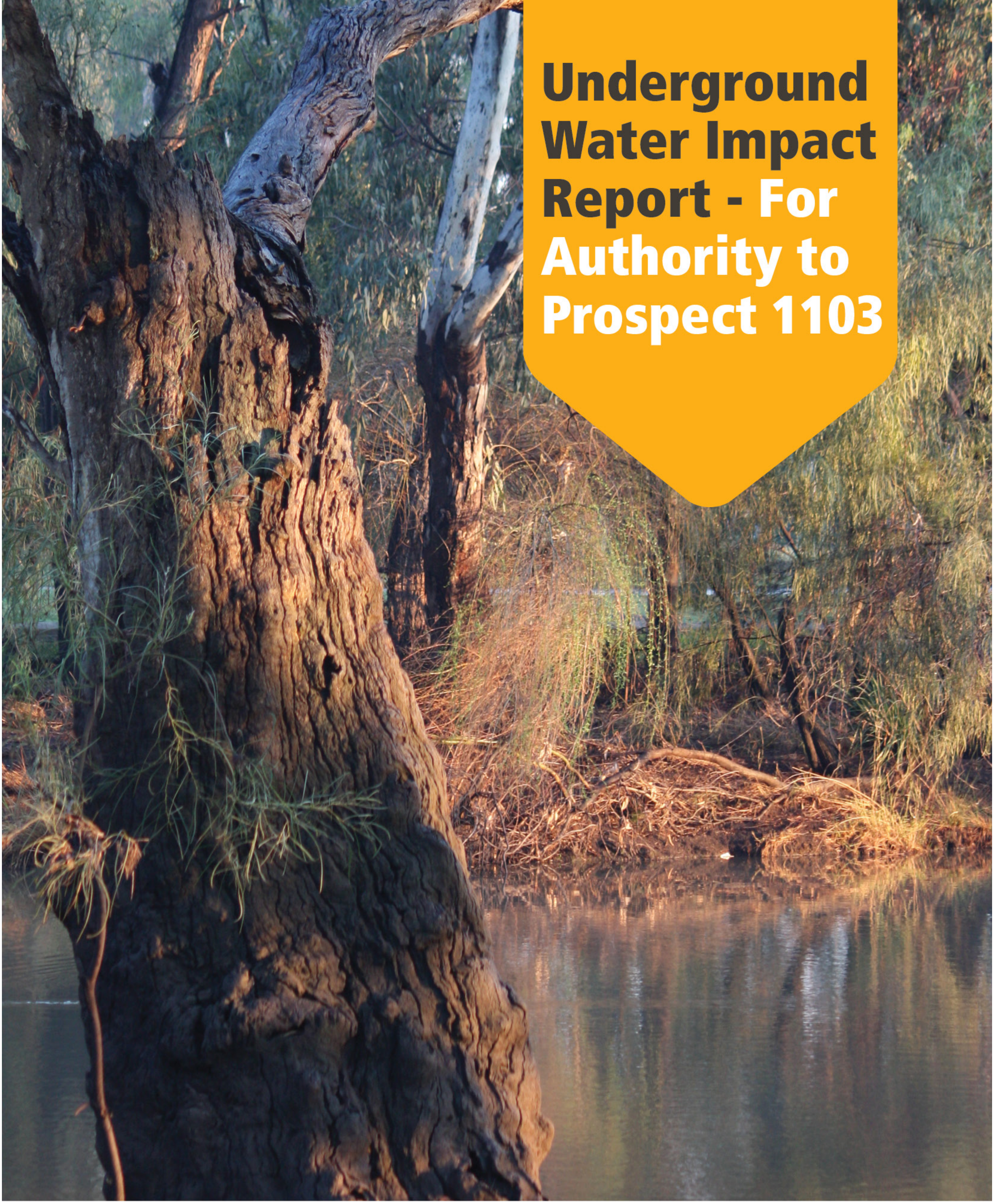
Underground Water Impact Report - For Authority to Prospect 1103



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July 2012

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EXECUTIVE SUMMARY

This report provides information on the potential decline in water levels in aquifers within Authority to Prospect (ATP) 1103 as a result of the taking of water during production testing.

The report includes:

- the quantity of water taken because of the exercise of any previous relevant underground water rights;
- the quantity of water estimated to be taken because of the exercise of any relevant underground water rights over the next three years;
- a description of aquifers potentially affected including how the aquifer interacts with other aquifers;
- the predicted water level decline as a result of the taking of water and a description of the methods and techniques used to make the prediction;
- information on water bores that may be impacted by a water level decline in excess of the bore trigger threshold; and
- a program for conducting an annual review of the predictions.

It is concluded that the impacts of extraction of underground water during and after production testing within ATP1103 are negligible considering that:

- limited volumes of water (181 ML) were taken during production testing carried out between 2008 and 2011;
- shallower aquifers (the main resource aquifers used in ATP1103) are separated from the perforated intervals of the production testing wells by intervening lower permeability formations;
- production testing wells are fully cased and cemented;
- groundwater modelling indicates;
    - ◊ the extremely limited extent (in the immediate vicinity of a single production testing well only) of water level decline equal to the bore trigger threshold within the Moranbah Coal Measures;
    - ◊ no water level decline by more than the bore trigger threshold elsewhere within the Moranbah Coal Measures;
    - ◊ no water level decline by more than the bore trigger threshold anywhere within the alluvial aquifers; and
    - ◊ no water level decline by more than the trigger threshold (0.2m) for springs.

1 INTRODUCTION

This report provides information on the potential decline in water levels in aquifers within Authority to Prospect (ATP) 1103 because of the taking of water during production testing undertaken by CH4 Pty Ltd and Arrow CSG (ATP 364) Pty Ltd on behalf of themselves and AGL Energy Limited.

The registered holders of Authority to Prospect N0. 1103 (**ATP1103**) are AGL Energy Limited ACN 115 061 375 (99%), CH4 Pty Ltd ACN 092 501 016 (0.7%) and Arrow CSG (ATP 364) Pty Ltd ACN 092 970 557 (0.3%) (**Registered Holders**). CH4 Operations Pty Ltd ACN 099 540 726 is the operator of ATP 1103 for and on behalf of the Registered Holders. CH4 Pty Ltd and Arrow CSG (ATP 364) Pty Ltd are related bodies corporate [as that term is defined in the *Corporations Act 2001* (Cth)] wherein both companies have as their ultimate holding company, Arrow Energy Holdings Pty Ltd ACN 141 385 293.

The subject ATP spans the area around the towns of Glenden, Moranbah, Dysart and Middlemount.

The state government may declare cumulative management areas (CMAs) in areas of concentrated CSG development where the impacts on water levels caused by individual petroleum and gas projects can overlap. In Queensland, the area of planned concentrated CSG development has been declared as the Surat CMA. CH4's operations in the Bowen Basin falls outside of this CMA, and under the Water Act (QLD) 2000, there is a requirement to prepare an Underground Water Impact Report (UWIR). This report forms the UWIR for CH4 Energy's CSG Operations contained within the bounds of the ATP1103.

The purpose of this report is to address Chapter 3, and in particular, s376 of the Water Act (Qld) 2000 which stipulates that the UWIR must include:

a) For the area to which the report relates –
   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;
b) For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights–
   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
   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
   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
   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;
c) A description of the methods and techniques used to obtain the information and predictions under paragraph (b);
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;
e) A program for –
f) Conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and
g) Giving the chief executive a summary of the outcome of each review, including statement of whether there has been a material change in the information or predictions used to prepare the maps;
h) A water monitoring strategy;
i) A spring impact management strategy;
j) Other information or matters prescribed under a regulation.

1.1 Legislation

The primary legislative requirements for the management and development of groundwater for the ATP1103 summarised below.

1.1.1 *Petroleum and Gas (Production and Safety) Act 2004 and Petroleum Act 1923*

The *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act, 2004) and the *Petroleum Act 1923* regulate coal seam gas activities and also govern groundwater management in relation to CSG development. ATP1103 is permitted under the P&G Act (2004).

Under the P&G Act, the petroleum tenure holder may take or interfere with groundwater to the extent that it is necessary and unavoidable during the course of an activity authorised under the petroleum tenure.

P&G Act, 2004 and the Petroleum Act 1923 require tenure holders to comply with underground water obligations specified in the Water Act 2000 Chapter 3.

1.1.2 *Water Act 2000*

The *Water Act 2000:*

- 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 coal seam gas producers 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 the petroleum holder reasonably requires to undertake a baseline assessment of any bores.
- Sets out the process for applying for a Water Licence (where water is to be 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 coal seam gas production on aquifers.

The management of impacts on underground water caused by the exercise of underground water rights by petroleum tenure holders is achieved primarily by:

a) providing a regulatory framework to:

- require 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;
- manage the cumulative impacts from 2 or more petroleum tenure holders' underground water rights on underground water; and

b) giving the Queensland Water Commission functions and powers for managing underground water.

If a water bore has an impaired capacity as a result of CSG activities, an agreement will be negotiated with the owner of the bore about the following:

- The reason for the bore's impaired capacity.
- The measures the 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.

A UWIR will identify whether an 'immediately affected area' will result from CSG activities. An immediately affected area is defined as an area where the predicted decline in water levels within 3 years is at least:

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

UWIRs are published to enable comments from bore owners within the area. Submissions made by bore owners will be summarised by CH4, addressed as appropriate and provided to the Department of Environment and Heritage Protection (DEHP). UWIRs are submitted for approval by DEHP. The Queensland Water Commission (QWC) may also advise DEHP about the adequacy of these reports.

The QWC will maintain a database of information collected under monitoring plans carried out by petroleum tenure holders in accordance with approved UWIRs. The database will also incorporate bore baseline data collected by petroleum tenure holders.

1.2 Summary of Methods

An assessment of impacts to groundwater from the production testing activities has been undertaken by referencing available groundwater related data including available neighbouring coal mine data, available hydrogeological reports, and records obtained from the DEHP and Department of Natural Resource Management (DNRM). A review of existing available groundwater information relevant to the CSG Operations within the ATP1103 includes the following sources:

- DNRM, Groundwater Database search results (2011)
- Water Management System (WMS), Groundwater Use and Allocation search results (2011)
- CSIRO, Bowen Basin Structural Geology (2008)
- BMA, Caval Ridge EIS (2009)
- BMA, Daunia EIS (2009)
- Rio Tinto, Clermont Coal Mine EIS (2004)
- Peabody Energy Australia, Eaglefield Expansion Project EIS (2010)
- CWiMi, Scoping Study: Groundwater Impacts of Coal Seam Gas Development – Assessment and Monitoring (2008)
- CRC LEME, A Geoscience atlas for natural resource management in the Upper Burdekin and Fitzroy Catchments, Queensland Australia (2006)
- CSIRO, Bowen Basin Supermodel 2000 (2002)
- CSIRO, Bowen Basin Structural Geology (2008)
- Arrow Energy (internal document), Regional Bowen Geology (2011)
- AECOM, Arrow Energy: Moranbah Groundwater Assessment (2011)
- CHRRUP, Central Highlands Natural Resource Management Plan (2003)
- Pearce, B; Hansen, J; Hydrogeological Investigations of the Comet River Sub-Catchment, Central Queensland, Australia (2006a)
- Pearce, B; Hansen, J; Jackson, J; Hydrogeological Investigation of the Dawson River Sub-Catchment, Central Queensland, Australia (2006)
- Pearce, B; Hansen, J; Hydrogeological Investigations of the Fitzroy River Sub-Catchment, Central Queensland, Australia (2006b)
- Pearce, B; Hansen, J; Hydrogeological Investigations of the Isaac and Mackenzie River Sub-Catchment, Central Queensland, Australia (2006)
- Pearce, B; Hansen, J; Hydrogeological Investigations of the Nogoa River Sub-Catchment, Central Queensland, Australia (2006d)
- SKM, Fitzroy Basin Water Resource Plan Amendment – Callide Catchment Groundwater Project Groundwater Dependent Ecosystem Assessment (2008)
- DEHP, Fitzroy Basin Draft Water Resource Plan Environmental Assessment – Stage 1 Background Report (2009)

- DEHP, Fitzroy Basin Draft Water Resource Plan Environmental Assessment – Stage 2 Assessment Report (2010)
- SKM, Isaac Connors Groundwater Project Part A: Conceptual Model for Groundwater (2009a)
- SKM, Isaac Connors Groundwater Project Part B: Assessment of Groundwater Dependent Ecosystems (2009b)
- JBT Consulting Pty Ltd, Grosvenor Coal Project Environmental Impact Study Groundwater Impact Assessment (2010)
- URS, Caval Ridge Groundwater Impact Assessment (2009)
- Cranstoun Geological Pty Ltd, North Bowen Basin Rangal Coal Measures Geological Compilation & Preliminary Ranking of Potential Coal Seam Gas Targets (2004)
- Clifton, C.; Evans, R. Environmental water requirements to maintain groundwater dependent ecosystems. Environmental flows initiative technical report (2001)
- Hatton, T.; Evans, R. Dependence of Ecosystems on Groundwater and its significance to Australia (1998)
- Fetter, C.W. Applied Hydrogeology, Volume 1 (1994)
- Freeze, R.A. and Cherry, J.A. Groundwater (1979)
- Haitjema, H.M. and Mitchell – Bruker, S. Are water tables a subdued replica of the topography, Ground Water (2005)
- Zhou, Y. And Li, W. A review of regional groundwater flow modelling, Geoscience Frontiers (2011)

A desktop review of this data was undertaken to provide input into the development of the conceptual hydrogeological model for the operations on the ATP1103 lease. This incorporates available data from surrounding mines relevant to describing aquifers. The conceptual understanding of the groundwater occurrence and processes form the basis of a numerical groundwater model. The model was developed in order to predict potential impacts to groundwater and underpin the development of management strategies.

A summary of the reporting requirements as stipulated in the Water Act (QLD) 2000 for this UWIR and relevant sections of this report in which they have been addressed is included in Table 1 below.

Table 1 – *Water Act 2000* reporting requirements for this UWIR

UWIR reporting requirement	Report Section
a) For the area to which the report relates – i. The quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights; and	Section 2
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 2
b) For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights– i. A description of the aquifer; and	Section 3
ii. An analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and	Section 3
iii. A description of the aquifer; and	Section 3
iv. An analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and	Section 3
v. 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	Section 5
vi. 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	Section 5
vii. 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;	Section 5
c) A description of the methods and techniques used to obtain the information and predictions under paragraph (b);	Section 5
d) A summary of information about all water bores in the area shown on a map mentioned in paragraph	Not applicable see Section 5

(b)(iv), including the number of bores, and the location and authorised use or purpose of each bore;	
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
ii. Giving the chief executive a summary of the outcome of each review, including statement of whether there has been a material change in the information or predictions used to prepare the maps;	Section 6
f) A water monitoring strategy;	Section 6
g) A spring impact management strategy;	Not applicable – see Section 5
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 ATP1103
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 ATP1103
i) Other information or matters prescribed under a regulation.	No matters identified
S378 1(a) (i) Water Monitoring Strategy	No immediately or long term impacted areas identified.
(i)Strategy for monitoring the quantity of water produced	
(ii) Strategy for monitoring changes in water level	
(b) Rationale for the strategy	
(c) Timetable for implementing the strategy	
(d) Program for reporting the implementation of the strategy	
2 Strategy must include:	
(a) The parameters to be measured	
(b) Locations for taking the measurements	
(c) Frequency of the measurements	
3 A program for a baseline assessment for each bore that is:	
(a) Outside the tenure, within an immediately or long term affected area	

2 BOWEN BASIN OPERATIONS

The spatial distribution of CH4's ATP1103 in the Bowen Basin is shown in Figure 1.

2.1 Project Area

ATP1103 is the subject of exploration activities for CSG. The project area for which this UWIR will be focussed on encompasses the entirety of the ATP1103 lease. ATP1103 has included a number of wells used for 55 production tests for CSG between 2008 and 2011 as summarised in Table 2. These wells are shown in Figure 1.

2.2 Water Production Schedule

Available historical water production data has been compiled for the production wells to provide an indication of the quantity of water taken for ATP1103 summarised in Table 2. This indicates an average of 8.5 KL/day during testing and a cumulative total of 181 ML of water.

Progressive cavity pumps (PCPs) are used in production and production test wells. A PCP pump includes a helical moving screw inside a matching cover.

The pumps are driven at surface via a hydraulic drive head powered by an electric motor. The manufactures specifications provide each pump with a theoretical pump rate. The discharge is measured in the field to assess the actual pumping rate at a specified pump speed. Based upon this a pump efficiency number is calculated and entered into the pump monitoring system. The volume of water produced is then calculated from the actual pump speed and efficiency.

ARROW ENERGY - BOWEN BASIN GAS PROJECT

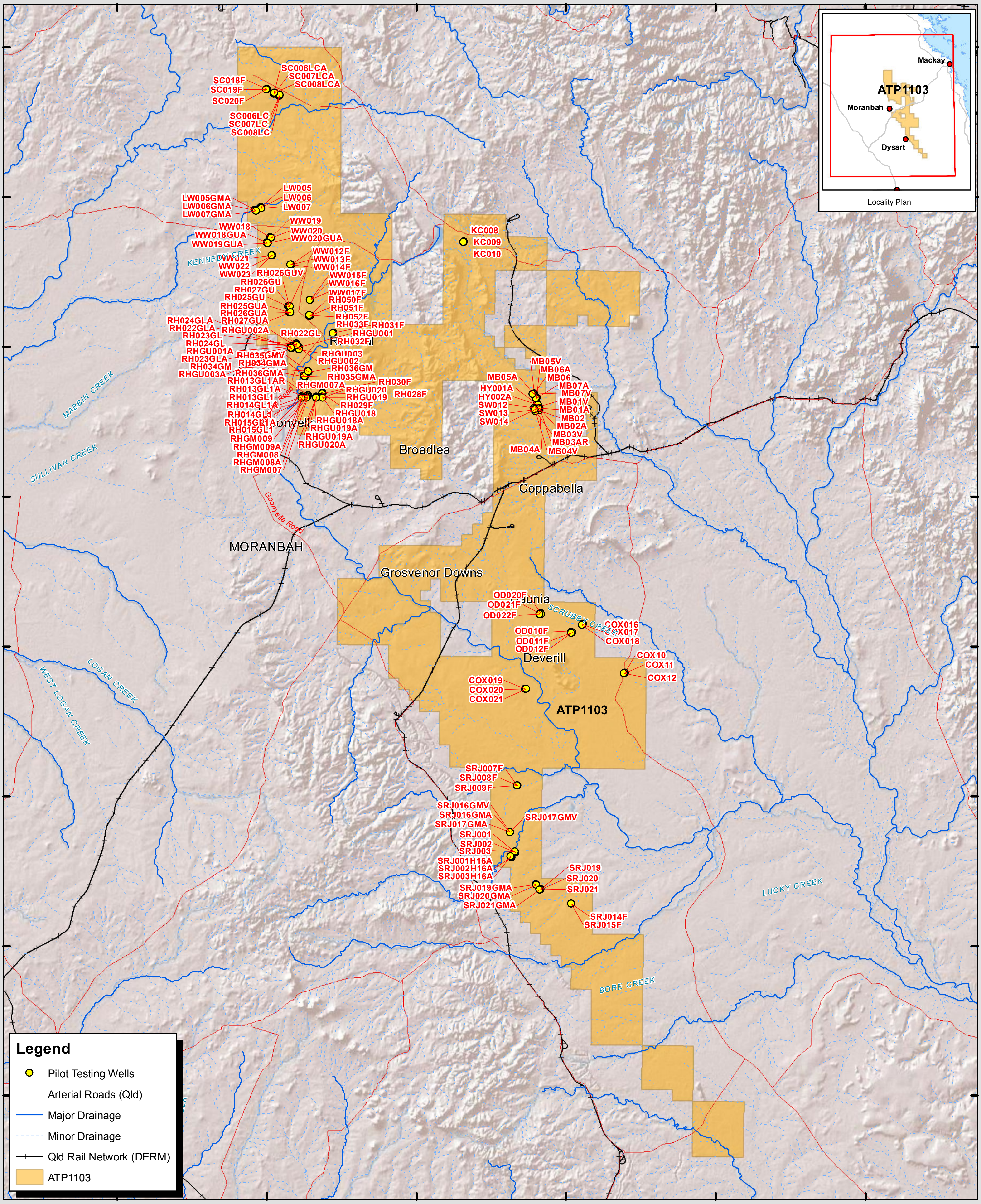

Figure 1. Arrow Energy's ATP1103 Tenements in the Bowen Basin

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/17/2012
Issued To: K Chand
Author: tstringer

0 25 50
Kilometres
Scale: 1:600,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

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The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

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NOT FOR CONSTRUCTION

Table 2 : Summary of Production Testing in ATP1103

Bore Name	Date Start	Date End	Average Flow L/day	Cumulative Flow (L)	Target Formation
COX016	19-May-10	25-Jan-11	7467.4	1067832.0	Rangal Coal Measures
COX018	21-Apr-10	24-May-11	10427.1	3659904.0	Rangal Coal Measures
COX019	10-Jun-10	15-Nov-11	6570.7	2188058.9	Rangal Coal Measures
COX020	09-Jun-10	14-Nov-11	8482.7	2646605.0	Rangal Coal Measures
COX021	10-Jun-10	15-Nov-11	7420.6	2530425.4	Rangal Coal Measures
COX10	04-Nov-09	04-Oct-10	16223.2	3341988.0	Rangal Coal Measures
COX11	04-Nov-09	24-May-11	7051.3	3032039.5	Rangal Coal Measures
RH013GL1	19-Mar-09	30-Jan-11	834.7	565920.0	Moranbah Coal Measures
RH014GL1	29-Dec-08	03-Nov-10	4297.9	3081600.0	Moranbah Coal Measures
RH015GL1	29-Dec-08	24-Mar-11	4877.3	3823776.0	Moranbah Coal Measures
RH022GL	09-Apr-10	16-Sep-11	5943.2	3411403.2	Moranbah Coal Measures
RH023GL	09-Apr-10	04-Aug-11	4503.0	2075904.0	Moranbah Coal Measures
RH024GL	09-Apr-10	16-Sep-11	1709.2	977673.6	Moranbah Coal Measures
RH025GU	10-Apr-10	03-Oct-11	4928.9	2651760.0	Moranbah Coal Measures
RH026GU	18-Apr-10	14-Nov-11	6101.8	3374308.8	Moranbah Coal Measures
RH027GU	18-Apr-10	11-Aug-11	5788.2	3131438.4	Moranbah Coal Measures
RH031F	29-Oct-11	14-Nov-11	6895.1	117216.0	Fort Cooper Coal Measures
RH033F	01-Nov-11	14-Nov-11	3110.4	46656.0	Fort Cooper Coal Measures
RHGU001	12-Nov-08	08-Oct-10	7190.4	5529456.0	Moranbah Coal Measures
RHGU002	14-Dec-08	01-Nov-10	20363.9	15008198.4	Moranbah Coal Measures
RHGU003	11-Nov-08	24-Feb-11	5248.5	4009824.0	Moranbah Coal Measures
HY001	29-Nov-08	23-Apr-09	1801.0	243135.0	Rangal Coal Measures
HY01	23-Apr-09	28-Aug-09	1906.7	244053.0	Rangal Coal Measures
HY02	18-Nov-08	28-Aug-09	498.6	136122.0	Rangal Coal Measures
RHGM007	11-Nov-08	02-Jun-11	2987.0	2643468.7	Moranbah Coal Measures
RHGM008	11-Nov-08	01-Feb-11	4182.6	3358656.0	Moranbah Coal Measures
RHGM009	11-Nov-08	01-Feb-11	2165.7	1791072.0	Moranbah Coal Measures
RHGM035	01-Sep-11	15-Nov-11	4191.9	318585.6	Moranbah Coal Measures
RHGM35	14-Oct-09	17-Aug-11	7206.4	4842691.2	Moranbah Coal Measures
RHGU019	26-Aug-09	19-Jul-10	2073.4	665568.0	Moranbah Coal Measures
RHGU020	26-Aug-09	24-Apr-10	3669.6	880704.0	Moranbah Coal Measures
KC008	03-Jul-10	24-Mar-11	4792.9	1509752.0	Rangal Coal Measures
KC009	02-Jul-10	24-Mar-11	528.6	134786.2	Rangal Coal Measures
LW005	03-Aug-09	15-Aug-10	105362.0	39826843.8	Moranbah Coal Measures
LW006	03-Aug-09	06-Aug-10	15837.8	4973068.9	Moranbah Coal Measures
LW007	03-Aug-09	14-Aug-10	25974.3	8337752.7	Moranbah Coal Measures

MB03V	12-Nov-08	27-Aug-09	213.3	59303.0	Moranbah Coal Measures
MB04V	12-Nov-08	26-Aug-09	148.0	41152.9	Moranbah Coal Measures
MB05V	12-Nov-08	10-Jul-09	438.7	122397.8	Moranbah Coal Measures
MB06	12-Nov-08	26-Aug-09	245.8	68074.4	Moranbah Coal Measures
MB07V	12-Nov-08	27-Aug-09	118.4	32445.9	Moranbah Coal Measures
SC006LC	28-Sep-09	31-Jan-11	3034.9	1541747.6	Rangal Coal Measures
SC007LC	30-Sep-09	09-Feb-11	1654.0	889826.8	Rangal Coal Measures
SC008LC	28-Sep-09	24-Mar-11	2461.6	1299706.5	Rangal Coal Measures
SRJ001	29-Jun-09	03-Mar-10	23183.5	6653664.0	Moranbah Coal Measures
SRJ002	29-Jun-09	04-Mar-10	20525.0	5911192.0	Moranbah Coal Measures
SRJ003	29-Jun-09	04-Mar-10	45644.1	12186970.0	Moranbah Coal Measures
SRJ019	10-May-10	06-Sep-11	1155.1	630661.0	Moranbah Coal Measures
SRJ020	10-May-10	15-May-11	1562.8	834527.5	Moranbah Coal Measures
SRJ021	25-May-10	12-Jun-11	2434.4	1273216.2	Moranbah Coal Measures
WW018	12-Dec-09	31-Mar-11	16262.3	7659525.4	Moranbah Coal Measures
WW019	22-Dec-09	31-Jan-11	1790.6	816517.8	Moranbah Coal Measures
WW020	19-Dec-09	31-Jan-11	3522.3	1641379.6	Moranbah Coal Measures
WW021	28-Aug-10	24-Apr-11	12875.2	2678040.0	Fort Cooper Coal Measures
WW023	24-Aug-10	31-Jan-11	3052.1	656208.0	Fort Cooper Coal Measures
Average Flow (L/day)			8526.1		
Cumulative Total (L)				181174802.8	

2.2.1 *Forecast 2012 Appraisal Program*

Given that only Pilot testing is planned for ATP1103, a forecast of production data for each formation cannot be provided. A forecast of the 2012 Appraisal Program for ATP1103 can however be provided and is shown in the table below.

Table 3 : Forecast 2012 Appraisal Program

Program	Project Name	Type
SIS		
	PD(140-142)MCM SIS	SIS
	NP(008-010)MCM NWT	NWT
	NP(050-052)MCM SIS	SIS
	GC(050-052)RCM SIS	SIS
	GC(020-022)MCM SIS	SIS
	WL(010-012)RCM SIS	SIS
	CX(013-015)RCM SIS	SIS
	PD(110-112)MCM SIS	SIS
	PD(120-122)MCM SIS	SIS

Program	Project Name	Type
	SW(070-072)RCM SIS	SIS
	KC(030-032)RCM SIS	SIS
	PY(010-012)RCM SIS	SIS
	PY(020-022)RCM SIS	SIS
	VM(010-012)RCM SIS	SIS
	BE(050-052)RCM SIS	SIS
	CX(100-102)RCM SIS	SIS
	PD(130-132)MCM SIS	SIS
	RH(080-082)MCM NWT	NWT
FRAC		
	PD(032-034)MCM Frac	Frac
	WB(020-022)RCMG Frac	Frac
	EF(020-024)RCMG Frac	Frac
	PD(070-074)MCM Frac	Frac
	NP(040-044)MCM Frac	Frac
	CX (120-122)RCM Frac	Frac
	Bow BW Frac	Frac
	Arrow BW Frac	Frac

3 EXISTING HYDROGEOLOGICAL REGIME

3.1 Geological Summary

Formed in three distinct phases, the Bowen Basin, (which includes the ATP1103) overlies the Early-Palaeozoic metamorphic and sedimentary strata of the Drummond Basin and Anakie Block. Figure 2 below provides an overview of the geological evolution of the Bowen Basin.

Commencing in the Early-Permian, a period of extension produced a series of isolated fault-bounded basins. In the case of the Bowen Basin, subsequent partial filling occurred in the form of volcanic (e.g. Lizzie Creek Formation) and sedimentary, Group I, (e.g. Reids Dome Beds) deposits. Secondly, after the period of rifting had ceased, thermal relaxation caused subsidence allowing for further deposition. This second phase, or Group II deposits, lasting until the Late-Permian, was dominated by a series of marine deposits including the Back Creek Group and Tiverton Formation. The final phase in the formation of the Bowen Basin was produced by the subsequent overtaking of the thermal relaxation by foreland loading. This transition occurred as progressive, Group III, deposits were laid down under conditions which varied from the marine-influenced deltaic environment of the German Creek Formation, to the dominantly fluvial flood plain environments of the Moranbah Coal Measures. A period of compression in the Middle to Late-Triassic terminated any further sedimentation within the basin.

Coal accumulations occur throughout the 3 phases and large volumes of Coal Bed Methane (CBM) are known to be held within the Permian coals in the north of the basin.

Dominating the north of the Bowen Basin are two north-south trending depositional centres, the Denison Trough to the west and the Taroom Trough to the east.

The area is mantled by an irregular cover of poorly consolidated Tertiary sedimentary strata and basalt (fresh and weathered) of the Suttor Formation. The Tertiary cover overlies the sediments and main coal-bearing units of the Late Permian Blackwater Group (Table 4). The Blackwater Group is divided into three terrestrial units, namely the Rangal, Fort Cooper and Moranbah Coal Measures (RCM, FCCM and MCM).

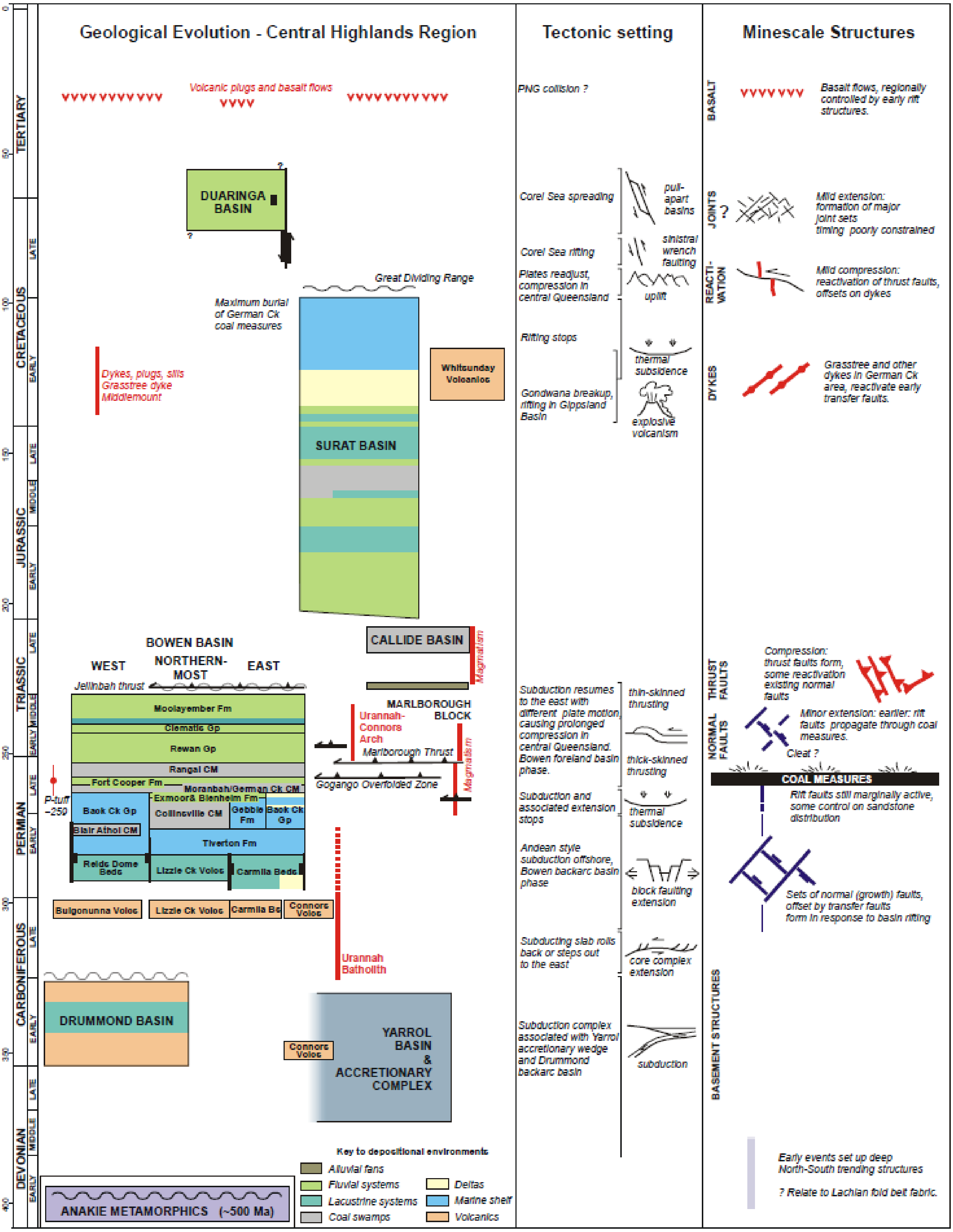

Figure 2 : Geological Evolution of the Bowen Basin

Table 4 Regional Stratigraphic Nomenclature of the Bowen Basin

Age	Formation	South	North
Triassic	Mimosa Group	Moolayember Formation	Moolayember Formation
		Clematis Sandstone	Clematis Sandstone
		Rewan Formation	Rewan Formation
Late Permian	Blackwater Group	Rangal Coal Measures	Rangal Coal Measures
		Burngrove Formation	Fort Cooper Coal Measures
		Fairhill Formation	
		MacMillan Formation	Moranbah Coal Measures
		German Creek Formation	
Middle Permian	Back Creek Group	Ingelara Formation	Blenheim Formation

The surface geology of the project area is shown in **Figure 3**.

3.1.1 *Target Geological Formations*

The principle exploration targets for the Project have traditionally been the MCM. Recent testing of the FCCM has showed net coal thicknesses of up to 50 metres and high gas contents.

The FCCM conformably overlies the MCM and are approximately 400 m thick. Along with the coal seams, sediments of the FCCM include sandstones, siltstones and mudstones. The FCCM are characterised by up to seven formations (6 – 60 m thick) rich in carbonaceous mud and thin coal seams. These formations are interbedded with 10 m to 30 m thick siltstone and sandstone sequences. The target seam of the FCCM is the Girrah Seam. This seam marks the roof of the FCCM and is one of the few identifiable horizons. The seam is approximately 30 m in thickness with numerous stone bands.

The MCM form part of the Late Permian 'Group III" coals deposited in the third and final phase of the formation of the Bowen Basin. The MCM consist of coals, sandstones, siltstones and mudstones and average from 250 m to 300 m in thickness. They are characterised by several laterally persistent, relatively thick coal seams interspersed with several thin minor seams. The predominant target seams in order of importance are the GM, P and QA2 seams. The Q seam is split into three main plies, the QA1 (3.5 m thick), QA2 (3 m thick), and QB (1.75 m thick). The P seam is the second most targeted source of coal seam methane within the MGP. The P seam consists of 3 plies, the GR (3 m thick), PL1 (1.5 m thick), PL2 (0.5 m thick) and averages about 5 m in total thickness. The GM seam is the primary target seam within the GMP. The seam averages 5 m in thickness but thins towards the southeast as a result of seam splitting. The GML seam also forms part of the MCM and in relatively small local pockets, the seam can reach thicknesses of up to 6.5 m.

Figure 4 provides an overview of significant faults within the area. It can be seen that low angle thrust faults are known to exist on the western portion of the basin. On the eastern side of the basin, faulting is generally high angle in nature.

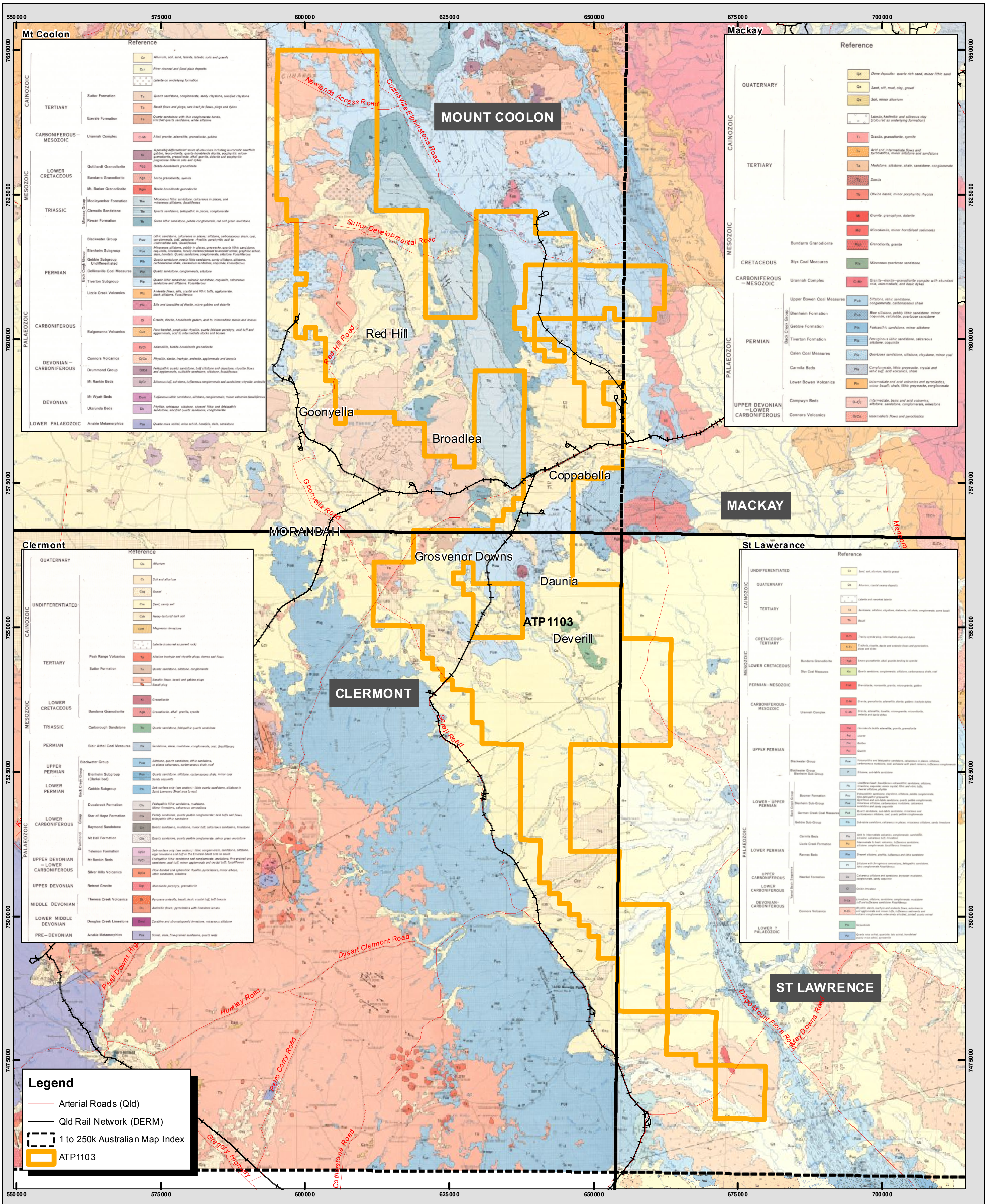

Figure 3. Surface Geology of the ATP1103 Area

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envic and Resource Mgmt.

Date: 30/11/2011
Issued To: K Chand
Author: tstringer

0 25 50
Kilometres

Scale: 1:608,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

N

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Document: V:\Products\Australia\Queensland\Bowen_Basin\Environment\11124 UWIR ATP1103 (KC)\mxd\Surface_Geology.mxd

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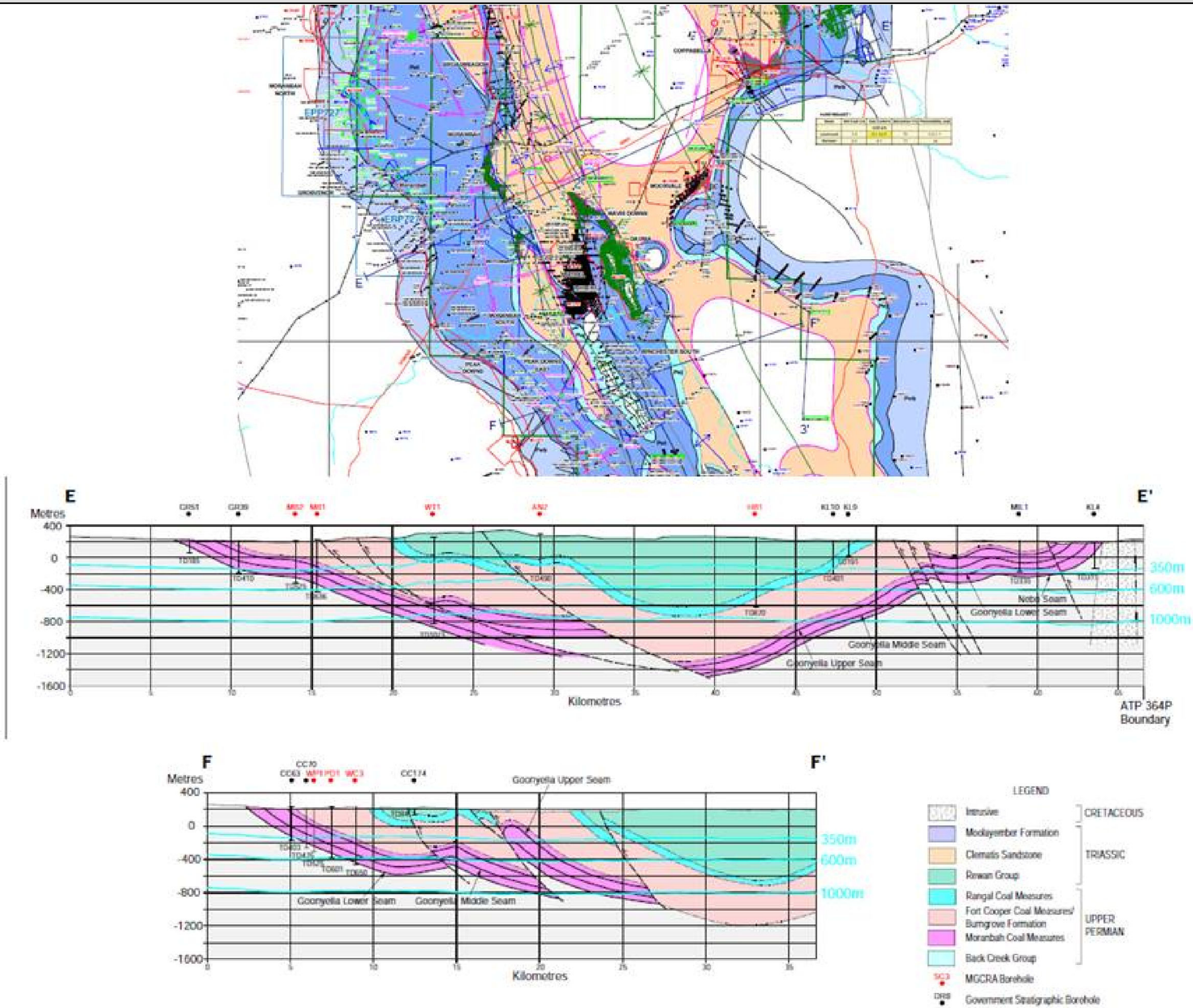


Figure 4. **Geological Structure of the project area**

3.2 Aquifers

The description of aquifers has been undertaken based on the methodology outlined in Section 1.2 of this report.

3.2.1 *Overview*

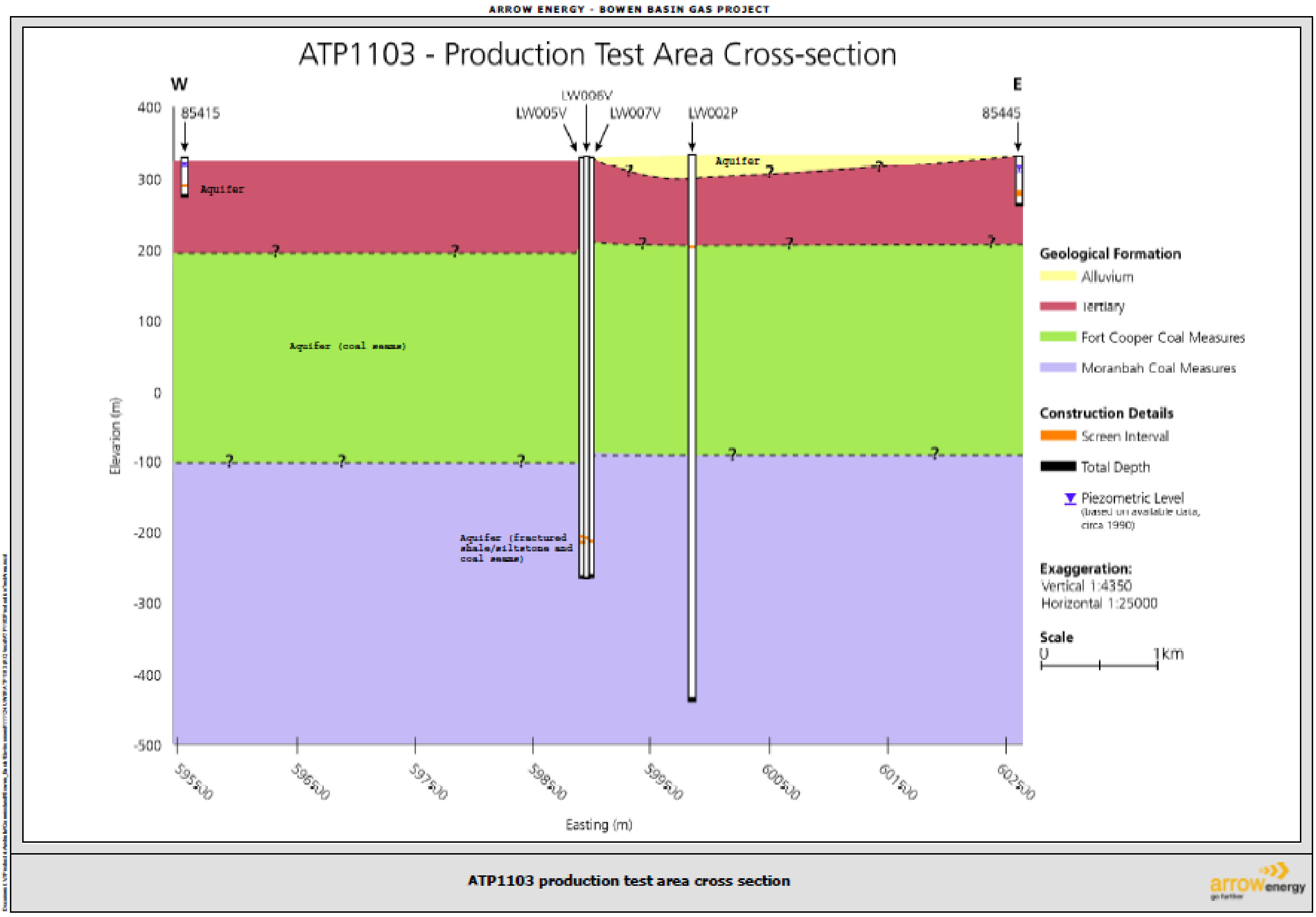
Groundwater supply is not considered to be a major water source in the project area. Based on a review of available data, the beneficial use of groundwater in the Bowen Basin is considered to be low due to low sustainable yields and poor groundwater quality. Groundwater supply is not considered to be a major water source in the ATP1103 area of the Bowen Basin. The major relevant aquifers consist of:

- Quaternary Alluvial Aquifers;
- Tertiary Sediment Aquifers;
- Tertiary Basalt Aquifers; and
- Permian – Triassic Strata Aquifers.

The occurrence and continuity of the above mentioned aquifers will be highly dependent on the spatial distribution of the corresponding geological units in the Bowen Basin. In general, the occurrence of the Quaternary and Tertiary aquifers is not well defined in the Basin.

A hydrogeological cross section, through production testing bores LW005, LW006 and LW007, which provides an overview of the aquifers are depicted in the Figure below.

Figure 5: ATP1103 Hydrogeological Cross Section.



These aquifers are summarised in more detail in the below sections.

3.2.1.1 Quaternary Alluvial Aquifers

Quaternary alluvial aquifers are extensive throughout the Isaac and Mackenzie River sub-catchments (Pearce .B, Hansen .J, 2006). Data coverage across the alluvial aquifers is uneven with the greatest concentration of bores occurring in the alluvium of Fennel Creek, Nebo Creek, Denison Creek and the Connors River.

In the Project area, the Alluvial aquifers exist in association with the Isaac River. The Alluvial aquifers associated with the Isaac and Connors Rivers and their tributaries, form the most significant groundwater resource in the catchment and are considered to be strongly linked to surface water (SKM, 2009a). Quaternary alluvium consists of clay, silt, sand and gravel and exists predominantly around creeks, rivers and associated flood plains. This aquifer is composed of alluvial sediments associated with the major river system and older sediments associated with floodplains and alluvial flats. The most reliable aquifers are located closest to the main river systems while shallower aquifers in more elevated areas are often dry. Alluvial groundwater resources are exploited along the Isaac River but the distribution of production bores is considered erratic (Pearce .B, Hansen .J, 2006). Based on available data, the thickness of the alluvium in the Project area is typically between 15 m and 25 m but downstream bore data show that the thickness can reach greater than 35 m.

The alluvial aquifer is classed as a porous media aquifer where groundwater occurs within the voids between individual grain particles. The alluvial aquifer in general represents an unconfined or semi-confined aquifer. The volume of groundwater stored within the aquifer and the ability of the aquifer to transmit groundwater are largely a function of the particle size of the material comprising the aquifer and the saturated thickness of the sediments. Aquifer properties are variable depending on the nature of the sediments.

Groundwater is often hydraulically connected to the surface water systems. Recharge processes in the alluvial aquifers are via:

- direct infiltration of rainfall and overland flow where no substantial clay barriers exist in the subsurface; and
- direct infiltration from surface water flow and/or flooding (losing stream).
- Primary discharge mechanisms in the alluvial aquifer are likely to be:
- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams);
- evapotranspiration;
- discharge to surface water systems (gaining stream); and
- groundwater extraction.

3.2.1.2 Tertiary Sediment Aquifers

The undifferentiated Tertiary sediments and the Suttor Formation are the dominant Tertiary sediment units. The Tertiary sediments in the Project area is made up of the mud, sands, gravels, residual soils and colluviums of the undifferentiated Tertiary strata; as well as the sandstone, mudstone, claystone, minor oil shale, diatomite, and carboniferous claystone of the Suttor Formation. These Tertiary sediments generally consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays. The thickness and extent of these Tertiary sediments are variable and for the most part, groundwater resources are very limited and typically have poor quality.

This aquifer is classed as a primary porosity aquifer where groundwater movement is via inter-granular flow and are expected to represent unconfined to confined aquifers depending on the location, degree of weathering and clay content. The volume of groundwater stored within the aquifer and the ability of the aquifer to transmit groundwater are largely a function of the particle size of the material comprising the aquifer and the saturated thickness of the sediments. Aquifer properties are variable depending on the nature of the sediments.

Recharge processes in the Tertiary sediment aquifers are via:

- direct infiltration of rainfall and overland flow where Tertiary sediments outcrop and no substantial clay barriers exist in the subsurface; and
- see page from overlying Quaternary alluvial aquifers.
- Primary discharge mechanisms in the Tertiary sediment aquifers are likely to be:
- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams);
- evapotranspiration; and
- groundwater extraction.

3.2.1.3 Tertiary Basalt Aquifers

The spatial distribution of the Tertiary basalt aquifer is limited within the ATP1103 area of the Bowen Basin. The largest mass occurs to the west of Dysart with several other masses occurring near Moranbah, west of Nebo and northeast of Middlemount (Pearce .B, Hansen .J, 2006c). In the Project area an isolated mass of Tertiary basalt exists near Moranbah which is composed of flat lying flows that contain a higher number of vesicular layers. The basalt is in general less that 50 m thick and almost completely weathered (Pearce .B, Hansen .J, 2006c). Groundwater supplies are primarily contained in weathered fractured zones.

The Tertiary basalt aquifers are classed as a secondary porosity aquifer and are expected to represent unconfined to confined aquifers depending on location. Groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass. The volume of groundwater contained within the fractured rock aquifer and the ability of the aquifer to transmit water is largely a function of the degree of fracturing and extent of interconnection of the fracture systems as well as the degree of weathering. Aquifer properties are highly variable.

Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall in rock outcrop areas where no substantial clay barriers exist in the shallow subsurface; and
- vertical seepage or though flow from overlying or adjacent alluvial or tertiary sediment aquifers.
- Primary discharge mechanisms in the Tertiary basalt aquifers are likely to be:
- downgradient Tertiary basalt outcrop areas;
- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams);
- evapotranspiration; and
- groundwater extraction.

3.2.1.4 Permian - Triassic Aquifers

The Permian – Triassic formations constitute the two dominant Permian formations which are the Blackwater Group and the Back Creek Group as well as the Triassic Rewan Formation, Clematis Sandstone and Moolayember Formation.

Small exposures of the Rewan Formation occur in two main areas, the first to the south near Blackwater and the other in the north, to the northeast of Moranbah. The Rewan Group contains shale and siltstone with minor sandstone that typically yield only minor groundwater supplies (Pearce .B, Hansen .J, 2006c). There are isolated exposures to of the Clematis Sandstone and Moolayember Formation which are located in the same region as the Rewan Formation. The Moolayember Formation consists of siltstone and sandstone and the Clematis Sandstone consists of sandstone, siltstone, mudstone and conglomerates. These two formations form part of the basal section of GAB recharge beds (Pearce .B, Hansen .J, 2006c).

In the Bowen Basin the Permian Formations generally consist of siltstone, sandstone, calcareous and carbonaceous shales and coal. The Blackwater Group is widespread throughout the basin and the Project area and is overlain by Quaternary sediments between Moranbah and Middlemount and north of Blackwater. Minor groundwater supplies are contained in porous sandstone layers but the majority of resources in the formation are contained in fractured shale and siltstone (Pearce .B, Hansen .J, 2006c). The Back Creek Group occupies the eastern and western margins of the Bowen Basin. Groundwater in the Back Creek Group is typically contained within porous sandstones at varying depths and also in fracture zones in shale and siltstone (Pearce .B, Hansen .J, 2006c). Aquifers in the Back Creek Group range from being unconfined to confined. The unconfined aquifers exist within the porous sandstones of the Back Creek Group and yield reliable groundwater supplies. In the western part of the Isaac River sub-catchment confined aquifers occur that have sufficient hydraulic head to yield artesian flows of several litres per second (Pearce .B, Hansen .J, 2006c). These confined aquifer systems are likely to represent localised systems and occur at depths as shallow as 50 m below ground surface. Water quality and yields in the Blackwater and Back Creek Group has however, been identified as commonly being very poor. In the coal measures sequences of these Formations, the jointed sandstone overburden and interburden may also be locally important for storage and transmittal of groundwater.

Whilst aquifers in the Permian - Triassic Formations have been identified as being primary porosity aquifers (particularly in sandstone) and secondary porosity aquifers (shales, siltstones and coal), the secondary porosity aquifer (fractured rock aquifer systems) are generally the most dominant. In secondary porosity aquifers, groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass. The volume of groundwater contained within the fractured rock aquifer and the ability of the aquifer to transmit water is largely a function of the degree of fracturing and extent of interconnection of the fracture systems as well as the degree of weathering. Unconfined aquifers have also been identified as occurring in the Permian – Triassic aquifers, however these Formations are generally expected to represent semi-confined to confined aquifers. Based on this, aquifer properties of the Permian – Triassic Formations are highly variable.

Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall and overland flow in outcrop and sub-crop areas;
- downward seepage or though flow from overlying or adjacent alluvial or tertiary aquifers where no significant clay barriers exist; and
- leakage between aquifers by faulting and other structural discontinuities in overburden and interburden sediments.

- Primary discharge mechanisms in the Permian – Triassic strata aquifers are likely to be:
- downgradient Permian –Triassic strata outcrop areas;
- through flow into adjacent (outcropping or sub-cropping coal seams) or seepage into underlying aquifers (structural discontinuities); and
- groundwater extraction (CSG and other mine dewatering activities).

3.3 Groundwater Levels

The primary source of groundwater level data has been from the DNRM groundwater database and relevant CH4 Production testing and reservoir monitoring data. Within the Project area, groundwater level data is available for the Isaac River Alluvium aquifer, Tertiary aquifers, Triassic aquifers and the Permian aquifers. This data is included in Table 5 below.

Table 5 : Isaac River Alluvium Aquifer Groundwater Level and Yield Data

RN	Easting	Northing	Water Level (mBGL)	Yield (L/sec)	Aquifer
37147	652385	7493059	27.4	0.61	ALLUVIUM
85100	607014	7623268			ALLUVIUM
44161	647509	7540289	11.9	8.8	ISAAC RIVER ALLUVIUM
44164	647938	7540971	13.1	4.5	ISAAC RIVER ALLUVIUM

Groundwater levels in the shallow Isaac River Alluvium aquifer range from 11.9 to 27.4 mBGL. The groundwater bore yields recorded in this aquifer varies from 0.61 to 8.8 L/sec. This is indicative of low to moderate groundwater bore yields. However results obtained within the MGD UWIR completed by CH4 indicate yields can reach up to 50 L/sec which is in the high category.

The Tertiary aquifers are generally made up of the Tertiary Sediments and the Tertiary Basalts. The general depth to groundwater ranged from 17 to 30 mBGL from the data obtained for six (6) DNRM bores (Table 6) which exist within the bounds of ATP1103. Available groundwater yield data for this aquifer is generally variable however the recorded yields for the above wells ranged from 1.67 to 3.9 L/sec.

Table 6 Tertiary Aquifers Groundwater Level and Yield Data

RN	Easting	Northing	Water Level (mBGL)	Yield (L/sec)	Aquifer
85444	603968	7621287	22		SUTTOR FORMATION
85445	602717	7623622	30		SUTTOR FORMATION
85446	601413	7621726	17		SUTTOR FORMATION
85447	599144	7622824	20		SUTTOR FORMATION
105678	621020	7580303	18.35	3.9	BASALT
44053	660230	7501203	19.6	1.67	TERTIARY - UNDEFINED

Whilst limited data is available for the groundwater levels in the Triassic aquifers, available data suggests that groundwater levels range from 7 to 19 mBGL (Table 7). Groundwater yield data is only available for one of the bores within the Project area. This bore shows that the groundwater bore yield is approximately 0.25L/sec. However generally yield ranges within the region are between 3 to 6 L/sec.

Table 7 Triassic Aquifers Groundwater Level and Yield Data

RN	Easting	Northing	Water Level (mBGL)	Yield (L/sec)	Aquifer
46848	630826	7621419	7.6		Rewan Fm
81908	619562	7588213	19	0.25	Rewan Fm

Groundwater levels for the Permian aquifers range from 6.7 to 55 mBGL. Available data for groundwater bore yields (Table 8) indicate that yields range from 0.18 to 5 L/sec. In general, groundwater bore yields for bores installed in this aquifer are low.

Table 8 Permian aquifers Groundwater level and Yield Data

RN	Easting	Northing	Water Level (mBGL)	Yield (L/sec)	Aquifer
37861	650015	7505297	55	3	BLACKWATER GROUP
38997	665032	7481405	99.99	0.38	BLACKWATER GROUP
44080	664487	7480492		0.01	BLACKWATER GROUP
44625	650437	7509443	36.6	2.27	BLACKWATER GROUP
67248	659733	7501055	19	3.52	BLACKWATER GROUP
67250	659241	7500795			BLACKWATER GROUP
85464	600169	7627369	26		BLACKWATER GROUP
90475	645463	7513291	304.5	0.01	BLACKWATER GROUP
103210	616869	7560018	19.81	0.78	BLACKWATER GROUP
105479	627445	7565305		2	BLACKWATER GROUP
105480	627359	7565214		2	BLACKWATER GROUP
105481	626523	7564759		1	BLACKWATER GROUP
105482	628007	7563794		0.75	BLACKWATER GROUP
105483	627578	7563982		1	BLACKWATER GROUP
105484	628557	7564435		1	BLACKWATER GROUP
105485	627046	7565616		1	BLACKWATER GROUP
105486	627806	7563826		1	BLACKWATER GROUP
105487	629351	7563383		0.5	BLACKWATER GROUP
105488	627511	7566351		0.7	BLACKWATER GROUP
105489	626158	7565746			BLACKWATER GROUP
105490	628618	7564988		0.7	BLACKWATER GROUP
105491	626738	7562912		0.7	BLACKWATER GROUP
105492	626263	7564546		1.7	BLACKWATER GROUP
105493	629103	7564677		1.1	BLACKWATER GROUP
105494	624893	7565326		3.4	BLACKWATER GROUP
105495	626461	7564176		2.8	BLACKWATER GROUP
105496	627479	7565920		5	BLACKWATER GROUP
105497	627619	7565519		3	BLACKWATER GROUP

RN	Easting	Northing	Water Level (mBGL)	Yield (L/sec)	Aquifer
105498	628182	7564254		2	BLACKWATER GROUP
105499	626263	7564546		1.7	BLACKWATER GROUP
105500	629609	7563350		0.5	BLACKWATER GROUP
105501	628417	7564929		0.8	BLACKWATER GROUP
105525	627468	7564506		2	BLACKWATER GROUP
105526	627827	7566440		0.5	BLACKWATER GROUP
136091	650099	7508605	99.99	0.4	BLACKWATER GROUP
141157	639587	7560479	25	1.26	BLACKWATER GROUP
141664	649432	7584695	49.23	0.6	BLACKWATER GROUP
141665	649491	7584642	39.08		BLACKWATER GROUP
141666	648307	7584036	48.9	1	BLACKWATER GROUP
141667	648307	7583794	112	0.1	BLACKWATER GROUP
141668	650852	7584036	48.45	2.2	BLACKWATER GROUP
141669	648986	7583197	40.28	0.1	BLACKWATER GROUP
141670	648986	7583197	40.28	0.1	BLACKWATER GROUP
141671	649810	7582855	55	0.1	BLACKWATER GROUP
141673	651605	7582574	64.99	0.1	BLACKWATER GROUP
141675	647547	7583162	47.65	0.1	BLACKWATER GROUP
141676	651820	7580980	18.6		BLACKWATER GROUP
13040284	620264	7566309			BLACKWATER GROUP
131612	620803	7582641	17.91	5	BLACKWATER GROUP - UNDIFF.
131613	620721	7582804	12	3	BLACKWATER GROUP - UNDIFF.
38547	654098	7495068	12.2		BLENHEIM SUBGROUP
67130	642432	7504723			BLENHEIM SUBGROUP
90436	649819	7508098			BLENHEIM SUBGROUP
85078	639863	7579576	29.8		UPPER BOWEN COAL
81848	639608	7579708	14.8		UPPER BOWEN COAL MEASURES
63239	598193	7637015	99.99	5	RANGAL COAL MEASURES
63240	598468	7637915	19.6	9	RANGAL COAL MEASURES
63241	596849	7636982	99.99	10	RANGAL COAL MEASURES

CH4 has a number of production wells and reservoir monitoring data. Groundwater level measurements for the target coal measures from these wells are included in Table 9.

Table 9 CH4 Wells Groundwater Level Data

Well Name	Easting	Northing	Water Level (mAHD)	Aquifers
Q001	607771.6	7582546	175.4	Moranbah Coal Measures
Q002	607718.9	7582372	183.5	Moranbah Coal Measures

Well Name	Easting	Northing	Water Level (mAHD)	Aquifers
Q003	607693	7582156	164.1	Moranbah Coal Measures
GR068	612865.9	7582142	118.4	Moranbah Coal Measures
GR070	612279	7574896	165.4	Fort Cooper Coal Measures
GR071	612209	7574970	154.9	Fort Cooper Coal Measures
GR072	612307	7574994	163.2	Fort Cooper Coal Measures
GR073	610324.9	7585107	182.0	Moranbah Coal Measures
GR074	610279.7	7585018	156.2	Moranbah Coal Measures
GR075	610376	7585025	162.8	Moranbah Coal Measures
GR076	609213	7576231	103.4	Moranbah Coal Measures
GR077	612295	7574872	169.5	Moranbah Coal Measures
GR078	612226	7574947	224.9	Moranbah Coal Measures
WT019F	623105.2	7569029	217.5	Fort Cooper Coal Measures
WT020F	623078	7568889	216.0	Fort Cooper Coal Measures
WT021F	623179.6	7568947	229.0	Fort Cooper Coal Measures

3.3.1 *Time-Series Groundwater Level Monitoring Data*

A review of the available data was undertaken to identify time-series groundwater level data. Two separate data sets were obtained:

- Arrow Energy reservoir pressure monitoring data; and
- DNRM alluvium groundwater monitoring data.

These two datasets are presented in the following sections for reference purposes.

Monitoring data for multiple aquifers in target locations is required for a more detailed assessment of water level trends. The groundwater monitoring network proposed as part of the Water Management Strategy will enable collection of such datasets.

3.3.1.1 Arrow Energy Monitoring Data

Reservoir pressure monitoring was undertaken in four CH4 Energy bores in 2007 and 2008. The monitoring undertaken in these bores were short term only as they were installed to monitor pressure response from nearby production testing as an aide in delineating drainage patterns and extending reserve classifications. Once the monitoring objective was met, reservoir monitoring in these bores were discontinued. It is envisaged that a long term groundwater monitoring program will be implemented as part of the water monitoring strategy developed in this UWIR. This monitoring was undertaken by installing level loggers in the four boreholes in September 2007. Details of these monitoring sites are provided in (Table 10) below.

Table 10 CH4 Energy Wells Groundwater Level Data

Borehole	Logger Number	Depth to top of Coal (mBGL)	Sensor depth (m)
GR52v	493	277.5	224.3
SW12v	497	180	317.4
SW13v	491	192.8	319
SW14v	494	95	402.5

Groundwater level monitoring data for these four reservoir monitoring sites are shown in Figure 6 below. Groundwater levels vary from 383 to 474 mAHD. A review of groundwater levels over the groundwater monitoring period shows a declining trend in the coal measures aquifer.

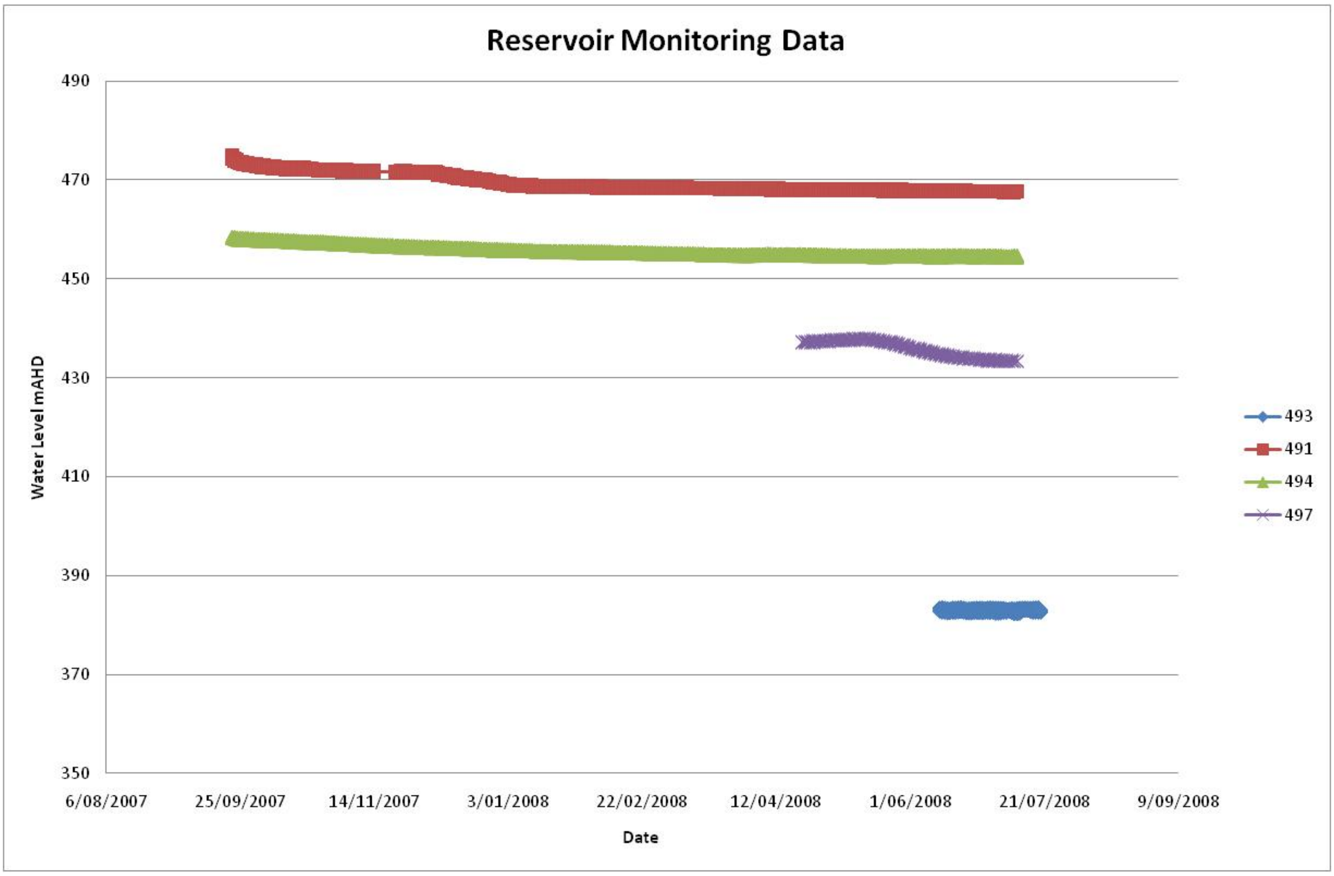


Figure 6 : Graph of Reservoir Monitoring Water Level Data

3.3.1.2 DNRM Monitoring Data

The Department of Environment and Resource Management have a number of long-term groundwater monitoring bores in Queensland. In the Project area, a number of long term groundwater level monitoring records are available in the DNRM groundwater database. The majority of these bores target the alluvial aquifer associated with the Isaac, Connors Rivers and Nebo, Bee, Funnel, Denison Creeks. Some of this long term data which spans over 1965 to 2004 is shown in Figure 7 below. It can be seen that there is low variability in groundwater level trends and no significant increasing or decreasing groundwater level trends are noted. Consequently no decrease in groundwater levels is attributable to CSG operations. Some water level variations noted may be due to seasonal/climatic influences or groundwater use (extraction) influences.

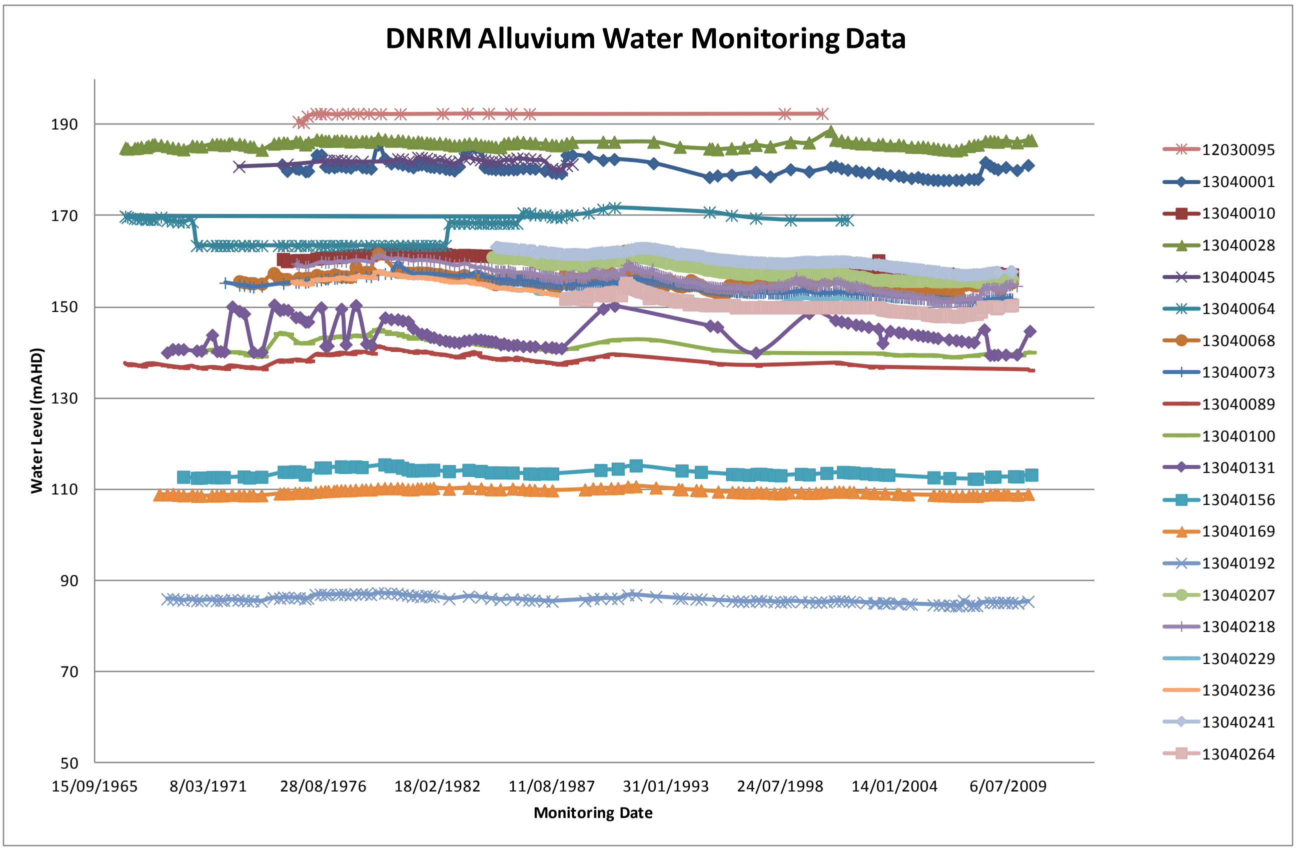


Figure 7 : Graph of DNRM Alluvium water level monitoring data

3.4 Groundwater Flow

A groundwater elevation contour map has been developed based on the available groundwater level data within the Project area. The contour map was developed in Surfer which is a contouring, gridding and surface mapping software package. Surfer is a grid-based mapping program that interpolates irregularly spaced xyz data into a regularly spaced grid. The gridding method selected for these groundwater elevation contour maps is the kriging geostatistical gridding method. This method is considered appropriate as it attempts to express trends suggested in the data and incorporates anisotropy in an efficient and natural manner.

At a catchment scale, groundwater in the alluvial aquifer flows down valley in the same direction as stream flow. It is anticipated that similar flow processes occur in the project area. Given the heterogeneous nature of the alluvial aquifer sediments and the variability in annual and seasonal recharge, the rate of this down valley flow is expected to be spatially and temporally non-uniform. Flows are likely to be constrained to higher permeability pathways where sands and gravels are present, rather than the entire cross sectional area of alluvium.

There is limited data and information on the interactions of groundwater between the alluvial aquifers and adjacent and underlying aquifers. It is expected that on the alluvium margins, lateral groundwater flow to alluvial aquifers from adjacent aquifers is likely, particularly near drainage lines. The magnitude and direction of leakage to/from the alluvial aquifer is unknown. Available long term monitoring data is primarily sourced from the DNRM database. Given the locality and reliability of some of this data, it is considered to be insufficient to provide and accurate analysis of aquifer interactions and water level trends. Therefore, a more detailed analysis of the interaction between aquifers cannot be completed at this stage. Long term monitoring data is required from multiple aquifers in target locations for a more detailed assessment of aquifer interactions and water level trend analysis.

Figure 8 to Figure 10 show potentiometric surfaces based on available groundwater level data for the alluvial, Tertiary and Permian aquifers. Based on these figures, groundwater generally flows from the north-west to the south-east.

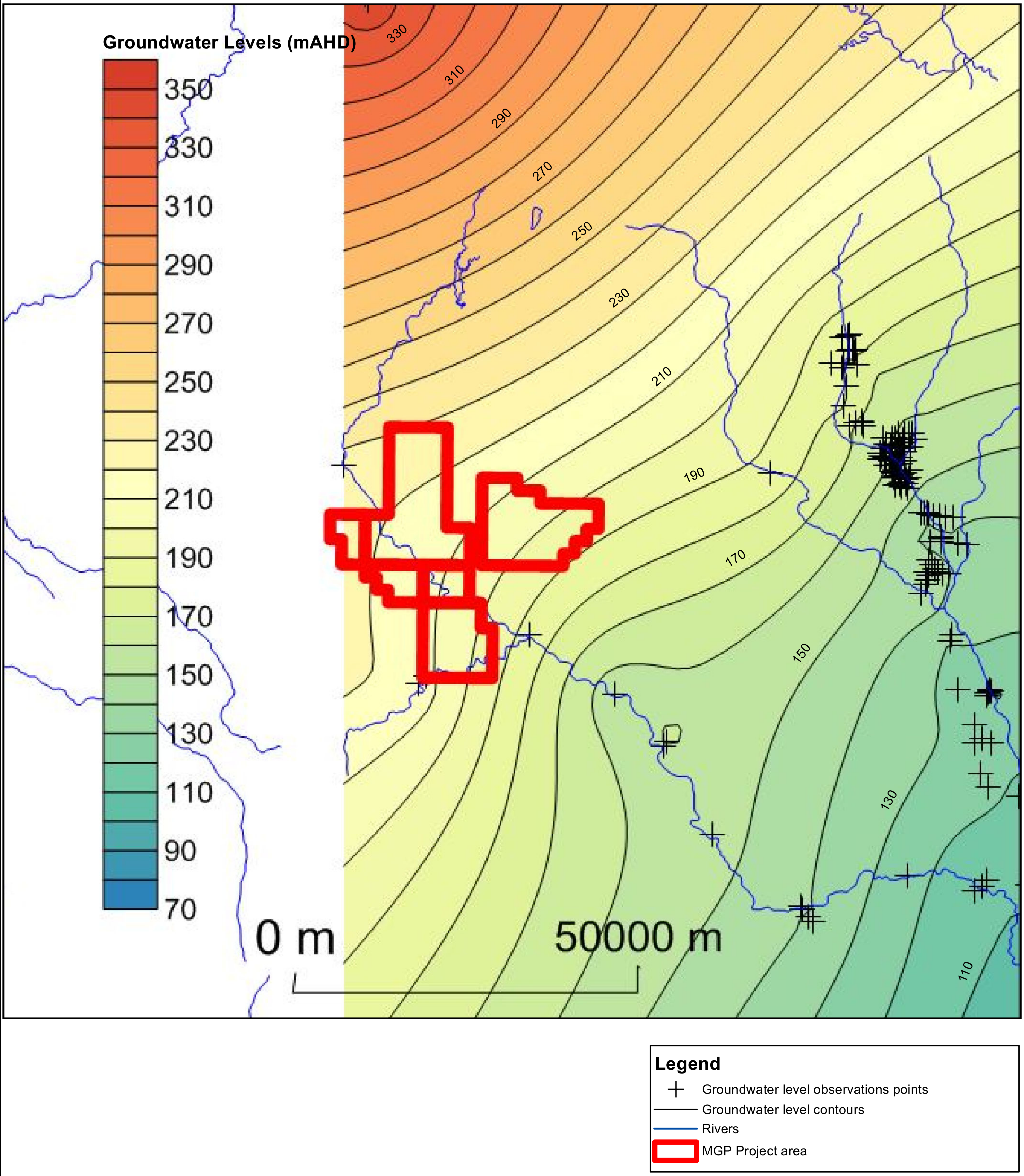


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Figure 8. Potentiometric surface plot for the alluvial aquifer

arrow energy go further

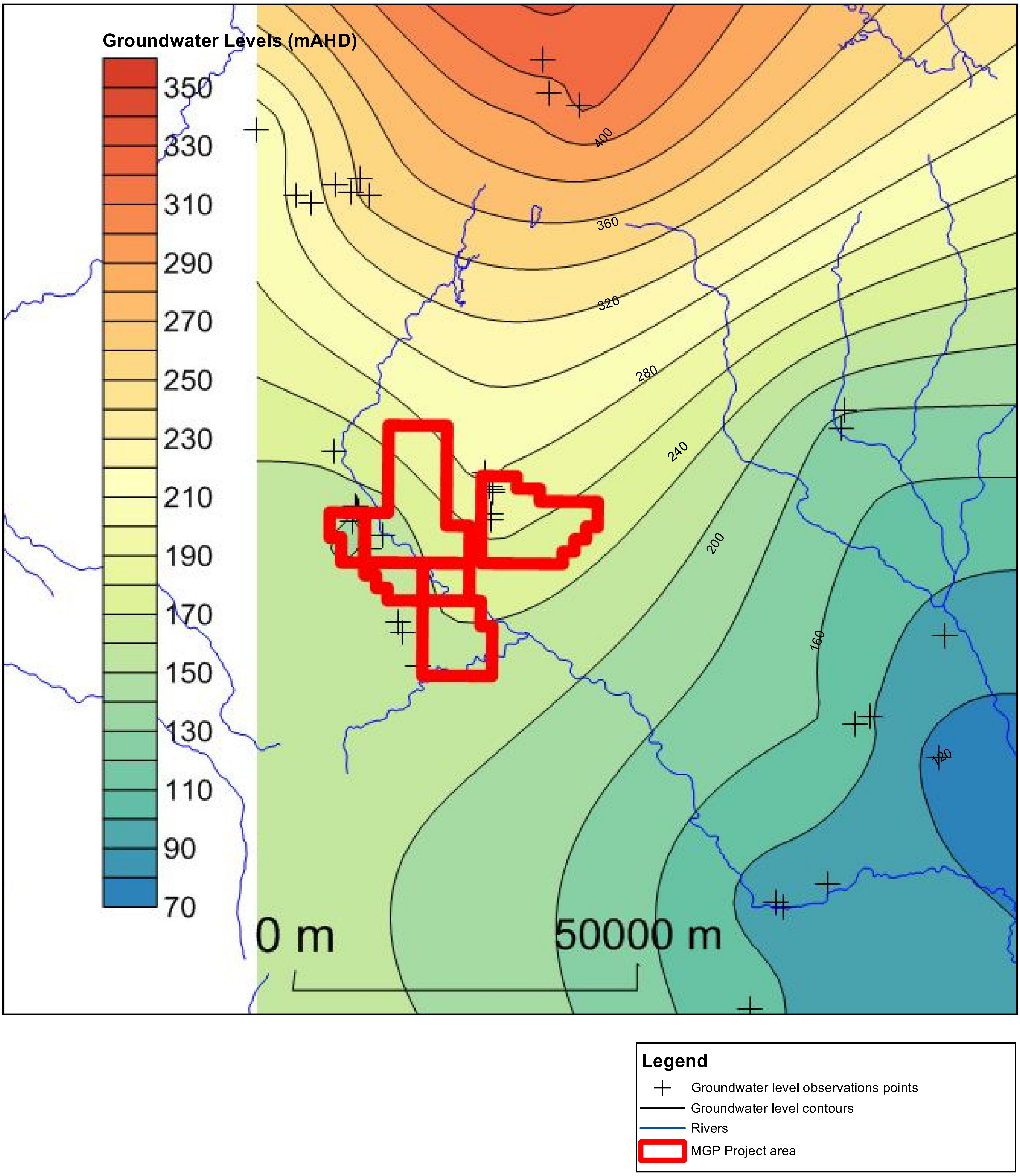

Figure 9. **Potentiometric surface plot for the tertiary aquifer**

arrow energy
go further

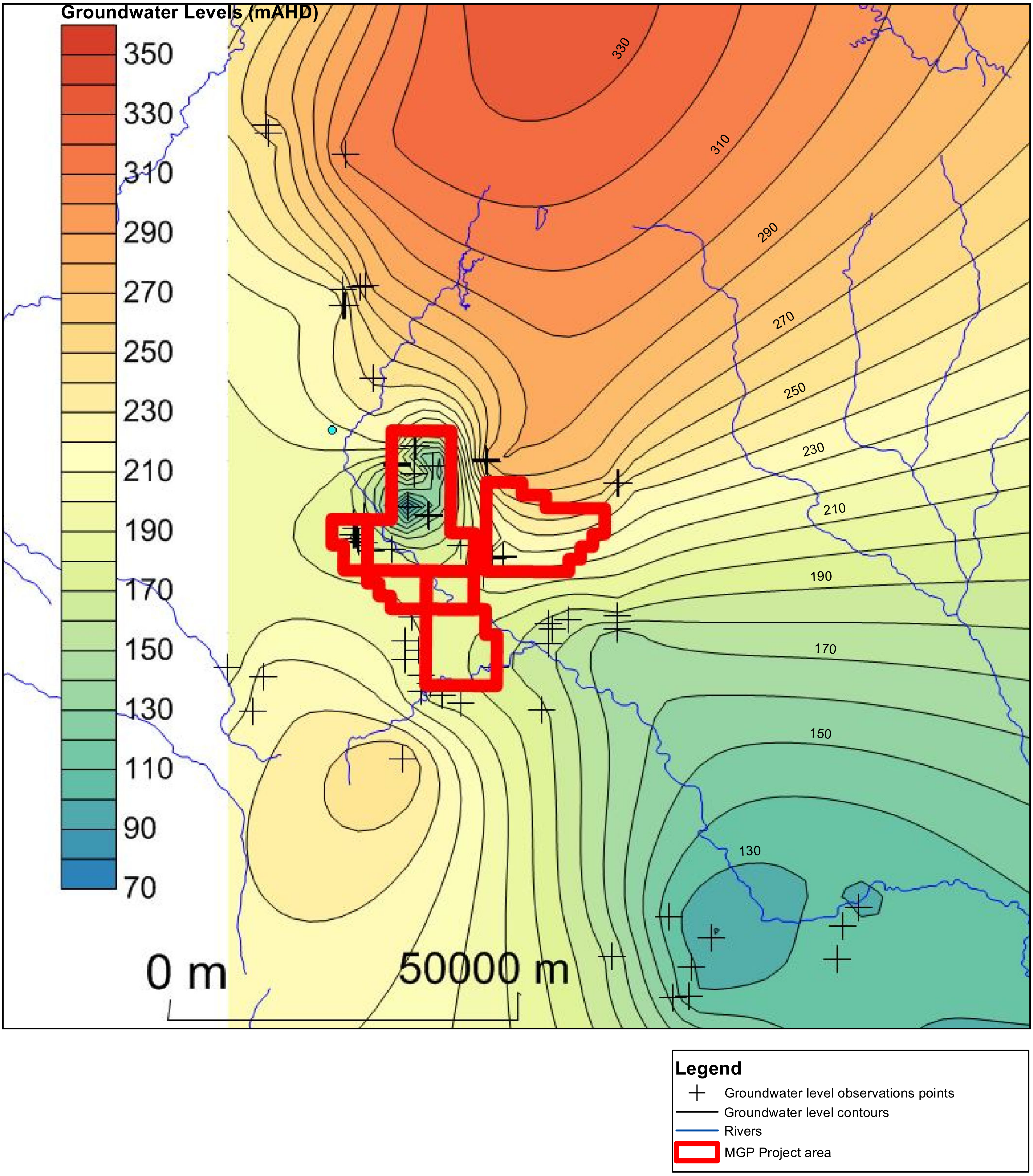

Figure 10. **Potentiometric surface plot for the coal measures**

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4 GROUNDWATER QUALITY

In the absence of a groundwater monitoring network on-site, groundwater quality data has been obtained from nearby sources including:

- CH_4 production well monitoring;
- Landholder groundwater bore monitoring; and
- DNRM groundwater database monitoring records.

The aforementioned groundwater monitoring data has been used to provide an indication of existing groundwater quality within the Project area.

In general, the private bores target the shallower groundwater aquifers in the Project area and provide an indication of groundwater quality conditions within the aquifers overlying the coal measures. The CH_4 production wells are installed in the deeper groundwater coal seam aquifers (i.e. Rangal Coal Measures, Fort Cooper Coal Measures, Moranbah Coal Measures). This data will characterise the groundwater quality of the coal measures.

4.1.1 *Field Parameters*

In January 2011, groundwater monitoring was undertaken in four private groundwater bores (SB-01, TB-01, BA-01, WB-01) located north of Moranbah township. These bores were monitored for physical parameters, results of which are shown in Table 11.

pH levels in these private bores ranges from 5.74 to 7.57 which suggest variable groundwater conditions from slightly acidic to slightly alkaline in quality. Omitting bore SB-01 (pH 5.74) these results are within the ANZECC (2000) water quality guidelines for irrigation and general water use (pH 6 to 8.5).

Electrical Conductivity (EC) results are highly variable ranging from 1.15 to 19.47 mS/cm. This suggests groundwater quality ranges from being fresh to brackish in quality. The majority of these results, with the exception of TB-01, are within the ANZECC (2000) water quality guideline limits for irrigation and general water use (0.95 – 12.2 mS/cm).

Total Dissolved Solids (TDS) was calculated from the measured EC value for each of the bores monitored. Based on the calculated TDS results, bores SB-01, BA-01, and WB-01 are within an acceptable TDS limit where no adverse impacts are expected for most animals according to the ANZECC (2000) water quality guideline limits for livestock drinking water quality. Total Dissolved Solids result for bore TB-1, has a higher calculated value of 13045 mg/L. Based on the ANZECC (2000) water quality guideline limits for livestock drinking water, this may result in a loss of production and decline in animal health conditions.

Table 11 – Physical Parameter Monitoring Dataset for Landholder Bores

Well Name	Date	Conductivity (mS/cm)	Calculated TDS (mg/L)	pH	DO (mg/L)	Temp (°C)	SWL m	Total Depth m
SB-01	28/01/2011	3.67	2459	5.74	0.4	27.8	28.83	78
TB-01	28/01/2011	19.47	13045	6.69	0.6	28	20.5	42.86
BA-01	28/01/2011	5.87	3933	7.57	6.5	28.9	9.09	30
WB-01	29/01/2011	1.15	771	6.99	0.39	26.9	15.08	27.75

A review of the DNRM groundwater database was undertaken to provide an indication of available field monitoring data for the aquifers within the Project Area. These are shown in Table 12, Table 13, Table 14 and Table 15 for the alluvial aquifer, Tertiary aquifer, Triassic aquifer and Permian aquifer respectively.

Table 12 – Groundwater Quality data (field parameters) in the Alluvium aquifer

RN	Conductivity µS/cm	Quality Observations	Formation Description
85100	-	-	ALLUVIUM
44161	3700	-	ISAAC RIVER ALLUVIUM
44164	-	-	ISAAC RIVER ALLUVIUM

Electrical conductivity in the Isaac River Alluvium ranges from 300 to 36800 µS/cm. This is indicative of fresh to saline groundwater quality conditions and suggests existing highly variable groundwater quality conditions in this aquifer.

Table 13 – Groundwater Quality data (field parameters) in the Tertiary aquifer

RN	Conductivity µS/cm	Quality Observations	Formation Description
62048	1310	-	Basalt
37108	3200	-	Basalt
43404	2500	-	Basalt
13040281	13840	-	Basalt
105678	2640	-	Basalt
43793	3500	-	Tertiary – Undefined
88527	-	Brackish	Tertiary – Undefined
88528	-	Brackish	Tertiary – Undefined
43063	890	-	Tertiary – Undefined
105676	1243	-	Tertiary – Undefined
105677	1055	-	Tertiary – Undefined
131000	1866	-	Tertiary – Undefined
131001	1732	-	Tertiary – Undefined
131002	1022	-	Tertiary – Undefined
131003	1362	-	Tertiary – Undefined

Electrical conductivity in the tertiary aquifer ranges from 890 to 13840 µS/cm which is indicative of fresh to brackish water quality. This suggests existing variable groundwater quality conditions in this aquifer.

Table 14 – Groundwater Quality data (field parameters) in the Triassic aquifer

RN	Conductivity µS/cm	Quality Observations	Formation Description
81909	-	Potable	Rewan Formation
81908	-	Salty	Rewan Formation

Table 15 – Groundwater Quality data (field parameters) in the Permian aquifers

RN	Conductivity µS/cm	Quality Observations	Formation Description
36138	2300	-	Back Creek Group
36428	3600	-	Back Creek Group
38971	2510	-	Back Creek Group
43064	8500	-	Back Creek Group
44613	3150	-	Back Creek Group
47362	3890	-	Back Creek Group
36429	2750	-	Back Creek Group
97809	7900	-	Back Creek Group
43602	-	Salty	Back Creek Group
37147	11000	-	Back Creek Group
43639	7300	-	Blackwater Group
37861	-	Brackish	Blackwater Group
43509	2300	-	Blackwater Group
43305	-	Very Good	Blackwater Group
44625	-	Good	Blackwater Group
90074	-	Good	Blackwater Group
90075	-	Good	Blackwater Group
90076	-	Good	Blackwater Group
103417	2100	-	Blackwater Group
13040284	14310	-	Blackwater Group
131612	2900	-	Blackwater Group
131613	1680	-	Blackwater Group
131614	1080	-	Blackwater Group
131615	3660	-	Blackwater Group
44053	1190	-	Blackwater Group
89454	16000	-	Blackwater Group
89469	-	Salty	Fair Hill Formation
43463	38400	-	Rangal Coal Measures
43461	32000	-	Rangal Coal Measures

Electrical conductivity in the Permian aquifers range from 1080 to 38400 µS/cm, which is indicative of fresh to salty groundwater quality. This suggests highly variable existing groundwater quality conditions in this aquifer.

There are over 100 CH_4 production wells targeting the coal measures within the MGP Project area that provide an indication of the water quality in the Moranbah Coal Measures that extend into ATP1103. The majority of the wells have been monitored for physical parameters pH and Electrical Conductivity (EC) from 2004 to 2007. This data has been included in Appendix A for reference purposes to provide an indication of variability in groundwater quality based on longer term time series data of the deeper coal seam aquifers. Table 16 below provides a summary of water quality results.

Table 16 – Summary of groundwater quality monitoring data (field parameters) in the CH4 production wells (2004 to 2007)

Field Parameter	Number of Wells	Lowest	Highest	Mean	Standard Deviation
pH	67	6.3	9.3	7.3 to 8.2	0.07 to 0.73
Electrical Conductivity (µS/cm)	65	1020	15300	4103 to 12153	485 to 4094

Groundwater quality monitoring for physical parameters pH, EC and Total Dissolved Solids (TDS) was also undertaken in CH4 production wells in August 2010. This data is summarised in **Table 17** below. This data has also been included in **Appendix B** for reference purposes.

Table 17 – Summary of groundwater quality monitoring data (field parameters) in the CH4 production wells (2010)

Field Parameter	Number of Wells	Lowest	Highest	Mean	Standard Deviation
pH	147	6.62	8.76	8.01	0.85
Electrical Conductivity (µS/cm)	147	3570	19690	9010	3111
TDS (ppK)	147	2.19	11.66	5.15	1.79
TDS (mg/L)*	147	2190	11660	5150	1790

*Calculation is based on TDS ppK

Based on the data summaries in the above tables pH ranges from 6.3 to 8.76 which is indicative of slightly acidic to alkaline water quality. The mean pH values of 7.3 to 8.2 are within the ANZECC (2000) guidelines for irrigation and general water use (6 to 8.5). The standard deviation calculated for the pH dataset suggests that the data points are close to the mean. Electrical Conductivity ranges from 1020 to 19,690 µS/cm which is indicative of fresh to brackish water quality. The mean EC values of 4103 to 12153 are within the ANZECC (2000) guidelines for irrigation and general water use (950 to 12200 µS/cm). The calculated standard deviation values for EC suggest that the data points are spread out over a large range of values which may suggest high variability of EC within this aquifer. Total Dissolved Solids (TDS) were monitored in August 2010 and range from 2190 to 11660 mg/L. The mean TDS value of 5150 is considered to be acceptable to most animals based on the ANZECC (2000) water quality guidelines for livestock drinking water quality. Based on this, animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production. The standard deviation calculated suggests that the data points are spread out over a large range of values which may suggest high variability of TDS within this aquifer.

4.2 Groundwater Use

A review of the DNRM groundwater database was undertaken to identify registered groundwater bores within the Project area. **Figure 11** displays the locations of existing and abandoned or destroyed registered groundwater bores within the Project area based on data provided by DNRM. **Table 18** below provides a summary of the number of registered groundwater bores that are located within the CH4 tenements.

Table 18 – DNRM registered groundwater bores within ATP1103

<table>
<tr><th>Number of Groundwater Bores</th><th>Facility Type</th><th>Number</th><th>Facility Status</th><th>Number</th><th>Data Owner</th><th>Number</th></tr>
<tr><td rowspan="6">149</td><td rowspan="4">Subartesian Facility</td><td rowspan="4">131</td><td>Abandoned and Destroyed</td><td>29</td><td>DNR</td><td>7</td></tr>
<tr><td>Abandoned but still useable</td><td>2</td><td>DNR</td><td>-</td></tr>
<tr><td rowspan="2">Existing</td><td rowspan="2">100</td><td>DNR</td><td>25</td></tr>
<tr><td>NAP</td><td>2</td></tr>
<tr><td>Artesian Facility</td><td>17</td><td>Existing</td><td>17</td><td>DNR</td><td>-</td></tr>
<tr><td>Surface Water Facility</td><td>1</td><td>Existing</td><td>1</td><td>DNR</td><td>-</td></tr>
</table>

A search was undertaken of the DNRM Water Entitlements System to identify the types of groundwater uses and entitlements associated with licensed bores within the Project Area (Table 19). The uses are industrial and are located in the northern portions of the tenement. Figure 12 shows the locations of licensed bores and their purpose based on data provided by the DNRM (QLD, 2011). Appendix D lists the entitlements in ATP1103.

Table 19 – Groundwater use and entitlement details for bores within ATP1103

Registered Number	Latitude	Longitude	Purpose
105678	-21.87	148.17	Industrial
131612	-21.85	148.16	Dewatering, Industrial
131613	-21.85	148.16	Dewatering, Industrial
105678	-21.87	148.17	Industrial
131612	-21.85	148.16	Dewatering, Industrial
131613	-21.85	148.16	Dewatering, Industrial

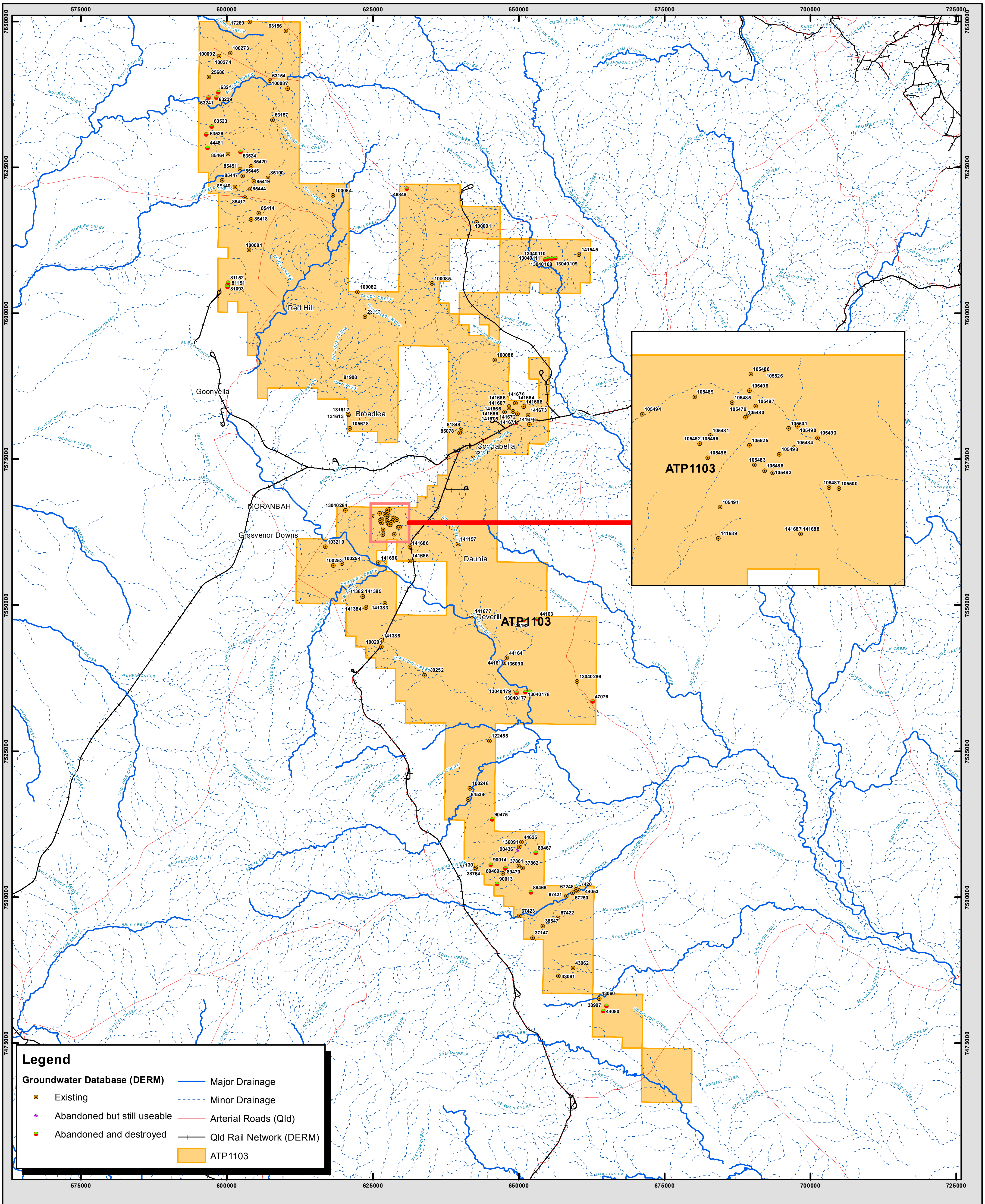

Figure 11. Locations of DERM Registered Groundwater Bores

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

0 25 50
Kilometres
Scale: 1:600,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

N

arrow energy go further

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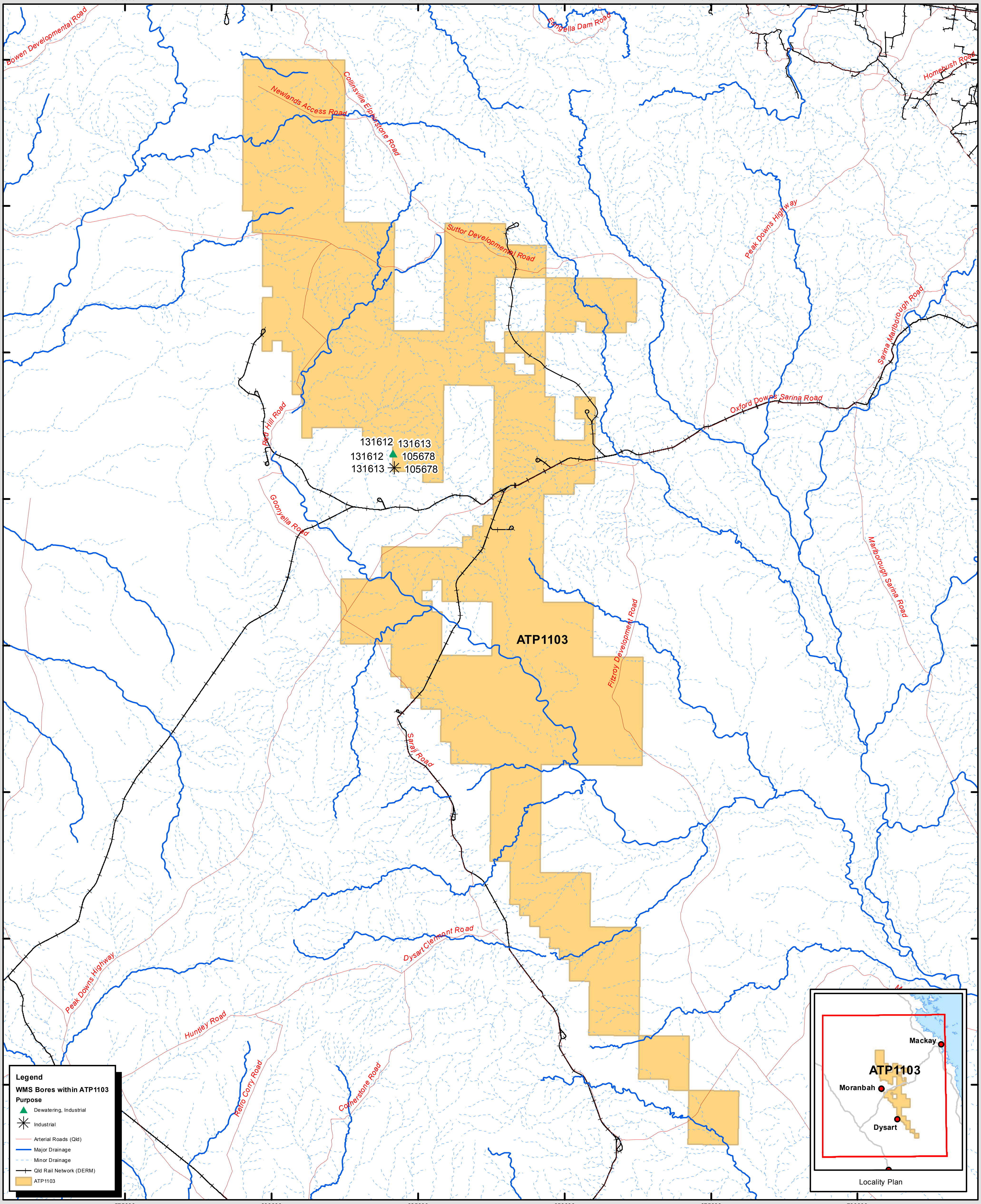

Figure 12. Groundwater Use data for ATP1103

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

0 25 50
Kilometres
Scale: 1:613,551 @ A3
Coordinate System: GDA 1994 MGA Zone 55

N

arrow energy
go further

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

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4.3 Springs

A review has been undertaken of the springs dataset prepared by QWC using the Herbarium datasets. Based on this data, no springs have been identified to exist within proximity of ATP1103. This is illustrated in Figure 13 below. Based on this, impacts to springs as a result of the Project will not be considered further in this UWIR.

4.3.1 *Groundwater Dependent Ecosystems (GDEs).*

A desktop review of available data with respect to Groundwater Dependent Ecosystems (GDEs) within the Project Area has been undertaken. Groundwater Dependent Ecosystems are ecosystems that need groundwater to support any aspect of their growth or function. Six broad functional groups of GDEs have been classified: terrestrial vegetation, river base flow systems, estuarine and near shore marine, aquifer and cave systems and wetlands (Clifton and Evans, 2001) (Hatton and Evans, 1998). Groundwater dependant ecosystems function (i.e. health) is generally defined by four groundwater parameters: flux, level, pressure and quality, with dependence being a function of one or all of these factors.

According to SKM (2009b), there is no long-term historical data or detailed field assessments to describe the groundwater dependence or response functions of GDEs in the Isaac Connors catchment. The Isaac Connors Groundwater Project undertaken by SKM (2009b) provides a conceptual model for the likely relationships between ecosystems and groundwater in the Isaac Connors alluvium. In the Isaac Connors alluvial area, which encompasses a large area of interest, groundwater is considered to support riparian vegetation, in-stream pools, riverine wetlands, hyperheic zones and in some areas, baseflow ecosystems.

Within the Project Area, the Isaac River is ephemeral and ceases to flow for extended periods. Flows are seasonal and linked to regional rainfall patterns. Available drilling data indicates that the sediments adjacent to the river are generally dry to a depth below the base of the bed sands. This suggests that baseflow of groundwater to the Isaac River is not significant (JBT Consulting, 2010). Nonetheless, it is considered that during periods of river flow (wet season, storm events etc.), the alluvium may become fully saturated and discharge to sub-cropping coal seams as is supported by URS (2009).

A review of the DEHP Regional Ecosystems mapping and Referable Wetlands data show that a Wetland Protection Area of high ecological significance exists along the Isaac River. The majority of the area along the Isaac River consists of Regional Ecosystems with a Biodiversity Status that is deemed to be 'Of Concern (dominant)' to 'Endangered (sub0dominant). Terrestrial vegetation GDEs typically access groundwater via root uptake from the water table or overlying saturated zone (capillary fringe). Riparian vegetation GDEs are observed to occur within about 10m to 300m from streams and wetlands (SKM, 2009b).

In the Project Area, it is considered that the level of groundwater dependency by terrestrial vegetation is likely to be relatively low. Give the local climatic conditions and drainage characteristics of these areas, surface water runoff and infiltrated rainfall is likely to represent the primary source of flux required to satisfy plant water requirements. Established vegetation may potentially utilise groundwater opportunistically during dry periods.

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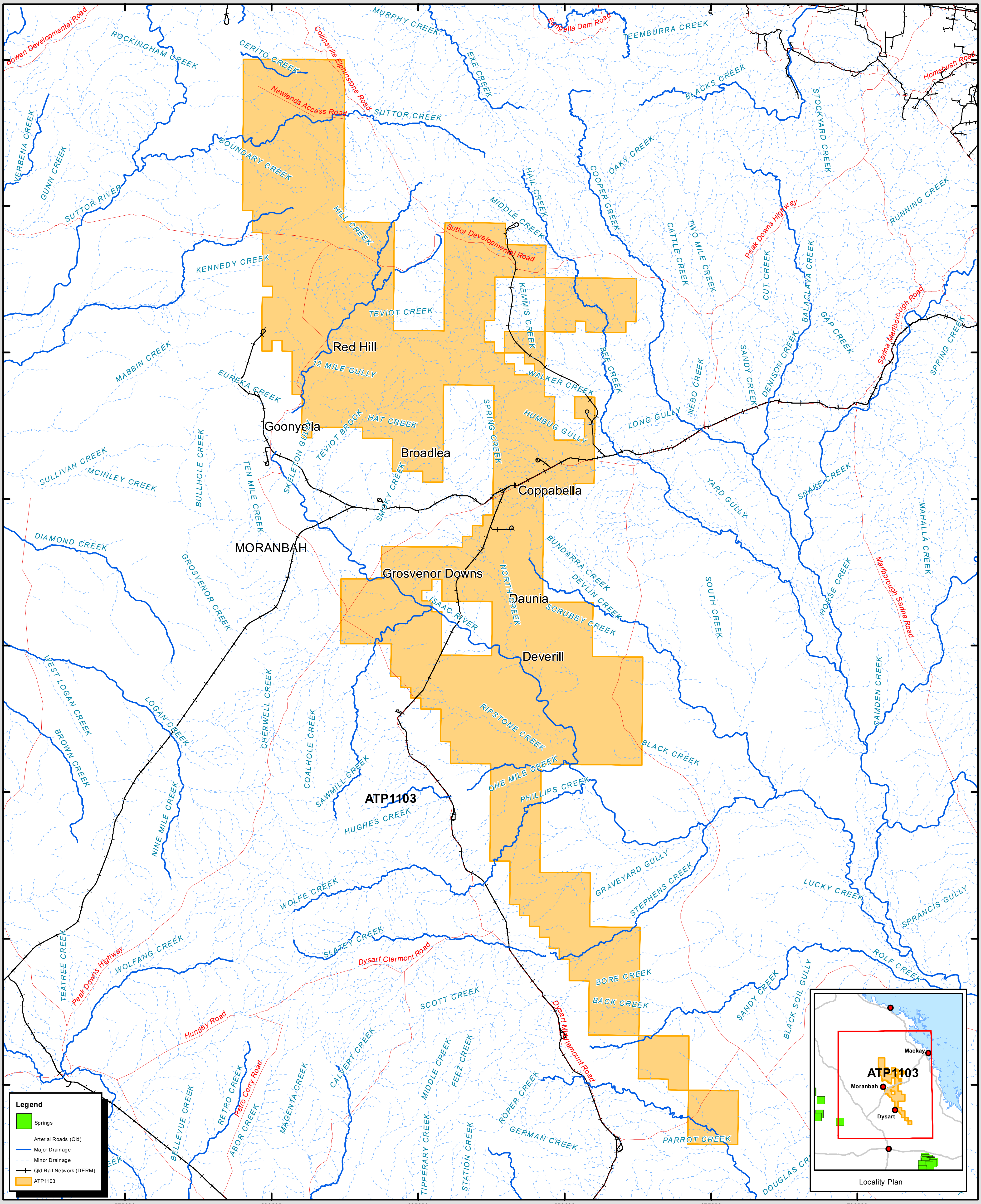

Figure 13. Location of Springs

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

0 25 50
Kilometres
Scale: 1:613,551 @ A3
Coordinate System: GDA 1994 MGA Zone 55

N

arrow energy
go further

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

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5 CONCEPTUAL HYDROGEOLOGICAL MODEL

A conceptual hydrogeological model has been formulated for the anticipated hydrogeological conditions within the study area. This was based on a summary of all the data presented Sections 1, 2 and 3 of this report. There is some level of uncertainty associated with the conceptual framework as a result of data limitations. Given the level of mining activity in the Bowen Basin, it has been identified that data from surrounding mining operations may be important in describing aquifers. Where available, groundwater data primarily from existing mine EIS's has been reviewed and incorporated in the understanding of the conceptual hydrogeological model. The hydrogeological model included flow regimes for porous and fractured aquifer systems that occur in the area. Review of these models is required following field investigations to assess their relative significance and refine the assumptions made. Hence, where data is obtained which significantly changes our understanding of the groundwater process, the conceptual model will be revised. A schematic representation of the conceptual model is shown in Figure 14.

5.1 Fractured Rock Aquifer Flow

In the Project area, the fractured rock aquifer is represented by the Tertiary basalts and the shales, siltstones and coals of the Permian-Triassic formations. Groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass. The volume of groundwater contained within the fractured rock aquifer and the ability of the aquifer to transmit water is largely a function of the degree of fracturing and extent of interconnection of the fracture systems. Aquifer properties are typically highly variable and available data indicates that permeability is generally low. Groundwater recharge occurs from infiltration of rainfall in rock outcrop areas and in some areas from overlying alluvial and Tertiary Aquifers. Groundwater is expected to discharge in topographically low areas and it is anticipated that groundwater flows towards the south-east and in general towards the basin axis. Groundwater discharge in some areas can also occur to adjacent alluvial or tertiary aquifers. This flow regime is considered to form only a small part of the overall flow regime in the project area.

5.2 Primary Porosity Aquifer Flow

The alluvial and Tertiary aquifers are classified as a porous media aquifer where groundwater occurs within the voids between individual grain particles. In the project area, the sandstone and weathered rock of the Permian-Triassic aquifer are also considered to represent primary porosity aquifers.

The alluvial aquifer is expected to occur within the immediate vicinity of the Isaac River and other associated tributaries. The Tertiary aquifer underlies the alluvium and outcrops over a large area of the Project area. Whilst there are small exposures of the Triassic aquifer particularly to the north, north east of Moranbah, the Permian aquifer underlies the entire Project area.

The volume of groundwater stored within the aquifer and the ability of the aquifer to transmit groundwater are largely a function of the particle size of the material comprising the aquifer and the saturated thickness of the sediments. Aquifer properties are variable depending on the nature of the sediments. The permeability and storage capacity of this aquifer is expected to be significantly larger than the Fractured Rock Aquifers. Groundwater is often hydraulically connected to the surface water systems. The alluvial sediments are recharged by infiltrating rainfall and in some areas via through-flow from the adjacent Fractured Rock Aquifers. Groundwater is expected to discharge down valley and into the creeks and rivers of the study area. Given that the majority of the drainage lines are ephemeral, both recharge and discharge processes are expected to occur in the aquifer based on the relative differences in water levels between surface water and groundwater systems.

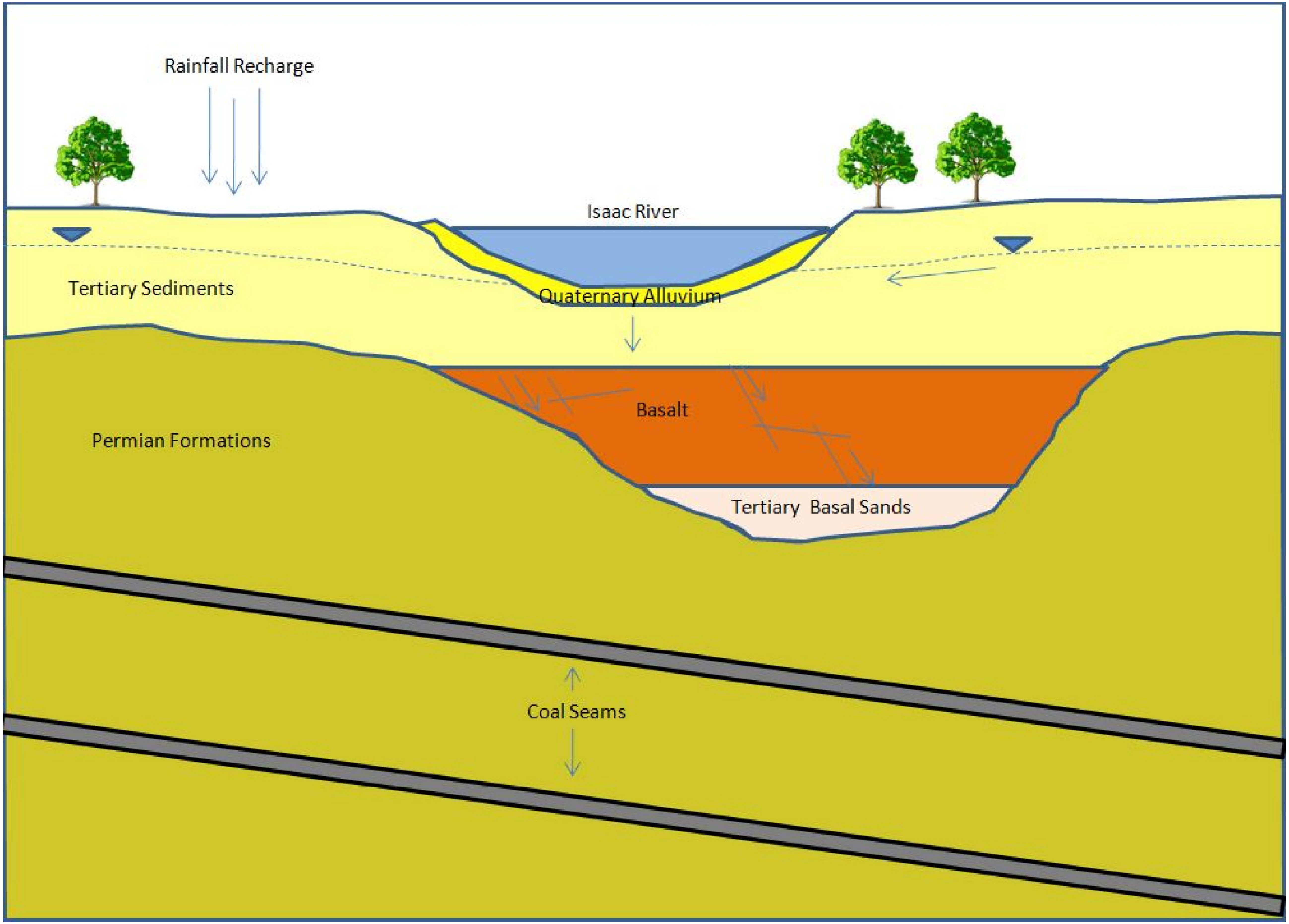


Figure 14. **Conceptual Hydrogeological Model**

6 GROUNDWATER MODELLING

Numerical groundwater modelling has been undertaken to provide estimates of decline in water level in response to the abstraction of groundwater associated with CSG activities in the Bowen Basin. The model that has been developed to include the Production wells in ATP1103. It also includes the CSG production from the Moranbah Gas Project to assess potential cumulative effects.

6.1 Groundwater Modelling Set up

A three dimensional groundwater model was developed to assess potential impacts of groundwater extraction as a result of CSG existing production tests at ATP1103. The production at PL191, PL196, PL223 and PL224 were included to assess potential cumulative impacts. The model is aimed at predicting decline in water level emanating from the CSG production well water extraction which may lead to depressed groundwater levels at locations of existing groundwater users or sensitive ecosystems.

6.1.1 *Modelling Strategy*

The model has been developed using MODFLOW-SURFACT (HydroGeoLogic Inc.) within the graphical user interface Groundwater Vistas, Version 6.07 (ESI, 2011). MODFLOW-SURFACT is a proprietary finite difference code, based on MODFLOW (open source software developed by the United States Geological Survey), but designed to overcome some of MODFLOW's limitations, including its inability to rewet cells that have drained.

The model has been set up in steady state, with regional groundwater flow driven by net recharge distributed uniformly over the landscape. The dominant direction of groundwater flow was from northwest to southeast, sub-parallel to the Isaac River. In order to ensure that water table elevations did not exceed land surface elevation, several major surface drainage lines, including the Isaac River, have been represented as "drains" which ensure that the water table does not rise above assigned bed elevations and which remove water that flows towards these locations.

The steady state model is not calibrated against historical measurements of water table elevations but rather, more generally, against depth to water table. The objective was to simulate a water table that is approximately in the right place relative to the land surface.

Given the level of mining activity in the area, it is likely that there is an impact to groundwater where active mine dewatering is being undertaken. Existing open cut or underground mines have not been incorporated or represented inside the model domain. For UWIR purposes, an assessment of cumulative impacts is not required. Therefore, this level of investigation has not been undertaken as part of the UWIR. Where possible, available hydrogeological, data from nearby mines have been incorporated into the development of the conceptual hydrogeological model. .

Fractured rock flow has not been simulated in the model. Given that this flow regime represents a small component of the groundwater system as a whole, it is considered that modelling of the project area as a primary porosity aquifer is adequate at this scale and provides a conservative assessment of impacts.

Production tests that have been undertaken have been included in the model and in addition CSG production has been simulated by a large number of pumping wells within the various MGP leases. As the performance of future production tests is not known, the simulation assesses potential impacts from existing production testing undertaken in concert with MGP production in order to assess potential cumulative impacts over the production testing period. Pumping rates have been assigned based on historical records for the MGP, and based on projections until December 2016.

6.1.2 *Model Design*

The groundwater flow model covers a large area of approximately 150 km square, an area much larger than the area likely to be impacted by CSG production testing. The model was formulated to cover the entire ATP1103 and MGP area with an additional buffer zone to ensure that all potential impacts are observed within the model domain. The model domain is 150 km in the north-south direction and 150 km in the east-west direction. The model has been discretised into a grid of elements that are 1000m squares (150 rows and 150 columns). This choice of grid size is effectively limited by the numerical effort required to solve for more refined grids and by the need to maintain manageable model run times. The model origin is at 550000 mE, 7500000mN (GDA 1994, Zone 55). Each model layer is composed of 22500 cells, and a total of 157500 cells for the model. The model layers are shown in Figure 15.

Based on a map of subcrop geology, the Back Creek Formation rises both east and west of MGP. The potential impacts of the project are most likely to be seen within this trough. For this reason, significant parts of the square grid have been made inactive. Inactive cells do not contribute to calculations of groundwater flow, so they are effectively outside the boundary of the model.

The model layer structure was based on available geological data and the conceptual hydrogeological model developed in this UWIR. The extent and base of the layer has been sourced directly from the Petrel geological model. Table 20 below correlates model layers and stratigraphy. Given the lack of geological and hydrogeological data available, the Teriary undifferentiated sediments, basalt, Suttor Formation was grouped into layer 2 and the Moolayember Clematis, Rewan Formation was grouped into layer 3. Key data gaps included aquifer extents, aquifer properties, and aquifer interconnectivity.

Table 20 – MODFLOW model layers

Model Layer	Hydrostratigraphy	Color
Layer 1	Alluvium	
Layer 2	Tertiary undifferentiated sediments, basalt and Suttor Formation	
Layer 3	Moolayember Formation	
	Clematis Sandstone	
	Rewan Formation	
Layer 4	Rangal Coal Measures	
Layer 5	Fort Cooper Coal Measures	
Layer 6	Moranbah Coal Measures	
Layer 7	Back Creek Group	

The model layer structure in several rows of the model grid is shown in Figure 15. These three sections are from north to south. The width of the section is 150 km, and the vertical exaggeration is 10:1.

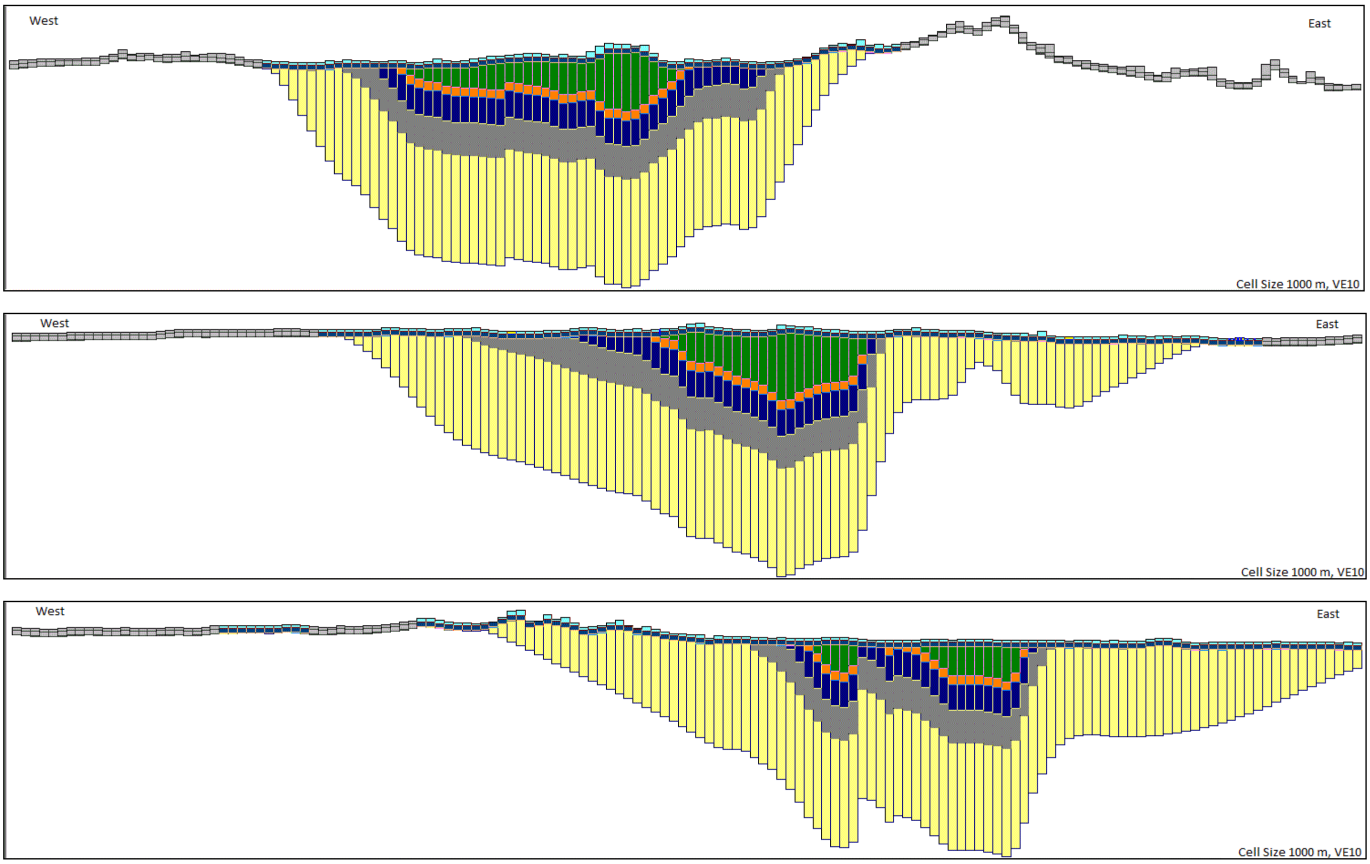


Figure 15: Diagram of Model Layer Structure

Layer thicknesses are small at the eastern and western margins where the cells are inactive, and therefore outside the active model domain. Thin layers also exist within the active model domain, where deeper layers subcrop beneath Tertiary sediments.

The geological model shows some evidence of sub-vertical faulting. While some faults may act to limit flow within hydrostratigraphic units, e.g. if vertical displacement across a fault causes aquifers to be juxtaposed against aquitards, there is currently insufficient data to support this phenomenon in the model, so layers are assumed to connect horizontally even if there appears to be some displacement. Layers 1 and 2 have been set as unconfined and the remaining layers have been set as confined. Each model layer has 22500 cells, so the model has a total of 157500 cells. Of these, 106,638 cells are active.

6.1.3 *Modelling Approach*

Model development has used available hydrogeological information that could be used to define appropriate hydrogeological parameters or to calibrate the model. A modelling approach has therefore been adopted using information gained from recently completed hydrogeological investigation projects in the Bowen Basin and close to the Project area.

The model was set up with the grid, hydrogeological parameters and boundary conditions The model was calibrated by matching predicted water table elevations to a surface sub-parallel to the land surface and matching stream invert levels in major drainage lines. Stream levels act as surrogates for measurements of water table elevation. Pumping wells were added. The model was then run for the period of historical abstraction, from January 2004 to December 2011 to assess impact from existing production testing. As no data on future production testing is available the predictive model run from 2011 to December 2014 assesses potential residual impacts from prior production testing against a background of ongoing MGP production in order to assess potential cumulative impacts.

6.1.4 *Model Parameters*

In order to assess model uncertainty, several sets of hydrogeological properties have been used. These parameters have been derived from existing Environmental Impact Statements and published reports relevant to the model region (BMA 2008, URS 2009, SKM 2004, MET Serve 2010, Hansen and Pearce 2006) as well as from general reference materials for representative aquifer types (Freeze and Cherry 1079, Fetter 1994). An average of the parameters collated was incorporated for the initial model runs. Analysis of this data indicated that the most variable parameters referenced in the reports were the values of hydraulic conductivity in the surficial Alluvial and Tertiary aquifers, the Rewan Formation and the various Coal Measures. Given the uncertainty associated with these parameters, sensitivity analysis has been proposed to be undertaken which is discussed in more detail in Section 6.1.8.

The hydrogeological parameters included in the model are summarised in **Table 21**. These values are based on assessment of properties used in other models in the region.

Table 21 – MODFLOW model layers parameters

Model Layer	Kxy (m/d)	Kz (m/d)	Ss (1/m)	Sy
Layer 1	20	2	$1x10^{-4}$	0.26
Layer 2	5	0.5	$1x10^{-4}$	0.2
Layer 3	0.005	0.0005	$1x10^{-5}$	0.05
Layer 4	0.05	0.005	$1x10^{-5}$	0.05
Layer 5	0.05	0.005	$1x10^{-5}$	0.05
Layer 6	0.01	0.001	$1x10^{-5}$	0.05
Layer 7	0.005	0.0005	$1x10^{-5}$	0.01
Kxy: horizontal hydraulic conductivity, Kz: vertical hydraulic conductivity Ss: specific storage, Sy: specific yield				

6.1.5 *Rainfall Recharge*

Based on a review of available EIS reports, recharge rates have generally been adopted based on a percentage of rainfall with percentages used ranging from 0.09 % to 5.5%. A review was undertaken of daily rainfall data for Moranbah (station No. 34038). A recharge rate of 0.000015 m/d was adopted for the Base Case, based on a calculation of 0.5% of annual rainfall.

6.1.6 *Boundary conditions*

Based on examination of plots of historical heads, prescribed head (Type 1) boundary conditions were assigned in the southeast of the model domain, at a level of 120 mAHD. The boundary conditions were set along a curved line, in all layers.

A total of 917 cells are on this boundary. Cells to the southeast of the boundary could have been made inactive, but groundwater flow on one side of a fully penetrating fixed head boundary has no effect on the other side, so leaving these cells active does not influence the main part of the model domain.

The effect of recharge is to cause heads to rise throughout the rest of the domain. For this reason, drain cells have been created in layer 1 along major drainage lines. A total of 662 cells act as drain cells, allowing excess recharge to discharge from the regional aquifer system.

Discharge from the drain cells should not be thought of as base flow, causing steady flow in rivers and streams. It is clear that drainage lines in the area only flow in response to heavy episodic rainfall. Discharge should therefore be interpreted as a form of localised evapotranspiration that occurs along drainage lines, where the depth to water table is shallow. The purpose of applying recharge and allowing evapotranspiration via drain nodes is to simulate a water table that reflects the topography, with shallow depth to water table near drainage lines and larger depth to water table far from drainage lines.

Pumping during recent years of production testing in ATP1103 was simulated with operations for the Moranbah Gas project to assess potential cumulative impacts. This has been represented by aggregating pumping from individual wells into a single rate for model cells. An average rate has been calculated to each of 20 x 6-month intervals.

Pumping has been applied in 177 cells, nearly all in layer 6 of the model (the Moranbah Coal Measures). The spatial distribution of pumping is not uniform. All but one of the cells have total abstraction less than 90 ML over the 10 years of pumping. All but 15 have total abstraction less than 50 ML over 10 years. Table 22 summarises the pumping regime for the production testing and Moranbah gas project applied in the model.

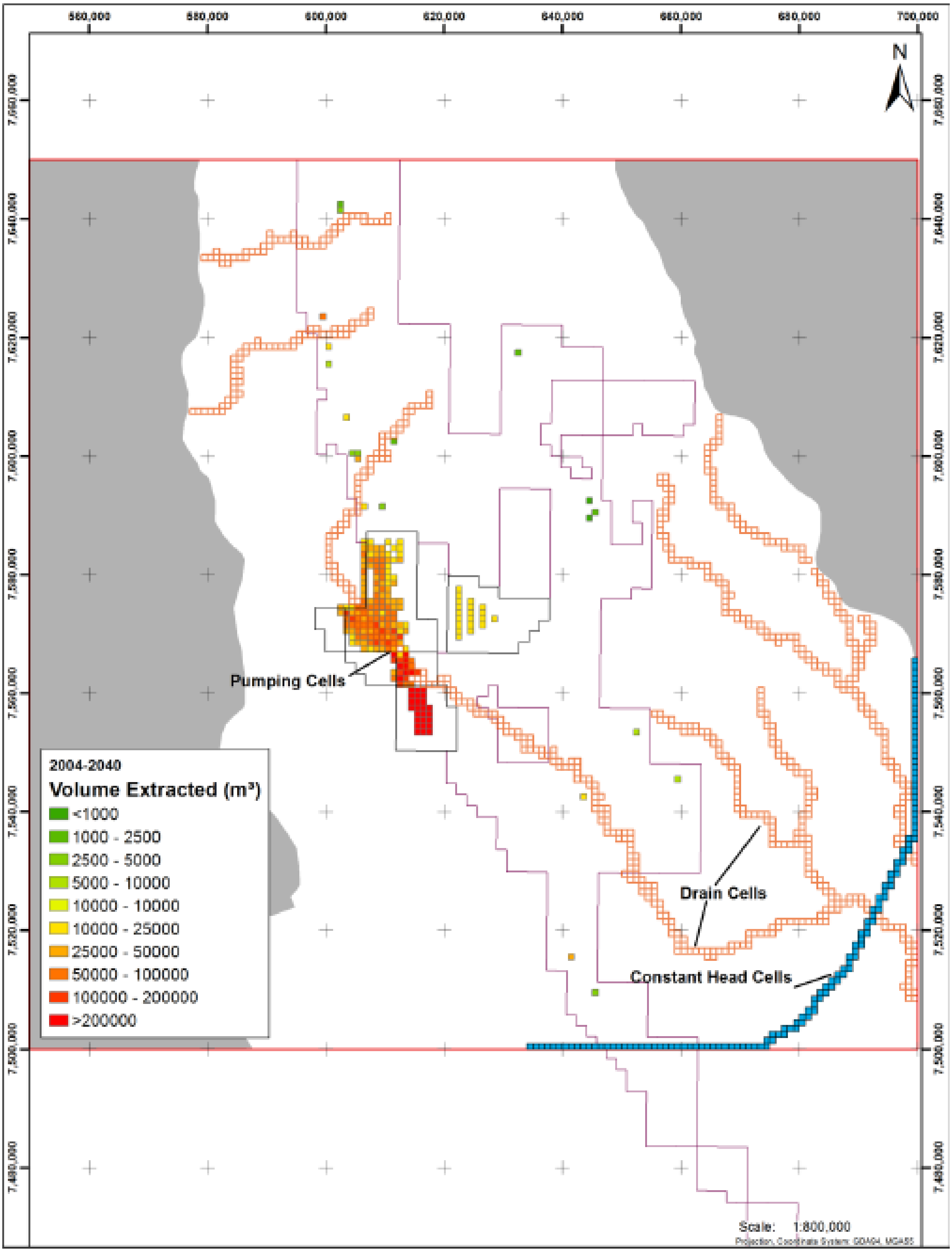
Table 22 – Pumping Regime in model

Period	Dates	ATP1103	Average Rates (m³/d)				Total (m³/d)
		Production testing Wells (m³/d)	PL191	PL196	PL224	Total	
1	2003	0	0	0	0	0	0
2	Jan 2004 - Jun 2004	0	306	0	0	306	306
3	Jul 2004 - Dec 2004	0	1511	0	0	1511	1511
4	Jan 2005 - Jun 2005	0	1552	0	0	1552	1552
5	Jul 2005 - Dec 2005	0	1161	9	0	1169	1169
6	Jan 2006 - Jun 2006	0	1240	25	0	1265	1265
7	Jul 2006 - Dec 2006	0	1107	106	0	1214	1214
8	Jan 2007 - Jun 2007	0	1052	268	0	1321	1321
9	Jul 2007 - Dec 2007	0	1061	412	0	1474	1474
10	Jan 2008 - Jun 2008	0	1040	178	0	1218	1218
11	Jul 2008 - Dec 2008	108	973	337	138	1448	1556
12	Jan 2009 - Jun 2009	116	1007	211	153	1372	1488
13	Jul 2009 - Dec 2009	588	896	118	121	1136	1724
14	Jan 2010 - Jun 2010	344	938	33	121	1092	1436
15	Jul 2010 - Dec 2010	224	582	0	39	621	846
16	Jan 2011 - Jun 2011	43	557	16	31	603	646
17	Jul 2011 - Dec 2011	37	776	67	104	948	985
18	Jan 2012 - Jun 2012	0	764	172	111	1047	1047
19	Jul 2012 - Dec 2012	0	1130	360	109	1599	1599
20	Jan 2013 - Jun 2013	0	992	318	106	1416	1416
21	Jul 2013 - Dec 2013	0	1218	622	106	1946	1946
Average rate		73	993	163	57	1213	1286
Number of bores			465	48	18	531	

Higher rates of abstraction would be expected to result in higher local decline in water level, but overall, regional decline in water level would be expected to reflect average rates of pumping. Figure 16 shows prescribed head and drain boundary conditions, as well as cells where pumping has been applied. The pumping cells are coloured according to the rate of pumping. The figure also depicts cells where pumping has been applied for Moranbah Gas Project (MGP). This is due to the fact that the groundwater model has been set up to predict impacts of water extraction during production testing at

MGP. These results are included in the UWIR for MGP. It can be seen that the pumping rates at MGP are considerably higher than the exploration rates in ATP1103.

Figure 16: Model Boundary Conditions



targetzero ► zero incidents ► zero injuries

6.1.7 *Calibration*

The groundwater model was designed to predict drawdown at a regional scale, with cell grids spaced 1km apart. Hence estimates of groundwater flow are necessarily averaged over individual model cells, and cannot predict precise water levels in individual monitoring wells. Similarly, pumping rates representing multiple coal seam gas wells are aggregated to act within one model cell and hence simulate rates larger than an individual extraction well. Nevertheless, the model should obey general principles applicable to the regional groundwater regime (Zhou and Li, 2011).

Differences in topographic elevation provide the driving force for regional flow, while the domain were included for both aquifers and aquitards, and groundwater and surface water interactions were simulated as line sources/sinks. Regionally, the water table and the topography are related (Haitejma and Mitchell-Bruker, 2005). Modern measurements of terrain elevation are quite accurate and precise, and hence the topography can be used as an approximation for the water table elevation.

The model was calibrated by requiring predicted water table elevations to reflect the topographic surface. Fixed drain boundary conditions imposed on the model represented major streams and rivers, while the MODFLOW – SURFACT model generated smaller streams representing increased evapotranspiration or ephemeral streams in order to maintain the water table below the ground surface. Although this methodology is less precise at a subgrid scale, the relative changes in the water table introduced by pumping are accurate and hence the depth to water table changes can be used as a predictive measure of pumping impact.

6.1.8 *Sensitivity Runs*

Based on the uncertainty identified in the hydraulic parameters, a sensitivity analysis was performed to investigate the effects of changing unknown model values. The purpose of the sensitivity analysis was to investigate how variable parameters would change the maximum drawdown predicted in model layers representing the coal seam pumping, and shallow aquifers accessed by nearby bores.

In the sensitivity runs, rainfall recharge rates were increased to represent 1% (S1, S2) and 5% (S3) of average yearly rainfall. In the surficial aquifers, hydraulic conductivity values were reduced or increased by a factor of two in runs (S2) and (S4) respectively. In the Rewan Formation, hydraulic conductivity was increased by a factor of 10 (S2, S3). In the coal seams, hydraulic conductivity was increased by a factor of 10 (S2, S3).

For each change in hydraulic properties, two sets of model runs were required. First the altered model was calibrated to match steady state water level conditions. Then the pumping rates associated with production testing and, in the MGP, projected CSG production were applied to the model and results simulated until the end of the model time period.

Drawdown associated with the pumping was analysed throughout the region. The maximum predicted drawdown within each hydrogeological unit was tabulated at the end of the historical pumping period in 2010. As a general principle, increasing the hydraulic conductivity allows water to move more freely in the aquifers. Increasing the rainfall recharge rate provides more water into the groundwater system, enabling faster recovery from effects of pumping. Hence the base case model, with the lowest simulated recharge rate and lower hydraulic conductivities, provides a larger estimate of drawdown within the pumped Moranbah Coal Measures and surficial Alluvial/Tertiary aquifer.

Hydrogeological properties and recharge rates were varied in three sensitivity runs, as shown in Table 23.

Table 23 – Sensitivity Run Parameters

	Sensitivity Run 1 (S1) 1% Recharge (3x10^{-5} m/d)		Sensitivity Run 2 (S2) 1% Recharge (3x10^{-5} m/d)		Sensitivity Run 3 (S3) 5% Recharge (1.5x10^{-4} m/d)	
Model Layer	Kxy (m/d)	Kz(m/d)	Kxy (m/d)	Kz (m/d)	Kz (m/d)	Kz (m/d)
Layer 1	20	2	10	1	40	4
Layer 2	5	0.5	5	0.5	5	0.5
Layer 3	0.05	0.005	0.05	0.005	0.05	0.005
Layer 4	0.05	0.005	0.5	0.05	0.5	0.05
Layer 5	0.05	0.005	0.5	0.05	0.5	0.05
Layer 6	0.01	0.001	0.1	0.01	0.1	0.01
Layer 7	0.005	0.0005	0.05	0.005	0.05	0.005
Kxy - horizontal hydraulic conductivity, Kz – vertical hydraulic conductivity						

6.2 Groundwater Model Predictions

Predictions have been made of decline in water level induced by CSG operations. Potential impacts are described in the following sections. The approach to numerical groundwater modelling has been determined based on the quality and quantity of available hydrogeological input data. Given the limited availability of reliable groundwater datasets, in particular hydrogeological parameters, it is considered appropriate to undertake sensitivity analysis in order to assess model uncertainty around hydrogeological parameters. Given the limitations due to data availability for construction of the groundwater model, it is not considered appropriate or beneficial to undertake predictive uncertainty assessment at this stage.

For underground water impact reporting purposes, an assessment of cumulative impacts, including the influence of mining operations, is not required and has not been undertaken.

Modelling results are described in the following sections.

6.2.1 *Steady Groundwater Flow*

The predicted water table elevation under steady state conditions with Base Case parameters is shown in **Figure 17** superimposed on subcrop geology. Water table contours are broadly consistent with expectations, with gentle gradients along the Isaac River valley, and steeper gradients in hilly terrain to the southwest, and also in the north central part of the model domain. The curvature of contours shows regions where groundwater is converging on drainage lines, supplying evapotranspiration.

Figure 18 shows a colour-shaded representation of depth to water table. The depth to water table is low along the Isaac River, including within the MGP leases.

With recharge at 0.5% of rainfall, the total recharge applied to the model domain is 226.5 ML/d. Of this, 41% discharges through prescribed head boundaries in the southeast and the remainder reports to drain nodes.

As further data on water levels in aquifers is collected more refined understanding of recharge or assumed discharge via evapotranspiration in areas with a shallow water table is anticipated.

One advantage of using MODFLOW-SURFACT is that water table elevations cannot be predicted to be above the land surface elevation. This means that predictions are inherently reasonable. All four initial distributions of head provide good starting values for predictions of decline in water level due to pumping.

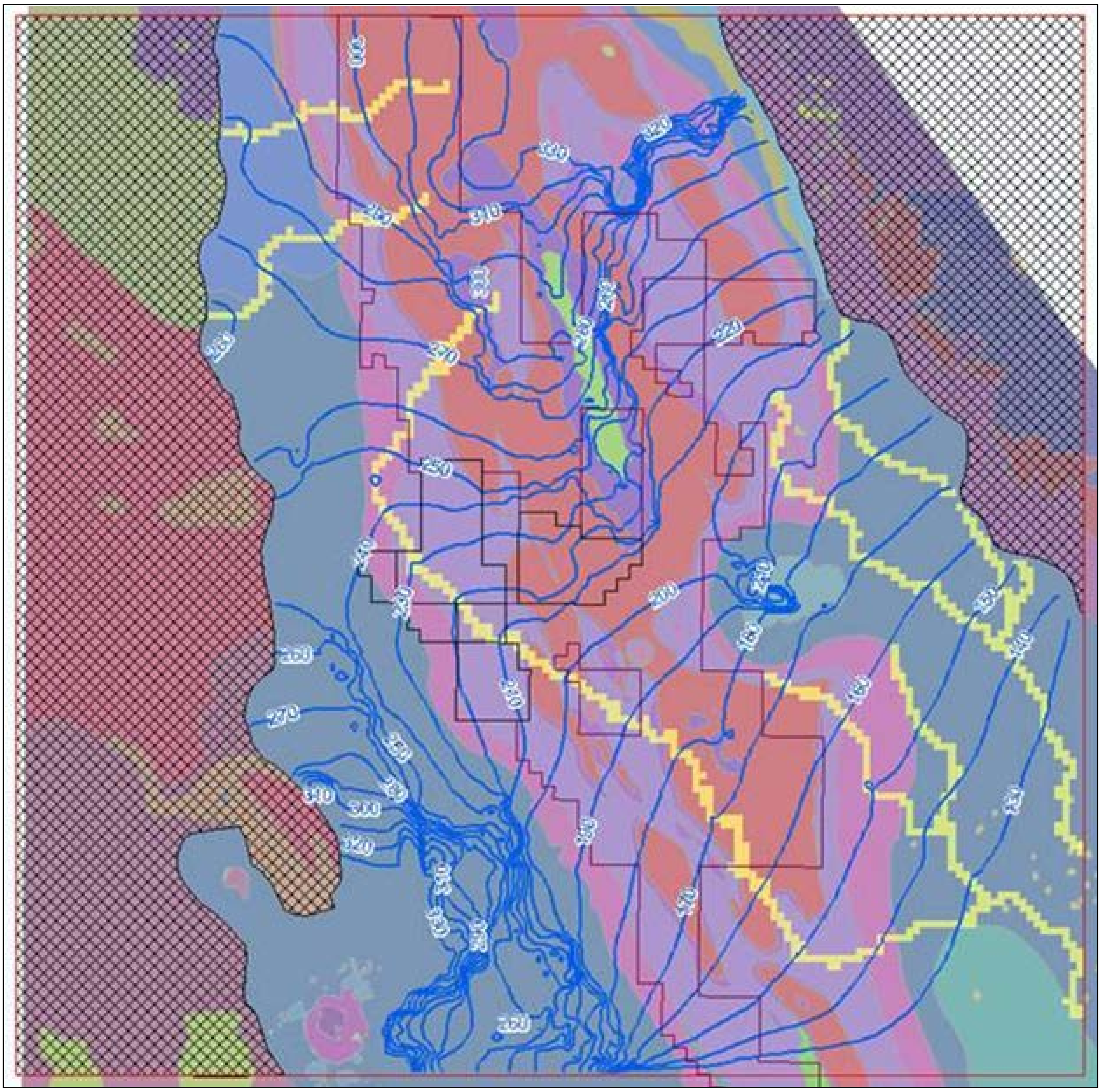


Figure 17 : Water table elevation under steady state conditions

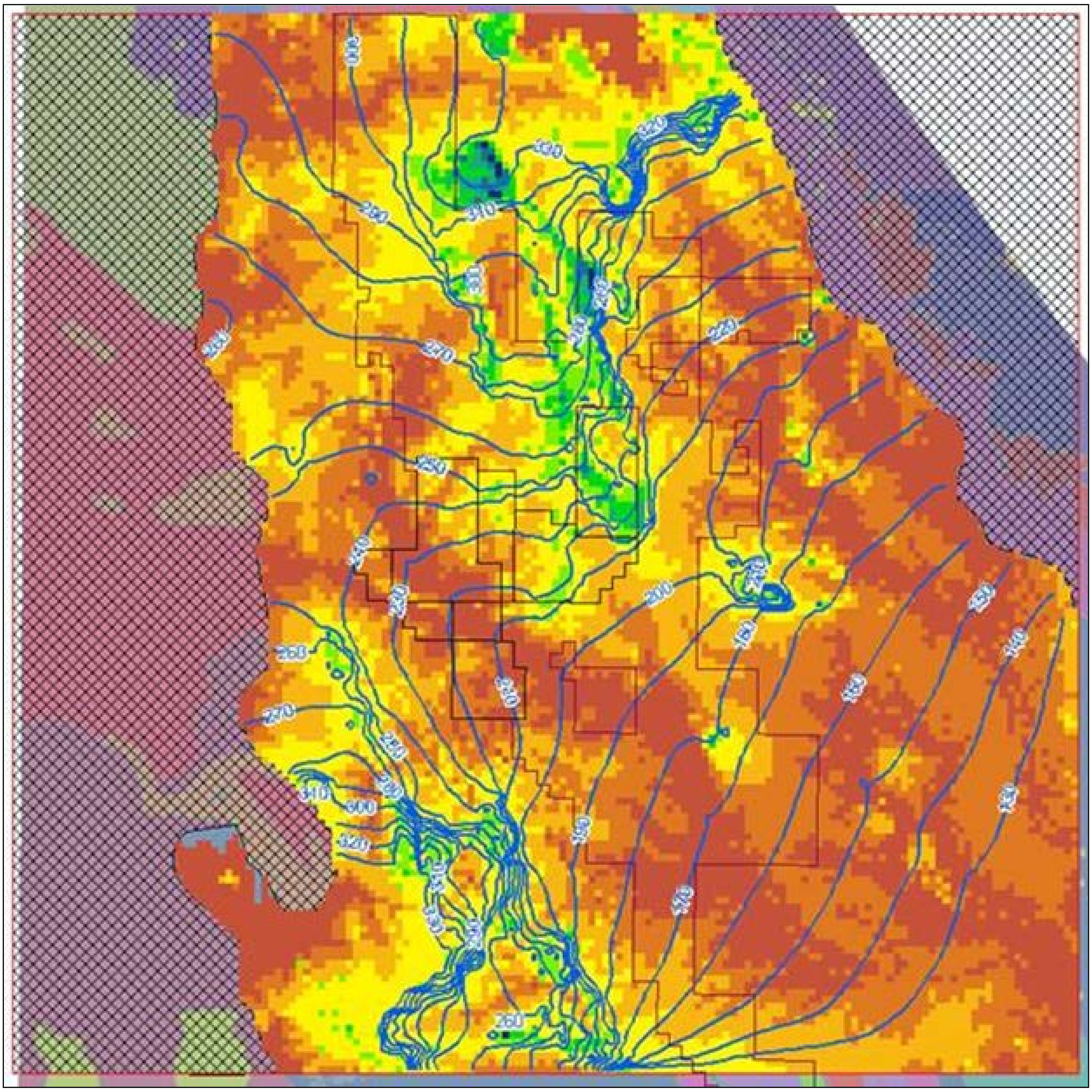


Figure 18 : Depth to water table under steady state conditions

6.2.2 *Groundwater Decline in Water Level*

The impact of decline in water level has been determined by a single transient simulation, and results were extracted at the end of historical pumping, to assess potential residual impacts from the prior Production testing. In addition, a model hydrograph around the largest production test has been presented. As production testing is of limited time and scale the impacts are shown at the end of the production testing dataset period (December 2011). As the hydrograph from a pilot test (**Figure 25**) shows, the greatest impacts occur at the time of pumping after which impacts rapidly reduce, hence, this output is considered to provide the best indication of maximum impact and take the place of maps of impact at three years and at any time.

Decline in water level is defined as the difference between initial (in this case, steady) heads and final heads after some period of pumping. Initial heads are almost equal in all model layers, because regional flow is almost horizontal, and vertical head gradients are therefore almost zero. However final heads are different in all layers, being lowest in the layer that is actively pumped. Vertical hydraulic conductivities combine with layer thicknesses and specific storativities to limit the rate at which abstraction affects the water table above.

Since most pumping draws water from the MCM, decline in water level in the MCM layer (Layer 6) is expected to be greater than at the water table. Decline in the water level in the MCM is greatest in those cells where cumulative abstraction is greatest. The greatest decline in water level at the water table is also consistently above the cells with the greatest pumping.

Figure 19 to 24 provides an overview of peak water level decline in each of the aquifers. Based on this, the maximum water level decline predicted in the water table aquifer is 0.05 m (5 cm) and is less than the bore trigger threshold of 2 m. The maximum water level decline predicted in the MCM is 4.6 m and this is less than the bore trigger threshold of 5 m.

The maximum water level decline predicted in all the other modelled aquifers is less than the appropriate bore trigger threshold.

Based on this, no Immediately Affected Area (IAA) or Long Term Affected Area (LAA) is predicted.

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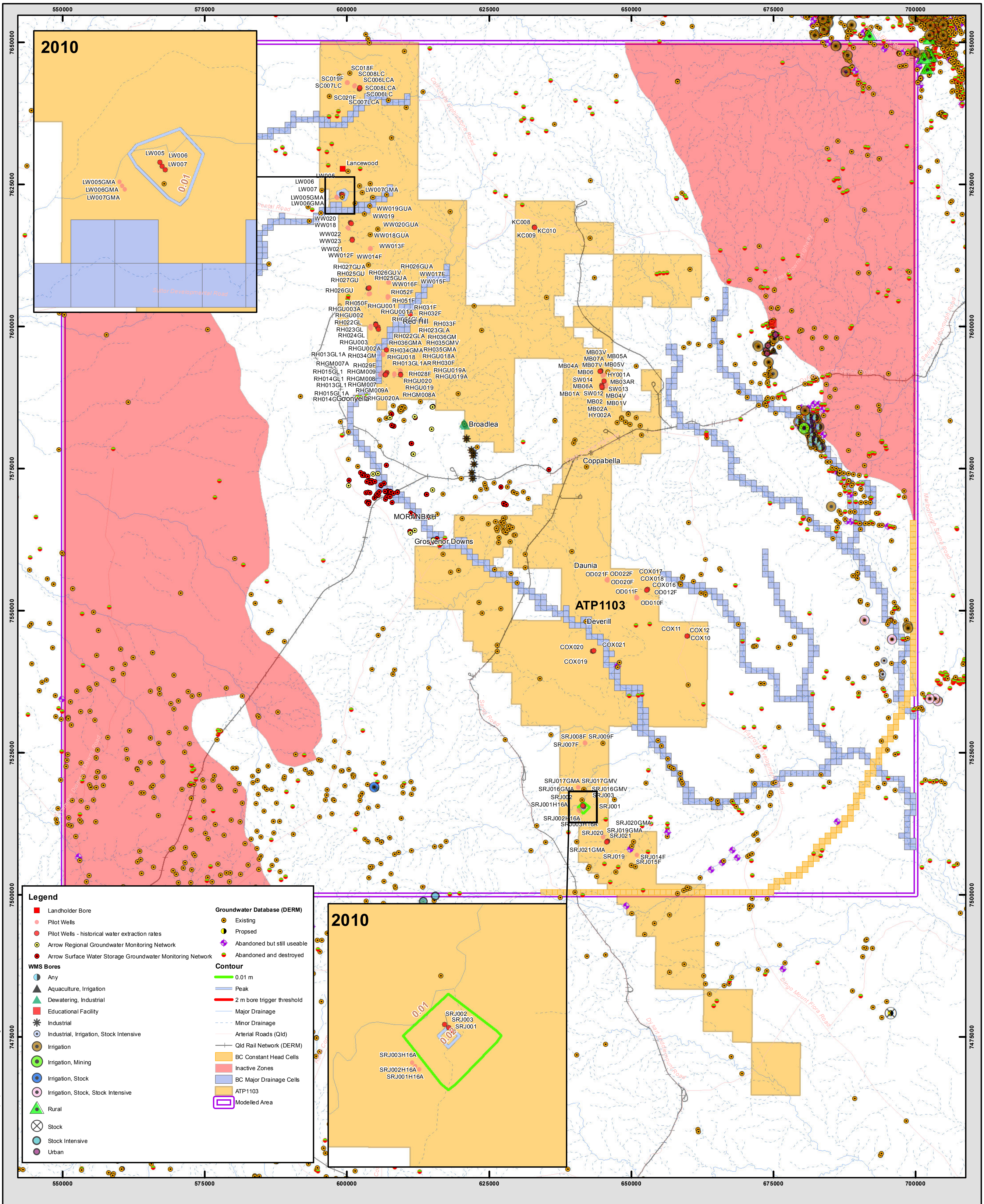

Figure 19. Peak decline in water levels in the water table aquifer

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

Scale: 1:615,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

0 25 50 Kilometres

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Document: V:\Products\Australia\Queensland\Bowen_Basin\Environment\111124 UWIR ATP1103 (KC)\mxd\Modelled Data\Figure 19.mxd

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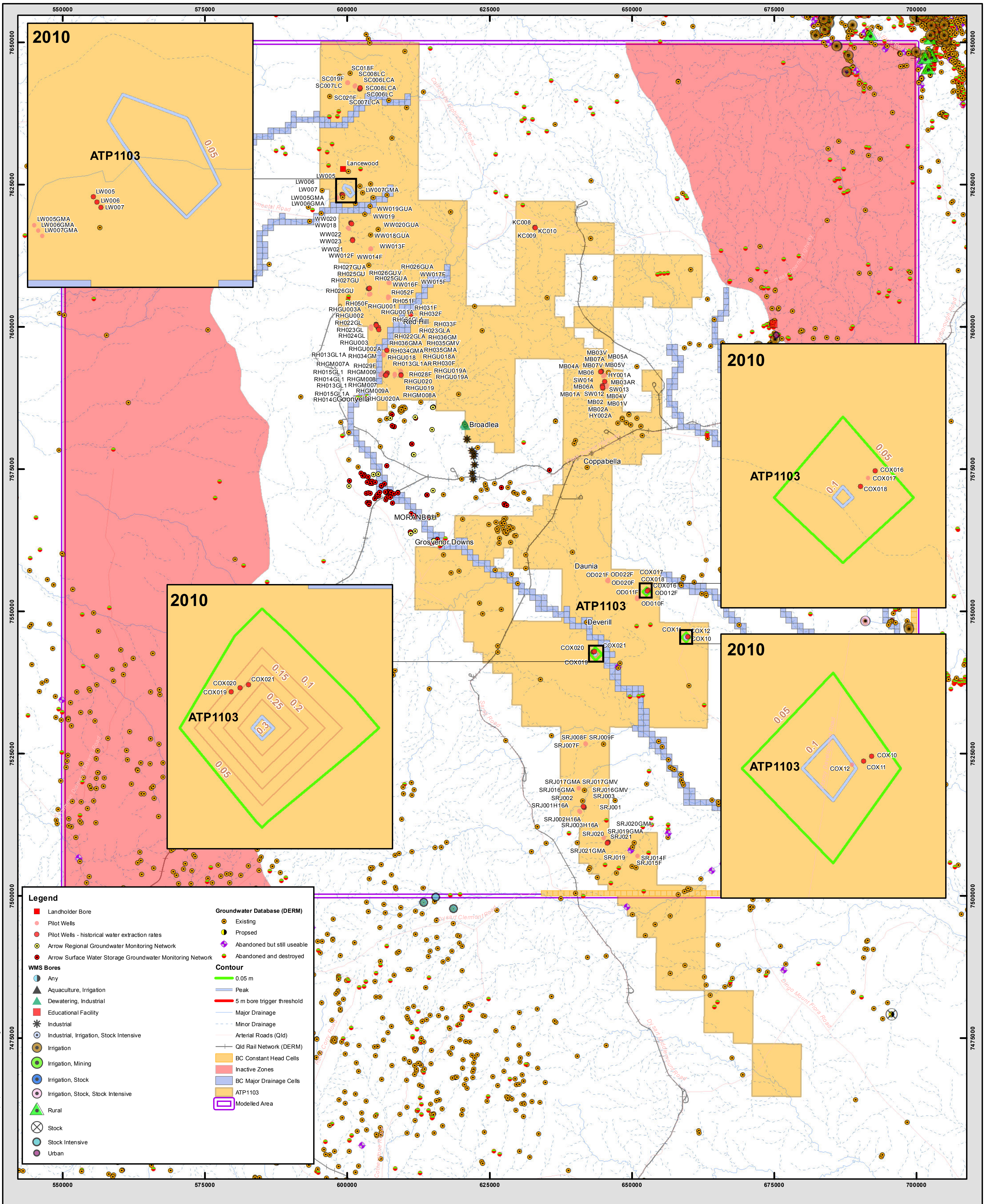

Figure 20. Peak decline in water levels in the Trassic Formation aquifer

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

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Kilometres
Scale: 1:615,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

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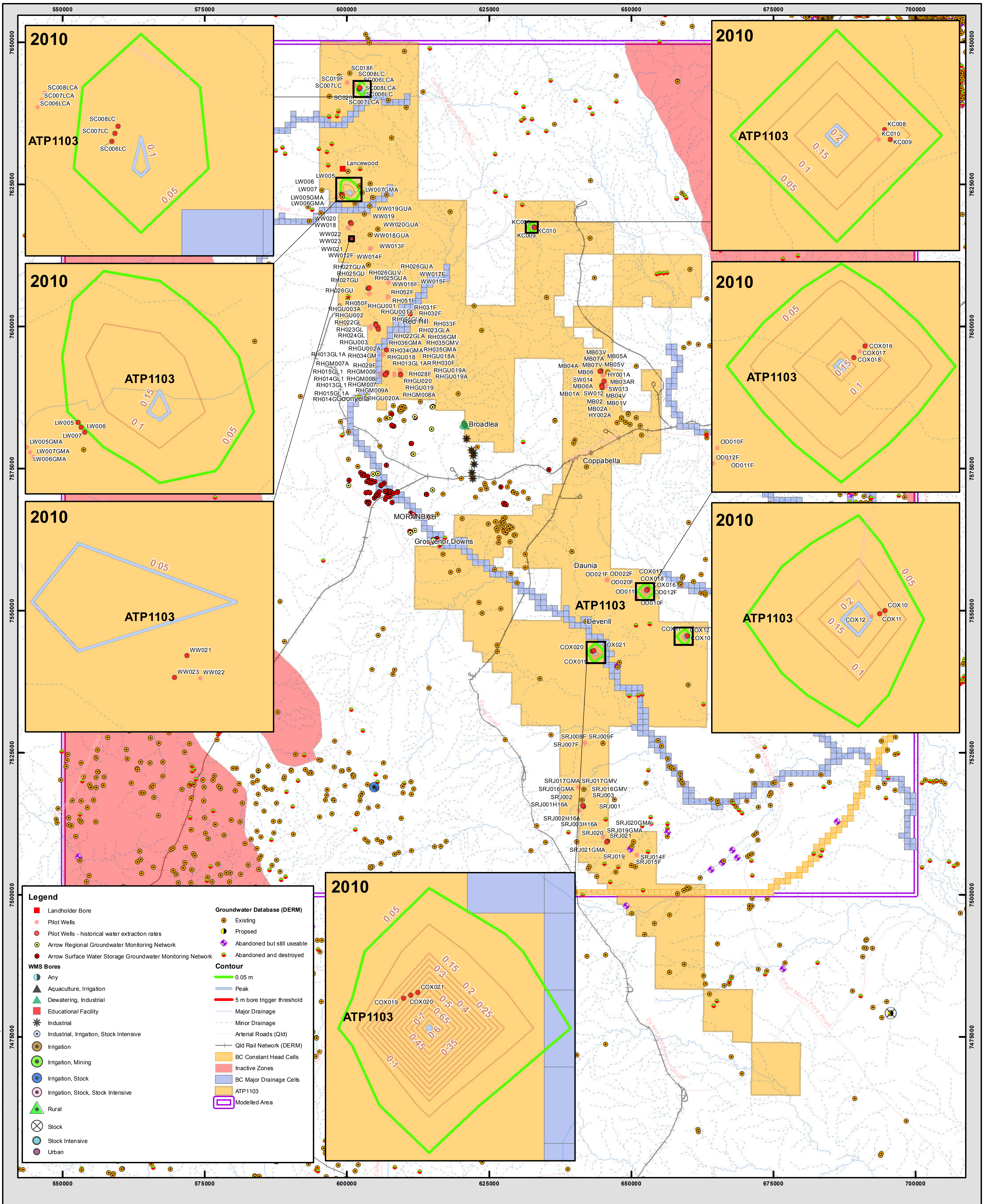

Figure 21. Peak decline in water levels in the Rangal Coal Measures aquifer

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

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Kilometres
Scale: 1:615,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

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The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

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Document: V:\Products\Australia\Queensland\Bowen_Basin\Environment\111124 UWIR ATP1103 (KC)\mxd\Modelled Data\Figure 21.mxd

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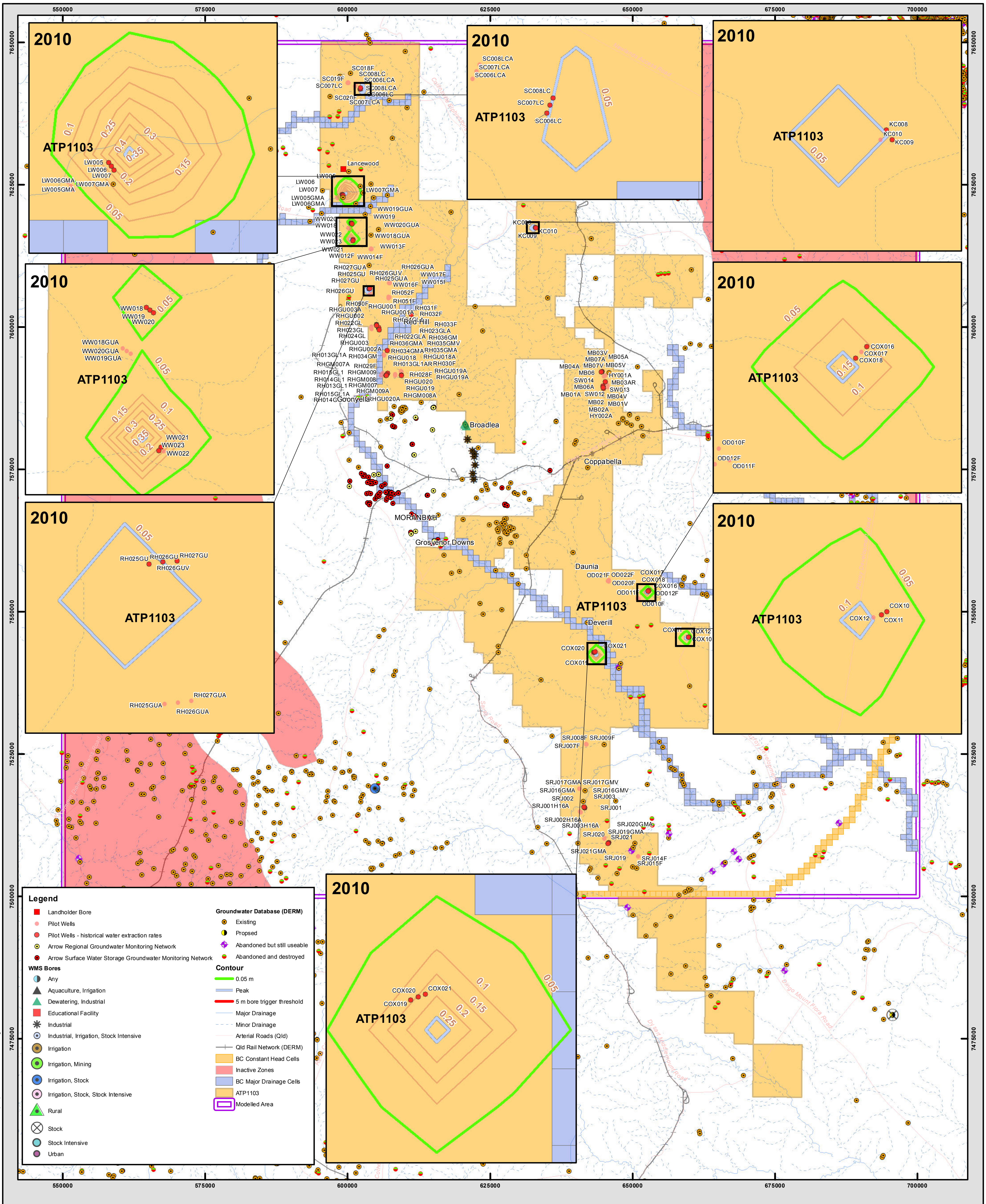

Figure 22. Peak decline in water levels in the Fort Cooper Coal Measures aquifer

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

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Kilometres
Scale: 1:615,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

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Document: V:\Products\Australia\Queensland\Bowen_Basin\Environment\111124 UWIR ATP1103 (KC)\mxd\Modelled Data\Figure 22.mxd

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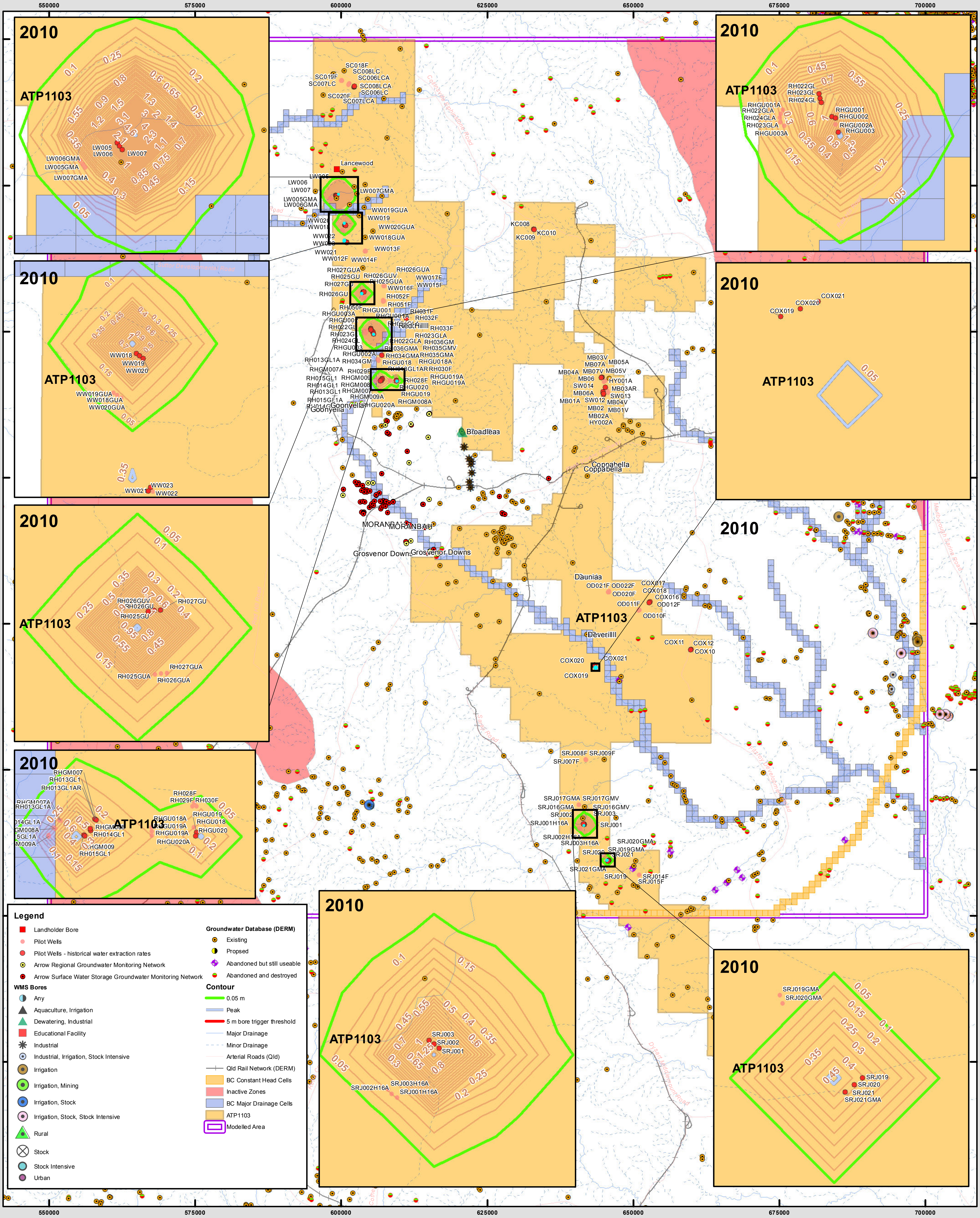

Figure 23. Peak decline in water levels in the Moranbah Coal Measures aquifer

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

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Kilometres
Scale: 1:615,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

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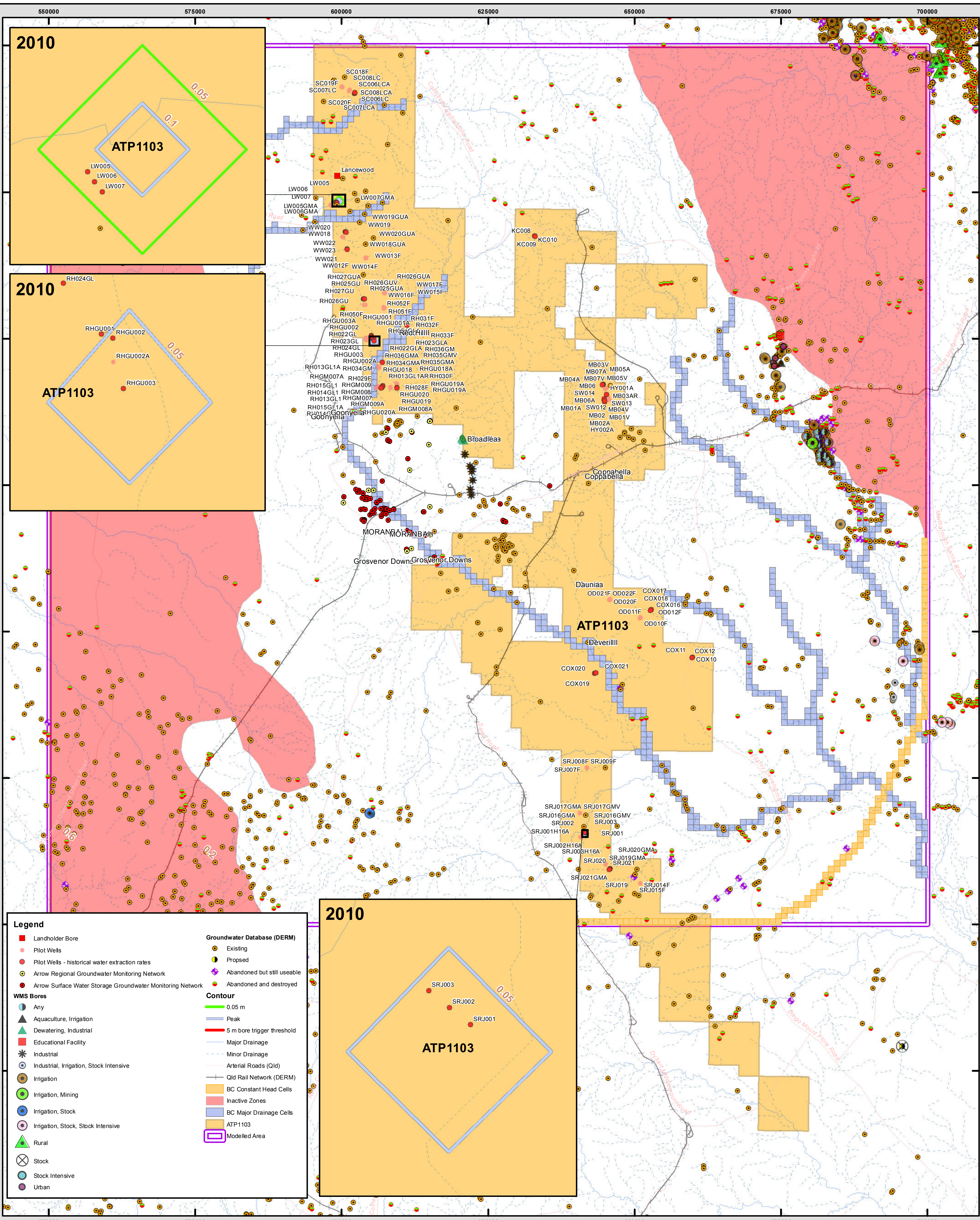

Figure 24. Peak decline in water levels in the Back Creek Group aquifer

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 7/12/2012
Issued To: K Chand
Author: tstringer

0 25 50
Kilometres
Scale: 1:615,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

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The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

Document: V:\Products\Australia\Queensland\Bowen_Basin\Environment\111124 UWIR ATP1103 (KC)\mxd\Modelled Data\Figure 24.mxd

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6.3 Localised Decline in Water Level at Production Tests

Production testing occurs over a limited time for each bore and abstracts a limited amount of water. The average water abstracted was 3.2 ML and was as low as 0.03ML. The maximum amount of water abstracted was 39 ML at Pilot well LW005. More detailed review of data from the simulation of this well indicated a peak impact of 5 m (Figure 25) in the Moranbah Coal Measures at the well prior to recovery of water levels. Thus impacts within the cone of depression away from the well will be less than this amount.

The nearest DNRM registered bore is located approximately 400 m from this production test and is screened in the overlying Suttor Formation aquifer. Both the distance and the much shallower formation indicate that impacts at this well (if any) would be much less than the bore trigger threshold, and this is borne out by the fact that it lies just inside the 1 cm (0.01 m) contour in Figure 23.

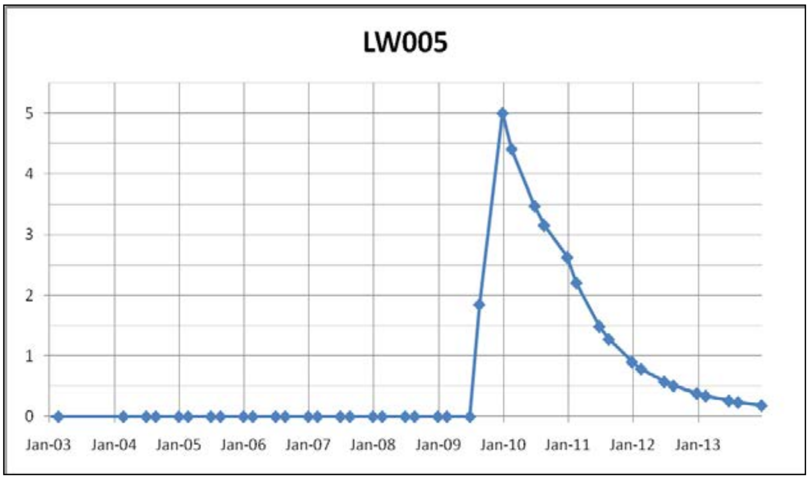

Figure 25 : Model hydrograph of production test LW005

A review of simulated model hydrographs for the next four largest production tests indicated peak impacts of:

- 4.7 m of decline in water level at LW007;
- 3.64 m of decline in water level at SRJ003;
- 2.13 m of decline in water level at RHGU002; and
- 1.13 m of decline in water level at WW018.

One registered bore (85447) occurs within 1 Km of LW007 (no registered bores are present within 1 Km of SRJ003; RHGU002 or WW018). However, this is again located in the overlying Suttor Formation and therefore not subject to the same level of decline in water level predicted in the coal measures. Based on this, a summary of information about water bores including the number of bores, location, authorised use or purpose of each bore is not required.

7 WATER MONITORING STRATEGY

7.1 Groundwater Monitoring Program

It is concluded that the impacts of extraction of underground water during and after production testing within ATP1103 are negligible considering that:

- limited volumes of water (181 ML) were taken during production testing carried out between 2008 and 2011;
- shallower aquifers (the main resource aquifers used in ATP1103) are separated from the perforated intervals of the production testing wells by intervening lower permeability formations;
- production testing wells are fully cased and cemented;
- groundwater modelling indicates;
    - ◊ the extremely limited extent (in the immediate vicinity of a single production testing well only) of water level decline equal to the bore trigger threshold within the Moranbah Coal Measures;
    - ◊ no water level decline by more than the bore trigger threshold elsewhere within the Moranbah Coal Measures;
    - ◊ no water level decline by more than the bore trigger threshold anywhere within the alluvial aquifers; and
    - ◊ no water level decline by more than the trigger threshold (0.2m) for springs.

However, in order to continue to refine the current understanding of the groundwater regime, as and when CH4 undertakes future production testing in ATP1103 the following monitoring will be undertaken:

- groundwater level monitoring is proposed in the wells to be tested; and
- water quality sampling is proposed in production wells to be tested to establish field parameters for the groundwater.

A water monitoring strategy incorporating a groundwater monitoring program has also been developed to collect hydrogeological data in ATP1103 around the MGP area. This includes:

- Site groundwater level and quality monitoring data in the deeper aquifers;
- Site groundwater level and quality monitoring data in the shallow aquifers;
- Site aquifer parameter data for shallow and deep aquifers; and
- Characterisation of interconnectivity of aquifers underlying the site.

The strata identified in ATP1103 have been grouped in to hydrogeological 'units' for the purpose of developing Arrow's Water Monitoring Strategy. Adjacent strata have been grouped together depending on whether or not they are aquifers and whether or not they are likely to be directly connected to the coal seams on which production testing will be conducted. The following 'units' are proposed:

- Quaternary Alluvium, Tertiary Basalt and Sediments: important local aquifers which are potentially directly connected to the Bowen Basin formations through sub-crop.
- Rewan Formation, Clematis Sandstone and Moolayember Formation: Triassic sedimentary formation aquifers, likely to be hydraulically separated from the coal seams by low permeability units within the underlying Permian formations ('Triassic').
- Fort Cooper and Rangal Coal Measures: coal seams (localised aquifers supporting small scale abstraction) and lower permeability interbeds ('upper Permian').
- Moranbah Coal Measures: coal seams (localised aquifers supporting small scale abstraction) and lower permeability interbeds.

The objectives of implementing this water monitoring strategy are to:

- Commence rigorous and publicly-presentable investigation and understanding of the hydrogeology of the Bowen Basin.
- Establish the ability to identify impacts of coal seam gas groundwater-related activities close to existing CSG production.
- Provide data for decision making and groundwater modelling.

7.1.1 *Groundwater Monitoring Network*

A regional aquifer groundwater monitoring network is to be developed. The MGP and the part of ATP1103 immediately surrounding the MGP area was divided into grid cells of 15km x 15km (225 km^2). Two groundwater monitoring bores are to be installed into each 'unit' within the MGP area, and one groundwater monitoring bore is to be installed into each 'unit' in ATP1103 and PLa222 (conditional on conversion to a Petroleum Lease).

The details for the proposed groundwater monitoring network are included in Appendix E. Figure 26 provides an overview of the spatial distribution of the groundwater monitoring network.

It is proposed that up to 24 groundwater monitoring bores will be installed on ATP1103 and adjacent PLa222 (conditional on conversion to a PL) prior to 31st December 2015. It should be noted that PLa222 has not yet been approved and production in this tenement is proposed only.

The primary reasoning behind the location and number of groundwater monitoring bores that make up the groundwater monitoring network is to provide good spatial coverage of groundwater monitoring points consistent with the hydrogeological significance of the unit and the likelihood for the unit to be impacted by the Project.. It is envisaged that this data will provide input into future refinement of the groundwater model. Proposed locations of each of the bores have been reviewed to take into consideration overlapping tenures with other mines to increase the longevity of the groundwater monitoring bores. It is important that any proposed open cut and underground mining operations do not destroy any of the groundwater monitoring bores so that long term groundwater level and quality data can be collated. The purpose of this monitoring network is to monitor the future effects of decline in water level and establish baseline groundwater level and quality data.

Further refinement of the groundwater monitoring strategy will be conducted as part of the annual review. The groundwater monitoring strategy will also be reviewed and amended for the revised UWIR due in three years from the date of this UWIR.

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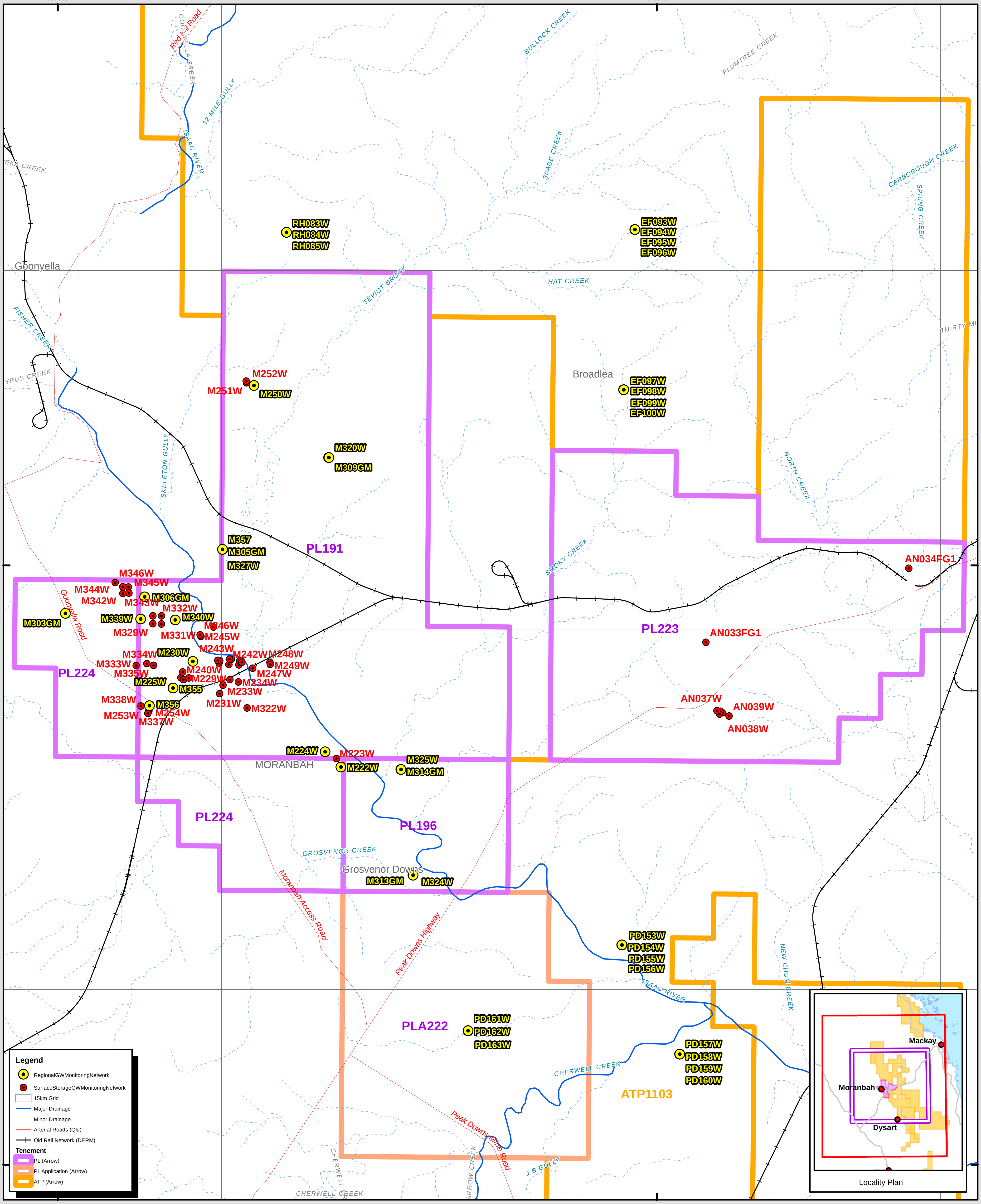

Figure 26. Groundwater monitoring network

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Envir. and Resource Mgmt.

Date: 26/07/2012
Issued To: K Chand
Author: sdenner

0 5 10
Kilometres
Scale: 1:150,000 @ A3
Coordinate System: GDA 1994 MGA Zone 55

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The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

Document: V:\Users\sdenner\BowenLARReportFigure2.mxd

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7.1.2 *Groundwater Monitoring Bore Specifications*

All groundwater bores will be installed as per the *Minimum Construction Requirements for Water Bores in Australia* (National Minimum Bore Specifications Committee, 2012).

Groundwater monitoring bores will be separately screened to accurately obtain groundwater level and hydraulic parameter information.

Bores targeting shallow aquifers will be drilled and constructed so that they are screened over the surficial (Quaternary/Tertiary) aquifer or Triassic aquifer or until sufficient water is intersected for monitoring and sampling purposes. Actual bore depths and target aquifers will be verified during drilling.

Bores targeting deep aquifers will be drilled and constructed so that they are screened within the target Permian aquifer (principally the Moranbah Coal Measures). Actual bore depths and target aquifers will be verified during drilling based on the geology intercepted.

It is proposed that vibrating wire piezometers will be installed alongside the standpipe groundwater monitoring bores to try and capture monitoring of multiple aquifers at each site. This will allow a basic assessment of aquifer interconnectivity and will be verified during drilling.

7.1.3 *Groundwater Monitoring Frequency*

Following the installation of the groundwater monitoring network, groundwater level/pressure monitoring is proposed to be undertaken on a monthly basis for a period of 12 months. Following this, groundwater level monitoring is proposed to be undertaken on a quarterly basis for the remainder of the CSG production operations on the MGP.

Following the installation of the groundwater monitoring network, groundwater quality monitoring is proposed to be undertaken on a six-monthly basis for a period of 12 months. Following this, groundwater quality monitoring is proposed to be undertaken annually for the remainder of the CSG operations on the MGP.

Following the first 12 months of monitoring, it is proposed that the data will be reviewed by a suitably qualified hydrogeologist. This assessment will characterise temporal and spatial variations in groundwater levels and quality to establish a baseline groundwater data set.

Following the establishment of baseline groundwater quality, the frequency of sampling and analyses may be modified for some or all of the chemical parameters.

7.1.3.1 Groundwater Monitoring Procedure

Groundwater monitoring will be conducted in accordance with Arrow Energy's (Arrow's) *Water Quality Sampling Manual*. This procedure has been prepared with reference to; the DEHP's (2009) *Monitoring and Sampling Manual 2009, Version 2*, AS/NZS 5667.1:1998 *Water quality - Sampling - Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*, and AS/NZS 5667.11:1998 *Water quality - Sampling - Guidance on sampling of groundwaters*.

During monitoring events, visual inspections will be undertaken by field staff to provide an assessment on bore integrity. Any observed bore defects will be noted and reported with follow up maintenance actions proposed. This aims to ensure that the bore is maintained and in a secured and operating condition.

7.1.4 *Groundwater Monitoring Suites*

It is proposed that an initial comprehensive laboratory analysis should be carried out for the first four groundwater monitoring events. Following this, an assessment should be undertaken by a suitably qualified hydrogeologist to assess the suitability of the groundwater quality parameters monitored. If considered appropriate, a reduced suite of chemical parameters and sample frequencies may be proposed.

The proposed field parameters and the laboratory analytical schedule for groundwater samples are listed in Table 24 and Table 25 below respectively.

Table 24: Field parameters monitoring suite

Parameter	
Temperature (°C)	Redox Potential (Eh)
Electrical Conductivity (EC)	Dissolved Oxygen (DO)
pH	

Table 25: Chemical parameters monitoring suite

Parameter	
Lab pH, EC and Total Dissolved Solids (TDS)	Calcium (Ca^{2+})
Total Alkalinity	Sodium (Na^{+})
Bicarbonate/Carbonate HCO_3^-/CO_3^{2-}	Potassium (K^{+})
Fluoride (F^-)	Magnesium (Mg^{2+})
Strontium (Sr)	Nitrite (NO^{2-}), Nitrate (NO^{3-}), Ammonia (NH^{4+})
Chloride (Cl^-)	Total Phosphorous (PO_4^{3-})
Sulphate (SO_4^{2-})	Total and Dissolved organic carbon (TOC/DOC)
Carbon Dioxide (CO_2)	Metals (dissolved): arsenic (As), barium (Ba), beryllium (Be), boron (B), chromium (Cr), cobolt (Co), Copper (Cu), Iron (Fe), Lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), vanadium (V), zinc (Zn)

8 SPRING IMPACT MANAGEMENT STRATEGY

No springs have been identified to exist within proximity of ATP1103. Therefore, based on available data, impacts to springs as a result of the project area activities will be negligible.

Within the project area, GDE's may exist within the Isaac Connors alluvial area. Impacts greater than the bore trigger threshold to the water table aquifer may impact GDE's. The maximum water level decline predicted in the water table aquifer is 0.02 m in 2010 and is less than the bore trigger threshold. Based on this a spring impact management strategy is not required to be prepared.

9 ANNUAL DATA REVIEW

This report will be reviewed annually. The review will consider:

- new hydrogeological data that significantly alters the conceptual model;
- whether new production testing has been undertaken or is planned; and
- whether the predictions made in Section 5 have materially changed.

The implementation of the water monitoring strategy will be reported to the commission on an annual basis in conjunction with the annual UWIR review.

The proposed schedule for the review will comprise:

- Summary of significant changes provided to DEHP two months before UWIR anniversary date; and
- Public consultation on anniversary date and subsequent DEHP review and report dissemination as required by the Water Act (2000).

Glossary

Abstraction	The removal of water from a resource e.g. the pumping of groundwater from an aquifer.
Adsorption	The adhesion of molecules of gas, liquid, or dissolved constituents to a surface (compare Desorption)
Aeolian	Sedimentary deposits formed by wind.
Alluvium	Unconsolidated deposits such as sands, gravels and clays deposited by flowing water such as rivers and streams.
Anistropy	Anisotropy is the property of being directionally dependent, as opposed to isotropy, which implies homogeneity in all directions.
Anthropogenic	Caused by human activity.
Aquatic Ecosystems	The abiotic and biotic components, habitats and ecological processes contained within rivers and their riparian zones and reservoirs, lakes, wetlands and their fringing vegetation.
Aquifer	A saturated geological layer or formation that is permeable enough to yield economic quantities of water.
Aquiclude	A geological formation having zero permeability to water, such as un-fractured crystalline rock.
Aquitard	A geological formation having low (but not zero) permeability to water, such as a silty or clayey layer.
Argillaceous	A geological formation containing significant proportions of clay minerals.
Artesian Aquifer	A confined aquifer with the potentiometric level above ground level.
Artesian Bore	A borehole where the potentiometric level is above ground level.
Attenuation	The reduction in concentration of a contaminant. This may be due to degradation, dispersion or dilution.
Avulsion	Abandonment of an old river channel and the creation of a new one.
Baseflow	Sustained flow of a stream in the absence of direct run-off, due to groundwater discharge.
Bore	A hole drilled in the ground to obtain samples of soil or rock, intersect groundwater for extractive use, monitoring or investigation, or for a range of other purposes. In Australia is also a commonly used term for a constructed groundwater well.
Brackish	Water containing moderate salt concentrations significantly less than sea water, with Total Dissolved Solids typically between 1,000 and 10,000 mg/L. (Compare Fresh, Saline and Brine).
Brine	Saline water with a total dissolved solids concentration greater than 40,000 mg/L or coal seam gas water after it has been concentrated through water treatment processes and/or evaporation.
Calcareous	Containing significant proportions of calcium carbonate.
Catchment	An area which discharges to a common point.

Coal Seam Gas Water	Groundwater that is necessarily or unavoidably brought to the surface in the process of coal seam gas exploration or production. Coal seam gas water typically contains significant dissolved salts, has a high sodium adsorption ratio (SAR) and may contain other components that have the potential to cause environmental harm if released to land or waters through inappropriate management. Coal seam gas water is a waste, as defined under the section 13 of the Environment Protection Act. (DEHP, 2011).
Colluvium	Sedimentary deposit formed primarily by gravity forces, typically at the base of a slope or a cliff.
Cone of Depression	The area of drawdown produced in the watertable or groundwater potentiometric surface due to pumping.
Confined Aquifer	An aquifer in which groundwater is confined under pressure.
Confining Layer	Geological material through which significant quantities of water cannot move, located below unconfined aquifers, above and below confined aquifers.
Contaminant	A contaminant can be a gas, liquid or solid, an odour, an organism (whether alive or dead), including a virus, energy (including noise, heat, radioactivity and electromagnetic radiation), or a combination of contaminants.
Contamination	The release (whether by act or omission) of a contaminant into the environment.
Cuesta	A ridge formed by gently tilted sedimentary rock strata.
Desorption	The processes releasing molecules of gas, liquid, or dissolved constituents from a surface (compare Adsorption).
Discharge	Removal of water from or flow out of an aquifer, including flow to surface water, another aquifer, or artificial means such as pumping. See also 'abstraction'.
Discharge Area	An area where groundwater flows out of an aquifer.
Disconformity	A break in the sequence of sedimentary deposition followed by resumed sedimentation, where the buried non-depositional surface lies between parallel strata on a regional scale.
Dissolved Solids	Soluble compounds such as salts which are in solution.
Down Warp	A downward bend in sedimentary layering caused by tectonic movement.
Drawdown	The drop in the watertable or potentiometric level when water is being pumped from a well.
Ecosystem	A system made up of the community of living things (animals, plants, and microorganisms) which are interrelated to each other and the physical and chemical environment in which they live.
Facies	A horizon of sedimentary rock formed under a particular set of environmental conditions, resulting in a distinct assemblage of sedimentary structures, mineralogy, grainsize, fossils and other features.
Fault	A structural discontinuity in a rock mass or geological formation.
Fluvial	Pertaining to a river or stream.
Fluvio-Lacustrine	Pertaining to a combined environment involving a river or stream and lake conditions.
Flux	The rate of flow (mass transport) of a fluid or other material or compound transported by that fluid.
Formation	A geological structure such as a rock mass or layer.

Fresh Water	Water containing low salt concentrations, typically less than 1,000 mg/L. (Compare Brackish, Saline and Brine).
Gilgai	A group of undulations and closed depressions at the soil surface, caused by the presence of swelling clays and seasonal movement due to changes in moisture content. Gilgai may range in size from a few meters up to 100 m across, and have a typical vertical amplitude of 30-50 cm.
Groundwater	Any sub-surface water, generally present in an aquifer or aquitard.
Groundwater Flow	The movement of water in an aquifer.
Heavy Metals	Metallic elements of atomic weight greater than that of Iron (e.g. Copper Arsenic, Mercury, Chromium, Cadmium, Lead, Nickel and Zinc).
Heterogeneous	Having different properties or composition at different locations.
Hydraulic Conductivity	A standard measure of the permeability of a geological formation or its ability to transmit groundwater flow.
Hydraulic Gradient	The slope of the watertable in an unconfined aquifer, or the potentiometric surface in a confined aquifer.
Hydraulic Head	A measure of the pressure head of water in aquifer, commonly measured as the elevation to which water will rise in a constructed well.
Hydrogeology	The study of the inter-relationships of geologic materials and processes with water, especially groundwater.
Hydrostatic Pressure	The pressure exerted by a fluid at equilibrium due to the force of gravity.
Indurated	Pertaining to a rock or soil hardened by mineral recrystallisation due to heat, pressure or chemical precipitation.
Infiltration	Rainfall penetration into the soil profile or sub-surface. Infiltrated water that accesses the watertable is one component of groundwater recharge.
Jumpups	The flat tops of mesas formed by erosional processes.
Labile	Unstable, likely to change or decompose.
Lateritisation	A process of weathering, dissolution and leaching resulting in a hard crust dominated by iron and aluminium oxides.
Lithology	The physical composition of a rock.
Marine Regression	A period of sea level fall over geological time.
Marine Transgression	A period of sea level rise over geological time.
Meander Scar	A remnant landform caused by the abandonment of a stream bend which has first produced a cutoff-meander, oxbow lake or billabong, and been gradually infilled by sediment such that it no longer contains open water.
Mesa	An elevated area of land with a flat top and sides that are usually steep cliffs.
Montmorillonite	A clay mineral with swelling properties.
Mound spring	A naturally occurring outlet of upwelling groundwater, with a characteristic mound or crater shape formed by deposition of minerals.
Nutrients	A chemical that an organism needs to live and grow, or a substance used in an organism's metabolism obtained from its environment.
Onlap	A sedimentation regime occurring during a marine transgression.
Offlap	A sedimentation regime occurring during a marine regression.
Palaeochannel	Unconsolidated sediments or semi-consolidated sedimentary rocks deposited in ancient, currently inactive river and stream channel systems.

Peat	A sedimentary deposit dominated by partially-decomposed plant material, and considered to be an early stage in the formation of coal.
Perched Aquifer	An unconfined aquifer of limited extent located above the true watertable.
Perennial	A stream or river (channel) that has continuous flow in parts of its bed all year round during years of normal rainfall.
Permeability	The ability to transmit fluids through a porous medium.
Piezometer	A type of well specifically constructed in an aquifer for monitoring purposes, and screened at a specific depth to provide measurements of pressure head at that point.
Piezometric Level	The pressure head of water measured in a piezometer, from a specific depth or point in an aquifer.
Porosity	The ratio of void spaces in a geological formation compared to the bulk formation volume.
Potable Water	Water of suitable quality for human consumption.
Potentiometric Level	A measure of the pressure head of water in an aquifer at a given location, usually used in reference to a confined aquifer.
Potentiometric Surface	An imaginary layer which defines the potentiometric levels for a confined aquifer. In an unconfined aquifer it is more commonly termed as the watertable.
Pyroclastic	Material which is deposited from air-borne particles ejected by a volcanic eruption.
Recharge	Addition of water to or flow into an aquifer (generally) from rain. Also used to describe water entering an aquifer from surface water, groundwater, or artificial means.
Recharge Area	An area in which water enters an aquifer.
Reactivated Fault	A pre-existing fault in a geological setting which becomes the preferred surface to accommodate movement during a new period of tectonic activity.
Regolith	The unconsolidated or weathered geological material at the Earth's surface.
Runoff	Rain water that flows across the land surface without entering the sub-surface.
Saline Water	Water containing high levels of dissolved salts, typically between 10,000 and 40,000 mg/L. (Compare Fresh, Brackish and Brine).
Saturated Zone	The zone in which the voids in the rock are completely filled with water. The watertable represents the top of the saturated zone in an unconfined aquifer.
Sediment	Unconsolidated geological material which has been formed by a process of deposition as discrete particles.
Sedimentary Sequence	A succession of layers of sedimentary rock caused by sequential deposition.
Semi-Confined Aquifer	A confined aquifer having a leaky confining layer.
Specific Yield	The ratio of the volume of water a rock will release by gravity drainage to the bulk volume of the rock.
Spring	The land to which water rises naturally from below the ground and the land over which the water then flows.
Standing Water Level	The depth below natural ground surface to the water level in a well or bore when it is at equilibrium with the surrounding formation (i.e. 'at rest' or 'fully recovered' from pumping). Also referred to as Static Water Level.
Storage Coefficient	A measure of the ability of aquifer material to store water, due to volumetric storage (Specific Yield) plus elastic storage.

Storativity	A measure of the ability of an aquifer to store water. Storativity is a function of storage coefficient and aquifer thickness.
Stratigraphy	The sequential classification of geological materials based on their age of formation.
Sustainable Yield	Amount of water that can be abstracted from an aquifer over a long period of time without dewatering the aquifer or impacting the resource.
Total Dissolved Solids	Concentration of dissolved salts (TDS).
Through Flow	The horizontal movement of water beneath the ground surface, including flow in the unsaturated zone (eg. soil) or saturated zone (eg. aquifer).
Transmissivity	The rate at which an aquifer can transmit water. It is a function of properties of the aquifer material and the thickness of the porous media.
Travertine	A mineral commonly found in caves, composed of finely crystalline calcium carbonate which has been precipitated from solution in groundwater.
Unconfined Aquifer	An aquifer with no confining layer between the water table and the ground surface where the water table is free to rise and fall.
Unsaturated Zone	The part of the geological stratum above the saturated zone, also called the vadose zone. The unsaturated zone may be dry, or may contain water under partially saturated conditions.
Uplift	The relative upward movement of rocks due to tectonic forces.
Vertical Anisotropy	Differing properties of a geological material in the vertical direction compared to horizontal direction.
Watertable	The top of the saturated zone in an unconfined aquifer.
Well	A hole drilled into a groundwater resource (aquifer), oil or gas resource reservoir) and constructed with a casing and screen or similar. In Australia also commonly referred to as a 'bore'.
Well Field	A group of boreholes in a particular area having a common use, such as for groundwater, oil or gas extraction.
Well Yield	The flow rate obtainable from an extraction well or bore.

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APPENDIX A – Physical parameter monitoring data from Arrow Energy wells (2004 – 2007)

	9/09/2004	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007	25/09/2007
	pH	pH	pH	pH	pH	pH	pH	pH	pH	pH	pH
GM001			8.1	8	6.3	6.3	7.80	7.80	7.7	7.6	6.60
GM002		7.6	7.8		7.3	7.3	7.90	7.80	7.9	7.4	
GM003	7.29	8.1	8	7.9			7.30	6.90	7.7	7.4	
GM004	7.45	7.9	7.9	7.8		7.7	7.90	7.80	7.8	7.5	7.60
GM005	7.61	8.1	8	8.1		7.7	8.20	8.10	6.6	7.5	7.70
GM006	7.56		8	8.3			8.50	8.00	7.2	8.3	
GM007	7.47			8.2		7.8	8.20	7.80	7.7	7.6	7.50
GM008	7.41		7.9	8		7.1	8.00	7.70	7.8	7.6	7.50
GM009	7.49	7.7	8	7.9	8.2	8.2		7.90	7.8	7.7	7.80
GM010	7.69	7.8	7.8	7.7	8.1	8.1	8.00	7.60	7.7	7.7	
GM011	7.47	8	8	8.2	8.1	8.1	8.20	7.80	7.9	7.7	7.40
GM012	7.63	7.9	7.9	8.1	8.1	8.1	8.00	7.70	7.9	7.6	
GM013	7.62	7.7	7.8	7.7			8.00	7.70	7.8	7.6	7.60
GM014		8	8	8		7.3	8.00	8.00	8.0	7.7	7.70
GM015		8		8.2		8	8.30	8.70	8.2	7.6	7.60
GM016		8.2	8.1	8.1		8	8.40	8.20	8.1	7.8	
GM017		8.3	8.3				8.80		8.0	7.9	
GM018		8.4	8.2	8.1		7.3	6.80	8.20	8.3	8.2	7.80
GM019		8.1	8.1	8.2		8.2	8.40	8.20	8.4	7.6	8.30
GM020		8.2	8.2	8.3	8.2	8.2	8.20	8.10	8.0	7.7	

	9/09/2004	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007	25/09/2007
GM021		8	7.9	8.1	8.2	8.2	8.10	8.40	7.9	7.6	7.90
GM022		7.9	7.8	8	7.2	7.2	7.90	8.00	8.0	7.6	
GM023		8	7.8	7.9	7.9	7.9	N/A	7.80	8.0	7.4	7.80
GM024		7.6	7.7	7.7	7.6	7.6	7.90	7.50	7.6	7.5	
GM026		8.3	8	8.1		7.6	8.60	8.20	8.1	7.7	
GM027		8.2	8.1	8.2		8.1	8.20	8.00	8.1	7.9	
GM028	8.43	8.4	7.9	7.9	8	8	8.40	7.80	8.2	7.8	7.40
GM029		8.2	8.1	8	8.3	8.3	8.20	8.30	8.2	7.7	
GM030		8.2	8.2	8.1		8	8.50	8.10	7.9	7.6	
GM031			7.7	7.9			8.00	7.80	7.6	7.6	6.50
GM032		7.9	7.8	7.9		7.8	7.60	7.50	7.6	7.6	
GM033			7.7	7.8			8.10	7.70	7.6	7.7	
GM034				8		6.7	8.00	8.00	7.7	7.5	
GM035							7.90	8.20	8.0	7.6	8.70
GM036				7.8	7.9	7.9	7.90	7.60	7.8	7.5	
GM037							7.90	7.70	8.1	7.8	
GM038							7.90	8.10	8.3	8.2	7.80
GM039							7.90	8.10	8.2	8	
GM040							7.80	8.20	8.3	8.2	8.00
GM041							7.70	8.30	8.3	8.2	
GM042							7.80	8.20	8.5	8.1	6.80
GM045							7.70	8.10	8.0	7.5	
GM046					7.9	7.9	7.90	7.60	7.7	7.7	8.70

	9/09/2004	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007	25/09/2007
P001	7.64	8.1	8	8.1		7.7	8.10	8.00	7.9	7.8	
P002	7.72	7.3	7.8	7.4	7.5	7.5	8.00	8.10	8.0	7.7	
P004	7.29	8	8	7.8		7.8	8.00	7.90	7.7	7.6	7.9
P005	7.33	8	8.1	8.3		7.9	8.30	8.00	8.0	7.9	7.7
P006	7.47		8.1				8.00	7.90	7.8	7.4	
P007	7.32	8	7.9	7.9		7.8	8.10	7.80	7.7	7.5	7.9
P008		8.1	7.9	8.8		7.7	8.10	7.80	7.7	7.6	7.7
P009	7.68	8	8	9.3	8	8	8.00	8.10	7.9	7.8	7.7
P010	8.18	8	8.1	8.1			8.40	8.00	8.2	7.8	
P011	7.81	8.2	8.1	8.2	8.2	8.2	8.30	8.00	8.0	8.0	7.9
P012	7.73	7.8	8	8.3	7.7	7.7	8.20	8.00	8.0	7.8	
P013	7.71	7.6	8	8.2				7.70	8.0	7.7	7.9
P014		8.3	8.2		8	8	8.10	8.00	8.0	7.7	7.4
P016		8.1	8.1	8.1		8.1	7.90	8.00	8.1	7.8	
P017		8.4	8.1	8.2		no water	8.10	8.50	7.8	7.6	
P018				W/O			N/A	7.90	N/A	N/A	8.2
P019		8.4	8.1	8		8.3	8.30	8.60	8.3	7.7	8.7
P021		7.9	8.1	8.2	8.2	8.2	8.00	8.40	7.9	7.7	7.8
P031		8.2	7.8	7.9		7.9	8.00		7.8	7.6	7.9
Q023		8.3	8.2	W/O	8.1	8.2	8.30		8.5	8.2	
P038								7.6	8.2	8.0	8.1
P039								7.7	8.3	7.9	
P040								8.2	8.2	8.0	8.3

	9/09/2004	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007	25/09/2007
P047									8.0		7.9

	9/09/2004	1/06/2005	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007
	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity
GM001		10500		10300	11100	10100	10100	8500	8800	8000	7800
GM002		11000	11500	12600		9300	9300	8200	7600	7400	8600
GM003	11650	11700	11500	10400	10700			9100	9300	8300	8200
GM004	12990	12900	11900	10700	11200		9000	9700	9800	8200	8100
GM005	13210	15300	14100	12400	13100		1110	11100	11100	8100	8800
GM006	13530	14800		12400	13300			12500	14400	11700	4600
GM007	8930	8700			9200		8100	7300	6300	6600	6800
GM008	10560	10200		9800	9500		9100	8100	7300	7800	7700
GM009	9570	10300	9000	9300	9400	8800	8800		7200	7000	7500
GM010	10920	10400	10800	11300	10200	9700	9700	7800	7600	6900	8400
GM011	10100	10600	10600	11200	9800	9100	9100	8100	8300	7300	7700
GM012	10740	10700	11200	11300	10000	8800	8800	8200	8100	7200	8000
GM013	10890	11100	10900	11700	10600			8400	8100	7600	8400
GM014		10700	9900	9200	9600		8900	8800	7800	7300	7800
GM015		10700	10200		9300		8500	8200	8200	8200	9200
GM016			12400	7900	7900		6900	6900	6500	6400	6300
GM017		7200	6800	6300				5800		5800	5400
GM018		6100	5900	9600	5100		4500	4500	4100	4200	4600

	9/09/2004	1/06/2005	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007
GM019		7300	7700	8500	7200		6100	5800	5300	5200	6100
GM020		10600	11000	9600	10100	8900	8900	8100	7300	7400	8800
GM021		11900	11500	10600	11200	9700	9700	8800	8300	8100	9800
GM022		12600	12500	10300	11900	10100	10100	9500	9000	8900	10200
GM023		12000	12300	10400	11500	10100	10100		9500	8900	10300
GM024		11300	11600	12800	11300	7800	7800	8700	9000	8000	9000
GM025											6600
GM026		7900	7600	6800	9600		6300	6500	6000	6100	6000
GM027		9400	8400	7600	7700		6600	6100	5600	6300	5700
GM028	5870		7500	6800	7200	5700	5700	5800	5100	5500	5500
GM029		7400	7100	7000	7000	5400	5400	5200	4300	4700	4300
GM030		10800	11500	10800	10600		9500	8700	8400	8800	7000
GM031		14100		12000	12500			8900	10700	9200	7400
GM032		12400	11800	10600	10700		9900	9200	9500	8800	7100
GM033		12700		11100	10100			9100	7400	8200	6800
GM034					12700		1130	10200	11400	9800	9700
GM035								10300	9500	9600	11300
GM036					10300	9500	9500	8300	8400	7800	8600
GM037								8600	8700	7800	7800
GM038								6300	6200	6200	7200
GM039								7200	5900	6000	6800
GM040								6500	5300	5500	5900
GM041								5900	4700	4900	4300

	9/09/2004	1/06/2005	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007
GM042								5700	4200	4500	5100
GM043											
GM044											
GM045								8800	8400	8000	9200
GM046						9800	9800	8400	8800	8000	7700
GM047											
P001	10590	10700	10800	9800	10000		9100	8200	7300	8200	8000
P002	6450	5600	6500	6300	5500	4100	4100	4200	3900	4100	4700
P004	11050	12600	11500	10700	10700		9300	9600	9400	8400	8000
P005	13330	14700	13600	11500	13200		1140	10600	10000	9800	8900
P006	12620	12700		11000				9900	9600	8900	8700
P007	12670	12100	12600	11700	11600		1040	9600	9300	10200	8600
P008		9800	9800	9300	9200		8100	7500	6800	7000	6600
P009	10490	8700	9000	8000	8300	7300	7300	8500	7000	6100	6300
P010	4730	4400	4400	5000	4500			3600	3400	3200	3700
P011	6890	7100	7100	7900	6600	6200	6200	5600	5600	5200	5300
P012	6500		7900	11500	6500	5700	5700	5200	5200	4700	5300
P013	8460	8000	7600	8500	7500				6000	5800	6000
P014		11000	11900	10700		10200	1020	9800	8900	9500	10500
P016		12600	8500	12000	10100		1040	9900	6100	8800	10500
P017		10700	10100	9500	9100			7900	1400	8200	7100
P018			0		W/O				7500	N/A	N/A
P019		9500	10200	10500	9500		8300	7500	7000	7200	8600

targetzero ► zero incidents ► zero injuries

	9/09/2004	1/06/2005	1/07/2005	1/08/2005	1/09/2005	1/10/2005	1/11/2005	13/01/2006	1/05/2006	4/08/2006	14/01/2007
P021		9300	9800	8700	8800	7900	7900	7300	6600	7200	8900
P031			11000	9900	10400		9200	10500		7800	6500
Q023		4400	4500	4300	W/O	6600	3600	3600			4100
P038									9100	7300	8200
P039									7600	6800	8000
P040									6200	6200	7100
P047										5800	

APPENDIX B – Physical parameter monitoring data from Arrow Energy wells (2010)

Well Name	Date	Water Testing		
		Conductivity	pH	TDS
		(µS/cm)		(ppk)
GM003	31/08/2010	12.85	7.55	7.16
GM004	31/08/2010	12.48	7.41	6.98
GM005	31/08/2010	11.52	7.19	6.39
GM006	31/08/2010	4.33	8.02	2.25
GM030	31/08/2010	8.27	7.58	4.49
GM031	31/08/2010	12.26	7.38	6.89
GM032	31/08/2010	13.05	7.58	7.36
GM033	31/08/2010	8.79	7.35	4.83
GM034	31/08/2010	13.65	7.62	7.91
P004	31/08/2010	13.23	7.35	7.50
P005	31/08/2010	14.51	7.82	8.03
P006	31/08/2010	13.23	7.48	7.52
P031	31/08/2010	12.90	7.55	7.15
GM007	31/08/2010	7.88	7.35	4.25
GM008	31/08/2010	8.65	8.62	4.73
GM026	31/08/2010	8.35	7.77	4.47
GM027	31/08/2010	7.07	7.66	3.88
GM028	31/08/2010	7.41	7.45	4.09
P001	31/08/2010	18.67	7.77	10.55

Well Name	Date	Water Testing		
		Conductivity	pH	TDS
P007	31/08/2010	14.44	7.23	8.22
P008	31/08/2010	10.91	7.68	5.96
GM001	31/08/2010	12.85	7.55	7.16
GM002	31/08/2010	12.13	7.39	6.7
GM009	9/09/2010	8.25	7.34	4.86
GM010	31/08/2010	10.55	7.47	5.84
GM011	31/08/2010	11.55	7.59	6.24
GM012	31/08/2010	10.84	7.4	11.66
GM013	31/08/2010	8.92	7.32	4.89
GM036	31/08/2010	11.16	7.43	6.25
GM037	9/09/2010	6.58	7.53	3.6
P002	31/08/2010	4.62	7.04	3.44
P009	9/09/2010	8.65	7.26	6.02
P010	31/08/2010	4.44	7.8	2.34
P012	31/08/2010	12.96	7.36	5.71
P013	31/08/2010	8.62	7.66	4.69
P037	9/09/2010	7.9	7.83	4.16
GM014	31/08/2010	5.59	8.08	2.97
GM015	31/08/2010	9.23	7.92	5.02
GM016	31/08/2010	6.23	7.93	3.38
GM017	31/08/2010	4.23	8.36	2.41

Well Name	Date	Water Testing		
		Conductivity	pH	TDS
GM018	31/08/2010	4.2	7.99	2.19
GM035	31/08/2010	13.38	7.9	7.47
P014	31/08/2010	9.9	7.93	5.4
P015	31/08/2010	12.24	7.94	6.79
P017	31/08/2010	10.39	7.99	5.67
P018	31/08/2010	9.12	8.05	5.01
GM020	1/09/2010	10.48	7.91	5.73
GM021	1/09/2010	11.06	7.76	6.05
GM022	1/09/2010	8.75	7.98	4.76
M082GM	3/09/2010	5.18	8.17	2.83
M082P	3/09/2010	7.88	7.96	4.26
M084GM	3/09/2010	9.9	7.93	5.23
M084P	3/09/2010	8.3	7.97	4.52
M085GM	3/09/2010	10.54	7.64	5.78
M085P	3/09/2010	9.12	7.97	4.96
M086GM	3/09/2010	5.25	8.25	2.8
M086P	3/09/2010	6.01	8.64	3.2
M087GM	3/09/2010	5.15	8.45	2.72
M087P	3/09/2010	5.34	9.41	2.85
M088GM	3/09/2010	5.56	8.24	3.05
M088P	3/09/2010	5.73	9.35	3.02
M089GM	3/09/2010	6.27	8.36	3.28

targetzero
► zero incidents ► zero injuries

Well Name	Date	Water Testing		
		Conductivity	pH	TDS
M089P	3/09/2010	6.81	8.76	3.63
M151GM	3/09/2010	6.83	8.21	5.59
M151P	3/09/2010	6.64	7.59	3.56
P019	3/09/2010	9.78	7.93	5.32
P020	3/09/2010	9.72	7.96	5.33
P021	1/09/2010	9.29	7.99	5.1
GM038	30/08/2010	7.48	8.04	4.01
GM039	30/08/2010	6.15	7.95	3.31
GM040	30/08/2010	6.66	8.28	3.55
GM041	30/08/2010	4.97	8.05	5.01
GM042	30/08/2010	4.92	8.33	2.62
GM057	30/08/2010	7.8	7.92	4.23
M054	30/08/2010	5.9	8.4	3.12
M055	30/08/2010	15.84	7.52	8.8
M056	30/08/2010	6.92	8.05	3.68
M058	30/08/2010	8.02	8.08	4.34
M059	30/08/2010	10.05	7.88	5.4
M075	30/08/2010	11.31	8.13	6.28
M077	30/08/2010	16.49	7.73	9.05
M078	30/08/2010	14.2	7.63	7.85
M079	30/08/2010	6.75	8.18	3.63
M080	30/08/2010	7.08	7.97	3.79

Well Name	Date	Water Testing		
		Conductivity	pH	TDS
M081P	30/08/2010	5.53	8.16	2.94
M081GM	30/08/2010	6.32	8.23	3.39
M158GM	30/08/2010	4.82	8	2.53
M158P	30/08/2010	8.14	8.04	4.41
P038	30/08/2010	10.58	8.12	5.8
P040	30/08/2010	8.37	8.25	4.58
P041	30/08/2010	6.99	8.35	3.75
P042	30/08/2010	6.75	8.47	3.62
M060	28/08/2010	7.15	7.86	3.89
M061	28/08/2010	14.65	8	8.15
M069	28/08/2010	17.33	7.85	9.78
M070	28/08/2010	9.21	7.68	4.93
M071	28/08/2010	19.69	7.69	5.78
M072	28/08/2010	9.52	7.68	5.16
M073	28/08/2010	7.06	7.99	3.88
M074	28/08/2010	7	8.08	3.83
M076	28/08/2010	12.3	7.28	6.8
M099	28/08/2010	7.46	14.45*	4.05
M100	28/08/2010	5.94	7.9	3.27
M101	28/08/2010	6.38	7.74	3.42
M102	28/08/2010	9.48	7.1	5.14

Well Name	Date	Water Testing		
		Conductivity	pH	TDS
M103	28/08/2010	7.2	7.91	4
M104	28/08/2010	7.88	7.99	4.25
M105	28/08/2010	8.23	7.89	4.57
M106	28/08/2010	7.6	7.42	4.12
M107	28/08/2010	6.05	8.11	3.3
M108	28/08/2010	7.61	7.88	4.14
M109	28/08/2010	8.76	7.86	4.88
M110	28/08/2010	11.36	7.87	6.17
M113	28/08/2010	8.1	7.58	4.3
M114	28/08/2010	9.41	7.6	5.35
M126	28/08/2010	13.8	7.02	7.95
M127	28/08/2010	9.46	7.37	5.14
M128	28/08/2010	8.95	7.48	4.92
M129	28/08/2010	9.63	7.51	5.22
M130	28/08/2010	8.47	8.01	4.68
Q001	28/08/2010	8.75	7.96	4.75
Q002	28/08/2010	9.3	7.92	5.3
Q003	28/08/2010	11.8	7.54	6.5
M117	28/08/2010	7.68	8.02	4.06
M118	28/08/2010	6.27	8.37	3.42
M119	28/09/2010	7.97	8.3	4.26

Well Name	Date	Water Testing		
		Conductivity	pH	TDS
M121	28/08/2010	8.73	8.61	4.72
M122	28/08/2010	8.72	8.66	4.66
M123	28/08/2010	8.95	8.33	5
M124	28/08/2010	8.96	8.26	4.79
M125	28/08/2010	6.83	7.86	3.77
GM046	9/09/2010	10.77	11.19	5.94
GM051	5/09/2010	6.83	8.1	3.71
M048	5/09/2010	9.54	8.61	5.23
M049	5/09/2010	9.26	8.21	5.01
M052	5/09/2010	6.9	8.54	3.74
M067	5/09/2010	6.03	8.89	3.23
M093	5/09/2010	11.15	7.46	6.2
P047	5/09/2010	9.95	8.09	5.47
M094	9/09/2010	4.87	8.91	8.62
M095	9/09/2010	4.78	9.03	7.95
M096	5/09/2010	6	10.69	7.28
M097	5/09/2010	3.57	6.62	7.54
M098	5/09/2010	6.76	12.32	7.2
M134GM	31/08/2010	14.03	7.54	7.82
M134P	31/08/2010	13.18	8.31	7.39
M135GM	31/08/2010	14.58	7.39	8.20

*erroeneous data

targetzero ► zero incidents ► zero injuries

APPENDIX C – Chemical parameter monitoring data from Arrow Energy wells

External Analysis			15-March-2004			15-March-2004		
SAMPLE DESCRIPTION			GR3	GR4	GR5	P12 V	GM12 V	GM13 V
CCI LAB ID			CHO11	CHO12	CHO13	CHO11	CHO12	CHO13
PHYSICAL ANALYSIS								
Total Dissolved Solids		mg/L	5000	7220	7670	5000	7220	7670
pH			7.22	7.06	7.11	7.22	7.06	7.11
Electrical Conductivity		(us/cm)	7570	10930	11660	7570	10930	11660
Turbidity		pcu	1840	142	125	1840	142	125
Turbidity (filtered)		pcu	0.3	<0.1	2.2	0.3	<0.1	2.2
Colour (Apparent)		pcu	1000	140	100	1000	140	100
Colour (True)		not	2	2	90	2	2	90
CHEMICAL ANALYSIS								
Calcium	filtered	mg/L	29.00	50.00	55.00	29.00	50.00	55.00
Magnesium	filtered	mg/L	10.00	15.00	18.00	10.00	15.00	18.00
Sodium	filtered	mg/L	1330	2040	2140	1330	2040	2140
Potassium	filtered	mg/L	56.5	11.4	93.2	56.5	11.4	93.2
Hydroxide as CaCO3		mg/L	<1	<1	<1	<1	<1	<1
Carbonate as CaCO3		mg/L	<1	<1	<1	<1	<1	<1
Bicarbonate as CaCO3		mg/L	727	548	612	727	548	612
Alkalinity as CaCO3		mg/L	727	548	612	727	548	612

Sulphate	filtered	mg/L	1.3	<1.0	<1.0	1.3	<1.0	<1.0
Chloride		mg/L	1800	2670	2790	1800	2670	2790
Aluminium	filtered	mg/L	0.06	7.02	3.07	0.06	7.02	3.07
Barium	filtered	mg/L	0.09	0.08	0.07	0.09	0.08	0.07
Iron	total	mg/L	17	19.5	19.1	17	19.5	19.1
Manganese	filtered	mg/L	7.27	12.9	13.2	7.27	12.9	13.2
Silica	filtered	mg/L	0.06	7.02	3.07	0.06	7.02	3.07
Strontium	filtered	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Iron	total	mg/L	6.8	12.5	11.1	6.8	12.5	11.1
Fluoride		mg/L	2	1.6	1.5	2	1.6	1.5
Ammonia as N		mg/L	2.85	3.85	4.16	2.85	3.85	4.16
Nitrate as N		mg/L	<0.01	0.02	<0.01	<0.01	0.02	<0.01
Total Organic Carbon		mg/L	28	3	9	28	3	9

External Analysis			15-April-2004				15-April-2004		
SAMPLE DESCRIPTION			GM010v	GM011V	GM012V	GM013V	P011V	P012V	P013V
CCI LAB ID			CH015	CH016	CH017	CH018	CH020	CH021	CH022
PHYSICAL ANALYSIS									
Total Dissolved Solids		mg/L	6020	5470	5480	5840	4000	3080	4170
pH			8.02	8.12	8.08	7.93	8.15	8.21	8.14
Electrical Conductivity		(us/cm)	9750	9800	9800	10200	7020	5300	7870
Turbidity		pcu	30.9	7.6	38	40	8.5	21	55
Turbidity (filtered)		pcu	<1.0	2.94	0.1	1.1	2.8	0.2	0.1

targetzero ► zero incidents ► zero injuries

Colour (Apparent)		pcu	200	125	85	260	150	55	130
Colour (True)		not	1	1	2	2	110	2	2
CHEMICAL ANALYSIS									
Calcium	filtered	mg/L	74.3	51.4	51.6	55	31.1	19.1	39.6
Magnesium	filtered	mg/L	27.2	13.9	15.5	17.6	8.5	6	14.2
Sodium	filtered	mg/L	2100	2160	2050	2170	1470	1130	1580
Potassium	filtered	mg/L	39.7	61.6	11.5	64.1	90.1	11.4	93.6
Hydroxide as CaCO3		mg/L	<1	<1	<1	<1	<1	<1	<1
Carbonate as CaCO3		mg/L	<1	<1	<1	<1	<1	<1	<1
Bicarbonate as CaCO3		mg/L	489	589	524	591	803	774	677
Alkalinity as CaCO3		mg/L	489	589	524	591	803	774	677
Sulphate	filtered	mg/L	2	<1.0	<1.0	<1.0	1.6	<1.0	<1.0
Chloride		mg/L	3253	3350	3140	3500	2080	1390	2400
Aluminium	filtered	mg/L	<0.01	<0.01	0.07	<0.01	7.32	0.18	0.07
Barium	filtered	mg/L	0.11	0.07	0.05	0.12	0.11	0.06	0.1
Iron	total	mg/L	17	18.3	18.9	18.1	16.7	16.2	14.7
Manganese	filtered	mg/L	16.4	12.2	13	12.9	7.1	4.4	9.6
Silica	filtered	mg/L	8.49	6.17	3.45	10.8	8.34	4.08	8.29
Strontium	filtered	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Iron	total	mg/L	15.9	12.2	12.9	10.5	7.5	3.92	7.34
Fluoride		mg/L	1.6	2	2.1	1.9	2.5	2.4	1.7
Ammonia as N		mg/L	3.63	3.64	3.66	4.02	2.71	1.83	3.06

Nitrate as N		mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Organic Carbon		mg/L	6	9	32	10	6	48	16

External Analysis			18-October-2004								
SAMPLE DESCRIPTION			GM005V	GM006V	GM007V	GM008V	GM009V	GM002V	GM003V	GM004V	GM010V
CCI LAB ID			CH074	CH075	CH076	CH077	CH078	CH079	CH080	CH081	CH082
PHYSICAL ANALYSIS											
Total Dissolved Solids		mg/L	7480	7632	6072	5730	5656	6316	6226	6808	5962
pH			7.64	7.54	7.34	7.24	7.7	7.19	7.46	7.44	8.27
Electrical Conductivity		(us/cm)	12430	12760	10240	9560	9890	10660	11000	12180	10270
Turbidity		pcu	29.6	17	30.2	44.5	85.1	8.37	11.8	14.2	27
Turbidity (filtered)		pcu	0.13	0.18	0.19	0.16	0.19	0.21	0.14	0.17	0.16
Colour (Apparent)		pcu	55	85	>100	>100	>100	55	50	30	85
Colour (True)		not	<5	5	<5	<5	5	<5	<5	5	5
CHEMICAL ANALYSIS											
Calcium	filtered	mg/L	43	59	34	40	48	101	67	72	45
Magnesium	filtered	mg/L	17	24	13	15	15	58	35	37	23
Sodium	filtered	mg/L	2940	2940	2370	2170	2160	2220	2430	2760	2290
Potassium	filtered	mg/L	14	14	10	12	26	26	24	26	22

Hydroxide as CaCO3		mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate as CaCO3		mg/L	21	1	4	<1	27	<1	24	14	15
Bicarbonate as CaCO3		mg/L	1010	892	1090	965	564	445	677	632	303
Alkalinity as CaCO3		mg/L	1030	893	1090	965	591	445	701	647	318
Sulphate	filtered	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloride		mg/L	4200	4500	3300	3050	3300	3710	3800	4200	3800
Aluminium	filtered	mg/L	1.12	0.13	0.02	0.02	0.15	0.01	0.06	0.02	0.08
Barium	filtered	mg/L	0.03	0.06	0.04	0.1	0.24	0.07	0.04	0.02	0.12
Iron	total	mg/L	22.3	19.4	21.4	18.4	20.3	19.6	19.7	20.4	10.5
Manganese	filtered	mg/L	12.4	16.4	10	9.9	11.1	19.1	13.2	15.5	16.4
Silica	filtered	mg/L	3.58	4.22	3.93	9.01	12.2	3.91	2.2	2.38	7.77
Strontium	filtered	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	total	mg/L	12.4	17	9.6	8.7	9.9	22.7	14	17	16
Fluoride		mg/L	1.7	1.8	2.1	1.6	2.2	1.4	1.6	1.5	1.7
Ammonia as N		mg/L	4.3	4.82	4.18	4.19	4.01	4.32	4.06	4.46	4.41
Nitrate as N		mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Organic Carbon		mg/L	25	23	38	55	8	4	9	10	10

External Analysis	18-October-2004								
SAMPLE DESCRIPTION	GM011V	GM012V	GM013V	GM014V	GM016V	GM017V	GM018V	GM026V	GM028V

CCI LAB ID			CH083	CH084	CH085	CH086	CH087	CH088	CH089	CH090	CH091
PHYSICAL ANALYSIS											
Total Dissolved Solids		mg/L	5494	5670	6168	5413	4706	3660	3368	4032	3564
pH			7.38	7.45	7.34	7.77	7.94	7.7	7.79	7.56	7.41
Electrical Conductivity		(us/cm)	9650	9670	10500	8720	7530	6060	5550	6960	5920
Turbidity		pcu	68.8	32.3	97.1	81.2	32.4	50.5	43.8	35.4	72.6
Turbidity (filtered)		pcu	0.14	0.14	0.22	0.17	0.13	0.13	0.14	0.18	0.25
Colour (Apparent)		pcu	55	50	75	55	40	45	35	>100	>100
Colour (True)		not	<5	<5	5	<5	<5	5	<5	<5	10
CHEMICAL ANALYSIS											
Calcium	filtered	mg/L	53	50	60	22	14	13	15	20	15
Magnesium	filtered	mg/L	15	16	16	9	6	4	4	6	4
Sodium	filtered	mg/L	2220	2090	2430	2070	1880	1480	1340	1630	1420
Potassium	filtered	mg/L	21	13	18	10	29	7	7	9	6
Hydroxide as CaCO3		mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate as CaCO3		mg/L	<1	<1	<1	104	146	99	80	66	55
Bicarbonate as CaCO3		mg/L	536	495	519	1400	1880	1350	1020	1020	847
Alkalinity as CaCO3		mg/L	536	495	519	1500	2020	1440	1100	1090	902
Sulphate	filtered	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloride		mg/L	3320	3370	3670	2500	1760	1440	1440	2050	1750
Aluminium	filtered	mg/L	0.03	0.04	0.04	0.35	0.09	0.52	0.29	0.06	0.04
Barium	filtered	mg/L	0.04	0.03	0.26	0.02	<0.01	<0.01	<0.01	0.07	0.09

Iron	total	mg/L	19.6	18.5	20.1	20.4	26.1	22.4	23.6	19.1	19.5
Manganese	filtered	mg/L	12.6	13.2	13	7.1	5.9	3.9	4	5.3	4.1
Silica	filtered	mg/L	5.75	1.09	7.86	3.77	3.37	2.31	1.55	8.01	18.2
Strontium	filtered	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	total	mg/L	13.6	14.3	11.1	6.3	5	3.1	3	4.6	3.3
Fluoride		mg/L	2.2	2.4	2.2	1.8	2.2	2.1	2.6	3	3.7
Ammonia as N		mg/L	3.25	3.5	4.2	3.02	2.78	2.31	1.99	2.46	2.26
Nitrate as N		mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Organic Carbon		mg/L	15	7	31	160	43	76	45	49	23

External Analysis				18-October-2004									
SAMPLE DESCRIPTION			P013V	P001V	P004V	P006V	P007V	P008V	P010V	P012V	P014V	P018V	P019V
CCI LAB ID			CH092	CH064	CH065	CH066	CH067	CH068	CH069	CH070	CH071	CH072	CH073
PHYSICAL ANALYSIS													
Total Dissolved Solids		mg/L	4550	5596	5950	6581	7050	5860	2536	2968	7042	4520	4964
pH			7.53	7.74	7.35	7.31	7.45	7.24	8.29	7.59	7.29	7.92	7.46
Electrical Conductivity		(us/cm)	7850	9750	10810	12000	12030	10200	4310	5040	12010	8000	8890
Turbidity		pcu	27.4	160	79.4	83.3	41.2	39	40.9	3.22	31.6	59.5	52.2
Turbidity (filtered)		pcu	0.15	0.28	0.58	0.22	0.17	0.14	0.2	0.14	0.13	0.43	0.38
Colour (Apparent)		pcu	95	>100	60	>100	>100	65	45	30	30	>100	60
Colour (True)		not	5	10	<5	<5	10	<5	<5	<5	<5	15	<5
CHEMICAL ANALYSIS													
Calcium	filtered	mg/L	40	44	73	73	72	64	18	19	50	28	36

Magnesium	filtered	mg/L	15	16	58	37	32	33	7	6	18	7	11
Sodium	filtered	mg/L	1760	2200	2320	2580	2650	2170	964	1140	2620	1870	1980
Potassium	filtered	mg/L	24	16	24	22	25	27	14	8	13	8	11
Hydroxide as CaCO3		mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate as CaCO3		mg/L	37	<1	<1	<1	<1	<1	31	26	<1	45	<1
Bicarbonate as CaCO3		mg/L	622	675	577	596	686	673	515	815	818	875	700
Alkalinity as CaCO3		mg/L	659	675	577	596	686	673	546	841	818	919	700
Sulphate	filtered	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloride		mg/L	2500	3250	3720	4250	4150	3470	1300	1380	4000	2500	2900
Aluminium	filtered	mg/L	0.12	0.06	0.02	0.03	0.03	0.03	0.66	0.04	0.02	2.76	0.22
Barium	filtered	mg/L	0.14	0.38	0.03	0.06	0.08	0.06	0.11	0.03	0.04	0.08	0.03
Iron	total	mg/L	17	13.8	17.9	18.1	17.1	17.9	11.2	18.4	17.8	19.8	17.4
Manganese	filtered	mg/L	10.9	11.9	12.2	16.3	18.4	13.6	3.8	4.8	14.7	7.8	10.2
Silica	filtered	mg/L	8.44	24.8	3.3	4.52	6.04	4.13	15.4	1.19	2.52	6.78	2.63
Strontium	filtered	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	total	mg/L	8.7	9.9	13.2	18.1	19.9	14.1	3.4	5.1	14	6.6	8.5
Fluoride		mg/L	1.8	1.4	1.3	1.4	1.2	1.2	2.7	2.9	1.3	1.5	1.9
Ammonia as N		mg/L	2.74	3.76	3.77	4.41	4.78	3.74	1.69	1.89	4.23	2.97	3.1
Nitrate as N		mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Organic Carbon		mg/L	8	21	7	11	21	5	12	24	28	45	15

External Analysis			05-January-2005								
SAMPLE DESCRIPTION			GM8V	GM1V	GM14V	GM15V	GM16V	GM17V	GM18V	GM19V	GM20V
CCI LAB ID			CH129	CH130	CH131	CH132	CH133	CH134	CH135	CH136	CH137
PHYSICAL ANALYSIS											
Total Dissolved Solids		mg/L	5944	6796	5696	5826	4684	3740	3256	4262	5612
pH			7.45	7.38	7.79	7.45	7.78	7.94	7.95	7.6	7.74
Electrical Conductivity		(us/cm)	9680	11040	9030	9260	7220	5950	5170	6790	9190
Turbidity		pcu	27	10.3	3.96	58.9	6.37	24	23.5	137	70.8
Turbidity (filtered)		pcu	0.71	0.7	0.65	0.31	0.53	0.55	1.06	1.99	0.73
Colour (Apparent)		pcu	25	35	<5	75	<5	25	25	>100	75
Colour (True)		not	<5	<5	<5	<5	<5	<5	<5	20	<5
CHEMICAL ANALYSIS											
Calcium	filtered	mg/L	29	76	20	22	12	14	13	21	40
Magnesium	filtered	mg/L	22	55	9	12	6	4	3	8	13
Sodium	filtered	mg/L	2110	2270	1960	2120	1650	1430	1150	1500	1970
Potassium	filtered	mg/L	18	46	10	12	18	7	6	11	13
Hydroxide as CaCO3		mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate as CaCO3		mg/L	<1	<1	53	<1	<1	75	52	<1	7
Bicarbonate as CaCO3		mg/L	879	519	1480	1640	1700	1420	1090	916	690
Alkalinity as CaCO3		mg/L	879	519	1530	1640	1700	1490	1140	916	697
Sulphate	filtered	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloride		mg/L	2931	3679	2397	2373	1495	1317	1151	1875	2872
Aluminium	filtered	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Barium	filtered	mg/L	9	11.5	5.9	6.7	3.8	2.7	2.3	4.2	8.2
Iron	total	mg/L	<0.01	0.06	0.21	<0.01	<0.01	0.08	0.16	0.74	0.52
Manganese	filtered	mg/L	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01	0.04	0.03
Silica	filtered	mg/L	8.67	8.65	9.29	10.1	10.4	10.6	10.1	9.71	8.99
Strontium	filtered	mg/L	10.8	12.3	7.1	7.8	4.5	3.8	3.2	5.7	9.4
Iron	total	mg/L	3.28	1.91	0.58	2.12	0.48	1.42	1.08	6.4	4.08
Fluoride		mg/L	1.8	1.7	2.4	2.5	2.9	2.9	3.5	3.3	2.7
Ammonia as N		mg/L	4.14	3.64	3.38	3.21	2.84	2.45	2	2.37	3.62
Nitrate as N		mg/L	<0.01	0.01	<0.01	0.015	<0.01	<0.01	<0.01	0.026	0.016
Total Organic Carbon		mg/L	34	20	167	85	93	66	47	130	29

External Analysis						04-January-2005				05-January-2005	
SAMPLE DESCRIPTION			GM23V	GM27V	GM30V	GM13V	GM24V	GM26V	GM28V	P14V	P19V
CCI LAB ID			CH138	CH139	CH140	CH120	CH121	CH122	CH123	CH127	CH128
PHYSICAL ANALYSIS											
Total Dissolved Solids		mg/L	6516	4952	6210	6102	4262	4334	4660	7233	5190
pH			7.43	7.66	7.46	7.47	7.3	7.57	6.95	7.42	7.67
Electrical Conductivity		(us/cm)	10530	7860	9700	10810	11390	7430	7730	11710	8570
Turbidity		pcu	554	98.3	30.1	8.32	77.9	30	4.46	11.6	3.83
Turbidity (filtered)		pcu	1.16	0.75	0.86	0.71	3.37	1.03	1.77	0.5	0.71
Colour (Apparent)		pcu	>100	75	>100	15	>100	50	15	35	30
Colour (True)		not	<5	<5	<5	<5	10	<5	<5	<5	<5
CHEMICAL ANALYSIS											

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Calcium	filtered	mg/L	55	22	26	55	96	19	16	34	31
Magnesium	filtered	mg/L	15	9	12	18	35	6	6	17	10
Sodium	filtered	mg/L	2290	1650	2130	2070	2220	1460	1350	2530	1830
Potassium	filtered	mg/L	12	9	11	26	16	8	8	13	11
Hydroxide as CaCO3		mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate as CaCO3		mg/L	<1	22	3	<1	<1	<1	23	<1	8
Bicarbonate as CaCO3		mg/L	587	1150	1340	524	343	1080	812	736	617
Alkalinity as CaCO3		mg/L	587	1170	1340	524	343	1080	835	736	626
Sulphate	filtered	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloride		mg/L	3489	2136	2824	3228	3584	1816	1745	3786	2635
Aluminium	filtered	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	filtered	mg/L	12.3	5.2	7.5	11.6	20	4.3	3.8	11.3	6.9
Iron	total	mg/L	0.02	0.05	0.1	<0.01	0.02	<0.01	0.09	<0.01	<0.01
Manganese	filtered	mg/L	0.06	<0.01	0.06	0.02	0.16	0.02	<0.01	<0.01	0.02
Silica	filtered	mg/L	9.43	9.03	9.91	8.6	7.48	8.51	8.82	7.71	7.63
Strontium	filtered	mg/L	13.4	6.2	8.8	13.9	18.8	5	4.5	12.8	8.8
Iron	total	mg/L	10.5	2.2	5.68	1.67	13.3	2.66	1.67	2.07	1.62
Fluoride		mg/L	2.4	3	2.2	2.4	2	3.5	4.1	1.3	1.8
Ammonia as N		mg/L	4.08	3.34	3.78	4.08	4.32	2.87	2.64	4.38	3.17
Nitrate as N		mg/L	<0.01	0.011	0.011	0.014	0.01	<0.01	<0.01	<0.01	<0.01
Total Organic Carbon		mg/L	24	61	59	23	18	47	36	28	24

APPENDIX D – Water entitlement data for bores within the Project area

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Isaac Connors Water Management Area	Basalt	67257F	Licence to take water	Issued	28-Feb-2021	JC & SK MICKAN	Irrigation, Stock	40	12/RP611319	67257F	Water Bore	Installed	67257
Isaac Connors Water Management Area	Basalt	500165	Licence to take water	Issued	31-Jul-2021	GR, GJ, & RH GARSIDE	Stock Intensive	24	10/SP125737	31452	Water Bore	Installed	103820
Isaac Connors Water Management Area	Blenheim Subgroup	184598	Licence to take water	Issued	30-Sep-2012	AR, J, & RN WEDEL	Stock Intensive	40	3/CNS374	18436	Water Bore	Installed	89479
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	46640L	Water Bore	Installed	46640
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63181L	Water Bore	Installed	63181

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Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63182L	Water Bore	Installed	63182
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63183L	Water Bore	Installed	63183
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63184L	Water Bore	Installed	63184
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63185L	Water Bore	Installed	63185
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63186L	Water Bore	Installed	63186
Isaac Connors Water Management	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63187L	Water Bore	Installed	63187

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Area													
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63188L	Water Bore	Installed	63188
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63189L	Water Bore	Installed	63189
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63190L	Water Bore	Installed	63190
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63191L	Water Bore	Installed	63191
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63192L	Water Bore	Installed	63192

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63193L	Water Bore	Installed	63193
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63194L	Water Bore	Installed	63194
Isaac Connors Water Management Area	Denison Creek Alluvium	406041	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Irrigation	284	4/WHS354	63195L	Water Bore	Installed	63195
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	46640L	Water Bore	Installed	46640
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63181L	Water Bore	Installed	63181
Isaac Connors Water Management	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63182L	Water Bore	Installed	63182

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Area													
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63183L	Water Bore	Installed	63183
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63184L	Water Bore	Installed	63184
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63185L	Water Bore	Installed	63185
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63186L	Water Bore	Installed	63186
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63187L	Water Bore	Installed	63187

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63188L	Water Bore	Installed	63188
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63189L	Water Bore	Installed	63189
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63190L	Water Bore	Installed	63190
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63191L	Water Bore	Installed	63191
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63192L	Water Bore	Installed	63192
Isaac Connors Water Management	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63193L	Water Bore	Installed	63193

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Area													
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63194L	Water Bore	Installed	63194
Isaac Connors Water Management Area	Denison Creek Alluvium	406042	Licence to take water	Issued	31-Jan-2013	BHP MITSUI COAL PTY LTD	Any	3250	4/WHS354	63195L	Water Bore	Installed	63195
Isaac Connors Water Management Area	Denison Creek Alluvium	44375L	Licence to take water	Under Amendment	14-May-2020 12:32:52 PM	FJ WHITEHEAD	Irrigation	469	1/WHS3	44374L	Water Bore	Installed	44374
Isaac Connors Water Management Area	Denison Creek Alluvium	63420L	Licence to take water	Issued	30-Nov-2020	AHR SYMONDS	Irrigation, Mining	300	36/KL811178	63420L	Water Bore	Installed	63420
Isaac Connors Water Management Area	Funnel Creek Alluvium	174593	Licence to take water	Under Amendment	31-May-2020	KEMP GRAZING PTY LTD AS TRUSTEE	Irrigation	222	8/SP168491	11757	Water Bore	Installed	111732

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Isaac Connors Water Management Area	Funnel Creek Alluvium	174593	Licence to take water	Under Amendment	31-May-2020	KEMP GRAZING PTY LTD AS TRUSTEE	Irrigation	222	8/SP168491	11758	Water Bore	Installed	111733
Isaac Connors Water Management Area	Funnel Creek Alluvium	43910U	Licence to take water	Issued	30-Jun-2012	JD & JL LLOYD	Irrigation, Stock, Stock Intensive	139	11/KL117	43910U	Water Bore	Installed	43910
Isaac Connors Water Management Area	Funnel Creek Alluvium	43910U	Licence to take water	Issued	30-Jun-2012	JD & JL LLOYD	Irrigation, Stock, Stock Intensive	139	11/KL117	88778U	Water Bore	Installed	88778
Isaac Connors Water Management Area	Funnel Creek Alluvium	57578U	Licence to take water	Issued	30-Nov-2012	LB & SW GREEN	Industrial, Irrigation, Stock Intensive	700	15/KL116	57578U	Water Bore	Installed	57578
Isaac Connors Water Management Area	Funnel Creek Alluvium	57578U	Licence to take water	Issued	30-Nov-2012	LB & SW GREEN	Industrial, Irrigation, Stock Intensive	700	15/KL116	91368U	Water Bore	Installed	91368
Isaac Connors Water Management	Funnel Creek Alluvium	57578U	Licence to take water	Issued	30-Nov-2012	LB & SW GREEN	Industrial, Irrigation, Stock Intensive	700	15/KL116	91369U	Water Bore	Installed	91369

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Area													
Isaac Connors Water Management Area	Nebo Creek Alluvium	0548138L	Licence to take water	Issued	14-May-2020 1:55:34 PM	GJ BARR DA BROWN	Irrigation	150	95/WHS259	0548138L	Water Bore	Installed	548138
Isaac Connors Water Management Area	Nebo Creek Alluvium	0548138L	Licence to take water	Issued	14-May-2020 1:55:34 PM	GJ BARR DA BROWN	Irrigation	150	95/WHS259	6242	Water Bore	Installed	81937
Isaac Connors Water Management Area	Nebo Creek Alluvium	100373	Licence to take water	Issued	31-Jan-2014	BLUEVALE BEEF PTY LTD	Irrigation	55	5/RP615643, 5/WHS138, 47/WHS402	63363L	Water Bore	Installed	63363
Isaac Connors Water Management Area	Nebo Creek Alluvium	100539	Licence to take water	Issued	31-Aug-2019	ISAAC REGIONAL COUNCIL	Urban	75	50/WHS259	63459L	Water Bore	Installed	63459
Isaac Connors Water Management Area	Nebo Creek Alluvium	100539	Licence to take water	Issued	31-Aug-2019	ISAAC REGIONAL COUNCIL	Urban	75	50/WHS259	63460L	Water Bore	Installed	63460

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Isaac Connors Water Management Area	Nebo Creek Alluvium	100539	Licence to take water	Issued	31-Aug-2019	ISAAC REGIONAL COUNCIL	Urban	75	50/WHS259	81822L	Water Bore	Installed	81822
Isaac Connors Water Management Area	Nebo Creek Alluvium	100539	Licence to take water	Issued	31-Aug-2019	ISAAC REGIONAL COUNCIL	Urban	75	50/WHS259	81823L	Water Bore	Installed	81823
Isaac Connors Water Management Area	Nebo Creek Alluvium	100539	Licence to take water	Issued	31-Aug-2019	ISAAC REGIONAL COUNCIL	Urban	75	50/WHS259	81824L	Water Bore	Installed	81824
Isaac Connors Water Management Area	Nebo Creek Alluvium	63203L	Licence to take water	Issued	31-Aug-2021	D & ER BURGESS	Irrigation	63	1/PER3074	63203L	Water Bore	Installed	63203
Isaac Connors Water Management Area	Nebo Creek Alluvium	63363L	Licence to take water	Issued	04-Mar-2020 2:39:13 PM	BLUEVALE BEEF PTY LTD	Irrigation	6	5/WHS138	63363L	Water Bore	Installed	63363
Isaac Connors Water Management	Nebo Creek Alluvium	63460L	Licence to take water	Issued	31-Aug-2012	ISAAC REGIONAL COUNCIL	Urban	75	601/N1101, 1/SP132656	63459L	Water Bore	Installed	63459

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Area													
Isaac Connors Water Management Area	Nebo Creek Alluvium	63460L	Licence to take water	Issued	31-Aug-2012	ISAAC REGIONAL COUNCIL	Urban	75	601/N1101, 1/SP132656	63460L	Water Bore	Installed	63460
Isaac Connors Water Management Area	Nebo Creek Alluvium	63460L	Licence to take water	Issued	31-Aug-2012	ISAAC REGIONAL COUNCIL	Urban	75	601/N1101, 1/SP132656	81822L	Water Bore	Installed	81822
Isaac Connors Water Management Area	Nebo Creek Alluvium	63460L	Licence to take water	Issued	31-Aug-2012	ISAAC REGIONAL COUNCIL	Urban	75	601/N1101, 1/SP132656	81823L	Water Bore	Installed	81823
Isaac Connors Water Management Area	Nebo Creek Alluvium	63460L	Licence to take water	Issued	31-Aug-2012	ISAAC REGIONAL COUNCIL	Urban	75	601/N1101, 1/SP132656	81824L	Water Bore	Installed	81824
Isaac Connors Water Management Area	Nebo Creek Alluvium	81007L	Licence to take water	Issued	31-Jul-2021	MJ GOODE	Irrigation	82	2/SP156177	81007L	Water Bore	Installed	81007

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Isaac Connors Water Management Area	Nebo Creek Alluvium	81489L	Licence to take water	Issued	18-Nov-2019 2:35:55 PM	THE STATE OF QUEENSLAND - REPRESENTED BY THE DEPARTMENT OF EDUCATION	Educational Facility	5	6/N11014	81489L	Water Bore	Installed	81489
Isaac Connors Water Management Area	Nebo Creek Alluvium	81797L	Licence to take water	Issued	18-Feb-2020 2:05:21 PM	A & BJL HAYWARD	Aquaculture, Irrigation	2	5/RP612732	81797L	Water Bore	Installed	81797
Isaac Connors Water Management Area	Nebo Creek Alluvium	81810L	Licence to take water	Issued	31-Jul-2020	AG & AHR SYMONDS	Irrigation	150	6/RP826438	81810L	Water Bore	Installed	81810
Isaac Connors Water Management Area	Slatey Creek Alluvium	62551F	Licence to take water	Issued	30-Jun-2013	GR, GJ, & RH GARSIDE	Stock Intensive	24	10/SP125737	62551F	Water Bore	Installed	62551
Pioneer Groundwater Management Area	Pioneer River Alluvium	36165X	Licence to take water	Issued	31-Oct-2012	BJ & DT CARROLL AS TRUSTEE	Irrigation	55	1/RP891546	8106	Water Bore	Installed	36165
Pioneer Groundwater Management	Urannah Complex	46091L	Licence to take water	Issued	21-Jul-2014 9:48:47	GWR HEAD	Irrigation	22	4/RP720369	46091L	Water Bore	Installed	46091

Group Description	Water Name	Authorisation No	Type	Status	Expiry Date	Client Name	Purpose	Entitlement (ML/ Water Year)	Activity Parcel	Works No	Works Type	Works Status	Registered No
Area					AM								
Pioneer Groundwater Management Area	Urannah Complex	46091L	Licence to take water	Issued	21-Jul-2014 9:48:47 AM	GWR HEAD	Irrigation	22	4/RP720369	46092L	Water Bore	Installed	46092
Pioneer Groundwater Management Area	Alligator Creek Alluvium	38933L	Licence to take water	Issued	31-Aug-2012	AR & JT WERNER	Irrigation	40	32/C124714	38933L	Water Bore	Installed	38933
Pioneer Groundwater Management Area	Carmila Beds	46023L	Licence to take water	Issued	31-Aug-2012	FREDERICK MICHAEL AGIUS	Irrigation	49	5/SP121679	46023L	Water Bore	Installed	46023
Pioneer Groundwater Management Area	Carmila Beds	46023L	Licence to take water	Issued	31-Aug-2012	FREDERICK MICHAEL AGIUS	Irrigation	49	5/SP121679	46024L	Water Bore	Installed	46024
Pioneer Groundwater Management Area	Sandy Creek Alluvium	43963L	Licence to take water	Issued	31-Jul-2020	MA & WG HARRIS	Irrigation	97	2/RP718259	43963L	Water Bore	Installed	43963

Appendix E – Groundwater Monitoring Network

Bore Name	Location	Bore Status	Target Aquifer	Easting (GDA94 Zone 55)	Northing (GDA94 Zone 55)	Rationale
RH083W	ATP1103	Proposed	Tertiary Aquifer	609540	7588894	Develop baseline groundwater level and quality conditions for the shallowest aquifer.
RH084W	ATP1103	Proposed	Moranbah Coal Measures Aquifer	609542	7588894	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters.
RH085W	ATP1103	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	609544	7588894	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
PD161W	ATP1103	Proposed	Tertiary Aquifer	617118	7555590	Develop baseline groundwater level and quality conditions for the shallowest aquifer.
PD162W	ATP1103	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	617120	7555590	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
PD163W	ATP1103	Proposed	Moranbah Coal Measures Aquifer	617122	7555590	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters.
PD153W	ATP1103	Proposed	Tertiary Aquifer	623534	7559168	Develop baseline groundwater level and quality conditions for the shallowest aquifer.
PD154W	ATP1103	Proposed	Triassic Aquifer	623536	7559168	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
PD155W	ATP1103	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	623538	7559168	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
PD156W	ATP1103	Proposed	Moranbah Coal Measures Aquifer	623540	7559168	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters.
EF097W	ATP1103	Proposed	Tertiary Aquifer	623612	7582329	Develop baseline groundwater level and quality conditions for the shallowest aquifer.
EF098W	ATP1103	Proposed	Triassic Aquifer	623614	7582329	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
EF099W	ATP1103	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	623616	7582329	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
EF100W	ATP1103	Proposed	Moranbah Coal Measures Aquifer	623618	7582329	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters.
EF093W	ATP1103	Proposed	Tertiary Aquifer	624079	7589011	Develop baseline groundwater level and quality conditions for the shallowest aquifer.
EF094W	ATP1103	Proposed	Triassic Aquifer	624081	7589011	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.

Bore Name	Location	Bore Status	Target Aquifer	Easting (GDA94 Zone 55)	Northing (GDA94 Zone 55)	Rationale
EF095W	ATP1103	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	624083	7589011	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
EF096W	ATP1103	Proposed	Moranbah Coal Measures Aquifer	624085	7589011	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters.
PD157W	ATP1103	Proposed	Tertiary Aquifer	625948	7554612	Develop baseline groundwater level and quality conditions for the shallowest aquifer.
PD158W	ATP1103	Proposed	Triassic Aquifer	625950	7554612	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
PD159W	ATP1103	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	625952	7554612	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters.
PD160W	ATP1103	Proposed	Moranbah Coal Measures Aquifer	625954	7554612	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters.
M303W	MGP	Proposed	Moranbah Coal Measures Aquifer	600318	7573000	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M339W	MGP	Completed	Tertiary Aquifer	603459	7572764	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.
M306W	MGP	Proposed	Moranbah Coal Measures Aquifer	603623	7573688	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M356W	MGP	Proposed	Moranbah Coal Measures Aquifer	603823	7569147	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M225W	MGP	Completed	Tertiary Aquifer	604808	7569886	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.
M355W	MGP	Proposed	Moranbah Coal Measures Aquifer	604810	7569885	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M340W	MGP	Completed	Tertiary Aquifer	604903	7572726	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.
M230W	MGP	Completed	Tertiary Aquifer	605636	7570996	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.

Bore Name	Location	Bore Status	Target Aquifer	Easting (GDA94 Zone 55)	Northing (GDA94 Zone 55)	Rationale
M305W	MGP	Proposed	Moranbah Coal Measures Aquifer	606870	7575667	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M357W	MGP	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	606870	7575669	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M327W	MGP	Proposed	Tertiary Aquifer	606880	7575667	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.
M250W	MGP	Completed	Tertiary Aquifer	608185	7582505	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.
M224W	MGP	Completed	Tertiary Aquifer	611155	7567225	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.
M309W	MGP	Proposed	Moranbah Coal Measures Aquifer	611302	7579497	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M320W	MGP	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	611312	7579497	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M222W	MGP	Completed	Tertiary Aquifer	611811	7566589	Develop baseline groundwater level and quality conditions for the shallowest aquifer. Confirm extent of groundwater decline in water level in the overlying aquifers within the mining lease boundary.
M314W	MGP	Proposed	Moranbah Coal Measures Aquifer	614314	7566488	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M325W	MGP	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	614324	7566488	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M313W	MGP	Proposed	Moranbah Coal Measures Aquifer	614818	7562075	Develop baseline groundwater level and quality conditions for the target aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.
M324W	MGP	Proposed	Fort Cooper or Rangal Coal Measures Aquifer	614828	7562075	Develop baseline groundwater level and quality conditions for the intermediate aquifer. Undertake slug testing to identify aquifer parameters. Monitor the extent of groundwater decline in water level in the target aquifer within the mining lease boundary.