An analysis of coal seam gas production and natural resource management in Australia

Issues and ways forward

A report prepared for
The Australian Council of
Environmental Deans and Directors

by

John Williams Scientific Services Pty Ltd

October 2012

Acknowledgements

The authors are indebted to Belinda Crozier of John Williams Scientific Services Pty Ltd, who provided copy-editing and layout of the various drafts and worked on very short time lines with strong commitment that is much appreciated. The authors also acknowledge the time made available to us by Dr Tom Measham of CSIRO Ecosystem Sciences through the Gas Industry Social and Environmental Research Alliance (GISERA) who introduced us to key sources in the economics and social science literature in mining and coal seam gas production. The project was greatly assisted by the input of Mr Bruce Brown of the Namoi Catchment Management Authority who gave insight into their regional land-use cumulative assessment tool.

This report should be cited as:

Williams J., Stubbs T. & Milligan A. (2012) *An analysis of coal seam gas production and natural resource management in Australia* A report prepared for the Australian Council of Environmental Deans and Directors by John Williams Scientific Services Pty Ltd, Canberra, Australia.

Information sources and referencing

This report was derived from an extensive range of literature, most of which is accessible via the internet. The authors have sought to ensure that sources for their use of text, figures, diagrams and images are provided in text, footnotes or references. If inadvertently the authors have failed to adequately acknowledge a source of material used they would appreciate prompt notification so the matter can be corrected in the electronic copy of the document and a full acknowledgement provided.

ISBN 978-0-9874098-1-2

The authors

John Williams FTSE BSc Agr (Hons1) PhD (USYD) MAIAST
John Williams Scientific Services Pty Ltd, 8 Harcourt St, Weetangera, ACT 2614

Tim Stubbs B Eng (Env) (Hons)
Yellow & Blue Pty Ltd: Environment and Natural Resource Consulting

Ann Milligan BSc(Ag) Hons Grad Dip NRM Policy and Planning
ENRiT: Environment & Natural Resources in Text

Contents

The context of this report

The report has addressed many natural resource and environmental matters, along with an overview of economic and social issues associated with exploration and production of coal seam gas in Australia. However the report is unlikely to prove exhaustive in the matters examined.

We are aware there are other issues, including those listed here, which we have not covered and which may emerge as important:

- the source of water to replenish the coal seam 'aquifers' once production of gas has ceased;
- decommissioning and management of the legacy of large numbers of wells in a gas field so that the integrity of the geological strata is maintained indefinitely; it is an issue for the long-term sustainability of water resources;
- management of surface infrastructure with respect to bushfires and surface flooding;
- seismic impacts, which are clearly an issue with shale gas;
- other social issues, such as those around impacts of coal seam gas operations on the values of rural land.

In the time and resources available this report has sought to give an overview of the key natural resource management issues that need consideration with the development of coal seam gas.

John Williams
15 October 2012

1. Executive summary

What we did

This report outlines a review and analysis of some of the rapidly growing published literature, grey literature, and documentation on coal seam gas (CSG) production, from perspectives of government, industry and community.

- The first chapters describe and examine the science and engineering which underpin CSG production in Australia and overseas, with a view to considering potential impacts of the industry on natural resource management issues in the Australian landscape.
- Next, an outline is provided of the social, economic and community development issues associated with expansion of the CSG industry, with particular attention to research and analysis in Queensland and to a lesser extent in NSW.

The current and emerging legislative and regulatory frameworks in Queensland and NSW are examined, along with actions of the Australian Government to manage the natural resource issues for CSG development.

What we discovered

In principle, CSG production is no different to any other land use development within a landscape and should be treated as such.

Managing the production of CSG, an 'unconventional' gas requiring unconventional methods of extraction, is essentially another part of managing the whole landscape. It is one more demand on the landscape, competing with production of energy, water, food, fibre, minerals, and with human settlement, and with the need to maintain biodiversity to underpin the ecological functioning of the landscape itself.

Fundamentally, CSG production is no different to any other development of our landscapes. Like them, it poses risks to the condition of the water, soil, vegetation and biodiversity, and has the potential to reduce the capacity of our natural resources to supply human, as well as ecological, needs.

It is important to see CSG operations in this context. The potential impacts of CSG could be significantly less than the impacts and degradation already experienced as a result of agricultural and urban development over the past two centuries in Australia.

CSG production and protection of water resources and aquatic ecosystems is a significant natural resource issue.

There is an increasing amount of work in Australia becoming available on the subject of CSG production in relation to the protection of water resources. It is now clear that the potential impacts of CSG on water resources are significant, require very careful attention, and merit being the focus of much public concern.

The establishment of the Independent Expert Scientific Committee on CSG and Coal Mining (IESC) under a COAG national partnership agreement on CSG and large coal-mining development is an important step forward. This body will provide advice to the federal environment minister and other decision-makers about all CSG and large coal-mining developments in Australia that are likely to have a significant impact on water resources, and their implications relative to the Commonwealth *Environment Protection & Biodiversity Conservation (EPBC) Act 1999*. It will oversee bioregional assessments and research and development activities that will build knowledge and capacity to provide society with increased certainty for management of CSG operations to mitigate their potential impacts on water resources.

Of critical importance will be the development of a formal nexus between the work of the IESC and the State regulatory processes, particularly in NSW and Queensland, around their respective mechanisms for Strategic Regional Land Use Planning and Strategic Cropping Land Assessment. The exchange and procurement of relevant information, and the capacity to deliver that information in regional strategic planning, will be of paramount importance.

Every effort should be made to build and evolve COAG partnership agreements such as this one, so that knowledge can be assembled to guide effective regional strategic planning. To take us forward from a piece-by-piece approval mechanism, regional strategic planning must be proactive and have capacity to inform statutory processes while using whole-of–landscape analysis frameworks.

The following issues with respect to CSG production and water resources must receive attention:

- water extraction to de-pressurise coal seams, and the impacts of subsequent water pressure changes on water movement to and from freshwater aquifers located in other strata of the geological basin;
- replacement of the extracted water in coal seams once gas production has ceased. The water originally extracted is likely to have been disposed of or used, and must be replaced by some redistribution mechanism. Methods of recharge have so far received very little attention. Re-injection is one option.
- disposal of the extracted water and salt and other chemical entities liberated from coal and other geological fabric during the dewatering process;
- the containment management and disposal of ‘fraccing’ (hydraulic fracturing) fluids. Management of fraccing fluids and any resultant contamination is a high profile issue with the general public.

CSG production and the protection of biodiversity and landscape function via vegetation and habitat management is a critical but neglected natural resource issue.

Fragmentation and loss of native vegetation resulting from the considerable surface footprint of CSG infrastructure represent a serious threat to biodiversity, threatened species and landscape function. Evidence from CSG developments to date indicates that severe effects are possible. Potential impacts include direct clearing of bushland, fragmentation of important remnant vegetation, spread of invasive species and increased fire risk.

The Native Vegetation Acts in both NSW and Queensland deal well with issues of clearing of native vegetation; however, overall, CSG operations are exempt from these Acts. If there is a particular threat to threatened species, then the Commonwealth EPBC Act can be brought to bear, as can the State threatened species legislation. Unfortunately these Acts do not easily deal with broad-scale fragmentation and loss of habitat.

These potential effects arise from installation of closely spaced well-head infrastructure, access roads and pipelines. The resulting fragmentation will have significant impacts on overall landscape function and biodiversity, particularly in landscapes that have already received extensive clearing, and is yet to be dealt with adequately in the policy and regulatory environments of either State or Commonwealth legislation.

The cumulative impact of these surface installations is critical and requires careful consideration and attention. It can best be addressed by use of tools such as one currently under development by the Namoi Catchment Management Authority (see Chapter 5).

Landscape function and biodiversity appear not to be primary concerns in the regional strategic land-use planning mechanisms of either the NSW or the Queensland governments. This is a major environmental and natural resource issue and has not received much attention in terms of public debate nor government–industry discussions.

CSG production and protection of agricultural and forestry land uses for food and fibre production and carbon sequestration needs better resolution as part of whole-of-landscape planning.

The public debate on CSG has often focussed on concerns that CSG activities could affect food production through threats to surface and groundwater and loss of strategic agricultural land. A balanced co-existence of mining and agriculture is possible, but requires careful management. For this reason, good bioregional planning and assessment is an absolutely fundamental issue that requires priority attention.

Clearly the loss of agricultural land for intensive cropping and horticulture is a primary issue and both NSW and Queensland have formulated responses. There is the Strategic Regional Land Use Policy in NSW and the *Sustainable Planning Act 2009* and the *Strategic Cropping Land Act 2011* in Queensland where protection of strategic cropping land has commenced.

Will these approaches work to provide protection for agriculture where CSG development cannot coexist with agriculture and food production? Will governments establish ‘no go’ zones for CSG development?

If so, as already mentioned, similar protection responses for biodiversity, habitat and landscape ecological function are also required.

Clearly there will be some forms of agriculture where coexistence with CSG production will work better than others. Extensive grazing appears to be one of these, while in other circumstances coexistence will not be possible. For example, there is evidence that coexistence with cropping and irrigated agriculture is problematic.

Will ‘balanced coexistence’ between resource development, agricultural production and environmental protection actually work? Or will CSG development be able to over-ride the processes?

The early assessment by Namoi CMA of the findings of the NSW Government land-use planning mechanisms and the CMA’s cumulative risk assessment tool suggest there are significant differences in outcomes. The CMA tool makes a fuller examination of the multiple issues than does the traditional approach used in Strategic Regional Land Use Planning.

CSG projects will always be competing for land, water and infrastructure with other resource development projects, agricultural uses and urban needs. We therefore conclude, as we do for biodiversity protection, that for all development within a landscape it is essential to establish only those landscape activities that appear to allow the landscape to maintain its function indefinitely.

An examination of cumulative impact is essential and requires careful consideration and priority attention. It can best be addressed by use of tools such as one currently under development by the Namoi CMA.

It is encouraging to note that the NSW Government is now calling for new work to be done in the design and utilisation of Cumulative Impact Assessment Methodologies as part of future planning tools. The Queensland Government has produced a consultation paper which seeks to evaluate the cumulative impact of CSG on underground water in the Surat Basin. This direction of analysis is welcome and points the way forward. It is a beginning, and much more is required.

Economic impacts of CSG production are very significant; there is opportunity for good public policy to broaden benefits and provide foundation for future community well-being.

Industry economic modelling has suggested that the CSG industry could deliver thousands of new jobs and billions of dollars in investment to regional areas, and generate billions of dollars in royalties. However, the economic benefit from CSG production is contested in public debate, in part because of perceptions of how that benefit is or should be distributed between state capital, regional centre and local community, and particularly how the social and economic costs tend to fall on local governments, community and individuals.

A brief examination of the economic modelling suggests that a rapidly growing CSG industry in Queensland and NSW has the potential to deliver very significant economic benefits to the state and to the nation. As expected, the magnitude of the predicted benefit is dependent on the reliability of the estimates of size and rate of expansion of the CSG infrastructure, and on the income streams from local gas consumption and export of liquefied natural gas (LNG).

The distribution of the economic benefit can be strongly skewed towards benefits accruing to capital cities and large centres, with many of the costs and social impacts falling on small regional and local communities, particularly Indigenous people.

There appears, however, to be some scope to mediate how the economic benefits and costs are distributed depending on how the development of the industry is governed, managed and supported by good public policy.

Social impacts of CSG production are becoming better understood and new insights provide opportunity for innovative government policy, community awareness and action.

There is an increasing number of useful reports and journal publications on the social impacts of mining and CSG developments, particularly in Queensland. These studies are bringing greater clarity to some anecdotal perceptions of social impacts arising from such operations, and they are beginning to inform government policy, community awareness and action.

Several studies indicate broad social issues that will need to be addressed in the projected expansion of the CSG industry. These are some examples of the issues raised,

- Information sharing, communication and transparency are critical for enabling good governance and change management at the community level. Information is also critical for effective on-going management of regional opportunities from the CSG energy boom. Information is crucial for being able to plan, to make policy decisions and to evaluate past policies.
- Gain and revenue sharing, and economic diversification, are essential to increase the social acceptability of mining operations and to increase the local economic opportunities from mining which create wealth but usually not in an evenly distributed

way. Economic diversification leveraged off the energy boom is essential to the long-term well-being of the regional communities. The evidence in the literature indicates that economic development based on mining industries alone over the long term will not allow for sustained economic growth.

- Investment in hard and soft infrastructure is crucial to meet the demands of an increased population. Investment in roads, utilities, health-care, policy, transport and other services, as well as in skills, housing, planning and soft infrastructure needs to be increased accordingly, to allow local communities to deal proactively with the inter-related aspects of social change as well as maintain their communities as desirable places to live and work.

The establishment of regional development plans and the actions outlined in, for example, the Queensland Government's Surat Future Directions Statement, indicate a way forward. This is an active area of policy and program development which needs the support of good applied social and economic research.

What are some ways forward?

Whole-of-landscape analysis and cumulative risk assessment

It is clear that mining for gas extraction, whether from coal seams or shales, has the potential to put at risk the function and value of key long-term renewable natural resources assets and uses such as:

- water resources and aquatic ecosystems,
- agricultural land use, and thus food and fibre production,
- biodiversity and landscape function and connectivity via vegetation and habitat management.

It would be folly to secure one natural resource while putting at risk renewable long-term resource use. Therefore it is imperative to manage the effects of CSG operations on all the above three areas of natural resource management in a whole-of-landscape framework that can take account of long-term cumulative impacts.

We argue that adoption of a knowledge-based, long-term regional strategic land-use planning approach for managing CSG regulation should help avoid perverse outcomes. We recommend that the way forward, at the highest level, for managing CSG production is to treat it in the same way as the many other industries competing for land, water and biodiversity resources in our landscapes.

We recommend two key steps to support adoption of this approach.

Recommendation 1: The approach used for assessing CSG developments (and any other developments) should be, first, to understand regional landscape capacity, and then to determine if there is capacity for the development without crossing landscape limits.

Recommendation 2: Current development approval processes should be updated to approve new developments only on the basis of landscape limits and the expected cumulative impacts of the existing and proposed developments.

There is some common ground between these recommendations and the approaches currently in use in both NSW and Queensland through the Strategic Regional Land Use Planning Policy and the Strategic Cropping Land Act, respectively.

However, the difference is that our recommendations require a whole-of-system analysis, and use of new methods and thinking such as cumulative risk assessment.

We are convinced that the ideal, for all development within a landscape, is to only permit landscape activities that are within the capacity of that landscape to maintain its function indefinitely. To achieve that ideal, an examination of cumulative impact is essential, and is now becoming possible via tools such as the one being developed by the Namoi CMA.

New needs in teaching, research and academic leadership

The production of unconventional gases such as CSG, in a context of wise management of natural resources, highlights new needs in teaching, research and academic leadership to foster public discourse and development of public policy.

It would seem a timely opportunity for the Australian Council of Environmental Deans and Directors (ACEDD) to contribute to building an integrated knowledge platform around the environmental, economic and social issues that arise from unconventional gas production. There is a role for ACEDD to synthesise knowledge across at least these five sectors: energy, climate change, water resources, food and fibre production, and protection of biodiversity and landscape function[1]. All these knowledge areas have strong connections with CSG and shale gas production. Through ACEDD's academic leadership in teaching, research, public discourse and contribution to public policy there is an opportunity to provide a whole-of-system perspective and approach to resolving environmental problems.

The present report highlights knowledge areas that need to be tapped to manage CSG production in a natural resource management context. The following are some of these that are worth considering in teaching research and discourse.

- A whole-of-system perspective in teaching and research would elucidate the nature of the crossovers and feedbacks between gas energy production, climate-change mitigation, water resources, food and fibre production and protection of biodiversity.
- The potential effects of leaks of methane from natural gas operations, including well fields and management infrastructure, should be examined as part of climate-change mitigation policy. This is an issue that, in our view, requires further research and careful analysis, relative to national and global climate-change policy. Again a whole-of-system approach would be essential in clarifying the issues of debate in the role of unconventional gas in climate-change mitigation.
- Recent work on whole-of-life energy analysis illustrates that unconventional gas production and its role in climate-change mitigation is subject to strong interactions, both positive and negative, with water resource use and management. This is an active area for academic work.
- More science and engineering knowledge in, for example, hydrology, structural geology, hydrogeology, drill engineering and new technologies, and predictive modelling capacity, along with a great deal more field data on geology and groundwater systems, will be absolutely essential to managing unconventional gas production and its interface with natural resource management.
- New tools, which enable cumulative risk analysis and impact assessment of multiple land-use developments within a landscape to be understood and evaluated, are critical to the proposals in this report. Without new knowledge and its application in a whole-of-systems perspective, the way ahead will be littered with attempts to solve one problem whilst creating another.

1 PMSEIC (2010). Challenges at Energy–Water–-Carbon Intersections. Prime Minister's Science, Engineering and Innovation Council, Canberra, Australia

- The findings of this review suggest that economic analysis of CSG impacts using powerful modelling tools and the most realistic underlying assumptions would benefit from further research, peer review, and publication. Economic analysis provides valuable insights into how the impacts of CSG can be understood and managed effectively with good public policy and governance. A better future will depend on robust knowledge being applied to marshal economic benefits in the interests of all.
- Social impact analysis appears to show that regional development planning, where social, economic and environmental matters related to gas operations are brought together to drive action, has much to commend it. Social impact analysis is itself a move towards a whole-of-system approach to regional planning and development. The challenge is to bring social, economic and environmental concepts together to lead the way to sustained and enduring action on the ground. There is evidence that social impact analysis is a valuable way forward, and this report recommends it be used.

2. Science and engineering of coal seam gas and its production

Coal seam gas (CSG) is one of several naturally occurring gases with potential to help meet the world's huge appetite for energy. As the name suggests, CSG is found associated with coal seams. Unlike 'natural gas', which is also one of these naturally-occurring fossil fuel gases, CSG cannot be extracted by 'conventional' methods of drilling into a pocket of natural gas trapped by rock strata. Therefore, CSG is termed an 'unconventional' gas.

Shale gas and tight gas are other 'unconventional' natural gases which are even more difficult to extract than CSG. Shale gas is held within organic-rich source rocks such as shales and fine-grained carbonates. Tight gas is found in rocks of low permeability. (See Figure 2.1.)

The four types of natural gas mentioned here are similar in that they are composed mainly of methane. The key differences between conventional and unconventional natural gas resources are in the manner, ease and costs associated with extracting them.

Conventional natural gas ('natural gas') has been produced and transported without undue controversy for decades. However, in recent years the economically viable extraction of the unconventional gases has involved using methods some of which are having unwelcome side effects.

Conventional natural gas supplies 25% of energy used in the United States of America (USA) and 21% of global total primary energy supply (Cull et al. 2011). The production rate of conventional gas in the USA has declined by 39% over the years 1990–2009.

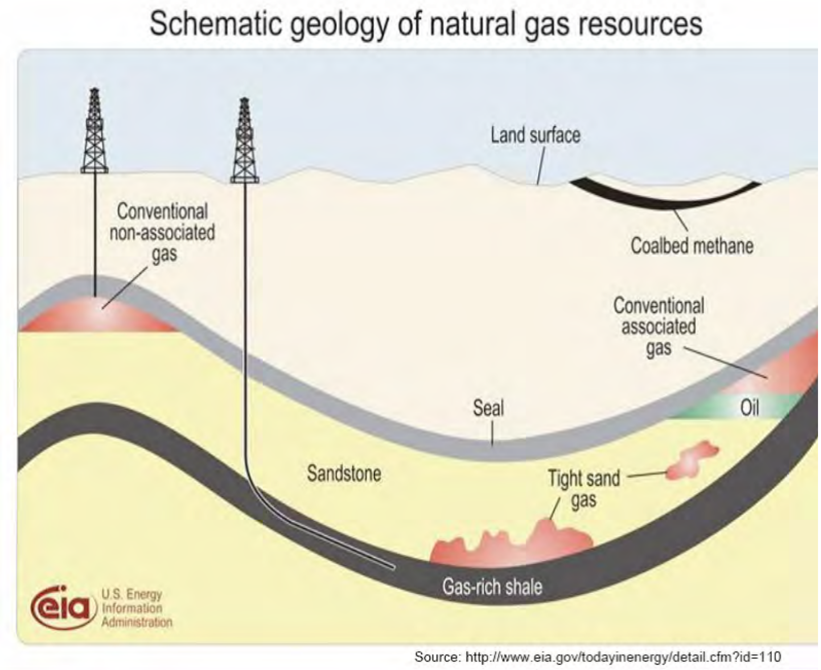


Figure 2.1. Schematic geology of hydrocarbon resources, showing typical arrangements for coal seam gas (coal bed methane), shale gas, tight gas and conventional 'natural gas'.

The production of unconventional gas has accelerated in the last decade, principally through the rapid expansion of shale gas, because of developments in extraction technology. As a result, shale gas is expected to account for nearly half of total USA natural gas production in 2035. Recently the rate of production of shale gas has been growing by nearly 50% per year. As our understanding of unconventional resources improves, and further advances are made in technology, unconventional resources are destined to contribute a far greater share of future energy supplies.

Unconventional resources are changing the energy landscape relatively quickly. Until recently, it was expected that Canada and the USA would supply their domestic needs by re-gasifying imported liquefied natural gas (LNG) in newly-built gasification plants. Now, the high gas price, resulting from market conditions combined with advances in technologies (especially horizontal drilling and hydraulic fracturing, outlined in Section 2.4), has enabled huge shale gas reserves to be unlocked across North America. Both Canada and the USA have secured their own substantial domestic supplies. In the USA, as much as 50% of gas consumption is now sourced from unconventional deposits of, for example, shale gas, tight gas, and coal bed methane (another name for CSG). These recent developments have resulted in a lowering of domestic gas prices and given the USA an opportunity to start exporting its own LNG. Canada is also developing its oil sands — another unconventional resource which is not discussed further in this report.

2.1. Natural gases: composition and occurrence

The gas industry is rapidly enlarging in Australia and will undergo considerable transformation as society decides on the changes needed to retain increasing access to energy while reducing carbon emissions to mitigate climate change. It is, therefore, helpful to establish some definitions and terminology.

Geoscience Australia and the Bureau of Resources and Energy Economics (part of the Australian Government Department of Resources, Energy and Tourism) have recently published the Australian Gas Resource Assessment 2012 (AGRA 2012), and this report draws heavily on that document.

2.1.1. Conventional gas

Natural gas ('conventional natural gas') is a combustible mixture of hydrocarbon gases, found alone or with oil in oil fields. It is formed by the alteration of organic matter over millions of years within geological formations, and consists mainly of methane (CH_4) with varying proportions of heavier hydrocarbons and other gases such as carbon dioxide (CO_2).

Fields of natural gas, whether conventional or unconventional, can be 'dry' (almost pure methane) or 'wet' (in which the methane is associated with 'wet gas' components: ethane, propane, butane and condensate). Dry gas contains less energy than wet gas.

Conventional natural gas often collects in the pore spaces of sandstone material (see Figure 2.2). It is usually contained in well-defined structures within permeable sandstone and overlain by a low-permeability seal. Entrapment of the gas is usually structural or stratigraphic. Extraction of the gas is usually helped by natural pressure in the reservoir, and displaces very little water in the process.

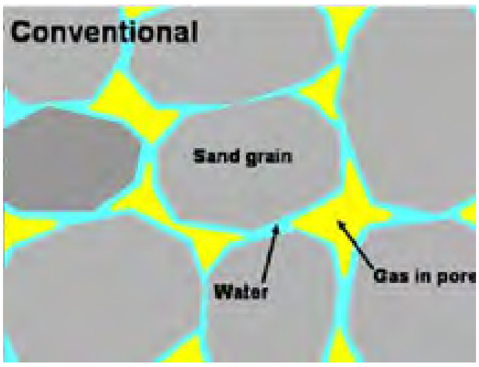


Figure 2.2. A schematic diagram of sandstone containing conventional natural gas (courtesy of Geoscience Australia).

Australia's conventional natural gas resources are spread across the continent (Figure 2.3), though current production is mainly from reserves located off the north-west coast of Australia which are being developed for domestic use and LNG exports.

2.1.2. Unconventional gases

Shale gas is a natural gas that is dispersed within source rocks such as shales and carbonates. It has the same general composition as conventional natural gas — that is, it is a mixture composed mostly of methane with varying concentrations of other hydrocarbons and CO_2.

Rocks containing shale gas usually are fine-grained (often over 50% of the silica in them is in the forms of silt and clay) with very low porosity (where porosity is a measure of proportion of pore volume to total volume) and a negligible content of water. Shales that host economic quantities of gas are rich in organic material (0.5–25%), are sufficiently brittle and rigid to maintain open fractures, and are mature petroleum source rocks in which high temperatures and pressures have converted petroleum to natural gas (Wiki 2012). These formations are generally found at much greater depths than rocks containing coal seam gas: for example at 2–4 km below surface (Figure 2.1). Economic production depends on exploiting or forming (by hydraulic fracturing) networks of fractures in the host rock.

Australia has large shale gas potential but exploration is in its infancy and these resources are, as yet, poorly understood and quantified (AGRA 2012).

Tight gas is a poorly-defined category of the unconventional natural gases, with some similarity to both conventional and shale gas. Generally, tight natural gas is that which is found dispersed in low permeability rocks (where permeability is a measure of the ease with which a fluid can pass through the rock). To achieve economic rates of flow or economic volumes, these rocks require large-scale hydraulic fracture treatments (called 'fraccing') and/or horizontal drilling. Tight gas can be regionally distributed (for

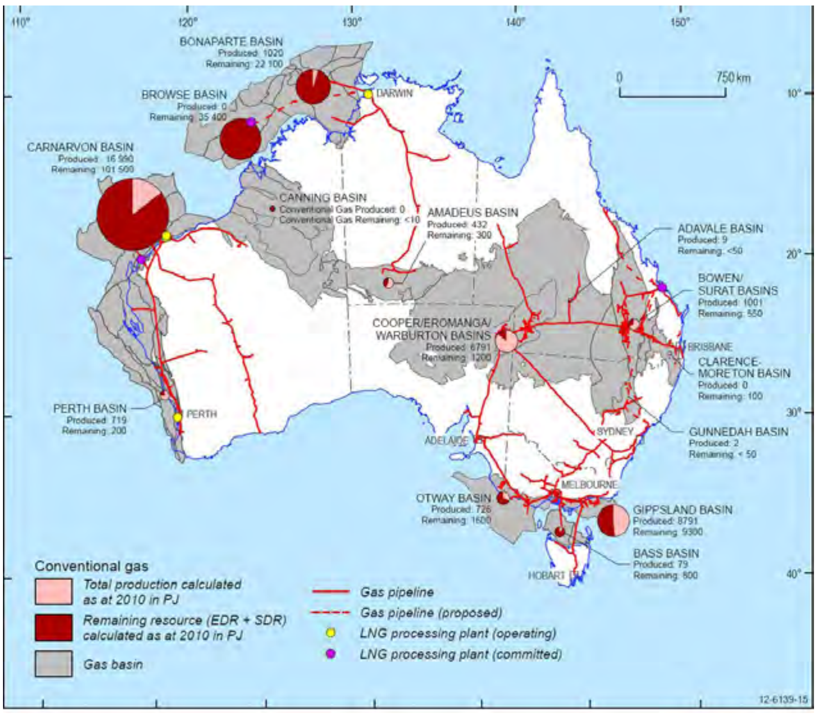


Figure 2.3. Location and extent of conventional natural gas production in Australia. (AGRA 2012, p 14)

example, basin-centred gas), or accumulated in a smaller structural closure or stratigraphic trap as in conventional gas fields. The name 'tight' often refers to the complexity involved in its extraction.

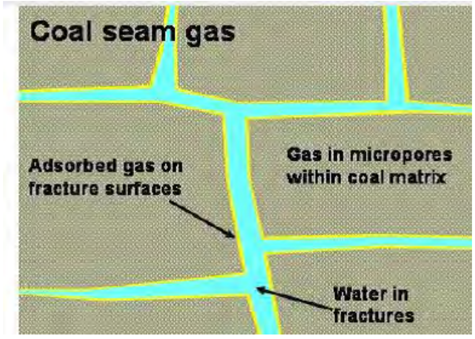


Figure 2.4. Schematic of the formation of coal seam natural gas (courtesy of Geoscience Australia).

Coal seam gas (CSG) is termed 'dry', being almost entirely methane with very little of the heavier hydrocarbons such as propane or butane and no natural gas condensate. As stated above, it occurs in association with coal seams. The gas is also referred to as coal seam methane (CSM) and coal bed methane (CBM). (It differs from methane released as part of coal-mining operations, called coal mine methane (CMM).) The methane can be in a near-liquid state, lining the inside of pores within the coal matrix and adsorbed onto the coal surfaces. The open fractures and micropores in the coal can also contain free gas or can be saturated with water. Water pressure and reservoir pressure hold the gas in place. (See Figure 2.4.)

Production relies largely on the release of water pressure within the coal seams, supplemented with 'fraccing' (hydraulic fracturing) where needed, to connect the natural fractures and micropores within the coal seam. The extent of fracturing required is variable and depends on the coal characteristics. Generally, the coal seams occur at relatively shallow depths (for example, 200–1,000 m).

In Australia, large-scale CSG production commenced during the late 1990s. Since 2007 many reserves of CSG have been discovered. Coal seam gas production represented 10% of Australian gas production in 2010, and is growing rapidly because of domestic and export demand. The gas is currently used for industrial and domestic purposes including power generation.

CSG exploration and production is maturing in Queensland — the productive basins are the Surat and the Bowen where there is ongoing exploration and development, and existing coal mines. There is advanced exploration and appraisal in New South Wales within the Sydney, Gunnedah, Clarence–Moreton, and Gloucester Basins. Figure 2.5 shows these basins and other prospective areas for CSG.

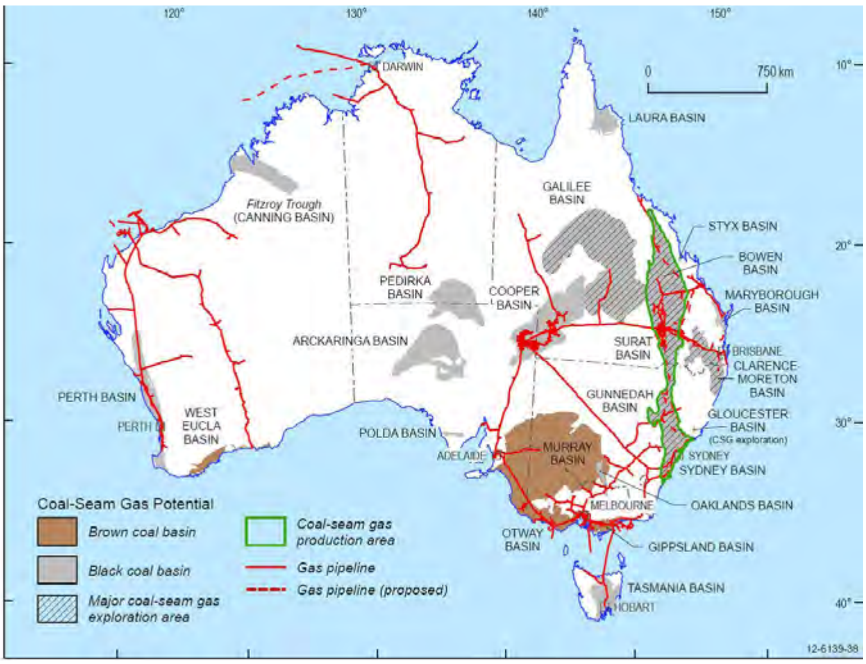


Figure 2.5. Basins with coal and coal seam gas potential. (AGRA 2012, p 37)

2.2. *Australian gas reserves*

The Australian Gas Resource Assessment 2012 report (AGRA 2012) states that:

> *Total identified gas resources are sufficient to enable expansion in Australia's domestic and export production capacity. Australia's combined identified gas resources are of the order of 431,706 PJ. This is equal to around 184 years of gas at current production rates, of which the economic demonstrated resources account for 64 years.*

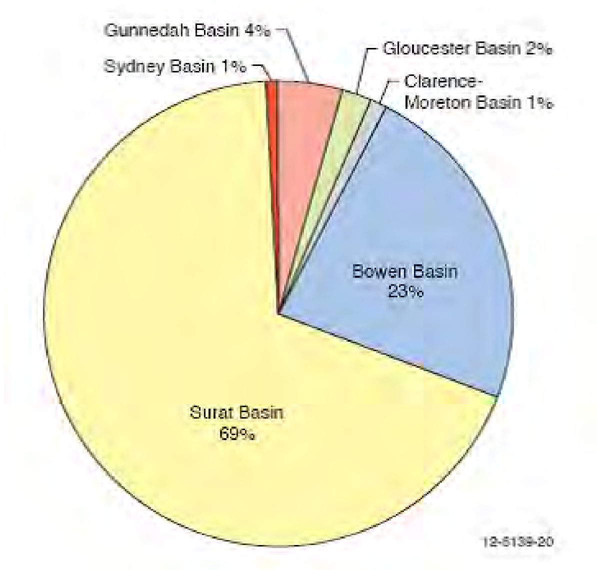


Figure 2.6. Reserves of coal seam gas by basin. (AGRA 2012 page17)

The report also indicates that Australia has significant unconventional gas resources — CSG, tight gas and shale gas (see Table 2.1). Unconventional gas resources are generally associated with proven coal or conventional hydrocarbon basins. Current exploration is very active, tending to focus on basins with existing gas production infrastructure. Exploration interest in unconventional gas is likely to continue to accelerate in line with increasing energy demand locally and in the Asia Pacific.

The economic demonstrated resources of CSG have doubled in the last three years, and at the end of 2011 were 35,905 PJ (petajoules). This is equivalent to about a third of the recoverable reserves from Australia's conventional gas fields. Total identified resources of CSG (223,454 PJ) include sub-economic demonstrated resources estimated at 65,529 PJ and 122,020 PJ of inferred resources (Table 2.1). Another source (EIA 2011) puts the potential CSG resource at 275,000 PJ. Production is underway. Figure 2.6 illustrates the distribution of CSG reserves.

Table 2.1. Total Australian gas resources. (AGRA 2012, Table 10)

Resource category	Conventional gas (PJ)	Coal seam gas (PJ)	Tight gas (PJ)	Shale gas (PJ)	Total gas (PJ)
EDR	113,400	35,905	–	–	149,305
SDR	59,600	65,529	–	2,200	127,329
Inferred	~11,000	122,020	22,052	–	155,072
All identified resources	184,000	223,454	22,052	2,200	431,706
Potential in-ground resources	Unknown	258,888	Unknown	435,600	694,488
Resources identified, potential and undiscovered	184,000	258,888	22,052	435,600	900,540

Note: Conventional gas demonstrated resources as of January 2011; CSG demonstrated resources as of January 2012. Note CSG 2P reserves and 2C resources are used as proxies for EDR (economic demonstrated resources) and SDR (sub-economic demonstrated resources) respectively. Source: Geoscience Australia

Current CSG developments tend to be situated where existing gas infrastructure is available. This is particularly true in New South Wales and central Queensland. Figure 2.7 shows recent economic demonstrated reserves of CSG, and natural gas infrastructure (for both conventional natural gas and CSG).

Total identified tight gas resources are currently estimated at around 22,052 PJ. Significant on-going exploration activity suggests these values are likely to grow, especially in basin-centred gas provinces with established infrastructure (e.g. Cooper and Perth Basins). As of November 2011, there was no production, although development is underway.

A recent estimate suggests total technically-recoverable shale gas resources in Australia may be as high as 435,600 PJ (EIA 2011; Table 2.1). The report only assessed four main basins in Australia, and so potential for additional resources exists across the country. Those assessed basins are the Cooper Basin in South Australia, the Maryborough Basin in Queensland, and the Perth Basin and Canning Basin in Western Australia. The Canning Basin has the highest technically-recoverable resource.

In 2011, the first contingent shale gas resources were reported in the Cooper Basin (2,200 PJ) and the amount of exploration activity has significantly increased in the last few years, suggesting future growth in this area. As of November 2011, there was no production, but Beach Energy has drilled a target well in the Cooper Basin (Beach Energy, July 2011). Current exploration for shale gas is mainly in western and central Australian basins, namely the Canning, Bonaparte, Perth, Amadeus, Officer, Beetaloo, Georgina, Cooper, and Galilee basins. International exploration interest in Australia is likely to result in a shale gas boom. This will require importation of specialised exploration equipment.

Figures 2.7 (CSG) and Figure 2.8 (tight and shale gases) together give an indication of the extent of the potential unconventional gas resource (grey shading).

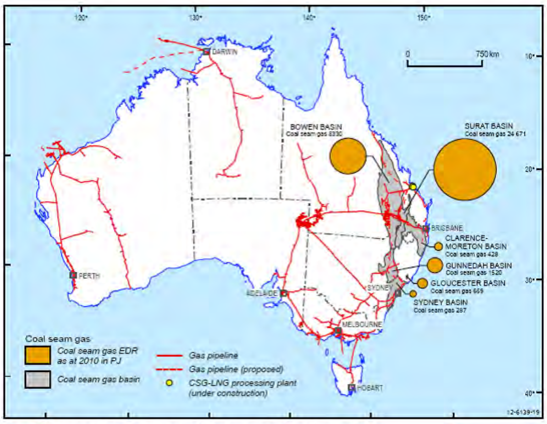


Figure 2.7. Location of Australia's coal seam gas reserves and gas infrastructure. (AGRA 2012 p. 16)

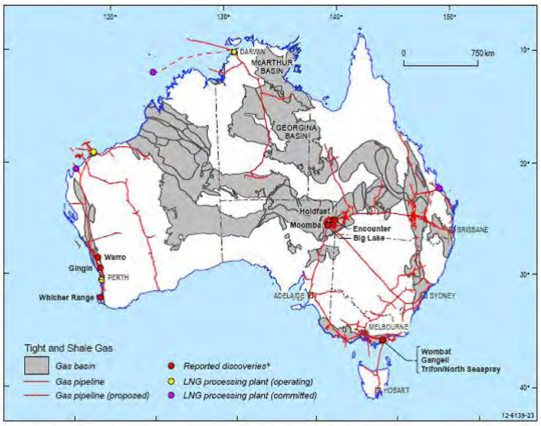


Figure 2.8. Basins with tight gas and shale gas potential and gas infrastructure. (AGRA 2012 p. 18)

2.3. Geological setting for coal seam gas

To understand how gas production, whether conventional natural gas or unconventional gas such as CSG, interfaces with natural resources and their management, it is important to have an appreciation of the geological and hydrological features of the sedimentary basins in which they are found.

The relationships between coal seam gas production and water resources, land use, and biodiversity require an understanding of where these gas-bearing strata sit with respect to the water-bearing aquifers. Some aquifers intersect with the land surface, and these intersections as well as the aquifers' hydrological characteristics, determine the nature of their recharge and discharge, both of which are most important to natural resources management.

The geological settings for CSG resources relate directly to the sedimentary basins in which there are hydrocarbon and coal-rich strata. These strata and sequence of strata are associated with the Permian–Triassic period in the Sydney–Gunnedah–Bowen Basin system, the (more recent) Jurassic–Cretaceous periods in the Great Australian Basin (GAB) and the largely Devonian period (much older) in the gas-prospective Darling Basin. Thus the younger GAB overlies the older Darling and Sydney–Gunnedah–Bowen Basin systems. The GAB itself comprises parts of the Clarence–Moreton, Surat, Eromanga and Carpentaria Basins.

The major geological basins with coal resources, and thus the subject of current exploration and coal seam gas development, are set out in Figure 2.9.

Geoscience Australia provides a comprehensive description of the primary sedimentary basins which exhibit large potential for coal seam gas production (GA (a) 2012). Based on information from that organisation and State agencies, short summaries of relevant characteristics of the main basins are now provided.

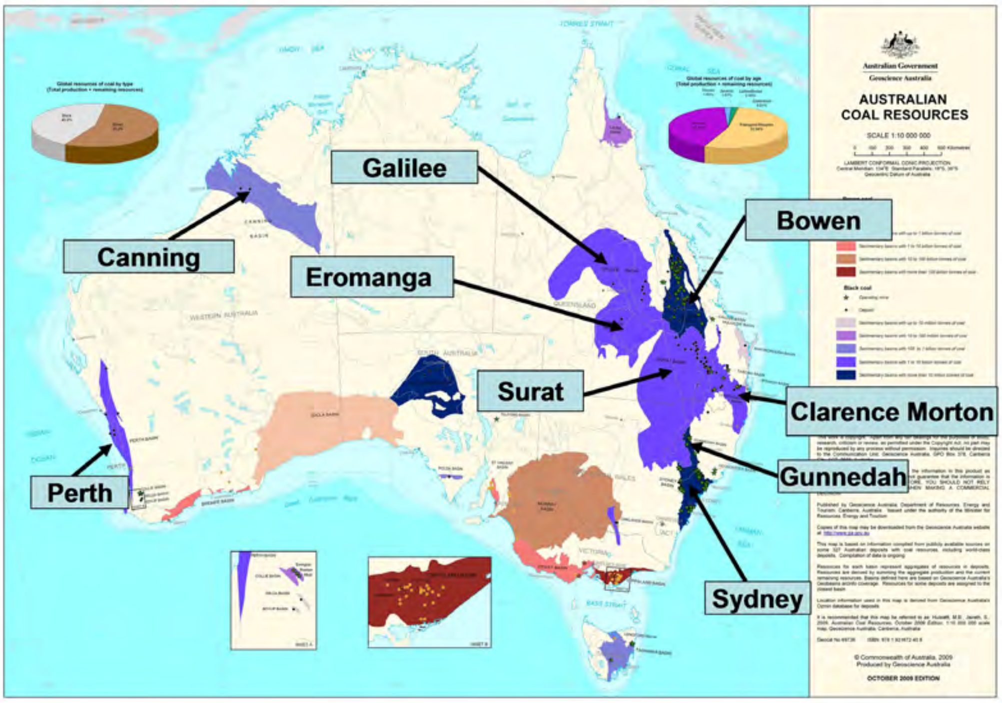
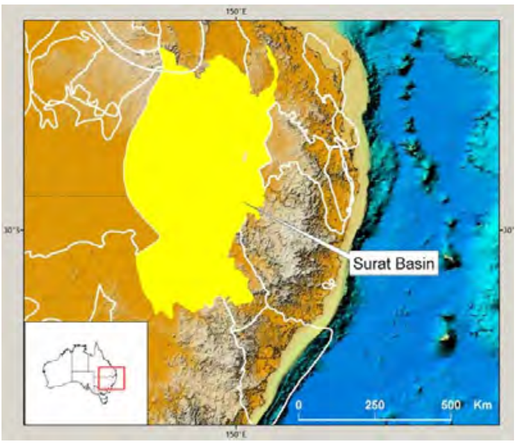


Figure 2.9. The major Australian basins with large reserves of coal seam gas

2.3.1. The Surat Basin

The Surat Basin (Figure 2.10) occupies 300,000 km^2 of central southern Queensland and central northern New South Wales. It has a maximum sediment thickness of 2,500 m and deposition was relatively continuous and widespread. During the Jurassic, lakes, streams, and coal swamp deposition predominated over much of the basin to form various coal measures wherein about 100 hydrocarbon accumulations have been discovered, of which about half are producing fields. Most accumulations are stored in early Jurassic sands, sourced from the Permian non-marine sediments of the underlying Bowen Basin.



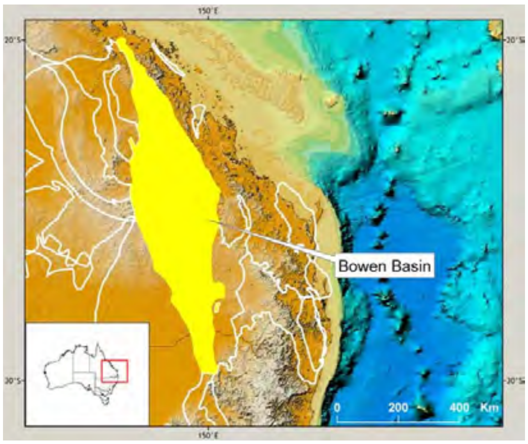


Figure 2.10 (left) and Figure 2.11 (right) The locations of the Surat Basin and Bowen Basin. GA (2012)

2.3.2. The Bowen Basin

The Bowen Basin (Figure 2.11) is situated in eastern Queensland where it occupies about 160,000 km^2. The southern half of the Bowen Basin is covered by the Surat Basin. It has a maximum sediment thickness of about 10,000 m. Over 100 hydrocarbon accumulations have been discovered in the Bowen Basin, of which about one third are productive gas fields. The Bowen Basin also has vast coal resources, with major open cut and underground coal mines in the north of the basin. Large volumes of methane gas are held at shallow depths within Permian coals in the north and have potential for CSG development.

2.3.3. Clarence–Moreton Basin

The Clarence-Moreton Basin (Figure 2.12) is situated in south-east Queensland and north-east New South Wales and covers about 26,000 km^2 onshore and at least 1,000 km^2 offshore in water depths up to 90 m. The basin is subdivided into the Logan, Laidley, and Cecil Plains Sub-basins. The Logan Sub-basin contains the greatest thickness of sediments with up to 3,000 m of silica-rich sediments deposited by rivers and lakes which now hold dispersed coal seams and some minor basaltic volcanics. It is poorly explored with sparse seismic coverage.

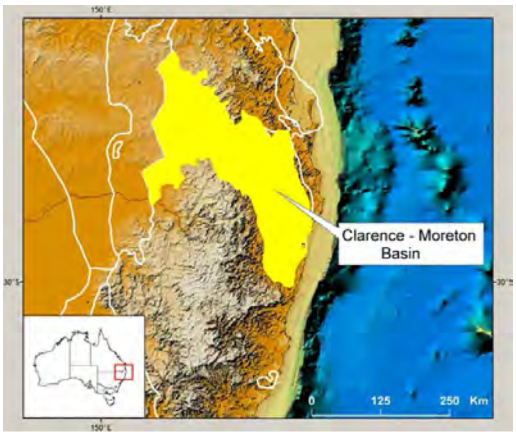


Figure 2.12. Location of the Clarence–Moreton Basin. (GA 2012)

The Clarence–Moreton Basin has abundant oil-prone organic matter in the Walloon Coal Measures and the subjacent Koukandowie Formation. Proven reservoirs lie within the Woogaroo and Marburg Subgroups.

2.3.4. The Sydney Basin

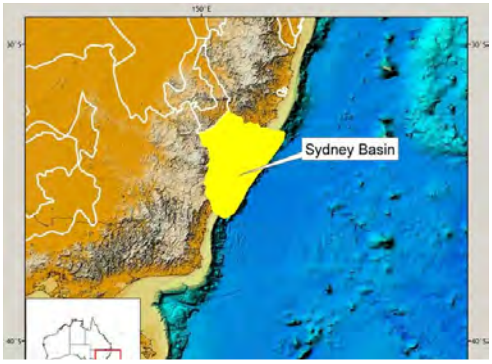


Figure 2.13. Location of the Sydney Basin. (GA 2012)

The Sydney Basin (Figure 2.13) straddles Australia's central eastern coast in New South Wales. The basin covers 64,000 km^2, with 36,000 km^2 onshore and 28,000 km^2 offshore, under water-depths of up to 4,500 m. The Sydney Basin is part of a major basin system that extends over 1,500 km from the Bowen Basin in Queensland through to the Gunnedah Basin in New South Wales. Over 100 wells have been drilled in the onshore Sydney Basin, although no wells have yet been drilled offshore. The onshore basin contains rich coal deposits with associated natural gas and minor oil shows. The geochemistry of oil shows indicate a terrestrial source from a clay-rich environment, although not associated with the coal seams.

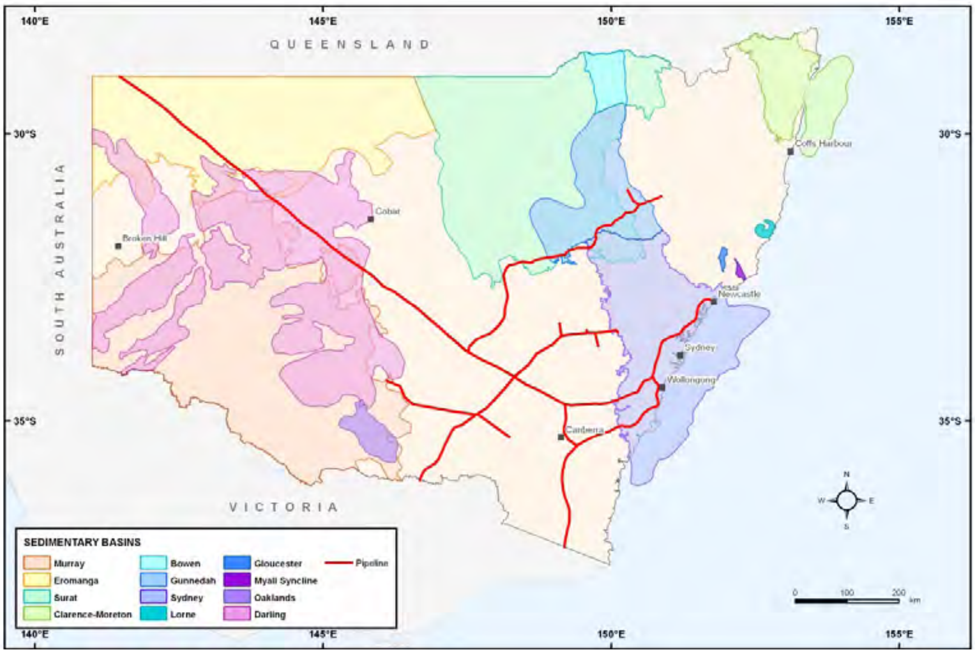


Figure 2.14. Location of the Gunnedah Basin (blue with blue edge). (NSW TIRE 2012)

2.3.5. The Gunnedah Basin

The Gunnedah Basin (Kingham, 1998) is located in north-eastern New South Wales, between the Bowen Basin to the north and the Sydney Basin in the south (Figure 2.14). This basin forms the central part of the Sydney–Gunnedah–Bowen Basin system which extends along the eastern margin of Australia. The Gunnedah Basin covers an area of just over 15,000 km^2. The boundary between the Gunnedah Basin and the Bowen Basin to the north is largely arbitrary, taken as being a high area north of Narrabri where some of the sediments have been eroded. The boundary between the Gunnedah Basin and the Sydney Basin, to the south, lies near the Liverpool Ranges.

The Gunnedah Basin is in part overlain by strata of the Surat Basin and is an important Permian coal-bearing basin (Tadros 1993). Exploration in the Gunnedah Basin has

increased in recent years, focusing on CSG (coal seam methane). The Wilga Park Power Station has been in operation since 2004 and uses gas supplied from production wells within the Gunnedah Basin.

2.3.6. The Great Artesian Basin

The Great Artesian Basin comprises three major sedimentary basins: namely, the Eromanga, the Surat, and the Carpentaria, and also includes parts of the Bowen and Galilee Basins (Figures 2.15, 2.16). These primary sedimentary basins are continuous across shallow ridges and platforms of older sedimentary, metamorphic and igneous rocks of pre-Jurassic and pre-Triassic ages. The Mesozoic sediments sequences of the central basin can be over 3,000 m thick.

Knowledge of these sedimentary basins and the manner in which the sediments are situated to each other (particularly the respective coal measure and aquifers), while often complex and at some scale not well-understood, is critical to thinking about possible impacts of CSG production on water resources in these areas.

2.3.7. The stratigraphy and hydrology of the Great Artesian Basin

The Great Artesian Basin (GAB) is one of the largest artesian groundwater basins in the world. It extends 2,400 km from Cape York in the north to Dubbo in the south. At its

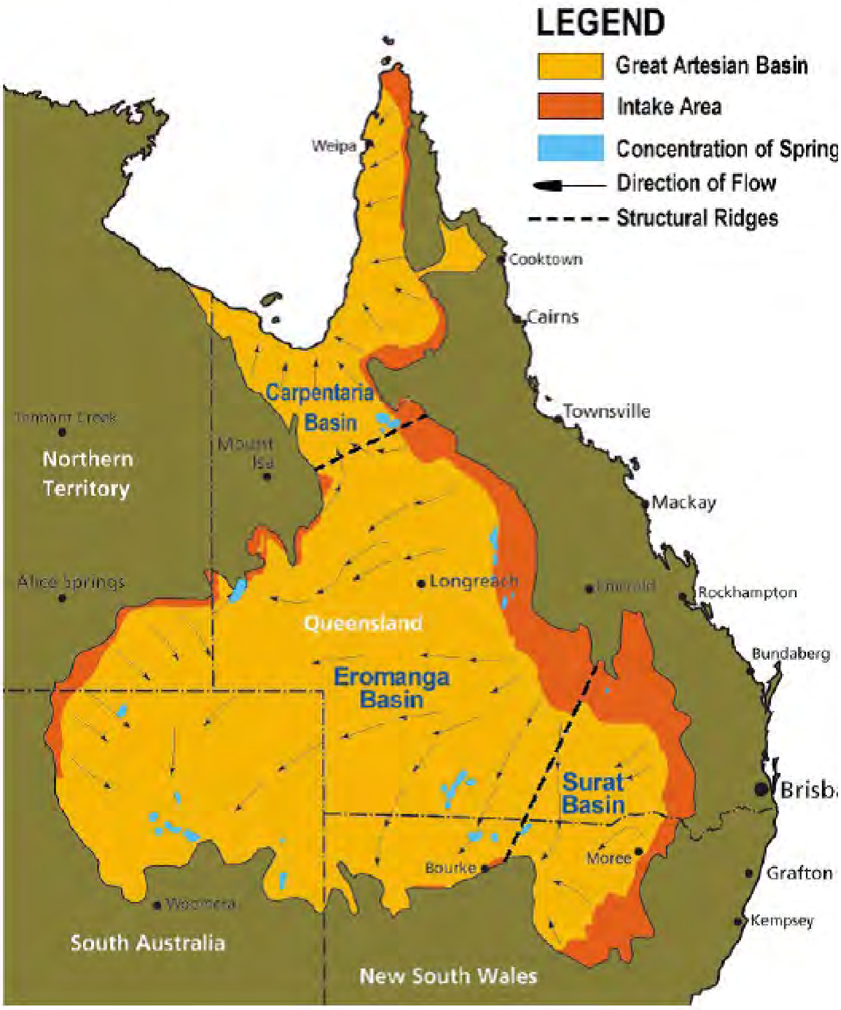


Figure 2.15. Directions of groundwater flow (arrows) in the Great Artesian Basin, shown in relation to three major sedimentary basins (shaded ochre). (Queensland DERM 2011)

widest it is 1,800 km from the Darling Downs to west of Coober Pedy. With an area of over 1,700,000 km^2, the basin underlies approximately one-fifth of the Australian continent (Habermehl 1980). The GAB stores a huge volume of water that is estimated to be 64,900 gigalitres (GL) which is about twice the capacity of the dams of the Murray-Darling Basin.

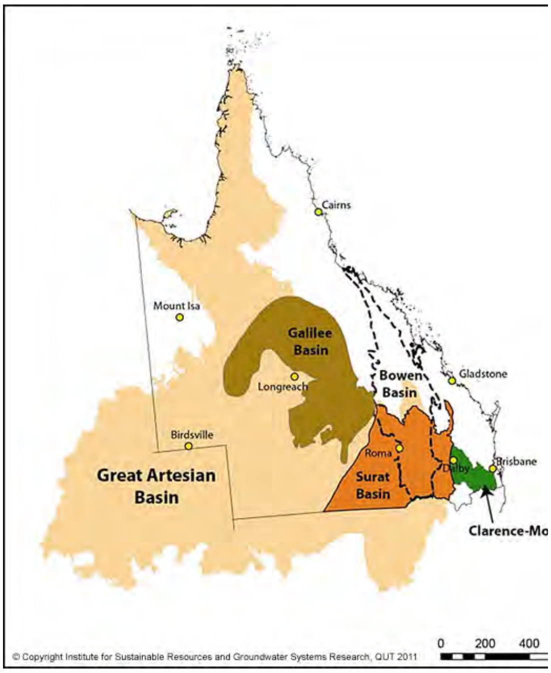


Figure 2.16. Great Artesian Basin (shaded pale brown) in relation to two major sedimentary basins. (QUT 2011)

At the end of the Triassic period (about 200 million years ago) there was uplift on the margins of these basins, and erosion of these areas led to sedimentation. Throughout the period, sand and gravel were deposited by streams and rivers, and clays and clayey sands were laid down on floodplains and in lakes. This process produced a profile of alternating layers. In simple terms, the GAB was created by the deposition of sediments that eventually formed alternating layers of permeable sandstone and impermeable siltstones and mudstones. Within the layers laid down over the period from the Permian to the late Jurassic and into the Cretaceous periods, coal seams were interlaced with permeable aquifers and the siltstones, shales and mudstones. The deposits occurred in three major depressions: the Carpentaria, Eromanga and Surat Basins which together form the GAB (Figures 2.15, 2.16).

One of several coal deposits is the Walloon Coal Measures (Figures 2.18, 2.20). To date, it is the main gas producing formation targeted for CSG extraction in the GAB. There are other coal formations where CSG activities will be operating but these are in geological basins sitting beneath the strata of the GAB. Connectivity of Walloon Coal Measures with underlying and overlying aquifers varies depending upon the thickness and permeability of the separating formation material. The thickness of the combined layers varies from less than 100 m at the basin extremities to over 3,000 m in the deeper parts.

As the Cretaceous period ended, about 65 million years ago, further uplift ended sedimentation in the region of the GAB. Erosion resulted in exposure of the permeable sandstones in the marginal areas of the basin (as seen in the Burra Range between Balfes and Torrens Creek in North Queensland). The schematic diagram in Figure 2.17 shows a greatly simplified stratigraphy and aquifer layout for the GAB, omitting the coal measures.

Figures 2.18 and 2.19, produced by the Queensland Institute of Technology and FrOG Tech (a Canberra natural resources company), illustrate the detailed work that is required to be sure the locations and lithologies of coal measures, aquifers and aquitards (that is, boundaries preventing water flow) are well-understood. Details of geology and hydrology are essential foundations for predictive modelling to estimate the impact of CSG on the water flow patterns in the stratigraphy. This knowledge should help avoid damaging the water resource in CSG production.

Notice that to produce CSG it is usually necessary to dewater and thus de-pressurise the coal measures as shown in this diagram.

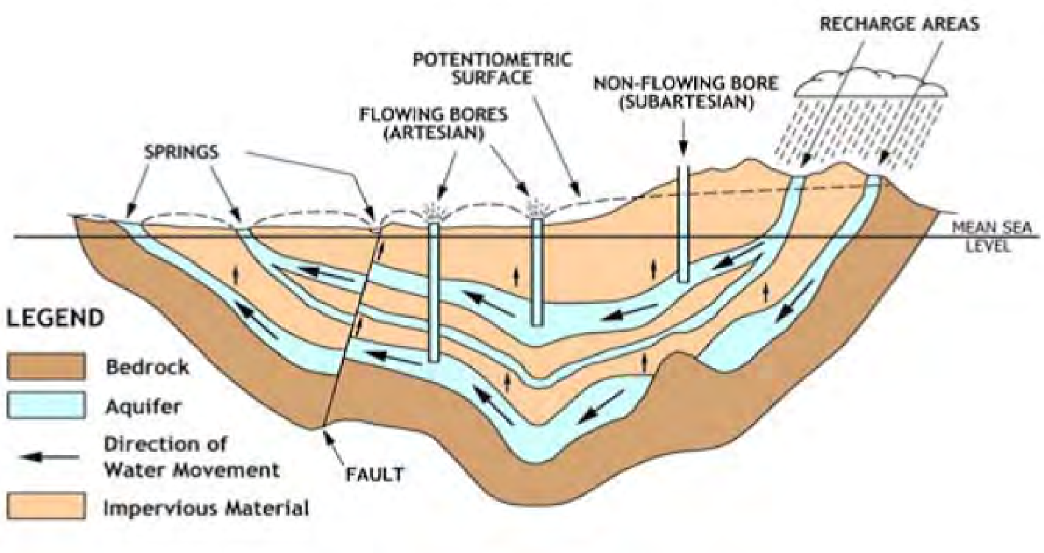


Figure 2.17. Simplified vertical cross-section of the Great Artesian Basin. (DERM 2011)

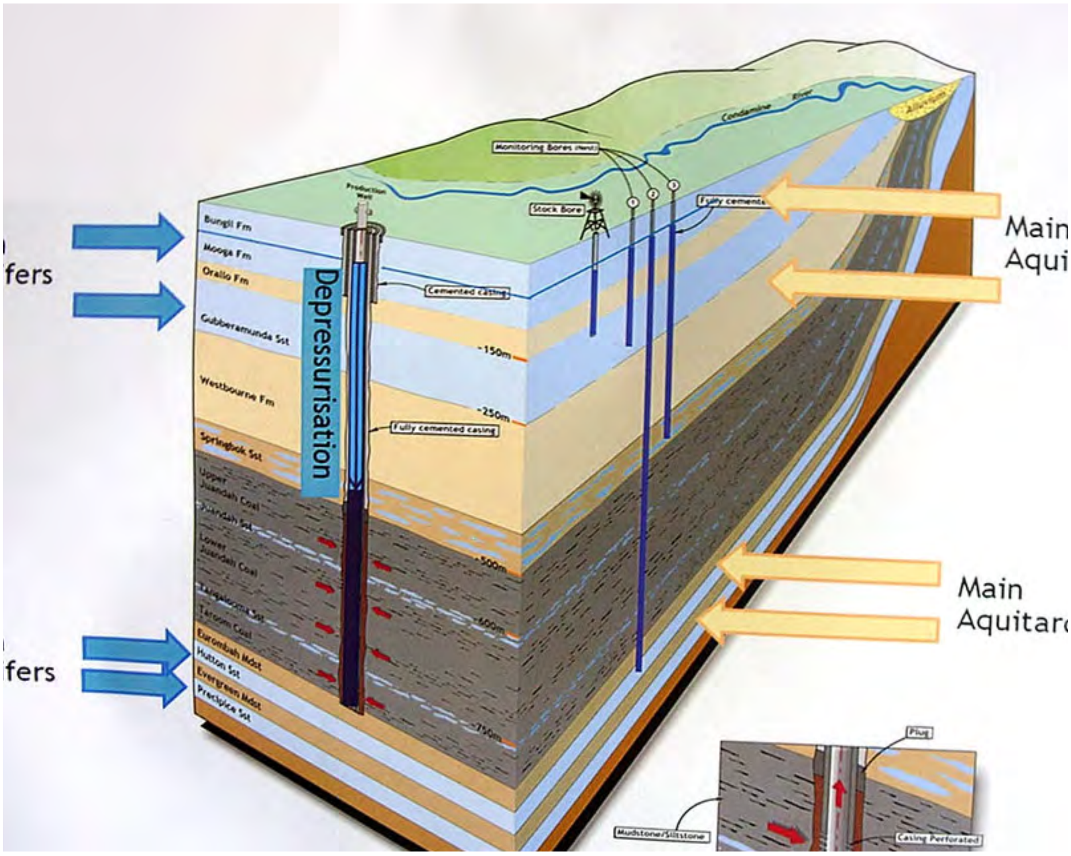


Figure 2.18. Block diagram of general stratigraphy of Surat Basin. (QUT (b) 2011)

Litho-stratigraphy	Main Rock Types
Condamine Alluvium	Unconsolidated sand, gravel and silt
Tertiary Sediments	Unconsolidated sediments
Griman Creek Formation	Sandstone, siltstone, mudstone conglomerate and coal
Surat Siltstone	Interbedded carbonaceous siltstone, mudstone and lithic sandstone
Wallumbilla Formation	Mudstone, siltstone, sandstone lenses with conglomerate and limestone
Bungil Formation	Mudstone siltstone and lithic sandstone
Mooga Sandstone	Fine to medium grained sandstone and shales
Orallo Formation	Sandstone carbonaceous siltstone mudstone coal
Gubberamunda Sandstone	Medium and coarse quartz sandstone
Westbourne Formation	Shales, siltstones and fine grained sandstone
Springbok Sandstone	Sublabile, lithic sandstone with calcareous cement
Walloon Coal Measures	Shale, siltstone, labile argillaceous sandstone, coal, mudstone, limestone
Hutton Sandstone*	Sandstone, siltstone, shale, conglomerate, coal, oolitic ironstone
Evergreen Formation	Sandstone, siltstone, shale, mudstone (carbonaceous with minor coal), oolitic limestone
Precipice Sandstone	Sandstone, pebbly sandstone, siltstone.
Sedimentary sequences of the Bowen basin	Predominantly sandstone, siltstone, shale and mudstone with Coal measures

Figure 2.19. Stratigraphy and rock types in a vertical section of the Surat Basin. (FrOG Tech 2011)

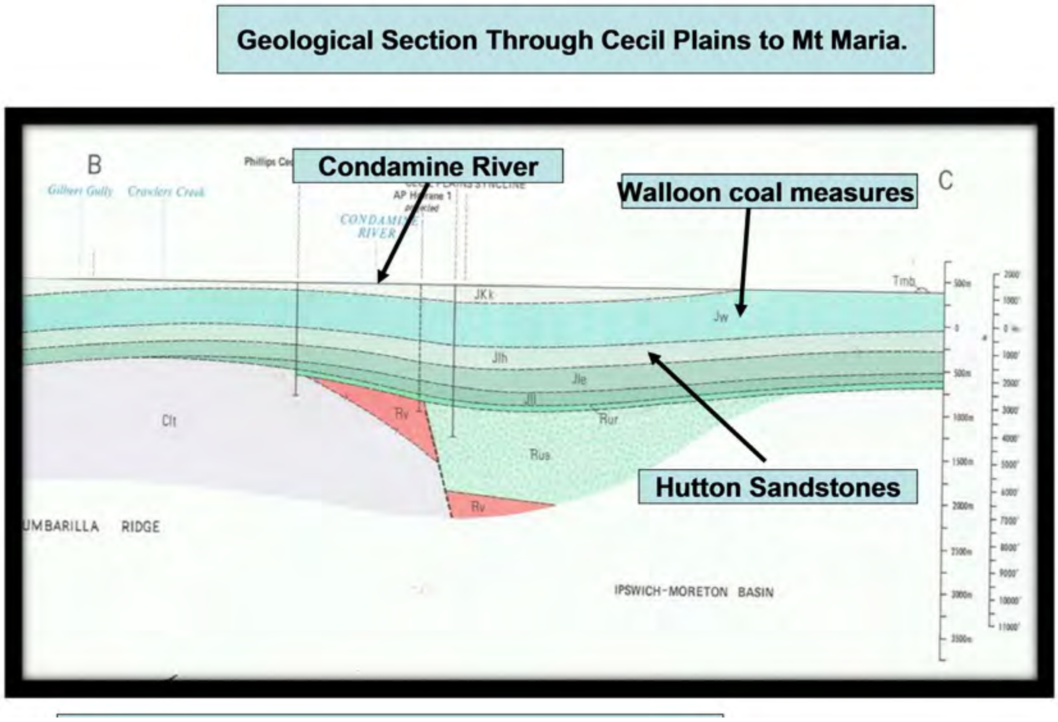


Figure 2.20. Geological section through Cecil Plains to Mt. Maria. (Hillier 2010)

It is important to appreciate that the stratigraphy has been modified by uplift and erosion as these basins have been tilted. One consequence is that, in the eastern margins of the Surat Basin, the Walloon Coal Measures of the GAB approach the surface where they are overlain with Tertiary sediments and soil regolith and incised by the Condamine River (Figure 2.20; Hillier 2010).

The GAB stratigraphy in Figure 2.20 is quite different from that depicted in the earlier Figure 2.18.

When extracting the gas from coal measures, engineering based on sound understanding of the geology and the hydrology is essential to prevent leaks and losses of water and gas. Not only would those sap the profitability and success of the extraction operation, but they would undermine community and government confidence in well safety.

Confidence is important in exploration and production, and it is equally and perhaps more important that well integrity can be sustained indefinitely following de-commissioning and the conclusion of hydrocarbon extraction.

The section which follows outlines the considerations used in vertical drilling for water, oil or gas, and particularly as adapted for the extraction of unconventional gas. It also outlines the 'fraccing' operation and touches on the extra challenges of shale gas mining.

2.4. Engineering of coal seam gas production

A CSG well will have, in principle, the form and function shown in Figure 2.21. The coal seam is usually saturated and under pressure. When water is removed, the gas can desorb from the coal and be pumped out. The water (blue line in Figure 2.21) is pumped to a water reservoir within a water treatment facility. The gas can also be pumped with the water to a gas separator, and then to the gas drying facility and a gas compression unit within a network of gas distribution pipelines (e.g. Figure 2.22).

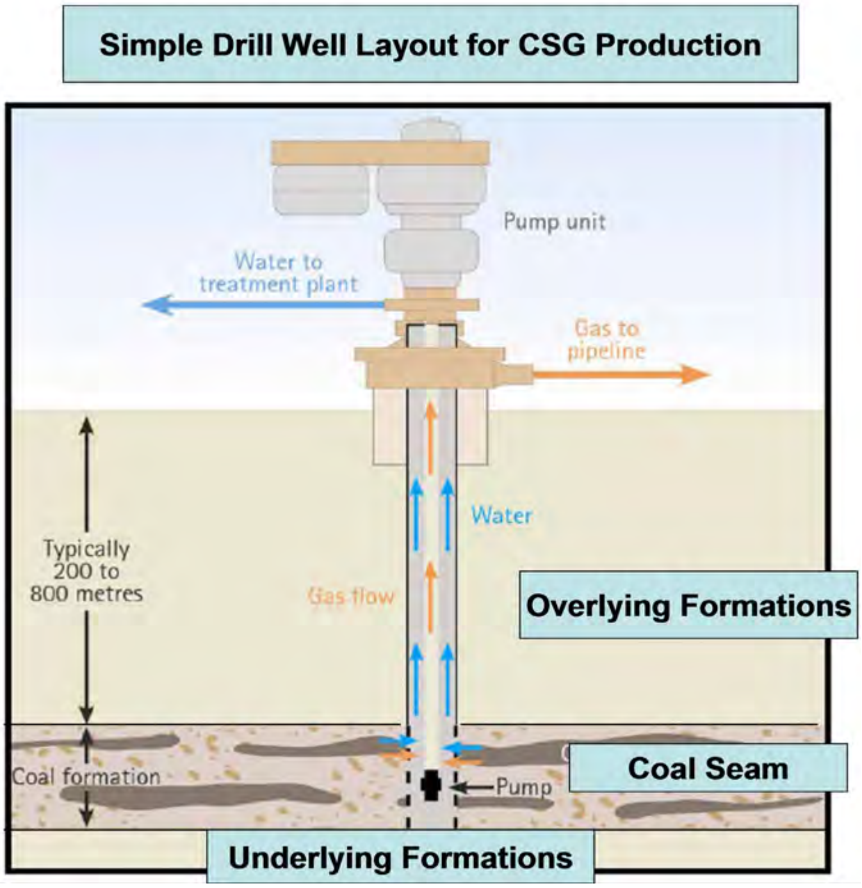


Figure 2.21. Simple drill well layout for CSG production.

To manage real-world geological stratigraphy, well design is much more complex than shown in Figure 2.21. Figure 2.23 shows well design for the CSG reserves in the Gunnedah basin of New South Wales.

The integrity of gas wells is one of the most important aspects of CSG engineering for reducing the impact of CSG production on natural resources. The recent Royal Society investigation (TRS/TRAE 2012) of contamination from shale gas production in the United Kingdom made this very clear in their recommendations and investigation. They summarised by saying "Ensuring well integrity must remain the highest priority to prevent contamination. The probability of well failure is low for a single well if it is designed, constructed and abandoned according to best practice."

The opportunity to have well design, construction and operation examined and reviewed by independent, specialist experts was seen as being of primary importance.

The way the well is constructed is critical to it retaining its seals and overall integrity. There must be enduring seals in the well between the coal seam and the underlying and overlying formations. The depth of overlying formations can vary greatly, for example from 100 to 1,000 m.

To put CSG wells into context, we should note that wells designed for the extraction of oil and gas from conventional reserves may also have to meet similar specifications. Indeed, wells designed to extract water from an aquifer below others of differing water quality must also be well sealed and keep their integrity *ad infinitum*.

Figure 2.22. Parts of typical infrastructure for natural gas. Images courtesy of Santos Pty Ltd.

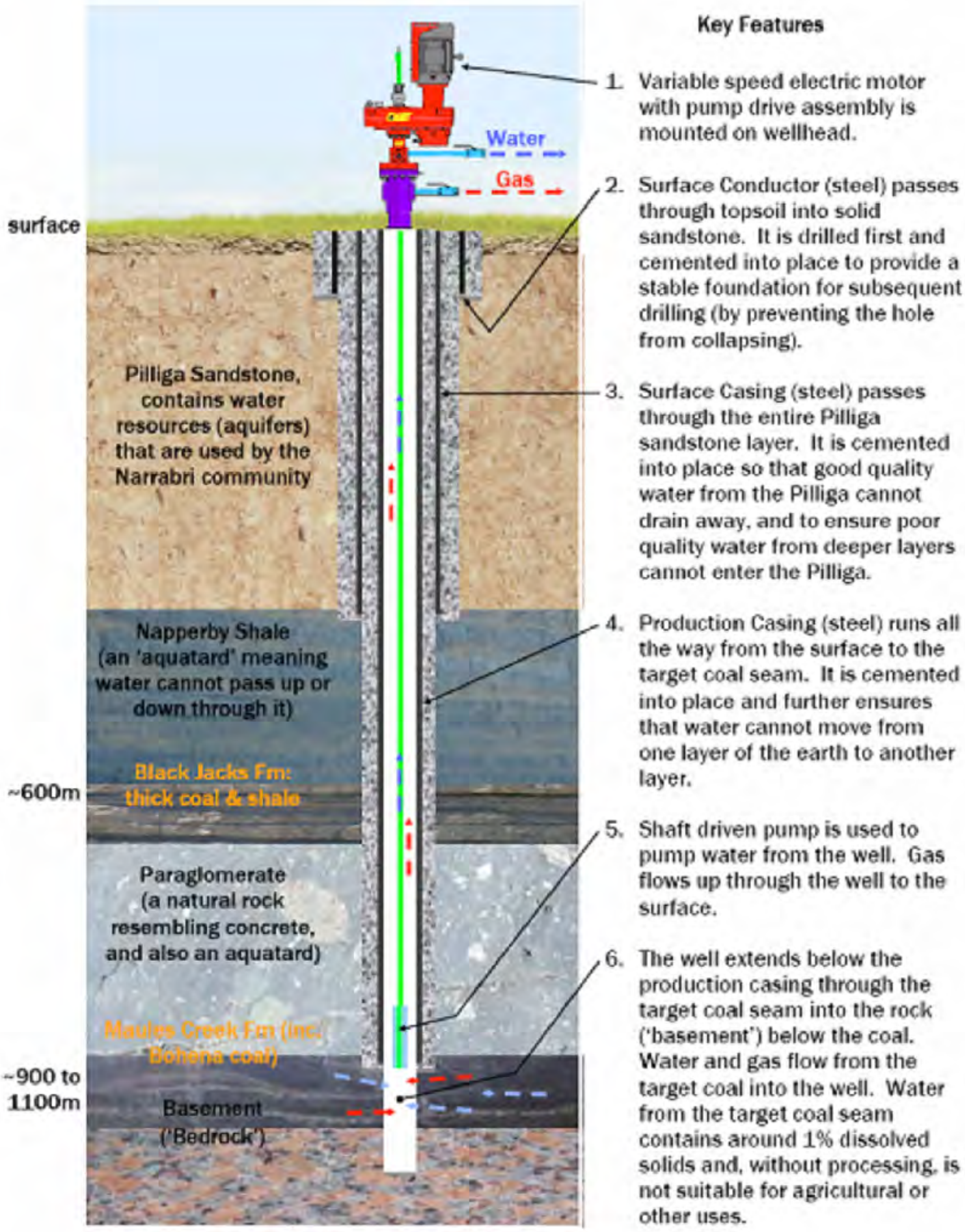


Figure 2.23. Basic schematic of a coal seam gas well. (NSW Legislative Council Inquiry into Coal Seam Gas p. 9)

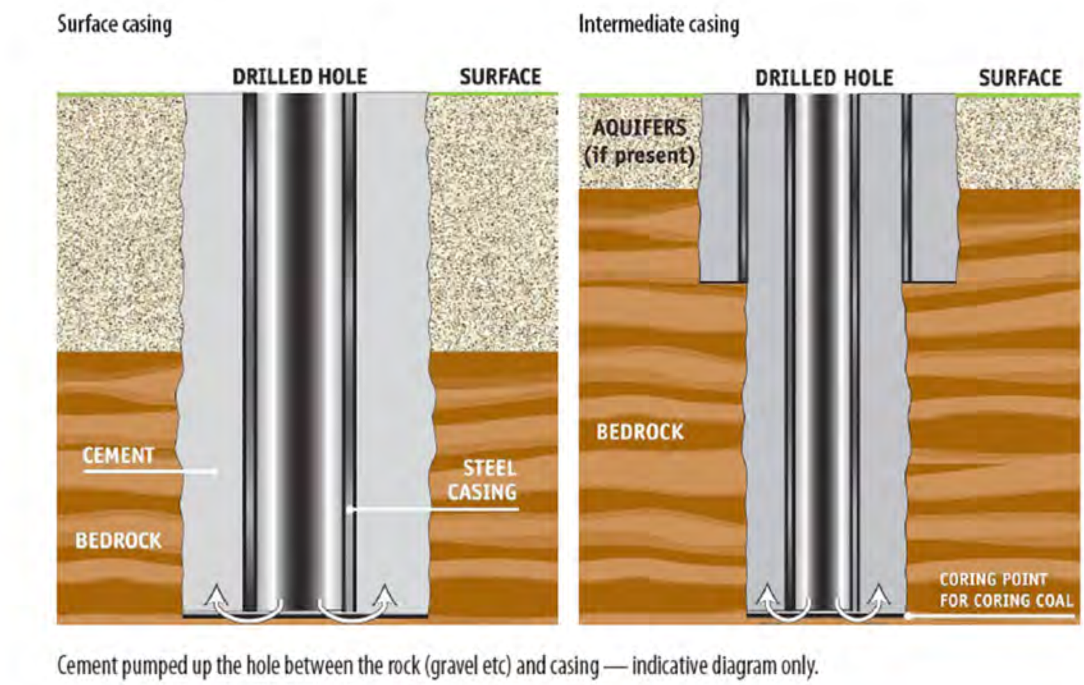


Figure 2.24. Casing a drilled hole. (APPEA 2012)

2.4.1. Exploration hole design

The well construction details outlined briefly here are built on the text and information provided by APPEA (2012).

In commercial drilling, each core hole has a specific design that complies with the relevant regulations, and integrates the expected core point and total depth of the finished hole. CSG companies use an exploration core hole design that isolates aquifers behind one or two layers of steel casing held in place with pressure tested cement.

A core hole of between 10 cm and 30 cm diameter is drilled through alluvial and weathered material until it reaches solid rock. Depending on the core hole design, one or two layers of steel casing are run from the surface through the alluvial and weathered material to the competent rock, and cemented in place (Figure 2.23).

The casing is pressure tested to ensure it is sealed. A single casing is used if the distance from surface to competent rock is short, and double casing is used if the distance is further. The casing is strong enough to handle subsurface pressures.

Freshwater aquifers are generally shallower than the coal seams targeted by the CSG industry. It is therefore important to ensure the steel casing and cement form a barrier that prevents drilling mud and water from lower aquifers mixing with water in upper aquifers (Figures 2.23, 2.24).

After solid rock is reached, the drilling method switches to coring. Six-metre long cylinders of rock and coal are extracted and tested on site before being sent off site for further testing. This continues until the hole reaches basement, the point at which all known formations have been found.

2.4.2. Pilot testing

Pilot tests are done to gather on-the-spot detailed information (permeability, reservoir pressure, gas and water production and composition) about gas-bearing coal seams. Pilot testing is carried out in areas where exploration has shown that the coal seams have indicated potential to produce gas. It also allows for trials of water handling methods which may vary from region to region.

Pilot testing involves drilling a well to just below the coals of interest and using a down-hole pump to extract water from the coal seam. When enough water has been removed from the coal seam the reduction in water pressure allows the gas to flow from the seam. The hole is sealed at the wellhead when sufficient data has been obtained from the well.

2.4.3. Production/pilot well design

Pilot well design follows the same construction design principles as those used in core holes. There may be one, three, or five wells for each pilot test. Closer spacing than that used for production wells allows data to be gathered more quickly. The volume and quality of the water pumped from the coal seam help the engineers identify options for putting the water to beneficial use or disposing of it in some way. If gas is produced it is also extracted and tested.

Production wells have the same design, but more wells are spread over a wider area.

2.4.4. Well site equipment

The well is lined with pressure-rated steel casing from the surface to just above or below the coal seams and cemented in place. The casing is pressure tested to ensure that it can tolerate higher pressures than the pressures expected over the life of the well. A 'blow out preventer' (BOP) may be installed in the cellar to ensure that, in the event of unexpectedly high water or gas pressures, the drilling rig can shut the well in.

At surface level, a wellhead is installed. It ensures that all produced water and gas is safely handled. Inside the wellhead is a steel tubing hanger — the tubing hangs inside the steel casing with the pump at the bottom.

The test string (all components of the pumping mechanism) comprises a progressive cavity pump (PCP), a rod string which rotates inside the tubing and transmits power from the motor at the wellhead to the down-hole PCP, which is just above the coals of interest. This pump pushes water from the coal seam to the surface.

Just below the PCP is the torque anchor, which fits against the inside of the casing and prevents the tubing from being twisted out of place by the constant rotation of the sucker rod. Below the anchor is the tailpipe and pump intake. It is designed to assist with down-hole separation of gas and water, and prevents gas being pulled through the pump. The lighter gas rises and is trapped between the tubing and the steel casing, while the heavier water falls to the bottom of the well and is pumped up inside the tubing string by the PCP.

The wellhead equipment performs all functions required to carry water from the coal seam to the surface and is powered by a motor on site. The drivehead powers a pulley system which drives the rod string and the PCP. There are three outlets on the wellhead. There is one tubing outlet to carry water from the well to allow water testing. The two casing annulus outlets enable gas to flow from the well to the flare line, and fluid levels in the well to be measured.

The stuffing box provides a seal between the rotating rod string and atmosphere. This prevents water and gas leaking from the wellhead. During a pilot test, pressures and water volumes will be monitored by a flow meter. The results are reported in accordance with regulatory obligations.

Figure 2.25. Four phases in ensuring that gas wells cannot leak into the strata they traverse. (Boling 2012)

2.4.5. *Well integrity*

Well integrity, which is critical in protecting an underground water resource, involves four phases (Figure 2.25) including thorough risk management. The phases are:

- evaluating stratigraphic confinement;
- specifying well-construction standards;
- evaluating the mechanical integrity of the well; and
- monitoring the fraccing job and monitoring producing-well performance and function.

Well construction standards

Drilling techniques used by the CSG industry and well-construction specifications are set by industry organisations (e.g. Factsheet illustrated here). State regulations are also now being developed to ensure that well integrity is maintained throughout the life of the well at a level that maximises the protection of the groundwater resource from CSG exploration and production. The highest order of specifications and engineering practice must be applied to prevent significant risk to water resources, and it appears that there is scope for improvement. Industry associations appear to be willing to set standards and support engineering-best-practice, and this is to be encouraged.

Site-specific data must be used to inform the design of CSG activities, develop appropriate monitoring programs and to establish reporting mechanisms to ensure that any unforeseen impacts can be responded to rapidly.

It is essential that wells are cased and the casing set in a strong seal of cement to prevent the leakage of gases or fluids around the outside of the casing, by which they could enter nearby groundwaters or the air. (See Figure 2.24.)

Technical aspects of well design and specification for best protection of water resources, based on experience in USA, are explained by Mark Boling (Boling 2012).

To evaluate the mechanical integrity of a well, it is first necessary to examine the internal mechanical integrity, as shown in Figure 2.26. Integrity checking requires verifying

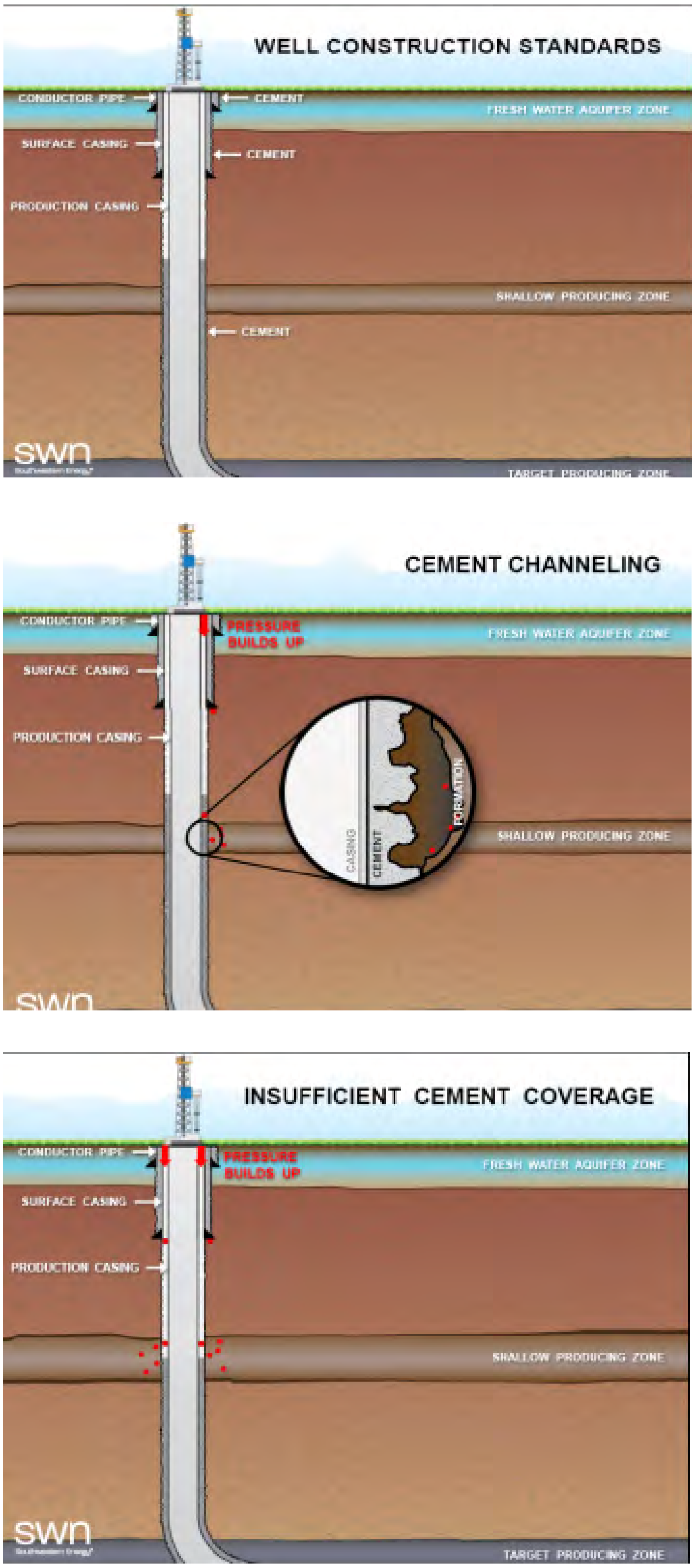


Figure 2.26. (Boling 2012) (top)–(bottom) Three stages in verifying the mechanical integrity of a well, by testing the quality of the casing and the soundness of the cement or seals in relation to strata.

that the proposed casing program is appropriate (e.g. size, grade, minimum internal yield pressure, etc). It also means testing the casing string to ensure it can withstand the maximum stimulation pressure (Figure 2.26 top). Checking the external mechanical integrity involves verifying the quality of cement used and identifying the location of the top of the cement (Figure 2.26 middle). Finally, a test of the cement job is required (formation integrity test (FIT), cement bond load (CBL), etc.) when operations indicate inadequate coverage (Figure 2.26 bottom).

2.4.5. The use of hydraulic fracturing ('fraccing')

Hydraulic fracturing, or fraccing, is used by some oil and gas companies in some locations to increase the recovery of underground gas or oil resources. In the case of coal seam gas, fraccing involves pumping a fluid, mostly comprising water and sand, under pressure into a coal seam (Figure 2.27). This pressurised fluid opens up fractures in the coal, increasing the opportunity for water and gas to move within the coal seam.

The pressure required to fracture the coal seams without impacting on other aquifers requires careful management, including analysis of the strength of overlying and underlying strata, and progressive monitoring and reporting of the outcomes of the fracturing activity.

The Royal Society and The Royal Academy of Engineers (TRS/TRAE, 2012) have recently published an extensive analysis of the key science and engineering issues associated with hydraulic fracturing for extracting shale gas in the UK. The issues for shale gas have similarities to issues for coal seam gas, which are addressed in principle in Chapter 3 of this report.

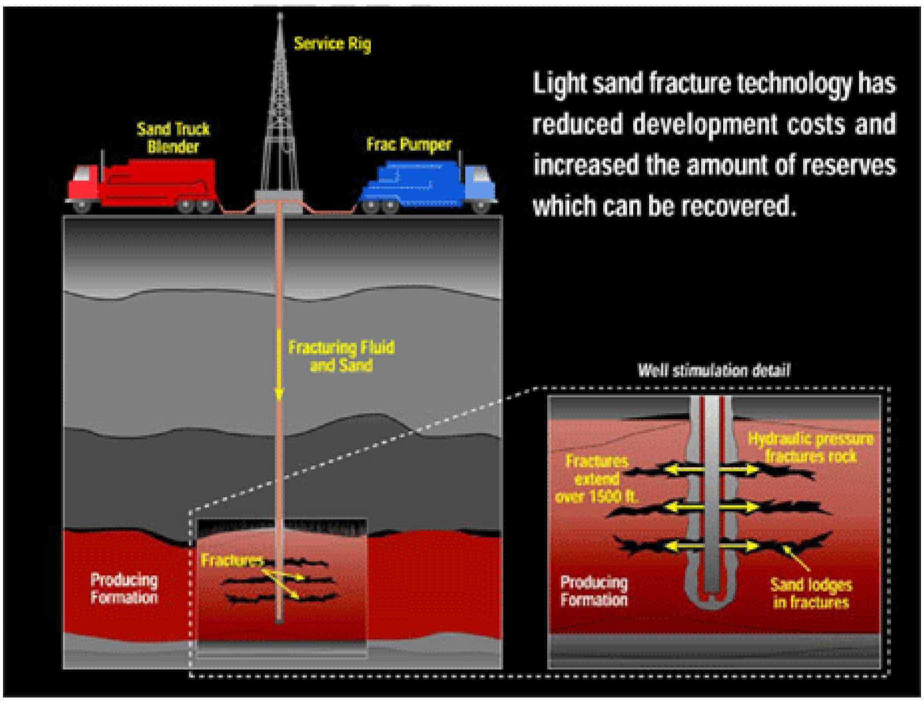


Figure 2.27. Generalised diagram of the hydraulic fracturing ('fraccing') process. (Leahy 2012)

References

AGRA (2012) Australian Gas Resource Assessment 2012. Geoscience Australia and the Bureau of Resources and Energy Economics (part of the federal Department of Resources, Energy and Tourism), Canberra. http://www.ga.gov.au/image_cache/GA20708.pdf

APPEA (2012) About CSG. Australian Petroleum Production & Exploration Association Ltd. http://www.appea.com.au/coal-seam-gas.html

Beach Petroleum (2011) Media Release, Major and Historic Success at Australia's First Shale Gas Well, 12 July. http://www.beachenergy.com.au/IRM/Company/ShowPage.aspx/PDFs/2597-40510231/MediaReleaseHoldfast1

Cull, Alex; Hoare, Rebecca; Joyce, Michael; Dwyer, Vincent; Currie, Simon; Pittman, Miles; Rogers, Ben; Kozlowski, Adam and Nick Prowse (2011) Australia: Unconventional series - The shale gas revolution comes to Australia. http://www.mondaq.com/australia/x/143146/Renewables/Unconventional+series+The+shale+gas+revolution+comes+to+Australia

DERM (2011). The Great Artesian Basin. Fact sheet. http://www.derm.qld.gov.au/factsheets/pdf/water/w68.pdf

EIA (2011) World shale gas resources: An initial assessment of 14 regions outside the United States. Energy Information Administration, Washington. April 2011. (Cited in AGRA 2012).

FrOG Tech (2011) Bowen and Surat Basins. From Oil to Groundwater Pty Ltd, Deakin, ACT. http://www.frogtech.com.au/bowen-surat-basin-csg/

GA a (2012) Australian Geological Provinces. Geoscience Australia, Canberra, ACT. http://www.ga.gov.au/provexplorer/provinceDetails.do?eno=27354

GA b (2012) Surat Basin. Geoscience Australia, Canberra, ACT. http://www.ga.gov.au/oceans/ea_Surat.jsp

GA c (2012) Bowen Basin. Geoscience Australia, Canberra, ACT. http://www.ga.gov.au/oceans/ea_Browse.jsp .

GA d (2012) Clarence–Moreton Basin. Geoscience Australia, Canberra, ACT. http://www.ga.gov.au/oceans/ea_ons_ClrMrtn.jsp .

GA e (2012) Sydney Basin. Geoscience Australia, Canberra, ACT. http://www.ga.gov.au/oceans/ea_ons_Sydny.jsp .

Habermehl, M.A. (1980) The Great Artesian Basin, Australia. BMR Journal of Australian Geology and Geophysics 5, 9–38.

Hillier, J.R. (2010) Groundwater connections between the Walloon Coal Measures and the Alluvium of the Condamine River. A report for the Central Downs Irrigators Limited. August 2010.

Kingham, Robert (1998) Geology of the Murray-Darling Basin —Simplified lithostratigraphic groupings. AGSO Record 1998/21. Australian Geological Survey Organisation (now Geoscience Australia), GPO Box 378, Canberra, ACT 2601. http://www.brs.gov.au/mdbsis/mdbgeol.pdf

Leahy S. (2012) http://stephenleahy.net/2012/03/02/fracking-and-shale-gas-a-bridge-to-more-global-warming-additional-new-research-now-confirms/

NSW TIRE (2012) Minerals and petroleum. Gunnedah Basin geological overview. NSW Trade & Investment, Resources & Energy. http://www.resources.nsw.gov.au/geological/overview/regional/sedimentary-basins/gunnedah#Geology

QUT (2011) Active research projects: Sedimentary basins and coal seam gas. Queensland University of Technology, Brisbane, Queensland. http://www.isr.qut.edu.au/gsr/active_res/coal_seam_gas/#coal_seam

QUT b (2011) Surat Basin stratigraphic profile. Queensland University of Technology, Brisbane, Queensland. http://www.isr.qut.edu.au/gsr/csg_notebook/surat_basin/

Tadros, N.Z. (Ed.) (1993) The Gunnedah Basin, New South Wales. Geological Survey of New South Wales, Memoir Geology 12, 649 pp.

TRS/TRAE (2012) Shale gas extraction in the UK: a review of hydraulic fracturing. DES2597. The Royal Society and The Royal Academy of Engineering, June 2012.

Wiki (2012) Shale gas (reference 18). Wikipedia. http://en.wikipedia.org/wiki/Shale_gas

3. Coal seam gas operations and natural resource management

Currently there is much public debate about the growth of the CSG industry in Australia. The industry has significant potential to contribute to the economy and provide cost-effective energy supplies, but there are concerns that methods of extracting this resource will adversely affect communities and the natural environment.

This chapter first draws attention to the potential for further loss of species as a result of fragmentation of the natural environment for CSG operations. The role of ecosystems in Australia's well-being is often overlooked in assessments of benefits and hazards to humans, and it has not been subject to much study for the CSG industry. The rest of the chapter reviews impacts — known and potential — to air and water resources, including groundwater. Experiences in the USA are instructive and warn Australia that things can go wrong. Extractive industries must be subject to knowledgeable policy and strong regulations, with continual monitoring and careful planning for the decades beyond the life of a well.

There are good scientific grounds (Bellamy et al., 2002; Williams 2012) for examining the impacts of unconventional gas exploration, production and decommissioning on natural resources. These activities must fit into the framework of integrated catchment management (ICM) (or 'integrated watershed management' in USA) if we are to create, within a desired set of values, a mosaic of appropriate land uses that do not exceed the underlying capacity of natural systems.

It is possible —and desirable — to use our knowledge of Australian landscape processes to work out beforehand where we can safely mine and where mining operations would compromise agriculture, water resources, urban and other land uses, biodiversity and environmental function.

Production of unconventional gas adds to the many competing demands humans make on the landscape. Effects of supplying energy, water, food, fibre, minerals and human settlement compete fundamentally with the maintenance of biodiversity — a need that underpins the ecological functioning of the landscape itself.

The large-scale exploration and development of the infrastructure required for extracting unconventional gas from extensive coal measures in Australia is a recent phenomenon. Export of natural gas from north-west Australia has been a very large component of wealth generation in Australia since the early 1980s. Development and extraction of CSG will inevitably become equally important to the Australian economy. Meanwhile, communities are finding the huge changes to the landscape confronting (e.g. Figure 3.1).

It is clear that mining for coal assets, CSG or shale gas has the potential to put at risk the long-term function and value of vital renewable natural resources and ecosystem services, such as:

- water resources and aquatic ecosystems;
- biodiversity, landscape function and amenity via vegetation and habitats; and
- land resources used in agriculture and forestry (food and fibre production).

Figure 3.1. Aspects of CSG production in Queensland; (left) general directions in which CSG must travel to reach Gladstone; where it can be exported from the harbour (top) via LNG carriers (right); and an aerial view of new tracks and wellhead locations across farmland. (ANU 2012)

These issues, which are outlined below, are increasingly well-understood by the gas industry peak bodies, which now recognise the need to develop their practices within a regulatory framework. A recent US study (Groat & Grimshaw 2012) outlines a way forward for shale gas. It states:

> *The most rational path forward is to develop fact-based regulations of shale gas development based on what is currently known about the issues and, at the same time, continue research where needed for information to support controls in the future. Additional or improved controls must not only respond to the issues of controversy, but also address the full scope of shale gas development. Priorities must be set on the most important issues as well as on public perceptions. The path ahead must take advantage of the substantial body of policies and regulations already in place for conventional oil and gas operations. Enforcement of current and future regulations must also be ensured to meet the twin objectives of protection of environment and other resources and gaining public acceptance and support.*

The Canadian Association of Petroleum Producers has guidelines for hydraulic fracturing (fraccing) in shale gas production (CAPP 2012) which state:

> *We will safeguard the quality and quantity of regional surface and groundwater resources, through sound wellbore construction practices, sourcing freshwater alternatives where appropriate, and recycling water for reuse as much as practical. We will measure and disclose our water use with the goal of continuing to reduce our effect on the environment. We will support the development of fracturing fluid additives with the least environmental risks. We will support the disclosure of fracturing fluid additives. We will continue to*

advance, collaborate on and communicate technologies and best practices that reduce the potential environmental risks of hydraulic fracturing.

Other recent studies point to high rates of decline at some shale gas wells, and see that as an indication that shale gas production may ultimately be much less than is currently projected.

For Australia, the following possibilities need to be considered in relation to gas production (conventional or unconventional):

- air emissions, including from processes related to gas production;
- effects on surface-water resources;
- effects on biodiversity via effects on habitats and vegetation;
- impacts on land used for agricultural and forestry production; and
- impacts on community amenity through changes to infrastructure, and traffic and noise.

This chapter examines the key natural resource management issues; that is, potential effects on biodiversity and the natural landscape, air quality, and water including groundwater, in a way that facilitates management via governance, regulation and practice. Impacts on community amenity (fifth point above) are considered in Chapter 4.

3.1. Biodiversity and the landscape

CSG mining represents a serious threat to native vegetation, biodiversity and threatened species. Its effects include direct clearing of bushland, fragmentation of patches of native vegetation, spread of invasive species and increased fire risk; and, as discussed briefly below (e.g. Section 3.3.2), dewatering could change the hydrology of wetlands (including Ramsar wetlands) and groundwater-dependent ecosystems.

These potentially significant impacts of the large dispersed footprint of CSG operations are often overlooked during discussion of the CSG industry. However, it is salutary to recognise that such impacts on vegetation and habitat are usually smaller than the historical impacts of land clearing for agriculture or urban development. Nevertheless, further loss of an already highly fragmented vegetation cover or reserves for such landscapes can be a significant threatening process.

However, note that the environmental assessment undertaken by CSG companies for exploration and production activities in NSW and Queensland is required to demonstrate that the dewatering of the coal seam aquifer will result in no more than minimal harm to other aquifers, other water-users and groundwater-dependent ecosystems.

Wells for CSG extraction may be 200–750 m apart in a grid pattern, depending on the nature of the coal seam, and they may be connected by a network of roads, pipelines and compressor stations (e.g. Figures 3.2, 3.5). The network can block pre-existing access to private and public land, as well as intruding into formerly reserved areas of native vegetation.

Native Vegetation Acts in NSW and Queensland have substantially slowed broadscale clearing of native vegetation for agriculture. However, CSG developments cut large tracts for transport access, pipelines and well infrastructure (e.g. Figure 3.2). These developments to date appear to be able to remove native vegetation in ways that landholders are not able to do under the current Acts.

Figure 3.2. Tracks and patches cleared in native vegetation for CSG operations.

Case study: The Pilliga Forest and effects of fragmentation

A recent study for the Namoi Catchment Management Authority has identified that most of the woodland vegetation ecosystem in the Pilliga Forest is highly likely to be groundwater-dependent.

Therefore, activities such as CSG operations which significantly alter groundwater levels and movement in that region are likely to have substantial repercussions for those woodlands, and for the species which use them as habitat.

The Pilliga is the largest temperate woodland left in eastern Australia, and one of our most important natural assets (Figure 3.3). It is 'a million wild acres', some 500,000 ha in size, and it has recognised national and international conservation significance.

The Pilliga is in the wheat–sheep belt of NSW. Surrounded by largely cleared agricultural land, it is a last stronghold of remnant vegetation for many species, including numerous bird species that are now declining throughout their range. It is located in a national biodiversity hotspot, the Brigalow Belt South, and is an internationally listed Important Bird Area, and it provides habitat for up to 30 listed matters of national environment significance and up to 48 threatened species and communities under NSW legislation.

Figure 3.3. Part of the Pilliga Forest in the northern part of NSW.

Experience in the Pilliga indicates that CSG exploration and production lead to clearing and fragmentation of native vegetation that may have major consequences. Even during the exploration phase, the following impacts have occurred: clearing of up to 150 ha of native vegetation, heavy fragmentation of 1,700 ha of native vegetation and an increased footprint across 44,000 ha of native vegetation.

If the full production project proposed by Eastern Star Gas is approved, it would allow the clearing of at least 2,400 ha of native vegetation and the fragmentation of

an area of 85,000 ha. Well-pads would be cleared to a size of 1.2 ha, some 1,000 km of pipelines would be cleared, and there would be additional clearing for roads, tracks and infrastructure. Well-pads would be placed on a 500–700 m grid, effectively carving up the most intact patch of bush in western NSW into a highly fragmented industrial zone.

Numerous scientific studies have reviewed the impacts of fragmentation of bushland on native fauna. Fragmentation of a landscape that has already received extensive clearing can have very large impacts on biodiversity and landscape function. This cumulative impact is critical and requires careful consideration and attention.

For example, Figure 3.4 shows that in landscapes with fragmented native vegetation at around 30% the intactness index can fall to less than 8%.

These studies show that fragmentation is likely to have a detrimental effect on fauna and flora species that survive initial clearing, because it often leads to small, isolated populations. These small populations may be subject to loss of genetic variability and inbreeding depression, and fixation of deleterious mutations. They are more likely to become extinct through stochastic environmental events such as fire.

Fragmentation may reduce food availability for fauna, increase predator abundance, and restrict normal adaptive behaviour.

While the impacts of CSG operations on native vegetation and biodiversity in the Pilliga are likely to be severe, other parts of both Queensland and NSW are also at risk; a particular example is public land in the Clarence–Moreton Basin in the Northern Rivers region.

Case study: Crown lands (including travelling stock routes and State Forests)

Travelling stock routes are Crown lands managed in trust by state governments. Some groups have suggested these areas could be used as a location for CSG infrastructure (wells and pipelines), particularly in localities that support strategic agricultural lands.

A number of travelling stock routes represent connected corridors which stretch for some distance (many kilometres). More often, they are disconnected single lots used as

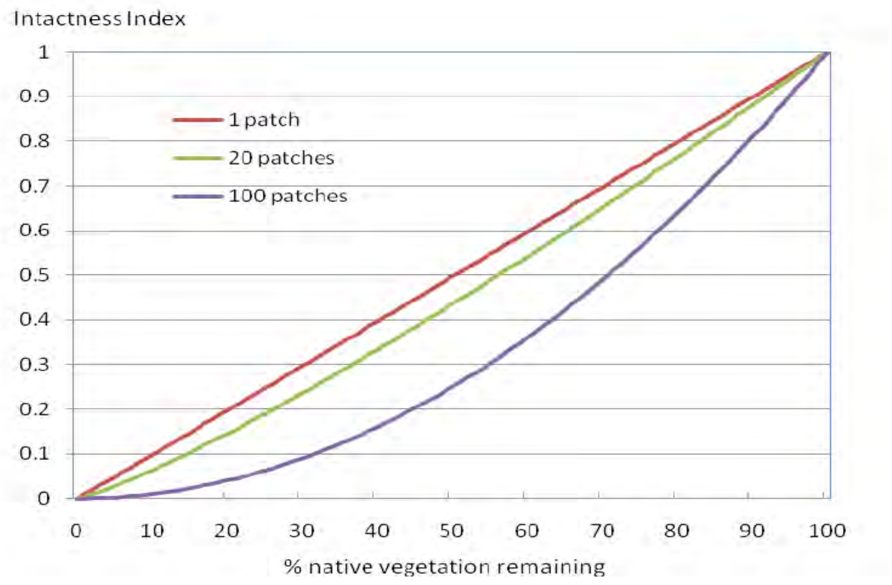


Figure 3.4. Effect of fragmentation of remnant native vegetation on its intactness. (Namoi CMA 2011, p. 15)

stock camps. Travelling stock routes may contain the last remaining remnants of native vegetation in the landscape. They can embrace unique and valuable ecological values that require protection from further development.

To ensure these issues are considered more fully, the NSW Government is preparing an analysis of options for the use of Crown lands, including the consideration of biodiversity, agricultural and Aboriginal values.

3.2. *Impacts on the productive landscape*

CSG production generally compromises the landscape for productive agricultural and pastoralist activities (which now potentially include carbon sequestration) as well as for its habitat values and scenic and aural qualities (e.g. Figure 3.5). Consequently, CSG production has to be seen as a new land use competing with other land uses in a region.

Shale gas production may have similar effects, to a lesser extent.

Figure 3.5. White lines across agricultural land show a network of new CSG developments.

Concerns have been raised that CSG activities could affect food production by reducing supplies of fresh surface-water and groundwater to agriculture and the usability of strategic agricultural land. With food demand worldwide expected to double by the middle of the century, governments and resource managers need to defend the Earth's productive capacity against factors such as water scarcity and loss of land to other uses.

Extensive grazing appears to be one form of agriculture that may be better than others at coexisting with CSG production (Figure 3.6).

Figure 3.6. A CSG well makes only small interference in a grazed paddock.

Figure 3.7. Productive farmland in southern Queensland

A balanced coexistence of mining and other forms of agriculture is possible, but requires careful management. For this reason, good bioregional planning and assessment is an absolutely fundamental issue that requires priority attention.

Queensland was the first state in Australia to introduce legislation that will protect that state's strategic cropping land (see Chapter 5). The aim is to strike a balance between the competing interests of the agriculture, resource and urban development industries. In Queensland, projects such as open cut mining, CSG, underground coal gasification, long-wall/underground mining, urban development and industrial development will all be assessed under the laws.

Strategic cropping land (e.g. Figures 3.7, 3.8) is an important finite resource that is subject to competition from other types of agriculture as well as mining and urban development. Legislation relating to strategic cropping land aims to strike a balance between these sectors to help maintain the long-term viability of our food and fibre industries, and support economic growth for regional communities.

The strategic cropping land legislative and planning framework is designed to protect this type of land in Queensland from developments that lead to permanent impacts or diminished productivity. This framework includes a new Act, and a new State Planning Policy under the *Sustainable Planning Act 2009*. On 30 January 2012, the *Strategic Cropping Land Act 2011*, Strategic Cropping Land Regulation 2011 and State Planning Policy 1/12: Protection of Queensland's strategic cropping land commenced (QDERM 2012).

In NSW (Figure 3.9) a similar approach has been adopted. Both state governments have attempted to provide a form of strategic regional land-use plan that can then set an operational framework in which industry can operate. The aim is for industry to work with local government, the regional natural resource management bodies and individual landholders to ensure that infrastructure is planned and developed in a manner that reduces surface impacts, minimises inconvenience and adds value to local infrastructure.

Figure 3.8. Harvesting wheat, with an exploration CSG well in the background.

Figure 3.9. Productive farmland in northern NSW surrounding a CSG exploration and testing development.

The NSW Government's Strategic Regional Land Use Plans will identify criteria for strategic agricultural land and define appropriate protection requirements under a risk management framework (NSW Government 2012). The regional plans will identify the best locations for land uses such as mining, agriculture, CSG extraction, conservation and urban development. The regional plans will involve community consultation to ensure issues are clearly identified and considered in the land-use planning process. Priority plans are being prepared for the Upper Hunter and Gunnedah regions.

The work of the Namoi Catchment Management Authority to build on the Catchment Action Planning process with the regional land-use plan has pioneered new ways to build in cumulative analysis of multiple industry development (Eco Logical Australia 2011).

Land-use issues similar to those encountered with CSG developments will accompany development of other forms of unconventional gas, such as shale gas resources. The development and operation of shale projects requires a large number of wells, rigs and collection and transmission pipeline networks. Projects will be competing for land, water and infrastructure with other resource development projects, agricultural uses and communities.

Will the approaches set up so far by state governments provide protection for biodiversity and the environment, food and fibre production and communities? Will they stop CSG developments from coexisting with agriculture and food production, by establishing 'no go' zones for CSG, or will they promote 'balanced coexistence' that includes environmental protection? Will CSG development be able to over-ride the legislative and regulatory processes?

3.3. Air emissions

3.3.1. Gas compared to coal and fuel oil as a clean source of energy

Natural gas, although composed largely of methane, is widely considered to be an environmentally cleaner fuel than coal because it does not produce detrimental by-products such as sulfur, mercury, ash and particulates and because it provides twice the energy per unit of weight with half the carbon footprint during combustion. These points are not in dispute (Cathles et al. 2012).

There are, however, two issues that have caused concerns and debate in the scientific community. The first is the level of fugitive leaks of methane over the life of the gas field and the second is the adequacy of the full life-cycle energy balance of the gas production system. Both matters remain actively under debate.

Shale gas

The concerns above prompted the US Council of Scientific Society Presidents (2010) to caution against a national policy of developing shale gas without a more certain scientific basis for the policy.

Howarth et al. (2011) claimed that once the potential impacts of methane leaks and venting are included, the greenhouse gas footprint over the life-cycle of shale gas is far worse than those of coal and fuel oil when viewed for the integrated 20-year period after emission. On the 100-year integrated time frame, this analysis claims shale gas is comparable to coal and worse than fuel oil and that this larger footprint "*undercuts the logic of its use as a bridging fuel over the coming decades*".

In contrast, Cathles et al. (2012) argue that the Howarth et al. analysis is seriously flawed in four ways: first, in significantly overestimating the fugitive emissions associated with unconventional gas extraction; second, in undervaluing the contribution of 'green technologies' in reducing those emissions to a level approaching that of conventional gas; third, in basing their comparison between gas and coal on heat rather than electricity generation (almost the sole use of coal); and fourth, in assuming a time interval over which to compute the relative climate impact of gas compared to coal that does not capture the contrast between the long residence time of CO_2 and the short residence time of methane in the atmosphere. High leakage rates, a short methane global-warming potential, and comparison in terms of heat content are seen as the inappropriate bases upon which Howarth et al. (2011) ground their claim that gas could be twice as bad as coal in its greenhouse impact. Using more reasonable leakage rates and bases of comparison, shale gas has a greenhouse gas footprint that is half and perhaps a third that of coal, according to Cathles et al. (2012).

Coal seam gas

Comparing CSG to coal, a NSW Parliamentary Inquiry (NSWLC 2012) concluded that while it is impossible to reach a definitive conclusion, the Committee considers that at worst the greenhouse gas emissions of energy produced from CSG are likely to be equal to those from coal. However, the Committee believed that the dispute around greenhouse gas emissions should not prevent the development of the industry in NSW.

It is worth remembering here that CSG extraction can involve dewatering of coal seams that are generally at relatively shallow, though significant, depths, typically 200 m to 1 km. Shale gas in Australia is generally at 2 km depths and below, by contrast, and is held in shales rather than coal seams, and its extraction can involve little or no dewatering.

Nevertheless, the whole-of-life energy budget and the greenhouse gas emissions associated with CSG production appear to require more thorough and more robust analysis. As outlined above for shale gas, there is keen dispute and debate among industry analysts and scientists in the USA and Australia about the total emissions from CSG on a whole-of-life-cycle basis compared to coal. In Australia, no independent field studies have been done so far, but the issues of fugitive methane emissions and the overall whole-of-life energy balance and greenhouse gas emissions of CSG production will increasingly need to be based on robust scientific observation and prediction.

According to Origin Energy, approved CSG and liquefied natural gas (LNG) projects — including gas field operations, LNG plants and associated infrastructure — could generate 34.7 million tonnes of CO_2-equivalent (CO_2-e) each year. Origin Energy says substituting LNG for coal would be the equivalent of reducing Australia's 2007 emissions by as much as 13.7%.

3.3.2. Gas in relation to climate change and water resources

Recent work by Hou et al. (2012) illustrates that unconventional gas production and its role in climate-change mitigation is subject to strong interactions, both positive and negative, with water resource management in the whole-of-life energy analysis. This is demonstrated in Figure 3.10. Whilst the figure relates to shale gas, the principles apply similarly to CSG.

Analysis of how unconventional gas, and particularly CSG, can contribute as a transitional energy in mitigation of climate change will ultimately depend on how the linkages between water resource management and gas production are understood and managed, and on the nature and extent of fugitive methane emissions.

All of this demonstrates the need for careful further research and analysis in these matters. There are many questions that are subject to debate and require scientific resolution. This uncertainty and need for solid science is raised by Hou et al. (2012) as a critical factor determining the future of shale gas production, its regulation and role in climate-change mitigation when they state:

> *Shale gas can be a powerful tool in combating climat change. However, its exploitation may also lead to undesired environmental effects that can conversely worsen climate change.*

The lessons for CSG are similar. Energy policy implications are very important indeed.

3.3.3. Air emissions during shale gas extraction

There is disagreement between studies relating to the release of greenhouse gases during the extraction and use of shale gas. Hultman et al. (2011) and Howarth et al. (2011) have alleged that the extraction and use of shale gas may result in the release of more greenhouse gases than conventional natural gas, but, as already mentioned, other studies, including Ridley (2011), have criticised one of these for relying on implausibly high leakage rates and misstating the global warming potential of methane (Cathles et al. 2012). Either way, fugitive leakage of methane (CH_4), during the extraction of conventional and unconventional natural gases (themselves largely methane), require attention.

Methane is a very powerful greenhouse gas, although it stays in the atmosphere for only one-tenth as long a period as carbon dioxide. Recent evidence suggests that methane has a global warming potential that is 105-fold greater than that of carbon dioxide when viewed over a 20-year period and 33-fold greater over a 100-year period, compared mass-to-mass. However, the UN Intergovernmental Panel on Climate Change ascribes methane a global-warming potential of 72 over a 20-year period and 25 over a 100-year period.

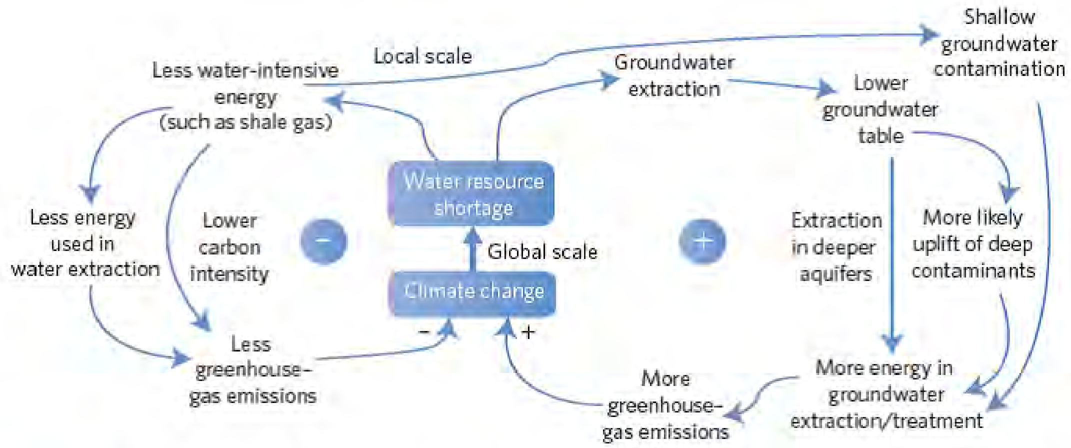


Figure 1 | The complexity surrounding shale-gas exploitation manifests itself through feedback loops. In a negative feedback loop, climate change drives up the use of low-carbon intensity and low-water intensity shale-gas resources, consequently mitigating climate change. In a positive feedback loop, climate change leads to more energy in groundwater extraction and treatment, thus enhancing climate change.

Figure 3.10. Potential positive and negative feedback loops in relation to natural gas as a source of energy. (Hou et al. 2012)

Policy discussions about the role of gas versus other fuels in mitigating climate change need to consider factual information about the nature and risks of methane leakage during the extraction of gas. At present, leakage and GWP remain matters for scientific debate because the facts are unclear. Wigley (2011) states:

> *...unless leakage rates for new methane can be kept below 2%, substituting gas for coal is not an effective means for reducing the magnitude of future climate change.*

This is contrary to claims such as that by Ridley (2011, p. 5) who states, with regard to the exploitation of shale gas, that it will "*accelerate the decarbonisation of the world economy*".

The key point here is that it is not decarbonisation alone that is the goal, but the objective of reducing climate change. Indeed, the shorter-term effects are in the opposite direction. There are only small differences in effects on climate between the baseline and the coal-to-gas scenarios. Therefore, decisions regarding further exploitation of gas reserves should be based on resource availability (of both gas and water), economics of extraction, and environmental impacts unrelated to climate change. These matters are addressed later in this chapter.

3.3.4. Air pollution from contaminants associated with gas production

In the USA, there has been considerable public concern about air pollution from activities associated with shale gas production. Debate between industry and academic research on the nature and levels of emission of benzene and other pollutants has focused on the very high density drilling for shale gas west of Dallas, Texas (Figure 3.11). That example has given us some indications of how emissions from processes associated with shale gas production can affect air quality. The air emissions are from diesel generators, compressors and the very high density traffic transporting waste material such as contaminated water and residue. CSG extraction may require similar associated processes.

It is unlikely that such high intensity of gas production infrastructure producing air emission of this order will develop in Australia, but it is worth understanding that the issue does exist in the USA.

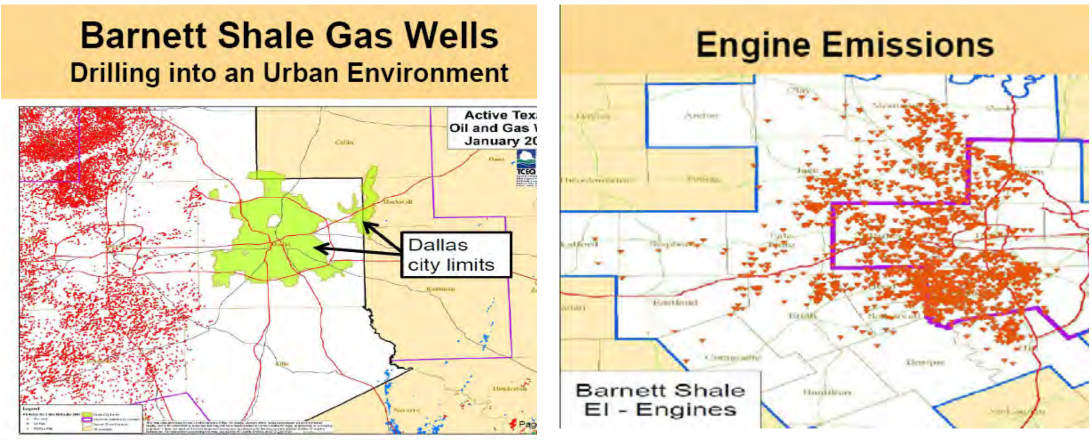


Figure 3.11. (Left) The large number of wells (red dots) in the Barnett shale gas field, just outside Dallas; and (right) the large number of diesel engines (brown triangles) associated with gas production in the Barnett shale gas field. (Duncan 2012)

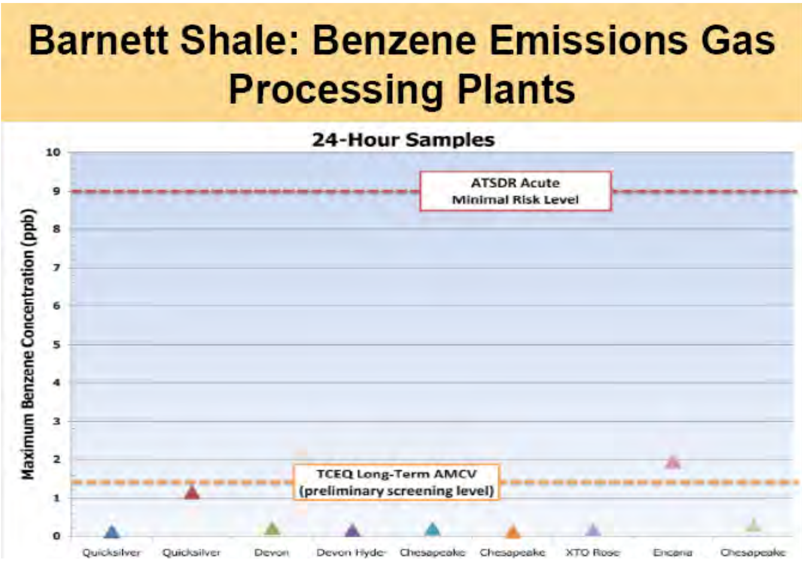


Figure 3.12. Benzene emissions associated with shale gas production in the Barnett field. (Duncan 2012)

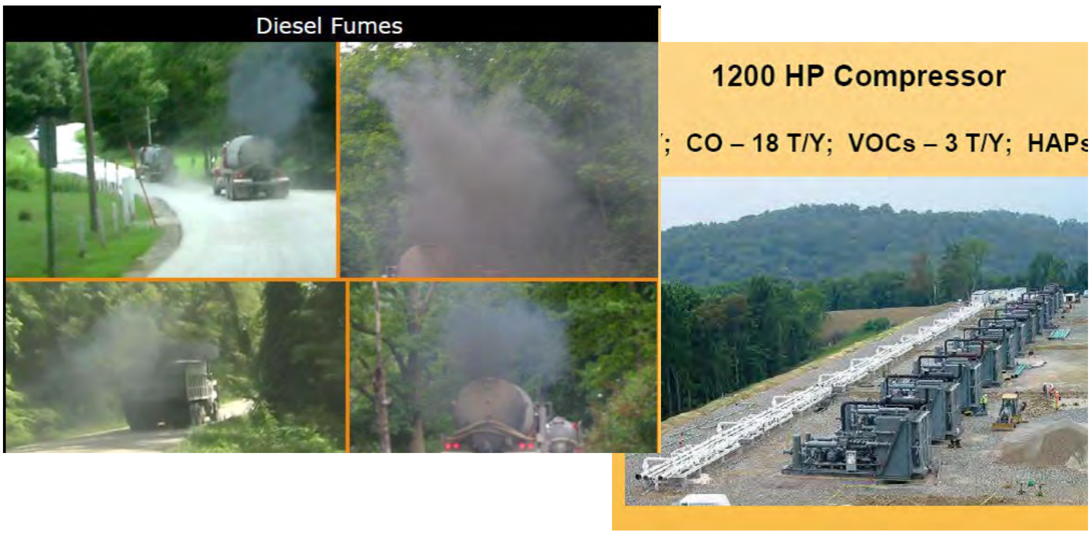


Figure 3.13. Visible emissions associated with shale gas production.

Benzene measurements over time near nine wells at the Barnett gas field show that maximum benzene concentrations (ppb) are at or below long-term recommended levels (Figure 3.12).

Figure 3.13 shows visible evidence of emissions from high-power compressors (right) and diesel fumes from trucks (left), which have recently been observed in the USA and are of public concern. Intensive development of shale gas production is often located near major cities and urban centres (Duncan pers. comm. 2012).

3.4. Surface-water and groundwater

3.4.1. Management of surface-water resources

A report from the National Water Commission (NWC) has provided an early analysis of CSG extraction in relation to water resources in Australia (NWC 2012). The report recognised the implications of having a rapidly expanding unconventional gas industry within a governance and regulatory environment that has really had little or no experience with the issues of unconventional gas exploration and production.

The report outlined potential risks to sustainable water management. The major risks are listed here.

- Extraction of large volumes of groundwater (probably of low quality) to de-pressurise the coal seams, may reduce the water resources available in connected surface-waters and groundwater systems. Some of those systems may already be fully or over-allocated, including the Great Artesian Basin and the Murray–Darling Basin.
- Rapid de-pressurisation of a coal seam may affect other water users and the environment through, for example:
  - changes in pressures of adjacent aquifers with consequential changes in water availability;
  - reductions in surface-water flows in connected systems; and
  - subsidence over large areas, potentially affecting surface-water systems, ecosystems, irrigation, and grazing lands.
- If large volumes of water, including treated wastewater, are released to surface-water systems they are likely to alter natural flow patterns and water quality and, therefore, river and wetland health. This risk includes the possibility that the water may cause ‘clean water’ pollution of naturally turbid streams.
- The practice of hydraulic fracturing (‘fraccing’) of a coal seam to increase its output of CSG has the potential to induce connection and cross-contamination between aquifers, with impacts on groundwater quality.
- Injection of extracted water or treated wastewater into other aquifers has the potential to change the beneficial use characteristics of those aquifers.

These potential impacts of CSG extraction on water resources are among issues that continue to cause much public concern about the industry. (See also Chapter 4.)

The Federal Government has responded to this public concern by establishing an Independent Expert Scientific Committee on CSG and Coal Mining in 2012 (first as an Interim body during 2011–12), under a COAG national partnership agreement on CSG and large coal-mining development. This body replaces an earlier expert panel, ‘the Water Group’, which advised the Australian Government with respect to three CSG developments and their implications in relation to the Environment Protection and Biodiversity Conservation (EPBC) Act.

The Independent Expert Scientific Committee is a $150 million commitment by the Federal Government. Its role is to provide advice to the Federal Environment Minister and other decision-makers about all CSG and large coal-mining developments in Australia that are likely to have a significant impact on water resources.

The Committee seeks to ensure that future decisions about the potential water-related impacts of CSG and large coal mining activities are guided by substantially improved science and independent expert advice. As an Interim body it had three key roles:

- providing advice to governments on CSG and coal mining projects (IIESC 2011a);
- overseeing bioregional assessments in areas where CSG and/or large coal mining developments are underway or planned (IIESC 2011b); and
- overseeing research on potential water-related impacts of CSG and/or large coal mining developments (IIESC 2011c).

The potential impacts of CSG on water resources as specified by the NWC were key questions faced by the NSW Parliamentary Inquiry (NSWLC 2012). The high priority question the NSW Parliamentary Inquiry repeatedly faced, but could not resolve, was whether CSG activities could contaminate or deplete water resources. The scientific evidence on this question appeared to be contested.

The NSW Legislative Council Parliamentary Inquiry considered that the uncertainty about the likelihood of these impacts occurring underscored the need for more data to be gathered and analysed at a regional scale in locations where exploration is taking place. To this end, the Inquiry recommended that the Commonwealth Government's Independent Expert Scientific Committee work closely with the CSG industry to overcome barriers to data-sharing, and to fund the conduct of regional-scale water assessments in NSW and the development of models of cumulative water impacts, as a matter of priority. CSG companies hold data that could be used for assessing cumulative water impacts, and in some cases they consider the data to be commercial in-confidence. Gaining access to this data should be a priority for the Commonwealth's Independent Expert Scientific Committee.

The need for comprehensive scientific catchment-based analyses of the ecology, hydrology and geology of an area — that is, comprehensive bioregional assessment — appears to have become well-established in the thinking of all stakeholders. The analyses must assess the potential risks to surface-water and groundwater resources in the area as a result of the direct and indirect impacts of CSG development or large coal mining development.

For this to be done well, we should not underestimate the huge demands on Australia's scientific capacity, and that there will need to be intense scrutiny of what will always be limited data.

Bioregional assessment in relation to water resources

Bioregional assessment is a critical and essential step forward in protecting water resources and ecosystems from impacts of CSG development. Nevertheless, it is but the first step in considering the cumulative assessment of CSG and mining on the capacity of the landscape to sustain long-term energy extraction.

The Independent Expert Scientific Committee on CSG and Coal Mining has the key role of scoping and advising on such bioregional assessments in areas where CSG and/or large coal mining developments are underway or planned.

Bioregional assessments will be conducted in conjunction with relevant state and territory government agencies and natural resource management bodies. They will involve an

Figure 3.14. Ecologically valuable habitat dependent on surface and groundwater regime being maintained. (IIESC 2011b)

assessment of all available data on surface-water, groundwater and their related ecology. At the end of the day, the objective is to protect the ecological and hydrological function of the landscape (such as in Figure 3.14) whilst extracting the energy stored there as natural gas and coal.

3.4.2. CSG effects on water resources above and below ground

The energy balance and greenhouse gas emissions related to CSG and shale gas are to a very large extent determined by the water management of the production field and its array of production wells (see Figure 3.10).

For CSG, one of the most contentious issues around its extraction is the need to pump water from aquifers overlying a coal seam or from the coal seam itself to release pressure.

The hydrogeological model in Figure 3.15 is the form of knowledge that will be essential to protecting water resources from the impacts of CSG production.

This figure illustrates the very large perturbation ('drawdown', the red dotted line) to the distribution of water pressure in the geological strata that is brought about by the dewatering of the coal seam. Before the dewatering, the pressure in the coal seam was similar to the water pressure in the shallow freshwater aquifer (blue dotted line). These differences in pressure heads under gas production can drive water from upper freshwater aquifers towards the coal seam. The magnitude of the flow will depend on the permeability of the geological strata that separate the two systems: particularly the continuity of aquitards and the proximity of the coal seam and more permeable strata.

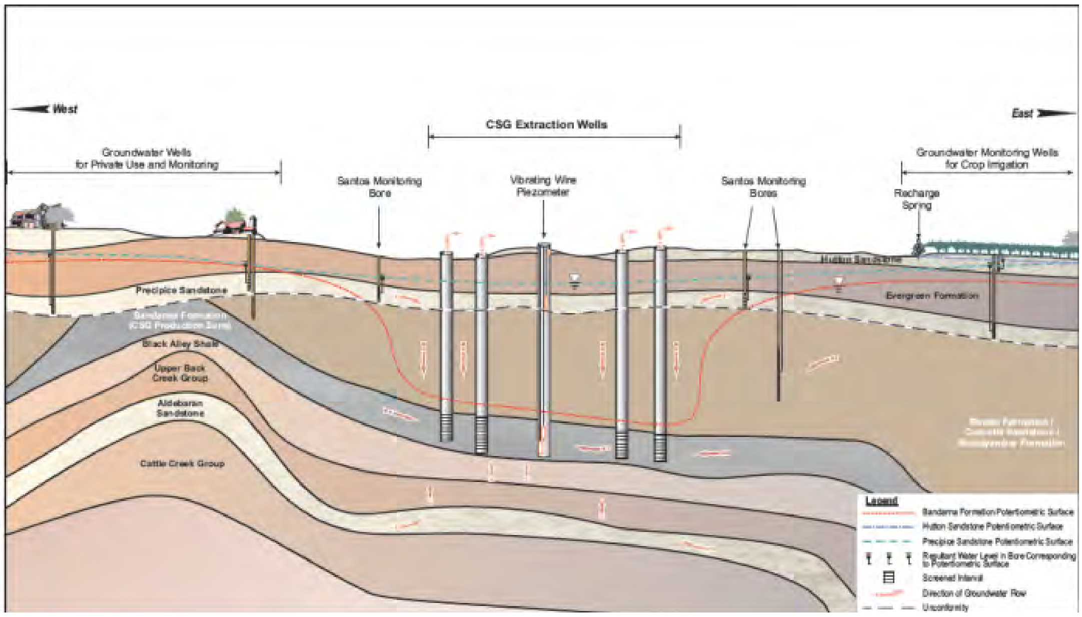


Figure 3.15. Diagram of potential influence of groundwater drawdown from dewatering. (Santos 2010)

Overall, dewatering of coal seams is likely to cause water to flow towards the coal seam and thus contamination by coal seam water flowing to regional aquifers is unlikely (CSIRO 2012).

Pumping of groundwater aquifers may affect other aquifers and connected streams — for example, in the Murray-Darling Basin or the Great Artesian Basin — some of which may already be fully or over-allocated. Agricultural industries rely on underground freshwater supplies in both basins, and some of the most productive farming areas in Australia are in those regions.

Water from coal seams would not be seen as a freshwater resource, for it is usually saline and often has high concentrations of other naturally occurring chemicals.

The freshwater aquifers that supply water to agricultural and urban uses and contribute to baseflow in rivers, wetlands and billabongs, can be, but are not always, much shallower than the deeper coal measures. However, groundwater flow towards connected surface-waters can be reversed or reduced, or may change in velocity if potentials or gradients are changed elsewhere in a sedimentary basin, such as by reduced water pressure in or above coal seams. The rate of change and direction of change will depend on the permeability of the strata and any faults and fractures within and between these geological strata. Gradients can also be affected by land subsidence following dewatering of an aquifer.

Thus while water extractions from coal measures usually do not take water from a prescribed groundwater resource, they can still have serious effects. Potential impacts of dewatering for CSG production are usefully conceptualised in Figure 3.16 for the Great Artesian and the Murray-Darling Basins, which shows the whole water balance in relation to CSG production and decommissioning. (See also Figure 3.17.)

Careful analysis of the whole system water balance, such as that undertaken by Moran & Vink (2010) shows how we can understand, anticipate and manage the nature and extent of impacts from CSG production on water resources in Australia.

CSG production also entails some demand for water — for use in well-base operations such as fraccing operations, in basins where that is necessary, and for dust suppression.

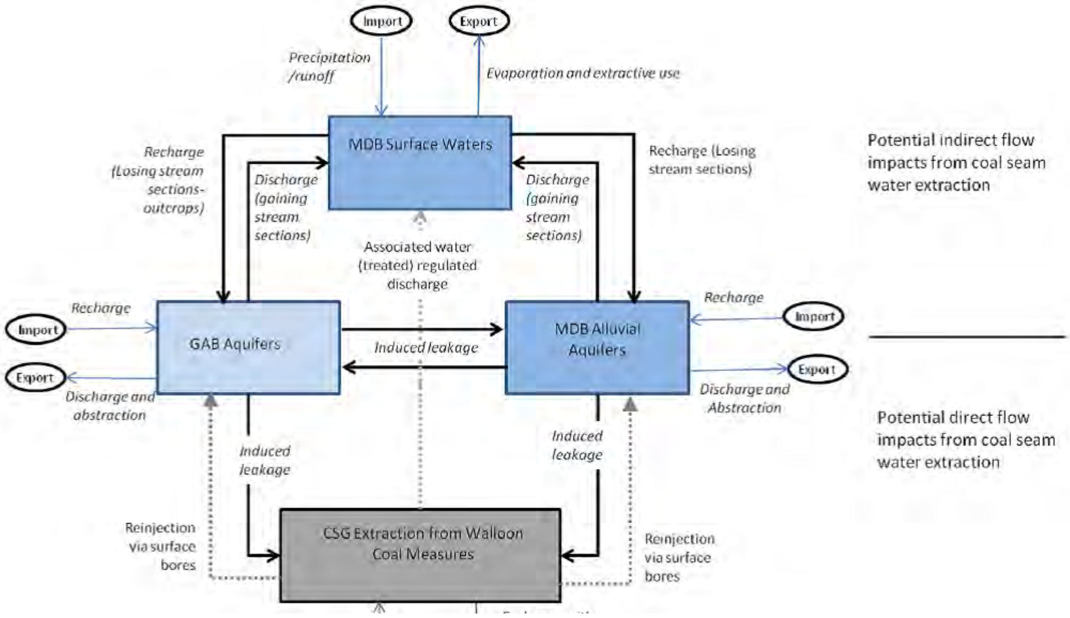


Figure 3.16. Conceptual diagram of effects on the water balance (surface-water and groundwater) in relation to CSG extraction. (Moran and Vink 2010 Figure 4)

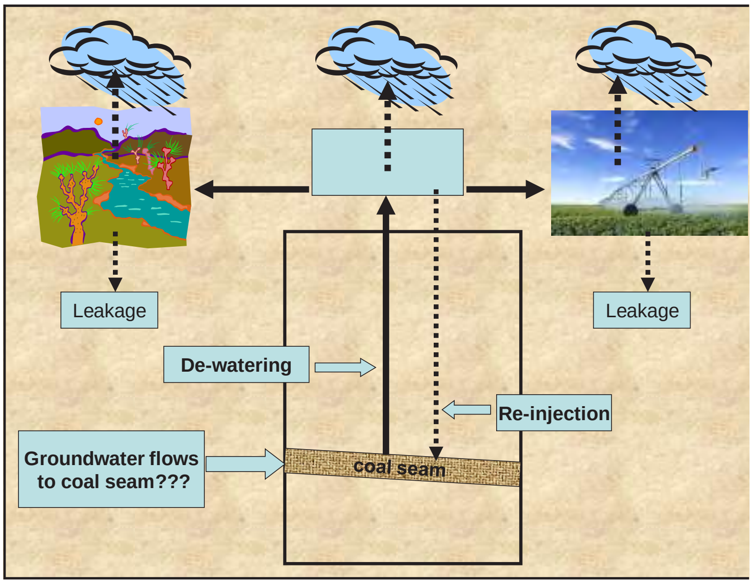


Figure 3.17. Simplified diagram of the essential components of the water balance for CSG extraction.

It is important to recognise that water extraction from the coal measure to release the gas is largest in the initial stages and generally declines over the 20-40 year life of the production well as depicted in Figure 3.18.

Dewatering during CSG production is effectively a form of water demand, and has to be seen as part of the overall water balance for the whole water resources system.

Similarly, after gas depletion the aquifer or coal measure may be refilled or reinjected with water (Figures 3.16, 3.17). That water will need to be sourced, and accounted for, if the water extracted during dewatering has been discharged to rivers and streams, or has evaporated from storage ponds, or has been supplied for a consumptive use.

3.4.3. Estimated volumes of water involved in CSG production

As a consequence of the complexity of resolving the flows of water in the surface-waters and groundwater within the geological strata, and as a result of the perturbation introduced by dewatering of the coal measure to produce gas, the computation of the water use in CSG production is generally uncertain.

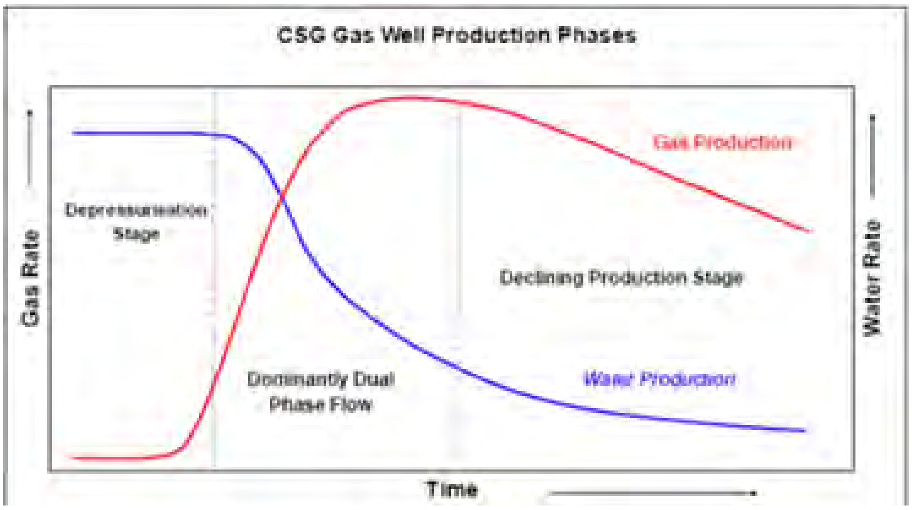


Figure 3.18. Typical rates of production of water (during dewatering) and gas from a CSG well, over time. QWC 2012b)

Estimates of water-resources impacts of CSG production in Australia differ greatly, because the whole system is conceptualised very differently by the various analysts and interest groups.

For instance, 'the Water Group' reporting to the Australian Government during 2009–10 indicated that for the Surat Basin Groundwater Management Zone, the total co-produced groundwater from the current CSG developments is approximately 1,819 gigalitres (GL), based on the analyses provided by the companies involved.

The companies project a lowering of groundwater pressure over most of the area of the Walloon Coal Measures by at least 400 m to approximately 30–35 m above the top coal seam. The Water Group's analysis suggests that from the Walloon Coal Measures alone, an estimated 229–23,000 GL of groundwater (with a most likely range of approximately 6,000–14,000 GL) will be co-produced by current CSG developments over a 30-year life. Further analyses by the Water Group to include other strata in the Great Artesian Basin suggest "*that the total estimated volume of groundwater to be produced (and lost to the GAB as a whole) is most likely in the order of 14,035 to 27,411 GL*".

Further, the Water Group state (WG 2010, p. 11):

> *It should be noted that a best case scenario for total water extraction, from our analysis, ranges from 307 GL — about 6 and a half times less than that predicted by the proponents — to approximately 45,000 GL — 22 times more than predicted by the proponents.*

If we use a 30-year life for the current developments examined by the Water Group, their analysis is equivalent to a range of estimation of 10.2–1,500 GL/yr with a most likely range of 468–914 GL/yr of overall extraction from the GAB systems.

For comparison, recharge into the GAB is estimated at 323 GL/year (Kellett et al. 2003) and current groundwater use in this area of the GAB is 549 GL/yr (AWR 2005). For the Murray-Darling Basin, the estimated groundwater extraction for the whole MDB is in the order of 1,832 GL/year (CSIRO 2008b). These estimates underline the size of potential impacts from CSG production if the Water Group's preliminary estimates prove to be of the correct order of magnitude.

The large amount of water and the large range of the estimates are excellent grounds for applying a precautionary approach (NRC 2008). Clearly science needs to be applied carefully to reduce this high level of uncertainty. Other estimates differ again.

In this context, note that the geology and hydrogeology of current Sydney Basin gas fields differ from those in the Surat and Bowen Basins in Queensland. The volumes of water required to dewater coal seams in the Sydney Basin to date are very small relative to the large amounts of water that must be managed in the basins associated with the GAB.

The National Water Commission estimate (NWC 2011) of water production from CSG wells was 300 GL/yr. It was based on an assessment of average water production per energy unit in each production basin, for CSG reserves that will be, or potentially will be, developed. This 'water to energy ratio' method was chosen at the time, because energy information was widely and nationally available.

Whilst the 300 GL/yr estimate could now be considered historical, given it was based on data available in 2008–09, it remains an independent national estimate that is backed by a transparent method using publicly available data sources that are clearly referenced. Furthermore it is of the same order of magnitude as the estimated range, 126–281 GL/yr, provided by the Queensland Water Commission (QWC 2011). These estimates are larger than the CSG industry estimates of approximately 60 GL/yr for the current developments (WG 2010).

This fundamental matter of the volumes of water to be extracted, and how the perturbation of the water balance by CSG development can be resolved for the long-term, is an absolutely critical requirement that must be addressed by proper resourcing of the science and engineering required. The role of the Independent Expert Scientific Committee on CSG and Coal Mining is extremely important and this matter will need their focused attention.

It is worth noting that in NSW, all water taken in the course of dewatering must be fully accounted for and licensed. This approach differs from regulations in the USA and Queensland.

3.4.4. Water management planning: handling, reuse and disposal

Planning of water use and water management is perhaps the most important natural resource management challenge confronting successful CSG exploration, production and decommissioning. An integrated water management plan and its effective operation are very important in minimising the impact of water use, water handling and water disposal involved in developing unconventional resources. The regulatory environment is constantly evolving in Australia to better manage the water extraction, treatment and disposal.

The drilling and fraccing processes require water, which means CSG companies must compete with other users of water supplies. Shale gas formations typically need fraccing with a mixture that is mostly water. Some shale gas formations will need dewatering in much the same way as for CSG extraction.

The substantial quantities of fraccing waste water pumped back to the surface will typically contain additional total dissolved salts and suspended solids along with other contaminants and will need to be disposed of, possibly after treatment, together with any volumes of water produced by dewatering. Shale gas formations often need re-fraccing over time — and re-fraccing is also required in some CSG reserves to maximise recovery. Therefore water management is likely to be an ongoing, expensive and key operation.

Figure 3.19 sets out the options for managing water in the production of CSG (Arrow 2009).

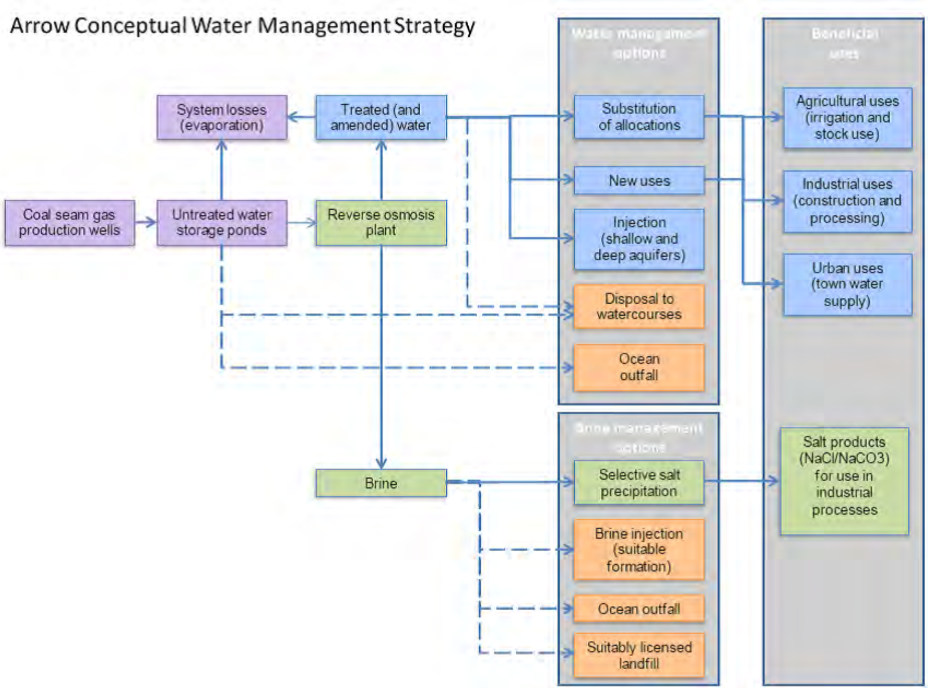


Figure 3.19. Conceptual diagram of Arrow Energy's water management strategy, courtesy of Arrow Energy.

Figure 3.20. Reuse of processed water extracted from coal seam gas for irrigated crops. These operators are taste-testing the water to demonstrate its good quality. (Santos 2011)

Disposal of water and contaminants from CSG production

Most CSG production involves managing the extraction, treatment, storage and disposal of often large volumes of usually saline water. CSG water quality varies by region but is typically brackish (100–10,000 mg/L of total dissolved solids) and alkaline (high in bicarbonate), making it unsuitable for many uses without treatment.

The volume of water to be extracted varies and is hard to calculate, as noted above. It depends on the geology and hydrology of the coal seam. In the Sydney Basin, CSG produces relatively small water volumes while wells in the Surat Basin can routinely produce up to 20,000 L/day. The storage, treatment and disposal of this water in ways that do not impact on the aquatic ecology and hydrology of the landscape remain, to a large extent, an unsolved problem. Treatment often involves desalination.

Strong brines and contaminated residual material resulting from water treatment also present a disposal problem as discussed briefly below— and the amounts of salt to be managed can be large indeed. A well discharging 20,000 L/day of saline water with 5,000 mg salt/L will yield about 100 kg of salt a day.

The disposal of treated water is a much more tractable problem that could be partially solved by reuse. Water use options that are being investigated include:

- irrigation of agricultural crops and forestry plantations (e.g. Figure 3.20);
- urban and industrial uses;
- discharge of an interim or occasional surplus of treated water into local rivers and streams; and
- reinjection into suitable underground aquifers.

In relation to the third dot point, the NWC report (Section 3.4.1 above) outlined the risk that large volumes of treated wastewater, if released to surface-water systems, could alter natural flow patterns in streams and have significant impacts on water quality, and consequently damage the ecological health of affected rivers and wetlands. Aspects of stream water-quality which could be at risk include its turbidity (water that is too 'clean' could unnaturally dilute naturally turbid systems), its temperature and its content of dissolved oxygen and nutrients such as phosphorus and nitrogen. Timing the release of large volumes of water into streams that in many cases are ephemeral is yet another issue that needs careful consideration.

One matter that is of concern is the Queensland Government's decision to allow water from CSG dewatering to be released into rivers before it has been tested for its toxicity to freshwater organisms and compared to environmental standards. To mitigate the risks of this approach operators will need to give careful attention to the dilution process and

Figure 3.21. Water storage ponds associated with CSG production.

the heterogeneity of mixing in the stream. The impacts on aquatic ecology require careful analysis.

The disposal of brines and residual solids and slurries from the water treatment process is still an active area of work and is not yet resolved. Until it is, the waste salt will be stored in brine ponds and salt pits on the gas fields (e.g. Figure 3.21).

Evaporation ponds were widely used in the pioneering days of the CSG industry but are no longer permitted in NSW or Queensland. Existing evaporation ponds, and the brine ponds that are part of the current industry practice, are a legacy issue to be addressed. The ponds will be contaminated with a range of chemical entities, depending on geology and, in some instances, the use of operating chemicals associated with hydraulic fraccing. Contaminants can be expected to include heavy metals, radionuclides and other toxic materials which, while naturally occurring in the geological strata, will be concentrated in these brines and slurries as a consequence of evaporation and water treatment processes.

Some CSG companies have considered disposing of the salt at sea or transporting it to a waste facility such as landfill (e.g. Figure 3.19). These options would require a large fleet of tankers operating 24 hours a day, each travelling approximately 500 km. These options have been ruled out on environmental and economic grounds. Arrow Energy, in its water management strategy (Figure 3.19), also considers selective precipitation with the resulting salts being sold for industrial purposes, and injection of brine into suitable formations. There are two brine injection wells in operation and another one under trial.

The Queensland Government has asked the industry to come up with a salt plan by 2013.

3.4.5. Contamination of groundwater during gas production

To protect groundwater resources reliably from contamination during CSG operations, companies need to understand the local (at the well field) and regional geology and hydrology: stratigraphy, rock properties and structure, hydrological properties of the strata and locations of discontinuities, fractures and faults (see Figure 3.22). As the diagram shows, the coal seams are usually isolated from shallow freshwater aquifers by aquicludes, generally thick shales and claystones, which act as natural barriers to vertical movement of groundwater.

Methane

Leakage of methane gas from poorly sealed wells or fractures into aquifers or into atmosphere is a very strong concern of the community. It has received a great deal of media coverage in the USA and more recently in Australia. For example, Figure 3.23 is an image from a US video shown on TV about the health hazards of shale gas production.

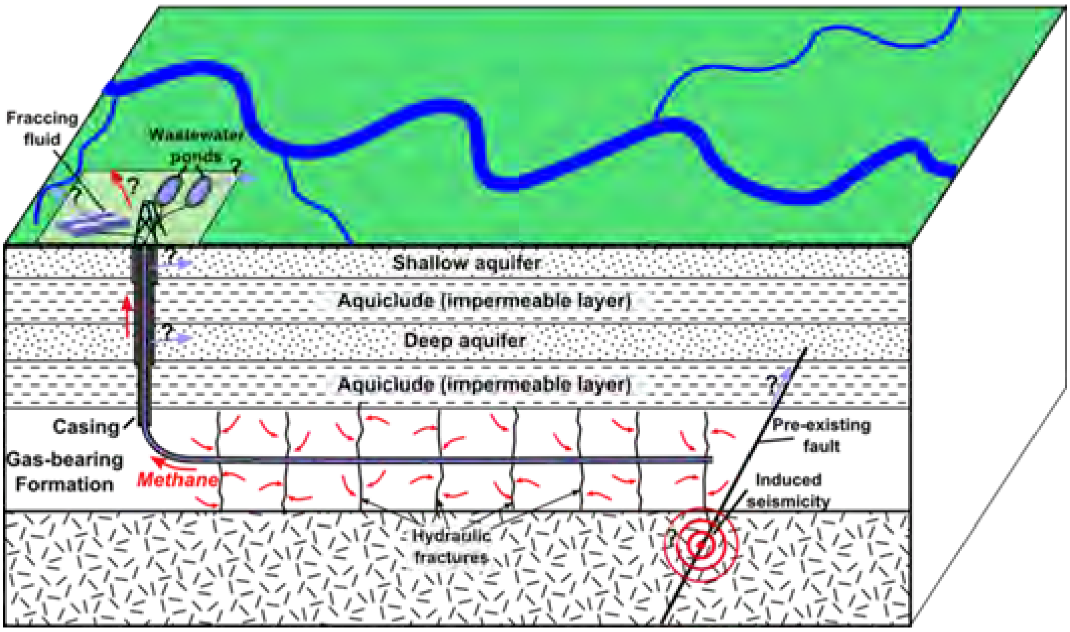


Figure 3.22. Diagram showing properties of the lithosphere that need to be understood for gas production without damage to water resources.

There is evidence in the USA of unconventional gas production leaking methane into groundwater (USEPA 2011).

In Australia, some groundwaters may naturally contain some methane as a result of the geological and biochemical processes in the aquifer. Most state water agencies maintain a bore database which records naturally occurring methane levels in existing groundwater aquifers.

Factors preventing leakage of methane into groundwater include well-construction standards and the integrity of the geological structures that lie between source formation and shallower freshwater aquifers (see Figure 3.22). There are geological circumstances — for example, in the Walloon Coal Measures — where the coal seams are relatively shallow and closely associated with some aquifers used to supply freshwater.

Although well-construction is part of the engineering of gas production, leakage of methane is also a natural resource management issue which must be addressed and carefully managed.

Figure 3.23. Methane, revealed by flames, coming through a US kitchen tap with water. (Source: Video 'Gasland')

3.4.6. Other possible contaminants of surface- and groundwater

Groundwater and surface-waters near to wells producing CSG or shale gas can become contaminated from the industrial activities nearby, and with the chemicals, including diesel and 'BTEX', that may be involved in fraccing (see Chapter 2). Benzene, toluene, ethylbenzene and xylene — BTEX — are all hazardous to organisms.

Public concern has focused on the risks of contamination of groundwater, although there is a far greater risk of contamination of surface-waters near well sites with the chemicals used in fraccing. This was reflected in the NSW Parliamentary Committee's concerns that any leaks or spills of fraccing fluids or produced water could contaminate water resources (NSWLC 2012).

The Committee recommended that the open storage of fraccing fluids and 'produced water' be banned. In both NSW and Queensland, the chemicals used in the extraction of CSG must be disclosed as part of the application process. Agencies assessing the application determine whether the use of those chemicals is safe for both the community and environment.

New techniques, such as horizontal drilling underground, use smaller inputs of these chemicals and are emerging as an alternative to fraccing in CSG production. This technology also allows greater distances between production wells in a gas field.

CSIRO studies (CSIRO 2012, 2012b) have examined the risks of groundwater contamination from CSG operations and conclude that there is only a low risk:

> *This is because hydraulic fracturing, when conducted correctly, is unlikely to introduce hazardous concentrations of chemicals into groundwater or to create connections between fresh and coal-containing aquifers. Most of the chemicals are of low inherent toxicity, undergo considerable dilution, and the majority (60–80%) are understood to be removed during flow back of the hydraulic fracturing fluid to the well from the coal seam. It is possible to further reduce risks of contamination by restricting hydraulic fracturing to coal seams that are isolated from surrounding aquifers by substantial aquitards.*
>
> *Water extraction from coal seams makes cross contamination of aquifers unlikely; most of the inter-aquifer transfer will be of higher quality water into neighbouring coal measures as water flows from high to low pressure. This may result in groundwater depression and reduced volume in freshwater aquifers.*

In contrast to these assurances for CSG in Australia, concerns remain in the USA that fraccing for shale gas extraction has the potential to induce connection and cross-contamination between aquifers, with impacts on groundwater quality (USEPA 2011).

Certainly the reinjection of treated wastewater into other aquifers has the potential to change the beneficial use characteristics of those aquifers.

Both the NSW and the Queensland governments state that they are committed to introducing fraccing standards to ensure that inter-aquifer leakage is prevented. This work is currently in progress.

The NSW Government has placed a moratorium on new fraccing approvals pending the completion of an independent review process. The NSW Parliamentary Inquiry found that large numbers of participants expressed particular concerns about fraccing and its potential to heighten the risks of water contamination and depletion. It concluded that it would be premature for the Government to lift its moratorium on fraccing before the chemicals used are tested (by the National Industrial Chemicals Notification and Assessment Scheme), and a stringent regulatory framework is put in place.

Queensland permits fraccing but has prohibited the use of BTEX chemicals. Although these chemicals can be found in a number of everyday products, such as paints, oil-based lubricants, diesel and petrol, they are hazardous substances. The chemicals used in fraccing in Queensland must be declared and the Queensland Government requires all CSG companies to regularly test for BTEX to enforce the regulation. Small traces of the chemicals can still be detected because they can be found in petroleum-based products used in the well-drilling process, and also occur naturally in coal and petroleum.

Irrespective of the degree of actual risk, these activities continue to stimulate significant public debate over the possible and perceived risks. Robust data and monitoring, combined with modelling of likely outcomes and honest provision of the facts to the public, are essential.

The US experience is that public understanding of shale gas extraction has failed in the past because industry and government have not been transparent in process, data and analysis. Australia can learn from this.

3.4.7. Cumulative impacts on groundwater

Scientists and engineers are seriously constrained in their capacity to evaluate cumulative impacts on groundwater resources — both quality and quantity — from multiple gas field developments. For analysis and modelling they need more than the rudimentary data and decision tools available at current levels of investment in practical geology and hydrogeology and field research.

The GAB and its associated sedimentary basins will be increasingly subject to exploration and development of hydrocarbons including natural gas. Science must be able to examine quantitatively, and predict by modelling, potential effects on aquifer interaction, vertical recharge, structural integrity and artesian pressure from existing and new fields for gas and mineral production. Therefore, new field data are essential for describing the hydrological processes actually operating in the ground.

A regional-scale multi-layer model of the cumulative effects of multiple developments will need to be developed to assess and manage the impacts, using a regional-scale monitoring and mitigation approach. Such a model could be used to set the parameters for an adaptive management framework in which monitoring and mitigation strategies can be developed and be applicable at both the project and regional scale. The aim is to support long-term monitoring and management of groundwater resources and ecological communities dependent on groundwater (such as in mound springs fed by the GAB).

We consider that concerted Commonwealth and State action will be necessary to develop such a model as a high priority (AG 2010).

3.4.8. Subsidence at the land surface

Land subsidence in relation to CSG extraction is a natural resource issue that has been considered in Environmental Impact Statements (EIS) in Queensland and by the Water Group in their advice to the Australian Government (WG 2010).

Subsidence within a landscape is generally expected when groundwater aquifers are dewatered. It is a well-understood process in over-exploited groundwater systems around the world. Land subsidence over large areas can affect surface-water systems, ecosystems, irrigation and grazing lands (NWC 2011; see Section 3.4.1 above).

In the original EIS in Queensland for the Surat Basin, the CSG industry indicated that up to 30 cm of land subsidence might occur. After questions were raised in preliminary drafts of the independent assessment by Geoscience Australia, the industry reduced the size of expected subsidence.

The Water Group expressed surprise that the estimates were reduced without any clear analysis. Water extraction in this part of the Surat Basin and the GAB is reported to have lowered the head of water pressure by 100 m in some areas, and subsidence amounting to metres has been observed in some locations near wells.

Further significant land subsidence is likely to occur, and that likelihood needs to be part of the analysis of the impacts of CSG extraction. It is a natural resource management issue that will need some attention.

References

AG (2010) Summary Of Advice In Relation To The Potential Impacts Of Coal Seam Gas Extraction In The Surat And Bowen Basins, Queensland Phase One Report Summary For Australian Government Department Of Sustainability, Environment, Water, Population And Communities provided by Geoscience Australia and Dr M.A. Habermehl, Canberra, 29 September 2010. http://www.environment.gov.au/epbc/notices/pubs/gladstone-ga-report.pdf

ANU (2012) Unconventional gas production and water resources: Lessons from the United States on better governance — a workshop for Australian government officials. Figure 3.1, p. 38., Australian National University, Canberra Australia.

Arrow Energy (2009) Arrow conceptual water management strategy. http://www.arrowenergy.com.au/content/Document/surat-eis/Volume%202%20(attachments)/Attachment%20009%20-%20Coal%20Seam%20Gas%20Water%20Management%20Strategy.pdf

Bellamy J., Ross H., Ewing S. & Meppem T. (2002) Integrated catchment management: Learning from the Australian experience for the Murray-Darling Basin. Final Report, January 2002, CSIRO Sustainable Ecosystems, Canberra ACT.

CAPP (2012) Canadian Association of Petroleum Producers (CAPP) Hydraulic Fracturing Operating Practices. http://www.capp.ca/canadaIndustry/naturalGas/ShaleGas/Pages/default.aspx#operating. And http://www.capp.ca/getdoc.aspx?DocId=195096&DT=NTV

Cathles L.M. III, Brown L., Taam M. & Hunter A. (2012) A commentary on "The greenhouse-gas footprint of natural gas in shale formations" by R.W. Howarth, R. Santoro, and Anthony Ingraffea. Climatic Change, 113,525–535. http://www.springerlink.com/content/x001g12t2332462p/fulltext.pdf

CSIRO (2012) Coal seam gas developments predicting impacts. http://www.csiro.au/news/coal-seam-gas

CSIRO (2012b) Water in mining and industry. Prosser I., Wolf L. & Littleboy A. Chapter 10: http://www.publish.csiro.au/?act=view_file&file_id=9780643103283_Chapter_10.pdf

Duncan I. (2012) Unconventional gas production and water resources: Lessons from the United States on better governance — a workshop for Australian government officials. Figure 3.1, p. 20, Australian National University, Canberra Australia.

Duncan pers. comm. (2012) Personal Communication, Bureau of Economic geology, University of Texas at Austin.

Eco Logical Australia (2011) Proposed Framework for Assessing the Cumulative Risk of Mining on Natural Resource Assets in the Namoi Catchment. Project 11COFNRM-0006 prepared for Namoi CMA. September 2011. http://www.namoi.cma.nsw.gov.au/namoi__risk_assessment_final_v5_14sept11.pdf at p15.

Groat C.G. & Grimshaw T.W. (2012) Fact-based regulation for environmental protection in shale gas development. Energy Institute, University of Texas, Austin, Texas USA. http://iopscience.iop.org/1748-9326/6/4/044008

Hou D., Luo J. and Al-Tabbaa A. (2012) Shale gas can be a double-edged sword for climate change. Nature Climate Change 2, 385–387.

Howarth R.W., Santoro R. and Ingraffea A. (2011) Methane and the greenhouse-gas footprint of natural gas from shale formations. Climate Change Letters 106, 679–690.

Hultman N., Rebois D., Scholten M. and Ramig C. (2011) The greenhouse impact of unconventional gas for electricity generation. Environmental Research Letters 6, 1–9.

IIESC (2011a) Interim Independent Expert Scientific Committee on coal seam gas and coal mining-Project Advice http://www.environment.gov.au/coal-seam-gas-mining/project-advice.html

IIESC (2011b) Interim Independent Expert Scientific Committee on coal seam gas and coal mining-Bioregional assessment. http://www.environment.gov.au/coal-seam-gas-mining/bioregional-assessments.html

IIESC (2011c) Interim Independent Expert Scientific Committee on coal seam gas and coal mining-Research Program. http://www.environment.gov.au/coal-seam-gas-mining/research-program.html

Kellett J.R., Ransley T.R., Coram J., Jaycock J., Barcaly D.F., McMahon G.A., Foster L.M. & Hillier J.R. (2003) Groundwater Recharge in the Great Artesian Basin Intake Beds, Queensland Department of Natural Resources and Mines Technical Report; p. 16 and p. 15

Moran C. & Vink S. (2010) Assessment of impacts of the proposed CSG operations on surface and groundwater systems in the Murray-Darling Basin. Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland.

NSW Government (2012) Draft Strategic Regional Land Use Plan, New England North West. NSW Department of Planning and Infrastructure, 2011. http://www.planning.nsw.gov.au/slurp

NSWLC (2012) New South Wales Parliament, Legislative Council. (2012) General Purpose Standing Committee No. 5. Report No. 35 (2012). Inquiry into CSG. Sydney, NSW. xxi + 330 pp. Available at: http://www.parliament.nsw.gov.au/Prod/parlment/committee.nsf/0/318a94f2301a0b2fca2579f1001419e5/$FILE/Report%2035%20-%20Coal%20seam%20gas.pdf

NWC (2011) Position Statement — Coal seam gas and water. http://www.nwc.gov.au/__data/assets/pdf_file/0003/9723/Coal_Seam_Gas.pdf

NWC (2012) Coal seam gas Update — June 2012, National Water Commission, Canberra. http://www.nwc.gov.au/reform/position/coal-seam-gas

QDERM (2012) Strategic Cropping Land Act 2011, Strategic Cropping Land Regulation 2011 and State Planning Policy. http://www.derm.qld.gov.au/land/planning/strategic-cropping/legislation-planning.html

QWC (2012) Draft Underground Water Impact Report: Surat Cumulative Management Area. Consultation Draft, Queensland Water Commission, May 2012. Available at: http://www.qwc.qld.gov.au/csg/water-impact-report.html

QWC (2012b) Draft Underground Water Impact Report: Surat Cumulative Management Area. Consultation Draft, Queensland Water Commission, May 2012. p. 6. http://www.qwc.qld.gov.au/csg/water-impact-report.html

Ridley M. (2011) The shale gas shock. GWPF Report 2, Global Warming Policy Foundation, London, UK, 34 pp.

Santos (2010) Diagram of potential drawdown for the Southern Fairview gas field in Queensland. (Figure 3.15) http://www.santos.com/library/Southern_Fairview_field_Golder_June2010.pdf

Santos (2011) Coal seam gas water to boost private farm output. http://www.santos.com/Archive/NewsDetail.aspx?p=121&id=1280

Shindell D.T., Faluvegi G., Koch D.M., Schmidt G.A., Unger N. & Bauer S.E. (2009) Improved attribution of climate forcing to emissions. Science 326, 716–718.

USEPA (2011) Draft Investigation of Groundwater Contamination near Pavillion, Wyoming (2011). United States Environmental Protection Agency. Available at: http://yosemite.epa.gov/opa/admpress.nsf/0/EF35BD26A80D6CE3852579600065C94E

USCSSP (2010) US Council of Scientific Society Presidents (2010) See: http://www.eeb.cornell.edu/howarth/CCSP%20letter%20on%20energy%20&%20environment.pdf

WG (2010) Water Group Advice On EPBC Act Referrals Referral - 2008/4399 Santos-Petronas Referral - 2008/4059 And Comments On Ap Lng Referral - 2009/4974 Based On Information Provided By The Proponents To Close Of Business 03/09/10, Water Group, September 2010.

Wigley T.M.L. (2011) Coal to gas: the influence of methane leakage. Climatic Change 108, 601–608.

Williams J. (2012) Catchment management — setting the scene: an overview of catchment management models in Australia. WATER, April 2012, 1–5.

4. Economic and social considerations in CSG production

This chapter first outlines some of the predictions of wealth benefits — jobs, regional investment, royalties, etc. — that indirectly pressure governments and communities to welcome mining developments. Then it looks at the hopes and fears of the regional communities that live with the developments. They have valid experience of factors that contribute to regional growth or decline, and have valuable proposals to maximise the benefits of the CSG industry to Australia.

The statistics in Figure 4.1 provide a factual context for this chapter, showing that at national scale the mining industries have been contributing increasing proportions of jobs and export earnings since 2005 (Reeson et al. 2012).

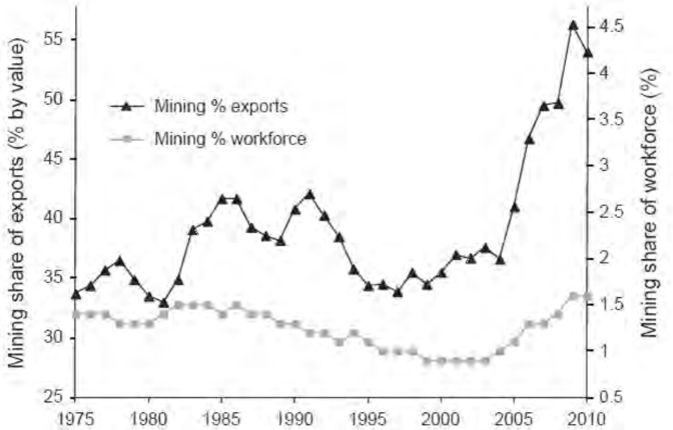


Figure 4.1. Less than 2% of Australia's workforce was helping the mining industry earn half of Australia's export revenue in 2010 (Reeson et al. 2012)

4.1. Analysis of economic effects of the coal seam gas industry

4.1.1. New South Wales

The NSW Parliamentary Inquiry into Coal Seam Gas (NSWLC 2012), earlier this year, was presented with inconsistent evidence on the economic benefits of CSG developments. Some submissions (e.g. Santos 2011) suggested that the CSG industry could deliver thousands of new jobs and billions of dollars in investment to regional areas, and generate billions of dollars in royalties. However, other participants in the Inquiry countered that the industry's economic benefits have been overstated.

In public debate, differences in opinion about CSG arise partly from different perceptions of how the economic benefit is or should be distributed between state capital, regional

centre and local community. Of particular concern is how the social and economic costs are managed for regional and local governments and community.

To maximise the industry's economic benefits for NSW, the Parliamentary Committee recommended that the five-year royalty holiday offered originally for CSG producers should be abolished, and that regional areas where most CSG activity is occurring should have a greater share of royalties. In fact, in July, the royalty holiday was abolished.

Industry viewpoints

Several comprehensive modelling studies (Allen Consulting 2011, ACIL Tasman 2011) were run to support CSG industry submissions to the NSW Parliamentary Inquiry. They attempt to estimate the economic impact of CSG production in NSW.

The Allen Consulting Group Study (2011) reports on the likely economic impacts of a potential CSG development in the north or north-east of NSW. Potentially, the region has the capacity to produce up to 210 PJs of CSG per annum (Figure 4.2). However, current total CSG production in NSW is only approximately 6.2 PJ per annum (Figure 4.3).

The projected expansion of CSG production from 6.2 to 201 PJ per year is a very large increase. It is particularly large in comparison to the industry currently, which is largely in the Sydney Basin plus a small volume produced from the Gunnedah Basin.

Effects of large-scale investments such as an injection of $16 billion between now and 2035 are likely to spread through many industries, and regions of the economy. This assumption is based on the idea that a change in one industry will flow through the economy when, for example, higher incomes raise demand. For an economy trading with the rest of the world, the flow-through effects can be complex. Very large investments may change relative costs in the economy, such as the price of labour (that is, wages), and can affect underlying factors such as the exchange rate.

To assess these impacts and their interconnections, the Allen Consulting Group applied an economy-wide model of the Australian economy. They used a Computable General Equilibrium (CGE) model. It can take account of most of the indirect effects that arise from changes in a single industry or product. Presented below are the initial CGE modelling results, which have been made using the Monash Multi Region Forecasting model (MMRF). The MMRF model allows for an evaluation of the proposed development at a regional, state and national level. This model accounts for the interconnections and relationships that exist

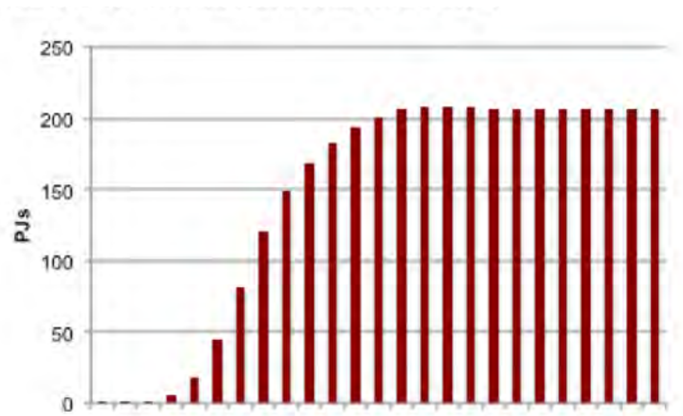


Figure 4.2. A projection of the capacity of 'Northwest' NSW to produce CSG. (Santos 2011)

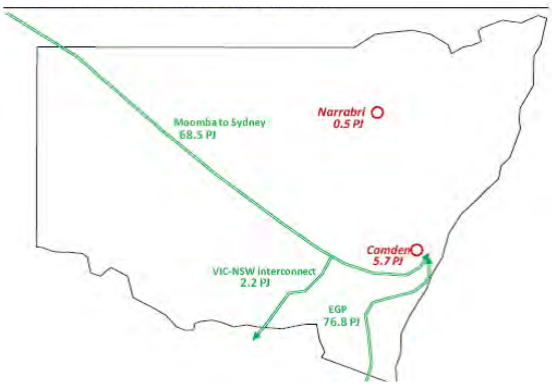


Figure 4.3. Potential gas yield in NSW and gas passing through in pipelines. (ACIL Tasman 2011)

throughout the community and adopts the framework used by the Australian Treasury and the Garnaut Climate Change Review. Inputs to the analysis include publicly available data (such as Census data and other information about the economy) and information provided by Santos Limited regarding the scale and capacity of a potential development in the region.

Allen Consulting (2011) estimated that the combined direct and indirect impacts of the development would:

- expand employment opportunities through increased economic activity throughout NSW, increasing to around 2,900 ongoing full time positions;
- create 200 direct permanent full time positions on the project, and additional direct employment during construction peaking at 1,800 jobs in 2015;
- increase the level of NSW gross state product (GSP) by 0.20% per annum, adding $15.2 billion to the state economy out to 2035;
- increase the gross regional product of 'Northwest' NSW by some 3.2% per annum — equating to an annual increase of around $470 million in today's dollars (retaining over half of the expected increase in NSW's GSP);
- expand national incomes (gross domestic product) by an expected 0.04% per annum; and
- by producing an extra 5 GL per annum of water from deep coal seams, the potential development could benefit agricultural production in the region by an average of nearly 1% per annum during the operations phase.

While NSW at large would accrue significant benefits from the development, these benefits would be likely to be particularly concentrated in the so-called 'Northwest' region itself.

More than two-fifths of the benefits would accrue directly back to the regional economy — including the communities of Boggabri, Coonabarabran, Gunnedah, Muswellbrook, Narrabri, Quirindi, Scone and Singleton.

The North Central Plains, Northern Slopes and Central Macquarie regions would be likely to experience the greatest growth. Allen Consulting working with information from Santos estimated that a project of this scale would require an investment in the region between now and 2035 in excess of $16 billion and would create around 200 direct full time employment opportunities.

The initial economy-wide analysis undertaken here suggests that the development of CSG operations in the north/north-east ('Northwest') NSW region would have a significant positive influence on the regional, state and national economies that would not be experienced if the proposed development did not proceed. Table 4.1 summarises the results.

Table 4.1. Summary of effects and increases in output likely from a proposed NSW coal seam gas development. (Allen Consulting 2011)

Region	Construction phase	Operation phase	Cumulative impact to 2035	NPV (@7% real)	NPV (@12% real)
			$2011		
NSW	$253 million per annum	$821 million per annum	$15.2 billion	$5.8 billion	$3.1 billion
Regional	$28 million per annum	$470 million per annum	$8.5 billion	$3.0 billion	$1.6 billion
National	$309 million per annum	$531 million per annum	$10.7 billion	$4.2 billion	$2.5 billion
			Per cent change		
NSW	0.06	0.20	na	na	na
Regional	0.80	3.20	na	na	na
National	0.02	0.04	na	na	na

In a separate study, commissioned in 2011 by the Australian Petroleum Production & Exploration Association, ACIL Tasman was asked to examine the impact on the NSW, regional and national economies of freezing CSG development at current levels. In that situation, these economies would not capture the economic benefits of CSG development that are potentially available given the very large reserves of CSG in NSW.

This study (ACIL Tasman 2011) compares economic outcomes under a scenario in which NSW CSG production expands steadily so that it becomes the main source of gas supply in the state (the Base Scenario) with an alternative scenario in which NSW CSG production does not expand beyond current levels.

The ACIL Tasman study used demand, supply and price projections prepared using GMG (GasMark® Global) Australia, ACIL Tasman's proprietary model of the eastern Australian gas market. The GMG Australia model is a long range (20–30 year) economic model that attempts to match supply and demand in each of the regional markets in eastern Australia. Its dual objectives are:

- minimising the cost of gas to consumers; and
- maximising field netbacks to producers (where the 'netback' is the delivered price less transport costs).

The model takes account of assumptions about gas supply (reserves, production rates, and minimum selling prices), gas demand and individual customer or customer group level (annual quantity, price tolerance) as well as existing and possible future transmission pipelines (current capacity, future expansions, tariffs). A driving factor is the assumed growth in gas production (Figure 4.4).

The assumption is that there will be almost linear continuous growth in production, reaching over 250 PJ per annum in 2032. This compares with the Allen Consulting Group

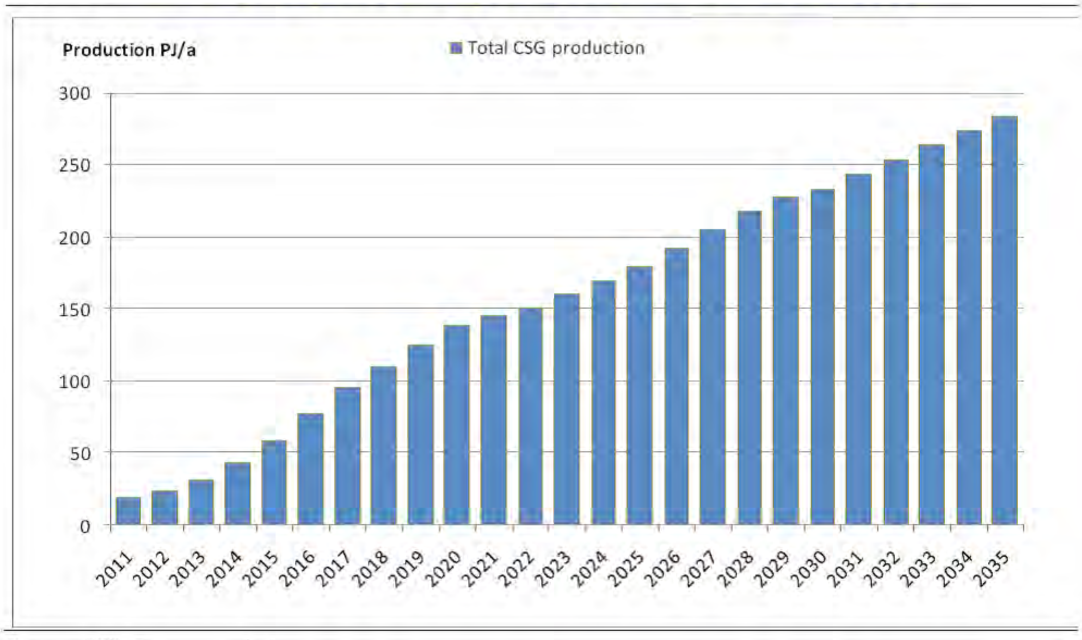


Figure 4.4. Assumed linear growth in gas production from NSW fields in the ACIL Tasman model. (ACIL Tasman 2011)

study (2011) in which production rises more rapidly and stabilises at just over 200 PJ per annum by 2021 (Figure 4.2).

These different driving assumptions need to be considered in comparing the estimates generated.

The key finding in the ACIL Tasman report (2011) was that:

- a growing CSG industry in NSW has the potential to deliver significant economic benefits to the state and to the nation.

It finds that such a scenario would have impacts on the gas market, the electricity market and the general economy.

In the gas market, impacts would be:

- a reduction in overall gas consumption in eastern Australia compared to the Base Scenario, with the gap widening over time to 139 PJ per annum by 2035;
- up to 25 PJ per annum lower consumption of gas in NSW;
- higher prices for wholesale gas: 20–25% higher in NSW, Victoria, South Australia and Tasmania; 8–9% higher in Queensland by 2030; wholesale gas prices (in real 2010 dollars per gigajoule) in Sydney would be $1.34/GJ higher on average, relative to the Base Scenario, over the period 2025–35.

Impacts in the electricity market include:

- increased dispatch of coal-fired plant with less gas used for electricity generation compared to the Base Scenario, leading in turn to the electricity generation sector emitting about 4 million tonnes (Mt) more CO_2 per year by 2030;
- electricity prices generally higher in all regions of the eastern Australian electricity market, with the price gap relative to the Base Scenario increasing over time and strongest in Victoria, South Australia and Tasmania;

- NSW wholesale electricity prices, overall, 7.4% higher on average, relative to the Base Scenario over the period 2020–30.

General economic impacts would include:

- a reduction of around $4.3 billion (real 2011 dollars) in direct capital investment in upstream CSG development, and around $2.7 billion in associated recurrent operating expenditure foregone in NSW over the period to 2035; while these losses would be at least partly offset by increased investment and expenditure on gas production elsewhere in the country, the net result would be that real NSW Gross State Product would be reduced by $7.15 billion in total over the period to 2034–35 compared to the Base Scenario in terms of net present value (7% discount rate) this equates to a $2.4 billion reduction in real added value;
- $15.5 billion less real income in NSW in total over the period to 2034–35 ($5.1 billion less in net present value terms, which equates to approximately $700 per NSW resident);
- average total employment in NSW 1,361 lower per year (FTE basis);
- NSW Government revenue $1.5 billion lower in total over the period to 2034–35 (which equates to $174 million in net present value at a 7% discount rate).

4.1.2. Queensland

Over the past ten years CSG in Queensland has emerged as an important contributor to energy supply in eastern Australia. Recent growth in known reserves has exceeded domestic market demand and CSG producers have therefore sought alternative markets. Among these, the export market for liquefied natural gas (LNG) is the most attractive in terms of the netback value of gas that can be achieved.

In May 2007 six projects to export gas from Gladstone, Queensland, were announced. The proposed exports were planned to begin in 2011 and reach 35–40 Mt per annum (Mtpa) of LNG by the early 2020s. That amount is double the demand anticipated in the domestic market in eastern Australia by that time.

In 2009, the Queensland Department of Infrastructure and Planning called for an analysis (MMA 2009) somewhat similar to the later NSW study described above (ACIL Tasman 2011). The Queensland study examined the costs and impacts of:

- a Standard LNG scenario, and
- a Baseline scenario in which there are no LNG exports from Gladstone.

The Standard LNG scenario was based upon 2009 project proposals. It envisaged a series of eight LNG trains each of 3.5 Mtpa capacity, totalling 28 Mtpa, constructed at the rate of one per year. The first would commence deliveries in 2014 and the last would begin deliveries in 2021. Assuming that each train operates for 20 years, the total CSG volume requirement would be approximately 35,200 PJ. Clearly it was a scenario rather than a forecast and a wide range of alternative outcomes are possible.

Two other policy scenarios were examined.

- The 15% Reservation scenario, which examines the impact of the hypothetical introduction by the Queensland Government of a policy to ensure that adequate CSG volumes are reserved for domestic gas markets.
- The 10% Royalty scenario, which examines the impact of the hypothetical introduction by the Queensland Government of an increase in the royalty rate applicable to LNG exports, from approximately 8% of CSG revenue to 10% of revenue.

The study was designed and used only for the specific purpose of estimating the impacts, both economic and non-economic, of the production of CSG, its conversion to LNG and the export of the LNG from the Port of Gladstone.

The findings of this study by McLennan Magasanik and Associates (MMA 2009) are dependent on the assumptions it made at the outset. Economic models and tools brought together in this and the studies in NSW are powerful and make a valuable contribution to understanding possible economic impacts of CSG development. Nevertheless, they are limited to the scenarios chosen.

In the Baseline scenario, the study found that by 2027:

- CSG production would be around 500 PJ per annum from more than 2,000 wells (current production is 130 PJ per annum from 600 wells);
- water production would reach 25,000 ML per annum;
- direct industry employment would average 425;
- an average of 4 rigs would drill more than 200 wells per annum to maintain and extend production.

These CSG cost and resource figures would grow by several multiples in the Standard LNG scenario, as follows:

- incremental production would peak at 1,760 PJ per annum produced from up to 11,000 wells;
- incremental water production would exceed 120,000 ML per annum;
- incremental direct CSG industry employment would be sustained at 3,500;
- an average of 25 additional rigs would drill the additional wells required.

The study's estimates of long-term effects on the national and Queensland economies

The study (MMA 2009) estimated that the creation of a 28 Mtpa LNG industry (the Standard LNG scenario) would lead to national GDP being higher by 0.10%, or $1,034 million in real terms (2005–06 dollars). In the 15% Reservation scenario national GDP would increase slightly less, by 0.09%, or $967 million in real terms (2005–06 dollars).

In general, the effects on the Queensland GSP would exceed effects on the national GDP because the LNG industry is located in Queensland. That is, in the Standard LNG scenario, Queensland GSP would be 1.0% higher ($3,056 million in 2005–06 dollars), and in the 15% Reservation scenario a GSP increase of 1.0% would equate to $3,003 million in real terms (2005/06 dollars).

These expected increases in GSP would result in economic resources being reallocated from other states to Queensland to meet the needs of the new industry, thus lowering productive capacity in those states and other industries.

It is an example of the 'two-speed economy' effect which is strongly evident in current public comment and analysis.

The study estimated that in the Standard LNG scenario national final household consumption expenditure would be $815 million higher in 2005–06 dollars, or 0.13%. In the 15% Reservation scenario this benefit would fall to $686 million, or 0.11%.

Effects predicted on employment

A necessary assumption of the MM600 model used to estimate the economic impacts is that the amount of labour available in the economy is fixed (MMA 2009). Note that, as a result, the net impacts on national employment would sum to zero; that is, the creation

Table 4.2. Summary of results of the study by McLennan Magasanik and Associates (MMA 2009)

	Scenario			
	Standard LNG		15% Reservation	
Variable	$ million	%	$ million	%
Gross domestic product (GDP)	1,034	0.10	967	0.09
Gross state product (GSP) for Queensland	3,056	0.98	3,003	0.99
Royalties	850		685	
Employment	18,195	0.82	17,775	0.80
Household final consumption expenditure*	815	0.13	686	0.11

*an estimate of the impact on the standard of living

of a 28 Mtpa LNG industry in Queensland would draw in labour resources from other states, and employment would need to decrease in those states by the same amount (see Figure 4.5).

This prediction is similar to that noted above, with Queensland drawing in economic resources from other states, leading to a 'two-speed economy' situation.

The model estimates that the total number of persons employed in Queensland would be 18,195 higher, or 0.82%. This figure is widely reported in the analysis and promotion of CSG benefits by industry and government (Santos 2011; Jobs 2012). Applying the 15% Reservation scenario reduces the effect on employment slightly to 17,775 persons, or 0.80%.

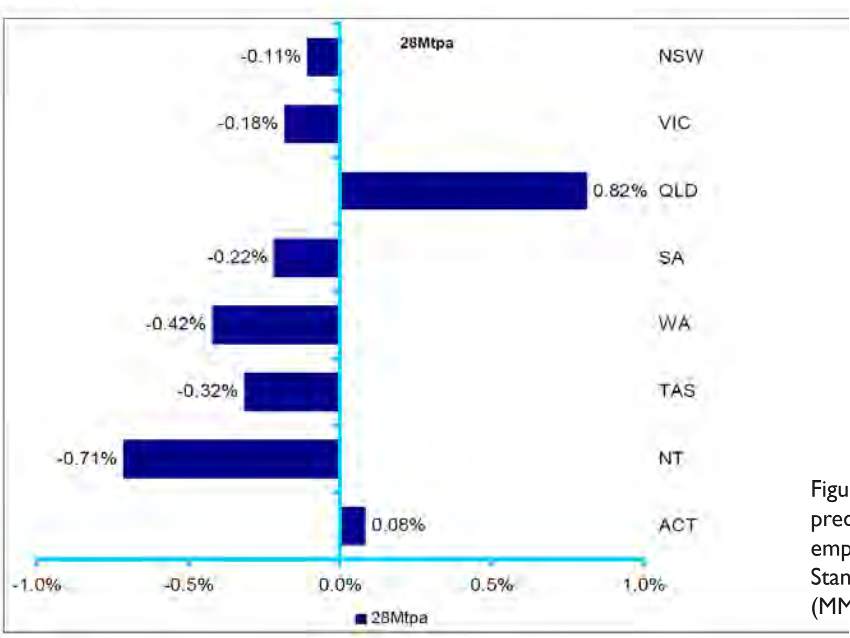


Figure 4.5. Changes predicted in national employment figures in the Standard LNG scenario (MMA 2009)

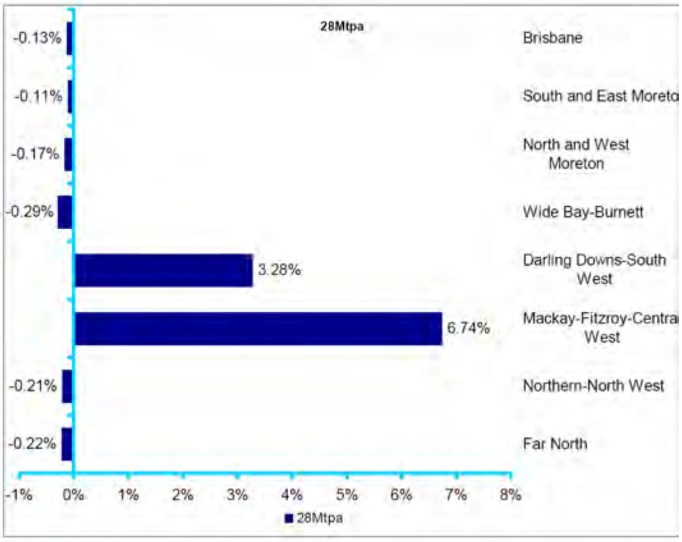
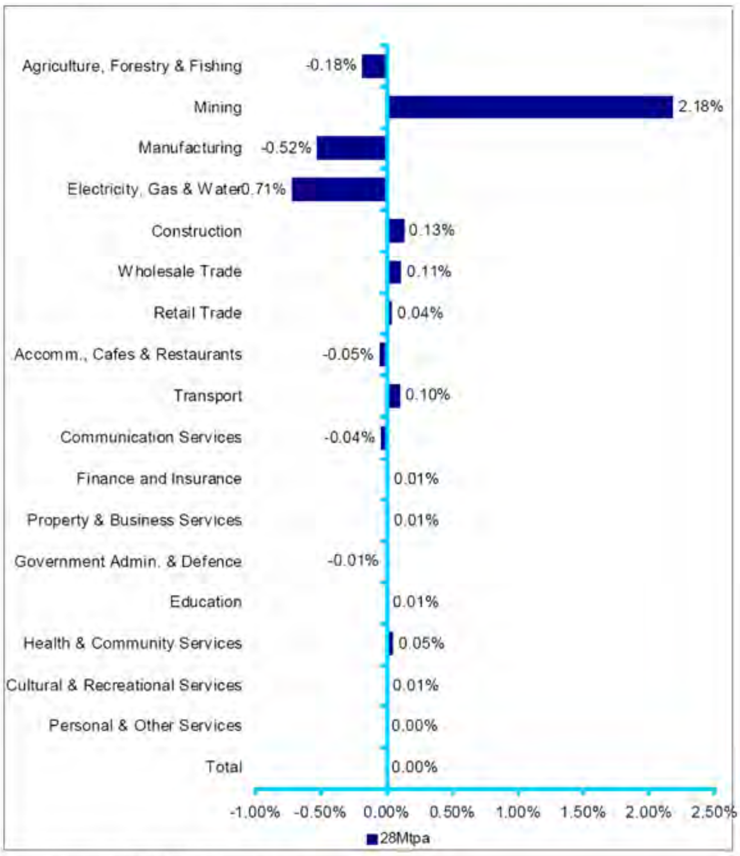


Figure 4.6. Predicted distribution of jobs across regions of Queensland (MMA 2009)

Expansion of the Queensland CSG industry would also redistribute employment across the state (Figure 4.6). Central Queensland and the Darling Downs would gain employment whilst all other regions would lose.

Just as an employment gain in one area will balance a loss in other areas it is also true under this model's assumptions that a gain in employment in the industries associated with the mining of natural gas in CSG production will be balanced against losses in other industries (Figure 4.7).



Source: Econtech MM600+ simulation

Figure 4.7. Predicted gains and losses of jobs in various industries in Queensland (MMA 2009)

The study (MMA 2009) concludes that:

> *In addition to contributing to the Australian economy in general, the LNG project would make a significant economic contribution to Queensland's production and economic activities in various industries, including those industries upstream and downstream to the oil and gas sector. Notably, in contrast to the national industry production effects, most of the industry production effects in Queensland are all positive. This is because the LNG projects would be built specifically in this State. As such, the increase in production in all the industries in Queensland due to the additional industry activity stemming from the LNG projects would more than offset the negative effects of the terms of trade and the increase in prices in the Electricity, Gas and Water industry discussed earlier.*

At the state level it appears that the production gains in the consumer-oriented industries and the industries upstream to the oil and gas sector more than offset the losses in production in other trade-exposed industries. Figure 4.8 (Figure 6-8 in MMA 2009) also shows the production contribution that the Standard LNG Scenario would make to the Queensland industries.

As in the national scene noted above, the figure demonstrates impacts consistent with the development of a two-speed economy in Queensland. Clearly the distribution of employment is an issue that needs management.

Figure 4.8. Imbalances predicted in the distribution of jobs between industries in Queensland (MMA 2009)

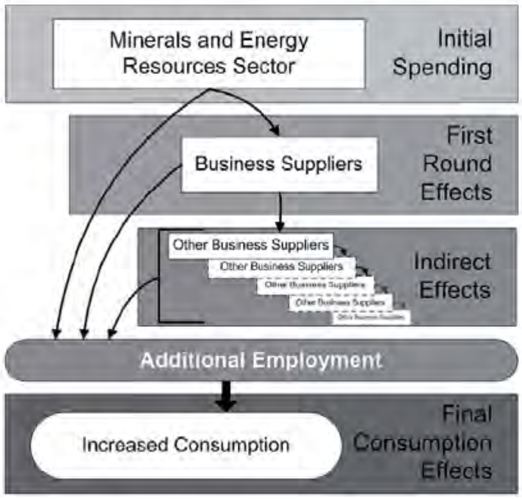


Figure 4.9. Diagram to explain input–output modelling (Rolfe et al. 2011, Figure 2)

Other modelling studies of CSG in Queensland

As noted above, the study by McLennan Magasanik and Associates (MMA 2009) and the NSW modelling studies which have attempted to estimate the economic impact of projected CSG development in both states are dependent on the assumptions used to drive the models. The large unknown in these is the projected form of the mathematical function used to describe the rate and magnitude of CSG expansion.

A recent and significant study by Rolfe et al. (2011) looks at the economic contribution of the resources sector as a whole. It is therefore much broader than studies of only the CSG industry, and gives a useful perspective on how economic impact can be expected to be distributed across regional Queensland.

This study, like the earlier study (MMA 2009) uses Input–Output (I–O) modelling to estimate the sum of direct, indirect and final consumption by the resources industry in different regions of Queensland (see Figure 4.9).

Rolfe et al. (2011) argue that I–O techniques take account of the inter-relationships between the various sectors of the economy in the short term and hence are an appropriate tool for determining the direct, indirect and induced economic impact of economic stimuli.

Their results predict impacts of the resources sector on output and jobs in the various Queensland Local Government Areas (LGA). Highest impact would be in the Brisbane LGA, indicating that much of the stimulus flows through to south-east Queensland.

The study predicts substantial additions to the business supply chain in many LGAs including Brisbane ($8.4 billion), Mackay ($1.4 billion), Gladstone ($0.65 billion), Mt Isa ($0.69 billion), and Townsville ($0.42 billion).

The largest predicted total additions to Gross Regional Product would be in the following LGAs (Figure 4.10):

- Brisbane ($24.1 billion),
- Mackay ($5.0 billion),
- Gladstone ($2.5 billion),
- Mt Isa ($2.2 billion),
- Central Highlands ($2.1 billion), and
- Isaac ($2.0 billion).

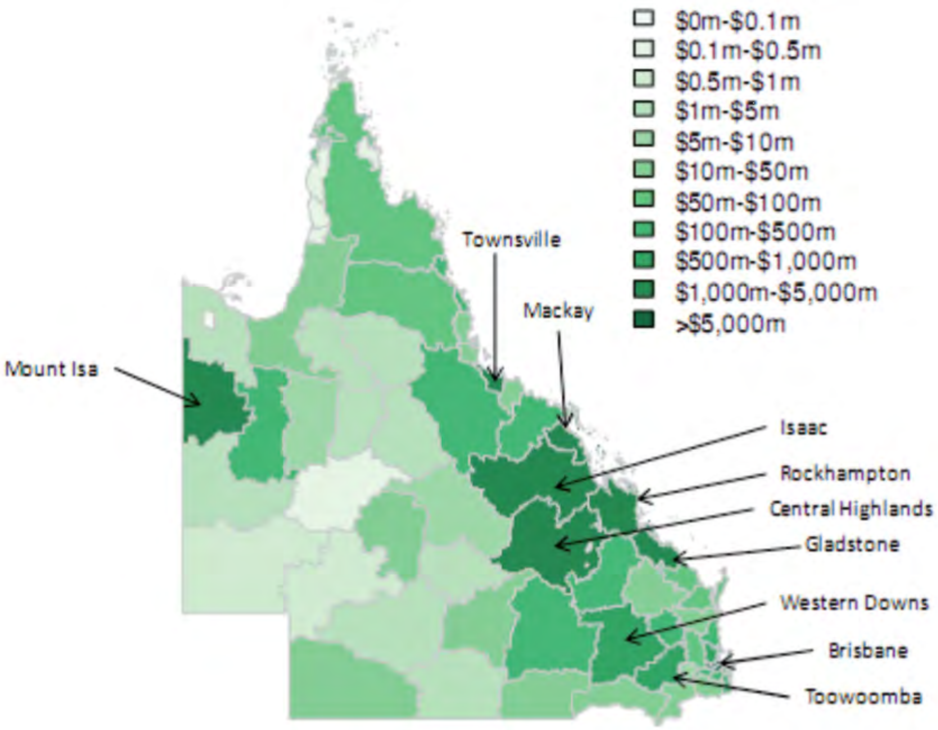


Figure 4.10. Predictions of total addition to the Gross Regional Product of Queensland LGAs (Rolfe et al. 2011)

It is economic studies like those above which contribute to the basis of government (Economic Benefits 2012) statements on the economic impacts of CSG. For example, the Queensland Government states:

> *Economic studies indicate a medium-sized 28 million-tonnes-per-annum (Mtpa) CSG to liquefied natural gas (LNG) industry could:*
>
> - *generate over 18,000 jobs in Queensland with 4,300 jobs in the Surat Basin alone,*
> - *increase gross state product by over $3 billion or 1%,*
> - *generate private sector investment of over $45 billion,*
> - *provide royalty returns of over $850 million per annum, which could help fund schools, hospitals and other vital* services.
>
> *Already, international resource companies have taken a direct stake in the development of Queensland's CSG-LNG industry including BG, Sinopec, Tokyo Gas, CNOOC, Petronas, ConocoPhillips and Shell.*
>
> *More investment in Queensland is great for home-grown businesses too. No matter what business you're in, investment growth is breathing new life into cities and towns. Already, a number of Queensland-based companies are winning multi-million dollar contracts, creating growth and employing new staff, trainees and apprentices along the way.*
>
> *For every major contract awarded in the construction and production phase, smaller companies in the supply chain are able to diversify, grow and employ more people. Everything from manufacturing, drilling, research, operational maintenance, training and labour services, through to retail and hospitality services is in demand.*

Policy and actions to manage these economic impacts

Given the above reasonable aspirations of government what are the principles that may assist communities achieve the desired spread of economic benefit?

Rolfe et al. (2011) outline the important issues that will determine how the economic benefit of CSG production will be distributed when they state:

> *A concept underlying I–O modelling is that an initial economic shock or stimulus can have multiplier effects through a series of successive spending rounds. The size of the economic multiplier in a local or regional area can be summarised in the following way. The key concepts of interest are (Jensen and West 2002):*
>
> - *the extent to which project operators purchase inputs from the local or regional economy; examples of inputs include wages for labour supplied from the local or regional area, and purchases of goods and services; the more that a project operator sources from the local or regional economy, the more money that is directly injected into the economy;*
> - *the extent to which money spent in a local or regional economy is retained within that economy; if there is not much opportunity for people receiving income to spend it on goods and services in their local or regional area, then not as much money will be kept in the local or regional area; larger and more diverse regional economies tend to be better at keeping expenditures in their economy and not 'losing' it to other regions.*

Clearly, economic analysis of CSG using powerful modelling tools and our best driving assumption would benefit from further research, peer review, and publication so the economic impacts can be fully understood in all their complexity. The work could underpin public policy and management of programs so that the opportunities presented by CSG can be optimised to yield sustainable economic and social benefit.

As open enquiries in Australia to date show, many in regional and local communities contest the findings of economic and social benefit, and a better future will require the best knowledge of how economic benefit can be best utilised in interest of all.

4.1.3. Examination of economic predictions about shale gas in USA

There are a number of modelling studies (e.g. Considine et al. 2009) in the USA directed toward estimating the economic impact of shale gas development. It is salutary to consider the detailed evaluation (Kinnaman 2011) of this type of work which has been conducted in the USA. Kinnaman states in his abstract:

> *Recent advances in drilling technology have allowed for the profitable extraction of natural gas from deep underground shale rock formations. Several reports sponsored by the gas industry have estimated the economic effects of the shale gas extraction on incomes, employment, and tax revenues. None of these reports has been published in an economics journal and therefore have not been subjected to the peer review process. Yet these reports may be influential to the formation of public policy. This commentary provides written reviews of several studies purporting to estimate the economic impact of gas extraction from shale beds. Due to questionable assumptions, the economic impacts estimated in these reports are very likely overstated.*

In two publications (2010, 2011), Kinnaman writes that two reports on the Pennsylvania economy contain three such shortcomings that could easily be corrected by:

i. including better assumptions of when and where households spend windfall gains,

ii. clarifying the process used to determine where suppliers to the industry and royalty earnings households are located (in Pennsylvania or not), and

iii. developing a more appropriate econometric model to estimate well drilling as a function of current price and other relevant variables.

Making these changes, Kinnaman says, would likely decrease the size of the economic impacts estimated in these papers, but new estimates would likely be more accurate. Comments made throughout these papers that estimates are "conservative" are for the most part not appropriate and should be ignored. Given the assumptions made in relation to these three shortcomings, the estimates are very likely overstated, Kinnaman says.

In his earlier publication, Kinnaman (2010) examines another study that compares populations and per-capita incomes in Texas, Arkansas and Pennsylvania and concludes that the work unfortunately misinterprets the data. He reports that the:

> *changes in population and incomes across these regions do not support the notion that shale gas extraction has increased populations or per-capita incomes. Providing accurate estimates of the economic impact of shale extraction is important to the functioning of the state economy. Households and firms can be expected to base investment decisions on such forecasts, and overstating the economic impacts to persuade government officials could cause other disruptions in the economy if investment decisions are based on poorly estimated economic impacts.*

In a final note Kinnaman (2010) concludes that:

> *comparing data in Texas and Arkansas with that of Pennsylvania crudely suggested that the impact on populations and per-capita incomes is negligible. It is possible, then, that the potential economic impact of gas extraction to the Pennsylvania economy could be quite small if (1) well drilling utilizes out-of-state economic resources, and (2) landowners save or spend their lease and royalty payments in other states or countries. The possibility of these two occurrences may not be remote.*

4.1.4. Government initiatives for sharing of CSG benefits in Australia

The Queensland Government is incorporating the principles of sharing economic benefits with the local or regional economy (Jensen and West 2002, quoted above; Kinnaman 2010, quoted above), into the policy it is currently developing and seeking to strengthen.

The *Queensland Industry Participation Policy Act 2011* was passed to ensure that key industry participation principles would be put into practice by successive governments. The Act details how local companies will be given a fair go when tendering for work on major government or government private sector partnership projects. It does not apply to the private sector.

Government and partnership projects

One example of new Queensland Government policy for major projects under the Act is the Local Industry Policy. This policy requires small- to medium-size businesses to be given a fair opportunity to be considered for major government-funded infrastructure and resource-based project work. Project owners, known as project proponents, have a responsibility to ensure the policy applies to the entire supply chain and are required to develop a local industry participation plan.

The policy aims to boost Queensland's economy and provide local businesses with a full, fair and reasonable opportunity to participate. Communities can benefit from major projects occurring in their regions. Since its introduction, Queensland manufacturers are reported to have won over $5 billion in contracts, with approximately $1.4 billion going to regional firms.

Figure 4.11. Advertisement for the Industry Capability Network in Queensland.

Businesses supplying to major projects can gain by adopting new technologies and processes to meet global benchmarks and compete for international business. Project proponents have opportunities to deal with globally capable and competitive local businesses and to contribute to the local community.

Note that while legislation can assist with government and partnership projects it does not apply to the private sector where by far the majority of commercial opportunities arising from CSG arise.

Private sector

The private sector, meanwhile, can benefit via networks and gateways set up to assist local and regional business to link up with the large companies in the CSG industry. The Industry Capability Network in Queensland (Figure 4.11) is one example of a Federal–State action benefiting the private sector.

The Industry Capability Network (ICN) has been established to help increase the participation of regional and local companies' share in the wealth-generating opportunities around the CSG industry. Figure 4.11 tells it all.

The Industry Capability Network (website http://www.icnqld.org.au/) seeks to provide services to clients in all industries by:

- finding the best Australian products and suppliers;
- increasing capabilities (through the Major Projects Supplier Program);
- supporting major industrial, energy and infrastructure projects;
- supporting compliance with the Local Industry Policy and Local Industry Participation Plans;
- accessing Global Supply Chains;
- providing research services for:
    - Tariff Concession Order applications,
    - the Project By-Law Scheme (EPBS),
    - information on the industry and sectors.

The Network technical experts and search technology (the ICN Gateway) help connect the CSG industry and local or regional products or services. Businesses register with the Network and can then link into regional and local enterprise. The ICN web site claims that the ICN Gateway (online database) has access to more than 50,000 suppliers and 100 projects.

Other government initiatives also support the private sector. For example:

- the Federal Government has new programs to foster purchase of services for the mining and CSG industries from Australian enterprise. For example, the 'Buy Australian at Home and Abroad' Initiative, through the Industry Capability Network, has boosted funding for Supplier Access to Major Projects (SAMP), to increase opportunities for Australian industry to supply Australia's resources boom.
- a Queensland Government website gives information on business opportunities being generated from the CSG and liquefied natural gas industry (Business Opportunities 2012).

Initiatives like these appear to be having success. The Industry Capability Network website mentions Queensland-based companies, both large and small local businesses, which have won contracts, creating growth and employing new staff, trainees and apprentices along the way. One example of a large company is Iplex Pipelines — $180 million in contracts to supply polyethylene pipe for the piping of CSG to the liquefied natural gas operations; and contracts to construct a new manufacturing facility in the Toowoomba region related to the CSG industry. The website also gives links to small local companies that are responding to opportunities in CSG development.

4.2. Social impacts of the CSG and other mining industry

There is a growing literature on the social impacts and social changes which are taking place with the expansion of mining and energy industries. Topics reported have included:

- Information sharing and trust, between companies and communities,
- Forward planning for the changes in population in a regional area,
- Infrastructure, soft and hard, including entertainment and retail,
- Revenue sharing,
- Gender and income inequality,
- Quality of life and good/bad aspects of the industries,
- Learning from the past.

The discussion of these topics in this section is derived mainly from several literature reviews based in Queensland. Many of the principles and trends will also have wider relevance.

4.2.1. Information sharing and trust; and forward planning

A literature review by CSIRO (Schandl & Darbas 2008) examined regional and community capacity to capture the opportunities for sustainable regional economic development driven by the mining and energy industries.

The purpose of the study was to assess community perspectives of potential impacts of such development in the Surat region, and to identify international and Australian examples of good practice in management of such effects, and viable ways to mitigate socially undesirable outcomes.

Their findings are derived from well-attended community workshops and from engagement with a project steering group in the Surat Basin.

One of their five major findings was that information sharing, communication and transparency are critical for enabling good governance and change management at the community level.

Community and regional council representatives expressed an urgent need for accurate and timely information about the long-term plans and activities with regard to mining development as the single most important factor for pro-active change management at the community level. Currently (2008), there was an imbalance between the commercial confidentiality granted to mining companies and the need for accurate information by regional councils and local communities. Establishing a tripartite arrangement might allow negotiation of a mutually satisfactory solution to this imbalance. Such an outcome would permit effective communication between all stakeholders involved concerning when, where and how development was to occur and thus enable a coherent communication strategy with local communities.

The groups said that information is critical for effective on-going management of regional opportunities from the energy boom. Information is crucial for being able to plan, to make policy decisions and to evaluate past policies. They wanted to develop an agreed set of indicators for the region, and an improvement of the EIS process to allow for institutionalised procedures for impact assessment. It should take account of all relevant social and environmental impacts at community level. This suite of activities would enable active regional planning for economic growth and sustainability based on a collaborative approach involving all stakeholders and tiers of government.

More recently than the CSIRO review, a small well-designed study by Capel (2011) in the central Western Queensland based in Longreach has examined community attitudes and the issues of social concern with CSG development. This study also found communities expressing a need for more — and honest — information, saying:

- there is a lack of impartial independent information available on CSG mining;
- people are distrustful of information from government and mining companies;
- information about the science of CSG and other mining needs to be written so it can be understood by non-scientists;
- more information is required and in a variety of formats to suit all learning styles, i.e. visual oral, hands-on, etc.;
- the way CSG companies work with landholders varies greatly — some companies do it well, some do it poorly.

Among recommendations from this study were these:

- a range of information on CSG and/or coal mining needs to be provided in a variety of formats so people can better understand benefits and issues;
- the Remote Area Planning and Development Board (RAPAD) should facilitate the development of a standardised code of practice between all CSG companies, communities and landholders in Central Western Queensland;
- further independent scientific/research studies may need to be conducted that focus on the Central West and the Great Artesian Basin specifically.

With respect to planning rather than information, Schandl & Darbas (2008) also found that in the Surat Basin:

- current planning capacity in the region was described as fragmented and the need for a united voice to negotiate with the Queensland Government and mining companies;
- shortages in affordable housing were anticipated; however, the issue was viewed as hard to deal with;
- skills shortages were expected but, in contrast to housing, clear and convincing strategies to address such shortages were articulated.

4.2.2 Infrastructure investment

Community concerns and recommendations with respect to various types of infrastructure investment were reported in several studies. The CSIRO study (Schandl & Darbas 2008) was told:

- there was inadequacy of soft and hard infrastructure, already experienced as at capacity, in the face of a mining boom;
- existing funding mechanisms were not considered adequate to address infrastructure deficits in a timely manner.

One of their report's five major findings was that investment in hard and soft infrastructure would be crucial to meet the demands of an increased population. The ambition expressed by the workshop participants to build larger resident populations in many towns in the Surat Basin would require considerable investment in both hard and soft infrastructure. The current (2008) situation with regard to the condition of road networks, public transport, utilities, education, health care, police and community services only met the requirements of the current population. There was preparedness at the State government level to invest in larger infrastructure projects directly related to developing the mining sector such as rail, rolling stock, port, water and energy infrastructure. However, investment into skills, housing, planning and soft infrastructure needed to be increased to allow local communities to deal proactively with the inter-related aspects of social change as well as maintain their communities as desirable places to live and work. Successful economic diversification would ensure the use of infrastructure established during the mining boom, for post mining economic prosperity.

Earlier than the CSIRO study, John Rolfe led a team from Centre for Environmental Management, Central Queensland University, to examine 'Impacts of the Coal Mining Expansion on Moranbah and Associated Community'. Moranbah is in the Bowen Basin, Queensland. While there are important difference between social impact between coal and other forms of mining and CSG production the work in mining in generals can be expected to shed light on the social issues that arise with CSG expansion.

The final report (Rolfe et al. 2007a) contains an overview of research into the economic and social impacts of mining on the Moranbah community and options for future development. Several of their key messages, all of which are listed here, relate to infrastructure investment.

i. The mining boom had stimulated a population increase in Moranbah, as well as a large non-resident workforce (estimated at 4,000 people). The 'core' workforce for mines within 50 km of Moranbah was expected to grow by a further 1,390 people by 2010. It had been estimated that there was potential for the town to grow by another 2,700 permanent residents over the next five years.

ii. Key needs that currently existed for the community included improved shopping and services, a more reliable water supply, cheaper housing, and a larger pool of labour.

iii. Key issues for the community in options for future development included the extent of work-camp accommodation, the security of water supplies, the price of rentals and housing, and the potential environmental impacts of future mining close to town.

iv. Moranbah residents preferred the development of housing rather than work-camps in their community; this value had been assessed at $3,144 per household per year.

v. Respondents indicated that they would reduce their length of stay in Moranbah by 2.6 years if work-camp development went from a low base to a high level of development.

vi. Having a satisfactory buffer against future environmental impacts of mine development was the next most important issue. The value of avoiding future impacts was assessed at $494 per household per year.

vii. The average number of years that residents expected to stay in Moranbah was approximately 8.5 years. Almost no resident planned to move to another mining town when they left Moranbah.

viii. At least 80% of the non-resident workforce indicated that they did not want to live permanently in Moranbah. Key reasons related to partner and family commitments, and to preferences for living in a larger centre.

ix. Mackay residents were asked about potential relocation to communities such as Moranbah. Results showed that for the average Mackay person to move to a mining town, a salary premium of $55,000 was required. A higher premium was needed to attract people to live in smaller communities. Key factors that were important in the choice of communities were: the level of health and education services, availability of jobs for partners and children, and the standard of public infrastructure.

x. The level of economic activity in Moranbah was slightly lower than in other comparable towns, suggesting that there were large spending leakages from the community.

In 2011, Regional Development Australia (RDA), commissioned by the Queensland Government, examined the regulatory and planning frameworks used to inform resource development decision making at the State level, particularly where competing land use activities of agriculture and mining exist. In relation to infrastructure, the study (RDA DDSWQ 2011) concluded that:

- resource development projects have significant social and economic impacts for local towns and regional areas, as currently experienced by communities in the Darling Downs and South West region; and
- it is critically important that government acts to ensure current proposed initiatives to address land use conflicts and infrastructure inadequacies in regional areas are addressed as a priority.

4.2.3 Revenue sharing

In 2008, Schandl & Darbas in their CSIRO study heard concerns that:

- the business community was viewed as at risk of being bypassed as service providers to mining companies. The chance to negotiate with mining companies in order to capture those servicing opportunities and grow regional businesses was perceived as very worthwhile.

One of that study's five main findings, therefore, was that gain and revenue sharing would be essential to increase the social acceptability of mining operations and to increase the local economic opportunities from mining in the Surat Basin region (Schandl & Darbas 2008).

Another finding (Schandl & Darbas 2008) was that economic diversification leveraged off the energy boom was essential to the long-term well-being of the Surat region.

Similarly, the RDA study in 2011 (RDA DDSWQ 2011) found that while increased activity in the resources sector has generated increased royalties and tax revenues to State and Federal Government, communities need to consider whether there will be sufficient Government funding to develop and sustain regional areas. The current 'Regional Budget Statements' provided by State (Queensland) Government delivers some transparency on monetary return to be invested in regions, however there is potential for a more targeted regional development funding model to be developed to complement existing strategies. The

'Royalties for Regions' policy in Western Australia provides an example model which could be adapted and applied to the Queensland context (RDA DDSWQ 2011).

Ultimately, sustainable regional development and continuing growth of the resources sector is a key priority for governments, communities and the mining industry. The success of an option relating to resource royalties and taxation opportunities in the development of effective infrastructure development relies on the commitment from State Government to achieve a positive long-term future for communities in regions (RDA DDSWQ 2011).

The international literature agrees that economic development based on mining industries alone will not allow for sustained economic growth due to its temporary nature. The failure of mining to generate long term economic benefits, particularly in remote regions, has also been acknowledged in the Australian context. The fact that the Surat Basin region enjoys an existing viable economic base bodes well for its prospects of economic diversification. Economic diversification needs to be an early and integral part of regional economic planning since post hoc efforts to address economic diversification have typically failed. The momentum of the mining boom should therefore be used to intensify human resource development, infrastructure construction and encouragement of regional procurement and export.

As already partially discussed in Section 4.1 of this chapter, mining activities create wealth but usually not in an evenly distributed way. Economic modelling (e.g. Allen Consulting 2012) demonstrates that states and national governments profit from royalties paid for mining leases and from tax revenues, companies gain from having access to precious resources which sell at increasingly profitable global prices. Individual workers and households profit from exceptionally high salaries and landlords or house owners may gain from higher rental incomes or increased property values. Because gains and revenues in mining activities are often much higher than those yielded by other economic activities, mining activities typically, as a consequence, constrain (Allen Consulting 2011, ACIL Tasman 2011, MMA 2009) other forms of development and usually result in increased income inequity (Reeson et al. 2012). This situation has caused civil dissatisfaction across the world.

The international mining-company community has an interest in obtaining and maintaining a social licence for their operations, so it is both advisable and opportune to identify and test approaches for gain and revenue sharing. Such gain sharing could be introduced by establishing a trust fund (see below) where those parties who earn over proportional amounts give some of the revenue and gains back to the community at large in a carefully targeted manner. Mining companies, as part of their corporate social responsibility, contribute to the development of rural communities by financial donations (and are already doing so in the Bowen and Surat Basins), State and Federal Governments who also gain considerably could add to these donations of mining companies. On this basis, it is also possible to request landlords and property owners who are earning high rents because of mining development to contribute a certain percentage of their gain back to the community.

4.2.4 Impacts on quality of life, and inequalities in income and gender

Research discussed below on inequality and quality of life shows that effects of extractive industries can appear quite different at national scale than they appear at local or regional scale.

At regional scale, Schandl & Darbas (2008) heard that, for the Surat Basin and similarly the Bowen Basin:

- the region's rural lifestyle was viewed as threatened by the influx of new workforces with minimal orientation to existing communities. However, the opportunity to attract workers to settle in the Surat communities with their families was highly valued.

However, at national scale, Hajkowicz et al. (2011) found no evidence for lowered quality of life associated with the mining industries.

In a study that examines the social and economic impact of mining across regional Australia, Hajkowicz et al. (2011) examine the relationship between quality of life indicators and the gross value of minerals production from Australian regions. The authors used quality of life indicators, aggregated for 71 local government areas containing mining activities, of household income, housing affordability, access to communication services, educational attainment, life expectancy, and unemployment.

They found no evidence of systematic negative associations between quality of life and the gross value of minerals production. Instead, mining activity had a positive impact on incomes, housing affordability, communication access, education and employment across regional and remote Australia. Whilst the authors (Hajkowicz et al. 2011) do not establish causality between mining activity and quality of life, their analysis prompts a rethink of the resource curse as it applies within a single country.

They did not find evidence of a resource curse, at the local government level, in Australia's mining regions. Nevertheless, they were careful to note well-established observations by many other researchers of negative social impacts on specific demographic sectors: localities, families of fly-in fly-out mining operations, and individuals.

This contrast may be a scale issue, with the regional benefits of mineral wealth masking highly localised inequalities and disadvantage. Their work suggests that there is a need to better understand these impacts and, more importantly, the types of policy mechanisms government and industry can adopt to mitigate or avoid them.

The need for more research in this field is underlined by the finding below that gender and income inequalities can be associated with mining industry at least at regional scale.

Reeson et al. (2012) have examined impacts of mining activity on income inequality and gender in regional Australia. They find that while income growth is an economic benefit, the high incomes associated with the mining sector may also lead to greater inequality.

The Gini coefficient (a measure of inequality) for personal income is found to be significantly associated with levels of mining employment. However, this relationship is not linear (Figure 4.12).

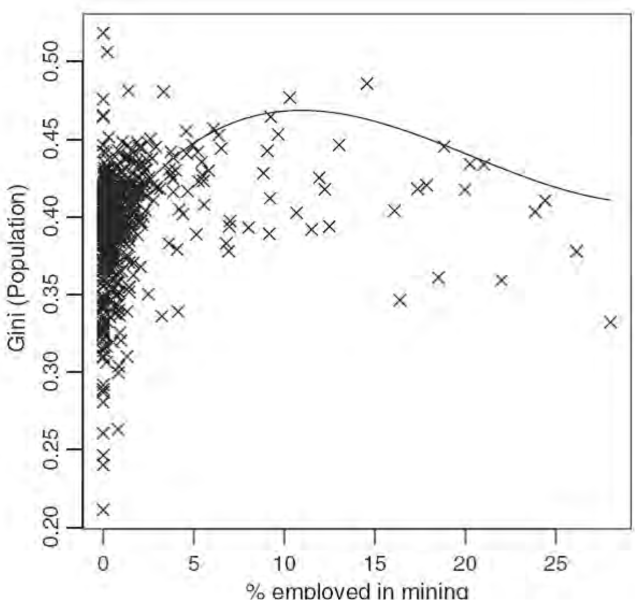


Figure 4.12. Inequality in personal incomes is significantly, but not linearly, associated with levels of employment in mining. (Reeson et al. 2012)

Among men, inequality initially increases as mining employment in a region increases, but then sharply decreases; at high levels of mining activity, income inequality among men is lower than is typically observed in non-mining areas. Among women, income inequality increases with mining activity throughout its range. This suggests that income inequality is most likely to be a problem in locales with intermediate levels of mining activity and that it affects men and women quite differently.

4.2.5. Capturing and learning from past community social responses

A valuable study (Petkova et al. 2009) on mining development and social impacts on communities in the Bowen Basin shows what has happened in the past as these communities responded to coal mining expansion. Some of these findings may forewarn policy-makers of likely impacts of an expansion of CSG in that region of Queensland.

This comprehensive study showed that while the mining boom has been generating social and economic impacts, the pattern of impacts appears to vary across communities depending on size of the mining projects, community structure and history, and the extent to which a non-resident work force is involved (Petkova et al. 2009).

The conclusions from this study have value in showing how different towns and villages often have very different responses to expansion of mining in their midst.

However, the following were some consistent messages from Petkova's et al. 2009 study.

- The increased reliance on a non-resident workforce and the increased mobility of local residents have meant that an increasing proportion of the economic stimulus from mining is flowing out of mining towns and into regional centres (Rolfe et al. 2007).
- Housing shortages and price spikes also have the potential for flow-on economic development and have created pressures on non-mining businesses and socio-economic groups.
- The increased use of non-resident workforces has brought additional problems of fatigue, family isolation and community fragmentation.
- The number of coal mines close to a town and the extent of the non-resident workforce, appear to have been key factors determining the extent of the social impacts. There was less social impact if the mining operations could be serviced largely by labour resident in the adjacent town. The mine employees located in these towns were seen as locals. In contrast, the impacts on existing residents were most acute where the itinerant population outnumbered the permanent population; such towns may in the process become even more attractive to the temporary residents.
- The ability of towns to attract and retain permanent residents could serve as a useful proxy indicator of the number and magnitude of social and environmental impacts associated with mining.
- The demographic of most towns was increasingly dominated by 'single' males with limited education or training. Any reduction in mine-related employment, such as was experienced during the global financial crisis, might well leave behind essentially unskilled workers with limited mobility.
- While some towns experienced less economic and social disruption than others, none in the study were able to use the current mining boom to leverage other economic development opportunities that might provide additional insurance against welfare dependence.

4.2.6. Overview of landholders' perspectives in NSW and Queensland

In Australia, a number of significant CSG fields underlie agricultural land and will draw upon existing infrastructure and social services. As discussed both in Chapter 3 and in this chapter above, in relation to communities close to mining developments, the social impacts from CSG developments are likely to flow from:

- access to, and use of, land and water resources;
- competing demands placed on human capital and social infrastructure;
- challenges to existing rural community identities and ways of life.

Landholders in agricultural regions have a number of concerns, of which these are some examples.

- The rapid influx of relatively high-income residents can result in a sharp increase in competition among residents for social and natural resources. This can create tensions at local and regional scales.
- The set of potentially negative and positive impacts are not uniformly distributed across space and time. Spatially, most negative impacts are accrued locally, and may not be off-set by substantial positive impacts that accrue at larger regional scales.
- CSG operations will upscale and downscale over time, altering the distribution of wealth to different stakeholders and regions and influencing the local availability of natural and social resources such as water or housing.
- Individuals and communities on agricultural land have motivations beyond economic concerns. Identities and affinities associated with activities and lifestyles such as 'farming', 'rural life' and 'life on the land' are powerful dimensions of the way in which communities perceive and understand CSG development and their potential impacts.
- CSG development is capital and labour intensive and creates significant demands for human and physical resources and can, as a consequence, test the capacity of local and regional governance to manage social and economic transformation, during both the up-scaling and downscaling of development.
- Freehold farmers own the top few centimetres of the land, but the state owns the soil and rocks underneath that. Mining companies have the right to explore any property for resources, though companies with a corporate image to protect have stressed they will not barge onto people's properties.
- Landholders have raised concerns that independent science hasn't been able to keep pace with the rapid development of CSG, particularly its long-term impacts on water.

Both the NSW and the Queensland governments have begun to address landholders' concerns. See below, Section 4.2.8.

4.2.7. Social and economic impacts of gas production operations in USA

Before reviewing the Australian state governments' responses to social concerns, it is useful to consider the social and economic impacts in the USA where there have been many decades of experience with the production of unconventional gas. There is a significant US literature on this matter which is worthy of examination.

In the US the gas resource is owned to a large extent by the landholder. That situation is very different from Australia where the gas resources are held in common for all the people. Despite this important difference it is surprising to see that many of the social impacts

have similarity except perhaps the relative magnitude of use of non-residential labour in unconventional gas production.

Here we consider a landmark paper from a group that has built up a reliable body of work on social and economic impacts in USA (Anderson & Theodori 2009).

In recent decades, the production of natural gas from unconventional reservoirs (i.e. tight gas sands, CSG and gas shales) has become commonplace within the US energy industry. The Newark East Fort Worth Basin field — known as the Barnett Shale — in north-central Texas is one of the largest unconventional natural gas fields in the United States. Unlike many conventional energy development projects, which typically occurred in small rural areas, much of the production from the Barnett Shale field is occurring in and around a highly urbanized geographical setting. (See also Chapter 3.)

In spite of recent efforts to assess the economic effects of Barnett Shale production, little attention has been directed toward understanding the social impacts associated with this immense unconventional energy development. In this paper, Anderson & Theodori use key informant interview data collected in two Barnett Shale counties to investigate the reported positive and negative outcomes of unconventional energy development, as well as the similarities and differences in perceptions between respondents from each of the study counties.

Overall, the findings (Anderson & Theodori 2009) demonstrate that localities experiencing the development of unconventional energy resources face both negative consequences and positive impacts. Economic benefits of unconventional energy development were readily acknowledged by local leaders and concerned citizens in Wise and Johnson Counties. However, these individuals also expressed apprehension over perceived adverse consequences.

Potential threats to public health and safety, such as increased truck traffic, unsafe driving practices, gas leaks, and explosions, were among the concerns mentioned. Environmental concerns were mostly related to water resources. Water use and management is a major issue and closely tied to unconventional energy development.

Participants expressed concerns over temporary disturbances caused by noise, lighting, traffic, and conflicts over mineral rights. Concerns about negative consequences were greater among respondents in Wise County, the site where energy development was more mature.

The authors called for further work to more fully understand the association between development of unconventional energy resources and social consequences, particularly in areas of expanding production and regions where production is mature or declining.

Continued reliance upon the indicators used to measure social disruption in the western energy boomtowns of the past would likely yield misleading results for unconventional energy development, particularly in a metropolitan context like that near the Barnett Shale. Here the issues of public health and safety concerns, and impacts on the environment and quality of life should all be given greater attention.

Future research should also empirically examine the differences in perceptions among diverse stakeholder groups. Municipal leaders and county-level officials, for example, face different challenges and, therefore, may perceive energy-related issues differently. While the present study (Anderson & Theodori 2009) included both types of officials, the interviews and participant selection processes did not allow for in-depth analyses of their responses.

Furthermore, an understanding of the similarities and/or differences between local leaders' perceptions and those of the general citizenry may offer valuable insights.

Anderson & Theodori also proposed examination of the interpersonal dynamics within energy-producing communities and investigations into the ways in which increased energy development affects wealth and power at the local level. Their study introduced indicators of social disruption designed to better reflect the experience and concerns of local leaders and the public in areas facing increased unconventional development of natural gas resources. It has demonstrated the need for further research into local-level impacts.

4.2.8. Management and policy responses to social impacts

The sections and the discussion above outline the primary social issues relating to mining and CSG production. Our level of understanding of their causes, at the scales of landholders, community or town and region, requires a great deal more work and analysis. Yet the knowledge base appears to be more than sufficient to build policy and programs to manage better the potential expansion of CSG in Australia.

The existing social-science studies, some of which have been outlined above, have built a platform of knowledge for current governments. They show there are key issues that demand attention if regional and local communities are to gain a better social and economic and environmental outcomes from mining and CSG production. The scale and scope of the changes planned (see below) for the Surat Basin suggest that all tiers of government, as well as the private sector and communities will need to work together in order to increase the benefits of mining and energy development and to avoid negative social and environmental outcomes.

The Queensland government statements on the websites associated with CSG show awareness of these issues. Legislation that now exists requires social impact assessment and social impact management statements, in an attempt to ensure that the issues receive attention.

The question is: how successful are these initiatives in the light of history and current trends in public discourse on these matters?

One Queensland Government website (QGGDIP 2012) on CSG states that:

> *while resource sector development can create more jobs and a stronger economy, it can equally place significant pressure on local infrastructure such as housing and community services, and present challenges for health and education service delivery. Skilling and workforce demand pressures associated with the resources boom are also a key consideration in planning for growth. One of the Queensland Government's key priorities is to maximise the community benefits of the CSG (CSG) and liquefied natural gas (LNG) sector whilst balancing any social impacts.*
>
> *Turning challenges into a positive social impact is part of the project approval conditions set by the Coordinator General (QGGDIP 2012) for CSG-LNG projects require Social Impact Assessments to help identify the issues that will require practical solutions through collaboration and partnerships with community, industry and all levels of governments. Part of each CSG-LNG company's plan also requires them to submit quarterly reports on the implementation of their integrated housing strategies.*
>
> *Examples of this commitment to balancing the needs of the community and industry include:*
>
> - *Major Resource Projects Housing Policy — the policy requires project proponents to address the impacts on housing and accommodation in local communities.*

- *Specifically in the Gladstone area all CSG-LNG companies who have local operations must provide a report every three months on how they are managing housing issues.*

The Queensland Government's 'Surat Future Directions Statement' outlines regional development plans and actions (QGDBI 2012). It indicates that the issues identified above are of concern to government and that it is an active area of policy development which needs the support of good applied social and economic science research.

The plan is designed to help build a prosperous and sustainable future for the Surat Basin region. The Statement:

- sets out an effective framework to shape the Surat Basin region through to 2030;
- identifies the major issues facing the region and provides an integrated approach to how the region will address them;
- establishes clear mechanisms to coordinate the work of the Queensland Government and Surat Basin stakeholders.

The final statement provides detail on the implementation of the headline initiatives and other activities from the Statement. These initiatives included:

- a Surat Basin regional development forum that was attended by stakeholders representing community, industry, and local and Queensland Government;
- developing a regional planning framework covering the Surat Basin region, including a regional vision, strategic directions and regional land use patterns;
- determining the preferred settlement pattern for the Surat Basin region to guide planning and service delivery;
- conducting a regional transport investigation and developing a regional transport strategy covering various transport modes as well as alternative or complementary non-infrastructure solutions to transport issues in the region;
- developing a resource-town housing-affordability strategy;
- developing guidelines to improve the consistency and quality of social impact management plans;
- developing an economic development strategy for the Surat Basin region, focusing on action plans to drive growth in the region's priority sectors and attracting investment to take advantage of the region's growth potential;
- continuing to develop and implement the land access policy framework to address land access issues between agricultural and resource sector stakeholders;
- developing a coordinated workforce development plan to support ongoing workforce needs arising from the impacts of rapid industry growth in the Surat Basin;
- developing a policy and planning framework to manage strategic cropping land to strike a balance between the competing land use interests of agriculture and mining;
- continuing to implement the CSG water-management policy initiatives including developing guidelines for performance standards to be met by beneficial uses of CSG water and implementing an adaptive approvals regime.

This is a comprehensive set of tasks and illustrates a move towards a much more whole-of-system approach to regional planning and development.

The social, economic and environmental knowledge that would be necessary to be assembled to complete all those above tasks with integrity represent a great opportunity

for whole-of-system thinking and new collaborations between industry, government, community and the knowledge industries in our research and educational institutions.

Many of these initiatives are consistent with the thinking in the CSIRO (Schandl and Darbas 2008) work and the associated literature (Rolfe et al. 2011, Ivanova et al. 2006, Petkova et al. 2009).

In NSW, in examining landholder concerns about CSG operations, the NSW Parliamentary Inquiry (NSWLC 2012) found that participants were concerned that CSG companies will take an aggressive approach to enforcing their access rights. Despite evidence to the contrary from several CSG companies, the inquiry did not dismiss the evidence that some operators have attempted to pressure landholders for access, nor the possibility that companies may force access in the future. The enquiry recommended that the NSW Petroleum (Onshore) Act 1991 be reviewed with a view to strengthening landholder rights. As we shall see in the discussion below Queensland has moved in this direction.

Many participants in the Inquiry (NSWLC 2012) expressed concern about the access agreements that landholders must sign before any exploration activity can be undertaken.

An important step forward, in redressing the unequal bargaining positions of landholders and mining licence holders, is for the Government to lead the development of a template access agreement to cover both the exploration and production phases. Landholders should also be given the opportunity to seek legal advice on access agreements and be reimbursed for reasonable costs of seeking this advice. In addition, if a landholder is required, or requests, to engage in arbitration over access, the reasonable costs of this process should be reimbursed by the relevant CSG Company (NSWLC 2012).

There appears to be limited guidance for landholders when determining appropriate compensation for hosting CSG activities on their properties. The NSW Inquiry (NSWLC 2012) recommended that the template access agreement for exploration and production should take a default position whereby the landholder can be compensated with the sum of $5,000 per well-head per annum.

In Queensland, to address these issues, the Queensland Government commissioned Regional Development Australia (RDA), which is a partnership between the Australian, State, Territory and Local Governments, to initiate a series of actions to improve the sustainability and quality of life in Queensland's resource communities.

Key actions that seek to address social impacts associated with mining and CSG development in Queensland's resource communities include:

- development of the 'Surat Basin Future Directions Strategy' to provide a strategic framework to shape future planning and growth in the Surat Basin region to 2030;
- the release of a draft State Planning Policy to protect Queensland's strategic cropping land, and development of a CSG Water Management Policy;
- introduction of guidelines and amendments to legislation to consider landowner rights, consultation and communication with landowners and residents;
- introduction of the 'Sustainable Resource Communities Policy' and associated Social Impact Management Plans to strengthen social impact assessment processes in proposed resource developments.

In developing these actions the RDA report (RDA DDSWQ 2011) examined the regulatory and planning frameworks used to inform resource development decision making at the State level, particularly where competing land use activities of agriculture and mining exist.

They considered key issues concerned with the granting of exploration and development licences for coal and CSG, as well the processes used to fund and provide regional social infrastructure requirements, including the allocation of royalties by government and voluntary funding contributions by proponents.

Among other conclusions, some of which have already been mentioned above, including the recommendation to examine WA's Royalties for Regions policy, the RDA (RDA DDSWQ 2011) decided that Queensland had been lacking a holistic appreciation by industry and government of the importance of impact assessment processes at each stage of the exploration and tenure approval process for resource projects. This was evident, for example, in the limited attention paid to land access and agricultural productivity issues in planning assessment processes (RDA DDSWQ 2011). That concern has now been acknowledged by the Queensland Government in its recently released 'Land Access Policy Framework' and 'Strategic Cropping Land Framework'.

The RDA's well-focused study (RDA DDSWQ 2011) provides a roadmap for many of the issues that need to be addressed on this matter. Like all good policy development it is built on an interaction between policy development and active research in order generate the knowledge and evidence for sound policy action.

Queensland 'Land Access Policy Framework'

The Queensland Government's 'Land Access Policy Framework' (QGDMS 2012) sets out important policy and legislative reforms to foster improved relationships between the agriculture and resources sectors. The policy framework, which was developed with the assistance of the Government's Land Access working group, aims to ensure consistent processes that are clear, fair and reasonable for all parties.

Queensland's land access laws give force to the Policy Framework (QGDMS 2012),

> *... and provide clarity and consistency so both the agricultural and resource sector can co-exist for the benefit of Queensland.*
>
> *The land access laws came into effect in Queensland on 29 October 2010 for the petroleum and gas, greenhouse gas and geothermal energy sectors. Land access laws for the minerals and coal exploration sector will start later this year (2012). This follows passage by the Queensland Parliament on 19 August 2010 following earlier introduction and debate of draft legislation included in the Geothermal Energy Bill 2010.*
>
> *These laws provide landholders with greater protection and security about their rights related to land access by resource companies carrying out activities on their land.*
>
> *They also set out the Government's required standards for conduct and compensation and provide landholders with a clear and consistent framework for negotiated compensation when they are affected by a resource company's activities.*

Key features of the laws (QGDMS 2012)

The laws include:

- a requirement that all resource authority holders comply with a single Land Access Code;
- entry notice requirements for 'preliminary activities', i.e. those that will have no or only a minor impact on landholders;
- a requirement that Conduct and Compensation agreements be negotiated before a company comes onto a landholder's property to undertake advanced activities, i.e. those likely to have a significant impact on a landholder's business or land use;

- a graduated process for negotiation and resolving disputes about agreements which ensure matters are only referred to the Land court as a last resort;
- stronger compliance and enforcement powers for government agencies where breaches of the land access code occur.

Industry transparency (QGDMS 2012)

Additional regulations have been put in place to deliver transparency in the petroleum and gas industry and ensure landholders are kept fully informed about the type and extent of authorised activities conducted on their land.

Companies must give landholders at least 10 business days' written notice before undertaking petroleum and CSG activities on their land. Companies must again notify landholders in writing within 10 business days of completing those activities.

Mandatory notification (QGDMS 2012) applies to the following activities:

- carrying out and completing hydraulic fracturing — notification must include the intended and actual chemicals and volumes used; drilling, completing, altering and abandoning a well or bore;
- carrying out and completing a seismic survey or scientific or technical survey.

Within two months of completing hydraulic fracturing activity, companies must also submit a detailed report to Government that includes the composition of all fraccing fluids used in each well and the potential impacts on water aquifers.

NSW Strategic Regional Land use planning

The NSW Government (NSWRLU 2011) has released a number of draft plans and policies that deliver on its Strategic Regional Land Use Policy to protect high-quality agricultural land and its water sources from inappropriate mining and CSG projects. These plans have been open to public consultation and now sit before government for further deliberation. It is an active area of policy development to meet the social issues outlined above and in particular to protect agricultural land and groundwater aquifers both of which are considered strategic to agriculture and food security.

References

ACIL Tasman (2011) Interim Report to Australian Petroleum Production and Exploration Association-Economic Significance of CSG in NSW by ACIL Tasman , September 2011. http://www.appea.com.au/images/stories/Policy_CSG/nsw%20csg%20stage%201%20report%20vf%2013%209%20 2011.pdf

Allen Consulting (2011) Report to Santos-The economic impacts of developing CSG operations in Northwest NSW by The Allen Consulting Group, December 2011. http://www.allenconsult.com.au/insights.php?s=economic-impacts-of-coal-seam-gas-mining-in-nsw

Anderson B.J. & Theodori (2009). Local Leaders' Perceptions of Energy Development in The Barnett Shale. Southern Rural Sociology, 24(1), 2009, Pp. 113–129. http://www.ag.auburn.edu/auxiliary/srsa/pages/Articles/SRS%202009%2024%201%20113-129.pdf

Capel C. (2011) Report to the Remote Area Planning and Development Board on coal/CSG impacts on Central Western Queensland Longreach Focus Group meeting 13 December 2011. Chris Capel Consulting Longreach, QLD 4730. http://www.rapadskilling.com.au/c/document_library/get_file?p_l_id=602394&folderId=6778090&name=DLFE-79460.pdf

Considine T., Watson R., Entler R. & Sparks J. (2009) An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play, The Pennsylvania State University, College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering, July 24, 2009. http://www.alleghenyconference.org/PDFs/PELMisc/PSUStudyMarcellusShale072409.pdf

Economic Benefits (2012) Queensland Government Web Site: CSG-LNG Industry Home-Economic Benefits. 14 July 2012. http://www.industry.qld.gov.au/lng/economic-benefits.html

Hajkowicz S.A., Heyenga S. & Moffat K. (2011) The relationship between mining and socio-economic well being in Australia's regions. Resources Policy 36, 30–38. http://www.sciencedirect.com/science/article/pii/S0301420710000486

Ivanova G., Rolfe J., Lockie S. & Timmer V. (2006) Assessing social and economic impacts associated with changes in the coal mining industry in the Bowen Basin, Queensland, Australia. Centre for Social Science Research, Central Queensland University, Rockhampton, Australia http://www.bowenbasin.cqu.edu.au/Ivanova%20et%20al%20Mining%20impacts.pdf

Jensen R.C. & West G. (2002) Community Economic Analysis, Department of Primary Industries, QLD Government, Brisbane

Jobs (2012) Queensland Government Web Site: CSG-LNG Industry Home-Jobs and Career. 14 July 2012. http://www.industry.qld.gov.au/lng/jobs-and-careers.html

Kinnaman T.C. (2010) The Economic Impact of Shale Gas Extraction: A Review of Existing Studies, Other Faculty Research and Publications. Paper 5. http://digitalcommons.bucknell.edu/fac_pubs/5

Kinnaman T.C. (2011) The economic impact of shale gas extraction: A review of existing studies, Ecological Economics Volume 70, Issue 7, 15 May 2011, Pages 1243–1249

Local Industry (2012) Queensland Government Web Site-Local Industry Policy for major projects. http://www.business.qld.gov.au/industry/manufacturing/local-industry-policy

MMA (2009) Final Report to Queensland Department of Infrastructure and Planning Queensland LNG Industry Viability and Economic Impact Study 1 May 2009 by McLennan Magasanik and Associates http://www.industry.qld.gov.au/lng/documents/QLD-LNG-industry-viability-economic-impact_2009.pdf

NSW RLU (2011) NSW Government Department of Planning and Infrastruture: Strategic Regional Land Use Policy. http://haveyoursay.nsw.gov.au/regionallanduse

NSWLC (2012) Inquiry into CSG. New South Wales Parliament, Legislative Council. General Purpose Standing Committee No. 5. Report No. 35 (2012). Sydney, NSW. xxi + 330 pp. Available at: http://www.parliament.nsw.gov.au/Prod/parlment/committee.nsf/0/318a94f2301a0b2fca2579f1001419e5/$FILE/Report%2035%20-%20Coal%20seam%20gas.pdf

Petkova V., Lockie S., Rolfe J. & Ivanova G. (2009) Mining Development and Social Impacts on Communities: Bowen Basin Case Studies. Rural Society,19,211-228 http://rsj.e-contentmanagement.com/archives/vol/21/issue/1/article/4413

QGDBI (2012) Queensland Government, Department of Business and Industry. The Surat Future Directions Statement. http://www.industry.qld.gov.au/lng/future-directions-statement.html

QGDDIP (2012) Queensland Government, Department of Development, Infrastructure and Planning. Social Impact Assessment and Social Impact Management plan. http://www.deedi.qld.gov.au/cg/social-impact-assessment.html ; http://www.deedi.qld.gov.au/cg/social-impact-management-plan.html ; http://www.deedi.qld.gov.au/cg/major-project-resource-housing-policy.html

QGDMS (2012) Queensland Government, Department of Mines and Safety: Land access policy framework. http://mines.industry.qld.gov.au/mining/land-access-policy-framework.htm

RDA DDSWQ (2011) Scoping Study – Mining and CSG Development, Parsons Brinckerhoff Australia Pty Limited, Sydney, p. 69. Regional Development Australia: Darling Downs and South West Queensland. http://www.rda-ddsw.org.au/File%20Downloads/RDA%20Scoping%20Study_Mining%20&%20CSG%20Development.pdf

Reeson R.F., Measham T.G. & Hosking K. (2012) Mining activity, income inequality and gender in regional Australia. The Australian Journal of Agricultural and Resource Economics, 56, pp. 302–313. http://onlinelibrary.wiley.com/doi/10.1111/j.1467-8489.2012.00578.x/pdf

Rolfe J., Petkova V., Lockie S. & Ivanova G. (2007b) Mining Impacts and the Development of the Moranbah Township RESEARCH REPORT No 7. Impacts Of The Coal Mining Expansion On Moranbah And Associated Community, June 2007. http://www.bowenbasin.cqu.edu.au/Moranbah%20Final%20Report%207.pdf

Rolfe J., Miles B., Lockie S. & Ivanova G. (2007a) Lessons from the social and economic impacts of the mining boom in the Bowen Basin 2004-2006. Australian Journal of Regional Studies, 13,134-153.

Rolfe J., Gregg D., Ivanova G., Lawrence R. & Rynne D. (2011) The Economic Contribution of the Resources Sector by Regional Areas in Queensland Economic Analysis & Policy, Vol. 41 No. 1, March 2011. http://www.eap-journal.com/archive/v41_i1_11_02-rolfe.pdf

Santos (2011) Santos Submission to NSW Legislative Council General Purpose Standing Committee #5: Inquiry into CSG, September 2011. http://www.santos.com/library/NSW_LegCo_inquiry_CSG_Santos_submission.PDF

Schandl H. & Darbas T. (2008) Surat Basin Scoping Study: Enhancing regional and community capacity for mining and energy driven regional economic development. Report to the Southern Inland Queensland Area Consultative Committee and Australian Government Department of Infrastructure, Transport, Regional Development and Local Government, June 2008, CSIRO Sustainable Ecosystems, Canberra. http://www.csiro.au/files/files/pm7h.pdf

Solomon F., Katz E. & Lovel R. (2008) Social dimensions of mining: Research, policy and practice challenges for the minerals industry in Australia Resources Policy, 33, 142-149. http://www.sciencedirect.com/science/article/pii/S0301420708000251

5. Current legislative frameworks for CSG operations

The current legislative frameworks that govern development of CSG (and shale gas) in Australia operate at:

- federal level — through the Environment Protection & Biodiversity Conservation Act (EPBC Act);
- state level — through state legislation, which varies from state to state; and
- regional level — through Catchment Management Authority (CMA) catchment action plans.

These levels are examined in more detail below and the positives and negatives of each are discussed.

5.1. New South Wales

5.1.1. The existing NSW approach

Figure 5.1 is a simplified description of the approval process currently in operation in NSW. A number of concerns have been raised in regard to sections of the current process and the process in its entirety.

There are concerns about the adequacy of the Regional Evaluation Framework (REF) process for exploration projects of less than five bores, and that it is an insufficient process for the granting of an exploration licence. To date, the requirement to prepare an Environmental Impact Statement (EIS) as a result of the REF has not been triggered (NSWLC 2012).

All other development activities related to CSG operations are dealt with as a 'State Significant Development' (SSD). Developments categorised as SSD are projects considered to have the potential to deliver a significant economic input to the NSW economy, and projects that are large-scale or complex and that may involve significant environmental impact.

The SSD approach overrides the requirement for a project to get concurrent approvals from a range of agencies under other laws. The following authorisations, which would normally act as environmental safeguards, ***are not required*** for SSDs such as CSG projects (EDO 2011):

i. the concurrence under Part 3 of the *Coastal Protection Act 1979* of the Minister administering that Part of that Act;

ii. a permit under section 201, 205 or 219 of the *Fisheries Management Act 1994*;

iii. an approval under Part 4, or an excavation permit under section 139, of the *Heritage Act 1977*;

iv. an Aboriginal heritage impact permit under section 90 of the *National Parks and Wildlife Act 1974*;

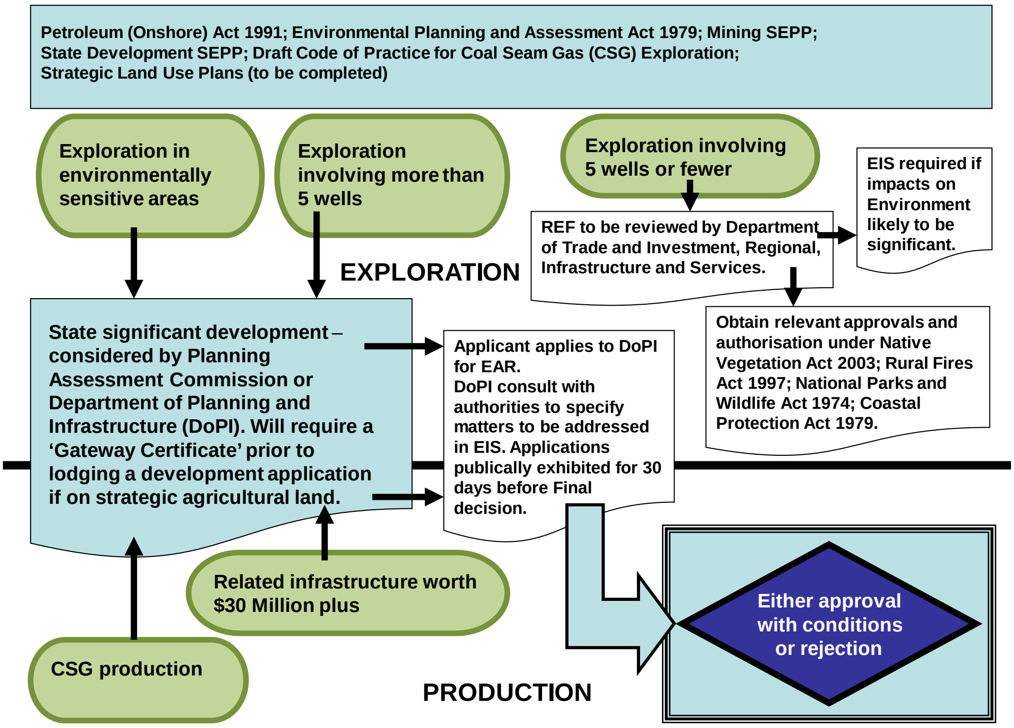


Figure 5.1. Outline of the approval process currently in operation in NSW.

v. an authorisation referred to in section 12 of the *Native Vegetation Act 2003* (or under any Act repealed by that Act) to clear native vegetation or State protected land;

vi. a bush fire safety authority under section 100B of the *Rural Fires Act 1997*;

vii. a water use approval under section 89, a water management work approval under section 90 or an activity approval (other than an aquifer interference approval) under section 91 of the *Water Management Act 2000*.

The following authorisations ***cannot be refused*** if they are necessary for carrying out an SSD that is authorised by a development consent under Part 4, Div. 4.1 (EDO 2011):

i. an aquaculture permit under section 144 of the *Fisheries Management Act 1994*;

ii. an approval under section 15 of the *Mine Subsidence Compensation Act 1961*;

iii. a mining lease under the *Mining Act 1992*;

iv. a production lease under the *Petroleum (Onshore) Act 1991*;

v. an environment protection licence under Chapter 3 of the *Protection of the Environment Operations Act 1997* (for any of the purposes referred to in section 43 of that Act);

vi. a consent under section 138 of the *Roads Act 1993*.

It is of concern that, by using the SSD approach, the largest projects potentially avoid many of the checks and balances in the system.

The NSW Department of Trade and Investment, Regional Infrastructure and Services, as the consent authority, administers the Government's regulation of CSG exploration activities.

Under the provisions of the Protection of the Environment Operations Act, any premises that has the capacity to produce more than five petajoules of gas per annum must hold an environment protection licence. The licences are administered by the EPA (NSW EPA 2012).

There is a new requirement in NSW for certain CSG projects to obtain an 'Aquifer Interference Approval'. This is outlined in the 'Draft NSW Aquifer Interference Policy'(NSW DoPI 2012). The policy requires activities that will intersect an aquifer to obtain an approval. However, certain state-significant mining and CSG developments will be exempt from the need to hold an aquifer interference approval.

Aquifer interference activities may or may not take water from the water source in which they occur. Water extraction activities must hold a licence under the *Water Management Act 2000* or the *Water Act 1912*, this includes extraction of water for dewatering of coal seams.

The NSW Government is planning to roll out Aquifer Interference Approvals under the Water Management Act 2000 with the first stage applying to groundwater that underlies 'Biophysical Strategic Agricultural Land' as defined in the Strategic Regional Land Use Plans. The second stage of the rollout will address aquifer interference in groundwater which does not underlie Biophysical Strategic Agricultural Land.

5.1.2 Strategic land use and cumulative impacts

NSW is trying to take a more strategic approach for the expansion of CSG, through the development of Strategic Regional Land Use Plans across the state.

The 'Gateway process' is the state's key policy response for resolving land-use conflict between mining or CSG proposals and agricultural land. Under this process a panel of independent experts will assess mining or CSG proposals on or within 2 km of strategic agricultural land early in the approvals process to determine their suitability. This Gateway process does not extend to assessing potential impacts on biodiversity, vegetation or surface water. Groundwater and aquifers in general are considered in the process through the Draft NSW Aquifer Interference Policy which must be considered as part of the Gateway process.

Strategic Regional Land Use Plans identify 'Tier 1 biodiversity value' areas. These are areas of terrestrial and aquatic habitat where impacts from coal mining and CSG should be avoided because the identified natural values cannot sustain further significant loss. Any SSD application for coal or CSG proposed to be carried out on Tier 1 biodiversity land, or that impacts on threatened species, populations or ecological communities and waterways, will need to demonstrate that all options to avoid impacts have been properly assessed and that the proposal is not likely to result in the significant permanent or long-term loss of the ecological values present in the terrestrial or aquatic habitats (NSW DoPI 2011).

Strategic Regional Land Use Plans are currently a policy document to be 'considered' but not necessarily acted upon. Although the NSW Government is planning to develop a set of methods for assessing cumulative impacts on ecological values, the lack of this methodology, combined with relative weakness of the requirements of the Strategic Regional Land Use Plans with regard to biodiversity, raise questions about the Plans' usefulness.

Overall, use of Strategic Regional Land Use Plans — and the NSW approach in general — is quite piecemeal and lacks the capacity to manage the development of the CSG industry at an appropriate scale and in a way that delivers positive outcomes, not only for CSG proponents or farmers but for the landscape.

Currently the attempt to address the issue at a strategic level is skewed heavily towards meeting the concerns of a vocal lobby about potential impacts on agricultural land. However, meeting the concerns of this group may not result in strategic decisions for the benefit of the landscape or the broader community.

5.1.3 New approaches

The Namoi CMA has taken a technically robust and holistic approach to make a strategic assessment of the cumulative impacts of CSG and mining. The CMA has been working with Eco Logical Australia to develop a framework for assessing cumulative risks to natural resource assets from mining in the Namoi Catchment (Eco Logical Australia 2011).

In the Namoi catchment area there are large coal reserves and consequently there is significant pressure for additional coal mining as well as CSG extraction. The CMA took a long-term view and recognised that mining had the potential to deliver substantial benefits to the region but also that mining (not just CSG) was a potential threat to the natural resource assets of the catchment.

The challenge for the CMA was to assess not only the impacts of any one mining development on the natural resource assets of the catchment, but also to be able to assess the potentially cumulative impacts of a number of mining developments.

The CMA has a detailed understanding of the natural resource assets of its region through its catchment planning process. The result of this planning process is the Namoi Catchment Action Plan (CAP) which outlines the objectives and targets of the Namoi CMA. This strategic vision for the catchment is the framework inside which a risk assessment process can be undertaken for mining and coal seam gas development.

CMA staff have identified the natural resource asset classes, and the datasets available for each class. These form the basic building blocks for the risk assessment process (Table 5.1).

The framework the CMA developed can assess both the risks associated with an individual project and the cumulative risks of any new project or projects when added to the existing pressures on the natural resources (Figure 5.2).

Using this framework and a GIS modelling tool, the CMA is producing a cumulative risk statement on the individual and cumulative impacts associated with any real or hypothetical mining scenario and lists the potential outputs that the tool would produce for a hypothetical scenario of four new mines in the catchment.

The CMA is also looking at developing the tool so that mining and CSG developers can run a range of scenarios to determine how best to structure their operation to minimise or remove completely, any negative impacts on the natural resource assets of the Namoi Catchment.

Table 5.1: Natural resource assets suitable for risk assessment in Namoi catchment

Theme	Asset	No. datasets (Appendix I)
Land (Agriculture)	Land use	20
	Soil type	17
Biodiversity	Threatened species	15
	Viable populations (connectivity)	5
	Vegetation condition (intactness)	21
	Vegetation extent (cover)	6
	Vegetation type #	8
Water	Groundwater	15
	Surface water	18

includes wetlands and groundwater-dependent ecosystems

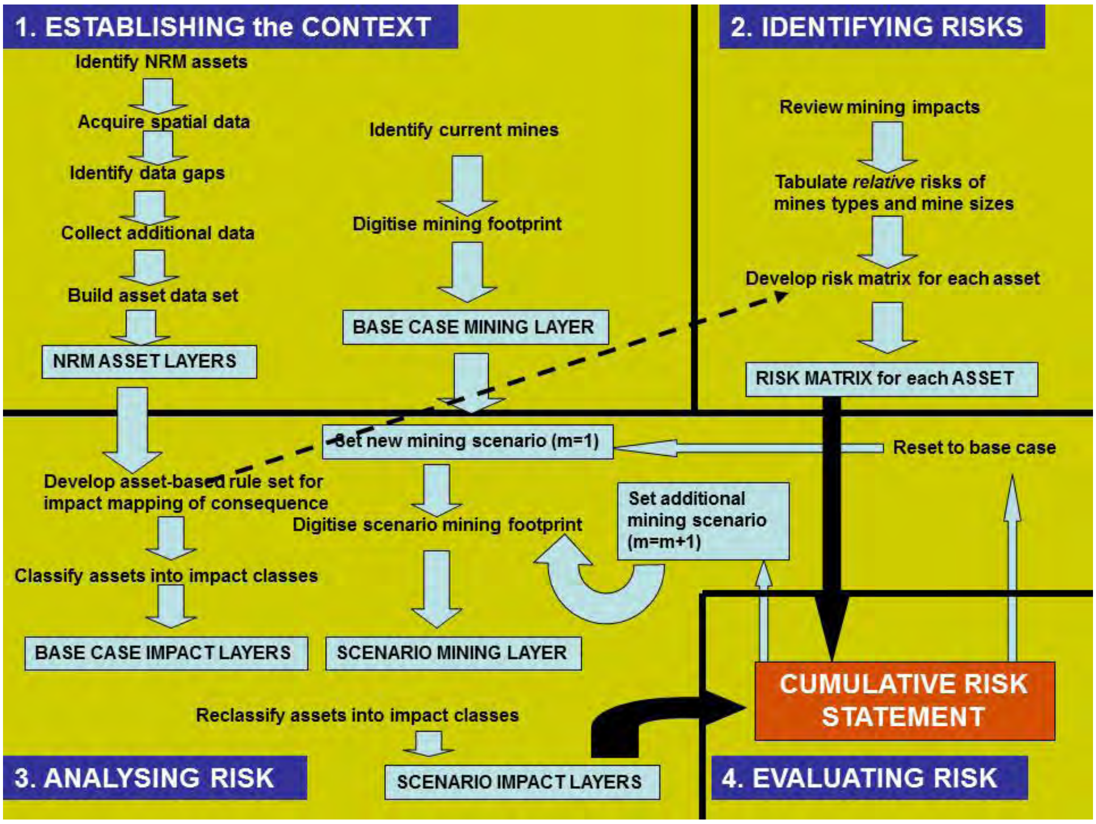


Figure 5.2. Namoi CMA proposed framework for cumulative risk assessment.

5.2. Queensland

Queensland has been wrestling with the challenges of the rapid development of the CSG industry for longer than NSW. Consequently, the legislative framework is further developed. Mining does not need to comply with the planning regime in Queensland because mining is an exempt development under the *Sustainable Planning Act 2009* (EDO Qld 2010).

To deal with the expansion of the CSG industry, Queensland has made changes to legislation to allow for an 'adaptive environmental management regime'. This has included actions such as the transferral of management of groundwater associated with CSG production from the *Petroleum & Gas (Production and Safety) Act 2004* to the *Water Act 2000*.

5.2.1. Environmental assessment and management

Chapter 5A of the *Environmental Protection Act 1994* requires all CSG developments to obtain an environmental authority. CSG activities are classified as either Level 1 or Level 2 based on the risk of environmental harm:

- a Level 2 Chapter 5A activity has a low risk of causing serious environmental harm and therefore cannot be a Level 1 environmentally relevant activity; and
- a Level 1 Chapter 5A activity, under section 309C of the Environment Protection Act, is so prescribed because it has a medium to high risk of causing serious environmental harm (DERM 2011a).

Figure 5.3 outlines the process for assessment of activities classified as Level 1.

Figure 5.3. The process for Level 1 CSG activities in Queensland to obtain an environmental authority

An environmental impact statement (EIS; Figure 5.3) is only required for large-scale projects or 'significant developments'. The EIS process includes public consultation and review, and the resulting EIS report must cover the following areas (DERM 2011b):

- the environmental values (including social and economic);
- the impacts of a proposed development on these values; and
- proposed avoidance, mitigation and offset measures to be used.

As part of the environmental assessment process for applications for an environmental authority, new Level 1 CSG activities are required to develop an environmental management plan. Under existing guidelines the environmental management plan must consider and detail the following criteria:

- impacts on air quality;
- CSG water management, treatment storage and disposal;
- mapping and protection of remnant vegetation and other important areas of habitat for native wildlife;
- nuisance noise impacts;
- impacts on the local communities;
- management and disposal of wastes; and
- a rehabilitation program for any areas disturbed by the proposed activity.

5.2.2. *Adaptive management*

The Queensland Government has taken an adaptive management approach to the environmental management of CSG operations. Existing provisions of the Environmental Protection Act 1994 allow the Department of Environment and Resource Management (DERM) to amend CSG environmental authorisations to protect the environment from unintended impacts (DERM 2011c). There is particular focus on adaptive management of impacts to groundwater.

The Petroleum and Gas (Production and Safety) Act 2004 and *Petroleum Act 1923* authorise holders of petroleum tenures to undertake activities related to the exploration for, and production of, petroleum and gas. This includes the right to take or interfere with groundwater. The Water Act 2000 establishes responsibilities for petroleum-tenure holders to monitor and manage the impacts caused by the exercise of these groundwater rights. They have a responsibility to 'make good' any impairment of private bore-water supplies.

The Queensland Government has recognised that groundwater extraction from multiple gas fields adjacent to each other will have overlapping impacts. Consequently, the government has identified 'Cumulative Management Areas'. Within a Cumulative Management Area, the former Queensland Water Commission is responsible for assessing impacts and establishing integrated management arrangements in an 'Underground Water Impact Report' (CSGW QWC 2012).

In March 2011, the Surat Cumulative Management Area was established. The Queensland Water Commission has prepared a Draft Underground Water Impact Report. On approval, the report becomes a statutory instrument under the Water Act 2000. Obligations for individual petroleum-tenure holders for activities arising from the Underground Water Impact Report will then become legally enforceable.

The Queensland Water Commission developed a regional groundwater flow model to predict the impacts of groundwater extraction by petroleum and gas operations. The model has been peer reviewed and was found to be a sound model that meets national standards for groundwater flow modelling (CSGW QWC 2012).

Criteria and predictions of the regional groundwater flow model

Queensland's regulatory framework requires that predicted water level impacts in aquifers be shown as, 'Immediately Affected Areas' and 'Long-term Affected Areas'. These were combined with trigger thresholds for changes in groundwater levels, the trigger being 5 m for consolidated aquifers (such as sandstones) and 2 m for unconsolidated aquifers (such as sand aquifers). An immediately affected area is the area within which water-level impacts are predicted to exceed the trigger threshold within three years. A long-term affected area is the area within which the impacts are predicted to exceed the trigger threshold at any time in the future.

Within the Surat Cumulative Management Area there are 21,000 private water bores. Of these it is predicted 85 will experience greater than trigger-level water decline within three years (after which they will be classified as 'immediately affected areas') and 528 will experience greater than trigger-level water decline in the long term ('long-term affected areas').

The Queensland regulatory framework requires that, for a bore tapping an aquifer in an 'immediately affected area' for the aquifer, a tenure holder must enter into a 'make good' agreement with the bore owner on approval of the Underground Water Impact Report (CSGW QWC 2012).

The groundwater flow model also identifies that there are 71 spring complexes in the Surat Cumulative Management Area. The Commission has set a nominal value of impact on these complexes of 0.2 m change in water table level. The flow-model report provides no ecological justification for this value, nor any explanation of how it was determined.

The model predicts that this nominal level of 0.2 m will be exceeded at five sites. Tenure holders simply have to "*assess mitigation options at the five sites and report these outcomes to the Queensland Water Commission*" (CSGW QWC 2012).

5.2.3. Regional natural resource management

The Queensland Murray-Darling Committee (QMDC) is the natural resource management body in Queensland with the largest amount of CSG development occurring within its area. The QMDC has developed a policy to address mining and energy industry impacts on natural resources (Todd et al. 2011). The QMDC's policy has been developed over an 18-month time period, and has included stakeholder consultation both within the region and outside it.

The policy identifies the natural resource assets which have the potential to be impacted by mining and CSG development. It also sets target intentions for these assets in the region's Natural Resource Management Plans. The document then outlines a set of policy statements for each of the assets. For example, for vegetation and biodiversity:

- *Prevent adverse impacts from the mining and energy industry on landscape functions of native vegetation coverage, ecosystem linkages, ecological processes and biodiversity condition in the Queensland Murray-Darling Basin.*
- *Manage the cumulative impact across the Queensland Murray-Darling Basin to vegetation and biodiversity assets from individual site activities by:*
  > *appropriate planning and design at a local and landscape level, to avoid unnecessary clearing causing fragmentation or loss of habitat; and*
  > *requirement to offset using native vegetation within the local area to cause no cumulative impact (or no net loss) in the Queensland Murray-Darling Basin.*

As that example shows, the policy sentiments of the document are relevant and important. However, it is unclear how these are to be translated into actions. The document provides no framework for linking the policies to the legislative requirements placed on CSG proponents. Nor does it explain how the policies are integrated into the planning system.

If the policies of the QMDC are not being integrated into the legislative requirements placed on CSG developers, it is difficult to see how the region's natural resource objectives will be factored into the approvals process in any more than a superficial way.

5.2.4. Landscape planning

The Queensland Government has no mechanism for dealing with CSG at a landscape scale across all asset classes, despite its detailed approvals process and cumulative impacts model for groundwater, and despite regional NRM organisations developing relevant policies.

Although CSG operations' effects on groundwater are addressed at a regional scale, it is not clear how the regional NRM objectives with regard to groundwater have been considered in the determination of the acceptability of impacts.

Surface water, vegetation, biodiversity and agricultural land are all considered through the EIS and environmental plan process by each CSG project proponent, but it is not clear how these issues are being managed at a landscape and cumulative level to ensure natural resource management objectives of the region are achieved.

5.3 Federal Government involvement in CSG

The Australian Government becomes involved in the licensing and regulation of a CSG project when the project has the potential to have an impact on matters protected under national environment law. Examples include nationally threatened and migratory species, wetlands of international importance, and national or world heritage places (SEWPaC 2012).

Relevant projects must undergo an environmental assessment to determine whether their likely impacts are acceptable under the legislation. The assessment process under national environment law includes opportunities for public comment.

When deciding whether to approve CSG projects under national environment law, the Environment Minister must consider likely significant impacts on matters protected under national environment law. The Minister must also consider economic and social matters and the principles of ecologically sustainable development. In assessing CSG proposals, the Minister may consider cumulative impacts, but is not required to.

If an approval is granted, environmental conditions are usually attached, as an attempt to minimise environmental impacts. State/Territory conditions are also considered in the development of federal conditions.

The Federal Government is investing $150 million over five years in a new Independent Expert Scientific Committee. As outlined in Chapter 3, the Committee is tasked with providing scientific advice to governments about relevant CSG and large coal mining operations where they have significant impacts on water. It is proposed that the Committee will commission bioregional assessments, and research into the impacts of CSG and coal-mine developments on water resources and methods for minimising those impacts.

A new National Partnership Agreement is being developed with the states through COAG. It agrees that the Commonwealth and states have to take into account the advice of the Committee in their assessment and approval decisions. A further $50 million will be provided in incentive payments to the states to deliver this outcome.

According to the Federal Environment Minister Tony Burke, the establishment of the Committee aims to ensure that robust, independent scientific evidence is available to all governments when they consider applications which potentially have direct or indirect impacts on water resources.

> *Under the agreement, signatory governments to the National Partnership Agreement are required to seek the committee's advice when considering approvals for CSG and large coal mining developments which are likely to have direct or indirect impacts on water resources. (Burke 2012)*

References

Burke T. (2012) Coal Seam Gas Expert Scientific Committee legislation introduced, media release. Tony Burke MP. http://www.environment.gov.au/minister/burke/2012/mr20120322.html

CSGW QWC (2012). Draft Underground Water Impact Report, Surat Cumulative Management Area Consultation Draft. Coal Seam Gas Water, Queensland Water Commission.

DERM (2011a) Information Sheet Environmental Protection Act 1994. Queensland Government Department of Environment and Resource Management.

DERM (2011b) Environmental assessment and management of coal seam gas developments. Queensland Government Department of Environment and Resource Management.

DERM (2011c) Adaptive environmental management regime for the coal seam gas industry. Queensland Government Department of Environment and Resource Management.

Eco Logical Australia (2011) Proposed Framework for Assessing the Cumulative Risk of Mining on Natural Resource Assets in the Namoi Catchment. Project 11COFNRM-0006 prepared for Namoi CMA. September 2011.

EDO (2011) Submission to NSW Legislative Council Inquiry into Coal Seam Gas. Environmental Defenders Office Ltd, Sydney 2011.

EDO Qld (2010) Mining and Coal Seam Gas. Environmental Defenders Office Queensland, October 2010.

NSW DoPI (2011) Draft Strategic Regional Land Use Plan, New England North West. NSW Government Department of Planning and Infrastructure.

NSW DoPI (2012) Draft NSW Aquifer Interference Policy — Stage 1. NSW Government Department of Trade and Investment, Regional Infrastructure and Services, 2012.

NSW EPA (2012) http://www.environment.nsw.gov.au/licensing/coalseamgas.htm

NSWLC (2012) Inquiry into coal seam gas. New South Wales. Parliament. Legislative Council General Purpose Standing Committee No.5. Sydney N.S.W. xxi+330 pages (Report No 35)

SEWPaC (2012) http://www.environment.gov.au/epbc/coal-seam-gas/index.html

Todd L., Fletcher K. and Penton G. (2011) QMDC Policy Document: Mining and energy industry impacts on natural resources in the Queensland Murray-Darling Basin. Queensland Murray-Darling Committee Inc., Toowoomba.

6. Ways forward for governance of the CSG industry in Australia

Before we can understand what additional knowledge is needed to make the best possible decisions on the development of coal seam gas (CSG) we must decide what the overall approach for managing CSG development should be.

There are two options. The first option, and the one we currently use, is a laborious approval process focused on localised impacts. The second option is to start with an understanding of the landscape, how it functions (water, land, biodiversity and vegetation) and the limits to it functioning effectively.

The first option 'considers' multiple policies, regional plans and the inputs of expert panels and commissioners. Although complex, these processes are geographically limited and the issues considered are isolated. Furthermore, the developments are not subsequently assessed in terms of the additional impacts they will have on an already degraded landscape and how it functions.

At the end of the approvals process, the Minister or a bureaucrat makes a decision based on this information and the politics of the moment.

Australia has been using this approach, and much less, to make decisions for a long time and we continue to lose our landscapes and their function. If we use it to manage CSG development we will continue to fail.

The second option — an ideal that we do not yet use in Australia —would start with an understanding of the landscape and its function (interactions of water, land, biodiversity and vegetation), and the limits to it functioning effectively.

Overlying this would be an understanding of the level of function society wants from that landscape. Do we want near-pristine landscapes with a high level of function? Do we want a working landscape where there is industry development that stays within the functional limits? Or do we want a situation where development extends past these limits so the function of the landscape degrades to collapse?

It is more than likely that this third scenario would deliver a huge financial gain for some, but mean that future generations have to pay for it.

With these parameters clearly set, decisions could then be made about whether the landscape can accommodate further development and retain the desired level of function or if there must be a trade-off with another land use. Decisions about trade-offs would be based on the costs and benefits to society.

This second option challenges us to clarify the future we want and forces society to make hard decisions about how to make best use of the landscape capacity available. The first option 'pretends' to consider the health of our landscapes but leads to the constant erosion of landscape function.

6.1. Coal seam gas

Development of CSG should be treated no differently from any other activity that creates wealth with subsequent impacts on the landscape and the potential to reduce its function.

Historically, and even today, agriculture has had a significant effect on the health and function of Australia's landscapes. The development of towns and cities has had a significant effect on the health and function of Australia's landscapes. Mining in general and CSG in particular are no different to these other impacts. They are merely the next human assault on the health and function of the landscape.

It is up to our society to decide at what point the degradation should stop; at what point we say "Enough!".

In making that decision, society must understand that the environment is not limitless and that a certain level of landscape health and function must be maintained if we are to maintain our society.

Therefore, it is very short-sighted of society to try and manage the potential impacts of CSG on the landscape through specific legislation without integrating CSG policies and management with those already in place for agriculture and urban development.

For example, it might be the case that the return on investment for a CSG development is significantly higher than for an existing irrigation development — therefore the CSG operations might result in less degradation of the landscape and may well be a better use of the landscape's capacity.

Governments have made some attempts to adopt more strategic approaches, but the attempts are piecemeal and the approaches generally consist of 'consideration' and approval with conditions. Further, the approval process is generally based on assessment undertaken by the CSG project proponent.

Geoscience Australia, in advice to the Federal Government, stated that cumulative impacts assessments by project proponents are "*unavoidably inadequate because of the inability of individual proponents to access commercial-in-confidence data from a number of sources*" (Habermehl 2010).

The impacts referred to in that statement (Habermehl 2010) specifically relate to groundwater, but the principle expressed could be applied to all other natural resource assets and the proponents of all other projects that have the potential to degrade natural resource assets and, subsequently, landscape function.

In preparing the present report, the authors have found only one piece of work — that of the Namoi Catchment Management Authority (CMA) —that is attempting to build a framework and model tool to assess proposed CSG and mining developments against the capacity of the landscape and the catchment community's landscape function objectives. At the time of writing, the Namoi tool was still under development and required additional information to become functional.

A bigger concern is that currently the CMA has no legislative power to use the outputs of this tool to guide decisions on development within the catchment.

The NSW Government has indicated that their Strategic Regional Land Use Plans will provide a strategic approach for assessing CSG operations. However, an analysis of a draft plan for the New England North West (NSW DoPI 2012) shows it to be big on rhetoric but light on technical content. It has a focus on agricultural land and groundwater. Ultimately

these Plans will only need to be 'considered' in the approval process — and that situation raises questions about their true value.

6.2. Knowledge needs

We already have much of the knowledge we need to make good decisions. Success will depend on whether or not we choose to use that knowledge, and how we value it against the opinions of vested interests, whatever side of the debate they are on.

The three main areas where additional knowledge would be helpful are:

i. physical — what are the limits to landscape function?;

ii. social and economic —what use of landscape capacity is best for society, and how do we decide?; and

iii. legislative — why is the current approach apparently not effective and what would the legislation of a new approach look like?

Each of these areas is looked at in brief detail below.

(i) Physical knowledge

The model development underway in the Namoi catchment appears to be at the very cutting-edge of knowledge in this area. Relatively speaking, the Namoi catchment is information-rich, and data and understanding about it are increasing over time. The Namoi Catchment Water Study, currently underway, will soon be the latest addition to knowledge in that region. However, even in the Namoi, the CMA has identified areas where more information is needed: for example, the most recent vegetation data; predicted distributions of threatened species; effective habitat and connectivity; vegetation condition; and the current mining footprint.

Not all regions are as well understood as the Namoi, and there are knowledge gaps that will need to be filled-in so that landscape function and its limits in each region are sufficiently well-understood for effective assessments of new development.

This knowledge does not need to be exhaustive before it can be used, and it will continue to develop over time. However, it must be a collection of the best available knowledge relevant to understanding the limits of landscape function as well as the potential cumulative impacts of existing developments and proposed new developments.

Physical knowledge of landscape limits and function must also be integrated into a social and economic context.

(ii) Social and economic knowledge

It may be that society decides that, even when the physical limits are understood, the economic return in the short term is such that these limits should be exceeded and the consequences suffered.

If society chooses to operate above the limits of landscape function, then social and economic knowledge will be necessary for making the decisions about the best use of the available landscape capacity before limits are exceeded.

(ii) Legislative knowledge

The legislative framework is currently extremely complex, with multiple Acts operating at varying levels and scales. This complexity increases the chances of the system being abused, and of a push to cut 'green tape' — with the possible outcome being further compromise of

landscape function. The complexity also can potentially distort the economics of different developments and result in perverse outcomes when it comes to effective use of resources.

The present report has gone some way in trying to unravel the existing legislative processes as they relate to CSG operations. However, more comprehensive work to identify the overlaps and gaps in the current systems could be useful.

It would be useful to look at developing a legislative framework based on a landscape-function approach. This would be an area for innovative work which, if done effectively, could lead to a much more efficient legislative framework that would be much clearer for developers and also ensure that landscape function is maintained and its limits not compromised.

References

Habermehl M.A. (2010) Summary Of Advice In Relation To The Potential Impacts Of Coal Seam Gas Extraction In The Surat And Bowen Basins, Queensland Phase One Report Summary For Australian Government Department Of Sustainability, Environment, Water, Population And Communities provided by Geoscience Australia and Dr M.A. Habermehl, Canberra, 29 September 2010. http://www.environment.gov.au/epbc/notices/pubs/gladstone-ga-report.pdf

NSW DoPI (2012) Draft Strategic Regional Land Use Plan, New England North West. NSW Government Department of Planning and Infrastructure.

7. Conclusions, options and recommendations for the future

The development of coal seam gas (CSG) is a hot topic in Australia at the moment. It is regularly in the news and the political debate. Consequently there is now a wealth of information available on the topic, published by groups from all sides. The information ranges from technical and scientific to opinion and propaganda, and includes everything in between.

The authors of the present report have attempted, within tight constraints of time and budget, to collect the facts from that huge amount of material and bring them all together in one place in a digestible form. Inevitably some points will have been missed, but this report condenses a great deal of information and analysis into its pages.

The conclusions and recommendations of this analysis are outlined below.

Conclusion 1. In principle, CSG production is no different to any other productive land use within a landscape

Managing the production of CSG, an unconventional gas, is essentially another part of managing the whole landscape. It is one more demand on the landscape, competing with production of energy, water, food, fibre, minerals, and human settlement, and with the need to maintain biodiversity to underpin the ecological functioning of the landscape itself.

Fundamentally, CSG production is no different to any other development of our landscapes. Like them, it poses risks to the condition of the water, soil, vegetation and biodiversity, and has the potential to reduce the capacity of our natural resources to supply human, as well as ecological, needs.

It is important to see CSG operations in this context. The potential impacts of CSG could be significantly less than the impacts and degradation already experienced as a result of agricultural and urban development over the past two centuries in Australia.

The challenge for CSG proponents is that this relatively new industry is arriving on the scene when landscapes are already degraded and highly developed. In the industry's favour, however, is its potential to deliver economic growth and wealth for companies and individuals, as well as tax revenue for governments.

In the current legislative and planning frameworks, it is more than likely that a compromise will be found to enable CSG production to fit in with all the other activities that are degrading the landscape. Where it encroaches on an existing activity it is likely that a solution will be found which allows the two activities to continue. Where no solution can be found, a decision will be made allowing one land use to preclude or compromise the other land use now and into the future.

Ultimately, under existing government approaches, the cost of this new industry to society will be further loss of landscape function. That raises some important high level questions, including these:

- Are we playing a dangerous game when we do not understand the limits to landscape degradation?

- At what point will we degrade the landscape and reduce its function so much that there is a collapse?
- Do we understand the impacts for our society if this happens, and who loses?

Do we want degraded and collapsing landscapes? If the answer is “Yes” then we appear to be well on the way. If the answer is “No” then we need to seriously reconsider and re-think how we make decisions about how we use our landscapes.

An analogy is the challenge of getting the groceries home with a single plastic bag. There is a temptation to just continue stuffing groceries into the bag. However, an overloaded plastic bag will always tear at the most inopportune time, spilling your groceries everywhere. The bag is now useless and you cannot get your groceries home.

A better approach would be, first, to determine the limit to capacity of the plastic bag, and then to make a decision about which groceries you could fit into the bag without it breaking. That decision might mean you do not get all the groceries you would like. However, it will mean you get the most important groceries home.

On different trips you might decide you wanted a different mix of groceries, but you would always make sure your total groceries for the trip were within the limits of what the plastic bag could carry without tearing and losing its function.

Managing our landscapes should be no different to the approach we take to managing our plastic bag.

First, understand the limits of the landscape, and then make decisions about what is the best mix of land uses that can be contained within those limits. At different times we may prefer a different mix of land uses, but the mix must stay within the limits. Just like the grocery choice, land-use choice should be made using social and economic analysis once the limits to the capacity of the landscape are understood. If, instead, we do the social and economic analysis first rather than the landscape analysis — that is, before we understand the limits of the plastic bag or landscape — then it is unlikely we will stay within the limits. Our history shows that in the past we have not.

Conclusion 2. Need for effective strategic regional planning and governance

A primary way forward is to explore robust strategic regional planning as one possible governance mechanism that could assist Australians to prepare for an orderly expansion of the exploration and development of CSG.

From any understanding of how the Australian landscape functions, and knowing the underlying capacity of natural systems to support a desired set of values, it is possible to use principles of ‘integrated catchment (or watershed) management’ to create a mosaic of appropriate land uses.

Put another way, it is possible and desirable to use our knowledge of landscape process to work out, upfront, where we can safely mine and where mining would compromise agriculture, water resources , biodiversity, other land uses and landscape environmental function.

It is clear that producing energy from CSG or other unconventional gases has the potential to put at risk the function and value of key long-term renewable natural resources assets and uses such as:

- water resources and aquatic ecosystems;
- agricultural land use, and thus food and fibre production;
- biodiversity and landscape function via vegetation and habitat management.

It is folly to secure one natural resource while putting at risk renewable long-term resource use. The need is paramount for:

- knowledge-based long-term regional strategic land-use planning to avoid perverse outcomes;
- recognition that an Environmental Impact Statements approach alone cannot deal with the cumulative impacts of multiple developments in a region; this current approach leads to 'death by 1000 cuts'! ;
- non-statutory strategic regional and landscape planning to inform and bind statutory planning.

Good strategic regional and catchment action planning, such as the NSW and Victorian Catchment Management Authorities (CMAs) are doing, incorporates frameworks and models that can be built upon to take us into a better future.

The Namoi CMA in NSW is developing a tool that will make it possible to determine the impacts of the existing activities in the landscape and the cumulative impacts of these activities and any new activities proposed for the region (Eco Logical 2011). To use the tool, the CMA applies some predetermined parameters to the model to see if there is capacity in the landscape for the proposed development or not.

This framework is predominantly focused on new mining and CSG proposals in the Namoi catchment, but it could be adjusted to include the impacts of any proposed development in its analysis.

This work by the CMA shows that it is possible to apply an approach that starts with landscape capacity and then looks at what activities can fit within that capacity without compromising limits.

Recommendation 1: The approach used for assessing CSG developments (and any other developments) should be, first, to understand regional landscape capacity, and then to determine if there is capacity for the development without crossing landscape limits.

Unfortunately the current legislative arrangements in NSW mean that the outputs of the Namoi CMA tool will have no legislative power. The existing legislative arrangements in NSW and Queensland and federally do not use an assessment of regional landscape capacity and landscape limits to determine what developments should proceed.

In Queensland an attempt has been made to use landscape limits in the Surat Cumulative Management Area. The policy focuses only on groundwater, setting limits for changes to water levels in private groundwater bores as well as in groundwater springs. However, these limits are only triggers at which the CSG proponent must take action; they do not absolutely limit the impacts.

Using the plastic shopping bag analogy again, our current approval process for development individually assesses each grocery item to decide if it is likely to tear the plastic shopping bag. A carton of milk will not tear a plastic bag; neither will a carton of juice, nor a tub of ice cream. However, a carton of milk, a carton of juice and a tub of ice cream together are likely to tear the bag. Unfortunately, in our current approvals process we are struggling to move from assessing the impacts of the individual items to assessing the cumulative impacts of the whole. We also do not include an understanding and articulation of the limits in our approvals process.

It would seem the average shopper is well ahead of governments in ability to determine limits, assess impacts and make decisions.

Recommendation 2: Current development approval processes should be updated to approve new developments only on the basis of landscape limits and the expected cumulative impacts of the existing and proposed developments.

The discussion below, of the potential impacts of CSG development on parts of the landscape, provides further support for this high-level approach.

7.1. CSG production and the protection of water resources and aquatic ecosystems

There is a great deal of work in Australia becoming available on the subject of CSG and protection of water resources.

7.1.1. Scientific leadership

Following an early report by National Water Commission it became increasingly clear that the potential impacts it flagged, of CSG on water resources, had substance and were a focus of much public concern. The establishment of the Interim Independent Expert Scientific Committee on CSG and Coal Mining, under a COAG national partnership agreement, was in large part a governmental response to this public concern. That body replaces an earlier expert panel, The Water Group, which advised the Australian government with respect to three CSG developments and their implications to the Environment Protection and Biodiversity Conservation (EPBC) Act.

The new Independent Expert Scientific Committee on CSG and Coal Mining (IESC) is a $150 million commitment by the Federal Government that will provide advice to the Federal Environment Minister and other decision-makers about all CSG and large coal mining developments in Australia that are likely to have a significant impact on water resources.

The Committee seeks to ensure that future decisions about the potential water-related impacts of CSG and large coal-mining activities are informed by substantially improved science and independent expert advice. It has three key roles:

- providing advice to governments on CSG and coal mining projects;
- overseeing bioregional assessments in areas where CSG and/or large coal mining developments are underway or planned;
- overseeing research on potential water-related impacts of CSG and/or large coal mining developments.

This initiative, and the fact that the committee was established under a COAG national partnership agreement on CSG and large coal-mining development, represents a significant step forward in science-based protection of water resources. The initiative in its early days has given attention to providing short-term formal advice with respect to the Commonwealth EPBC Act. However, it is the bioregional assessments and the research and development activities that will build knowledge and capacity to provide society with increased certainty of potential impacts of CSG production on water resources.

Of critical importance will be how relationships and a formal nexus might be built between the work of the Committee (IIESC 2012) and that of the relevant NSW and Queensland government bodies. Particularly valuable will be links with those governments' regulatory processes around their respective mechanisms for Strategic Land Use Planning (NSWG 2012) and Strategic Cropping Land Assessment (QG 2011).

Every effort should be made to build and evolve COAG partnership agreements such as this one, so that knowledge can be assembled to guide effective regional strategic planning.

To take us forward from a piece-by-piece approval mechanism, regional strategic planning needs to be proactive and have the capacity to inform statutory processes while using whole-of–landscape analysis frameworks (e.g. Eco Logical 2011).

7.1.2. Scientific knowledge

To address these issues, hydrogeological knowledge will need to develop considerably in predictive capacity based on geological field data. It is particularly important to increase data collection and data exchange between industry, research and policy institutions. There will be a need to expand monitoring, but equally — and in some instances more — important that analysis and evaluation receive a great deal of attention.

The following issues with respect to CSG production and water resources must receive attention.

Water extraction to de-pressurise coal seams, and the impacts of subsequent water pressure changes on water movement to and from freshwater aquifers located in other strata of the geological basin.

- One of the most contentious issues around CSG is its demand for water, and what impact this might have on the aquifers of the Great Artesian Basin (GAB). For the current level of CSG development in the GAB, the Water Group estimated overall extraction will be 10.2–1,500 GL/year with a most likely range of 468–914GL/year.

  The large amount of water and the large range of the estimates are excellent grounds for applying a precautionary approach. Clearly science needs to be applied carefully to reduce this high level of uncertainty.

- It is recognised that dewatering to relieve the water pressure in coal seams will affect the water pressures of freshwater aquifers located in associated formations of the geological basin or entity. The response times and magnitudes of the effects on water pressures will vary depending on spatial relationships and the hydrological characteristics of the aquifers and aquitards (impermeable formations) which make up the geological basin or entity.

  Hydrogeological models (e.g. Santos 2010), coupled with adequate field measurement of hydrological properties and field observation of water pressures, will help in predicting how coal-seam dewatering will influence associated groundwater systems. This is an area where there is great scope for science and engineering to be funded to give increased certainty.

Replacement of the extracted water in coal seams once gas production has ceased. The water originally extracted is likely to have been disposed of or used, and must be replaced by some redistribution mechanism. Re-injection is one option.

- How dewatered and degassed coal seams will be recharged with water, and from what entry point, is a topic that has received little attention. Yet natural recharge of the coal seam with water will inevitably occur by some process. The likely roles of nearby aquifers in the recharging process need to be understood. If we understand how the water entered the coal seam originally, and the coal seams water balance, that knowledge will be valuable in working out how to manage the coal seam hydrology at the end of the life of a gas well.
- The knowledge gained for the previous dot point will also be important in any robust understanding of how industry can fulfil its obligations under the 'make good'

(QWC 2012) provisions of the Queensland Water Act 2000. The Act gives petroleum-tenure holders the responsibility of monitoring and managing the impacts caused by the exercise of their water rights. That includes a responsibility to 'make good' any impairment of private bore-water supplies.

Disposal of the extracted water and salt and other chemical entities liberated from coal and other geological fabric during the dewatering process.

- Water management is central to CSG extraction. The water extracted with the gas from the coal seam is usually saline and alkaline, and can have many chemical entities present depending on geochemistry of the formations. Whilst solutions are rapidly developing to enable beneficial use of this water once treated, a major challenge is how to dispose of the large amounts of salt and associated chemical which must accumulate as water treatment proceeds. The amounts of salt are usually large and can often be 100 kg of salt per day for a well delivering 20,000 L of water per day. Salt disposal problems await resolution (QEHP 2012).
- The disposal of often large volumes of treated water into creeks and streams needs continued attention. Natural flow regimes can be strongly perturbed, and in extreme instances ephemeral streams will be turned into permanent streams with significant ecological impacts. Regulations set permissible concentrations for constituents of the stream water after the influx of treated water. Characteristics of the mixing of the treated water in the stream will affect the spatial variability of water temperature and concentrations of components such as oxygen and minerals, which can be very important to aquatic ecosystems. These matters are still matters of concern.

The containment, management and disposal of fraccing fluids. Management of fraccing fluids and any resultant contamination is a high profile issue with the general public. The public disclosure of all chemicals used in fraccing is essential, and currently is required in both NSW and Queensland. Water management plans are required to ensure that fraccing fluids are stored in a way that avoids spills and surface contamination. The resolution of a regulatory framework on this matter is evolving, and public concern remains high.

7.2. CSG production and the protection of biodiversity and landscape function via vegetation and habitat management

Fragmentation and loss of native vegetation resulting from the considerable surface footprint of CSG infrastructure represent a serious threat to biodiversity, threatened species and landscape function.

Evidence from CSG developments to date indicates that severe negative effects are possible. Potential impacts include direct clearing of bushland, fragmentation of important remnant vegetation, spread of invasive species and increased fire risk.

The Native Vegetation Acts in both NSW and Queensland deal well with issues of clearing of native vegetation; however, overall, CSG operations are exempt from these Acts.

If there is a particular threat to threatened species, then the Commonwealth EPBC Act can be bought to bear, as can the State threatened species legislation. Unfortunately these Acts do not easily deal with broad-scale fragmentation and loss of habitat.

These potential effects arise from installation of closely spaced wellhead infrastructure, access roads and pipelines, which could have major impacts on natural resources in some areas. The resulting fragmentation may be a serious threatening process to overall

landscape function, particularly in landscapes that have already received extensive clearing. It can have very large impacts on biodiversity and landscape function, and is yet to be dealt with adequately in the policy and regulatory environments of either State or Commonwealth legislation.

Landscape function and biodiversity appear to not be primary concerns in the regional strategic land-use planning mechanisms of either NSW or Queensland. This is a major environmental and natural resource issue and it has not received much attention in terms of public debate or government–industry discussions.

The cumulative impact of these surface installations is critical and requires careful consideration and attention. It can best be addressed by our recommendations to use tools such as that under use and development in the Namoi CMA (Eco Logical 2011).

7.3. CSG production and protection of agricultural and forestry land uses for food, fibre production and carbon sequestration

The public debate on CSG has often focused on concerns that CSG activities could affect food production through threats to surface and groundwater and loss of strategic agricultural land. A balanced coexistence of mining and agriculture is possible, but requires careful management. For this reason, good bioregional planning and assessment is an absolutely fundamental issue that requires priority attention.

Clearly the loss of agricultural land for intensive cropping and horticulture is a primary issue, and both NSW and Queensland have formulated responses through their regional Strategic Land Use State Planning Policy under the *Sustainable Planning Act 2009* and the *Strategic Cropping Land Act 2011*, respectively. Protection of Queensland's strategic cropping land has commenced.

Will these approaches work to provide protection for agriculture where CSG development cannot coexist with agriculture and food production? Will governments establish 'no go' zones for CSG development?

If so, as discussed above, similar protection responses for biodiversity, habitat and landscape ecological function are also required.

Clearly there will be some forms of agriculture where coexistence with CSG production will work better than others. Extensive grazing appears to be one of these. In other circumstances coexistence is not possible.

Will 'balanced coexistence' between resource development, agricultural production and environmental protection actually work? Or will CSG development be able to over-ride the processes?

An early assessment by Namoi CMA of the findings of the NSW Government land-use planning mechanisms and the CMA's cumulative risk assessment tool (Eco Logical 2011) suggest there are significant differences in outcomes. The CMA tool makes a fuller examination of the multiple issues than does the traditional approach used in NSW Regional Strategic Land Use Planning.

CSG projects will always be competing for land, water and infrastructure with other resource development projects, agricultural uses and urban needs. We therefore conclude, as we do for biodiversity protection, that for all development within a landscape it is essential to establish only those landscape activities that appear to allow the landscape to maintain its function indefinitely.

An examination of cumulative impact is essential (NC EDO TEC 2012) and requires careful consideration and priority attention. It can best be addressed by our recommendations to use tools such as the prototype of the Namoi CMA.

It is encouraging to note that the NSW Government is now calling for new work to be done in the design and utilisation of Cumulative Impact Assessment Methodologies as part of future planning tools.

7.4. Fugitive leaks of methane in CSG production and its place in climate-change mitigation policy

In our view, an important matter for further research and careful analysis is the role of unconventional gas development in national and global climate-change policies.

Methane leakage from unconventional gas installations can potentially contribute markedly to greenhouse gas concentrations in the atmosphere. It is therefore critical that policy discussions consider the role of unconventional gas in climate-change mitigation.

In addition, whole-of-system analyses to date have rarely been sufficiently comprehensive to address the complexity of a transition from coal-fired to CSG-fired systems. This remains a matter for scientific debate because of uncertainty over the potential benefits or otherwise.

Recent work (Hou et al. 2012) on whole-of-life energy analysis illustrates that unconventional gas production and its role in climate-change mitigation is subject to strong interactions, both positive and negative, with water resource use and management. There are strong links between gas energy production, water resource utilisation, food production and maintenance of landscape biodiversity.

We conclude that clarification of the science and engineering involved in determining how unconventional gas production sits within climate change policy is of increasing importance.

7.5. Analysis of economic impact of CSG production

The evidence on the economic benefits of the CSG industry is contested. Industry economic modelling (e.g. Santos 2011) has suggested that the CSG industry could deliver thousands of new jobs and billions of dollars in investment to regional areas, and generate billions of dollars in royalties. However, some regional and local communities considered that the industry's economic benefits have been overstated. In public debate, differences in opinion about CSG arise partly from different perceptions of how the economic benefit is or should be distributed between state capital, regional centre and local community.

A brief examination of the economic modelling suggests that, indeed, a growing CSG industry in Queensland and New South Wales has the potential to deliver significant economic benefits to the state and to the nation. As expected the magnitude of the predicted benefit is dependent on the reliability of the estimates of size and rate of expansion of the CSG infrastructure, and on the income streams from local gas consumption and the export of LNG. The distribution of the economic benefit can be strongly skewed towards benefits accruing to capital centres and large centres, with many of the costs and social impacts falling on small regional and local communities. There appears, however, to be some scope to mediate how the economic benefits and costs are distributed depending on how the development of the industry is governed, managed and supported by good public policy.

From input–output modelling, it appears that CSG operations are a 'zero-sum game' with respect to employment and in their economic effects on upstream and down-stream

industries. Under this model's assumptions, employment gain in one area of the economy will balance a loss in other areas — and also a growth in jobs in the industries associated with CSG operations will be balanced by job losses in other industries. At state level, it appears that gains in production in consumer-oriented industries and the industries upstream to the oil and gas sector more than offset the losses in production in other trade-exposed industries.

These economic modelling results demonstrate impacts consistent with the development of a two-speed economy particularly in Queensland. Clearly it is an issue that needs attention and management.

Our review of literature on the economics of CSG operations finds that there needs to be further economic analysis of CSG impacts, using powerful modelling tools and realistic sets of assumptions. It is important that there be further research, peer review, and publication of these analyses, so that the economic impacts can be fully understood in all of their complexity.

If sound independent economic analyses are used as bases for public policy and management of programs, the opportunities presented by CSG can be optimised to yield sustainable economic and social benefit.

Insights from economic analysis show how potential benefits can flow into the community and local business. For instance, the size of the economic multiplier in a local or regional area will largely depend on:

- the extent to which project operators purchase inputs from the local or regional economy; the more goods and services that a CSG project operator sources from the local or regional economy, the more money that is directly injected into the economy;
- the extent to which money spent in a local or regional economy is retained within that economy; if there is not much opportunity for people receiving income to spend it on goods and services in their local or regional area, then not as much money will be kept in the local or regional area; larger and more diverse regional economies tend to be better at keeping expenditures within their economy and not 'losing' them to other regions.

These principles are contributing to policy and legislation options as reflected in for example *Queensland Industry Participation Policy Act 2011* which seeks to ensure that key industry participation principles are put into practice by successive governments. The Act details how local companies will be given a fair go when tendering for work on major government or government/private sector partnership projects. For the private sector, an Industry Capability Network has been established to help increase Australian, regional and local companies' share in the wealth-generating opportunities from CSG and the mining sector generally.

The authors of the present report did not examine the success of these policies and programs, but it appears that working with good economics can illustrate how benefits and costs can flow through the economy from CSG operations. It would seem a fertile area of academic work which could greatly benefit policy and programs in both industry and government.

Nevertheless, as the public enquiries to date all show, many people in regional and local communities contest the economic and social benefits that have been claimed for CSG operations. A better future for all will require robust knowledge of how economic benefit can best be marshalled in the interests of all.

7.6. A consideration of social impact of CSG production

There is an increasing number of useful reports and journal publications on the social impacts of mining and CSG developments, particularly in Queensland. These studies are bringing greater clarity to some anecdotal perceptions of social impacts arising from such operations, and they are beginning to inform government policy, community awareness and action. For instance, one significant study in the Surat Basin (Schandl & Darbas 2008) has suggested that all tiers of government, as well as the private sector and Surat communities, will need to work together in order to increase the benefits of mining and CSG development and to avoid negative social and environmental outcomes.

From the studies reviewed for the present report these were the key matters that are thought to support the sustainable development of regional communities:

- Information sharing, communication and transparency are critical for enabling good governance and change management at the community level. Information is also critical for effective on-going management of regional opportunities from the energy boom. Information is crucial for being able to plan, to make policy decisions and to evaluate past policies.
- Gain and revenue sharing, and economic diversification, are essential to increase the social acceptability of mining operations and to increase the local economic opportunities from mining in the Surat Basin region. Mining activities create wealth but usually not in an evenly distributed way. Economic diversification leveraged off the energy boom is essential to the long-term well-being of the region. The evidence in the literature indicates that economic development based on mining industries alone over the long term will not allow for sustained economic growth.
- Investment in hard and soft infrastructure is crucial for meeting the demands of an increased population. The road networks, public transport, utilities, education, health-care, police and community services need to develop to meet future population needs. Investment in skills, housing, planning and soft infrastructure need to be increased accordingly, to allow local communities to deal proactively with the inter-related aspects of social change as well as maintain their communities as desirable places to live and work.

The social science studies to date appear to have built a platform of knowledge from which current governments can see some of the key issues that demand attention. Attention is important, if regional and local communities are to gain better social and economic and environmental outcomes from mining and CSG production in regional areas. The establishment of regional development plans and the 11 high-level actions outlined in, for example, the Queensland Government's Surat Future Directions Statement, indicate a possible way forward.

Regional development planning where the social, economic and environmental matters are brought together to drive action appears to have much to commend it. It is an active area of policy and program development which needs the support of good applied social and economic research. It also illustrates a move towards a much more whole-of-system approach to regional planning and development.

Social, economic and environmental knowledge needs to be assembled, and that is a great opportunity for whole-of-system thinking and new collaborations between industry, government, community and the knowledge industries in our research and educational institutions. Finding ways to bring these concepts together and empower the process so that it leads to sustained and enduring action on the ground will be challenging but there is evidence that it is a way forward and it is a key recommendation in this report.

References

Eco Logical Australia (2011). Proposed Framework for Assessing the Cumulative Risk of Mining on Nautral Resource Assets in the Namoi Catchment. Project 11COFNRM-0006 prepared for Namoi CMA. September 2011.

Hou D., Luo J. & Al-Tabbaa A. (2012) Shale gas can be a double-edged sword for climate change. Nature Climate Change 2, 385–387.

IIESC (2012) Australian Government Interim Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining. http://www.environment.gov.au/coal-seam-gas-mining/index.html

NC EDO TEC (2012). Planning for Ecologically Sustainable Development: Opportunities for Improved Environmental Outcomes and Enhanced Community Involvement in the Planning System. Recommendation 11. Nature Conservation of NSW, Environmental Defenders Office and Total Environment Centre, March 2012.

NSWG (2012) NSW Government Strategic Regional Land Use Plans. http://www.planning.nsw.gov.au/slurp

QEHP (2012) Queensland Government Salt and brine management in coal seam gas production. http://www.ehp.qld.gov.au/factsheets/pdf/environment/en9.pdf

QG (2011) Queensland Government Strategic Cropping Land Act 2011. http://www.derm.qld.gov.au/land/planning/strategic-cropping/legislation-planning.html#strategic_cropping_land_regulation_2011

QWC (2012) Draft Underground Water Impact Report: Surat Cumulative Management Area (2012). Consultation Draft, Queensland Water Commission, May 2012. http://www.qwc.qld.gov.au/csg/water-impact-report.html

Santos (2010) Santos coal seam gas and groundwater. http://www.santos.com/coal-seam-gas/groundwater.aspx; http://www.santos.com/library/Southern_Fairview_field_Golder_June2010.pdf

Santos (2011) Santos Submission to NSW Legislative Council General Purpose Standing Committee #5: Inquiry into Coal Seam GasCSG, September 2011. http://www.santos.com/library/NSW_LegCo_inquiry_CSG_Santos_submission.PDF

Schandl H. & Darbas T. (2008) Surat Basin Scoping Study: Enhancing regional and community capacity for mining and energy driven regional economic development. Report to the Southern Inland Queensland Area Consultative Committee and Australian Government Department of Infrastructure, Transport, Regional Development and Local Government, June 2008, CSIRO Sustainable Ecosystems, Canberra. http://www.csiro.au/files/files/pm7h.pdf

Glossary

Aquitards	impermeable strata preventing water flow
BTEX	acronym for the group of chemicals benzene, toluene, ethylbenzene and xylene
CAP	Catchment Action Plan
CAPP	Canadian Association of Petroleum Producers
CBM	coal bed methane
CGE	computable general equilibrium
CMA	Catchment Management Authority
CMM	coal mine methane: methane released as part of coal mining operations
COAG	Council of Australian Governments
CSG	**coal seam gas** (also referred to as coal seam methane (CSM) and coal bed methane (CBM))
CSM	coal seam methane
EA	Environmental Authority
EAR	environmental assessment requirements
EDR	economic demonstrated resources
EIS	environmental impact statement
EPBC	Environment Protection and Biodiversity Conservation (Act)
ERA	environmentally relevant activity
Fraccing	hydraulic fracturing (also called 'fracking'): using water with additives under pressure, to fracture rock strata, making a conduit to allow trrapped gases to flow
GAB	Great Artesian Basin
GDP	gross domestic product
GIS	geographic information system
GL	gigalitre = 1 billion litres
GSP	gross state product
GWP	global warming potential
ICM	integrated catchment ('watershed') management
ICN	Industry Capability Network
IIESC	Interim Independent Expert Scientific Committee on CSG and Coal Mining
I-O	input–output
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government areas
LNG	liquefied natural gas
MMRF	Monash Multi Region Forecasting model
NRM	natural resource management
NWC	National Water Commission
PJ	petajoule = 1 million gigajoules
QMDC	Queensland Murray–Darling Committee
SCL	strategic cropping land
SDR	subeconomic demonstrated resources
SRLUP	Strategic Regional Land Use Plans
SSD	State Significant Development
TDS	total dissolved solids
WCM	Walloon Coal Measures