With the development of the Statewide Draft Oil and Gas Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans (EIS) for CSG in Montana, there will be additional requirements identified and developed that will apply specifically to CSG operations. Among those included in the EIS is the requirement for a Project Plan.

The Project Plan will serve as an overall means for the CSG operator to specify how a particular area or field CSG operation will be conducted. The Project Plan would include such items as a Water Management Plan, Groundwater Monitoring Plan, and Wildlife Monitoring and Protection Plan as well as outline any provisions that are specific to the leasing arrangements or the siting of CSG facilities. Also included would be specific provisions for CSG operations that are conducted on lands or minerals that are owned or managed by the federal or state government or a tribal government. The Project Plan would also include a section on BMPs that would be implemented by the operator to address site-specific issues such as the mitigation of potential impacts to area resources.

In addition the Powder River Basin is a designated Controlled Groundwater Area due to the CSG development. As stated by Handbook on Coal Bed Methane Produced Water (All Consulting, 2003) “because the Montana PRB will be a primary area of CSG development, it is anticipated that significant quantities of groundwater will be removed, resulting in an overall lowering of water levels within the Powder River Basin. As such, the governing agency has adopted a Final Order creating a Controlled Groundwater Area within the Montana Powder River Basin. This Final Order designating the Montana PRB as a Controlled Groundwater Area (GMA) contains specific provisions that include the following.

- Applies only to CSG production and includes all formations above the Lebo member of the Fort Union Formation.
- The setting of specific standards for permitting, drilling, and producing CSG wells.
- Requirements for water source mitigation agreements.
- The creation of a Technical Advisory Committee to review, oversee, and advise on scientific and technical aspects of the PRB Controlled Groundwater Area.
- Requirements for reporting specific information on groundwater characterisation and monitoring.
- Requirements for the collection of specific data and sets procedures for notifications that will need to be made to appropriate state agencies and the public” (All Consulting, 2003).

Existing water management uses for the Powder River Basin

Existing production in the Powder River Basin applies a variety of options to manage CSG produced water. Deep injection, aquifer storage, surface water discharge (with government permits), land application (irrigation with amendments), livestock watering and impoundment are all being used to manage produced water.

5. Regional setting of the Surat Basin

5.1 Study area

The investigation area covers a large portion of the Surat Basin; a geological basin that forms an eastern limb of the Great Artesian Basin, Eastern Queensland. The regional geology covering the study area is shown in Figure 5.1. The general stratigraphy and a brief summary of the geology are presented in Table 5.1.

5.2 The Great Artesian Basin

"The Great Artesian Basin is one of the largest artesian groundwater basins in the world. It underlies approximately one-fifth of Australia and extends beneath arid and semi-arid regions of Queensland, New South Wales, South Australia and the Northern Territory, stretching from the Great Dividing Range to the Lake Eyre depression.

The Great Artesian Basin was formed between 100 and 250 million years ago and consists of alternating layers of waterbearing (permeable) sandstone aquifers and non-waterbearing (impermeable) siltstones and mudstones. The thickness of this sequence varies from less than 100 m on the Basin extremities to over 3000 m in the deeper parts of the Basin. Individual bore depths vary up to 2000 m with the average being 500 m. Some of the sandstone sequences contain oil and gas where conditions are suitable. The sandstones from which the artesian water flows were deposited as sediments into three large depressions: the Carpentaria Basin, the Eromanga Basin and the Surat Basin, which together form the Great Artesian Basin.

The sedimentary sequences making up the Great Artesian Basin include minor volcanic and intrusive rocks that have accumulated in sedimentary basins that existed in geological time. The sequence represents periods of deposition under different environments that include shallow marine, deltaic and fluvial flood plain deposits. Green (1997) discusses these associations in detail and shows that fine-grained sediments and coal are associated with swamps, shallow marine conditions or delta backswamps, while sandstones are associated with fluvial (river) or prograding deltaic depositional environments.

Groundwater in the Basin flows generally westward to the south-west over most of the Basin but to the north-west and north in the northern section. The rate at which water flows through the sandstones varies between one and five metres per year. Recharge by infiltration of rainfall into the outcropping sandstone aquifers occurs mainly along the eastern margins of the Basin, more specifically along the western slopes of the Great Dividing Range. Natural discharge occurs mainly from mound springs in the south-western area. Mound springs are natural outlets of the artesian aquifers from which groundwater flows to the surface." (NRM&E, 2003).

Table 5.1 acknowledges the identified major aquifers for the GAB. On a regional scale, units such as the Walloon Coal Measures, occupying the sequence between the major aquifers are usually fine-grained sediments and form confining layers so that aquifers are not hydraulically connected according to Cox and Barren (1998). The WCM are not considered to be a significant regional aquifer and are not considered to be hydraulically connected to the Great Artesian Basin aquifers. This is discussed in the following section.

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Figure 5.1
Geological map of investigation area

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Sources
Geology: DNRME Qld 1976
Base map: Geoscience Australia 2002

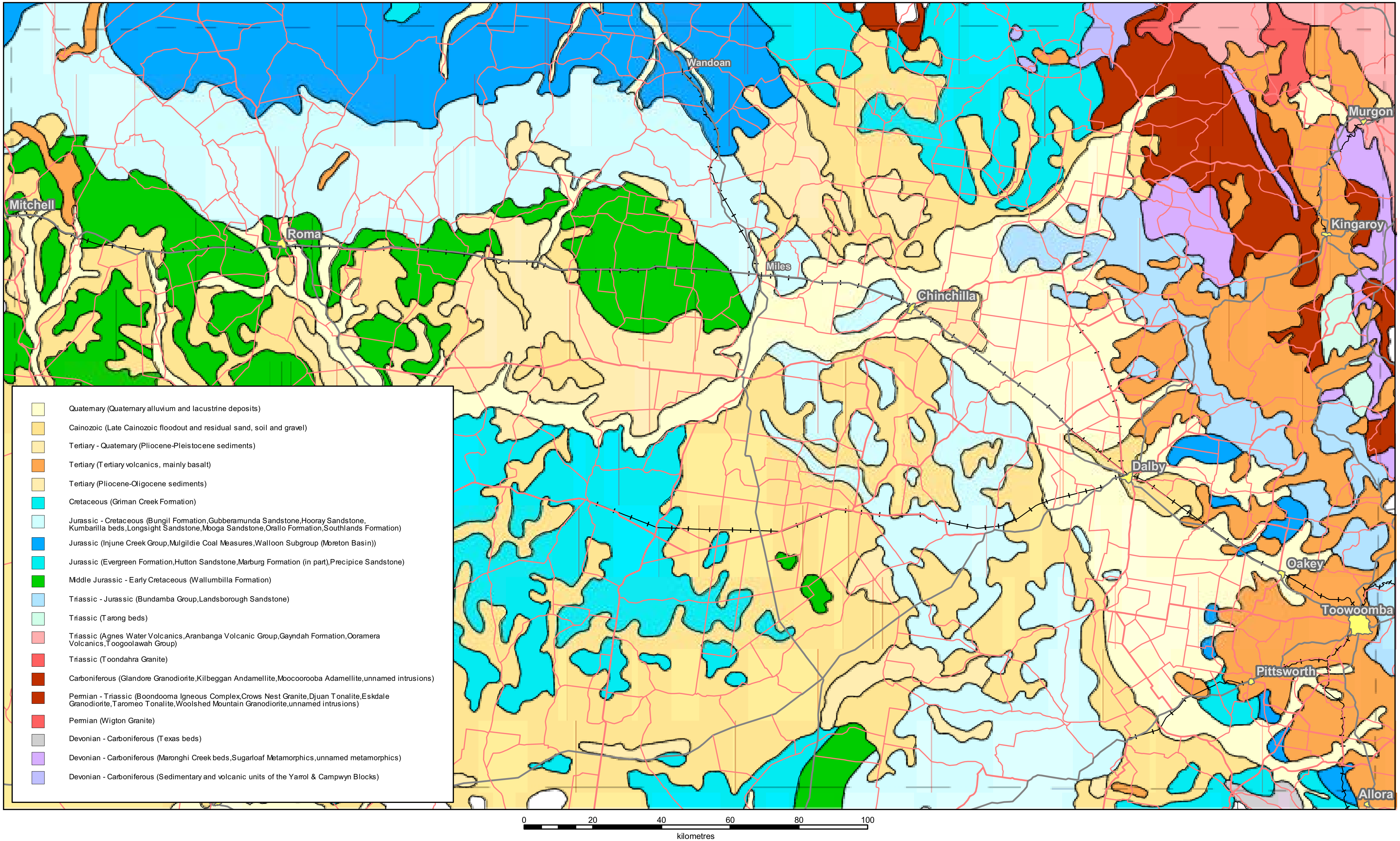


Table 5.1: Lithostratigraphic relationships of the Surat Basin in the area of investigation

Graphic	Litho-stratigraphy	Main Rock Types	Inferred Depositional environment	Approx. thickness (m)	Ground water
	Condamine Alluvium	Unconsolidated sand, gravel and silt	Flood plains, river terraces	Variable	V[1]
	Tertiary Sediments	Unconsolidated sediments	Pediment and floodplain remnants	Variable	V
	Griman Creek Formation	Sandstone, siltstone, mudstone conglomerate and coal	Deltaic, beach and near-shore marine	400	V
	Surat Siltstone	Interbedded carbonaceous siltstone, mudstone and lithic sandstone	Protected bays and tidal flats	100	
	Wallumbilla Formation	Mudstone, siltstone, sandstone lenses with conglomerate and limestone	Regressive shallow marine with mudflats, lagoons and swamps	475	
	Bungil Formation	Mudstone siltstone and lithic sandstone	Marine transgression sluggish fluvial to shallow marine	300	
	Mooga Sandstone	Fine to medium grained sandstone and shales	Braided and meandering stream	168	VV
	Orallo Formation	Sandstone carbonaceous siltstone mudstone coal	Fluvial lacustrine	150	V
	Gubberamunda Sandstone	Medium and coarse quartz sandstone	High energy shallow fluviatile	298 but thinner in N	VV
	Westbourne Formation	Shales, siltstones and fine grained sandstone	Lacustrine deltaic plain	220	
	Springbok Sandstone	Sublabile, lithic sandstone with calcareous cement	Fluvial, overbank and swamp deposits	157	V
	Walloon Coal Measures	Shale, siltstone, labile argillaceous sandstone, coal, mudstone, limestone	Lower predominantly inorganic units are overbank deposits, upper coal measures are a meandering stream system with coal swamps	507	U
	Hutton Sandstone*	Sandstone, siltstone, shale, conglomerate, coal, oolitic ironstone	Meandering streams in a broad floodplain	266	V
	Evergreen Formation	Sandstone, siltstone, shale, mudstone (carbonaceous with minor coal), oolitic limestone	Meandering streams in coastal plains and lacustrine deltas	307	U
	Precipice Sandstone	Sandstone, pebbly sandstone, siltstone.	Braided stream, low energy fluviatile environ	106	V
	Sedimentary sequences of the Bowen basin	Predominantly sandstone, siltstone, shale and mudstone with Coal measures	Upper fluvial, deltaic and swamp deposits. Lower shallow marine with prograding deltas and		

Source: QWRC, 1982 & PB, 2002

[1] V identify aquifers, VV identify major aquifers in the Great Artesian Basin.

5.3 Walloon Coal Measures

Rocks associated with the Walloon Coal Measures are exposed at surface in the eastern and northern parts of the investigation area and dip shallowly in a south-westerly direction below younger formations. The Walloon Coal Measures have been studied in more detail by industry representatives who have provided additional detail relating to the stratigraphic succession in the Surat Basin. This is presented in Table 5.2.

The Walloon Coal Measures (WCM) comprise carbonaceous mudstone, siltstone, minor sandstone and coal (refer to Table 5.2). Limited groundwater resources in the measures are restricted to the coal seams where the water is contained and moves in the cleats. The WCM are not considered to be a significant regional aquifer and are generally not considered to be hydraulically connected to the Great Artesian Basin aquifers. This assumption may alter depending on site specific hydrogeological data. It should be noted, that no detailed, site specific groundwater assessment has been undertaken as part of this study. Proposed legislation requirements will ensure that potential impact assessments are undertaken on a site-specific basis to address this issue.

The WCM has been described as 'essentially a water retarding unit, but (the) coal is a fractured aquifer' (QWRC, 1982). From information provided by industry representatives the coal seam may vary in thickness from 2 to 10 m and be separated by up to 30 to 80 m of predominantly silts and tight sands that restrict any vertical leakage between seams and overlying and underlying units. It should be noted that this may refer to an individual seam, and that multiple seams may be encountered in a single well, separated by 30 to 80 m of predominantly silts and tight sands.

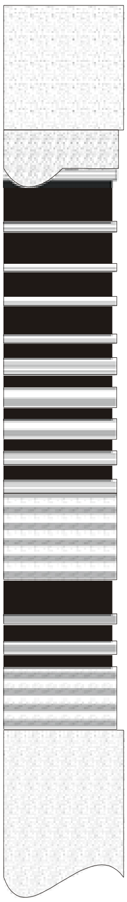
Historically, coal seams are reported to contain brackish stock water supplies with low/unreliable yields (i.e. 1–10 L/s). It is unknown whether this estimation of yield is based on the full thickness of the Walloon Coal Measures or only part of the thickness. These documented yields may have been estimated only from the upper seams of the WCM as the water volume figures given by industry relating to the amount of water being extracted from the coal seams appears to be contradictory to historical understanding of the expected water yields. Industry volumes (i.e. estimated peak flows from CSG extraction) are a magnitude larger than historical volumes.

Apart from information presented in this report, limited new groundwater information is provided that directly correlates hydrogeological response to CSG development. Limited detailed estimation of groundwater impact due to CSG development can be undertaken until dedicated monitoring system and baseline data is collated. The Walloon Coal Measures (WCM) is the CSG target unit within the Surat Basin. Limited groundwater resources in the WCM are restricted to the coal seams, where the water is contained and moves in the cleats. Therefore for this study, it is assumed that:

- based on geological information and inferred groundwater information from the NRM&E database, the WCM are not considered to be hydraulically connected to the Great Artesian Basin aquifers within proposed regions of CSG development;
- minimum groundwater is extracted from the WCM mainly for stock purposes, however based on information from the NRM&E groundwater database, this use is limited to the shallower outcrop regions of the WCM and away from the areas typically targeted for CSG development;

- no CSG exploration is undertaken in the vicinity (i.e. 20 to 50 km distance) of outcrop zones of the WCM, predominantly due to the shallow seams being un-prospective for CSG development;
- the coal cleats do not provide a continuous porous medium that has been simulated by low hydraulic conductivity (approximately 0.12 to 0.0113 m/day) (PB, 2002); and
- leakage from overlying or underlying aquifers is considered negligible due to the presence of fine-grained sediments (siltstone, mudstones and shale) below the coal measures and over or underlying formations.

Table 5.2: Walloon stratigraphy in area of investigation

	Litho-stratigraphy					
Graphic	**Group/ Subgroup**	**Formation**	**Member/beds**	**Main Rock Types**	**Thickness (m)**	**Ground water**
		Springbok Sandstone		Sublabile, lithic sandstone with calcareous cement	133	V
		Proud Sandstone			24	V
	Walloon Coal Measures	Juandah	Kogan Seams Macalister Seams Wambo Seams Iona Seams Argyle seams	Coal seams with intervening but unnamed shale, siltstone, labile argillaceous sandstone, and mudstone beds	165	V (local)
		Tangalooma Sandstone			80	V
		Taroom Coal Measures	Auburn Bulwer/Condamine		?	
		Eurombah		Shale and carbonaceous shale	?	
	Hutton Sandstone*			Sandstone, siltstone, shale, conglomerate, coal, oolitic ironstone	266	V

5.4 Existing groundwater use within the Surat Basin

The search area undertaken for available groundwater bore information does not encompass the whole Surat Basin. Figure 3.2 shows the distribution of registered groundwater bores within the study area. Figure 5.2 and Figure 5.3 shows the distribution of groundwater bores relating to the major aquifers that are considered as part of this study. Figure 5.4 presents the distribution of groundwater bore use within the study area.

Existing groundwater bores with in the WCM predominantly use limited groundwater supply for stock only due to the typically poor quality and low yield of groundwater supply. Within the study area, of approximately 13,000 registered groundwater users, only approximately 300 users are within the WCM. The majority of existing WCM registered users generally only access the shallower seams (i.e. less than 300 m below ground level) within the full unit and are not within the target areas for CSG development. CSG industry development typically targets the coal seams at depths from 500 m to 700 m below ground surface level.

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Figure 5.2
Distribution of Walloon Coal Measure groundwater bores

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Sources
Groundwater bores, coal seam gas wells, ATP expl titles: DNRME Qld 2003, 2004
Base map: Geoscience Australia 2002

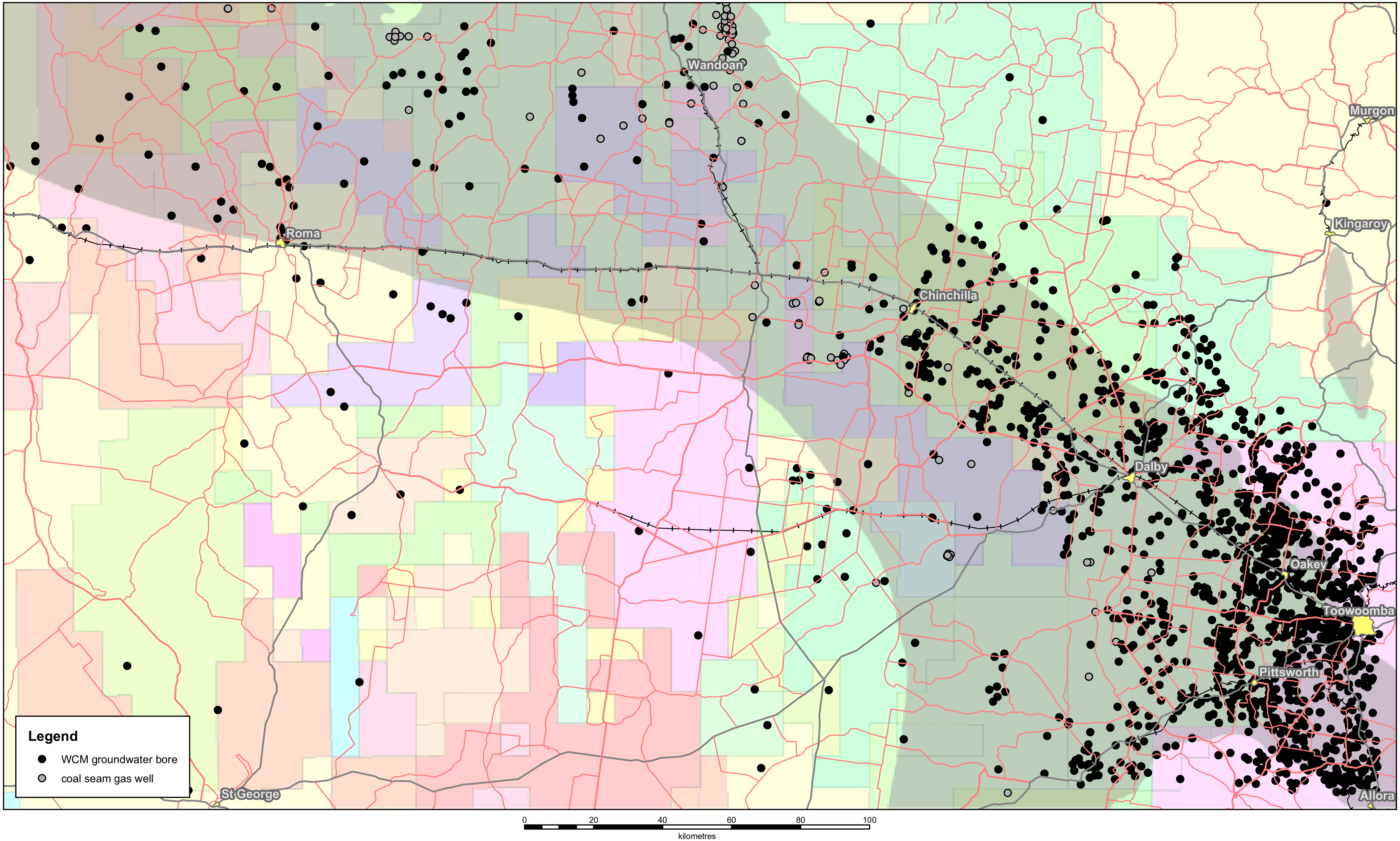

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Figure 5.3
Distribution of major aquifer groundwater bores

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Sources
Groundwater bores, coal seam gas wells, ATP expl titles: DNRME Qld 2003, 2004
Base map: Geoscience Australia 2002

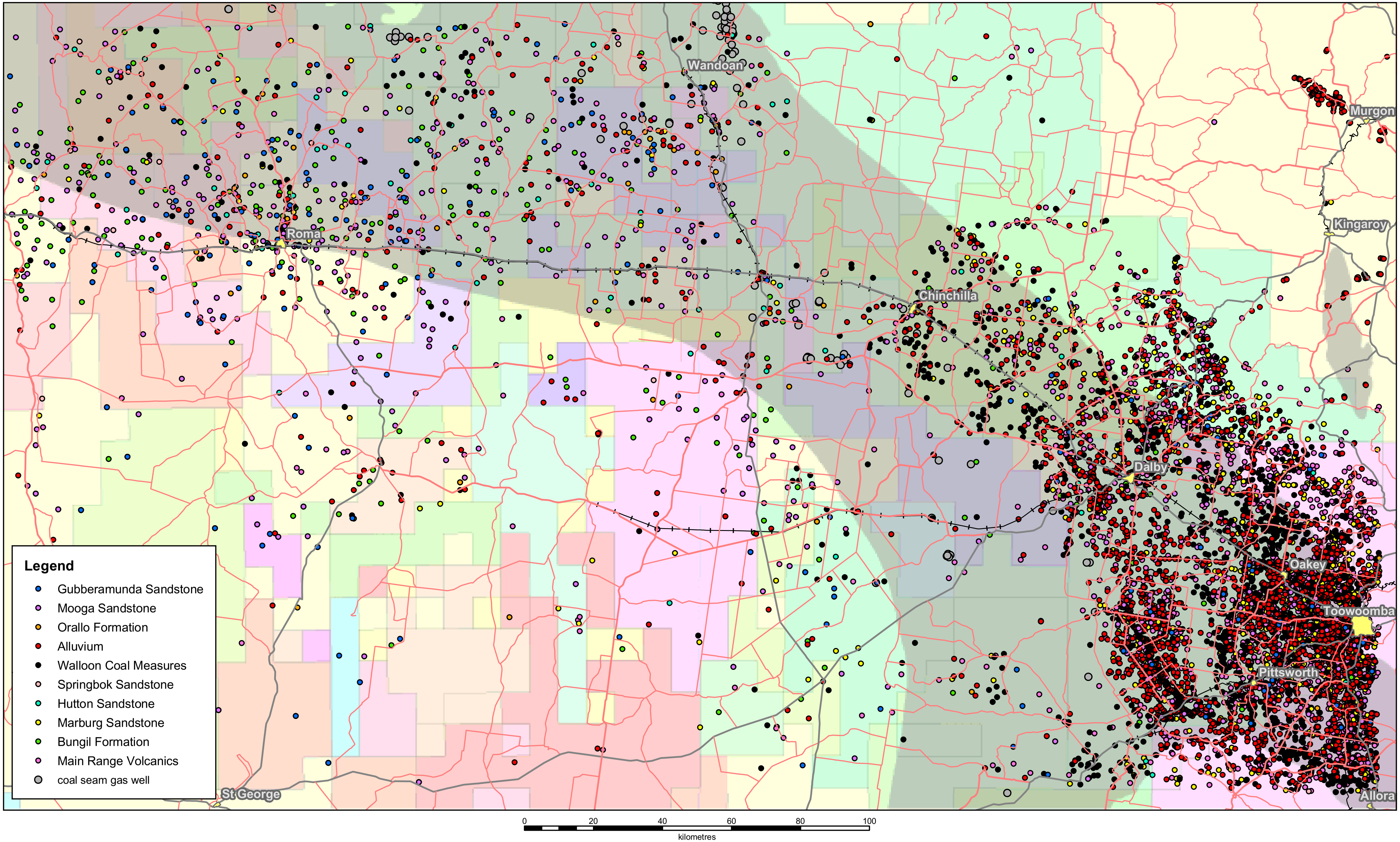

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Figure 5.4
Distribution of groundwater bore use within study area

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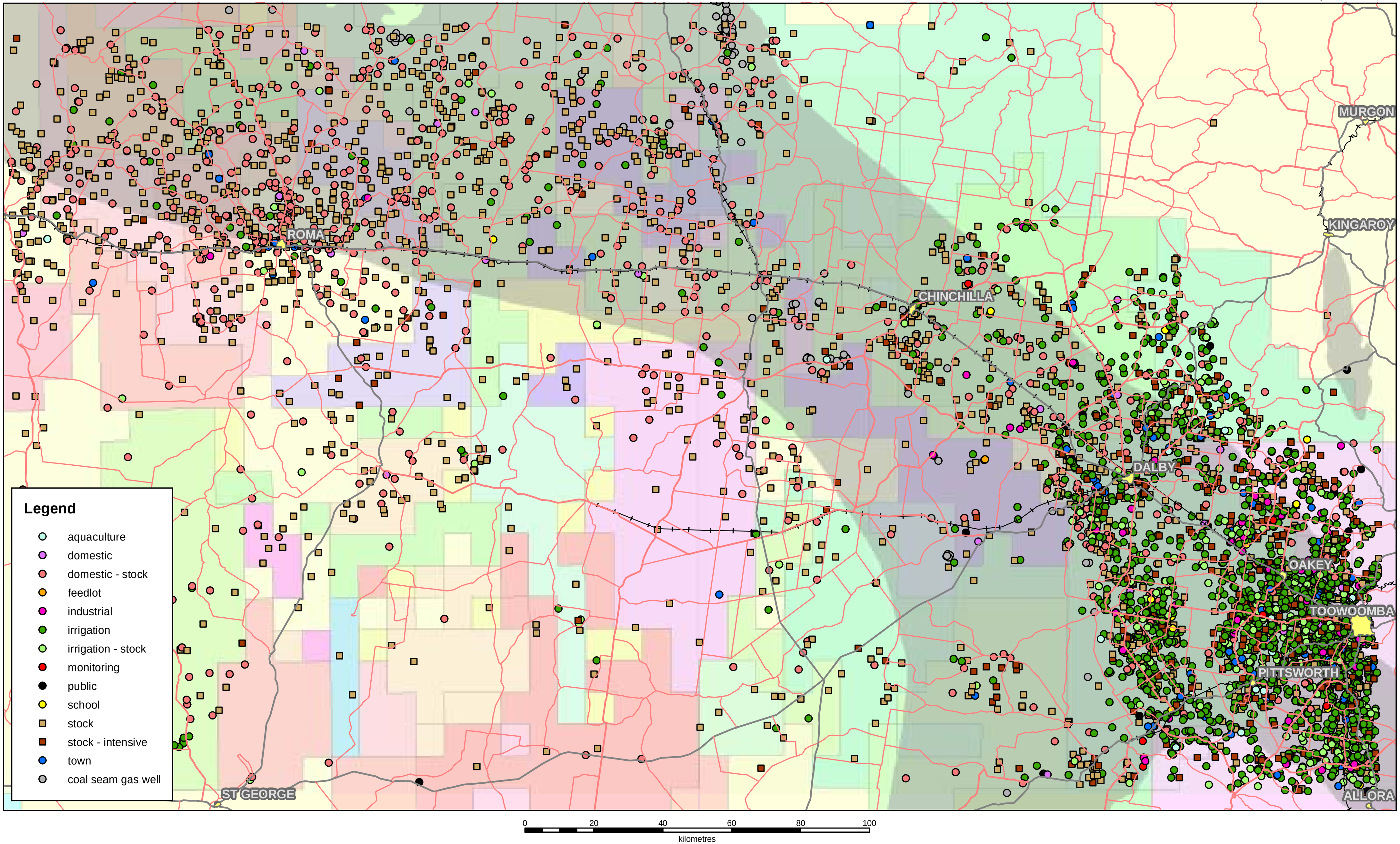
Sources
Groundwater bores, coal seam gas wells, ATP expl titles: DNRME Qld 2003, 2004
Base map: Geoscience Australia 2002



6. Evaluation of potential groundwater impacts due to CSG extraction

6.1 Introduction

The production of CSG has the potential to impact water resources in a variety of ways. Drawdown of coal seam aquifers is an unavoidable impact because the de-pressurisation of coal seams is inherent to the process of CSG production. Once brought to the surface during production operations, produced water is essentially a by-product that must be disposed of. The combination of potentially substantial water volumes combined with relatively poor to moderate water quality characteristics emphasises the need to closely evaluate and monitor CSG development and production. Depending on the area, groundwater may vary in potential vulnerability to contamination from surface activities or from depletion of resource. The amount of water that must be pumped off appears to vary not only from Basin to Basin, but also during the history of individual producing wells. To fully understand these potential vulnerabilities and impacts, analysis and clear understanding of the groundwater environment is required.

The proposed Petroleum and Gas (Production and Safety) Bill 2004 will provide a regulatory process for effective water management for the CSG industry.

Groundwater development to date

The following information summarising CSG development within the Surat Basin, has been provided by NRM&E (2004). Water currently produced in CSG production and testing in Queensland (Bowen, Galilee and Surat Basins) is in excess of 4000 ML/year. Of this approximately 2300 ML are produced at Fairview (Bowen Basin) near Injune with water being discharged into the Dawson River. Other operations contain the produced water in evaporation ponds.

At Fairview, since commencement of operations in 1998 to 30 June 2003, the overall ratio of water to gas production was approximately 400 ML/PJ. At June 2003 this ratio was approximately 200 ML/PJ. Whilst this ratio applies to part of the Bowen Basin, it is too early to predict what such a ratio may be for the Surat Basin. However, given the water production from the Surat Basin CSG activities to date and the lack of commercial gas production from these activities, the ratio of water to gas is likely to be greater.

Most CSG development of the Walloon Coal Measures occurs in an area aligned along formation strike to the north east of Kogan and west of Millmerran. Current activity is concentrated in the area between Wandoan–Chinchilla–Tara–Moonie. Water resource development of the Walloon Coal Measures by non-petroleum producers (i.e. landowners) is limited. The majority of water comes from aquifers above the coal measures.

In the Wandoan–Chinchilla–Tara–Moonie area, there are some 40 known stock bores and eight stock intensive and industrial bores taking water from the Walloon Coal Measures. There may be additional bores supplying domestic water and which do not require a water licence. Allocations for stock intensive and industrial purposes amount to about 210 ML/year. Stock use is estimated to add an additional 80 ML/year to the commitments within the main zone of CSG exploration.

Most water resource development of aquifers within the Walloon Coal Measures occurs up to 65 km to the east of the zone identified above. Some 540 ML/year is allocated to stock intensive, industrial, irrigation and town water supply use from about 12 to 14 bores. An additional 90 to 100 known stock bores in the same area would commit an additional 200 ML/year of the resource. In addition to existing developments to which water is committed, there is an additional 480 ML/year proposed for industrial use.

6.2 Overview of hydrogeological processes

Under natural conditions, an aquifer is usually in a state of dynamic equilibrium. A volume of water recharges the aquifer and an equal volume is discharged. The maximum amount of water any section of the aquifer can transmit is a function of the transmissivity and the maximum gradient of the potentiometric surface. If the water table is close to the surface of an unconfined aquifer, the aquifer is full and is transmitting the maximum amount of water. If however, the water table is far below the surface, the aquifer is not transmitting water at full capacity.

The amount of water that recharges an unconfined aquifer is determined by three factors:

- the amount of precipitation that is not lost by evapotranspiration and runoff and is therefore available for recharge;
- the vertical hydraulic conductivity of surficial deposits and other strata in the recharge area of the aquifer which determines the volume of recharged water capable of moving downward to the aquifer; and
- the transmissivity of the aquifer and potentiometric gradient which determine how much water can move away from the recharge area.

Recharge to confined aquifers can occur in places in which the confining layer is absent. Under such conditions, the three factors affecting unconfined aquifer recharge is controlling. If there is a hydraulic gradient across a leaky confining layer in a direction that promotes flow into the aquifer, then recharge can occur across the confining layer. In this case, the vertical hydraulic conductivity of the confining layer, the thickness of the confining layer and the head difference across it control the amount of recharge. Recharge to a confined aquifer may come from both downflow from a higher aquifer or upflow from a lower aquifer.

When a well begins to pump water from an aquifer, the water is withdrawn from storage around the well and from vertical leakage. As the cone of depression grows an increasingly larger portion of the aquifer will be contributing water from storage. The amount of water discharging naturally from the aquifer will remain at the predevelopment rate until the pumping cone reaches the recharge or discharge area. When the pumping cone reaches a discharge area, the potentiometric gradient town the discharge area is lowered and the amount of natural discharge proportionally reduced. If the pumping cone reaches the recharge area of an aquifer, it may induce additional recharge of water that was previously rejected.

To define the impact on the groundwater environment due to CSG extraction the aquifer characteristics of the existing groundwater environment must be better understood in order to properly identify the cone of depression due to water extraction and the area of influence in defining the potential impacts.

6.3 Existing groundwater environment

When describing the impact on a groundwater environment due to development, generally two key areas must firstly be assessed:

1. the characteristic of the existing groundwater resource in relation to quantity and quality; and
2. the existing and proposed beneficial use of the groundwater resource.

As described previously, the study area is within the Surat Basin. The discussion focuses on the process of water extraction from the coal seams and identifies potential impacts which may occur to the groundwater environment due to the potential large volumes of water extracted without equivalent replenishment.

6.3.1 Characteristic of the coals seams targeted for CSG development

6.3.1.1 Groundwater quantity

Due to the conceptual nature of this work and the confidentiality nature of information held by the industry representatives, the volumes of water that may potentially be extracted due to CSG production has been presented as an inferred average over the Basin, rather than site specific data. Table 6.1 presents the estimated demand and supply volumes that the industry could potentially be dealing with and will need to manage.

Table 6.1: Assumed water demand and supply volumes

	Demand Summary			Supply Summary		
Year	Upper Demand (Ml/Y)	Average Demand (Ml/Y)	Lower Demand (Ml/Y)	Upper Supply (Ml/Y)	Average Supply (Ml/Y)	Lower Supply (Ml/Y)
2004	1000	950	900	1300	950	600
2005	1000	950	900	8250	7565	6880
2006	4200	3350	2500	17050	12190	7330
2007	6400	5350	4300	24950	17590	10230
2008	10700	9150	7850	32850	22990	13130
2009	12200	10225	8250	42150	29090	16030
2010	13100	10750	8400	42150	29090	16030
2011	13950	11175	8400	42150	29090	16030
2012	14800	11600	8400	42150	29090	16030
2013	15700	12050	8400	42150	29090	16030
2014	15700	12050	8400	42150	29090	16030
2015	15700	12050	8400	42150	29090	16030

Source: NRM&E, 2004

It is important to note that the estimated 10 year average production rate was determined from a relatively small number of wells. Actual rates could vary by area as a result of variations in coal thickness, aquifer recharge, aquifer characteristics, and other geologic and hydrologic circumstances.

The rate of water production from CSG wells typically is high initially and declines with time. For example, water production rates given for the CSG wells in Powder River and Little Powder River averaged approximately 12 gal/m/well (45.43 L/m/well) in 1997 and declined to an average of approximately 7 gal/m/well (26.4 L/m/well) in the first eight months of 2001. The cumulative average over this five year period is reported to be approximately 10 gal/m/well (37.85 L/m/well) (Horpestad et al, 2001).

From the Horpestad paper (Horpestad et al. 2001) in another U.S. CSG project listed, water production rate for an individual well was observed to decline from approximately 15 gal/m (56.78 L/m) to 8 gal/m (30.28 L/m) over two years. If the rate of production from this individual CX Ranch well is considered representative of all potentially producing CSG wells in Montana, the projected production rate of this well can be used to estimate the average production rates of a field of wells. The development of CSG wells is likely to be staggered, with new wells producing at an initially high rate coming on each year while in older wells the production rate declines. Assuming approximately 10% of the Reasonable Foreseeable Development number of wells come on line in any one year, the estimated five year average water production rate is approximately 10 gal/m/well (37.85 L/m), similar to the five year average observed in Wyoming. The subsequent 10 year, 15 year and 20 year averages are estimated to be 8, 6 and 5 gal/m/well (30.28, 22.71 and 18.93 L/m/well), respectively. These values are roughly double the values calculated for a single well. The 20 year average is used in the moderate case impact analysis and the five year average is used in the restrictive-case impact analysis.

The CSG industry in Queensland is relatively new compared to the production being undertaken in the USA and therefore we do not have any long-term water volume rates to indicate the performance of the well field. Based on pilot development being undertaken with the Surat Basin, initial water extraction rates have varied from 100 to up to 500 bbl/day/well (15,898.73 to 78,493.65 L/day/well).

At each production site, the pumping rate will be specific to the hydrogeological conditions of each site and the demand of gas. For the purpose of this conceptual study we have assumed the following volumes presented in Table 6.1 above when discussing the quantity of water extracted from CSG production.

The information presented in Table 6.1 must be viewed as inferred values only. It must be noted that water extraction volumes is site specific and the rate of extraction is directly related to the demand of gas required.

6.3.1.2 Groundwater quality

The water quality in the coal seams generally has a variable salt and mineral concentration and is only suitable for limited stock watering. CSG water quality data supplied by an industry representative in the Surat Basin is presented in Table 6.2.

Table 6.2: Typical water quality for select parameters for coal seams within the Surat Basin

Water quality parameter	Unit	Range
pH	——	8 – 9
Total Dissolved Solids	mg/L	1200 – 4300
Calcium	mg/L	3 – 9
Magnesium	mg/L	1 – 3
Sodium	mg/L	300 – 1700
Chloride	mg/L	590 – 1900
Sulphate	mg/L	5 – 10
Bicarbonate	mg/L	580 – 950

For the purpose of this conceptual study, all further reference to water quality is referred to this representative range of parameters. It should be noted that the water quality characteristic of the WCM water is highly varied, depending on the geological environment. From the NRM&E database, an overview of the variation in electrical conductivity (EC) (i.e. a measure of salinity) for the Walloon Coal Measures is given in Figure 6.1 and the variation in electrical conductivity for bores with recorded water quality data is given in Table 6.3. As with the quantity of water extracted from CSG production, the water quality (in relation to salinity values) can be highly variable. Discussion with industry representatives has indicated that the average EC reading per well is within the range 2000 – 5000 µS/m.

Table 6.3: Range of EC values for Walloon Coal Measures registered groundwater bores

Average recorded EC range for Walloon Coal Measures	Number of register groundwater bores within EC range
below 1000	78
1000 – 5000	253
5000 – 10000	40
10000 – 30000	18
above 30000	4

Information from a published paper presented in the AAPG Bulletin (Van Voast, 2003) indicates that formation water associated with CSG have a common chemical character that can be an exploration tool, regardless of formation lithology or age. “Effectively devoid of sulfate, calcium and magnesium, the water contains primarily sodium and bicarbonate and where influenced by water of marine association, also contain chloride” (Van Voast, 2003). Low sulphate/bicarbonate ratios characterise these water and are also common but less pronounced with the occurrences of conventional oil and gas. Waters rich in sulfate, calcium and magnesium occur in many coal seam aquifers but are not found in association with methane (Van Voast, 2003).

Data collated from the Surat Basin industry representatives indicate that water quality parameters match the common chemical character of CSG product water.

6.3.2 Existing beneficial use of groundwater within the Surat Basin

A regional overview of groundwater users within the study area was achieved from data supplied from the NRM&E bore database. The distribution of registered bore users and their use has been shown previously in Figure 5.5. This information is limited to registered bore users only and may exclude a significant number of domestic and/or stock bores within the region. In addition, a number of bores may have multiple uses which can not be displayed on a single diagram (i.e. multiple use bores for stock, domestic, irrigation etc may only be displayed as irrigation). Therefore numbers presented are a general indication of use only. The majority of use is registered as irrigation and stock. Table 6.4 presents a range of registered bore use with the study area.

Table 6.4: Registered bore uses

Bore use category	Approximate number of registered users
Not classified	2
Irrigation	8237
Stock	1647
Domestic/stock	830
Stock intensive	716
Irrigation/stock	995
Town	400
Industrial	170
School	77
Public	35
Domestic	34
Aquaculture	31
Feedlot	3

On a regional scale, groundwater use from the coal seams is not significant. Of approximately 13,000 registered bores users, approximately 300 use groundwater from the WCM. The majority of groundwater use for the Walloon Coal Measures is limited and generally applied for stock only. The coal seams are regionally not considered a beneficial aquifer as groundwater use from the coal seams is generally limited to local areas where the coal seams outcrop. These areas are not targeted by the CSG industry for development as the shallow coal seams are generally unprospective.

Figure 6.1 Distribution of electrical conductivity ranges within the Walloon Coal Measures

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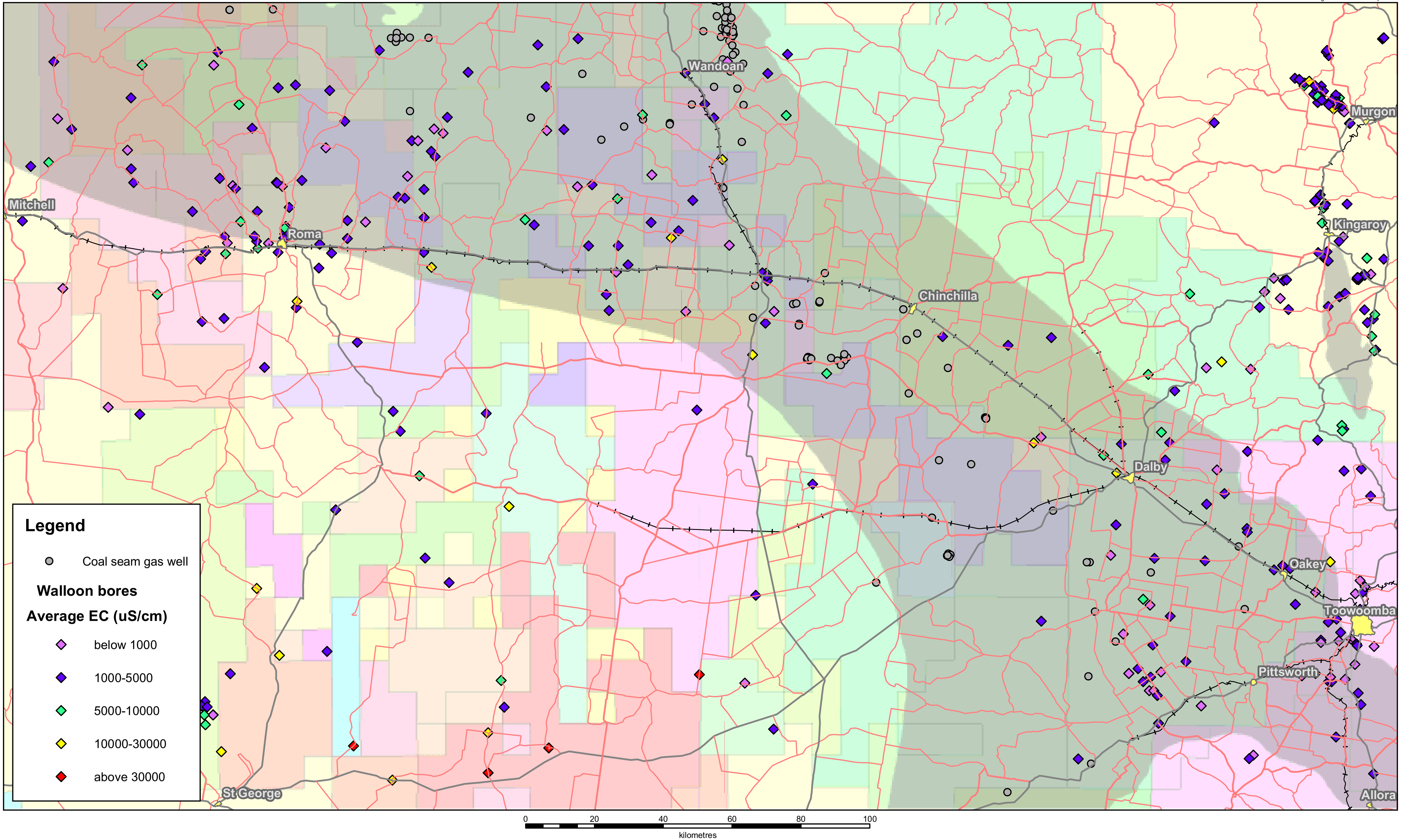
Sources
Groundwater bores, coal seam gas wells, ATP expl titles: DNRME Qld 2003, 2004
Base map: Geoscience Australia 2002



6.4 Potential groundwater impacts

Environmental concerns that have been highlighted in existing literature from CSG production arise from the following factors:

- the potential for drawdown of groundwater;
- the requirement to dispose of large volumes of produced water; and
- the potential for certain well completion technologies to affect shallow groundwater environments.

The key concern to address for evaluation of potential groundwater impacts due to CSG production is the drawdown of groundwater levels within the coal seam aquifer(s) and any indirect/long term impacts from this drawdown. The process of CSG extraction results in withdrawal of a water resource only. As with conventional coal mining operation, unless there is direct re-injection into the coal seams, this industry will essentially dewater the aquifer unit(s), as the rate of extraction will far exceed any replenishment of the coal seam groundwater resource. The operation of dewatering coal seams is currently occurring at existing open cut coal mines within the Surat Basin.

The nature of the Surat Basin coal seam units that contain the methane gas (i.e. layers of coal interbedded with confining layers having low vertical hydraulic conductivity) should minimise impacts to aquifers above these seams. Confining layers above the coal seam units should provide a degree of protection from drawdown associated with CSG production from the coal seams. Shale layers are confining units that isolate aquifers, such as coal seams and/or sandstone units. The shale layers limit vertical migration of groundwater, thereby reducing leakage and loss of resource from overlying aquifers. Although production of CSG water will enhance cleat within the coal seams, it should not propagate vertical fracturing into the adjacent confining units.

The extent of drawdown (i.e. its cone of depression due to extraction) within the coal seam units is unknown at this stage and is dependent on the intensity of CSG development and site-specific conditions. Actions from the proposed legislation changes will ensure that sufficient monitoring and reporting is in place and undertaken by CSG industry to ensure management of the water resource.

Indirect impact to shallow groundwater resources can not be defined at this stage due to lack of site-specific data relating to CSG groundwater extraction and dedicated groundwater monitoring. Based on previous work undertaken within the Surat Basin on the dewatering affects from coal mining of coal seams and the impact on shallow alluvial environments, no direct impact was seen (PPK, 2000). It is assumed that impact on overlying aquifers are estimated to be less vulnerable to drawdown from CSG development due to the low vertical hydrologic conductivity. However, both the overlying and underlying units to the coal seams within the Surat Basin are part of the Great Artesian Basin. Significant groundwater resources are utilised from these units and should be protected. In accordance with proposed legislation changes, water management strategies and monitoring will be put in place to ensure confidence in long term protection of the overlying/underlying aquifer units.

Recovery of the coal seam aquifers after production ends is a slow process involving recharge from undrained areas of the aquifer, infiltration of precipitation from the surface in areas where the coal seams outcrop and the slow process of infiltration from aquifers above and below the produced coal seams (this is expected to take the longest time due to the confined nature of the coal seam units).

Another indirect potential impact from CSG development may be water released to unlined evaporation/storage ponds may have the opportunity to infiltrate into shallow aquifers, causing measured impacts to the depth to water in the aquifers. The introduction of untreated CSG extracted water may degrade the usability of these waters, depending on site specific conditions. Any water storage structure must be designed to ensure minimal leakage to the shallow groundwater environment. CSG industry currently designs evaporation ponds in accordance with regulatory permitting requirements and sound engineering standards that are enforced to ensure no adverse impact. From information received from CSG industry representatives, pond lining or compaction of material and groundwater monitoring adjacent to evaporation ponds, is the current practice for existing water storages for the CSG industry, therefore reducing any potential impact to the shallow groundwater environment.

6.4.1 Predictive groundwater modelling

Previous work undertaken by PB for Queensland Gas Company Limited (PB, 2002), simulated a simple MODFLOW groundwater model to estimated drawdowns within the coal seams due to assumed CSG extraction volumes. The coal measures were assumed as a confined single layer aquifer. This information is unable to be duplicated in this study due to confidentiality of information. Assuming an upper rate of dewatering of the coal seams occurs at 500 bbl/day/well (79,493 L/day), a 60–70 m drawdown was developed within a three month development period with approximately a 1.0–1.5 km radius of cone of depression. Due to the coarse nature of the model developed, the implications of this must be tested with a refined model and more confident groundwater datasets.

Predictive modelling of groundwater in the Surat Basin is hampered by three data deficiencies: hydraulic parameters of the coal aquifers, anisotropy (directionality) of reservoir parameters, and geographic distribution of CSG development areas. Recommendations should not be considered as one solution only due to the variation between sites (and Basins). However what is consistent in every development area is the need to understand the groundwater process in order to confidently identify the magnitude of groundwater impact due to water extraction from CSG production.

While information from the CSG industry provided advanced understanding on the geological characteristic of the coal seams little scientific data is still not available on the hydrogeological parameters of the coal seams and therefore defining the impact from extraction. In order to fully comprehend any long-term impacts due to the CSG water extraction a number of baseline data sets must be collated in order to fully understand and identify upfront and adverse impacts to the groundwater environment.

Data requirements for assessment of potential groundwater impact due to CSG production are:

- confident understanding of regional groundwater flow;
- understanding of recharge/discharge zones for relevant aquifer units;
- coal groundwater characteristics; and
- basin structure.

Table 6.5 summarise the key data requirements for any baseline monitoring. Data requirements are site specific and the level of detail in collection of background information should reflect the estimated gas and water production per site. These requirements should be identified at the planning stage of the developments and in accordance with legislation requirements. This list is by no means complete and should be viewed as the minimum requirement dependent on site conditions.

Table 6.5: Key data parameters required for estimation of groundwater impact from gas and water production

Recommended information required	Purpose of information
Geologic Model	The geologic model to provide the key reservoir properties of coal seam depth, thickness, gas content and reservoir pressure.
Well Performance	A gas and water production database to be established to provide a foundation of actual CSG well performance.
Groundwater monitoring program	Monitoring of both coal seam and overlying aquifer units to develop understanding of groundwater behaviour due to CSG extraction. Monitoring bores should be strategically placed in order to develop understanding of rate of drawdown and radius of influence.
History Matching	History matching of gas and water production needs to be developed using the following information: - Water quality - Water volume - Water levels over time - Permeability (matrix, fracture) - Coal porosity (matrix, fracture) - Gas and water saturation - Confirmation of reservoir pressure and gas content.