



Amended Draft  
Underground Water Impact Report

ATP1056P – Cooper Basin

Date: 8 May 2014



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## Document Revision History

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27 November 2013	1	Nicola Fry	Draft UWIR for consultation
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## Glossary and Units of Measurement

<b>AD-1</b>	Andromedae 1, production testing well within ATP1056P
<b>Aquifer</b>	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
<b>Aquifer properties</b>	The characteristics of an aquifer that determine its hydraulic behaviour and its response to abstraction.
<b>Aquifer, confined</b>	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
<b>Aquifer, unconfined</b>	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
<b>AS-1</b>	Andromedae South 1, production testing well within ATP1056P
<b>ATP</b>	Authority To Prospect
<b>Baseline</b>	The natural situation.
<b>Beneficial aquifer</b>	An aquifer that can produce water at a sufficient rate and quality for an identified use.
<b>Bore</b>	A structure drilled below the surface to obtain water from an aquifer/reservoir or series of aquifers.
<b>Casing</b>	Steel pipe cemented in place during the construction process to stabilize the wellbore.
<b>Coal</b>	A sedimentary rock derived from the compaction and consolidation of vegetation or swamp deposits to form a fossilised carbonaceous rock.
<b>Coal seam</b>	A layer of coal within a sedimentary rock sequence.
<b>Confining layer</b>	Low permeability strata that may be saturated but will not allow water to move through it under ordinary hydraulic gradients.
<b>d</b>	days
<b>DEHP</b>	Department of Environment and Heritage Protection; as of 30 March 2012 some functions of the former Department of Environment and Resource Management will be delivered to the Department of Environment and Heritage Protection, including matters relating to UWIRs.
<b>DNRM</b>	Department of Natural Resources and Mines
<b>Drawdown</b>	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.
<b>Eh</b>	Reduction potential; also written as ORP
<b>Electrical conductivity (EC)</b>	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity. Measured in $\mu\text{S}/\text{cm}$ .
<b>GAB</b>	Great Artesian Basin
<b>GMA</b>	Groundwater Management Areas



<b>Groundwater</b>	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
<b>Groundwater system</b>	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.
<b>GWDB</b>	DNRM's groundwater database
<b>Head (hydraulic head)</b>	A specific measurement of water pressure above a geodetic datum.
<b>Hydraulic conductivity</b>	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water). Measured in metres per day (m/d).
<b>Hydrocarbon</b>	An organic compound consisting entirely of hydrogen and carbon
<b>Intracratonic sag basin</b>	A sedimentary basin that formed via sedimentary deposition of a large trough or depression within stable continental crust
<b>kL</b>	kilolitres
<b>km</b>	kilometres
<b>Lacustrine</b>	meaning "of a lake" or "relating to a lake"
<b>m</b>	meters
<b>mbgl</b>	meters below ground level
<b>microSiemens per centimetre (<math>\mu\text{S}/\text{cm}</math>)</b>	A measure of water salinity commonly referred to as EC (see also Electrical Conductivity). Most commonly measured in the field with calibrated field meters.
<b>ML</b>	megalitres
<b>mSS</b>	meters relative to sea level
<b>Oil-water contact</b>	A bounding surface in a reservoir above which predominantly oil occurs and below which predominantly water occurs.
<b>Permeability</b>	A measure of the ability of a porous material (e.g. a rock or unconsolidated material) to allow fluids to pass through it.
<b>Petroleum</b>	A liquid mixture of hydrocarbons which is present in suitable rock strata and can be extracted and refined to produce fuels including petrol, paraffin, and diesel oil; oil.
<b>pH</b>	Potential of Hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic).
<b>Pressure cement</b>	Cement inserted around casings of a well built to withstand a required pressure to ensure no leakage occurs.
<b>Produced water</b>	Groundwater generated from the production zone during production testing.
<b>Production well</b>	A well used to retrieve petroleum from the underground reservoir.
<b>Production testing program</b>	An exploration program designed to test the ability of pilot production wells to flow petroleum.
<b>Production zone</b>	Target stratigraphic unit(s) or formation(s) (or part thereof) where petroleum resources and/or groundwater is produced from.
<b>Recharge</b>	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.



<b>Reservoir</b>	Porous or fractured rock formations that can accumulate (in this case) petroleum resources
<b>Resistivity</b>	The ability of a material to oppose the flow of electric current
<b>RN</b>	Registered number (within DNRM groundwater database)
<b>Sandstone</b>	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).
<b>Sandstone aquifer</b>	Permeable sandstone that allows percolation of water and other fluids, and is porous enough to store large quantities of groundwater.
<b>Standing water level (SWL)</b>	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
<b>Stratigraphy</b>	The depositional order of sedimentary rocks in layers.
<b>TDS</b>	Total Dissolved Solids, measured in milligrams/litre (mg/L)
<b>Unconformity/</b>	An unconformity is a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.
<b>UWIR</b>	Underground Water Impact Report
<b>Water quality</b>	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
<b>Well</b>	Pertaining to a petroleum exploration or production well.



# 1 Introduction

The *Water Act 2000* (Qld) (Water Act) requires petroleum tenure holders to manage impacts of extraction of underground water from their exploration or production activities. To assist in achieving this, petroleum tenure holders must prepare an underground water impact report (UWIR), which is used to establish obligations on petroleum tenure holders and ensure measures and programs are in place to mitigate and measure impacts on underground water.

The key aspects of an UWIR are:

- > information about underground water extractions resulting from the exercise of underground water rights;
- > information about aquifers affected, or likely to be affected;
- > maps showing the area of the affected aquifer(s) where underground water levels are expected to decline;
- > a water monitoring strategy;
- > a spring impact management strategy.

This UWIR provides information about the relevant underground water extractions and the potential impacts on aquifers within ATP1056P as a result of dewatering during production testing. Specifically, production testing to date has occurred at one production test well within ATP1056P, which is located within the Cooper and Eromanga Basins and is approximately 150km east of Thargomindah town, Queensland, and 1150km west of Brisbane (Figure 1). This UWIR covers the entire ATP1056P block; however, it is specifically concerned with the area surrounding the production testing program at the Andromedae discoveries (Figure 2).

## 1.1 Project area

ATP1056P is the subject of petroleum exploration activities for oil. Location of the current exploration activity is shown in Figure 2.

AGL Cooper Basin Pty Ltd is operator of ATP1056P, on behalf of the joint venture (JV) between AGL, and other parties shown in Table 1.

The ATP area is approximately 3865 km<sup>2</sup>. Current and recent activities within the area include seismic programs, exploration drilling, and production testing.

Eight oil exploration wells have been drilled in two drilling campaigns in late 2011 and early 2013. Five of these wells have been plugged and abandoned (P&A) while two have been cased and completed and a third cased and suspended for production testing (Figure 2).

Production testing has occurred twice, during May 2012 and October 2012 – March 2013. In late October 2013, an additional extended production test commenced for two wells, Andromedae-1 (AD-1) and Andromedae South 1 (AS-1).





**Table 1: JV participants and interest within ATP1056P**

JV Participant	Participating Interest (%)
AGL Cooper Basin Pty Ltd (Operator)	40
Carson Energy, Inc	12
OG Operating, Inc	15.277
Discovery Geo Corporation	3
Foresight Australia Pty Ltd	10
Matariki Petroleum Partners	3
Rockwall Oil, LP	5
Tamark Pty Ltd	11.723
<b>Total</b>	100

**1.1.1 Summary of production wells**

AD-1 and AS-1 both target the Jurassic Hutton Sandstone reservoir. The completion details are shown in Table 2.

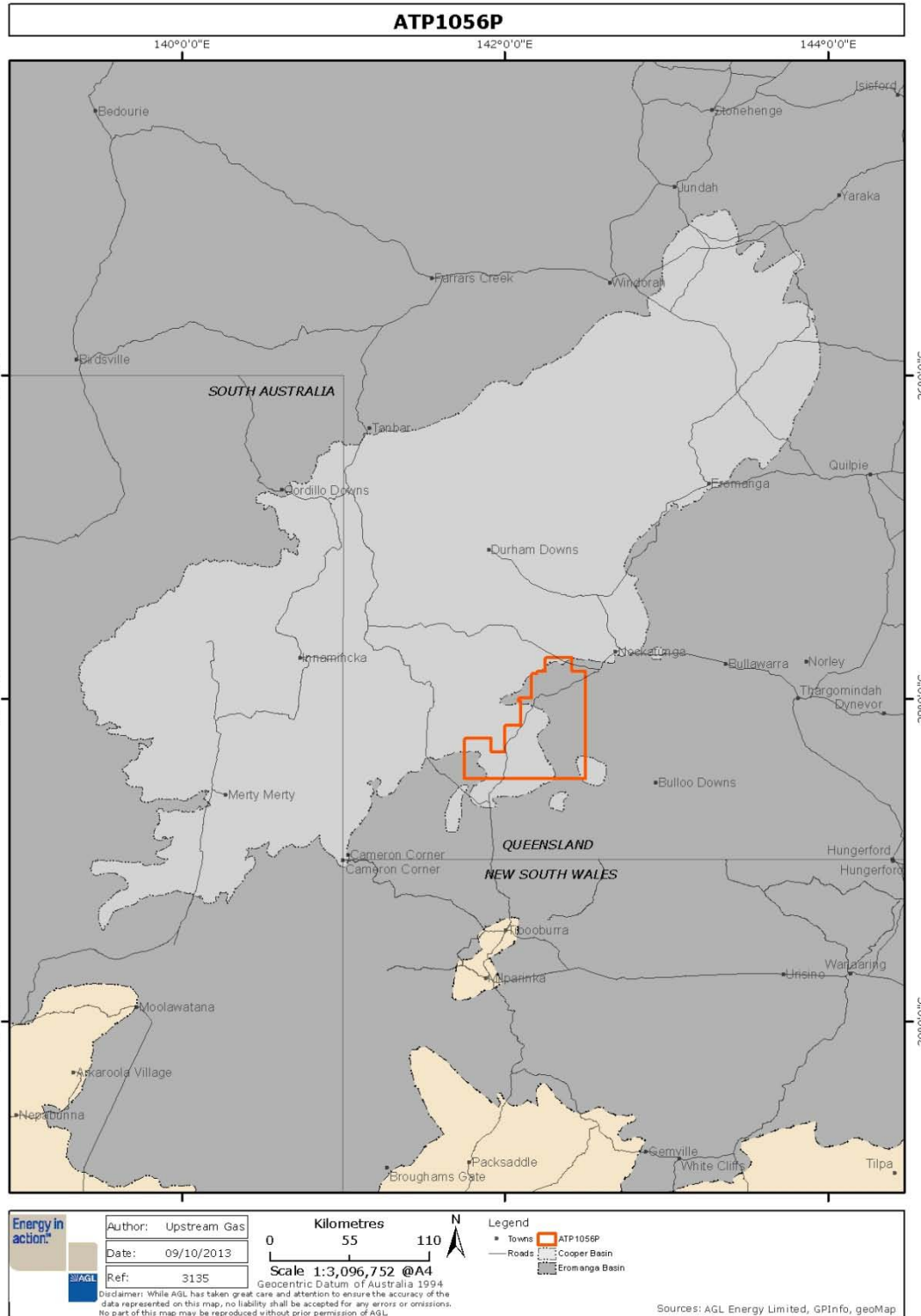
AD-1 was drilled as a near field oil exploration well in exploration permit ATP1056P. The permit sits within a north east trending string of small to moderately sized producing oil fields that exist directly adjacent to the western permit boundary. The major oilfields of the Jackson-Naccowlah trend lie less than 10km to the north (outside of ATP1056P). Oil is produced primarily at the Hutton Sandstone level although minor production does occur at all stratigraphic levels up to the Murta Formation in the surrounding region. Permian coals within the Nappamerri Trough primarily sourced this oil which is interpreted to have migrated vertically and laterally out of the kitchen areas. Prospects within the ATP1056P permit area lie on direct migration and spill pathways from the trough and existing fields.

The primary objective of the AD-1 well is to test an elongate, fault independent anticline within the Jurassic Hutton Sandstone lying on an interpreted migration pathway from the nearby producing Watson oilfield.

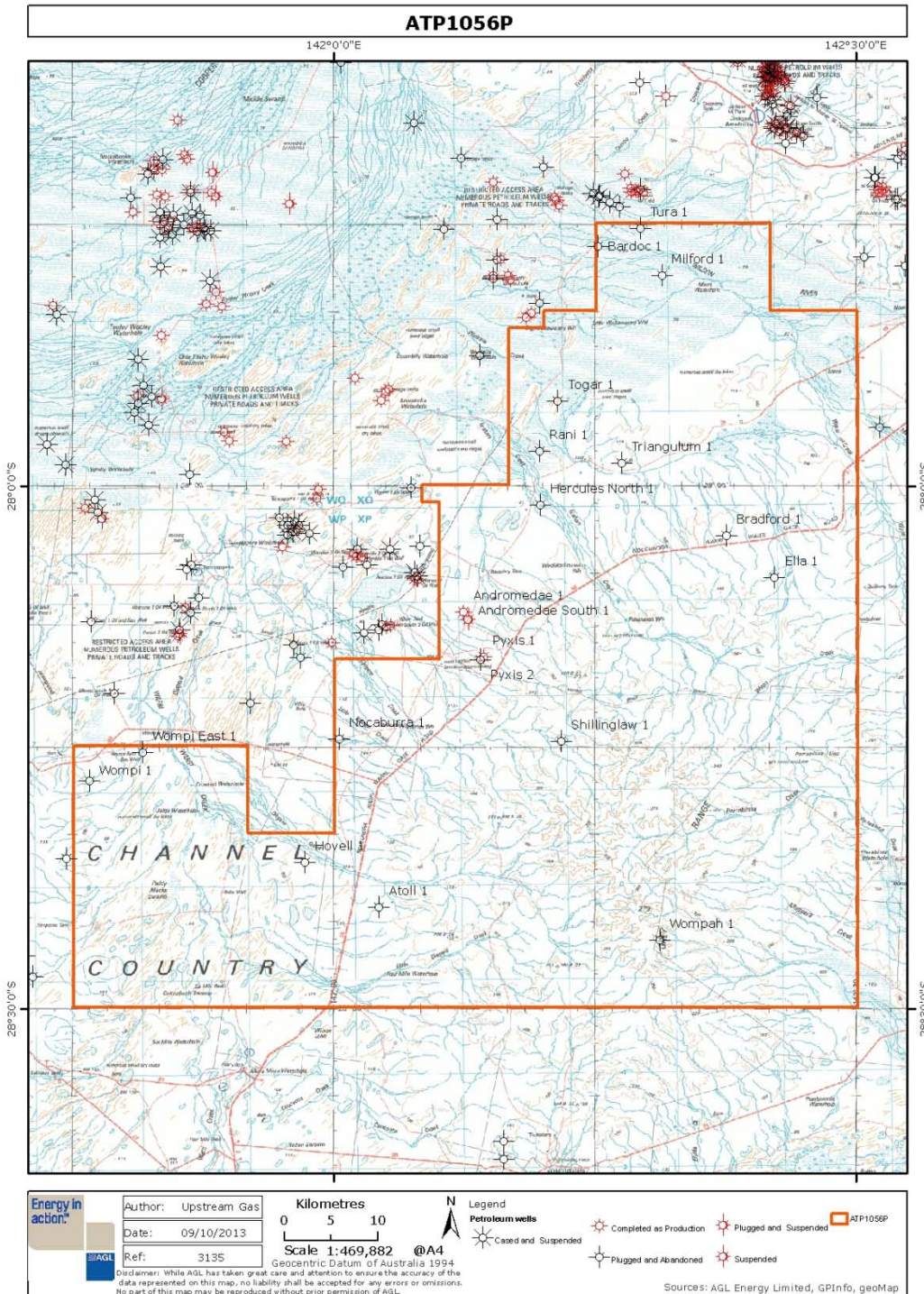
The primary objective of AS-1 is to test an interpreted structurally 4-way closed anticline within the Jurassic Hutton Sandstone. The well, drilled in early 2013, is located 930m south-southeast of AD-1.

**Table 2: Production well details**

Well	Andromedae – 1 (AD-1)	Andromedae South -1 (AS-1)
Spud date	27/09/2011	18/04/2013
Reservoir	Hutton Sandstone	Hutton Sandstone
Perforated interval (mSS)	1496.55 to 1498.55 (2 m interval)	1494.87 to 1496.37 (1.5 m interval)
Total depth	1699.00 m KB	1683.75 m MD



**Figure 1: Location of ATP1056P with respect to the Cooper and Eromanga Basins**



**Figure 2: Location of petroleum wells within the region. Within ATP1056P production testing has occurred at Andromedae 1 and is currently occurring there again and at Andromedae South 1 since late 2013.**



## 1.2 Summary of methods

An assessment of impacts on underground water from the production testing activities within ATP1056P has been undertaken by referencing available relevant data and reports. It should be noted, however, that there was not a lot of ATP specific data available as a result of the early stages of exploration.

A summary of the UWIR requirements under the Water Act 2000 (QLD) and the relevant sections of this report in which they have been addressed is included in Table 3.

It should be noted that a requirement of the UWIR is to predict the magnitude of water level declines for affected aquifers. To this end, the UWIR must include a map showing the area of the aquifer where water level is predicted to decline, because of the taking of the quantities of water, by more than the applicable trigger value:

- > within 3 years following the report consultation day (this area is defined as the Immediately Affected Area); and
- > at any time (this area is defined as the Long Term Affected Area).

Drawdown trigger threshold values, as defined by the Water Act, are 5 m declines in water level for consolidated rock (e.g. sandstone) aquifers, 2 m declines in unconsolidated aquifers, and 0.2 m declines in water level for spring source aquifers.

However, given the lack of available relevant data and the small scale of the previous and current production testing, no Immediately Affected Area or Long Term Affected Area can be accurately defined for aquifers within ATP1056P. Based on the logic discussed in Section 6.26, for the purpose of meeting s376b)(iv) and (v) of the Water Act, a conservative “potentially affected area” has been defined as a 2 km buffer within the Hutton Sandstone around both the wells currently under production testing. This area is shown in Figure 9. It should be emphasised that this area has been mapped highly conservatively and some first pass reservoir modelling indicates the likely affected area would be much smaller; it would be unlikely that any impact could actually be detected within much of the area (if there were receptors in place), let alone an impact close to or above the drawdown trigger threshold as defined by the Water Act. In addition, it should be noted, within this potentially affected area, there are no receptors (water bores, groundwater dependant ecosystems/springs, or exploration holes).

**Table 3: Reporting requirements from Water Act 2000, and which sections of this UWIR they apply to**

Reporting requirement as stated in the <i>Water Act 2000</i>	UWIR section
<b>Section 376</b>	
(a) for the area to which the report relates—	Section 4.1
(i) the quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights; and	
(ii) an estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3 year period starting on the consultation day for the report;	Section 4.2
(b) for each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights—	Section 5.1
(i) a description of the aquifer; and	
(ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and	Section 5.2
(iii) an analysis of the trends in water level change for the aquifer because of the exercise of the rights mentioned in paragraph (a)(i); and	Sections 5.3



(iv) a map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water mentioned in paragraph (a), by more than the bore trigger threshold within 3 years after the consultation day for the report; and	Figure 9
(v) a map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time;	Figure 9
(c) a description of the methods and techniques used to obtain the information and predictions under paragraph (b);	Section 6.2
(d) a summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore;	Section 6.3
(e) a program for— (i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and	Section 6.4
(ii) giving the chief executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps;	Section 6.4
(f) a water monitoring strategy;	Section 7
(g) a spring impact management strategy;	Not applicable to ATP1056P– refer to Section 8
(h) if the responsible entity is the commission— (i) a proposed responsible tenure holder for each report obligation mentioned in the report; and	Not applicable to ATP529P
(ii) for each immediately affected area—the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the immediately affected area;	Not applicable to ATP529P
(i) other information or matters prescribed under a regulation.	No matters identified
<b>Section 378</b>	
1) A responsible entity's water monitoring strategy must include the following for each immediately affected area and long-term affected area identified in its underground water impact report or final report— a) a strategy for monitoring— i) the quantity of water produced or taken from the area because of the exercise of relevant underground water rights; and ii) changes in the water level of, and the quality of water in, aquifers in the area because of the exercise of the rights; b) the rationale for the strategy; c) a timetable for implementing the strategy; d) a program for reporting to the commission about the implementation of the strategy. 2) The strategy for monitoring mentioned in subsection (1)(a) must include— a) the parameters to be measured; and b) the locations for taking the measurements; and c) the frequency of the measurements. 3) If the strategy is prepared for an underground water impact report, the strategy must also include a program for the responsible tenure holder or holders under the report to undertake a baseline assessment for each water bore that is— (a) outside the area of a petroleum tenure; but (b) within the area shown on the map prepared under section 376(b)(v). 4) If the strategy is prepared for a final report, the strategy must also include a statement about any matters under a previous strategy that have not yet been complied with.	Section 7



## 2 Legislation

The primary legislative requirements for the management of groundwater with respect to petroleum tenure holders for ATP1056P are summarised below.

### 2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Water and Other Legislation Amendment Act 2010* amends the *Water Act 2000* (Water Act) and other relevant legislation with the aim of improving the management of impacts associated with groundwater extraction that form part of petroleum activities. These amendments transfer the regulatory framework for underground water from *the Petroleum Act 1923* and *the Petroleum and Gas (Production and Safety) Act* (P&G Act) to the Water Act.

The P&G Act originally provided all rights of water extraction to a petroleum activity. However, through recent updates of the P&G Act and the Water Act, a petroleum tenure holder has an obligation to identify impact, establish baseline conditions and maintain groundwater supplies in private bores in the vicinity of petroleum operations. Where a bore owner can demonstrate reduced access to groundwater supplies, or a reduction in beneficial use class due to water quality changes, as a result of petroleum operations, “make good” provisions are available to address the loss incurred by an affected bore owner.

Under the P&G Act, the make good obligation for affected bores also applies to petroleum tenure obtained under the *Petroleum Act 1923* and are further defined in the Water Act.

### 2.2 Water Act 2000 (Qld)

The *Water Act 2000* (Qld) (as amended 2010):

- > Provides a comprehensive regime for the planning and management of all water resources (including vesting to the State the rights over the use, flow and control of all surface water, groundwater, rivers and springs) in Queensland.
- > Regulates water use and the obligations of petroleum tenure holders in relation to groundwater monitoring, reporting, impact assessment and management of impacts on other water users.
- > Provides a framework and conditions for preparing a Baseline Assessment Plan and outlines the requirements of bore owners to provide information that the petroleum holder reasonably requires to undertake a baseline assessment of any bore.
- > Sets out the process for applying for a Water Licence (where water is utilised outside of a petroleum lease or not on adjacent land owned by the same person).
- > Sets out the process for assessing, reporting, monitoring, and negotiating with other water users regarding the impact of petroleum production on aquifers.

The management of impacts on groundwater caused by the exercise of groundwater rights by petroleum tenement holders is achieved primarily by providing a regulatory framework that:

- > Requires petroleum tenure holders to monitor and assess the impact of the exercise of underground water rights on water bores and to enter into “make good” agreements with the owners of the bores;
- > Requires the preparation of UWIRs that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs;



If an existing water bore has an impaired capacity as a result of petroleum exploration or operation activities, an agreement is required to be negotiated with the owner of the bore about the following:

- > The reason for the bore's impaired capacity.
- > The measures the petroleum tenement holder will take to ensure the bore owner has access to a reasonable quantity and quality of water for the authorised use and purpose of the bore;
- > Any monetary or non-monetary compensation payable to the bore owner for impact on the bore.

If an agreement relating to a water bore is made the agreement is taken to be a "make good" agreement for the bore.

An UWIR will identify whether an Immediately Affected Area will result from petroleum activities. An Immediately Affected Area is defined as an area where the predicted decline in water levels within 3 years is above the drawdown trigger threshold:

- > 5 m for a consolidated aquifer
- > 2 m for an unconsolidated aquifer
- > 0.2 m for a spring.

UWIRs are published to enable the community, including bore owners and other stakeholders, within the area of testing, to make comments. Submissions made by stakeholders will be summarised by AGL, addressed as appropriate and provided to the Department of Environment and Heritage Protection (DEHP) together with the UWIR. UWIRs are submitted for approval by DEHP.

The relevant requirements within the Water Act applicable to the preparation of UWIRs, along with the reference to the section in this report where the requirement is addressed is presented in Table 3.

## **2.3 Other relevant water regulations**

The following legislations are also applicable to the oil production within ATP1056P:

- Environmental Protection Act 1994 (Qld)
- Environmental Protection (Water) Policy 2009 (Qld)
- Management of Water Produced in Association with Petroleum Activities (produced water), December 2007
- Great Artesian Basin Resource Operations Plan 2006
- Environmental Protection and Biodiversity Conservation (EPBC) Act 1994
- Water Resource (Cooper Creek) Plan 2000 (Qld)



## 3 Existing geological and hydrogeological regime

### 3.1 Geological summary

ATP1056P lies in the central portion of the Jurassic to Cretaceous Eromanga Basin wherein the primary targets for oil exploration lie. The permit also in part, unconformably overlies thin, remnant sediments of the Carboniferous to Triassic Cooper Basin with basement comprised of granodiorite and metasediments of the Cambro – Ordovician Warburton Basin.

The Eromanga Basin formed as an intracratonic sag basin comprising several depocentres formed around the underlying major basement troughs and platforms. Jurassic sedimentation occurred primarily within a fluvial to lacustrine environment consisting of three main fining upward clastic sequences. The Early Cretaceous period saw the Eromanga undergo subsidence at a much higher rate resulting in deposition of thick, shallow marine sequences transitioning finally to paralic and terrestrial environments. Deposition within the basin was terminated abruptly in the Late Cretaceous in which followed a period of predominantly erosion with minimal deposition through to the present.

Throughout the period of deposition the basin was structurally quiescent; however, periods of Late Cretaceous and Tertiary tectonism resulted in the majority of the structural features in the Eromanga. The majority of structures associated with these events generally post date hydrocarbon charge in the basin, and as such, closures associated are not prospective for exploration. Primary structures within the Eromanga sequence prospective for hydrocarbon exploration are simple, fault independent drape and compaction features over old basement highs.

#### 3.1.1 Local stratigraphy

Generalised stratigraphy is represented in Figure 3. Following, is a description of the stratigraphic units penetrated by the AD-1 well, with quoted depths relative to Kelly bushing (93.45 mSS).

The **Toolachee Formation** (1651.40 – 1668.96m KB) was deposited as a low energy meander belt to lacustrine facies. Stacked, fining up sequences of fine to coarse grained sandstones, dark grey siltstone, carbonaceous shale and channel capping coal seams dominate the unit. Moderate to high levels of siliceous cementation indicate poor porosity in these sandstone units.

The **Poolowanna Formation** (or Basal Jurassic facies) (1632.95 – 1651.40m KB) unconformably overlies the Permian sequences at this location and consists of a fine to medium, quartz dominated sandstone and interbedded siltstone. Thin and laterally discontinuous coals seams occur in the upper portion of the formation. Reasonably high energy fluvial sedimentation meandering within a floodplain and peat swamp facies is the likely environment of deposition for this unit.

The **Hutton Sandstone** (1589.97 – 1632.95m KB) comprises of a series of upward fining stacked channel sandstones deposited under high energy braided fluvial system. The quartzose and sublamine sands are predominantly medium to coarse grained with conglomeratic bands pervasive throughout the unit. Sandstone units occasionally grade into minor siltstone and mudstone beds.





The **Birkhead Formation** (1569.59 – 1589.97m KB) is a succession of interbedded mudstone, dark grey to brown siltstone and medium to coarse channel sandstones. Rare lenticular coals are present with the sandstones dominantly volcanolithic and well cemented authigenic clays comprising the matrix. The unit is interpreted to be deposited under meandering fluvial environment.

The **Adori Sandstone** (1563.00 – 1569.59m KB) is a thin, fine to medium grained labile sandstone deposited under high energy braided fluvial conditions. Occasionally the unit tends to coarse sandstone to conglomerate with low visual porosity.

The **Westbourne Formation** (1450.14 – 1563.00m KB) comprises of a lacustrine sequence of interbedded siltstone, mudstone and minor lenses of fine grained quartzose sandstones. Occasional thinly bedded and laterally discontinuous coal seams are present with the unit overall containing a moderate amount of carbonaceous material.

The **Namur Sandstone** (1355.25 – 1450.14m KB) deposition resulted from a period of high energy, braided fluvial conditions with intervening lower energy, distal floodplain type sedimentation. As such the sequence comprises fine to medium grained sub labile quartzose sandstone and thin interbedded siltstone with disseminated fine carbonaceous fragments.

The **Murta Formation** (1278.92 – 1355.25m KB) consists predominantly of thickly bedded siltstone with varying thickness of fine to medium grained sub-labile quartzose sandstones. The unit represents deposition under lacustrine to lower delta conditions.

The **Cadna-Owie Formation** (1194.67 – 1278.92m KB) was deposited as the transgressive interface between terrestrial and shallow marine environments. It consists of fine grained, clay rich sediments to fine calcareous sandstones with minor limestone and bioturbation occasionally noted.

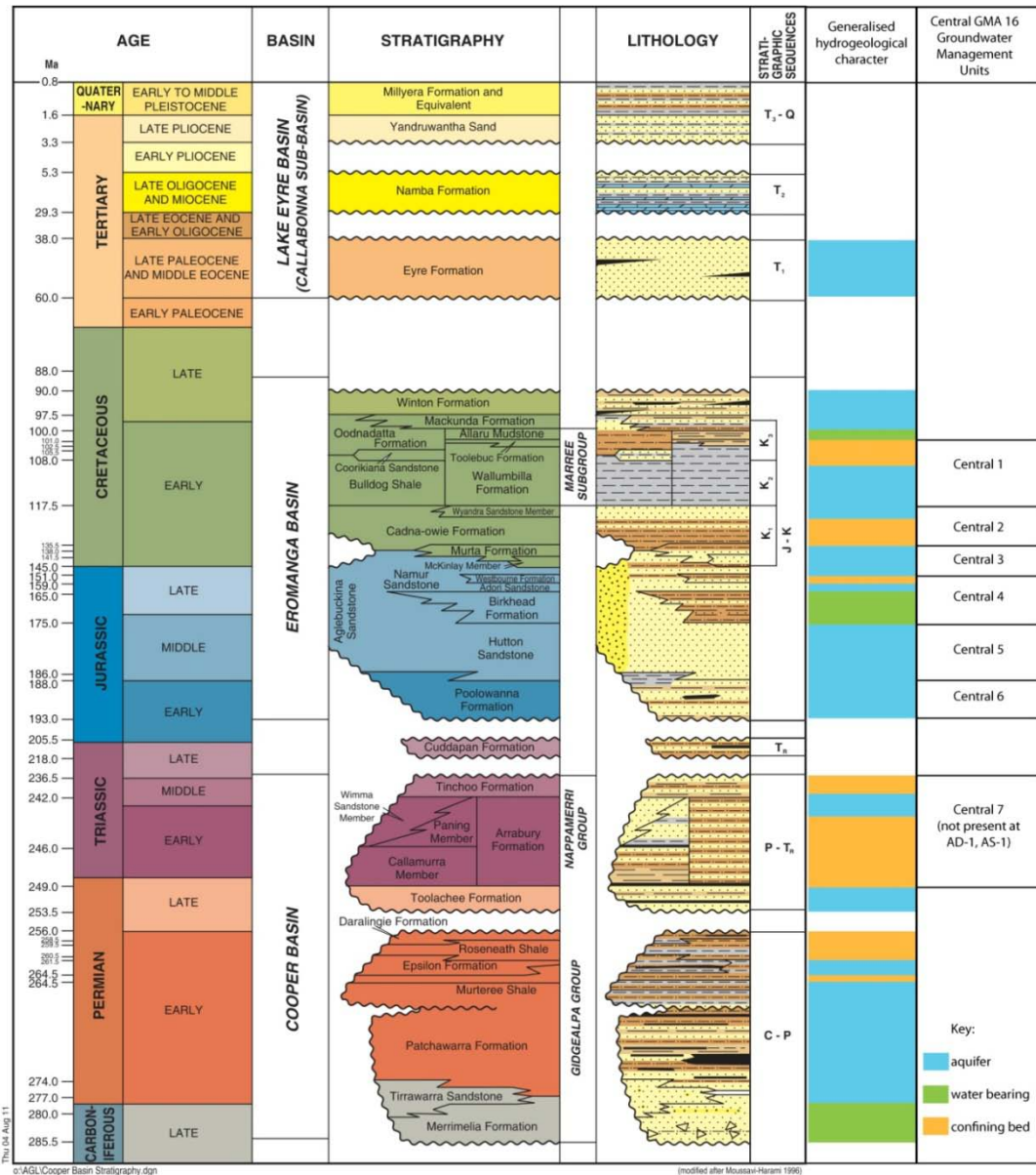
The **Bulldog Shale** (918.64 – 1194.67m KB) was deposited in a shallow to moderately deep open marine environment. The unit consists of a series of upward coarsening siltstones and fine grained sandstones. Glauconitic sandstones are common toward the base of the unit with disseminated pyrite common in the upper half of the unit.

The **Coorikiana Sandstone** (852.00 – 918.64m KB) was deposited as a regressive marine shoreface deposit. Sandstones are interbedded with minor medium to brown grey sandstones with minor medium to brown grey siltstones. Sandstones are fine grained, off white to light green to grey, with a calcareous matrix. Glauconite is a common accessory mineral.

The **Oodnadatta Formation** (650.93 – 852.00m KB) is a shallow marine sequence consisting of laminated claystone and siltstone with interbedded fine grained sandstone. Calcareous and ferruginous concretions and a thin unit of calcareous siltstone and fossil rich concretionary limestone exist in the lower part of the unit.

The **Mackunda Formation** (494.00 – 852.00m KB) was deposited during several cycles of alternating deep water marine sedimentation and shoreface deposition. Sandstones are typically fine grained, off white to light grey fine grained, and often have a calcareous cement. Siltstones are grey to dark grey, argillaceous and occasionally become pyritic near the base.

The **Winton Formation** (Surface – 494.00m KB) is a fluvial sequence, consisting of fine to coarse grained sandstones, carbonaceous and pyritic shale, siltstone and coal seams with intraclast conglomerates. Sandstone beds contain abundant fresh volcanogenic debris, lithics, felspar and traces of apatite, ferromagnesian minerals and mica.



Note: The Tertiary Eyre Formation is referred to as the Glendower Formation throughout this report.

**Figure 3: Stratigraphic chart for the ATP1056P (based on Moussavi-Harami, 1996, and Golder Associates, 2013)**

### 3.1.2 Geological Structure

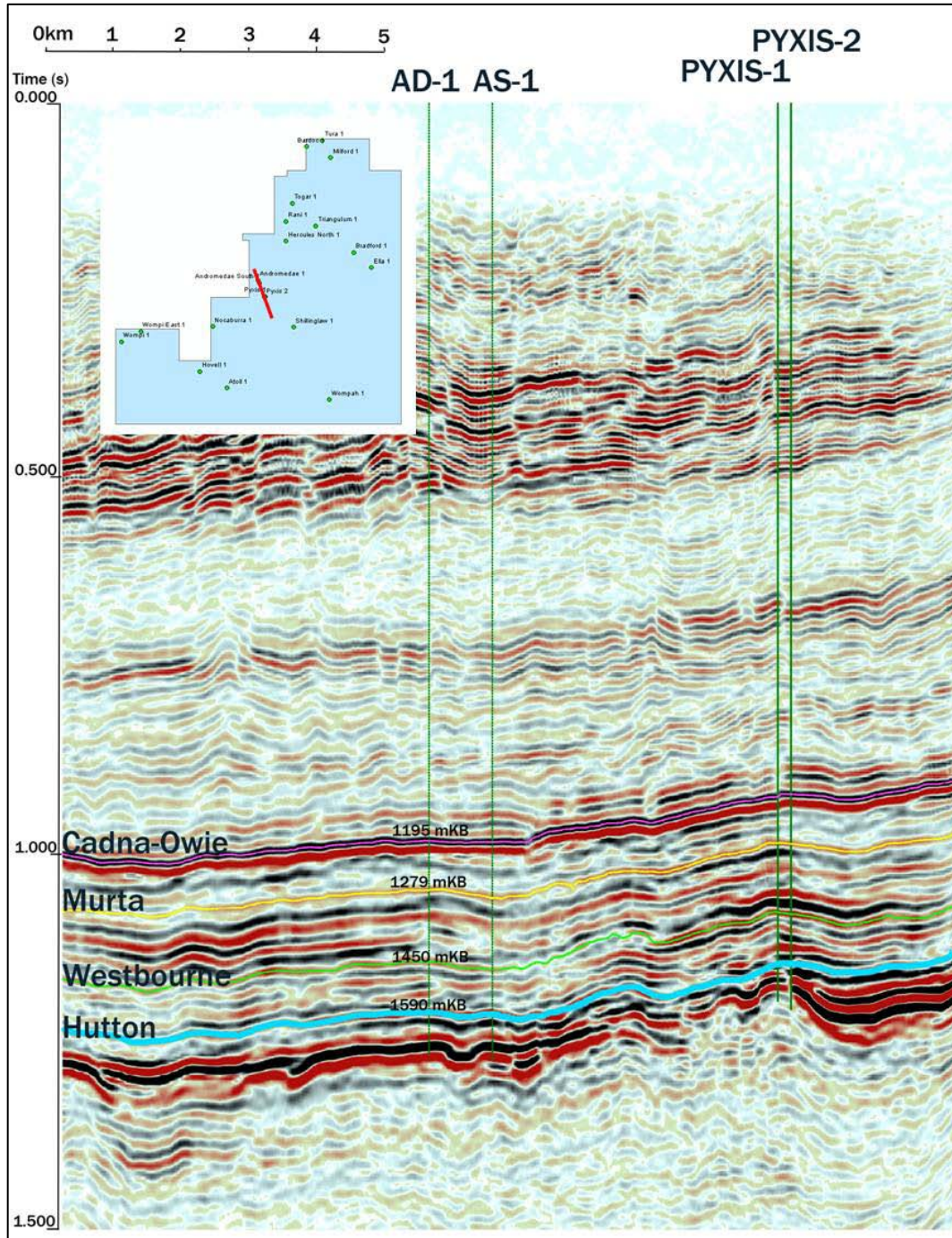
The sedimentary sequences within ATP1056P are predominantly Jurassic-Cretaceous Eromanga Basin units underlain by remnant thin Cooper Basin sequences or basement units. The basin throughout most of the tenement dips gently toward the north-west, plunging toward the underlying Cooper Basin depocentres of the Nappamerri Trough. The Eromanga Basin sequences thin toward the east and onlap remnant basement highs of the Thargomindah Shelf.

Faulting is minimal throughout the tenement however two main orientations have been identified trending toward the NE and N-NW. Isopach mapping suggests these features are



relatively recent and a result of up to four Late Cretaceous – Tertiary deformation events. Early basement induced faults appear to have undergone limited activity throughout the Jurassic – Cretaceous and rarely extend into the Eromanga section.

Figure 4 shows a seismic section (with offset locations of AD-1, AS-1, Pyxis-1 and Pyxis-2 identified) displaying the structure within the area of AGL's activities. No faults have been identified in this section, confirming the relatively structurally benign nature of the area. The structure shown in this seismic line is typical for the geology within the region of AGL's activities in ATP1056P.



**Figure 4: Seismic section displaying typical structure within the region. Vertical axis is in time (seconds). The location of the section is shown by the red line in the insert map. Mapped formation tops for the Cadna-owie, Murta, Westbourne and Hutton Sandstone are shown as coloured horizons. Depths to formation tops, as logged in AD-1, are also displayed. There are no water bores within the vicinity of this section. The Hutton Sandstone is the aquifer defined as the potentially affected aquifer (refer to Section 6).**



### 3.1.3 Petroleum resources

Within the region, significant oil reservoirs are present within the Hutton Sandstone, the Birkhead Formation and the Murta Formation. The Wyandra Sandstone Member, McKinlay Member (belonging to the Murta Formation) and Namur Sandstone, Westbourne Formation and Adori Sandstone and Lower Poolowanna hold minor oil reservoirs.

Within ATP1056P, the current exploration targets are Hutton Sandstone reservoirs known as the Andromedae discoveries, located at both AD-1 and AS-1. Structural mapping and petrophysical interpretation to date indicates that the oil-water contact lies at approximately 1500mSS at AS-1 and 1504mSS at AD-1.

## 3.2 Regional hydrogeological summary

The Quaternary/Tertiary fluvial deposits of the Lake Eyre Basin contain some water resources. However, it is the Triassic – Cretaceous Great Artesian Basin (GAB) that contains the major water resources across the region.

The main GAB aquifers within ATP1056P are the Winton Formation, Cadna-Owie Formation, Hooray Sandstone, Hutton Sandstone and Poolowanna Formation (Precipice Sandstone equivalent) within the Eromanga Basin. The aquifers within the Eromanga Basin are considered highly productive aquifers across most of the GAB.

The aquifers of the Cooper Basin are not considered within the defined sandstone aquifers of the GAB apart from the upper formations (Wimma Sandstone Member and younger).

Both the Cooper Basin and Eromanga Basin are multi-layered systems comprising alternating layers of sandstone, shales, mudstones and siltstone formations. Within the Eromanga Basin, the sandstone formations are typically the aquifers or water bearing zones. The siltstone, shale and mudstone formations typically are low permeability and not considered aquifers; however, local sandstone beds within these formations can be considered as groundwater resources.

QDNRM (2005) defined subdivisions of the GAB into Groundwater Management Areas (GMA), and each area is further divided into Groundwater Management Units, allowing for administration of access to water and water entitlements. ATP1056P is within the Central GMA. The Groundwater Management Units are for this GMA are shown in Figure 3.

The aquifers relevant to this UWIR are discussed in Section 5.

Shown in Figure 4 is a seismic section that displays the structure of the relevant hydrogeological units within the vicinity of the extraction activities in ATP1056P. The elevations of mapped formation tops are displayed with respect to AD-1. As discussed later in Section 6, the Hutton Sandstone is defined as the only potentially affected aquifer. There are no known water bores within the vicinity of the extraction activities that tap this aquifer. There are no significant faults identified within the area shown in the seismic section. There are no available groundwater levels for these aquifers in the vicinity of AGL's activities apart from the oil/water contact which is discussed in section 5.2.

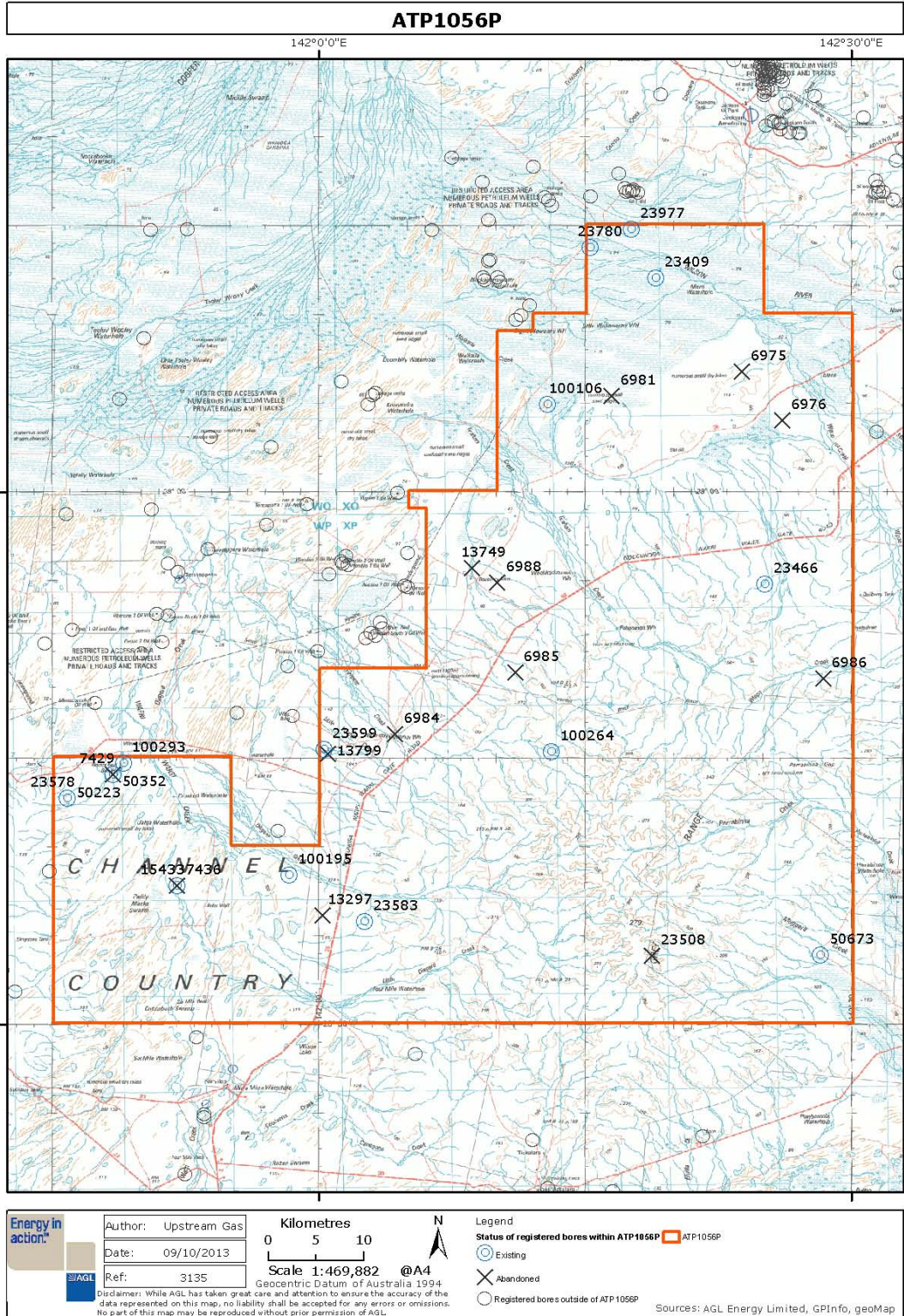
### 3.2.1 Groundwater use within ATP1056P

Within the region, only the shallow aquifers are of interest to the local population due to ease of access. As such, the deeper Hutton and Poolowanna Sandstone aquifers, for example, are not used as beneficial water supply aquifers.

Within the DNRM groundwater database (GWDB) there are 28 bores located within ATP1056P. These are presented in Table 7 of *Appendix B – Registered bores within ATP1056P* and in Figure 5. Thirteen (13) are described as abandoned and 15 are existing, however many of these are/were not water supply bores but were/are related to hydrocarbon exploration. Within the DNRM GWDB, only five of the 28 bores within



ATP1056P are assigned with a facility role (petroleum exploration); the remaining 23 bores are undefined. There are seven registered bores that have the target aquifer identified within the database.

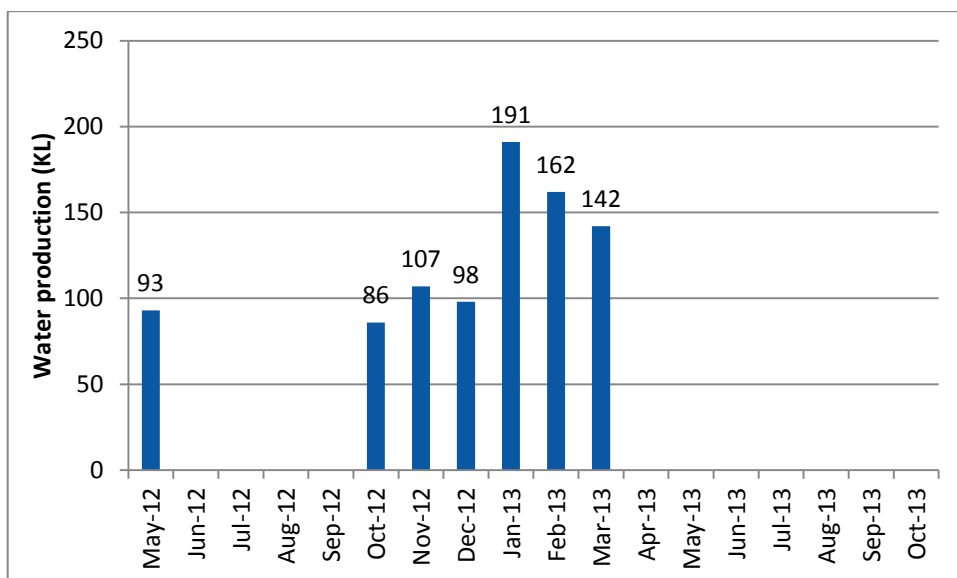


**Figure 5: Map of registered bores within ATP1056P (labelled with Registered Number)**

## 4 Part A: Underground water extractions

### 4.1 Quantity of water already produced

AGL has produced water from the Hutton Sandstone as part of production testing at AD-1. Production testing to date has occurred during two periods: October 2011 – March 2012 and October 2012 to March 2013. A total of 0.87 ML (870 KL) of water has been produced (as at October 2013). Figure 6 shows the water production data to date.



**Figure 6: Water production from the production testing program to date (as at October 2013) within ATP1056P (AD-1)**

### 4.2 Quantity of water to be produced in the next three years

Production testing will continue in late 2013 in both AD-1 and AS-1, and at this stage is licensed to proceed for a period of 12 months. The production philosophy for this current program is likely to be different from the previous two programs so it has been difficult to accurately predict the volumes of produced water. However, based on predicted oil and total fluid production, if the production testing continues for the full 12 month licensed period then it is expected the total volume of water produced could be approximately 10.5 ML. This prediction is currently being refined with modelling work and, although yet to be finalised, the preliminary model is currently estimating water production for a 12 month production test to be within the range of 5 – 40 ML.

There are no further plans for production testing within ATP1056P beyond this current program scheduled (which commenced late October 2013).





### **4.3 Currently producing zones**

To date, AGL has produced water and hydrocarbons from the Hutton Sandstone reservoir. Water produced is associated water from oil production. The produced water has been managed, and will continue to be managed, by simple gravity separation processes to recover oil and the water disposal via a lined evaporation dam.



## 5 Part B: Aquifer information and underground water flow

### 5.1 Description of each aquifer

The aquifer affected by water extraction is Central 5 (Hutton Sandstone) and is discussed in detail in the following section. Other units are not considered likely to be affected as a result of AGL's petroleum exploration activities within ATP1056P as they are segregated from the wells with casing and/or not in hydrogeological communication with the petroleum producing interval within this region. However, for comparison, the overlying Central 3 (Murta Formation, McKinlay Member, Namur Sandstone) and Central 4 (Westbourne Formation, Adori Sandstone, Birkhead Formation) are also included in the discussion following.

#### 5.1.1 Hutton Sandstone (Central 5 – production)

The Jurassic Hutton Sandstone contains significant GAB aquifers with yields of up to 50 L/s of good quality water (QDNRM, 2005). Within this region, however, its depth (around 1600 mbgl) prevents it from uses other than for petroleum exploration/production activities. There are no bores within the DNRM GWDB that identify the target aquifer as the Hutton Sandstone within ATP1056P.

Within the ATP1056P Hutton Sandstone, the groundwater flow is expected to be to the southwest to south-southwest, consistent with the flow of the major GAB units as described in the literature (Habermehl and Lau, 1997). There is insufficient water level data within the region to characterise Hutton Sandstone groundwater flow direction further. Recharge areas are on the eastern margins of the Eromanga Basin (QDNRM, 2005). Hydraulic conductivity for the Hutton Sandstone within the vicinity of this site is expected to be in the range of 0.35 – 0.01 m/d (Santos, 2013).

Within ATP1056P, two water samples have been collected from bores (Hercules North 1 and Pyxis 1 (refer to Figure 2 for location)) tapping the Hutton Sandstone aquifer. Details of these are presented in Appendix A – Water quality results. The groundwater is slightly alkaline (pH 7.89), slightly saline (~6,300  $\mu\text{S}/\text{cm}$ ), and is dominated by sodium-potassium-chloride-bicarbonate (Na-K-Cl- $\text{HCO}_3$ ) ions. (Note, the K-Cl may be residual drilling fluid contamination.) The chemistry of the Hercules North 1 sample is plotted in Figure 7.

It has long been recognised that within aquifers of the GAB, there are some areas where the naturally occurring fluoride content is significantly elevated (Evans, 1996). Most natural waters contain fluoride concentrations generally less than 1.0 mg/L (Hem, 1989, in Evans, 1996). The water sample from Hercules North 1 returned a fluoride concentration of 4.0 mg/L.

At AD-1, the Hutton Sandstone is 43 m thick and at AS-1 the Hutton Sandstone is 40m thick.

#### 5.1.2 Westbourne Formation, Adori Sandstone and Birkhead Formation (Central 4 – not producing)

The Westbourne Formation and Adori Sandstone are chronologically equivalent to the Namur Sandstone.

Regionally, the Jurassic Adori Sandstone of the Injune Creek Group contains reasonable GAB aquifers with generally good yields and good quality water (averaging 1000  $\mu\text{S}/\text{cm}$ ) (QDNRM, 2005). Recharge to the Adori Sandstone occurs along the eastern margin of the



Eromanga Basin (QDNRM, 2005). Regionally the Westbourne Formation and the Birkhead Formation are considered confining beds, but locally can be considered water bearing zones.

Within ATP1056P, there is one bore that is identified as tapping the Westbourne Formation between 1425 and 1692 mbgl (RN 23578) (but it is noted that the bore is open from 231 – 1844 mbgl, and so this would also include the Adori and Hutton Sandstones as well as any contribution from shallower aquifers). No bores are specifically identified to tap either the Adori Sandstone of the Birkhead Formation. RN 23578 is reported to have yielded slightly saline water averaging around 3515  $\mu\text{S}/\text{cm}$ , with an average pH of 8.85. Given the construction of the bore, however, it is not possible to assign this necessarily to the Westbourne Formation and given the depth of water sample used for the analysis (1387 m), it actually appears this can be allocated to the Namur Sandstone (especially given the chemical signature is very similar to that of the Namur Sandstone (Figure 7).

At AD-1, the thicknesses of these units are: 20 m (Birkhead Formation), 7 m (Adori Sandstone), and 113 m (Westbourne Formation). At AS-1, the thicknesses of these units are: 20 m (Birkhead Formation), 8 m (Adori Sandstone), and 106 m (Westbourne Formation).

### **5.1.3 Murta Formation, McKinlay Member and Namur Sandstone (Central 3 – not producing)**

The Jurassic – Cretaceous Namur Sandstone and the McKinlay Member are basin margin equivalents, and laterally continuous with the Hooray Sandstone, and are generally the shallowest major artesian aquifer intercepted by water bores within the GAB of Queensland (QDNRM, 2005). These formations are restricted to subsurface and are recharged from connecting Hooray Sandstone to the northeast and potentially also the Algebuckina Sandstone to the west (QDNRM, 2005).

Within ATP1056P's Murta Formation/McKinlay Member/Namur Sandstone, the groundwater flow is expected to be to the southwest to south-southwest, consistent with the flow of the major GAB units as described in the literature (e.g. Evans, 1996). There is insufficient water level data within the region to characterise groundwater flow direction within these units further. Hydraulic conductivity for these units within the vicinity of this site is expected to be somewhat similar to that described previously for the Hutton Sandstone (which is also similar to the Hooray Sandstone) (Santos, 2013).

Within ATP1056P one water sample has been collected from the Bradford 1 exploration bore from the Namur Sandstone, and one water sample has also been mentioned in the DNRM GWDB from bore RN 23466 (Dio Ella 1), which has been inferred (based on data in the DNRM GWDB) to also tap the Namur Sandstone. Details of these are presented in Appendix A – Water quality results. The groundwater is slightly alkaline (pH 8.2), slightly saline (2250  $\mu\text{S}/\text{cm}$  – 4800 mg/L), and is dominated by sodium-bicarbonate ( $\text{Na-HCO}_3$ ) ions. The chemistry of the Dio Ella 1 sample is plotted in Figure 7.

Similarly, to the sample obtained from the Hutton Sandstone, elevated levels of fluoride were observed in the Namur Sandstone (Dio Ella 1) at a level of 5.6 mg/L.

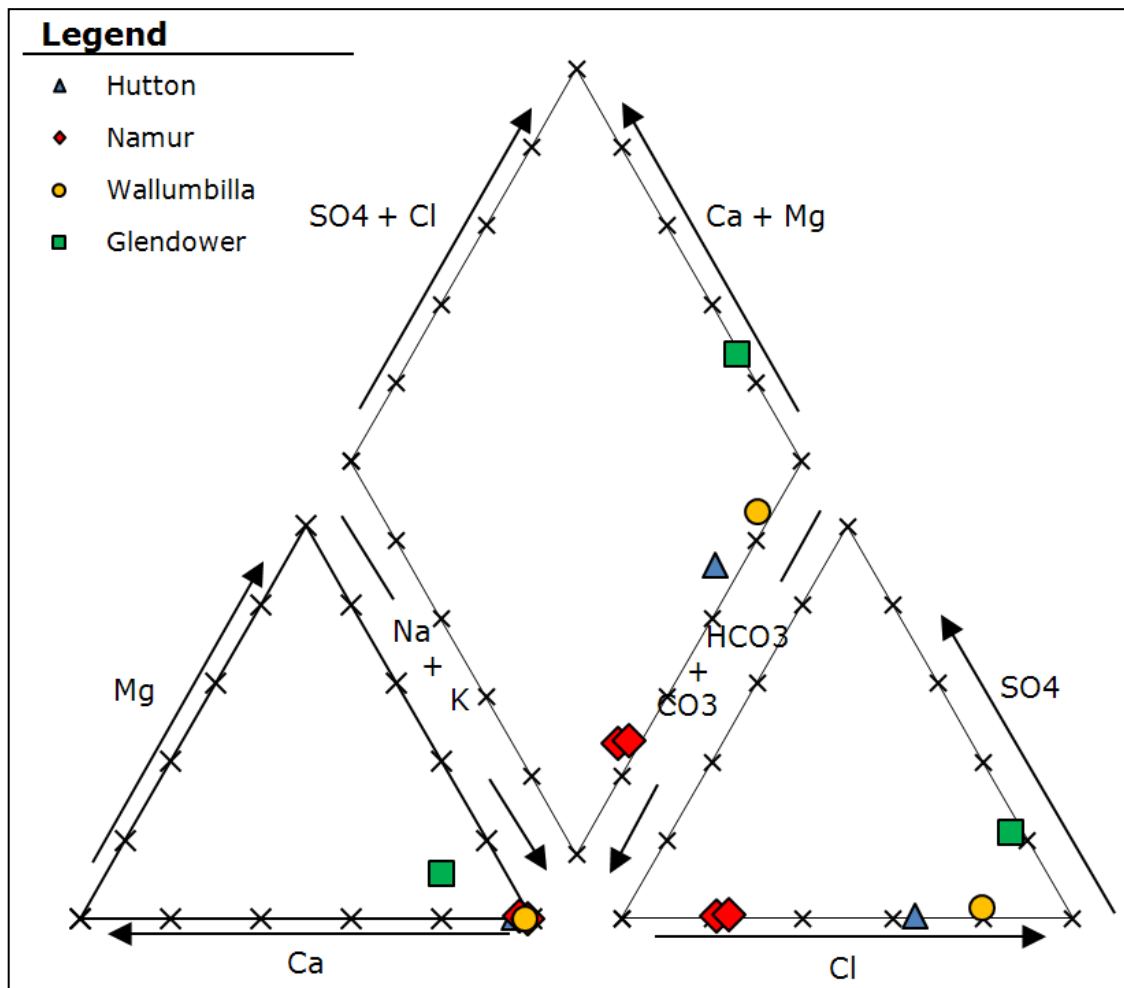
At AD-1, the Namur Sandstone is 95 m thick and the Murta Formation is 76 m thick. At AS-1, the Namur Sandstone is 103 m thick and the Murta Formation is 77 m thick. The McKinlay Member is not logged at either AD-1 or AS-1.

## **5.2 Underground water flow and aquifer interactions**

There is a lack of local data that can be used to interpret groundwater flow and aquifer interactions. However, groundwater flow within the confined GAB aquifers in the area is expected to be to the southwest to south-southwest, consistent with the flow of the major

GAB units as described in the literature (e.g. Evans, 1996). Within the GAB, recharge is dominantly by infiltration of rainfall directly into the outcropping sandstone aquifers along the eastern margins of the basin (QDNRM, 2005). Recharge within ATP1056P is expected to be mainly contributed by sub-surface flow from the laterally equivalent units to the northeast. Flow is expected to be dominantly lateral, rather than vertical, within the aquifers due to the presence of confining layers. The Hutton Sandstone is confined by the Birkhead Formation, which in the production testing area is predominantly arenaceous siltstone. This confining layer has sealed the hydrocarbons within the Hutton Sandstone reservoir at the Andromedae discoveries, and also, therefore, prevents groundwater flow between the Hutton Sandstone and shallower aquifers of the region.

The chemical composition of the water within each aquifer appears to be broadly distinct, (based on the limited available data) further suggesting relative isolation and limited connectivity between each aquifer (Figure 7).



**Figure 7: Piper plot of available water chemistry data from bores within ATP1056P (data in Appendix A – Water quality results)**

The affected stratum (Hutton Sandstone) lies within a depth range of 1496-1539 mSS (AD-1). All shallower aquifers/reservoirs are behind casing and have no access to the surface or other aquifers (that are not naturally connected) via the production wells. The oil/water contact lies at approximately 1500 mSS at AS-1 and 1504 mSS at AD-1.



What is known about the Hutton Sandstone within ATP1056P so far has been acquired through the drilling of exploration bores within the permit. It is not possible to determine if there is communication between the Hutton Sandstone and shallower zones. Well data in the field suggests that reservoir seals provide separation between known oil reservoirs and other aquifers. Based on drilling and production data it's not possible to quantify the degree of communication between the reservoirs.

Data obtained by AGL regarding the Hutton Sandstone is limited to exploration bores. This data does not permit an exhaustive review of communication between reservoirs. Field data suggests that reservoir seals provide adequate separation between the oil reservoir and shallower aquifers.

### **5.3 Underground Water Level Trend Analysis**

There is a lack of local data that can be used to interpret groundwater level trends over time within the region. However, it is noted, in recent times there have been significant pressure increases in regional aquifers (used for water supply) within the GAB because of the cap and pipe programs (QDNRM, 2005). Standing water levels recorded within the DNRM GWDB are shown in Appendix B – Registered bores within ATP1056P; no bore has had more than one measurement of data and, therefore, no trends can be inferred.

There is not enough data for the target reservoir/aquifer (Hutton Sandstone) within ATP1056P to analyse water level trends. However, the current oil/water contact, and therefore the water level, is estimated to be approximately 1500 mSS at AS-1 and 1504 mSS at AD-1. The reservoir/aquifer has shown no sign of pressure depletion due to previous production testing. During production testing, the oil/water contact will naturally rise as oil is produced from the reservoir, and because of the regional extent and water pressure within the Hutton Sandstone and the relatively small volume of water expected to be removed in the current program (currently estimated at ~10.5 ML), no water level / pressure declines are expected outside of the immediate production testing area. On a regional scale, the impact of fluid production on the Hutton Sandstone as a result of production testing at AD-1 and AS-1 is expected to be negligible.



## 6 Part C: Predicted water level declines for the affected aquifers

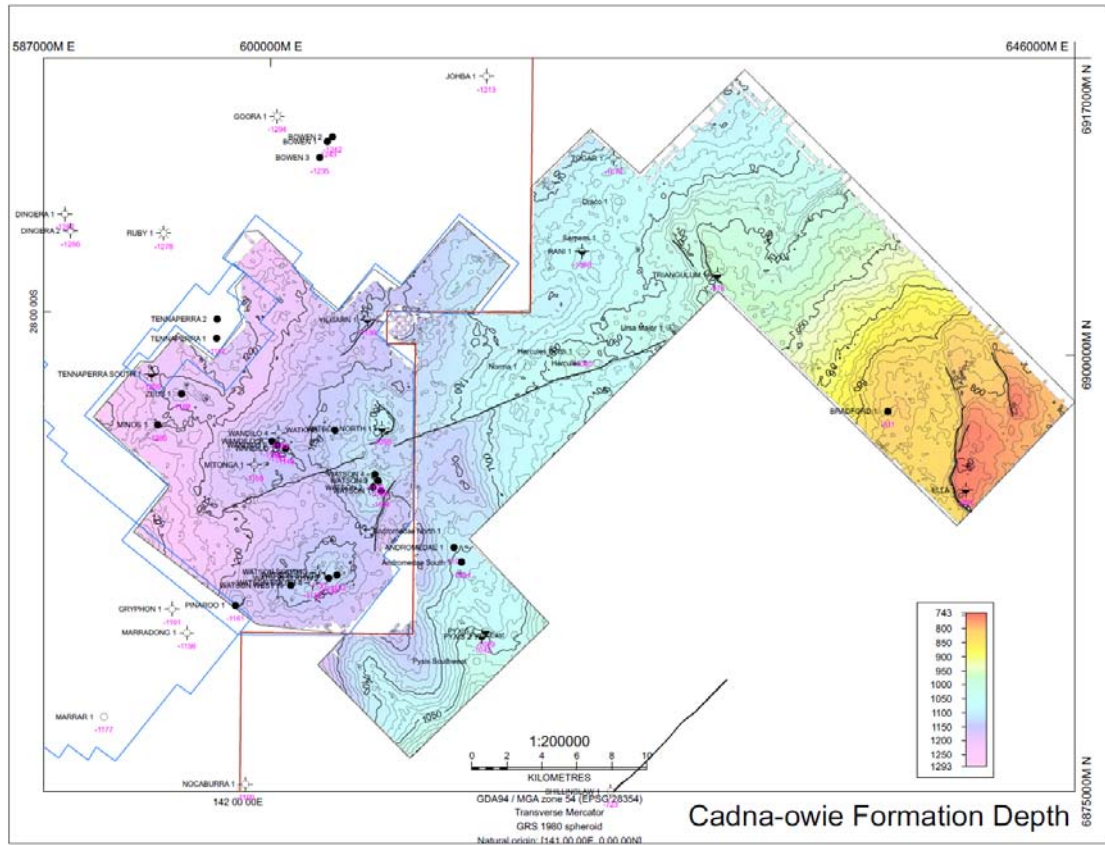
### 6.1 Maps of the affected area

The Andromedae discoveries have an area of approximately 1.1 km<sup>2</sup> within ATP1056P. The structure of the discoveries has been mapped from the interpretation of 3D seismic data and is shown in a regional context in Figure 8.

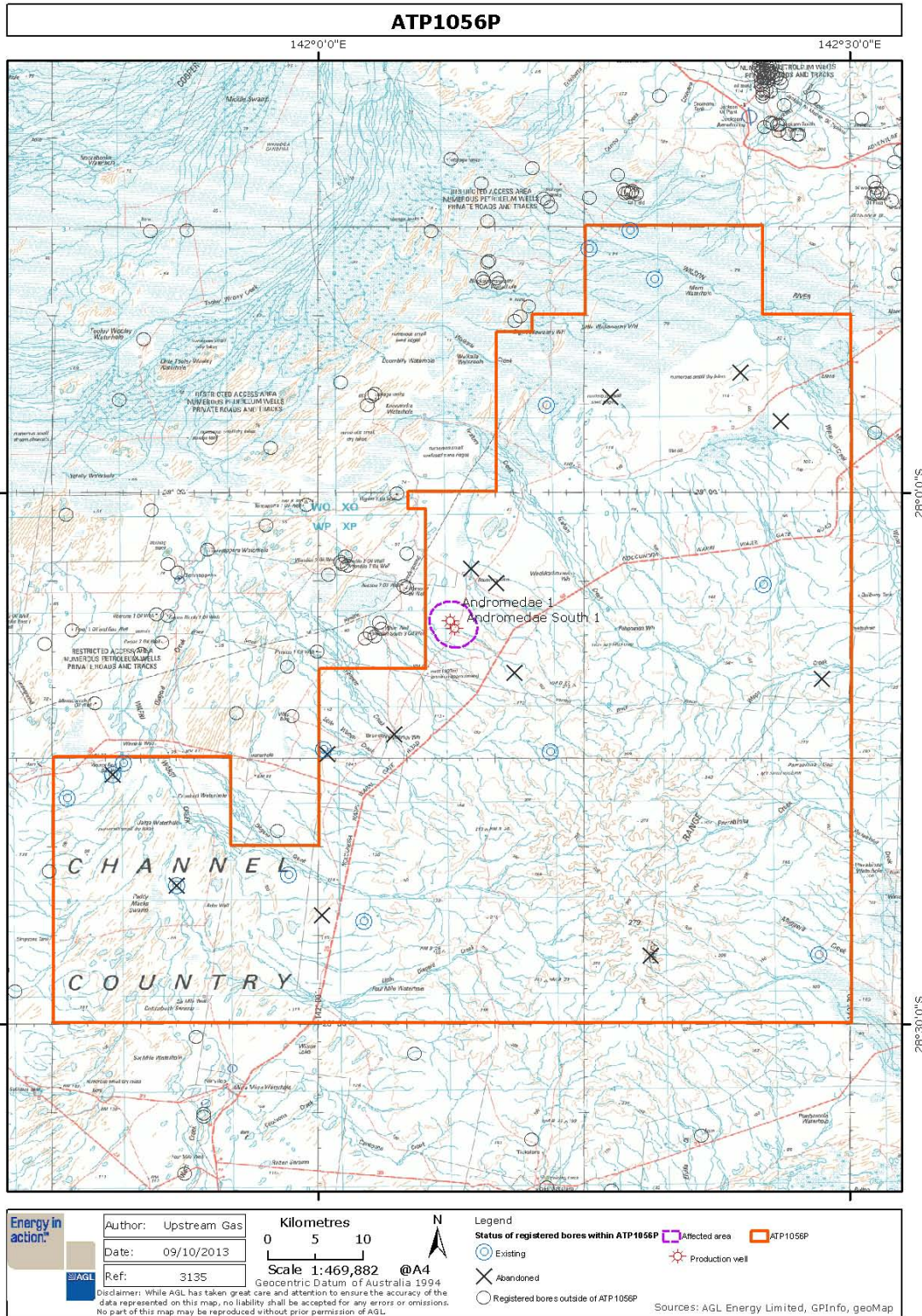
The target reservoir of the discoveries is the Hutton Sandstone. No decline in water production rate has been observed and there is no suspected decline in reservoir pressure during production testing. Due to the nature of the geology, the fact that the exploration activities are targeting a conventional oil deposit (i.e. oil is held in place by an impermeable seal) and the integrity of the well bores, it is interpreted that no aquifers other than the target Hutton Sandstone will be/have been affected by the exploration activities. The expected impact on the Hutton Sandstone is interpreted to be localised, given the small scale of the exploration activities to date and proposed.

Given the lack of available data and the small scale of the previous and current production testing, no Immediately Affected Area or Long Term Affected Area can be accurately defined for the Hutton Sandstone. Based on the logic discussed in Section 6.2, for the purpose of meeting s376b)(iv) and (v) of the Water Act, a conservative “potentially affected area” has been defined as a 2 km buffer within the Hutton Sandstone around both the wells undergoing production testing (AD-1 and AS-1). This area is shown in Figure 9. It should be emphasised that this area has been mapped highly conservatively, and it would be unlikely that any impact could actually be detected within much of the area (if there were receptors in place), let alone an impact above the drawdown trigger threshold as defined by the Water Act (a drop of 5 m of head in a consolidated aquifer as observed at a bore).

It should be noted, within this potentially affected area, there are no receptors (water bores, groundwater dependant ecosystems/springs, or exploration holes).



**Figure 8: Depth structure map of the Cadna-Owie Formation within the interpreted 3D area.**



**Figure 9: Map showing potentially affected area**





## 6.2 Methods and techniques used

The map of the potentially affected area within the Hutton Sandstone aquifer (Figure 9) was produced based on the following information.

Previous production testing at AD-1 was conducted in 2012 and 2013 (one period in May 2012 and a 6 month test from October 2012 – March 2013). During this production testing, oil and water was removed from the Hutton Sandstone via AD-1 only. A total of 0.87 ML of water was removed during these times. It appears there was no depletion in reservoir pressure at the site of the nearby AS-1 (located 1km to the southeast) which indicates the Hutton Sandstone aquifer that was affected by the AD-1 production test occurred within a 1 km radius surrounding AD-1 or less.

The current production test (commenced late October 2013) is currently licensed to be conducted for a 12 month period; during this test both AD-1 and AS-1 will be tested.

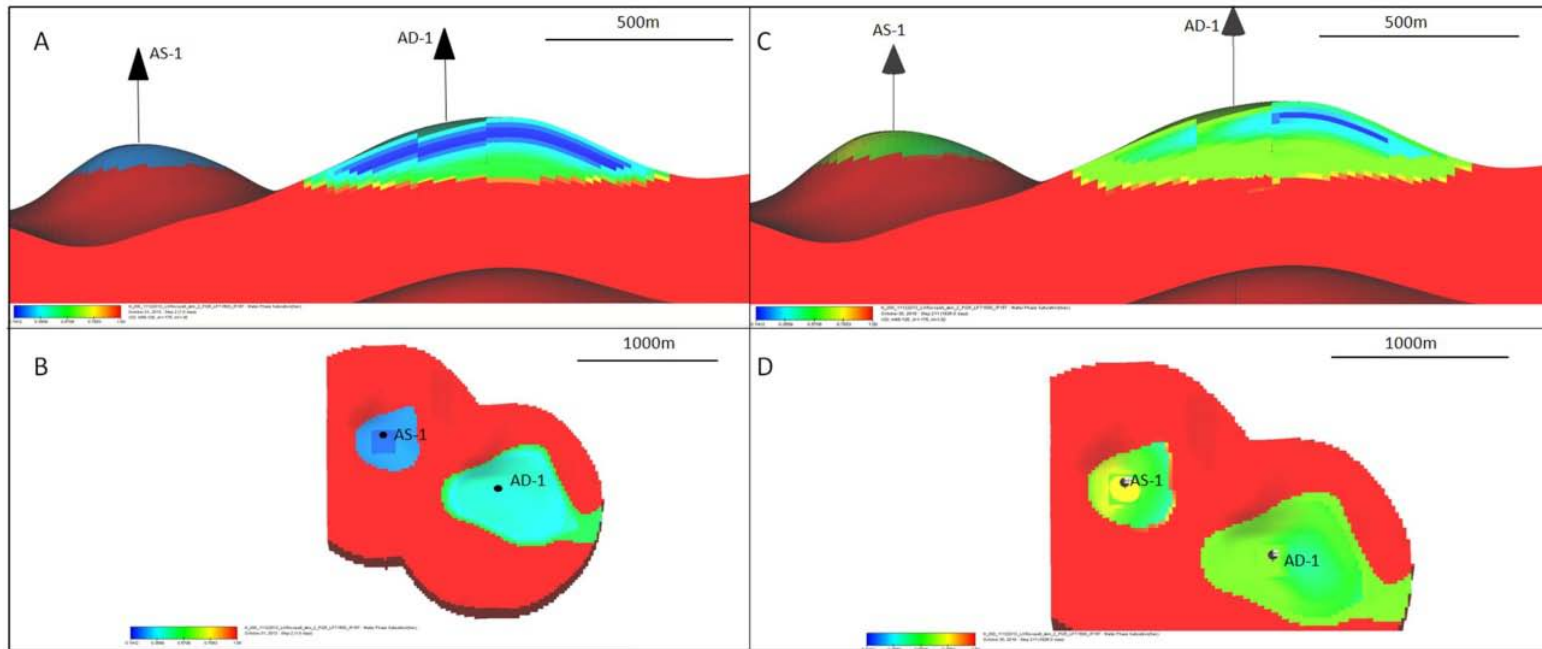
Based on this previous information and the assumption that the reservoir around AS-1 reacts in a similar way to that around the nearby AD-1 well, it is expected that the combined effect of production testing at both wells for a period of 12 months would influence an area within the Hutton Sandstone likely to be less than 2 kilometres in radius around the two wells.

To support this assertion, a Blackoil reservoir model was built using in-house Tempest (Roxar) to predict the potential impact on water pressure within the Hutton Sandstone reservoir as a result of AGL's activities for the current and planned extraction program using several scenarios. The maximum impact was predicted using a forecast of 5 years and irreducible water saturation of 0.15 (which was based on correlations with historical data). The model was calibrated against historical data based on the production test results. The model was forecast assuming production of 1500 barrels of liquid (oil and water) from both wells with installation of artificial lift.

A snapshot of the results of the model is shown in Figure 10. This has been presented in terms of water phase saturation; where a saturation level of 1.00 indicates the liquid present within the reservoir is 100% water, a saturation level less than that indicates the presence of oil. For the purpose of this report, these images can be interpreted as the areas coloured red are areas that have not been impacted upon as a result of the extraction activities occurring at AD-1 and AS-1.

The extent of the maximum impact within the Hutton Sandstone has been modelled as approximately 1000 meters from the AD-1 well and approximately 500 meters from the AS-1 well, with no impact predicted outside of these areas. Given the limitations of the input, the resultant models are interpreted as being a coarse representation of the real situation. As such, an arbitrary 2km boundary was defined around both the wells in order to accommodate an area greater than the predicted area of potential impact defined by the model. We believe that the actual drainage radius of each well would be smaller than this predicted area.

As mentioned previously, it should be emphasised that this area has been mapped highly conservatively, and it would be unlikely that any impact could actually be detected within much of the area (if there were receptors in place), let alone an impact above the drawdown trigger threshold as defined by the Water Act (being a decline in the water level by more than 5 m). This area represents the zone around the wells that could potentially observe a water pressure decline, but it is likely the decline would be well under the drawdown trigger threshold for much of the defined area. Outside the defined affected area there is expected to be zero change in water level within the Hutton Sandstone as a result of the production testing activities.



**Figure 10: Snapshot of output of Hutton Sandstone reservoir model showing water phase saturation at time zero (A, B) and a forecast of 5 years (C, D). The red colour indicates water saturation of 1.00, i.e. complete water saturation. For the purpose of this report, the red areas indicate the area where there is no change of water pressure predicted as a result of extracting liquid (oil and water) from the two wells.**

### 6.3 Water bores within the potentially affected area

There are no groundwater bores within the defined potentially affected area. The closest (assumed) water supply bore is located 4.4 km to the northwest of the potentially affected area boundary.

Within ATP1056P six registered groundwater bores are located greater than 15 km from the AD-1 and AS-1 wells and are summarised in Table 4. There is only one water bore within 15 km and it is located in nearby PL35. None of the bores are screened across the production unit (Hutton Sandstone) of the Andromedae discoveries.

On the basis of the distance of these water bores from the Andromedae discoveries and the fact that, to AGL's knowledge, none of these bores access the Hutton Sandstone (Central 5 Groundwater Management Unit of the Central GMA), there is no means of using these bores or the wells to infer any sort of aquifer interactions or impact on effective pressure.

Outside of ATP1056P, the closest (inferred) existing water bore is RN 6304 (Whim Well) and taps the Tertiary Glendower Formation. RN 6304 is 4.4 km northwest of the potentially affected area boundary, within the Watson oilfield. The next closest inferred water bore outside of ATP1056P is greater than 15 km from the potentially affected area boundary, and again is inferred to tap the Tertiary Glendower Formation (RN 6303, Whip Bore). There are no other bores outside of ATP1056P within 20 km of the production testing activities.

**Table 4: Private Water Bores located within 50km of Andromedae 1 and Andromedae South 1, as listed in DNRM's GWDB**

Local Bore Name	Registered Number	Tenure/Block/Sub Block	Total Depth (mbgl)	Main Aquifer	Distance from potentially affected area (km)
Dio Nocaburra 1	23599	ATP1056	1718	Namur Sandstone	15.5
Dio Ella 1	23466	ATP1056	1278	Namur Sandstone?	26.9
Winninia No 1 Bore	50223	ATP1056	27?	Glendower Formation	33
Winninia No 2 Bore	50352	ATP1056	32	Glendower Formation	33
Bobs Bore	15433	ATP1056	37	Glendower Formation	35
Muggera Bore	50673	ATP1056	1070	Wallumbilla Formation	45.9
Whim Well	6304	PL35	31	Glendower Formation	4.4
Whip Bore	6303	ATP752P W	29	Glendower Formation	15.7



## 6.4 Review of maps produced

Going forward, AGL will conduct annual reviews of the maps contained within this UWIR if any new data is available from the production testing activities. These reviews will note any significant increases or decreases in volumes and comment as to why they occurred (e.g. increase in number of production testing wells) and what the expected effect on the aquifer will be. These reviews will be incorporated and elaborated on in the relevant section in future UWIR's.

In line with 376(e) of the Water Act, AGL will commit to conducting an annual review of the accuracy of each map and provide a summary of the outcome of each review to the Chief Executive of the relevant department (DEHP at the time of writing). This review will occur annually during the life of the existing production testing program. The first annual review is scheduled to occur 1 year after approval of this UWIR.



## 7 Part D: Water Monitoring Strategy

### 7.1 Rationale

Due to the massive regional extent of these sandstone aquifers there is excellent pressure support during the entire period that production testing has and will occur.

The absence of water bores in the defined potentially affected area of the Andromedae discoveries means that there is no feasible way to assess changes in water levels. In addition, there are no groundwater receptors (water supply bores or groundwater dependant ecosystems) within the defined potentially affected area.

As a potentially affected area (*in lieu* of the definition of an Immediately Affected Area and/or a Long Term Affected Area) has been identified for the Hutton Sandstone, a WMS is required specifically for monitoring the water levels and volumes taken from this hydrogeological unit. In order to meet section 376(e) of the *Water Act 2000 (Qld)* requirement of a WMS and in order to continue to refine the current understanding of the groundwater system and to monitor any changes in groundwater within the Hutton Sandstone aquifer as a result of the production testing activities, the groundwater monitoring program as detailed in the following sections and listed in Table 5 will be undertaken for the duration of the upcoming production testing period.

As such, the rationale underpinning the WMS is to monitor and assess changes in water production and water chemistry of the produced water from the Hutton Sandstone aquifer as a result production testing activities. In addition, employment of the WMS will further improve the understanding on the hydrogeological system and potential impacts on the aquifer.

Given the low volume of water production as well as the lack of groundwater receptors within the defined potentially affected area of the Hutton Sandstone, the water monitoring strategy (WMS) proposed is simple.

### 7.2 Monitoring strategy

AGL's monitoring strategy is based on two primary parameters. These are formation water production history and water quality. By monitoring and maintaining records of these parameters, AGL has developed a monitoring strategy that meets the requirements of Section 376(f) of the Water Act. The following section provides more specific details of how these parameters are collected.

### 7.3 Timetable and methodology

The groundwater monitoring program, as shown in Table 5, will be employed during the upcoming production testing in late 2013 in order to satisfy the requirement of a water management strategy for the affected area as defined for the Hutton Sandstone (section 376(e) of the *Water Act 2000 (Qld)*).



**Table 5: Water monitoring program during production testing – site list and schedule**

Monitoring Site	Tenure	Location	Water production monitoring (in terms of cumulative flow) (in KL/day)	Water quality (refer Table 6)
AD-1	ATP1056P	-28.12021947, 142.12475914	Daily	-
AS-1	ATP1056P	-28°07'39.8337", 142°07'45.1317"	Daily	-
Storage dam	ATP1056P	-28.12073° 142.12506	-	Every 2 months (starting first month of production)

#### 7.3.1.1 Produced water volume monitoring

Previously, the volume of water produced from AD-1 was measured at the storage dam periodically. Water flow meters are now installed at both wells for the current production testing program. The meters will allow for daily collection of cumulative flow data for each well.

#### 7.3.1.2 Water quality monitoring

Surface water samples will be collected using standard industry practices, including use of appropriately preserved sample containers based on sample analytes. Field measurements (Electrical Conductivity (EC), pH, Eh, temperature and Total Dissolved Solids (TDS)) will be collected in accordance with standard industry practices and recorded. "

Water quality samples are sent to a NATA accredited laboratory in Brisbane in appropriate sample bottles within the specified holding time. The analytical suite shown in Table 6 has been adopted for water quality analysis.



**Table 6: Water quality laboratory analytical suite**

Category	Parameters	
Check on Field Parameters	Electrical conductivity and TDS	
Major ions (in mg/L)	<i>Cations</i> calcium magnesium sodium potassium	<i>Anions</i> chloride hydroxide carbonate bicarbonate sulphate fluoride
Dissolved metals and minor / trace elements (in mg/L)	aluminium arsenic barium beryllium cadmium chromium cobalt copper	iron lead manganese mercury nickel vanadium zinc
Hydrocarbons (in µg/L)	TPHs PAHs	BTEX

## 7.4 Reporting program

Given the small scale of the production testing and the short length of the programs (current program licensed to be 12 months duration), a frequent reporting program is not warranted. AGL proposes to maintain the monitoring data in house, which could be provided upon request to the Office of Groundwater Impact Assessment and/or Department of Environment and Heritage Protection. Data collected from previous production testing is presented within this Underground Water Impact Report.

In view of the fact this is currently planned to be a limited production testing program, and there will be limited data available from the wells in terms of recovery water levels, there will be very little new information to warrant an annual review. However, in line with 376(e) of the *Water Act 2000 (Qld)* AGL will commit to conducting an annual review of the accuracy of each map and provide a summary of the outcome of each review to the Chief Executive of the relevant department (DEHP at the time of writing). This review will occur annually during the life of the existing production testing program, although it is noted that this upcoming program is only currently licensed to occur for a 12 month period. The first annual review is scheduled to occur 1 year after approval of this UWIR. Otherwise, as required by the *Water Act 2000 (Qld)*, a new UWIR will be compiled every 3 years and submitted to DEHP, if production testing continues.

In addition, required under section 378 (1)(d) of the *Water Act 2000 (Qld)*, AGL will submit a report relating to the implementation of the water monitoring strategy to the Office of Groundwater Impact Assessment yearly for ATP1056P.



## 8 Part E: Spring Impact Management Strategy

### 8.1 Spring inventory

A review has been undertaken of the Queensland Wetland Data (version 3.0), prepared by the Queensland Department of Science, Information Technology, Innovation and the Arts in 2012. The dataset provides mapping of the 2009 extent and type of wetlands at 1:100,000 scale across Queensland. There are no springs identified within ATP1056P (Figure 11). The closest mapped spring in Queensland is approximately 200 km to the east of the production testing activities and is not within ATP1056P.

As no springs exist within ATP1056P or within the defined potentially affected area, a spring management strategy is not required for this UWIR.

### 8.2 Connectivity between the spring and the aquifer

Not applicable.

### 8.3 Management of Impacts

Not applicable.

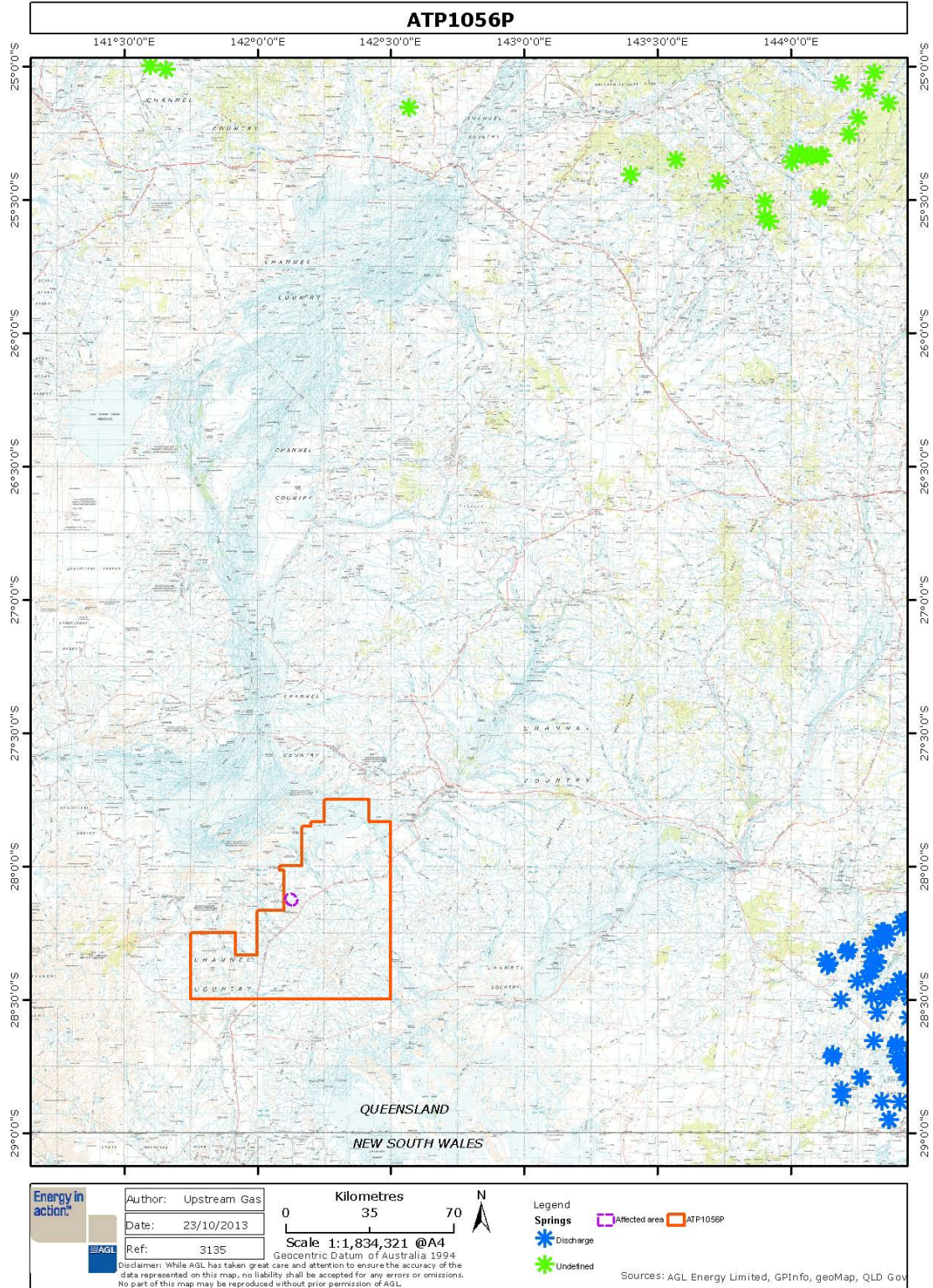
### 8.4 Timetable for Strategy

Not applicable.

### 8.5 Reporting Program

Not applicable.





**Figure 11: Location of springs within the vicinity of ATP1056P and defined potentially affected area.**



## 9 Part F: For a CMA assign responsibilities 8 to petroleum tenure holders

Not applicable as ATP1056P is not part of a CMA as per s376(i).



## 10 References

### 10.1 Documents

Evans, P.A., 1996. Fluoride anomalies in aquifers of the Queensland section of the Great Artesian Basin and their significance. In: Mesozoic Geology of the Eastern Australia Plate Conference, Brisbane, 23-26 September, 1996, Geological Society of Australia Extended Abstracts No. 43, p 172-178.

Golder Associates, 2013. Underground water impact report for Santos Cooper Basin oil and gas fields, SW QLD, Report prepared for Santos Ltd, Report number: 117636010-3000-001-Rev3. Accessed online October 2013: <http://www.ehp.qld.gov.au/management/coal-seam-gas/pdf/santos-uwir.pdf>

Habermehl M.A., and Lau J.E., 1997, Hydrogeology of the Great Artesian Basin (Map at scale 1:2500000), Australian Geological Survey Organisation, Canberra

Moussavi-Harami, R., 1996. Burial history. In: Alexander, E.M. and Hibburt, J.E., (Eds), 1996. The petroleum history of South Australia, Vol 2: Eromanga Basin, South Australia, Department of Mines and Energy, Report Book, 96/20, p111-124.

Queensland Department of Natural Resources and Mine (QDRNM), 2005. Hydrogeological framework report for the Great Artesian Basin Water Resource Plan Area, Version 1.0. Accessed online October 2013: <http://www.nrm.qld.gov.au/wrp/pdf/gab/gab-hydrogeological-framework-report.pdf>

### 10.2 External datasets

**Queensland Digital Groundwater Bore Data** (DNRM bore database), 2012, Licence for version 1.0 (May 2012), Department of Natural Resources and Mines, State of Queensland. Available by request <http://www.dnrm.qld.gov.au/>

**Queensland Wetland Data**, Version 3.0, obtained via download from the Queensland Government Information Service <http://dds.information.qld.gov.au/DDS/Search.aspx>, accessed 23<sup>rd</sup> October 2013

**Geoscience Australia**, 2009. 1:250 000 geoMAP Topographic map, zone 55. *Used as base map in figures throughout report (legend not shown)*. Available at <http://www.ga.gov.au/topographic-mapping/digital-topographic-maps.html>



## Appendix A – Water quality results

Sample location			Hercules North 1*	Pyxis 1*	Bradford 1*	Dio Ella 1 (23466)**	Dio Wompi 1 (23578)**	Muggera Bore (50673)**	Bob's Well (7436)**
Target aquifer			Hutton	Hutton	Namur	Namur	Namur?	Wallumbilla	Glendower
Sample date			26/05/2013	6/12/2011	16/11/2011	05/06/1988	10/7/1999	4/3/2008	24/8/1962
Analyte grouping/ Analyte	Units	Limit of reading							
pH Value	pH Unit	0.01	7.89			8.2	8.6	8.2	
Sodium Adsorption Ratio	-	0.01	31.5			38	76	49	19.5
Electrical Conductivity @ 25°C	µS/cm	1	6300			2250	3150	1960	
Salinity (NaCl equivalent)	mg/L	(Unknown)		3400	4800				
Total Dissolved Solids @180°C	mg/L	10	4570			1440	2027	1060	5406 (inferred)
Total Dissolved Solids (Calc.)	mg/L	1	4100						
Total Hardness as CaCO3	mg/L	1	128			41	20	13	1141
Resistivity at 25°C	ohm cm	1	159						
Hydroxide Alkalinity as CaCO3	mg/L	1	<1						
Carbonate Alkalinity as CaCO3	mg/L	1	<1			14	51	2	0
Bicarbonate Alkalinity as CaCO3	mg/L	1	1110			1200	1567	189	150
Total Alkalinity as CaCO3	mg/L	1	1110			1000	1370	158	123
Sulfate as SO4 - Turbidimetric	mg/L	1	27			13	25	32	1149
Chloride	mg/L	1	1200			185	291	474	2212
Calcium	mg/L	1	48			12	6	5	252
Magnesium	mg/L	1	2			2.8	1	0.1	124



Sample location			Hercules North 1*	Pyxis 1*	Bradford 1*	Dio Ella 1 (23466)**	Dio Wompi 1 (23578)**	Muggera Bore (50673)**	Bob's Well (7436)**
Sodium	mg/L	1	819			560	773	407	1517
Potassium	mg/L	1	930			12	27	2	-
Fluoride	mg/L	0.1	4			5.6	3	7	1
Total Anions	meq/L	0.01	56.6						
Total Cations	meq/L	0.01	62						
Ionic Balance	%	0.01	4.56						
Iron	mg/L	(Unknown)				0.21	0	0.01	
Manganese	mg/L	(Unknown)				0.03	0	0.01	

\* - data collected for AGL

\*\* - data obtained from DNRM GWDB



## Appendix B – Registered bores within ATP1056P

**Table 7: Registered bores within ATP1056P from DNRM’s 2012 groundwater database (GWDB)**

Registered Number (RN)	Drilled date	Easting	Northing	Original name of facility	Facility status	Facility role*	Facility type	Target aquifer	Aquifer age*	Water level mbgl (date)
6975		637611	6914536	EAGLE HAWK	Abandoned	Undefined within GWDB – interpreted to be water supply	Sub-artesian Facility			
6976		641243	6909354	WET CAMP BORE	Abandoned	Undefined within GWDB – interpreted to be water supply	Sub-artesian Facility			
6981		625526	6912113	PADDY PADDY WELL	Abandoned	Undefined within GWDB– interpreted to be water supply	Sub-artesian Facility			
6984		605237	6877135	BRANSBY HOMESTEAD	Abandoned	Undefined within GWDB– interpreted to be water supply	Sub-artesian Facility			
6985		616352	6883471	HUMES CREEK BORE	Abandoned	Undefined within GWDB– interpreted to be water supply	Sub-artesian Facility			
6986		644716	6882522	DITCHERIE WELL	Abandoned	Undefined within GWDB– interpreted to be water supply	Sub-artesian Facility			
6988		614818	6892786	SOUTH BOUNDARY BORE	Abandoned	Undefined within GWDB– interpreted to be water supply	Sub-artesian Facility			
7429		579237	6873142	WININNA	Abandoned	Undefined within GWDB - – interpreted to be water supply	Sub-artesian Facility	Winton Formation	Cretaceous	



Registered Number (RN)	Drilled date	Easting	Northing	Original name of facility	Facility status	Facility role <sup>+</sup>	Facility type	Target aquifer	Aquifer age*	Water level mbgl (date)
7436		585052	6861546	BOBS WELL	Abandoned	Undefined within GWDB – interpreted to be water supply	Sub-artesian Facility	Glendower Formation (inferred)	Tertiary	
13297	8/01/1957	598403	6858315	NARYILCO NO 5	Abandoned	Undefined within GWDB - interpreted to be water supply	Sub-artesian Facility	Glendower Formation	Tertiary	-39.6 (8/1/1957)
13749	30/08/1958	612518	6894307	NOCKATUNGA NO. 1	Abandoned	Undefined within GWDB - interpreted to be water supply	Sub-artesian Facility	Winton Formation	Cretaceous	-24.4 (30/8/1958)
13799	22/10/1958	599041	6875107	NOCKATUNGA NO. 2	Abandoned	Undefined within GWDB - interpreted to be water supply	Sub-artesian Facility	Glendower Formation	Tertiary	-32 (22/10/1958)
15433	1/01/1962	585052	6861546	BOBS BORE	Existing	Undefined within GWDB – interpreted to be water supply	Sub-artesian Facility	Glendower Formation	Tertiary	
23409	30/04/1985	629739	6924365	DIO MILFORD 1	Existing	Undefined within GWDB – interpreted to be water supply, previously petroleum exploration	Artesian Bore, Condition Unknown			
23466	15/11/1986	639477	6892343	DIO ELLA 1	Existing	Undefined within GWDB – interpreted to be water supply, previously petroleum exploration	Artesian Bore, Controlled Flow	Namur Sandstone (inferred)	Jurassic	
23508	27/01/1986	628618	6853828	DIO WOMPAH 1	Abandoned	Undefined within GWDB – interpreted to be petroleum exploration	Artesian Bore, Ceased to Flow			



Registered Number (RN)	Drilled date	Easting	Northing	Original name of facility	Facility status	Facility role <sup>+</sup>	Facility type	Target aquifer	Aquifer age*	Water level mbgl (date)
23578	20/02/1988	575021	6870671	DIO WOMPI 1	Existing	Undefined within GWDB – interpreted to be Petroleum Exploration	Artesian Bore, Controlled Flow	Westbourne Formation (inferred Namur Sandstone)	Jurassic	
23583	14/04/1988	602266	6857689	DIO ATOLL 1	Existing	Undefined within GWDB – interpreted to be water supply, previously petroleum exploration	Artesian Bore, Condition Unknown			
23599	1/08/1988	598660	6875570	DIO NOCABURRA 1	Existing	Undefined within GWDB – interpreted to be water supply, previously petroleum exploration	Artesian Bore, Condition Unknown			
23780	1/07/1988	623703	6927602	DIO BARDOC 1	Existing	Undefined within GWDB – interpreted to be water supply, previously petroleum exploration	Artesian Bore, Condition Unknown			
23977	29/05/1991	627524	6929435	DIO TURA 1	Existing	Petroleum Exploration	Artesian Bore, Condition Unknown			
50223	1/01/1979	579237	6873142	WINNINIA NO 1 BORE	Existing	Undefined within GWDB – interpreted to be water supply	Sub-artesian Facility			
50352	1/08/1980	579237	6873142	WINNINIA NO 2 BORE	Existing	Undefined within GWDB – interpreted to be water supply	Sub-artesian Facility			
50673	3/04/1989	644123	6853697	MUGGERA BORE	Existing	Undefined within GWDB – interpreted to be water supply	Artesian Bore, Controlled Flow	Wallumbilla Formation	Cretaceous	14.18 (3/4/1989)





Registered Number (RN)	Drilled date	Easting	Northing	Original name of facility	Facility status	Facility role <sup>+</sup>	Facility type	Target aquifer	Aquifer age <sup>*</sup>	Water level mbgl (date)
100106	20/08/1993	619596	6911265	SSL TOGAR 1	Existing	Petroleum Exploration	Artesian Bore, Condition Unknown			
100195	4/06/1995	595368	6862578	SSL HOVELL 1	Existing	Petroleum Exploration	Artesian Bore, Condition Unknown			
100264	25/05/1995	619590	6875162	SSL SHILLINGLAW 1	Existing	Petroleum Exploration	Artesian Bore, Condition Unknown			
100293	5/07/1993	580202	6874293	SSL WOMPI EAST 1	Existing	Petroleum Exploration	Artesian Bore, Condition Unknown			

Key - \* information not contained within GWDB; <sup>+</sup> - assignment of "facility role" within GWDB is limited. AGL has provided a best estimate interpretation of the facility role of each works where undefined within the GWDB. This information should be used with caution as it has not been ground truthed.