull, *Radiocarbon*, *32* (2):135-142 (1990). $\delta^{13}C$ was obtained from the source indicated. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error component based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

National Isotope Centre, GNS Science
PO Box 31-312 Lower Hutt, New Zealand Fax +64 4 570 4657 Phone +64 4 570 4644
Email radiocarbon@gns.cri.nz Website www.RafterRadiocarbon.co.nz

Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 55391
R 40404/6
Job No: 197161
Measured: 20/12/2013
TW No: 2909
Date issued: 23 Dec 2013

Sample ID	BWMB01D
Description	Groundwater
Fraction dated	Groundwater
Submitter	Ellen Kwantes Parsons Brinckerhoff

Conventional Radiocarbon Age (years BP)	**10508**	±	**30**	
$\delta^{13}C$ and Source of measurement	-1.8	±	0.2	C13
Fraction modern	0.2703	±	0.0010	
$\Delta^{14}C$ (‰) and collection date	-731.8	±	1.0	31 Oct 2013

Measurement Comment:

Sample Treatment Details

Sample was submitted in: Nalgene bottle with precipitate in bottom. Colourless liquid. Small bubble in top. No odour. No head space. Sample colour: colourless. Odour Description: no odour. CO2 was generated by phosphoric acid evolution, and carbonate content was 85.5mgC/kgH2O, total dissolved inorganic carbon (TDIC) 7.1mmol/kgH2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach, Radiocarbon 19:355-363 (1977) and $\Delta^{14}C$ is decay corrected to the collection date given, and not reported if no collection date was supplied. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25 permil, defined by Donahue, D. J., T. Linick, and A. T. Jull, *Radiocarbon*, *32* (2):135-142 (1990). $\delta^{13}C$ was obtained from the source indicated. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error component based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

National Isotope Centre, GNS Science
PO Box 31-312 Lower Hutt, New Zealand Fax +64 4 570 4657 Phone +64 4 570 4644
Email radiocarbon@gns.cri.nz Website www.RafterRadiocarbon.co.nz

Appendix I

ANSTO Laboratory Tritium results

Australian Government

Nuclear-based science benefiting all Australians

Institute for Environmental Research
Analytical Report

Client:	**Parsons Brinckerhoff** **GPO Box 5394** **Sydney** **NSW 2001**
Contact:	**Ellen Kwantes**
Tel:	**(02) 9272-5078**

Report Number:	**2013/0317**
Batch Description:	**tritium in groundwater**
Samples Received:	**6**
Registration Date:	**6-Nov-2013**
Report Date:	**2-Jan-2014**
Logged By:	**Kellie-Anne Farrawell**
ANSTO Cost Code:	**0205V-1**
Funds Type:	**Project - Commercial**
Supervising Analyst:	**Robert Chisari**

Signature: Robert Chisari Date: 2/01/2014

Robert Chisari

Australian Government

Nuclear-based science benefiting all Australians

LIMS ID#	Client Identification	Sample Description
2013/0317-1	FKMB01A	Groundwater
2013/0317-2	FKMB01B	Groundwater
2013/0317-3	BWMB01A	Groundwater
2013/0317-4	BWMB01B	Groundwater
2013/0317-5	BWMB01C	Groundwater
2013/0317-6	BWMB01D	Groundwater

Institute for Environmental Research
Analytical Report

Report Number: 2013/0317

Tritium Concentration at Sampling Date

Client Identification	Sample No.	Date Sample Collected	Tritium Ratio	Uncertainty [1]	Quant Limit [2]	Tritium Activity	Uncertainty [1]	MDA [2]
			TU	TU	TU	Bq/kg	Bq/kg	Bq/kg
FKMB01A	1	31/10/2013	0.03^	0.03	0.18	0.004^	0.003	0.022
FKMB01B	2	31/10/2013	0.07^	0.03	0.16	0.008^	0.003	0.019
BWMB01A	3	30/10/2013	0.40	0.04	0.16	0.048	0.004	0.019
BWMB01B	4	30/10/2013	0.25	0.03	0.16	0.030	0.004	0.019
BWMB01C	5	30/10/2013	0.13^	0.03	0.16	0.016^	0.003	0.019
BWMB01D	6	31/10/2013	0.08^	0.03	0.16	0.009^	0.003	0.019

Notes:

1. Values reported are combined standard uncertainty, calculated to 1 sigma. A Coverage factor, *k*, of 2 may be used to calculate Expanded Uncertainty to 95% confidence.
2. The MDA (Minimum Detectable Activity) and Quant Limit (Limit of Quantification) are calculated to 95% confidence.

^ This result is below the MDA/Quant Limit and therefore has an unacceptable level of uncertainty. Hence, the data should only be used as an indicator of the true concentration

Signature: Robert Chisari Date: 2/01/2013

Robert Chisari

AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION
New Illawarra Road, Lucas Heights (Locked Bag 2001, Kirrawee DC NSW 2232) T +61 2 9717 3111 F +61 2 9543 5097
www.ansto.gov.au

Appendix J

UC Davis Stable Isotope Facility - Carbon-13 and Methane results

Sample	$\delta^{13}C_{VPDB}$	µg C/mL	Comments
FKMB01A	-14.59	177.6	
FKMB01B	0.89	162.0	
BWMB01A	-12.98	89.2	
BWMB01B	-13.72	97.1	
BWMB01C	-13.30	29.2	
BWMB01D	0.59	83.5	

Project: 2193324A

CHECK STD

0.2 ml 10mM Li2CO3 (Acros)

MEASURED	KNOWN
-13.39	-13.37
-13.37	MEAN
-13.28	-13.37
-13.39	SD
-13.41	0.04
-13.37	
-13.38	

Sample	δ^2H_{VSMOW}	Comments
FKMB01A	-146.9	Below LOQ
FKMB01B	-221.7	
BWMB01A	-67.9	Below LOQ
BWMB01B	-163.9	Below LOQ
BWMB01C	-199.3	
BWMB01D	-210.8	

Project: 2193324A

CHECK STD (10 ppm tank)	MEASURED	KNOWN
UCDM3	-149.4	-150.0
UCDM3	-150.7	-150.0
UCDM3	-147.6	-150.0
UCDM3	-155.7	-150.0
UCDM3	-148.7	-150.0
UCDM3	-150.7	-150.0
UCDM3	-148.8	-150.0
UCDM3	-151.1	-150.0
UCDM3	-150.7	-150.0
UCDM3	-151.3	-150.0
avg	-150.5	
sd	2.2	

CALIBRATION STDS	MEASURED	KNOWN
H iso	-154.3	-156.0
H iso	-155.1	-156.0
H iso	-157.3	-156.0
L iso	-172.6	-171.0
L iso	-172.6	-171.0
L iso	-173.3	-171.0
B iso	-267.4	-266.7
B iso	-266.9	-266.7
B iso	-265.9	-266.7

2nd CHECK STDS	MEASURED	KNOWN
NG1	-182.0	-185.1
NG1	-183.7	-185.1
Mamm	-191.4	-189.1
Beecher	-215.8	-218.0

Sample	$\delta^{13}C_{VPDB}$	Comments
FKMB01A	-41.02	Below LOQ
FKMB01B	-42.24	
BWMB01A	-29.82	Below LOQ
BWMB01B	-34.62	Below LOQ
BWMB01C	-63.51	
BWMB01D	-57.75	

Project: 2193324A

CHECK STD (10 ppm)	MEASURED	KNOWN
UCDM3	-36.87	-36.7
UCDM3	-36.66	-36.7
UCDM3	-36.68	-36.7
UCDM3	-36.97	-36.7
UCDM3	-36.63	-36.7
UCDM3	-36.66	-36.7
avg	-36.74	
sd	0.14	

CALIBRATION STDS	MEASURED	KNOWN
NG1	-34.00	-34.2
NG1	-34.08	-34.2
NG2	-69.11	-68.9
NG2	-69.38	-68.9

2nd CHECK STDS	MEASURED	KNOWN
H iso	-23.70	-23.9
H iso	-23.62	-23.9
L iso	-66.11	-66.5
L iso	-66.31	-66.5
B iso	-54.66	-54.5
B iso	-54.89	-54.5
T iso	-38.50	-38.3
T iso	-38.63	-38.3

Appendix K

QA/QC

Summary Table K.1: Water quality QA/QC

Analyte	Units	LOR	BWMB01D	QA1	RPD
General Parameters					
pH	pH units	0.01	na	na	na
Conductivity	µS/cm	1	3,490	3,570	-2.27
TDS	mg/L	1	1,940	1,950	-0.51
Laboratory Analytes					
Hydroxide alkalinity as $CaCO_3$	mg/L	1	<1	<1	nc
Carbonate alkalinity as $CaCO_3$	mg/L	1	<1	<1	nc
Bicarbonate alkalinity as $CaCO_3$	mg/L	1	264	326	-21.02
Total alkalinity as $CaCO_3$	mg/L	1	264	326	-21.02
Sulfate as SO_4^{2-}	mg/L	1	30	20	40.00
Chloride	mg/L	1	792	793	-0.13
Calcium	mg/L	1	41	56	-30.93
Magnesium	mg/L	1	30	32	-6.45
Sodium	mg/L	1	602	611	-1.48
Potassium	mg/L	1	12	11	8.70
Silica	mg/L	0.1	13.6	16.3	-18.06
Fluoride			0.4	0.3	28.57
Dissolved Metals					
Aluminium	mg/L	0.01	<0.01	0.18	nc
Arsenic	mg/L	0.001	0.003	0.003	0.00
Beryllium	mg/L	0.001	2.630	3.000	-13.14
Barium	mg/L	0.001	<0.001	<0.001	nc
Cadmium	mg/L	0.0001	<0.0001	<0.0001	nc
Cobalt	mg/L	0.001	<0.001	0.002	nc
Copper	mg/L	0.001	<0.001	0.001	nc
Lead	mg/L	0.001	<0.001	<0.001	nc
Manganese	mg/L	0.001	0.054	0.115	**-72.19**
Molybdenum	mg/L	0.001	0.017	0.011	42.86
Nickel	mg/L	0.001	<0.001	0.001	nc
Selenium	mg/L	0.01	<0.01	<0.01	nc
Strontium	mg/L	0.001	1.770	1.990	-11.70
Uranium	mg/L	0.001	<0.001	<0.001	nc
Vanadium	mg/L	0.01	<0.01	<0.01	nc
Zinc	mg/L	0.005	0.570	3.880	**-148.76**
Boron	mg/L	0.05	<0.05	0.06	nc
Iron	mg/L	0.05	<0.05	0.52	nc
Bromine	mg/L	0.1	2	2	0.00
Nutrients					
Ammonia as N	mg/L	0.01	1.74	1.71	1.74
Nitrite as N	mg/L	0.01	<0.01	<0.01	nc
Nitrate as N	mg/L	0.01	<0.01	<0.01	nc
Nitrite + Nitrate as N	mg/L	0.01	<0.01	<0.01	nc
Total Phosphorous	mg/L	0.01	<0.01	<0.01	nc
Reactive Phosphorous	mg/L	0.01	<0.01	<0.01	nc
Total Organic Carbon	mg/L	1	13	15	-14.29
Dissolved Gases					
Methane	µg/L	10	2,660	7,060	**-90.53**
Ethene	µg/L	10	<10	<10	nc
Ethane	µg/L	10	<10	<10	nc
Propene	µg/L	10	<10	<10	nc
Propane	µg/L	10	<10	<10	nc
Butane	µg/L	10	<10	<10	nc
Butene	µg/L	10	<10	<10	nc
Phenolic compounds					
Phenol	µg/L	1	1.2	<1.0	nc
2-Chlorophenol	µg/L	1	<1.0	<1.0	nc
2-Methylphenol	µg/L	1	<1.0	<1.0	nc
3-&4-Methylphenol	µg/L	2	<2.0	<2.0	nc
2-Nitrophenol	µg/L	1	<1.0	<1.0	nc
2.4-Dimethylphenol	µg/L	1	<1.0	<1.0	nc
2.4-Dichlorophenol	µg/L	1	<1.0	<1.0	nc
2.6-Dichlorophenol	µg/L	1	<1.0	<1.0	nc
4-Chloro-3-Methylphenol	µg/L	1	<1.0	<1.0	nc
2.4.6-Trichlorophenol	µg/L	1	<1.0	<1.0	nc
2.4.5-Trichlorophenol	µg/L	1	<1.0	<1.0	nc
Pentachlorophenol	µg/L	2	<2.0	<2.0	nc
Polycyclic aromatic hydrocarbons					nc
Naphthalene	µg/L	1	<1.0	5.8	nc
Acenaphthylene	µg/L	1	<1.0	<1.0	nc
Acenaphthene	µg/L	1	<1.0	6.2	nc
Fluorene	µg/L	1	<1.0	4.8	nc
Phenanthrene	µg/L	1	<1.0	6.7	nc
Anthracene	µg/L	1	<1.0	<1.0	nc
Fluoranthene	µg/L	1	<1.0	<1.0	nc
Pyrene	µg/L	1	<1.0	<1.0	nc
Benz(a)anthracene	µg/L	1	<1.0	<1.0	nc
Chrysene	µg/L	1	<1.0	<1.0	nc
Benzo(b)fluoranthene	µg/L	1	<1.0	<1.0	nc
Benzo(k)fluoranthene	µg/L	1	<1.0	<1.0	nc
Benzo(a)pyrene	µg/L	0.5	<0.5	<0.5	nc
Indeno(1.2.3.cd)pyrene	µg/L	1	<1.0	<1.0	nc
Dibenz(a.h)anthracene	µg/L	1	<1.0	<1.0	nc
Benzo(g.h.i)perylene	µg/L	1	<1.0	<1.0	nc
Sum of polycyclic aromatic hydrocarbons					nc
Total petroleum hydrocarbons					nc
C6-C9 Fraction	µg/L	20	<20	<20	nc
C10-C14 Fraction	µg/L	50	<50	130	nc
C15-C28 Fraction	µg/L	100	<100	<100	nc
C29-C36 Fraction	µg/L	50	<50	90	nc
C10-C36 Fraction (sum)	µg/L	50	<50	220	nc
Total recoverable hydrocarbons					nc
C6-C10 Fraction	µg/L	20	<20	<20	nc
C6-C10 Fraction minus BTEX (F1)	µg/L	20	<20	<20	nc
>C10-C16 Fraction	µg/L	100	<100	140	nc
>C16-C34 Fraction	µg/L	100	<100	<100	nc
>C34-C40 Fraction	µg/L	100	<100	<100	nc
>C10-C40 Fraction (sum)	µg/L	100	<100	140	nc
Aromatic Hydrocarbons					
Benzene	µg/L	1	<1	<1	nc
Toluene	µg/L	2	<2	<2	nc
Ethyl Benzene	µg/L	2	<2	<2	nc
m&p-Xylenes	µg/L	2	<2	<2	nc
o-Xylenes	µg/L	2	<2	<2	nc
Total xlyenes	µg/L	2	<2	<2	nc
Sum of BTEX	µg/L	1	<1	<1	nc
Naphthalene	µg/L	5	<5	5	nc

RPD = Relative Percentage Difference (between the original and duplicate sample analytical results).

nc = RPD was not calculated as one result was below the LOR.

BOLD - RPD exceeds acceptable limits.

PARSONS BRINCKERHOFF