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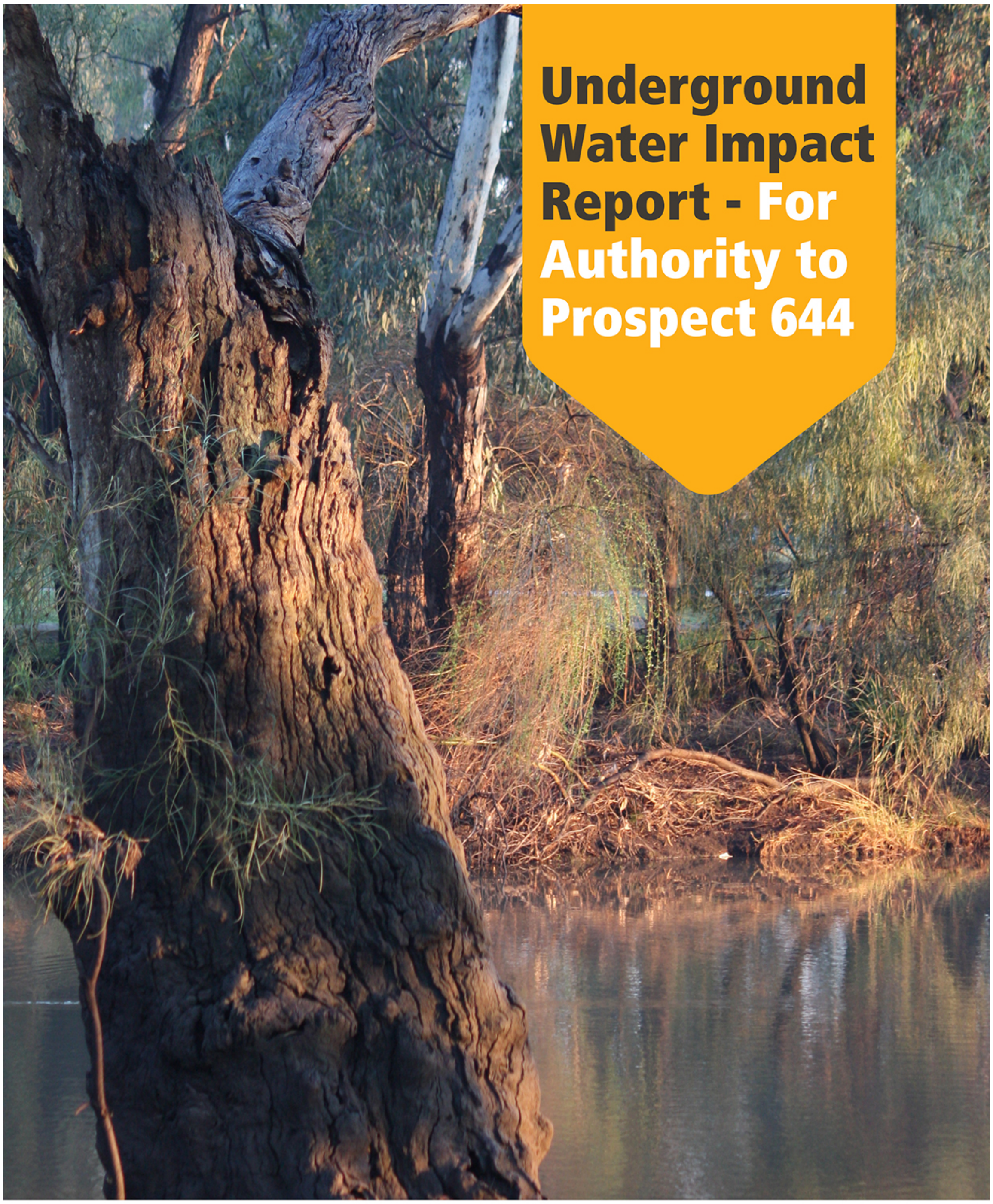
Underground Water Impact Report - For Authority to Prospect 644



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December 2012

targetzero ► zero incidents ► zero injuries

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EXECUTIVE SUMMARY

This report provides information on the potential decline in water levels in aquifers within Authority to Prospect (ATP) 644 because of the taking of water during production testing of 3 wells. The report includes:

- the quantity of water taken because of the exercise of any relevant underground water rights;
- a description of aquifers potentially affected including how the aquifer interacts with other aquifers;
- the predicted water level decline because 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.

The main facts underpinning the conceptual model of the local groundwater regime are:

- production tests occurred in three wells located within 200 metres of each other;
- the volumes of water taken were between 0.54 ML to 0.69 ML per well during the production test;
- the production test wells are fully cased and cemented to prevent flows between aquifers in the wells;
- the alluvial aquifer (which is the aquifer used by most landholders in the area) is separated from the intake zone of the wells by a 195 m to 380 m vertical thickness of rock;
- the intervening rock is of low permeability and thus acts as an aquitard or series of aquitards between the zones tested by the production tests and the overlying alluvial aquifer;
- landholder bores intersect the the alluvium and are located at least 500-900 m away from the production test wells; and
- No third party bores are located in the Walloon Coal Measures within c.10 km of the pilot test or within the area predicted to experience drawdown as a result of the production test.

The impacts from Pilot test production in ATP644 are indicated to occur within the coal measures at depths of 200m to 400m below the surficial alluvial aquifer and extend laterally approximately 500 m from the centre of the Pilot well test area. The coal measures are indicated to be very low permeability and hence generation and reduction of impacts is likely to occur slowly.

The groundwater modelling further carried out based on the observation of the testing indicates:

- there is a low probability of impacts extending significantly further than 500-600 m laterally from the centre of the Pilot well test area and negligible potential for propagation of impacts to the shallow surface alluvial aquifer. water level decline in excess of the bore trigger threshold of 5 m in the Walloon Coal Measures extends less than c.550m within three years; and

- no water level decline in excess of the bore trigger threshold is predicted within the alluvial aquifer.

This indicates that the pilot testing in this location has a low probability of presenting a risk to groundwater users in the vicinity of the pilot testing.

Based upon the above it is concluded that the potential impacts of extraction of underground water during and after production testing within ATP644 are extremely low.

1 *INTRODUCTION*

The registered holders of Authority to Prospect (ATP) 644 are B.N.G. Pty Ltd ACN 081 690 691 (70%) and Arrow CSG (Australia) Pty Ltd ACN 054 260 650 (30%).

B.N.G. Pty Ltd and Arrow CSG (Australia) 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.

B.N.G. Pty Ltd (BNG) is the operator of ATP 644.

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 –
    i. conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and

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;

f) a water monitoring strategy;

g) A spring impact management strategy;

h) other information or matters prescribed under a regulation.

1.1 Legislation

The primary legislative requirements for the management and development of groundwater for the ATP644 are summarised below.

1.2 Petroleum Act 1923

The Petroleum Act 1923 regulates coal seam gas activities and also govern groundwater management in relation to CSG development. ATP644 is permitted under the Petroleum Act (1923).
Under the Petroleum Act 1923 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 for the petroleum tenure.
The Petroleum Act 1923 requires tenure holders to comply with underground water obligations specified in the Water Act 2000 Chapter 3.

1.3 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 to the petroleum holder that 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); and
- 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 (QWC) 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; and
- 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' would result from CSG activities. An immediately affected area is defined as an area where the predicted drawdown within 3 years is at least:

- 5 m for a consolidated aquifer;
- 2 m for an unconsolidated aquifer; or
- 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 BNG, addressed as appropriate and provided to the Department of Environment and Heritage Protection (DEHP). UWIRs are submitted for approval by DEHP. The 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 baseline assessment data collected by petroleum tenure holders.

2 *CLARENCE-MORETON BASIN*

BNG is undertaking exploration in the Clarence-Moreton Basin for Coal Seam Gas (CSG) resources. This program targets the Walloon Coal Measures (WCM) in this basin.

The pilot testing undertaken occurred in three wells within 200 m of each other located in one small area of the ATP 644 as shown in Figure 1. Therefore, the model produced was designed solely to assess potential effects of the pilots on the area surrounding those pilots and was not designed to simulate basin wide groundwater flow.
Reference material used in the preparation of this report includes data from geological and hydro-geological reports and texts that are still valid in terms of the geological interpretation of the area and understanding of hydro-geological principles.

2.1 Site Location

Three production tests were undertaken on tenement ATP644 from the following wells:

- Mount Lindesay-7;
- Mount Lindesay-8; and
- Mount Lindesay-11.

These wells are located approximately 7 km south west of Beaudesert. The location of these production tests is shown in Figure 1.

2.2 Water Production Schedule

Production testing within ATP644 was undertaken between March 2010 to December 2010.

- The pumps used to bring water to the surface are progressive cavity pumps (PCPs). These pumps work by a rotating eccentric screw which pushes the water upwards as the screw moves eccentrically within the pump housing. This results in the flow rate being proportional to the rate of rotation of the pump. These pumps are rated for a given flow rate at a given number of revolutions per minute (rpm) rating. To calculate the volume pumped a flow test (also known as a "bucket test") is undertaken whereby the pump rate and time for a known volume of water to be pumped is used to calculate an efficiency factor and this is applied to a record of the pumps operating rpm to calculate the volume of water pumped. This flow test is undertaken regularly to maintain the accuracy of the flow calculation. In addition, the total volume of water pumped into the dam constructed to hold the pilot test water is used as a check on this calculation.

Production data for the three production tests is summarised below:

- for well Mount Lindesay-7, a total of approximately 0.694ML of water was taken over 9 months;
- for well Mount Lindesay-8, a total of approximately 0.55ML of water was taken over 9 months; and
- for well Mount Lindesay-11, a total of approximately 0.54ML of water was taken over 9 months.

More detailed data on the water production is provided in Appendix A.

> There are no current plans for further production testing in ATP644 in 2012.

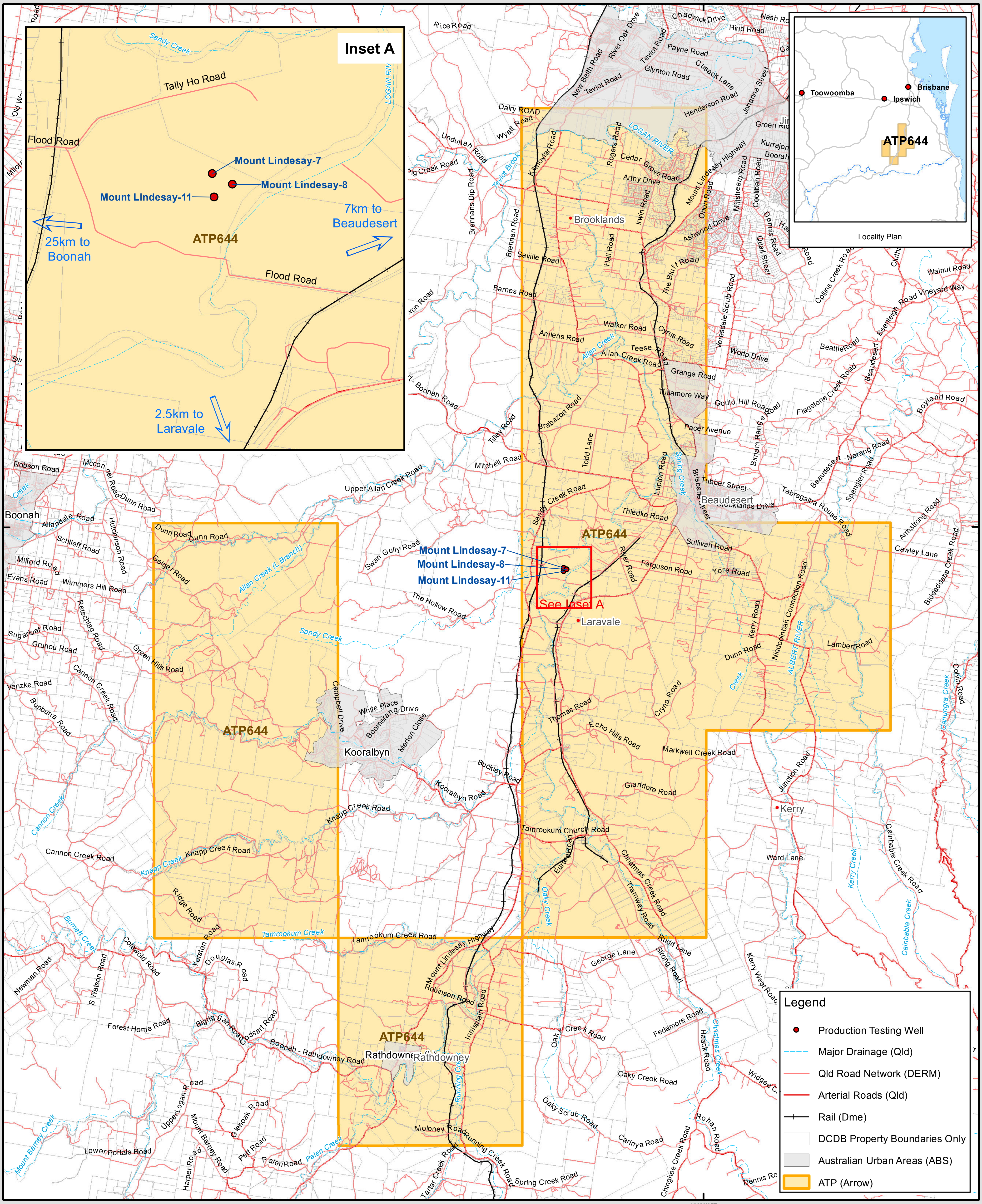

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Figure 1 — **ATP644 - Location and Production Testing Wells**

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

Date: 7/10/2012
Issued To: Issued To
Author: tstringer

0 5 10
Kilometres
Scale: 1:160,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

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Based on or contains data provided by the State of Queensland (Department of Environment and Resource Management) [2011]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws

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

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be at the sole risk of the user. Please verify the accuracy of all information prior to using it.

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3 *EXISTING HYDROGEOLOGICAL REGIME*

3.1 Regional Geological Summary

3.1.1 Geological context

The Clarence-Moreton Basin is a Jurassic to Cretaceous extension of the Surat Basin covering an area of approximately 48,000 km^2, containing up to 3500 m thickness of terrestrial sedimentary rocks (Powell et al., 1993). The basin is bounded by the Beenleigh Block in the east; Yarraman Block, Esk Trough, and South D'Aguilar Block in the north; and Woolomin-Texas, Silverwood, Emu Creek, and Coffs Harbour Blocks in the south. The western part of the basin is separated from the Surat Basin by the Toowoomba Straight. A regional cross-section is shown in Figure 2 and the regional structural geology is shown in Figure 3. In the vicinity of the pilot on the eastern flank of the South-Moreton Anticline are easterly dipping units.

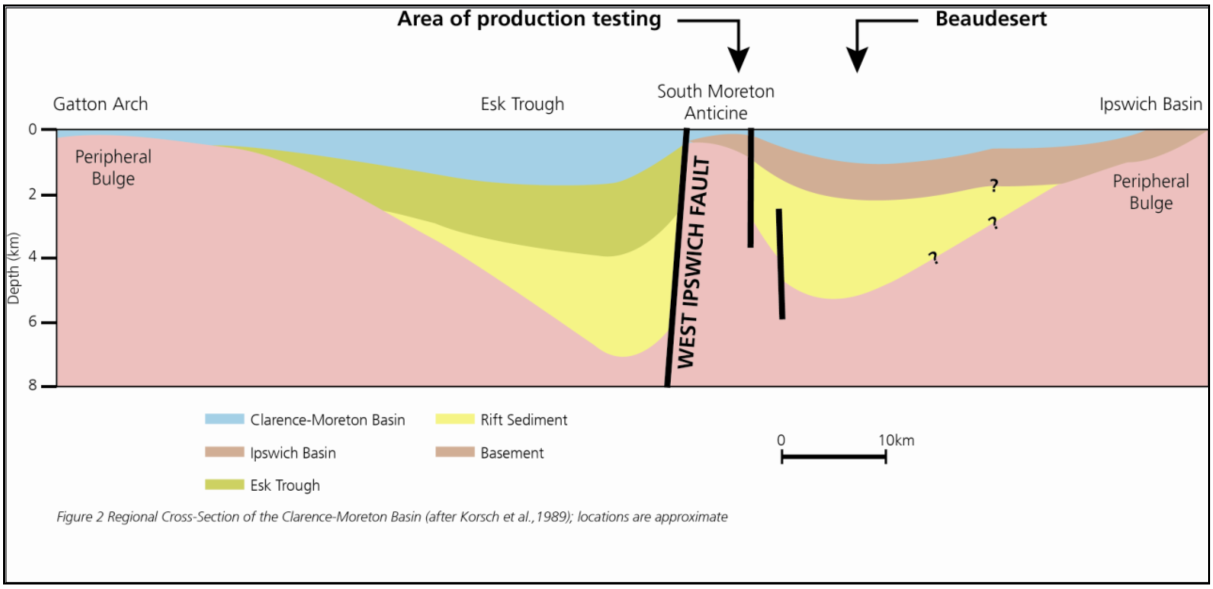

Figure 2 Regional Cross-Section of the Clarence-Moreton Basin (after Korsch et al., 1989) locations are approximate.

The basin was first named by McElroy (1962) when he combined the then separate Clarence River Basin and Moreton Basin into one continuous geological basin. Originally the Triassic coal measures (that is the Nymboida, Redcliff, Evans Head, and Ipswich Coal Measures) were included in the basin, but these were later separated as an angular unconformity and difference in style were noted (Martin & Saxby, 1982). The Clarence-Moreton Basin is divided into three north trending sub-basins (Martin & Saxby, 1982). In the west lies the Cecil Plains sub-basin, separated from the Warrill Creek Sub-basin by the Gatton arch. Then to the East is the Logan sub-basin which is separated by the South Moreton anticline/Richmond horst (Figure 3). The Clarence-Moreton Basin sequence unconformably overlies sedimentary rocks of the Esk Trough; Tarong Basin; Ipswich, Redcliff, Evans Head, and Nymboida Coal Measures; and their equivalents. Where these sedimentary units are not present, the basin overlies Palaeozoic rocks related to the New England orogen (Goscombe & Coxhead, 1995). A simplified stratigraphic section of the Clarence-Moreton Basin compared to the Surat Basin is shown in Figure 4. Basin fill started with the Aberdare and Laytons Range Conglomerates, which were overlain by the siltier Raceview Formation. A renewal of sedimentation laid down the Precipice Sandstone equivalent Ripley Road Sandstone. These were overlain by the Gatton Sandstone and Koukandowie Formation (Evergreen Formation and Hutton Sandstone equivalents). Above these the Walloon Coal Measures were conformably deposited. The Walloon Coal Measures are usually shales, siltstones, and claystones, with fine to medium calcareous sandstones and greywackes. There is also a reasonable amount of coal present (Gould, 1968). Individual lithologies usually form lenses that are only of limited lateral extent (Yago et al., 1994), although sand bodies may be quite extensive and thick (up to 30m; Fielding, 1993). Coal bodies are generally sheet-like when viewed locally, but lenticular over wider areas (Yago & Fielding, 1996). The coal measures reach up to 1000 m thick, but in most areas the top has been eroded (Gould, 1968). It is only in New South Wales where the Kangaroo Creek Sandstone is present that a complete section is preserved (Wells & O'Brien, 1994).

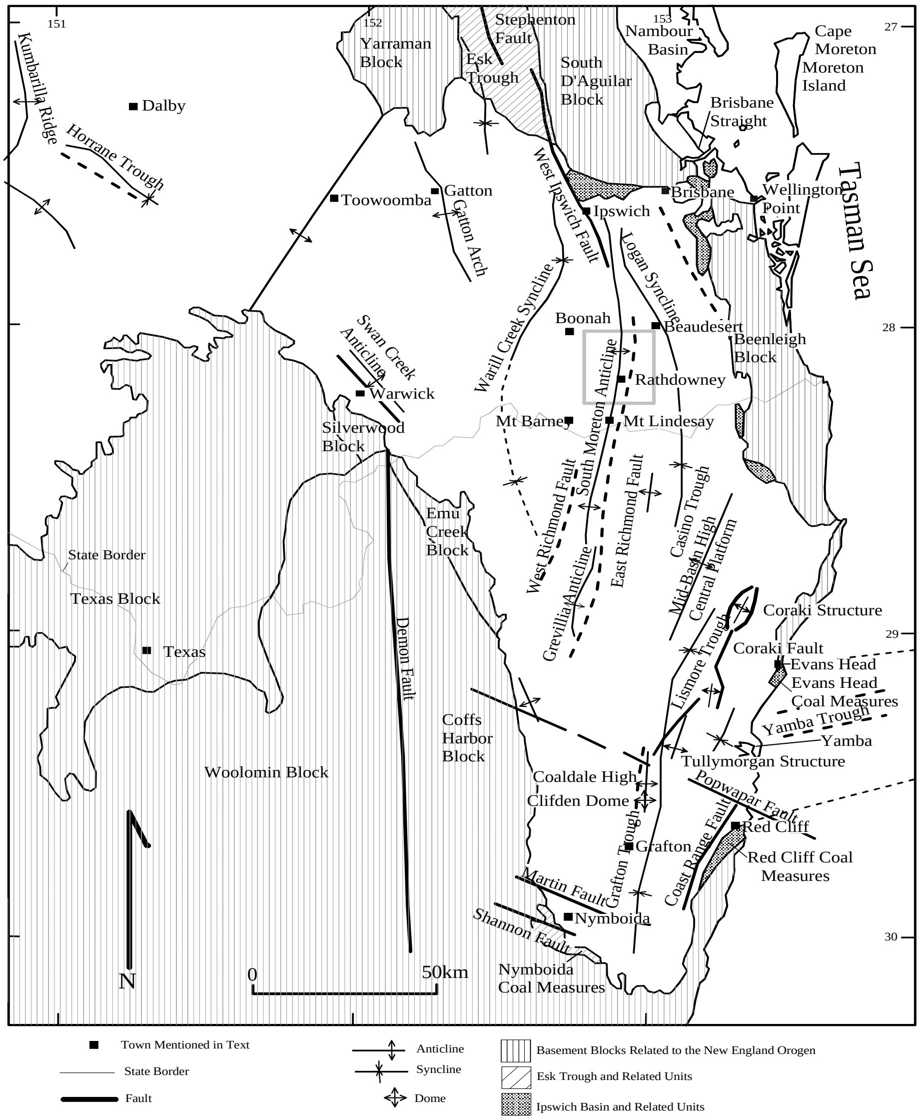

Figure 3 Structural Geology of the Clarence-Moreton Basin

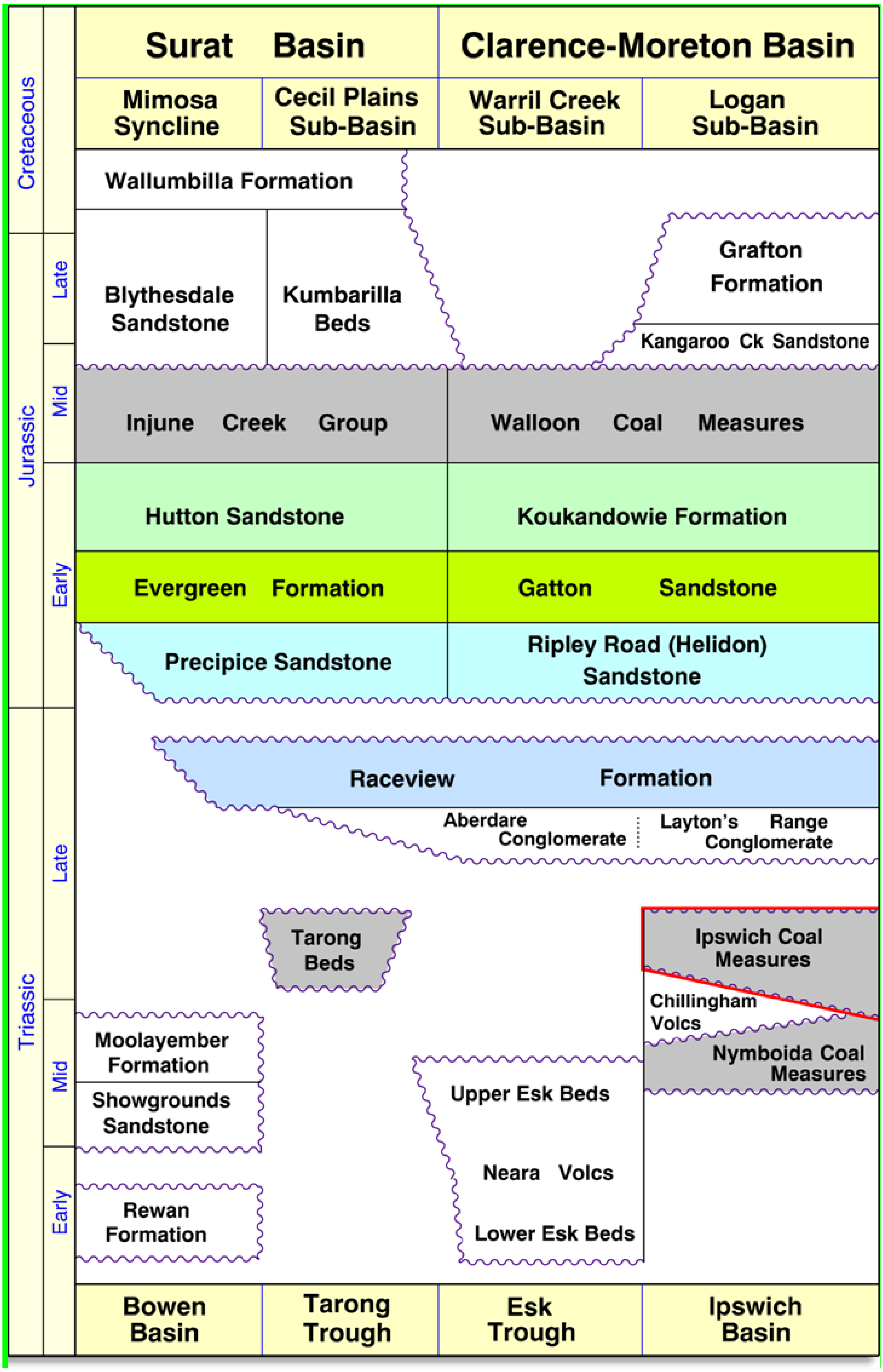

Figure 4 Stratigraphic Section of the Clarence-Moreton and Surat Basins

3.1.2 Local Geology

The Mount Lindesay production tests are located in the Logan sub-basin. A cross section across the Logan sub-basin is shown in Figure 5, showing the stratigraphic and structural relationship between the alluvial Grafton Formation and Kangaroo Creek Sandstone overlying the Walloon Coal Measures, which in turn overlies the Koukandowie Formation. As can be seen in Figure 5, the Logan Sub-basin offset by a number of faults which generally strike north-south across the basin.

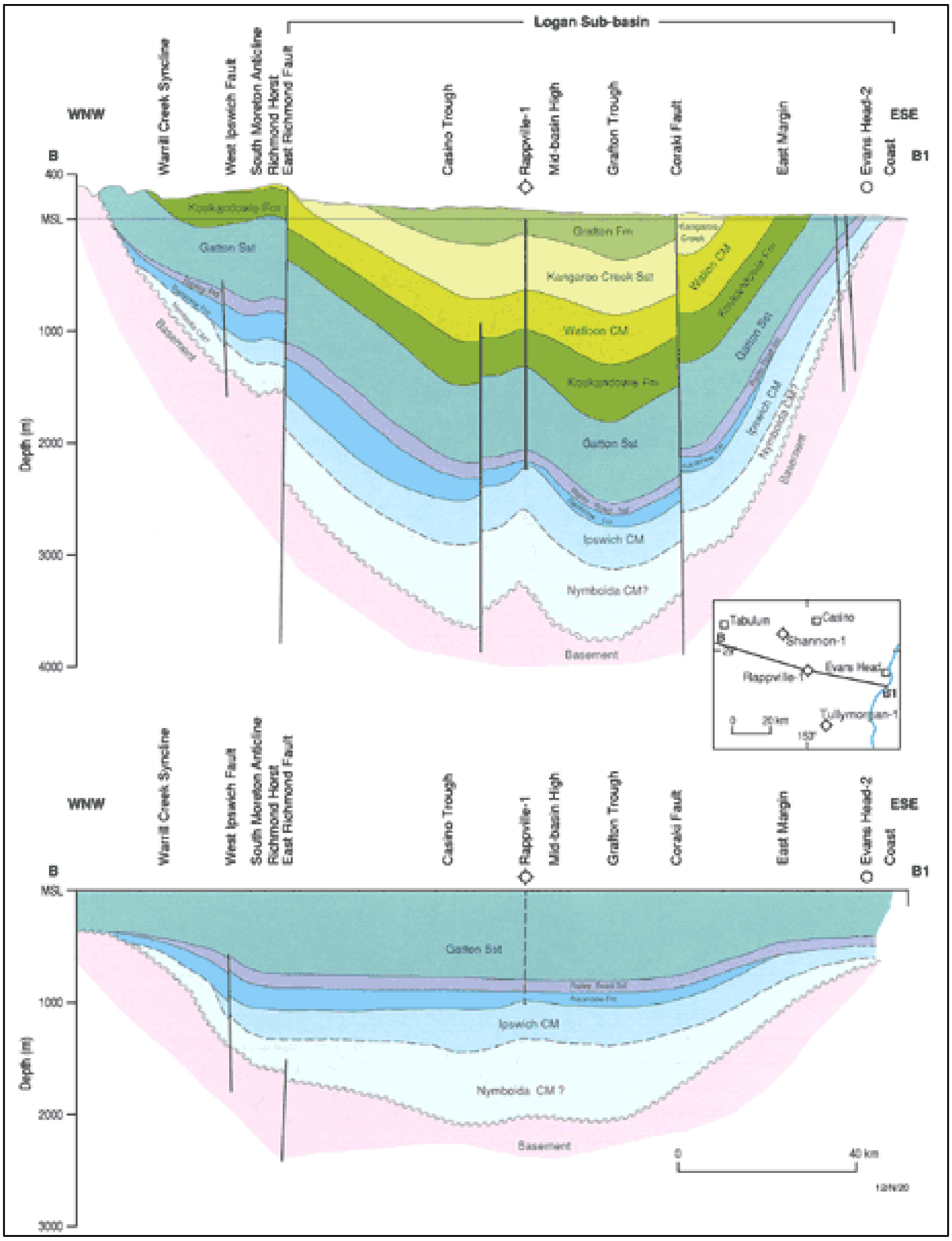

Figure 5 Cross-section of the Logan Sub-basin (After Ingram and Robinson, 1996)

3.2 Aquifers

3.2.1 Alluvium

The Logan Basin Draft Water Resource Plan Environmental Investigations Report: Volume I – Summary Report (DEHP, 2010) describes the groundwater resources in the Logan Basin as follows:

"Most of the groundwater resources in the study area are found in the alluvial aquifers of the Logan and Albert Rivers. The groundwater baseflow component is likely to be chemically variable, depending on local aquifer material. Long and Lloyd (1996) established that the Logan/Albert system follows a relatively simple model of recharge in the southern sector, with regional groundwater flowing northward with an associated increase in total dissolved salts, which is partly the result of evaporative concentration. As reported by Please et al. (1996), to the north the water gets 'older', suggesting that direct recharge to the aquifer in this region is either a very slow process through the unsaturated zone or it is negligible. Horn and Wong (1998) reported almost all groundwater in the catchment is abstracted from depths of between 5 m and 25 m. The primary use for this groundwater is for irrigation and private supplies on farms (Please et al., 1996)."

Data from the DEHP Groundwater Database indicates that a number of bores within 20 km of the production test are screened in the alluvial strata. The alluvial aquifers are comprised of alluvium including clay, silt, sand and gravel and exist predominantly around creeks, rivers and associated flood plains. The alluvial aquifers are classed as porous media aquifers where groundwater occurs within the voids between individual grain particles. The alluvial aquifers in the Logan sub-basin are expected be unconfined or semi-confined.

> Based on the description from the DEHP Groundwater Database the landholder bores in close proximity (<1 km) to the production test wells are located within the alluvium.

A summary table of registered bores within 1 km of the production test wells and a description of the deepest strata they intersect is provided in Table 1. No formal description of the aquifer/formations which are intersected by these bores was available from the DEHP Groundwater Database.

Bore ID	Deepest Lithological Description	Depth Lithological Description was Encountered (m below natural surface)	Bore Casing Depth (m below natural surface)
120450	Brown clay	42.7	NR
120449	Brown and grey sandy gravel and clay,	23.1	23.1
120448	Brown sandy gravel and clay	21.9	NR
120447	Brown sandy gravel and clay	21.3	NR
120446	Brown sandy gravel and clay	21.0	NR
120445	Brown sandy gravel and clay, soft sandstone	20.7	NR
142767	NR	NR	NR
145575	Brown/grey sandy clay and mudstone	30	30
145576	Brown sandy gravel and clay	27	27

Table 1 Summary of bore data from DEHP Groundwater Database (Note: NR - no reliable data)

3.2.2 Walloon Coal Measures

There are nine bores within 20 km of the production test intersecting the Walloon Coal Measures in this area. However, none of these bores are reported within 10 Km of the production test site. Strata descriptions from the DEHP Groundwater Database show that these bores are comprised of interbedded coal, shale, clay, mudstone and sandstone of varying grain size and induration.

Based upon the DERM Groundwater Database, there are no landholder bores screened within the Walloon Coal Measures within c. 10 Km of the production test bores.

Further information relating to the Walloon Coal Measures was available from production test well drilling. The production test well Mount Lindesay-7 was drilled as part of an appraisal program by BNG in August 2009. A total of 43.9 m of coal was intersected. A thickness of 16.4 m was intersected in the Upper Coal zone and 20.1 m was intersected in the Lower Coal Zone. Both zones were economically viable. The bore log for well Mount Lindesay-7 indicates an alluvium that persists to approximately 140 m, while in Mount Lindesay-8 alluvium extends to about 118 m depth. In Mount Lindesay-11 the alluvium extends to 149 m. The alluvium overlies the Walloon Coal Measures which persist to about 520 m below which lies the Koukandowie formation. Individual zones of coal were identified throughout the extent of the Walloon Coal Measures as can be seen from the cross section of the production test area shown in Figure 6.

For the production test bores the perforated intervals are as follows

- In Mount Lindesay-7 in the Walloon Coal Measures is at 521 m to 527 m;
- In Mount Lindesay-8, the perforated intervals of the wells (through which water enters) were at 339 m to 354 m, 433 m to 445 m and 510 m to 514 m; and,

- In Mount Lindesay-11 perforated intervals were at 344 m to357 m, 434 m to 446 m and 511 m to 515.3 m.

These wells are cased and cemented so that water is only accessed at these perforated intervals, indicating a vertical separation distance between the perforated interval of these wells and the overlying alluvium of approximately 195 m to 380 m.

Drill Stem Test (DSTs) of the units failed due to very low water yields which indicate low permeability coals.

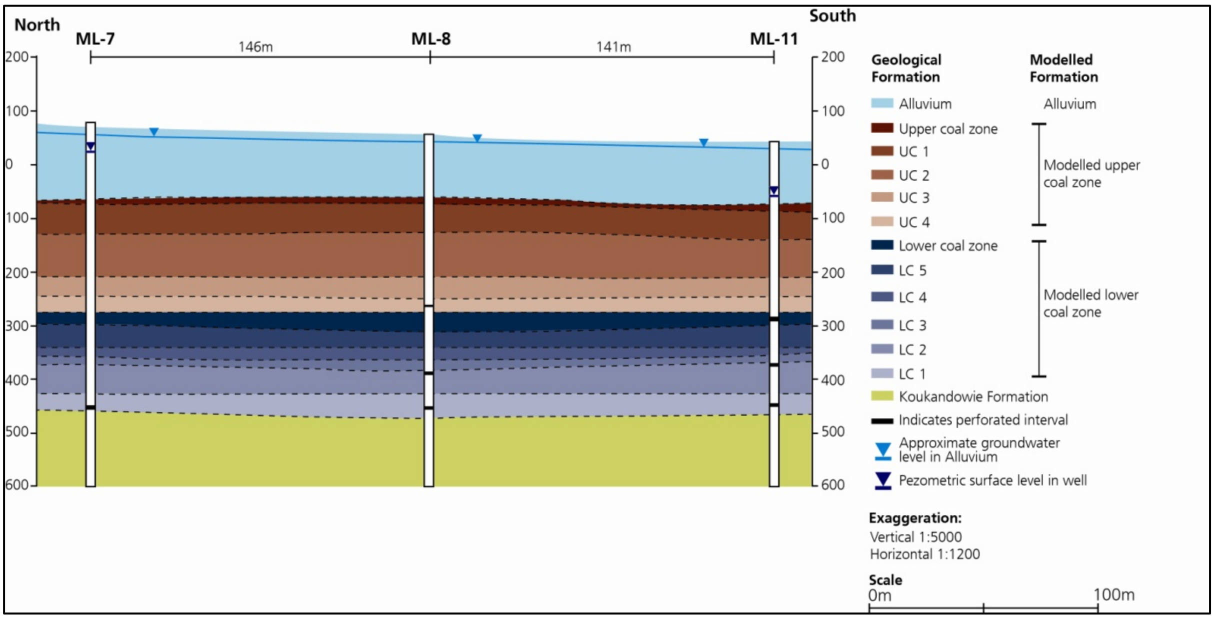

Figure 6 Cross-section of the Production Test Site

3.2.3 Koukandowie Formation

The Koukandowie Formation is described as being a fine to coarse grained, quartz to quartz-lithic sandstone with interbedded conglomerates, sands, and shales. As discussed above, the main resource aquifers used in the area are the alluvial aquifers. While the Koukandowie formation unit underlying the Walloon Coal Measures has the potential for groundwater use, the potential for current and future use in the area is considered low due to the depth of the formation in this area and presence of shallower and more readily accessible water resources.

3.3 Groundwater Bores

Bores registered in the DEHP Groundwater Database within 20 km of the production test wells are shown in Figure 7, the formations which these bores intersect, as shown on Figure 7, were derived from formation descriptions from the DEHP Groundwater Database.

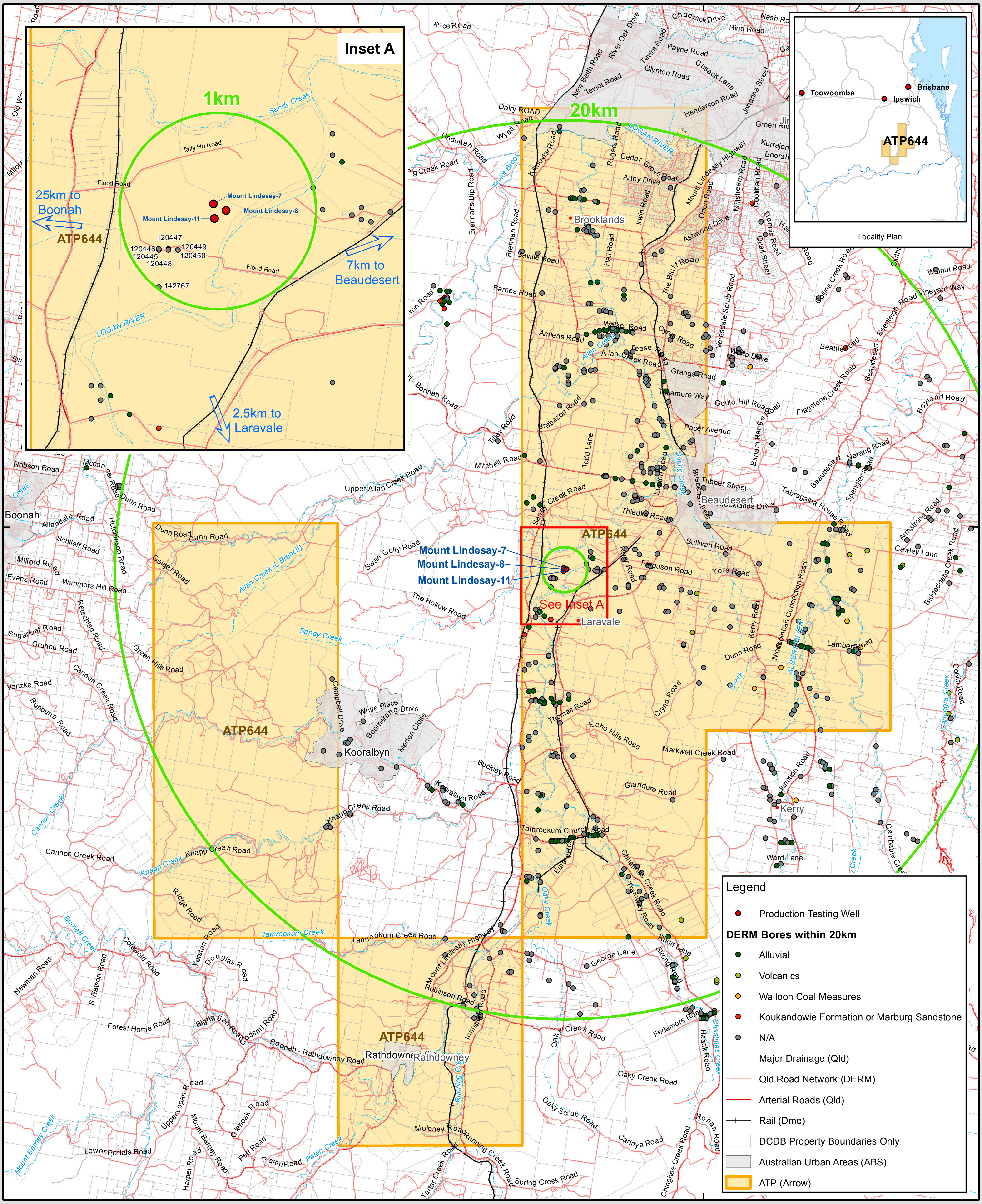

Figure 7 **Bores Registered in the DERM Database in the Vicinity of Production Testing Wells in ATP644**

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

Date: 7/10/2012
Issued To: Issued To
Author: tstringer

0 5 10
Kilometres
Scale: 1:160,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

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Document: V:\Products\Australia\Queensland\Bowen_Basin\Environment\111130_ATP644 Report Plans (SG)\MXDs\DERM Bore within 20km.mxd

3.4 Groundwater Levels

3.4.1 Alluvium

Groundwater levels in the alluvial aquifer in the vicinity of the production test wells are in the order of 10.5 m to 12.8 m below ground surface (based on available information from DEHP Groundwater Database data), A hydrograph of available groundwater level data within 1 km of the production test from the DEHP Groundwater Database is plotted in Figure 8 (note data was only available for one bore within 1 km of the production test).

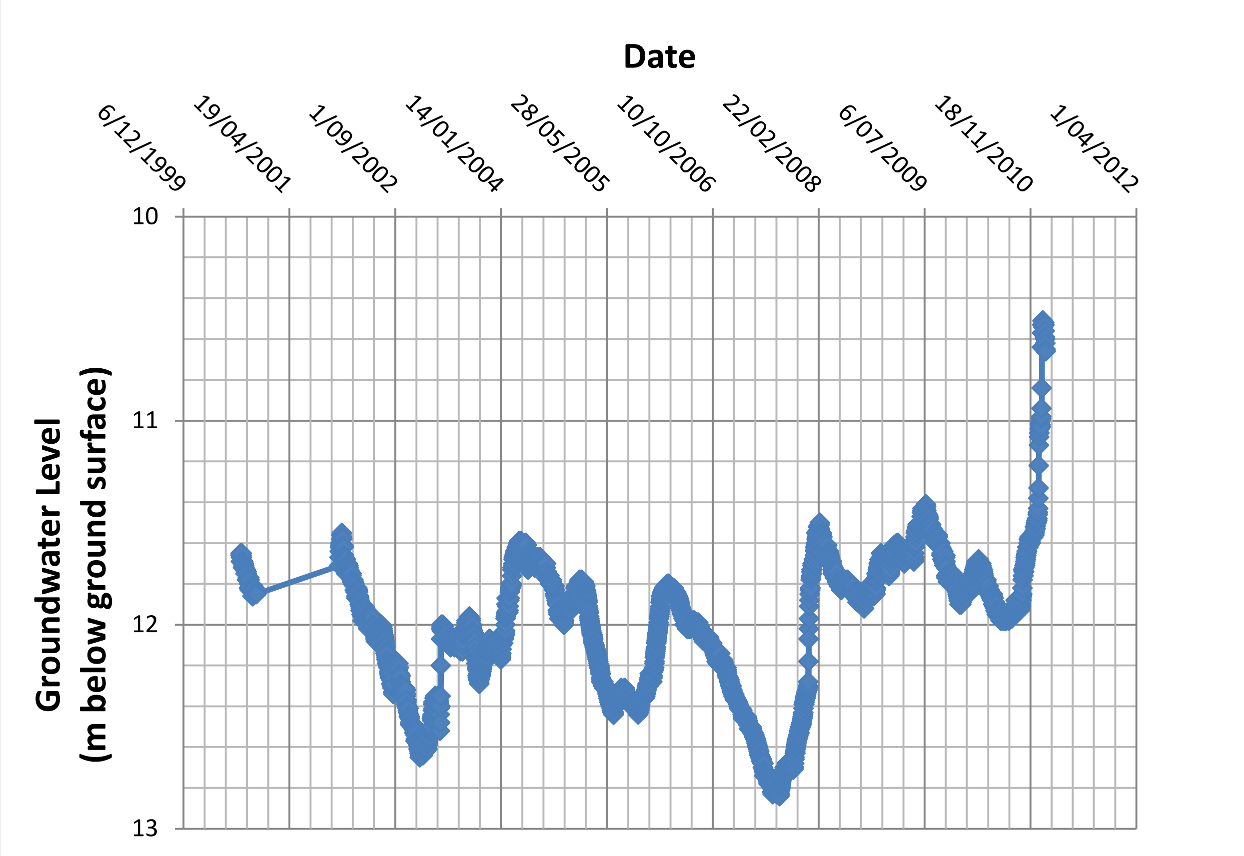

Figure 8 Hydrograph based on Groundwater Level Data from DEHP Groundwater Database (Bore Registration Number 142767)

3.4.2 Walloon Coal Measures

There is no groundwater level data available from the DEHP Groundwater Database for bore intersecting the Walloon Coal Measures within 20 km of the site so local groundwater levels for this formation are taken from information gathered during the production test.

Groundwater levels in the Walloon Coal Measures ranged from 45 m below wellhead (Mount Lindesay-7) to a maximum of 108 m below wellhead (Mount Lindesay-11). This suggests that the pressure in the Walloon Coal Measures is lower than in the alluvial aquifers and that downward vertical gradients may exist from the alluvial aquifers to the Walloon Coal Measures. The variability in groundwater levels within the Walloon Coal Measures may indicate very low hydraulic conductivities and/or lack of interconnectedness between layers within this unit.

3.4.3 Koukandowie Formation

There are a number of Landholder bores which are described in the DEHP Groundwater Database as intersecting the Koukandowie Formation within 20 km of the production test site. These bores are shallow bores (maximum depth is 54 m) so these may not be representative of the Koukandowie Formation in the vicinity of the production test wells which is present at several hundred metres depth. Groundwater levels for these bores are in the order of 13.8 m to 15.0 m below ground surface. These are similar to the values seen for the alluvial aquifer which may indicate these bores are screened within the alluvial aquifer rather than the Koukandowie Formation.

3.5 Groundwater Flow

3.5.1 Alluvium

As indicated in Section 3.2.1, the general flow direction in the alluvial aquifers is anticipated to be northwards in the direction of the Logan River.

3.5.2 Walloon Coal Measures

The flow direction in the Walloon Coal Measures is not apparent from the available water level data. This may be due in part to the low permeability of these units indicative of a lack of horizontal and vertical connection.

3.6 Groundwater Quality

3.6.1 Alluvium

Water quality data from bores in the alluvial aquifers recorded in the DEHP database indicates electrical conductivity of 1,430 µs/cm to 3,500 µs/cm indicating fresh to brackish groundwater.

3.6.2 Walloon Coal Measures

Total dissolved solids concentrations of groundwater in the coal measures ranged from 2,000 mg/L (Mount Lindesay-8 & Mount Lindesay-11) to 5,870 mg/L (Mount Lindesay-7). For comparison to alluvial aquifer water quality data this is approximately equivalent to 3,130 µs/cm to 9,170 µs/cm. This indicates that the water in the coal measures is generally more saline than the alluvial groundwater although it may have a similar salinity to the more saline alluvial groundwater. Water samples from the Walloon Coal Measures collected from flow during the production tests or development of wells are summarised in Figure 9. Data on major cation/anion analysis indicated that the groundwater was generally a sodium-bicarbonate (Na-HCO_3) dominated with lesser amounts of chloride. The data also indicates that the pH of water in the Walloon Coal Measures is variable and ranged from near neutral (6.55) to slightly alkaline 8.85. A summary of these analytical results is provided in Appendix B.

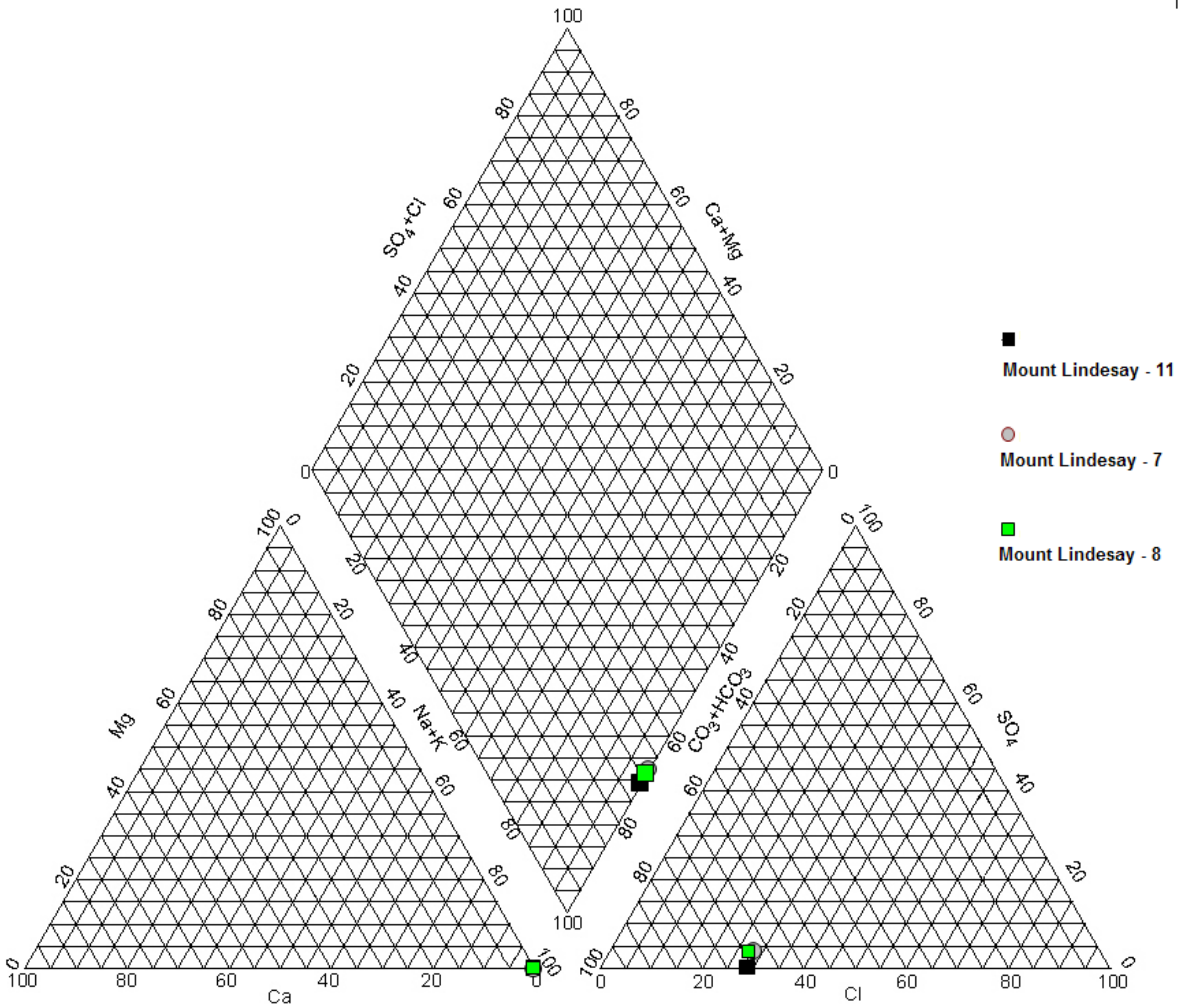

Figure 9 Trilinear Plot of Water Quality in the Walloon Coal Measures

3.7 Springs

A review of the Queensland Springs database found no documented springs within 20 km of the site. The nearest springs are understood to be springs on the basalts of the Lamington Volcanics to the east. These springs are understood to be fed by rainfall discharge from the basalts and not from underlying units and hence due to the distance from the test area and also due to the rainfall discharge source of the springs are not indicated to be impacted by the production test.

To assess potential GDEs, the DEHP wetlands mapping was reviewed and indicated that no areas of lacustrine or palustrine systems were present in the vicinity of the wells on the western side of the Logan River valley.

4 CONCEPTUAL HYDROGEOLOGICAL MODEL

The conceptual hydrogeological model comprises an alluvial aquifer of 118 m to 140 m thickness overlying a thick sequence of several hundred metres of low permeability shales, siltstones, claystones, greywackes, sandstones and coals comprising the Walloon Coal Measures.

The volume of groundwater stored within the alluvial aquifers and the ability of the aquifers to transmit groundwater is largely a function of the particle size of the material comprising the aquifers and the saturated thickness of the sediments. Aquifer properties are variable depending on the nature of the sediments. The alluvial groundwater is anticipated to be hydraulically connected to the surface water systems. Recharge processes in the alluvial aquifers are likely to be 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 aquifers are likely to be:

- through flow into adjacent or underlying aquifers (in particulart the Walloon Coal Measures);
- evapotranspiration;
- discharge to surface water systems (gaining stream); and
- groundwater extraction.

The Walloon Coal Measures is interpreted to be recharged through vertical leakage from the overlying alluvial aquifer and rainfall runoff on the eastern flank of the Logan Sub-basin with potential for some groundwater exchange between underlying Koukandowie Formation. The Walloon Coal Measures are very low permeability units as indicated by the failed DSTs carried out during production test well drilling; where insufficient flow was available for a successful test (i.e.fluid was unable to be recovered from the coals). The perforated intervals of the production test wells are between 195 m and 380 m below the alluvial aquifers and the wells are fully cased and cemented. The 195 m to 380 m thickness of low permeability intervening units therefore has the potential to act as an aquitard or series of aquitards between the zones tested by the production tests and the overlying alluvial aquifers.

In the area of the production test the permeable alluvium aquifer overlying a thick sequence of Walloons Coal Measures comprising interlayered low permeability strata and coal represents and non-complex stratigraphic sequence with little evidence of unconformity or significant structural variation. Groundwater flow is likely to be northward in the alluvium with a component of flow into the Walloon Coal Measures due to a lower groundwater pressure within these units (indicated in by the higher water level in the alluvial aquifer relative to the Walloon Coal Measures shown in Figure 6). However, the connectivity between the Alluvial aquifer and the Walloon Coal Measures is interpreted to be low based on groundwater elevation data. Groundwater flow within the Walloon Coal measures is likely to be structurally down dip. The non-complex nature and interpreted low connectivity of the formations local to the production test area justifies a simple conceptual model.

5 *GROUNDWATER MODELLING*

5.1 Introduction

A simple numerical model was used to assess the potential water level decline in the Walloon Coal Measures and overlying alluvial aquifer as a result of the water taken during the production testing. This model includes the critical components of the conceptual model, these being the permeable alluvium overlying a thick sequence of low permeability rock comprising the siltstone/mudstone interburden and coal layers in the Walloon Coal Measures in this area. It should be noted that relatively little data is available relating to groundwater levels, geology and structural information and this local scale for the area of the production test. As a result the majority of data used to construct the model was derived from exploration data gathered during drilling of the Mount Lindesay production test bores. Based upon the relatively small volume of water taken over a short period, a simple numerical model was considered appropriate. This is considered to be in accordance with the Murray-Darling Basin Commission Groundwater Flow Modelling Guideline (Middlemiss, 2000) which indicates a simple model is suitable for situations that are not complex and do not require detailed resource assessment.

5.2 Modelling Code

The model was formulated in the MODFLOW 2000 numerical code (Harbaugh et al, 2000) along with the user interface Groundwater Vistas, Version 6.07 (ESI, 2007) to simulate groundwater flow. The MODFLOW 2000 code is a finite difference simulation code that is considered one of the "industry standard" pieces of software for groundwater modelling.

5.3 Model Domain

The model domain consists of 80 rows and 80 columns covering an area of approximately 30 km^2. Grid dimension was refined from 100 m by 100 m to 10 m by 10 m in the vicinity of the production test wells. The model domain was based on a conservative physical extent of the potentially effected aquifers based upon the relatively small volume of water during the production test. The model domain is shown in Figure 10.

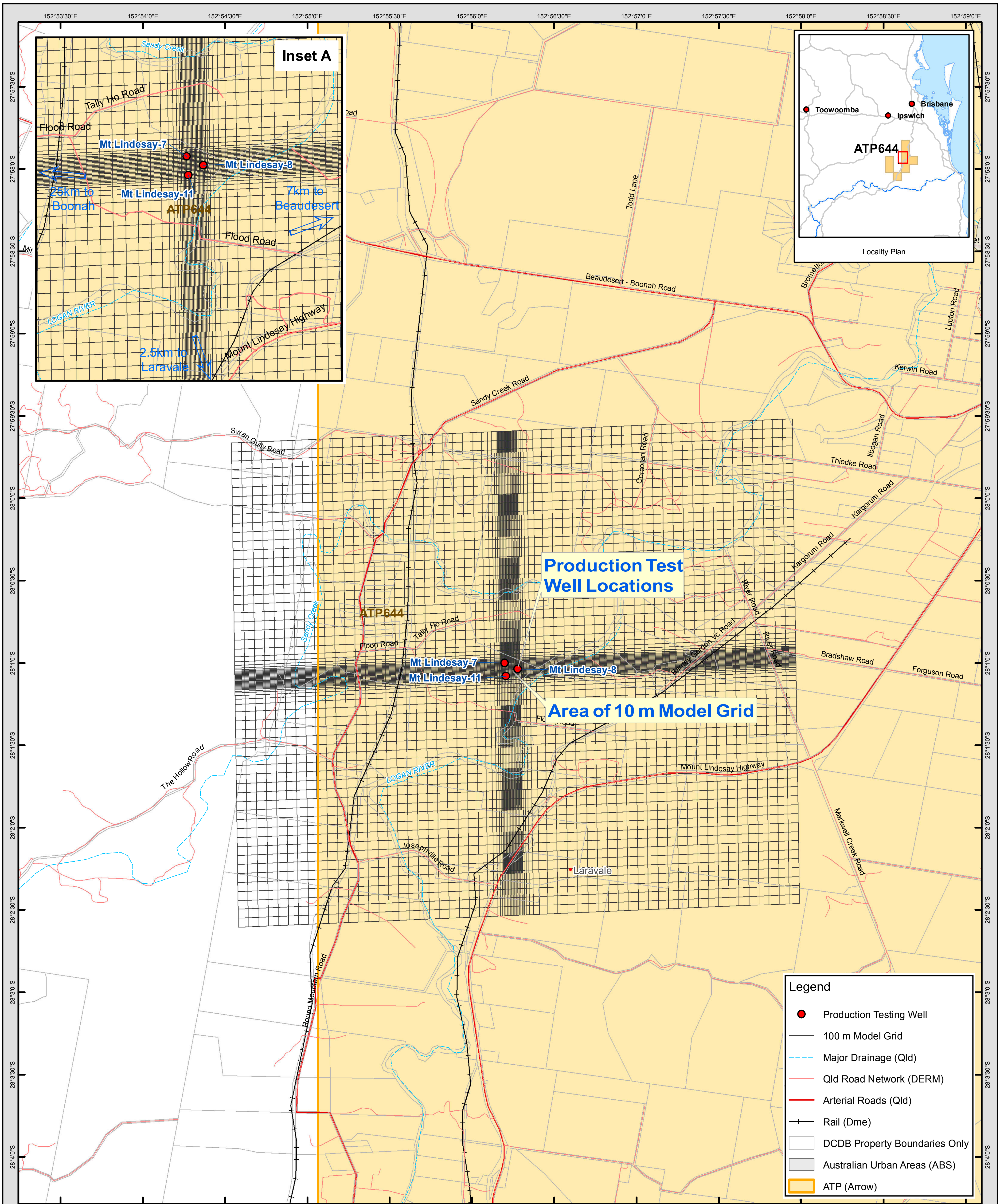

Figure 10 **Model Domain**

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

Date: 7/11/2012
Issued To: Issued To
Author: tstringer

0 2 4
Kilometres

Scale: 1:40,000 @ A3
Coordinate System: GCS GDA 1994

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arrow energy go further

Document: V:\Products\Australia\Queensland\Bowen_Basin\Environment\111130_ATP644 Report Plans (SG)\MXDs\Model Domain.mxd

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5.4 Layering

In order to effectively represent groundwater behaviour in the testing aquifer system and regard of model numerical stability in the calibration and prediction the model is vertically specified into 8 layers:

- The alluvium is represented as two layers. These are layers 1 and 2 and represent the alluvial aquifer that overlies the Walloon Coal Measures in some locations and which forms the primary resource aquifer used locally.
- The Walloon Coal Measures are represented by 6 layers (layers 3 to 8) in order to simulate the potential propagation of drawdown impacts through the Walloon Coal Measures from the perforated intervals of the wells to the alluvium

The model layer thicknesses were set as follows:

- layers 1 and 2 were each 50 m thick unconfined layers representing the alluvial aquifer; and
- layers 3 to 8 simulate 365 m of the confined Walloon Coal Measures and each layer was approximately 45 m thick.

Figure 11 shows a block view of the model in cross-section indicating the various layers as represented in the model.
Note the Koukandowie Formation underlying the Walloon Coal Measures was not modelled for three reasons:

- Data for bores (registered in the DEHP Groundwater Database) installed into this formation in the vicinity of the production testing wells is unreliable and suggest there are no bores in this unit in the vicinity of the testing;
- This formation is considered to have low potential for current and future use in this area as a water resource due to its depth; and,
- No other receptors were identified locally within the Koukandowie Formation.

As a “worst case” scenario it was conservatively assumed that the water level decline in this formation was of the same magnitude as that within the Walloon Coal Measures. In reality, water level decline will be lower in the Koukandowie Formation as it is separated from the zone of the coal measures where water was being taken from by an intervening thickness of the coal measures between the production zone in the coal measures and the top of the Koukandowie Formation.

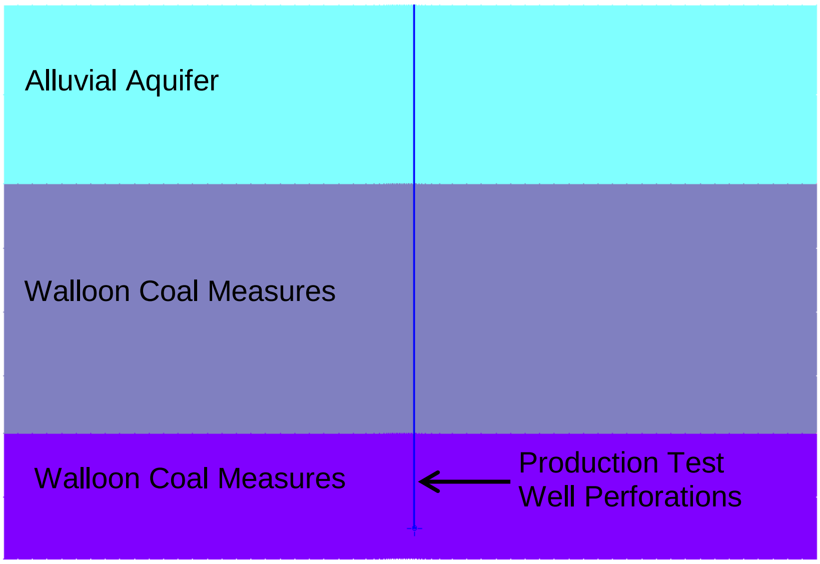

Figure 11 Block view of the model domain in cross-section

5.5 Boundary Conditions

The boundary conditions applied within the model were MODFLOW General head boundaries. These were applied to Layer 1 only and developed based on data from the DEHP Groundwater Database.

5.6 Input Parameters and Calibration

Hydraulic parameter values for the layers were originally estimated from published values (Krusemann & de Ridder, 1994) for the type of material present in each layer. Parameter values were refined and calibrated during the modelling process. The model calibration was carried out in transient case with the measured pumping rates in the three production wells and the observed groundwater levels in a period 224 days at well Mount Lindesay-8. The hydrograph of observed and simulated groundwater levels is shown in Figure 12. This is a simple model with a limited observation set for calibration, the scaled root mean square (SRMS) was 0.3. The calibration is considered to be simple and qualitative.

Calibrated parameters used in the predictive model were:

- Alluvial aquifer horizontal hydraulic conductivity of 0.1 m/day and specific yield of 5% (blue in Figure 11); and
- Walloon Coal Measures hydraulic conductivity of 9×10^{-5} m/day, specific storage of 9×10^{-5} to 9×10^{-6} (light and dark purple in Figure 11).

The three production wells (Mount Lindesay-7, Mount Lindesay-8 and Mount Lindesay-11) were included in the model. A single hydraulic conductivity value was applied to all the layers representing the Walloons Coal Measures essentially providing a series of low permeability layers that reflect the known data on this formation and matching the conceptual site model.

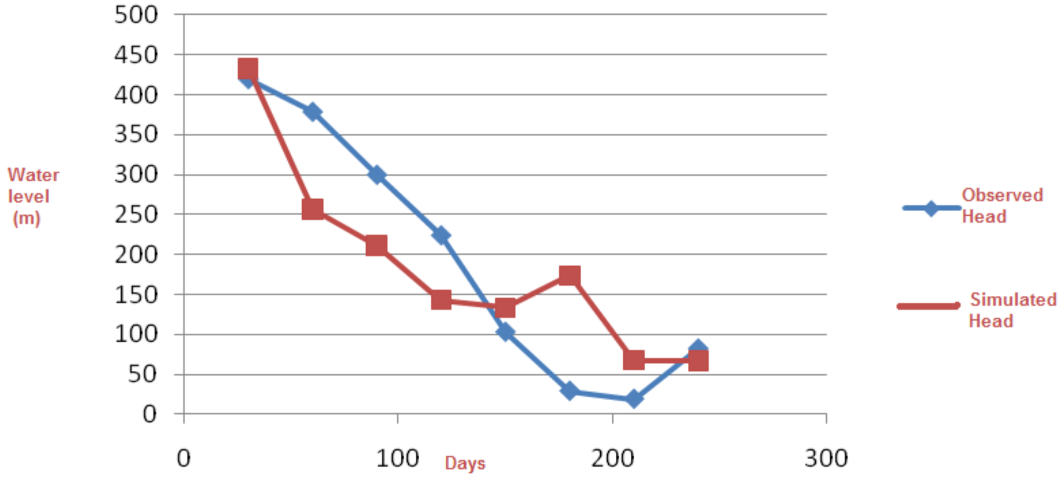

Figure 12 Observed and Simulated Water Levels

5.7 Simulation Time

The model was run to extract the water volumes taken from each well (as per Section 2.2) during the production tests over 224 days. This was followed by a three year period after production testing to assess the recovery in water levels.

5.8 Mass Balance

Mass balance data for the entire model run is presented in Table 2. The overall mass balance error for the model was <0.07%.

Description	Model Inflows	Model Outflows
TOTAL (m^3)	7711.40	7716.50
ERROR (%)	-0.07	

Table 2 Mass balance for model

5.9 Groundwater Model Predictions

Model predictions were undertaken to assess water level decline in the Walloon Coal Measures and overlying alluvial aquifer as a result of the water taken during the production testing.

5.9.1 Alluvial Aquifer

As discussed above, bores registered in the DEHP database were installed into the alluvial aquifer. Water level decline in the alluvial aquifer in the vicinity of the three production test wells (summarised in Table 2) did not exceed the bore trigger threshold of 2 m (for unconfined aquifers) upon completion of the production tests or three years after production testing was completed.

Days of Simulation	Drawdown in Alluvial Aquifer
100	Less than 0.001 m
224	Less than 0.001 m
1335	Less than 0.001 m

Table 3 Summary of maximum water level decline in the alluvial aquifer

No figures have been produced for the alluvial aquifer as the water level decline is simulated is too small to plot and is not predicted to exceed the bore trigger threshold within this aquifer within 3 years or at any time.

5.9.2 Walloon Coal Measures

Water level decline greater than the bore trigger threshold of 5 m (for a confined aquifer) in the Walloon Coal Measures was modelled extend approximately 550 m from the production wells at the end of production testing. Water level decline in the Walloon Coal Measures reduced following the completion of production testing so that the bore trigger threshold was not exceeded three years after production testing. This depressurisation causing water level decline greater than the bore trigger threshold occurs in the lowest model layer representing the Walloon Coal Measures and does not persist upwards through the coal measure layers. Figure 13 shows the area of the Walloon Coal Measures where the water level is predicted to decline by more than the bore trigger threshold within three years after the consultation day for this report (the 1st December 2011). As the production testing has ceased, no additional water level decline within the Walloon Coal Measures will occur. Therefore, Figure 13 also presents the area of the Walloon Coal Measures where the water level is predicted to decline by more than the bore trigger threshold at any time because of the exercise of underground water rights described in Section 2.2.

As described above, the water level decline in the Koukandowie Formation was assumed to be of the same magnitude. Figure 13 therefore also presents the area of the Koukandowie Formation where the water level is predicted to decline by more than the bore trigger threshold within three years and at any time. No bores registered in the DEHP database were identified as being installed into the Walloon Coal Measures within the area shown in Figure 13. Figure 7 showed that the nearest bores registered in the DEHP database are further than 500 m from the production tests and located in the alluvial aquifer.

5.9.3 Predictive Uncertainty

A stochastic run of the model was carried in order to assess the predictive uncertainty associated with the model results. The stochastic model was set up to run a set of 100 realisations using varying values of hydraulic conductivity within the alluvial aquifers. The value range used was 0.01m/d to 1 m/d with a standard deviation of 0.03 m/d. The results of this stochastic run are presented in Figure 14. The contours represent the probability of drawdown within the Walloon Coal Measures exceeding the Bore Trigger Threshold (5 m) over the entire model run based on the 100 realisations. The figure shows the drawdown exceeding Bore Trigger Threshold of 5m extending 200m away from the production test bores is about 25% of probability, while the drawdown of 5m extending 10m to 50m away from the production test bores could be 75% of probability. This result indicates that there is a low probability of impacts extending significantly further than 500-600 m laterally from the centre of the production well test area and negligible potential for propagation of impacts to the shallow surface alluvial aquifer at any known landholder bore locations.

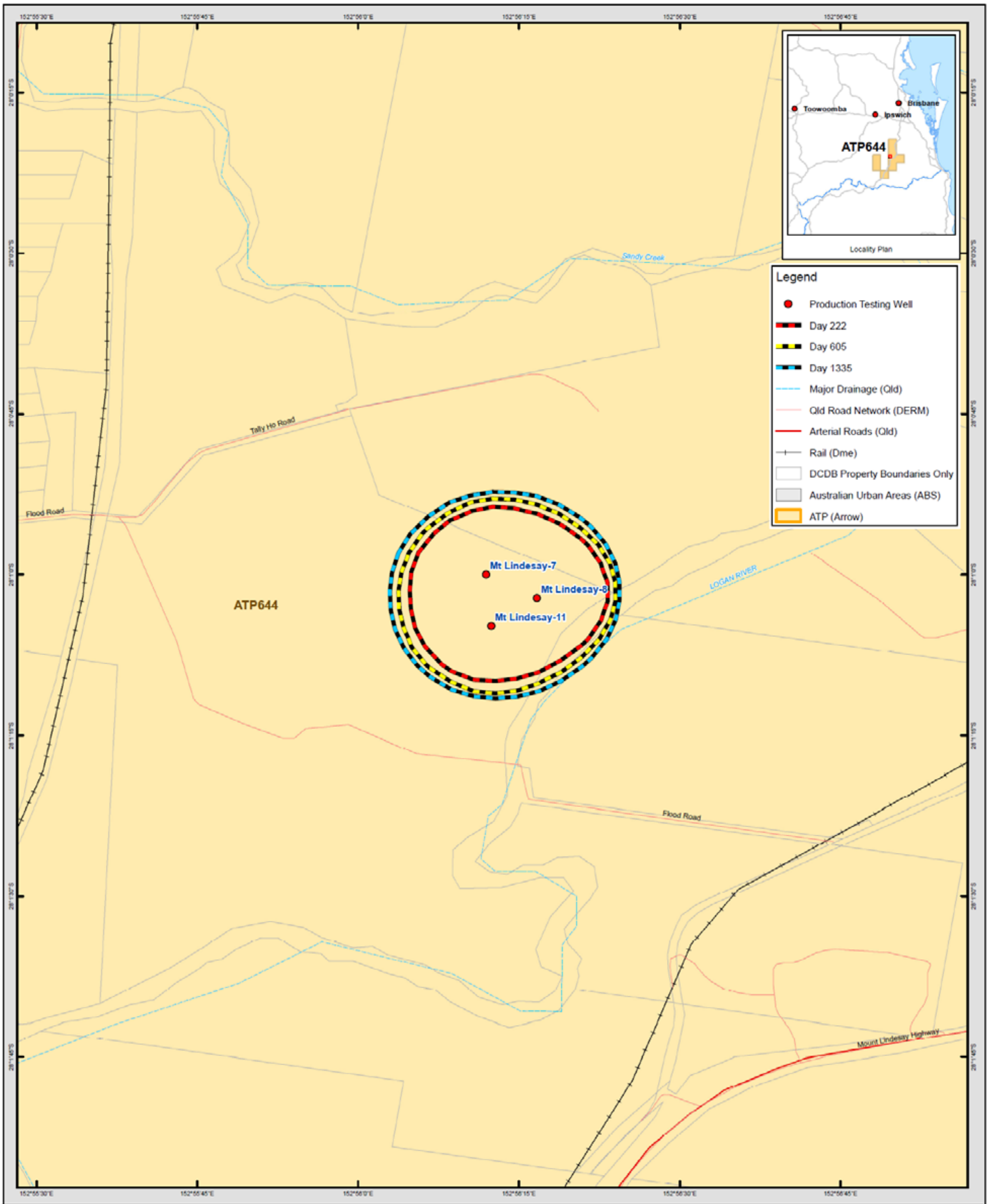

Figure 13 **Predicted Water Level Decline by More than the Bore Trigger Threshold within the Walloon Coal Measures**

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

Date: 7/11/2012
Issued To: Issued To
Author: tstringer

0 0.5 1
Kilometres

Scale: 1:10,100 @ A3
Coordinate System: GCS GDA 1994

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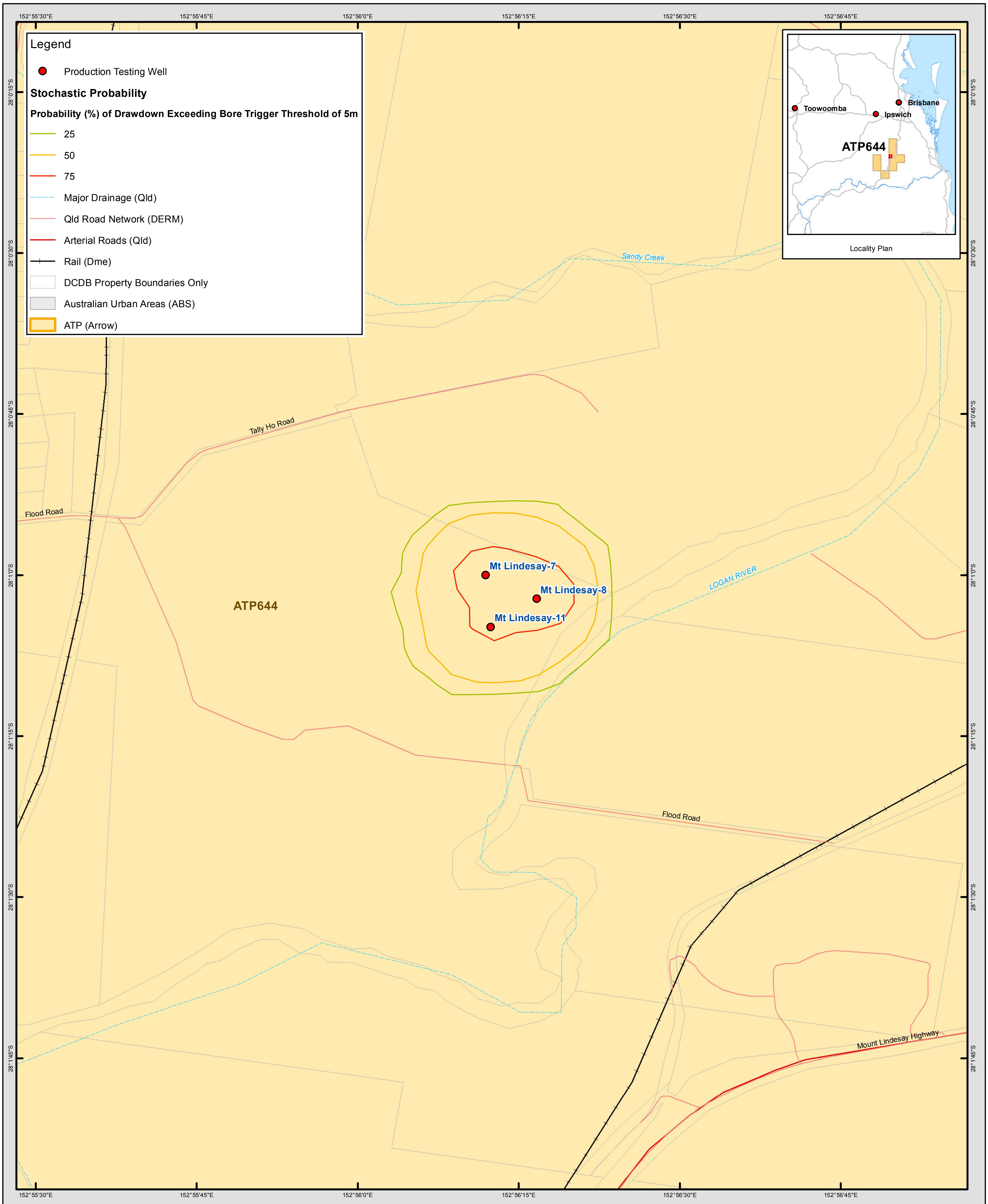

Figure 15 Stochastic Model Run Showing Probability of Drawdown Exceeding Bore Trigger Threshold of 5m within the Walloon Coal Measures (Day 1335)

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

Date: 23/07/2012

Author: tstringer

0 0.5 1
Kilometres

Scale: 1:10,100 @ A3
Coordinate System: GCS GDA 1994

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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_BasinEnvironment\111130_ATP644 Report Plans (SG)\MXDs\Stochastic Model Run.mxd

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6 *GROUNDWATER MANAGEMENT*

It is concluded that the impacts of extraction of underground water during and after production testing within ATP644 are extremely low given that:

- groundwater modelling indicates:
  - a limited extent (approximately 550m) and duration (less than three years) of water level decline in excess of the bore trigger threshold within the Walloon Coal Measures;
  - absence of water level decline in excess of the bore trigger threshold within the alluvial aquifers;
- limited volumes of water (0.54 ML to 0.69 ML per production test) were abstracted during the production tests;
- the alluvial aquifer (the main resource aquifer used in the area) is separated from the perforated interval of the wells by a 195 m to 380 m thickness of low permeability units for the 3 production test wells;
- the intervening low permeability units have the potential to act as an aquitard or series of aquitards between the zones tested by the production tests and the overlying alluvial aquifer;
- the production test wells are fully cased and cemented between different hydrogeological units. Groundwater behaviour at each unit in the production wells was observed to be significant difference; and
- landholder bores (within the alluvium) are located at least 500-900 m away from the production test wells. 6.1 Water Monitoring Strategy

As the immediately affected area is an area within the Walloon Coal Measures at the depth of the production well perforations and extending about 550m laterally from the pilot bores; and, as there are no landholder bores reported within the immediately affected aquifer (the coal measures) within the area of impact nor within c. 10Km of the pilot bores, the following Water Monitoring Strategy is proposed.

- If at any time in the future a bore is identified within the immediately affected area and within 2 Km of the pilot bores then a bore assessment will be undertaken.
- This would include a baseline bore assessment based upon the Water Act (2000) requirements for baseline bore assessments.

Should further production testing take place at any time in the future, then the proposed water monitoring strategy includes:

- The quantity of water produced will be assessed in the same manner as described in Section 2.
- A baseline assessment of identified bores within a 2 Km radius of the proposed production test will be undertaken. The pilot bores will be monitored and sampled to assess the change in water level in the affected aquifer.
- The underground water impact report will be updated at the review date to include the impacts of new production testing in its predictions.

6.1.1 Groundwater Level and Water Quality Monitoring

Water levels will be gauged by either manual methods or where appropriate by downhole datalogger. The laboratory analysis for the proposed field parameters and the laboratory analytical schedule for groundwater samples are listed in Table 4 below.

Table 4: Monitoring suite

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

6.1.2 Annual 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 have materially changed.

The implementation of the water monitoring strategy will be reported in the annual summary to DEHP and the Queensland Water Commission.

The proposed schedule for the review will comprise:

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

A spring management strategy is made for each potentially affected spring in the area to which the entity's report relates (S379 of the Water Act, 2000). As there are no identified springs in the area of potential impact, no spring management strategy is proposed.

It is therefore proposed that no specific spring management strategy for ATP644 is required.

No production tests are planned within ATP644 within the next 12 months. A production test may be considered after this period.

GLOSSARY

Abstraction	The removal of water from a resource e.g. the pumping of groundwater from an aquifer.
Alluvium	Unconsolidated deposits such as sands, gravels and clays deposited by flowing water such as rivers and streams.
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.
Aquitard	A geological formation having low (but not zero) permeability to water, such as a silty or clayey layer.
Artesian Aquifer	A confined aquifer with the potentiometric level above ground level.
Artesian Bore	A borehole where the potentiometric level is above ground level.
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.
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 and has a high sodium adsorption ratio (SAR). Coal seam gas water is a waste, as defined under the section 13 of the Environment Protection Act. (DEHP, 2011).
Cone of Depression	The area of drawdown produced in the water table 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.
Discharge Area	An area where groundwater flows out of an aquifer.
Dissolved Solids	Soluble compounds such as salts which are in solution.

Drawdown	The drop in the water table 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.
Fault	A structural discontinuity in a rock mass or geological formation.
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).
Groundwater	Any sub-surface water, generally present in an aquifer or aquitard.
Groundwater Flow	The movement of water in an aquifer.
Hydraulic Conductivity	A standard measure of the permeability of a geological formation or its ability to transmit groundwater flow. Units to measure the rate of flow include m/day (metres per day)
Hydraulic Gradient	The slope of the water table 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.
Infiltration	Rainfall penetration into the soil profile or sub-surface. Infiltrated water that accesses the water table is one component of groundwater recharge.
Nutrients	A chemical that an organism needs to live and grow, or a substance used in an organism's metabolism obtained from its environment.
Palaeochannel	Unconsolidated sediments or semi-consolidated sedimentary rocks deposited in ancient, currently inactive river and stream channel systems.
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 water table.
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.
Runoff	Rain water that flows across the land surface without entering the sub-surface.
Saturated Zone	The zone in which the voids in the rock are completely filled with water. The water table represents the top of the saturated zone in an unconfined aquifer.
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 (e.g. soil) or saturated zone (e.g. 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.
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.
Water table	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.
Analyte Abbreviations	The following abbreviations indicate the ion in solution or where used together the groups of ions in solution.
CO_3	Carbonate
HCO_3	Bicarbonate
SO_4	Sulphate
Cl	Chloride

Na	Sodium
Mg	Magnesium
Ca	Calcium
K	Potassium
mg/L	The concentration of an analyte in solution. A milligram is 1/1000th of a gram. L is litres.
µs/cm	micro-siemen per centimetre, a measure of how well a solution conducts electricity. A salt water solution will contain more ions and conduct electricity more readily than a fresh water solution.

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APPENDIX A – PRODUCTION DATA

	Flow Rate (L/day)		
Date	Mount Lindesay - 7	Mount Lindesay - 8	Mount Lindesay - 11
4/03/2010	1555	2160	
5/03/2010	1296	1980	
6/03/2010	2074	2160	
7/03/2010	1555	1980	
8/03/2010	1555	1800	
9/03/2010	2592	2700	
10/03/2010	1555	3060	
11/03/2010	1296	2520	
12/03/2010	1555	3240	
13/03/2010	1296	2520	
14/03/2010	1037	2340	
15/03/2010	1037	2160	
16/03/2010	1555	2880	
17/03/2010	1296	2340	
18/03/2010	1296	2160	
19/03/2010	1555	2700	
20/03/2010	1296	2520	
21/03/2010	1037	2340	
22/03/2010	1037	2160	
23/03/2010	1296	2160	
24/03/2010	1037	1980	
25/03/2010	1814	2700	
26/03/2010	1296	2340	
27/03/2010	1037	2160	
28/03/2010	1814	2700	
29/03/2010	1555	2520	
30/03/2010	1296	2340	
31/03/2010	1814	2700	
1/04/2010	1296	2520	
2/04/2010	1555	2160	
3/04/2010	1296	2160	
4/04/2010	1296	1980	
5/04/2010	1037	2160	
6/04/2010	1296	1980	
7/04/2010	1555	2700	
8/04/2010	1296	2340	
9/04/2010	2074	2880	
10/04/2010	1814	3240	
11/04/2010	1814	2700	
12/04/2010	1555	1620	
13/04/2010	1555	2880	
14/04/2010	1296	3004	
15/04/2010	2592	4720	
16/04/2010	1814	3433	
17/04/2010	2851	4935	
18/04/2010	2333	4077	

	Flow Rate (L/day)		
Date	Mount Lindesay - 7	Mount Lindesay - 8	Mount Lindesay - 11
19/04/2010	1814	3862	
20/04/2010	2592	4077	
21/04/2010	2074	3648	
22/04/2010	1925	3433	
23/04/2010	3301	4935	
24/04/2010	2475	4291	
25/04/2010	2475	2575	
26/04/2010	2200	2360	
27/04/2010	2200	2146	
28/04/2010	3301	3218	
29/04/2010	2475	2146	
30/04/2010	2200	2360	
1/05/2010	3576	3004	
2/05/2010	2750	2575	
3/05/2010	2475	2146	
4/05/2010	3686	1717	215
5/05/2010	3917	2789	215
6/05/2010	3917	2360	858
7/05/2010	4147	1931	644
8/05/2010	3686	2146	858
9/05/2010	3226	1931	644
10/05/2010	3456	1931	429
11/05/2010	3226	1931	644
12/05/2010	3686	1717	858
13/05/2010	3456	2146	644
14/05/2010	3686	1931	644
15/05/2010	3456	8797	4077
16/05/2010	3226	6008	2789
17/05/2010	3686	4506	2146
18/05/2010	4147	3648	1717
19/05/2010	4838	3433	2360
20/05/2010	4838	4077	2146
21/05/2010	5760	3218	2360
22/05/2010	5069	3862	2360
23/05/2010	4378	2575	1931
24/05/2010	4147	2575	1931
25/05/2010	2534	858	858
26/05/2010	2995	0	0
27/05/2010	3456	4077	0
28/05/2010	3226	2789	0
29/05/2010	2995	2146	0
30/05/2010	2995	2146	0
31/05/2010	2995	1717	0
1/06/2010	3686	1931	0
2/06/2010	3917	2360	1287
3/06/2010	4147	2360	2789

	Flow Rate (L/day)		
Date	Mount Lindesay - 7	Mount Lindesay - 8	Mount Lindesay - 11
4/06/2010	5069	2146	2360
5/06/2010	4378	2789	2575
6/06/2010	3456	2146	1931
7/06/2010	4147	1931	1931
8/06/2010	3226	2146	1931
9/06/2010	4838	2146	1717
10/06/2010	3226	2146	2360
11/06/2010	2534	1502	1931
12/06/2010	2534	2360	2146
13/06/2010	2534	1931	1717
14/06/2010	2304	1717	1717
15/06/2010	1382	1502	1502
16/06/2010	3226	644	429
17/06/2010	2995	1717	1931
18/06/2010	2765	1931	858
19/06/2010	3226	2360	1717
20/06/2010	3686	1717	1717
21/06/2010	2977	2360	1717
22/06/2010	4579	1931	1717
23/06/2010	3663	2360	1931
24/06/2010	4579	2146	1717
25/06/2010	3892	2360	1931
26/06/2010	3892	2360	1717
27/06/2010	3892	2146	1931
28/06/2010	4579	2360	1931
29/06/2010	4579	2146	1931
30/06/2010	4579	2575	2360
1/07/2010	4579	2146	2360
2/07/2010	4808	2575	2360
3/07/2010	5037	2360	2575
4/07/2010	4121	2575	2575
5/07/2010	4579	2360	2789
6/07/2010	4579	2789	2789
7/07/2010	4121	2146	2575
8/07/2010	4350	2789	2789
9/07/2010	4350	2360	3433
10/07/2010	2748	2789	2360
11/07/2010	3434	2146	2575
12/07/2010	3663	1931	2789
13/07/2010	2977	2360	3218
14/07/2010	3434	2789	2789
15/07/2010	2977	2575	3218
16/07/2010	1832	2575	2789
17/07/2010	2977	2360	2789
18/07/2010	3205	2575	3004
19/07/2010	3205	2714	3286

	Flow Rate (L/day)		
Date	Mount Lindesay - 7	Mount Lindesay - 8	Mount Lindesay - 11
20/07/2010	2290	3132	4225
21/07/2010	1603	3132	3521
22/07/2010	0	2923	4225
23/07/2010	4350	3132	4225
24/07/2010	2748	2714	4225
25/07/2010	2519	2506	4225
26/07/2010	2748	2923	4694
27/07/2010	2519	2714	4460
28/07/2010	3205	3341	4694
29/07/2010	2748	2923	5399
30/07/2010	2519	2714	5164
31/07/2010	2519	3132	5164
1/08/2010	2748	2506	4694
2/08/2010	2061	2923	3990
3/08/2010	5037	3341	3990
4/08/2010	3205	2714	3990
5/08/2010	4121	2714	3756
6/08/2010	2748	2923	3990
7/08/2010	2519	2506	3521
8/08/2010	3663	3132	3756
9/08/2010	4121	2506	3521
10/08/2010	2290	2506	3990
11/08/2010	2977	2923	4929
12/08/2010	3434	2923	4694
13/08/2010	0	3132	4929
14/08/2010	0	2923	4225
15/08/2010	7098	3550	4929
16/08/2010	6869	4802	5164
17/08/2010	3892	3132	4929
18/08/2010	0	3132	4225
19/08/2010	0	3341	5164
20/08/2010	0	3341	5399
21/08/2010	0	3550	4694
22/08/2010	0	3132	4460
23/08/2010	0	2714	4460
24/08/2010	8929	2297	4929
25/08/2010	12135	3341	4929
26/08/2010	5495	2923	4929
27/08/2010	5495	2714	4460
28/08/2010	4579	2714	4225
29/08/2010	3434	2088	3051
30/08/2010	3434	2506	1408
31/08/2010	5724	2923	3756
1/09/2010	5266	2297	4460
2/09/2010	4121	3341	4929
3/09/2010	4808	2714	4929

	Flow Rate (L/day)		
Date	Mount Lindesay - 7	Mount Lindesay - 8	Mount Lindesay - 11
4/09/2010	3434	2923	5164
5/09/2010	4579	2714	5164
6/09/2010	3434	3341	5399
7/09/2010	4350	2297	4694
8/09/2010	3434	3341	4694
9/09/2010	4350	2923	4929
10/09/2010	5495	1462	5633
11/09/2010	3892	2714	5399
12/09/2010	3663	2088	4929
13/09/2010	3663	2506	5399
14/09/2010	4121	1462	4929
15/09/2010	4579	2088	5399
16/09/2010	2977	2297	4929
17/09/2010	4350	2714	4694
18/09/2010	3892	1462	4929
19/09/2010	3663	2714	4460
20/09/2010	3663	1670	4929
21/09/2010	3434	2297	5164
22/09/2010	3663	2714	5399
23/09/2010	4121	1253	5399
24/09/2010	4121	2714	5633
25/09/2010	3205	1253	5633
26/09/2010	3434	2506	5633
27/09/2010	3434	1253	5633
28/09/2010	3892	2714	6103
29/09/2010	3663	1670	5868
30/09/2010	2519	0	4929
1/10/2010	3892	0	4694
2/10/2010	4350	0	5164
3/10/2010	4121	0	5164
4/10/2010	3434	0	5164
5/10/2010	3434	1044	5164
6/10/2010	4121	1879	2817
7/10/2010	3434	0	1174
8/10/2010	2748	209	3051
9/10/2010	3663	0	4460
10/10/2010	3205	0	4929
11/10/2010	4121	418	4460
12/10/2010	3205	0	5868
13/10/2010	2977	0	5164
14/10/2010	1603	0	4460

APPENDIX B – ANALYTICAL SUMMARY TABLE

Site ID	Cl (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	TDS (mg/L)
ML3	898	1	25	1180	333	103	466	45	3150
ML3	1190	1	157	1210	116	25	1060	448	4150
ML3	2260	23	791	874	85	21	1680	433	5870
Mt Lindesay-11	357	145	1220	2	2	1	815	6	2040
Mt Lindesay-7	362	153	1200	68	2	1	808	3	2090
Mt Lindesay-8	333	124	1200	60	2	1	788	3	2030