Parliamentary Inquiry into unconventional gas in Victoria

Victorian interdepartmental submission

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1 Introduction

The Legislative Council has tasked the Environment and Planning Committee to inquire into and consider matters relating to the exploration, extraction, production and rehabilitation of onshore unconventional gas. This submission seeks to assist the Committee by providing factual information and background on key activities and matters outlined in the Terms of Reference. The submission does not make comment on past or present government policy, or provide any future policy options.

This is a complex and difficult issue. Individuals and groups across industry and communities have diverse views on the future of onshore gas exploration and development in Victoria.

This submission does not make comment on the divergent stakeholder views, or make comment on past or present government policy. It instead provides a brief history of onshore gas in Victoria, and then describes the current regulatory framework, the prospectivity for different types of onshore unconventional gas and the current state of knowledge relevant to the Terms of Reference. It then articulates key knowledge or regulatory gaps as identified by government work programs.

Chapter 2 describes the current regulatory framework, provides a brief history of onshore unconventional gas policy and regulatory changes to provide context for the current arrangements and summarises key state and national work programs that have influenced those developments.

The subsequent chapters provide information relevant to each of the matters in the Terms of Reference. Chapter 3 describes the prospectivity of Victoria’s geology for commercial sources of onshore unconventional gas (matter 1), Chapter 4 the environmental, land productivity and public health risks during activities related to each stage of exploration, development and rehabilitation (matter 2), Chapter 5 the potential for unconventional gas activities to coexist with existing land and water uses (matter 3) and Chapter 6 the contribution of any potential onshore gas resources to Victoria’s overall energy sources (matter 4).

Chapter 7 responds to matter (5) of the Terms of Reference: the resource knowledge requirements and policy and regulatory safeguards that would be necessary to enable exploration and development on onshore unconventional gas resources. This information does not seek to pre-empt any government decision on whether or not an industry should proceed. Chapter 8 provides a table of some of the investigations into onshore unconventional gas with relevance to Victoria.

This submission has been prepared by departmental officers in the Victorian Government from the Department of Economic Development, Jobs, Transport and Resources (DEDJTR), the Department of Environment, Land, Water and Planning (DELWP), the Department of Health and Human Services (DHHS), the Department of Premier and Cabinet, the Department of Justice and Regulation and the Department of Treasury and Finance. The departments also sought advice from the Environment Protection Authority in preparing this submission.
2 Onshore gas in Victoria

Key points:

Gas is a naturally occurring hydrocarbon, mostly methane, found as accumulations in both conventional and unconventional reservoir rocks.

Conventional reservoirs are commonly porous and permeable rocks such as sandstones or limestones that contain gas. The gas is trapped in place by seal rocks like claystone or shale above the reservoir. When a petroleum well intersects a conventional gas reservoir, gas flows into the well relatively easily.

Unconventional reservoir types include coal seams, shale and tight formations. The gas in these formations is usually trapped where it formed and unable to migrate out of the rock. Gas in unconventional reservoirs is more difficult to extract.

Victoria has no history of onshore unconventional gas production and exploration for onshore unconventional gas is at an early stage.

Rights to explore for and produce gas are controlled by State and Federal legislation. Separate licences apply for exploration and production, and separate approvals are required under a range of legislation prior to undertaking exploration and production activities under a licence. There is a range of associated legislation that may also be relevant, including frameworks to manage risks to water quality, water supply and public health nuisance.

Victoria has been involved in national agreements and reform processes for coal seam gas regulation since 2011. At present there is a hold on granting new licences for all forms of unconventional gas, exploration drilling and hydraulic fracturing during the Parliamentary Inquiry and Government response. A ban on the addition of BTEX (the hydrocarbons benzene, toluene, ethyl-benzene and xylene) chemicals to hydraulic fracturing fluids was legislated in 2014 (noting that BTEX can occur naturally within the vicinity of natural gas and petroleum deposits) (Queensland Department of Environment and Heritage Protection, 2012).

The history of gas exploration and development in Victoria is dominated by conventional resources in Commonwealth waters offshore from Gippsland and south west Victoria. Onshore gas has been produced from the Port Campbell area from conventional reservoirs and continues today with commercial production of carbon dioxide from Boggy Creek and underground gas storage in depleted petroleum reservoirs. There has been no commercial production of gas onshore in the Gippsland area.

Government geoscience programs, part of a longer term program of regional scale investigations across the state, are building knowledge of the state’s geology. For example a seismic survey has been completed in South Gippsland, and will address some fundamental gaps in the scientific knowledge about the geological formations in the area.

2.1 What is unconventional gas?

The Geological Survey of Victoria (part of the Department of Economic Development, Jobs, Transport and Resources) has prepared prospectivity assessments for the Gippsland and Otway basins (Goldie Divko 2015a, 2015b). Unless otherwise indicated, the information in this section is drawn from those reports. General information on petroleum is also sourced from texts such as Beaumont and Foster (1999).
Gas from both conventional and unconventional sources is a naturally occurring hydrocarbon, mostly methane, but can also contain ethane, propane, butane and pentanes. Sulphur compounds, nitrogen, carbon dioxide, water and other substances may also be present, often in significant amounts.

Gas is found in conventional or unconventional reservoirs. Gas in unconventional reservoirs can be described as tight, shale or coal seam gas (Figure 1).

The majority of oil and gas produced across the globe comes from conventional reservoirs. This is also the case in Victoria, where all natural gas production to date is from conventional reservoirs. The majority of natural gas discovered and produced to date in Victoria has been from the offshore portion of the Gippsland Basin, with smaller but significant volumes from the offshore Otway Basin. Relatively smaller gas fields were discovered and produced between 1986 and 2006 in the onshore Otway Basin. Three discovered fields remain that have not been produced.

Figure 1 - Gas types.

Conventional gas reservoirs are commonly porous and permeable rocks such as sandstones or limestones. Impermeable rocks such as claystones or shale lie directly above the reservoirs and are known as a seal or cap-rocks. The gas is trapped in the reservoir and under the seal in geological structures. Geological structures are like an inverted dish, with the gas held underneath. A gas well drilled into the geological structure will intersect the porous gas reservoir and if gas is present it will flow into the well.

Tight, shale and coal seam gas are termed unconventional gas types. These differ from conventional gas in that the gas is trapped at or near the source, which may also act as the gas reservoir. In the case of tight gas, the gas is produced from relatively low permeability and low porosity sedimentary reservoirs. The lack of permeability in the rock prevents gas from migrating, and so it is trapped in the tight rock formation. A similar principle applies to shale gas where the gas is sourced from and trapped in fine-grained sedimentary rocks that have low porosity and permeability, and are organic-rich. The gas is held on organic matter in the rock, in tiny pores between grains, and in any fractures present in the rock. In the case of coal seam gas (also known
as coal bed methane), naturally occurring methane in the coal seams is held on the coal surfaces by water pressure and may also exist in the gaps and cracks in the coal seams.

Table 1 - Typical differences between conventional and unconventional gas resources

<table>
<thead>
<tr>
<th>Gas type</th>
<th>Conventional gas</th>
<th>Unconventional gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occurrence</td>
<td>Discrete accumulations or ‘pools’ within the host rock</td>
<td>Regionally pervasive, dispersed throughout the host rock</td>
</tr>
<tr>
<td></td>
<td>Porous and permeable reservoirs below structural or stratigraphic ‘traps’</td>
<td>Low porosity and/or low permeability reservoirs</td>
</tr>
<tr>
<td></td>
<td>Gas has typically migrated away from the source rocks</td>
<td>Gas is generated by and tends to remain trapped in the source rocks</td>
</tr>
<tr>
<td></td>
<td>Relatively easy to release gas from reservoir</td>
<td>Additional technology, energy or expense required to release resource from reservoir</td>
</tr>
<tr>
<td>Host rocks</td>
<td>Sandstone, carbonate</td>
<td>Sandstone, siltstone, carbonate (tight gas)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shale (shale gas)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coal (coal seam gas)</td>
</tr>
<tr>
<td>Landscape footprint</td>
<td>Fewer wells required because each well collects gas from a larger volume of rock</td>
<td>Larger well fields and more surface infrastructure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>because wells collect gas from a smaller volume of rock</td>
</tr>
<tr>
<td>Hydraulic fracturing or</td>
<td>May be used to enhance recovery during later stages of production</td>
<td>Used individually or in combination to increase permeability (tight gas, shale gas)</td>
</tr>
<tr>
<td>horizontal drilling</td>
<td></td>
<td>Not always necessary (coal seam gas)</td>
</tr>
</tbody>
</table>

The growth of the unconventional gas industry is relatively recent. Coal seam gas production in Queensland has grown from the first small scale commercial production in 1996 at Moura (Geoscience Australia, 2012) to a major export industry with over $50 billion worth of projects under construction (Queensland Government, 2015). Although shale gas has been produced in the United States since 1820 (Hill et al. 2004), it is only in recent years that the decades of experience and knowledge gained from the development of individual shale gas ‘plays’, and advancements in well completion technologies, has led to the growth of the industry. The rising price of the commodity has also contributed to the commercial viability of gas development projects that would not have been possible in the past.

The difference between conventional gas production and the unconventional gas types (tight, shale and coal seam gas) is that for most conventional wells, gas will flow from the reservoir into the well and to the surface infrastructure without assistance, whereas for the other gas types additional technologies are required to release the gas (Australian Council of Learned Academies, 2013). For instance, gas may not flow unless the rocks are hydraulically fractured to create artificial permeability in the formation to release the trapped gas. Horizontal drilling techniques may also be used to increase the area of reservoir in contact with the well. For coal seam gas, water must be drawn away from the coal seam by depressurising the coal to release the gas into the well.

Hydraulic fracturing
Hydraulic fracturing involves creating fractures or opening existing natural fractures in deep rock formations through injecting fluid, sand (proppant) and potentially, chemical additives at high pressure. Not all unconventional gas types require hydraulic fracturing or are suitable for hydraulic fracturing, and some conventional gas reservoirs are hydraulically fractured to maintain or enhance production. For instance, the
South Australian Government submission to its Parliamentary Inquiry into unconventional gas notes that more than 700 conventional and unconventional wells have been hydraulically fracture stimulated to enhance hydrocarbon recovery in the Cooper Basin since 1969. Coal seam gas requires hydraulic fracturing in instances of poor well production. Tight gas and shale gas production may use hydraulic fracturing, horizontal drilling or a combination of both techniques to improve well production.

2.2 Regulatory framework
This section provides an overview of the regulatory framework for unconventional gas. More detail is included in the section on current regulatory controls in Chapter 7.

Rights to explore for and produce gas
Victorian legislation prohibits all petroleum exploration and recovery unless authorised (Petroleum Act 1998 s 15; MRSD Act 1990 s 8). The Minister then may grant certain rights for specified areas via a licensing system. There are three main types of licence: an exploration title that authorises exploration activities such as surveys, drilling and sampling (Petroleum Act 1998 s 18; MRSD Act 1990 s 13), a production title that authorises commercial recovery (Petroleum Act 1998 s 46; MRSD Act 1990 s 14) and a retention title that authorises a titleholder to retain rights to a resource that is not commercially viable but is likely to become so in future (Petroleum Act 1998 s 36-7; MRSD Act s 14C), or for feasibility studies (MRSD Act 1990 s 14C). Each title confers an exclusive right to conduct the activities authorised by the title (MRSD Act 1990).

Allocation of petroleum exploration rights is either by direct application for a licence (for coal seam gas)(MRSD Act 1990 s 15) or by competitive tender (acreage release) (Petroleum Act 1998 pt 3 div 2; MRSD Act 1990 pt 2 div 5). Companies may nominate areas for consideration by the Minister (Department of State Development, Business and Innovation, 2014). Pre-competitive geological data is included in acreage release packages

1. Under the Petroleum Act 1998 (Vic) (Petroleum Act), tenders are assessed on work program and the technical and financial capability of the applicant. Applications under the Mineral Resources (Sustainable Development) Act 1990 (MRSD Act) are assessed on a range of criteria, including whether the applicant is a fit and proper person to hold a licence (MRSD Act ss 15(6), 16), work program and financial considerations.

Production licences may also be granted under the Petroleum Act 1998 (Vic) by work program, cash or royalty bid. The Minister may invite tender applications for production licences if the Minister is of the opinion that there is petroleum or a reservoir in the area. The tender invitation sets out the chief factors to be assessed, and under section 51 an applicant could also expect technical capability and financial resources to be considered.

Approvals to do work under a licence
Earth Resources Regulation in the DEDJTR regulates mineral and petroleum licensing and work approvals. No work on a licence (other than low impact exploration under the MRSD Act) may be undertaken without the necessary approvals, including planning permission, landholder consent or a compensation agreement in place and all environmental and water approvals.

Mineral and petroleum exploration and development in Victoria are also subject to other Acts, including:

- Water Act 1989 (Water Act)
- Native Title Act 1993 (Commonwealth)
- Aboriginal Heritage Act 2006

1 A combination of regional data acquisition, such as geophysical surveys, new interpretations of geology and prospectivity, and open file company data collected in previous exploration attempts.
Legislative requirements for water access and water supply protection
The Water Act deals with water resources and associated matters and includes the protection of aquifers, access to water, construction and operation of bores, and disposal of matter underground (which would include, for example, the injection of water and chemical substances used in hydraulic fracturing).

Under the Water Act, extraction or potential access to water (for any purpose) is treated in the same way. The Water Act requires that matters such as availability of water in the area, and adverse effects on other users, waterways or aquifers, and the environment be considered when assessing issuing water licences, including for mineral and petroleum activities.

The Safe Drinking Water Act 2003 and its associated regulations require Victorian water suppliers and water storage managers to prepare and implement risk management plans for the supply of safe drinking water.

In addition, there is the potential under the Catchment and Land Protection Act 1994 to declare potable water supply catchments to be special water supply catchment areas to limit development activities within these. This legislation may be enacted to prevent water quality impacts arising from development that would require management by Victorian water corporations.

Legislative requirements for environment protection
The Environment Protection Act 1970 (EP Act) establishes the Victorian Environment Protection Authority (EPA), defines EPA’s powers, duties and functions, and provides a number of instruments which are used to minimise wastes, pollution and environmental risks. The instruments used by EPA relevant to this activity include State Environment Protection Policies (SEPPs), Notices, Works Approvals and licences. Regulatory decisions and conditions included in work plans and operations plans for unconventional gas, as undertaken and required by Earth Resources Regulation, also need to be consistent with these SEPPs.

Victoria also has legislation aimed at protecting catchments and biodiversity, such as the Catchment and Land Protection Act 1994, the Flora and Fauna Guarantee Act 1988 and the Native Vegetation Permitted Clearing Regulations.

Other relevant legislation
Onshore unconventional gas activities have the potential to result in nuisance complaints to local government from affected communities. The correct management of potential nuisances from any petroleum project is important for protecting amenity and community health. It is the duty of Councils under the nuisance provisions of the Public Health & Wellbeing Act 2008 in the event of any such complaints (e.g. dust, noise and odour) arising from any operation that potentially impacts on local or neighbouring amenity, to investigate such complaints. In order for the provisions of the Public Health & Wellbeing Act 2008 to apply, a nuisance arising from noise or emission must be, or is liable to be, dangerous to health or offensive.

Government policy settings and national context
On 24 August 2012, a former Minister for Energy and Resources announced a hold on approvals for new coal seam gas exploration licences and a hold on approvals for hydraulic fracturing as part of onshore gas exploration. A ban on the addition of BTEX chemicals in hydraulic fracturing in Victoria was subsequently legislated (Resources Legislation Amendment (BTEX Prohibition and Other Matters) Act 2014). The holds are enforced through administrative arrangements. The reforms were put in place in the lead up to national reform processes.
The Council of Australian Governments (COAG) Standing Council on Energy and Resources\(^2\) endorsed a *National Harmonised Regulatory Framework for Natural Gas from Coal Seams* (Standing Council on Energy and Resources, 2013a) in May 2013. The intention of the initiative was to put in place a suite of leading practice principles to guide regulators in the management of coal seam gas and improve consistency and transparency of regulatory regimes across all Australian jurisdictions. The Framework was developed in response to concerns raised by communities and farmers regarding the protection and management of underground and surface water resources and focuses on four key areas of coal seam gas operations: well integrity, water management and monitoring, hydraulic fracturing and chemical use. The Framework draws on the COAG principles of best practice regulation (COAG 2007; Appendix 1). An assessment of the current regulatory framework against the leading practices is included in Appendix 2.

The *National Partnership Agreement on coal seam gas and large coal mining development* is an agreement between the Commonwealth and Queensland, New South Wales, South Australian and Victorian Governments was signed in 2012. The Agreement aimed to strengthen the regulation of coal seam gas and large coal mining development by ensuring that decisions are informed by substantially improved science and independent expert advice. Some outcomes of the Agreement were:

- A program of Bioregional Assessments in order to better understand the potential impacts of coal seam gas and large coal mining developments on water resources and water-related assets (Australian Government, undated). The program is delivered through collaboration between the Department of the Environment, the Bureau of Meteorology, CSIRO and Geoscience Australia. Gippsland is one of six bioregions under assessment.
- Victoria received $10.13 million in Commonwealth funding as part of the Agreement, which has been used to fund the onshore natural gas water science studies to date.

As part of the Agreement Victoria also amended its Ministerial Guidelines for Environment Effects Statements (Department of Transport, Planning and Local Infrastructure, 2014) to mandate referral to the IESC for all new coal seam gas and large coal mining projects undergoing an Environment Effects Statement process. This provision has not been used to date as there have been no new projects to trigger the process.

The Gas Market Taskforce, chaired by former Commonwealth Minister Peter Reith and consisting of industry representatives, was established in January 2013 to examine gas supply issues. The Taskforce did not canvass widely to identify community views. The Taskforce provided its report to the former Victorian Government in November 2013 and made 19 recommendations.

In response to the report of the Taskforce, the former Government invited public submissions on the report and announced two work programs: water science studies to examine the potential impacts of onshore natural gas activities on water resources, and a community and stakeholder engagement process to seek community views (Premier of Victoria, 2013; Minister for Environment (Commonwealth) and Minister for Water (Victoria), 2013). The moratorium was extended while the water science and community engagement programs were underway, and was expanded to cover all new onshore gas exploration licences.

The water science studies, which focussed on the Otway and Gippsland regions, are complete. The findings of the studies are relevant to the Parliamentary Inquiry’s Terms of Reference; further detail is provided in the relevant chapters of this submission.

\(^2\) Now the COAG Energy Council.
The former Department of State Development, Business and Innovation (now DEDJTR) engaged independent facilitators to conduct a 12 month community and stakeholder engagement program on onshore gas, which started in April 2014. In May 2014, the former Minister announced the moratorium would be extended to include exploration drilling (Minister for Energy and Resources, 2014).

The final report from the independent facilitator was delivered in April 2015 (Primary Agency, 2015).

The Victorian Auditor-General is conducting a self-initiated audit to inform Parliament about the preparedness of departments to respond to emerging risks and challenges in the event that unconventional gas activities proceed in this state (Victorian Auditor General’s Office, in prep). As noted by the auditors, ‘[t]he issues surrounding unconventional gas exploration and production in Australia and globally are complex, technical, wide ranging and in some cases, contentious’ (Victorian Auditor General’s Office, in prep). The Auditor-General is scheduled to table his report in August 2015.

The Commonwealth Government released its Energy White Paper on 8 April 2015, followed by its Domestic Gas Strategy on 14 April 2015. Both of these documents support the development of unconventional gas resources. The Domestic Gas Strategy in particular seeks to inform Commonwealth ‘discussions with state governments, who have the primary responsibility for onshore gas development, on ways to address unnecessary barriers to bringing on new gas supply’ (Australian Government 2015b). The Commonwealth Minister for Industry and Science will ‘report annually to the COAG Energy Council on the progress of implementation and continue to encourage jurisdictions to work together to facilitate the responsible development of coal seam, shale and tight gas resources for the benefit of Australians’ (Australian Government 2015b).

The Parliamentary Inquiry into unconventional gas in Victoria is an election commitment of the current Victorian Government. The Legislative Council tasked its Environment and Planning Committee with the inquiry on 26 May 2015. This submission responds to the Terms of Reference by providing factual information to assist the Committee in its deliberations.

The current Victorian Government has extended the moratorium while the Parliamentary Inquiry is underway and the Government considers its response to the recommendations of the inquiry.

### 2.3 History of onshore gas exploration and development

The offshore Gippsland Basin has been the most prolific oil- and gas-producing basin in Australia, making Victoria Australia’s second largest producer of conventional gas after Western Australia. Most of the State’s gas is produced from the offshore Gippsland Basin in Commonwealth waters, with some coming from the offshore Otway Basin, and a minor amount from the offshore Bass Basin (Hodgkinson et al, 2015).

The history of onshore gas exploration and development in Victoria is also dominated by conventional gas resources. Gas from conventional reservoirs has been recovered commercially from wells drilled in thirteen separate lease areas in the Port Campbell Embayment area since 1986 (Appendix 3).

Over three hundred wells have been drilled across the Gippsland and Otway regions in the search for either oil or gas. Since 1886, 197 wells have been drilled across the Gippsland region and in the Otway Basin 155 wells have been drilled since the early 1920s. Most wells have targeted conventional gas resources, although some have targeted unconventional oil and gas³.

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³ For example Lakes Oil, whose exploration targets include tight gas formations. <www.lakesoil.com.au>
While these activities provide vital information on aspects of Victoria’s geology, the relevance and applicability of the results of these investigations to unconventional gas exploration and development varies.

### 2.3.1 Otway Basin

Onshore production of conventional gas in the Otway Basin commenced in the Port Campbell Embayment in 1986 and continues today at one facility with carbon dioxide gas produced from the well Boggy Creek-1\(^4\). Between 1986 and 2006, commercial production of 15 gas fields occurred near Port Campbell. Some of the now-depleted onshore gas fields in this area are used for underground gas storage, for example the Iona Gas Plant\(^5\) (EnergyAustralia, 2014).

There are current Petroleum Production Licences over these areas, although activity is restricted to storage. Some gas remains in place but a relatively high proportion of carbon dioxide in the gas means that production from these fields would be more complex as the gas and the carbon dioxide need to be separated. Further discoveries are possible in the area (see Chapter 3).

Further detail is included in Appendix 3.

### 2.3.2 Gippsland Basin

In Gippsland, despite a history of petroleum (oil and gas) exploration in the area, no commercial accumulations of onshore conventional gas have been found to date. The discovery and recovery of relatively small volumes of oil at Lakes Entrance around the 1920s and 1930s would be considered the most successful historical petroleum encounter to date in the onshore area (Goldie Divko, 2015a).

### 2.3.3 Hydraulic fracturing

Hydraulic fracturing was allowed during onshore exploration activities prior to August 2012. Twenty-three hydraulic fracture operations occurred across two exploration licences in the Seaspray area between 2004 and 2009. Twelve were approved under the *Mineral Resources (Sustainable Development) Act 1990* with the other eleven approved under the *Petroleum Act 1998*.

### 2.4 Current government work programs

**Prospectivity review**

The Geological Survey of Victoria (GSV), part of DEDJTR, has reviewed the prospectivity of all gas types in the Otway and Gippsland regions to inform the onshore natural gas water science studies (see below). The review draws on current publicly-available information on the geology and resource distribution discovered to date.

Independent peer review of the prospectivity reports was completed by Professor Peter J Cook (for the Otway region report) and Dr Philip O’Brien (for the Gippsland region report).

The prospectivity review is presented in two reports (Goldie Divko, 2015a; Goldie Divko, 2015b) which describe past and current exploration efforts in the onshore parts of the Otway and Gippsland geological basins. The geology of each region is summarised to provide context, and the prospectivity of each gas type (tight, shale, coal seam and conventional gas) is reviewed on the basis of current available information. In  

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\(^4\) BOC produces carbon dioxide from a reservoir about one kilometre below the surface to supply the food, beverage and industrial markets.

\(^5\) This facility injects and stores gas underground during periods of low gas demand; the gas is then supplied back into the market during periods of high demand, for example during winter.
particular, the review focuses on where future development of each gas type would be more likely based on current knowledge of the geology and resource distribution discovered to date through exploration activity.

The prospectivity review is not a resource assessment. In Victoria, limited data about unconventional gas potential is available. The review is based largely on data that has been gathered to assess onshore conventional gas. The evaluation of an unconventional resource requires knowledge of a greater number of geological and petroleum related parameters across larger areas than for conventional gas resources. As such, current data is limited in its application.

**Seismic and gravity surveys**
The Geological Survey of Victoria recently completed a seismic survey in collaboration with Geoscience Australia to acquire data to better understand the deeper geology (Strzelecki Group) of South Gippsland, as part of a longer term program of regional scale geoscience investigations across the state. There are several gaps in the scientific knowledge about the geological formations in the South Gippsland region. Having a clear picture of the geology of the region is key to understanding where and how water moves through the ground. Seismic surveys also provide data about the earth’s crust that can be used for other purposes, such as hazard mapping.

Geoscience Australia, on behalf of GSV, engaged Terrex Group, a specialist contractor, to undertake the seismic survey in South Gippsland. The results will be used to improve the scientific understanding of the potential impacts of developing onshore gas and will be made publicly available on the [http://onshoregas.vic.gov.au/](http://onshoregas.vic.gov.au/) website in early 2016.

The GSV and Geoscience Australia completed a gravity survey (Matthews & McLean, 2015) over parts of South Gippsland in July 2014 to collect new geological data to inform the water science studies (see below). The data gathered during the gravity survey shows estimated positions and depths to rock features of different density, which are presented on a gravity variation map.

The gravity data will be used to build a digital 3D geological model to increase understanding of the region’s geology and aquifers in conjunction with data from the seismic survey.

**Water science studies**
The Department of Environment, Land, Water and Planning and the Geological Survey of Victoria (part of the Department of Economic Development, Jobs, Transport and Resources) undertook water science studies to examine the impacts of potential onshore natural gas developments on Victoria’s water resources.

The water science studies are presented in a series of ten reports, comprising two plain language summary reports (DELWP and GSV 2015c and 2015d) and eight technical reports, including the two prospectivity reports noted above (Goldie Divko 2015a and 2015b; Matthews & McLean 2015; DELWP and GSV 2015a and 2015b; DELWP 2015a and 2015b; DEDJTR 2015). A summary of the findings of the water science studies is presented in Appendix 4.

**Gippsland Basin Bioregional Assessment**

The Gippsland Basin Bioregional Assessment is a Commonwealth project that provides information for the independent expert scientific committee for consideration of applications for large coal mines and coal seam gas. The project is due for completion in June 2016. The groundwater modelling and groundwater sampling elements on the Gippsland Basin Bioregional Assessment were relied upon for the water science studies.
3 Prospectivity

Key points:

The onshore Otway and Gippsland regions have potential for unconventional gas although this has not yet been fully confirmed or quantified. Conventional gas has been discovered and produced offshore in both regions. The same geological units are present in the offshore and onshore areas, and so there is potential to find gas onshore.

Currently, Victoria has no unconventional gas reserves and no unconventional gas has been commercially produced.

Past exploration for gas in onshore Victoria has focused on conventional resources. There has been limited exploration in Victoria for unconventional gas. However, from the data available, it is possible to comment on unconventional gas prospectivity in the onshore Otway and Gippsland regions.

In the Otway region:

- Past exploration for coal seam gas has been unsuccessful with very little methane encountered. This applies to areas where black and brown coal seams have been targeted. There are other coal-bearing areas across the onshore Otway region, but these areas have not been tested for coal seam gas.
- There are geological units in the region that have shale gas potential, but the location and extent of these units is largely unknown.
- Some exploration for tight gas has occurred near Port Campbell, where conventional fields have been discovered and produced; in this area gas is present in the tight geological formations below the units that host conventional gas. There are also other areas in the Otway region which may host tight gas.

In the Gippsland region:

- Thick and extensive brown coal seams in the onshore Gippsland region have been the focus of coal seam gas exploration. The gas content in these coals has not been tested, and whether or not gas could be recovered from the coals is unknown.
- Thin and discontinuous black coal seams with low gas contents were encountered to the south of Warragul during exploration for coal seam gas.
- No exploration program has targeted shale gas in Gippsland. Shale units exist within the same geological formations as prospective tight gas but their distribution is unknown due to a lack of data.
- Data on tight gas prospectivity in the Gippsland region is sparse. A permit holder has published estimated tight gas resources for an area known as the Seaspray Depression.

Further exploration would reduce the uncertainty currently associated with onshore unconventional gas prospectivity across the Otway and Gippsland regions.

This chapter presents a non-technical summary of the prospectivity of Victoria’s geology for onshore unconventional gas. The Otway and Gippsland regions are the focus of this Chapter because these two regions are thought to be the most prospective areas in Victoria for onshore gas (Figure 2), based on their geological character.
Two companies have published estimates of onshore unconventional gas based on their exploration programs in Gippsland (Campbell, 2009; Ignite Energy Resources, 2014; Rawsthorn, 2013). These company estimates are not reserves. The term ‘reserve’ applies where commerciality can be shown, and is defined more rigorously than ‘resource’ (Society of Petroleum Engineers, 2007). Reserves are volumes anticipated to be commercially recoverable by a development project from a given date under defined conditions. There must be a high confidence in the commercial producibility of the reservoir (geological formation), as supported by actual production or formation tests. To date, Victoria has no unconventional gas reserves and no unconventional gas has been commercially produced.

### 3.1 Otway region

Goldie Divko (2015b) has assessed various areas within the onshore Otway region that are prospective for gas (with reference to Figure 3) as part of the onshore natural gas water science studies.
3.1.1 Coal seam gas

Potential coal seam gas from black and brown coal seams in the Otway region has been subject to past exploration.

Black coal seams were evaluated by Purus Energy for coal seam gas potential through the mid-2000s. Purus held tenements across the northern margin of the Otway geological basin where the coal measures are intersected at depths considered suitable for coal seam gas extraction (i.e. shallower than 1500 metres); results from coal samples acquired through a drilling program showed low gas contents and coal permeability indicating low potential for commercial development.

Low gas contents were also typical of the drilling and testing undertaken by Eastern Star for coal seam gas from brown coal seams near Anglesea and near Bacchus Marsh.

There are other coal-bearing areas, across the onshore Otway region, which have not been tested for coal seam gas.
3.1.2 Shale gas
The area considered most prospective for shale gas is the Penola Trough, where gas has been targeted in drilling activities across the border in South Australia in the same geological formation.

Other regions that may be considered a target for shale gas include the Ardonachie/Tahara troughs, the Windermere Trough/Tyrendarra Embayment, and the Port Campbell Embayment.

3.1.3 Tight gas
The primary prospective area for tight gas in the onshore Otway region is the Port Campbell Embayment; many petroleum wells drilled for conventional gas in this area have also encountered significant gas in the underlying prospective tight gas formation.

Other regions which may also be prospective for tight gas include the Eastern Otway region, the Windermere Trough/Tyrendarra Embayment to the northwest of Warnambool, and the Penola Trough.

3.1.4 Geological uncertainty
There is sufficient information derived from prior conventional petroleum and coal seam gas exploration to identify areas that are more prospective in the onshore Otway region. Overall there is greater geological certainty in the Otway region than for Gippsland. Knowledge is better constrained in some areas, and for some geological units, than for others. For example, the distribution of some of the deeper geological formations is not well understood. Like the Gippsland region, where data does exist, it is often insufficient for the proper characterisation of unconventional gas potential.

Unlike Gippsland, where there has been only one test for coal seam gas content, two separate exploration programs in the Otway region have tested gas contents and compositions.

3.2 Gippsland region
Goldie Divko (2015a) examined areas within the onshore Gippsland region prospective for gas, as discussed in the following paragraphs (with reference to Figures 4 and 5).
Figure 4 South Gippsland region structural elements. (After Holdgate, 2003).
Figure 5 Onshore and offshore elements of the Gippsland Basin.
### 3.2.1 Coal seam gas

Both black coal and brown coal seams are found in the rocks of the Gippsland region, and both have been the focus of past coal seam gas exploration in the region. There have been no commercial discoveries of coal seam gas to date and knowledge of the resource potential in Gippsland is limited.

The prospectivity of the black coals appears poor on the basis of the current information. In the only test for coal seam gas in 2004, the black coal seams were discontinuous and thin and the gas readings were low. However, there is no data available for most of the area where black coals may be found and evaluation of the prospectivity is therefore difficult.

The current tenement holder over the onshore Gippsland region (exploration licence EL4416; Ignite Energy Resources, 2014), claims that the brown coals may host 3.7 trillion cubic feet of gas. To date there have been no direct measurements of the gas content of the coals and whether the gas could be extracted. As there is a large volume of brown coal present, large prospective resources (i.e. undiscovered) of gas can be calculated on the basis of assumed gas content. If it was found that actual gas content or producibility was lower (or higher), then the prospectivity would be significantly downgraded (or upgraded).

### 3.2.2 Shale gas

Across Gippsland, the distribution of shales as potential shale gas reservoirs is unknown. Shaley units have been encountered in the few wells that have intersected prospective geological formations. It is therefore possible that shale gas reservoirs exist in Gippsland, particularly those areas that are prospective for tight gas (see below). Differences between the geology of Gippsland and the gas-producing shale formations elsewhere, for example in the United States, suggest that Gippsland is not highly prospective for shale gas, but a lack of data prevents any clear statement.

### 3.2.3 Tight gas

Data on tight gas prospectivity in the Gippsland region is sparse, as few wells have been drilled into a significant thickness of the prospective geological formations. Gas could potentially be irregularly distributed throughout the prospective formations or only found trapped in discrete areas. The Wombat/Trifon/Gangell tight gas fields are potentially an example of discrete traps. The fields are claimed by the permit holder to host 1.7 trillion cubic feet of gas (retention lease PRL2, held by Petro Tech Pty Ltd; Campbell 2009). The gas is found in tight rocks within and beneath geological structures in the Seaspray Depression. Whether gas is distributed throughout the prospective geological formations in quantities that may prove to be commercial is unknown.

### 3.2.4 Geological uncertainty

The largest barrier to better understanding the prospectivity of the Gippsland region is geological uncertainty associated with all gas types. In some cases a lack of basic geological data translates into uncertainty about the geological framework at a regional scale. Where data exists from previous exploration, it is often insufficient to characterise unconventional gas potential. Unknowns may include gross geological structure, the distribution and thickness of geological units, and the distribution of key rock types (lithologies) and their properties within formations (such as mineralogy and/or maceral content, gas content, porosity, permeability, organic content, maturity and mechanical properties).
4 Environment, land productivity and public health

Key points:

Unconventional gas exploration and development may create sources of risk to the environment, land productivity and public health, with the potential for impacts on land, ground and surface water resources, air quality, greenhouse gas emission levels, biodiversity and ecosystem function.

The Department of Environment, Land, Water and Planning and the Geological Survey of Victoria (part of the Department of Economic Development, Jobs, Transport and Resources) undertook water science studies to provide an initial screening analysis of the potential impacts of onshore gas developments on water resources. Limited scientific research has been conducted into human health impacts from onshore unconventional gas activities both nationally and internationally, including health impacts from air emissions, geogenic chemicals (naturally occurring chemicals released due to depressurisation of the geologic formations), contaminated land, contamination of surface and groundwater supplies and noise emissions.

Potential human health and environmental impacts may also arise from wastes including produced water, hydraulic fracturing fluids, drilling fluids and other contaminated substances. Release of fugitive gases may also present potential public health risks.

Loss of biodiversity and habitat fragmentation may result from land clearance for roads and other infrastructure, thereby reducing habitat. This is particularly relevant due to the higher number of wells typically required for unconventional gas production as compared to conventional gas production. Impacts on biodiversity are difficult to quantify without adequate baseline data on prevalence and vulnerability. Past and current efforts to protect biodiversity from disturbance as a result of industrial or other economic activities have had limited success.

Caution is required when considering potential environmental impacts from onshore unconventional gas activities. Regulatory frameworks for any industry are designed to address the potential for industrial accidents, negligence or unforeseen eventualities. Incidents that have a very low probability of occurrence can have major impacts if these do occur.

The high greenhouse gas potential of methane means that leakage or fugitive emissions from wells or directly from the soil could be significant from an emissions perspective in relation to human health and the environment. Some studies have pointed to high potential for greenhouse gas emissions from unconventional gas extraction; however, at present, this is relatively poorly understood.

Whether the potential use of unconventional gas by Victorian consumers would increase or decrease overall greenhouse gas emissions for the State depends heavily on whether the usage would displace electricity generated from coal fired power plants.

The livelihoods and prosperity of many rural and regional communities relies on the security of existing water supplies, as does the health of many important ecosystems. Community and stakeholder groups have expressed divergent views regarding the potential for impacts to water access and quality from possible onshore gas development (Primary Agency, 2015).
The COAG’s principal water policy agreement is the 2004 National Water Initiative (NWI). The National Water Commission has highlighted the need for appropriate management of coal seam gas developments, consistent with the objectives of the NWI. To meet NWI objectives, the Commission recommends that industry, water and land-use planners, and governments adopt a precautionary approach to coal seam gas developments, ensuring that risks to water resources are carefully and effectively managed (National Water Commission, 2010).

A staged approach is being applied in Victoria, based on science and consultation, to address the questions relevant to understanding the regional geology and increasing knowledge of the risks, impacts and mitigations that may be associated with an onshore unconventional gas industry.

Although a significant amount of baseline information on ecosystems, local threatened species and water systems are available, significant gaps remain.

Experience in other jurisdictions shows the importance of understanding the potential impacts of unconventional gas development, in particular the cumulative impacts of over different scales and time periods, prior to approving significant levels of activity.

4.1 Sources of environmental risk

As detailed in The National Harmonised Regulatory Framework for Natural Gas from Coal Seams (Standing Council on Energy and Resources, 2013a), there are recognised environmental risks associated with unconventional gas exploration and development, particularly with respect to well integrity, water management and monitoring, hydraulic fracturing and chemical use.

With the exception of produced water management associated with coal seam gas extraction, these risks also apply to conventional gas development, noting that conventional gas is out of scope of this Inquiry (see Table 2). The main difference between the two resource types that influences the sources of environmental risk is that conventional gas production tends to require fewer wells in an area, whereas unconventional gas development typically involves more wells spread across the landscape (see Table 1). Conventional gas recovery also uses hydraulic fracturing less often, with a correspondingly lower requirement for hydraulic fracturing chemicals. Where hydraulic fracturing is used in conventional gas recovery, it is mostly to enhance recovery of gas towards the end of a well’s production life.

This section of the report addresses sources of environmental risk, noting that many of these sources are equally applicable to public health, for example air quality impacts, or impacts on surface and groundwater supplies which may be subsequently used for drinking, or stock and domestic purposes.

4.1.1 Techniques for unconventional gas exploration and development

Many of the technologies and processes used in the unconventional gas sector are also used in other sectors. Some of the associated risks, impacts and mitigations are therefore common to other sectors. The main activities in the lifecycle of an unconventional gas project, sources of risk and examples of similar technology in other industries are set out in Table 2. This information is compiled from range of sources, including work conducted or commissioned by the NSW Chief Scientist and Engineer, the International Energy Agency, the US Department of Energy, the US EPA, the Australian Council of Environmental Deans and Directors and the CSIRO.
<table>
<thead>
<tr>
<th>Technology or process</th>
<th>Phase of project</th>
<th>Summary of technology or process</th>
<th>Sources of environmental risk</th>
<th>Examples of other industries that have used similar technology in Victoria*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geophysical data collection</td>
<td>Exploration, testing &amp; appraisal</td>
<td>Non-intrusive surveys used to map the subsurface and interpret the buried geology; can be used to predict where gas accumulations might be found.</td>
<td>No significant sources of environmental risk associated with onshore geophysical data collection.</td>
<td>Mineral exploration, civil engineering, conventional oil and gas exploration, natural resource management</td>
</tr>
<tr>
<td>Soil hydrocarbon surveys</td>
<td>Exploration, testing &amp; appraisal</td>
<td>Collects information on hydrocarbon concentrations in shallow soils (generally less than one metre depth), to interpret potential hydrocarbon pathways in the subsurface.</td>
<td>No significant sources of environmental risk associated with soil hydrocarbon surveys.</td>
<td>Conventional oil and gas</td>
</tr>
<tr>
<td>Drilling and well construction</td>
<td>Exploration, testing &amp; appraisal Development &amp; production</td>
<td>Exploration drilling involves obtaining rock cores using a drilling rig for examination and laboratory testing. Well construction involves installation of steel casing into boreholes and equipment for gas extraction (pumps, pipes and related infrastructure).</td>
<td>Losses of well control ('blow-outs') in conventional gas reservoirs have caused significant impacts and damage (Montara and Gulf of Mexico are recent examples). Blow outs can occur from poor construction or poor operation of the well, failure of equipment (i.e. barriers). Poorly constructed wells, or poor maintenance over time (wear and tear), can allow mobility of water, gases or extractive chemicals into or between aquifers, into the soil, or into the air. Connection between aquifers can cause a reduction in ground water level (due to equalisation of pressures between aquifers). It can also enable mobility of salts, organic gases and chemicals used in extraction, impacting water and soil quality. This may cause flow on effects to terrestrial ecosystems, organism and habitats, particularly in highly groundwater dependent ecosystems. Leaks can result from poorly constructed or maintained wells. Leaks may also occur into or from ground water systems due to potential increased mobility and new pathways for movement of water. There are a number of potential environmental risks associated with the potential for increased mobility.</td>
<td>Geothermal development, water resource development, minerals development, conventional oil and gas</td>
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<tr>
<td><strong>Hydraulic fracturing</strong></td>
<td><strong>Exploration, testing &amp; appraisal</strong>&lt;br&gt;Development &amp; production</td>
<td>Used to increase gas production from low permeability rocks. Involves creating fractures or opening existing natural fractures in deep rock formations through injecting fluid at high pressure</td>
<td>Hydraulic fracturing may create or stimulate conduits for flow of material between the target formation and surrounding strata. Leaks may also occur into or from ground water systems due to potential increased mobility and new pathways for movement of water. Surface spills and leaks of fracturing fluids can contaminate the immediate area of the spill and seep into the underlying soil, ground and surface waters. Note that potential BTEX chemicals within hydraulic fracturing fluids have previously been identified as a particular source of potential human health impacts but their addition has been banned in Victoria. Geogenic chemicals (contaminants that naturally occur underground) may be mobilised as a consequence of hydraulic fracturing. Mobilisation may occur in liquid or gaseous form. Mobilisation of geogenic chemicals has the potential for air, soil and water contamination (thereby posing potential risks to public health and the environment). Naturally occurring radioactive materials may accumulate and be concentrated during the extraction of gas, which may pose risks to workers, the public and the environment. Injection of fluids has the potential to trigger earth tremors (induced seismicity).</td>
<td>Geothermal development, conventional oil and gas</td>
</tr>
<tr>
<td><strong>Well testing</strong></td>
<td><strong>Exploration, testing &amp; appraisal</strong>&lt;br&gt;Development &amp; production</td>
<td>Various tests performed within the well and at surface to test the geological formations encountered during drilling and the integrity of the well.</td>
<td>Some down-hole well logging instruments incorporate a radioisotope as a low-level neutron or gamma ray source, for geophysical testing of the geological formation. If the well logging instrument should become stuck or lost in the well, then the radioisotope will continue to emit low-level electromagnetic radiation. In such cases, and where retrieval of the logging instrument is not possible, the well is generally filled with concrete to minimise the potential for ongoing emission of electromagnetic radiation beyond the well.</td>
<td>Geothermal development, water resource development, minerals development, conventional oil and gas. Neutron sources are typically used in geotechnical investigations; their possession and use is regulated by DHHS through a licensing system under the Radiation Act 2005.</td>
</tr>
<tr>
<td><strong>Produced water and solids management</strong></td>
<td><strong>Exploration, testing &amp; appraisal</strong>&lt;br&gt;Development &amp; production</td>
<td>Treatment and re-use (or disposal) of water produced with gas extraction.</td>
<td>The different management options for the water and solids produced by unconventional gas, from treatment and reuse to disposal, will give rise to different environmental and human health risks. For example, water disposal from coal seam gas through evaporation ponds has a different set of risks to desalination and brine disposal. The use of evaporation ponds may pose risks to public health and amenity, for example from dust and gas emissions, spills and odours. In addition, evaporative</td>
<td>Water desalination, waste water treatment</td>
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<tr>
<td>Technology or process</td>
<td>Phase of project</td>
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<td>Produced water management and disposal has the potential to impact water supplies, for example through inadequate treatment of wastewater prior to discharge to a receiving water, accidental releases during transport or leakage from wastewater storage pits, unpermitted discharges, migration of constituents in wastewaters following land application, inappropriate management of residual materials from treatment (USEPA, 2015) The reuse of produced water (and any associated chemicals) can pose risks to public health and the environment depending on the nature of the end uses.</td>
<td></td>
</tr>
<tr>
<td>Supporting infrastructure</td>
<td>Development &amp; production</td>
<td>Access roads and tracks, water pipelines, storage warehouses, workers accommodation camps, offices, telecommunications to facilitate gas production.</td>
<td>The location of supporting infrastructure may cause habitat fragmentation and loss of biodiversity. Supporting infrastructure can pose risks to public health and amenity. For example particulate matter in air (e.g. from dust from roads), noise etc.</td>
<td>Conventional gas development, water and waste water infrastructure</td>
</tr>
<tr>
<td>Gas treatment and transmission</td>
<td>Production</td>
<td>Gas processing plants, compressors, and pipelines to collect, treat and deliver gas to markets.</td>
<td>The location of treatment and pipeline infrastructure may cause habitat fragmentation and loss of biodiversity. Damage, leaks and maintenance of gas treatment and transmission infrastructure (for example pipelines) may also pose public health and environmental risks broader than loss of habitat and biodiversity. Gas losses can occur from operational activities (‘fugitive’ emissions).</td>
<td>Conventional gas development</td>
</tr>
<tr>
<td>Rehabilitation and site closure</td>
<td>End of project life</td>
<td>Sealing of wells and rehabilitation of land around wells to prevent harm to people or the environment.</td>
<td>Poor management of abandoned wells may impact local air and water quality, and have flow on effects to ecosystems and human health. May also have implications on the integrity of the reservoir if later used for gas storage or carbon dioxide sequestration.</td>
<td>Geothermal development, water resource development, minerals development, conventional oil and gas</td>
</tr>
</tbody>
</table>

*This column focuses on conventional gas and other industries that use these technologies, noting that the application of similar technologies in other circumstances may have unintended consequences, particularly given the shallower depths at which unconventional resources can be located and the different physiochemical properties of different geological conditions.
**4.1.2 Exploration, testing and appraisal phases**

Exploration typically involves several stages. Once a company is granted rights to explore in an area, a common starting point for gas exploration is desktop studies. Explorers gain an understanding of the geology of a region from understanding of previous gas finds and the investigation and analysis of pre-competitive data. A favourable outcome from these studies will lead to the point where a company is ready to acquire new data through on-ground activities such as geophysical surveys and drilling (Hodgkinson et al., 2015).

If on-ground activities identify a potential resource, the next phase, testing and appraisal, will determine whether there is an economically viable resource. This includes gas flow testing and may require additional localised geophysical surveys or drilling, at or away from the existing site. In addition, more modelling to ascertain economic viability and hydraulic fracturing may be carried out on unconventional reservoir types (depending on the geology). The typical timeframe for appraisal activities at a site is in the order of about six months, depending on the site, geology and activities being performed (Hodgkinson et al., 2015).

**4.1.3 Development and production phases**

If the resource is deemed commercial and consent to move to production is obtained, development of the necessary infrastructure and production may follow. This may include the completion and conversion of exploration wells or the development of new wells. Well construction, well testing and hydraulic fracturing can occur during the testing and appraisal phases as well as the development phase.

Typical timeframes for development of new unconventional gas are discussed in Chapter 6. The production life of an unconventional gas field will vary considerably with location, but could be expected to be in the order of one to three decades.

**4.1.4 Rehabilitation and site closure**

Once production is complete, the well is secured (plugged) and the surface infrastructure is removed. Well rehabilitation involves sealing the well to prevent fluids and pressure mixing between aquifers, prevention of fluid escape to the surface and prevention of harm to people or the environment (with appropriate pre-assessment, planning and permitting). The land around the well is rehabilitated, for example through re-vegetation and erosion control measures (Hodgkinson et al., 2015).

**4.2 Potential environmental impacts**

This section of the report addresses potential environmental impacts. As noted previously, many of the potential environmental impacts are equally applicable to public health.

Caution is required when considering potential environmental impacts from onshore unconventional gas activities. Regulatory frameworks for any industry are designed to address the potential for industrial accidents, negligence or unforeseen eventualities. Incidents that have a very low probability of occurrence can have major impacts if these do occur. Impacts on biodiversity are difficult to quantify without adequate baseline data on prevalence and vulnerability.

Past and current efforts to protect biodiversity from disturbance as a result of industrial or other economic activities have had limited success (Victorian Environmental Assessment Council, 2011).

**4.2.1 Potential impacts on water resources**

**Water science studies**

The Department of Environment, Land, Water and Planning and the Geological Survey of Victoria (part of the Department of Economic Development, Jobs, Transport and Resources) undertook water science studies to examine the impacts of potential onshore gas developments on Victoria’s water resources.
The water science studies are presented in a series of ten reports, comprising two plain language summary reports and eight technical reports (including the two prospectivity reports noted above). A summary of the findings of the onshore natural gas water science studies is presented in Appendix 4.

The studies have used the best available information, although noting that there are known gaps in the geological and hydrogeological data sets.

There are also issues that are beyond the scope of these water science studies. These include treatment and disposal of co-produced water, water use for hydraulic fracturing and gas production, and non-water resource issues such as amenity, air quality, fugitive gas emissions, on-site chemical management and bore integrity.

The studies also considered some potential measures for mitigating risks to water resources. These measured can be dealt with under the current regulatory framework. Their effectiveness in practice would depend a range of contextual factors.

**Gippsland Basin Bioregional Assessment**

The Gippsland Basin Bioregional Assessment is a Commonwealth project that provides information for the independent expert scientific committee for consideration of applications for large coal mines and coal seam gas. The project is due for completion in June 2016. The groundwater modelling and groundwater sampling elements on the Gippsland Basin Bioregional Assessment were used in the onshore natural gas water science studies.

### 4.2.2 Potential impacts on biodiversity

Loss of biodiversity and habitat fragmentation can be caused directly through land clearance for roads and other infrastructure, thereby reducing habitat (Moran *et al*, 2015). This is particularly relevant due to the higher number of wells that are typically required for unconventional gas production as compared to conventional gas production, noting that well spacing varies considerably from one location to another, and that at exploration stage well spacing is generally similar for both conventional and unconventional gas (typically in the order of kilometres).

Loss of biodiversity may also be caused indirectly through eco-toxicity of chemicals or brines and by hydrological changes. These impacts would be greater on ecosystems with high dependence on groundwater.

The Brolga, Little Egret, Southern Bent-wing Bat, Growling Grass Frog, Swamp Skink and Swamp Greenhood are examples of threatened species occurring within areas of greatest prospectivity in the Otway region. Overall 170 EPBC or FFG listed threatened species occur in these parts of the Otways region.

In the Gippsland region threatened species such as the Orange-bellied Parrot, Strzelecki Burrowing Crayfish, Strzelecki Gum and Dwarf Kerrawang occur in the areas of greatest prospectivity. Overall 100 EPBC or FFG listed threatened species occur in these parts of the Gippsland region.

Threatened species such as these may be impacted by land clearance or fragmentation, or indirectly by changes to water tables. These and other species would be candidates for further investigation regarding site specific and habitat related impacts.

Increased mobility of water, gases and other chemicals through strata has the potential to result in soil contamination if poorly monitored, which may in turn result in loss of biodiversity or ecosystem function.
4.2.3 Potential greenhouse emissions and climate change
Air pollution from gas emissions can be caused either by increased mobility of gases through the strata (for example by potential new pathways that may become available from the increased mobility of gases through the strata from aquifer depressurisation), or by leakage from poorly constructed or poorly maintained wells. There are also natural seeps of gas that occur, which could be enhanced by unconventional gas operations in some places or reduced in others as the reservoir gas pressure is relieved.

The high greenhouse gas potential of methane means that leakage or fugitive emissions of greenhouse gases from wells or directly from the soil via increased mobility of gases may be noteworthy from an emissions perspective. Some studies have pointed to an elevated potential for greenhouse gas emissions from unconventional gas extraction, however at present this is relatively poorly understood.

The CSIRO measured methane concentrations at a range of coal seam gas production wells in Queensland and NSW, to provide quantitative information on fugitive emissions (Day et al, 2014). Methane emissions were measured at 43 coal seam gas wells – six in NSW and 37 in Queensland. Of the 43 wells assessed, 40 had detectable levels of emissions; however, generally the emission rates were of a low level and considerably lower than those reported for U.S. unconventional gas production. The assessment found that the principal methane emission sources were venting and operation of gas-powered pneumatic devices, equipment leaks and exhaust from gas-fuelled engines used to power water pumps. At several sites, exhaust from gas fuelled engines operating at well sites comprised the main source of methane emissions. No evidence of fugitive methane emissions outside of well casings was found.

The report provides quantitative measurements of fugitive emissions from coal seam gas wells in Australia. The authors highlighted several key limitations of the study:

• the small number of wells assessed may not be representative of all operating coal seam gas wells;
• emissions may vary over time, for instance due to repair and maintenance activities;
• the study did not examine other potential emission points in the gas supply chain.

Another Australian study mapped the atmosphere over an area with production coal seam gas fields, an area containing coal seam gas exploration wells, and various other potential carbon dioxide and methane sources such as wetlands, sewage treatment plants, landfills, urban areas and bushfires (Maher et al, 2014). The results showed a widespread enrichment of both methane and carbon dioxide within the production gas field, compared to outside.

The NSW Environment Protection Authority has fined an energy company for a gas leak, which occurred from a coal seam gas well in Camden on 31 August 2014. The responsible entity acknowledged that 10,000 cubic feet of gas was released during the leakage.

4.2.4 Impacts of potential use of unconventional gas in electricity supply
Whether the potential use of unconventional gas by Victorian consumers would increase or decrease overall greenhouse gas emissions for the State depends heavily on whether the usage would displace electricity currently generated from coal fired power plants.

If it did not, then use of unconventional gas would lead to an overall increase in emissions. It is unlikely that the extraction costs of onshore unconventional gas would allow for effective competition against coal fired power plants.
4.3 Potential impacts on land productivity

Vacher et al. (2014) researched the impacts of coal seam gas activities on soils in agricultural areas in Queensland. They found construction and installation of coal seam gas infrastructure may result in soil degradation through compaction, erosion processes, changes to organic carbon and soil nutrient store, exposure of potentially reactive/poor quality soils (e.g. acid sulphate soils, hyper-saline soils) or introduction of outside contaminants (poor quality water, weeds). Soil compaction changes from vehicle impacts and trench line installation have been assessed by soil bulk density measurements and identified as a common impact of coal seam gas operations and a key element of soil degradation of agricultural areas, contributing to poor vegetation establishment, tunnel and surface erosion processes and an ongoing decline of soil productivity. Such impacts are not limited to the unconventional gas industry.

4.4 Potential impacts on human health

Limited scientific research has been conducted into human health impacts from onshore unconventional gas activities both nationally and internationally. Of the available studies, those relating to tight and shale gas operations would be most applicable to the Victorian context. Appropriate risk management requires comprehensive human health risk assessments for the full range of potential hazards and exposure pathways.

Human health risk assessment involves the following key steps: hazard identification, dose-response assessment, exposure assessment and risk characterisation. Public health impacts from onshore unconventional gas may arise from exposure to:

- Contaminated land (e.g. from chemical spills and inappropriate disposal of wastes) and secondary contamination of primary produced products (e.g. food crops and livestock)
- Contaminated surface and ground water supplies (e.g. through drinking water, irrigation, recreational use of waterways, and stock and domestic use)
- Pollutants in the air (e.g. due to fugitive gas emissions and dust from contaminated land)
- Chemicals (e.g. both those use in production and those which may be mobilised from geological sources)
- Noise from development operations.

4.4.1 Potential risks to public health resulting from land contamination

Land contamination may be associated with onshore unconventional gas developments, including from accidental chemical spills, waste disposal and other activities, such as the use and management of evaporation ponds on active and decommissioned sites. Such risks are present in other parts of the mining sector and industries that involve chemical and waste handling. The full range of contamination routes and exposure pathways warrants comprehensive and detailed investigation. This includes not only primary contamination and exposure, but includes impacts to surrounding agricultural land, livestock and crops grown for human consumption.

4.4.2 Potential risks to public health resulting from contamination of surface and ground water supplies

Ground water and surface water supplies may be contaminated through a range of activities associated with onshore unconventional gas activities including accidental spills, poor waste management practices, destabilisation and pressurisation of geologic formations. To date the largest published study was by the US EPA in June 2015, focusing on hydraulic fracturing chemicals and drinking water resources. A full literature search on all available evidence would be necessary to understand any potential risks in the Victorian context.
U.S. EPA assessment of the impacts of hydraulic fracturing on drinking water resources

In June 2015 the United States Environmental Protection Agency (USEPA) published a comprehensive assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources (United States Environment Protection Agency, 2015). The scope of the assessment included water acquisition for hydraulic fracturing fluids, chemical mixing at the well site to create hydraulic fracturing fluids, well injection of hydraulic fracturing fluids, the collection of hydraulic fracturing wastewater (including flowback and produced water), and wastewater treatment and disposal.

The report concluded that there are

‘...above and below ground mechanisms by which hydraulic fracturing activities have the potential to impact drinking water resources. These mechanisms include water withdrawals in times of, or in areas with, low water availability; spills of hydraulic fracturing fluids and produced water; fracturing directly into underground drinking water resources; below ground migration of liquids and gases; and inadequate treatment and discharge of wastewater’.

While the report found no consistent evidence of widespread, systemic impacts on drinking water resources in a US context, it highlighted that potential vulnerabilities in the water lifecycle exist which could impact drinking water. In their report the USEPA noted instances where hydraulic fracturing processes have impacted drinking water resources, specifically due to well integrity and waste water management, but that the incidence of these ‘were small compared to the large number of hydraulically fractured wells across the country’. However, the consequences of these incidences are not described. Further the report highlights that this finding:

‘...could reflect a rarity of effects on drinking water resources, but may also be due to other limited factors. These factors include: insufficient pre- and post-fracturing data on the quality of drinking water resources; the paucity of long-term systematic studies; the presence of other sources of contamination precluding a definitive link between hydraulic fracturing activities and an impact; and the inaccessibility of some information on hydraulic fracturing activities and potential impacts.’

4.4.3 Potential human health risks resulting from air emissions

Along with risks for greenhouse emissions and climate change (see 4.2.3), air pollution from gas emissions is also a source of public health risk. Fugitive gases from onshore unconventional gas activities may include methane and other potentially harmful chemicals, including volatile organic compounds. Further studies would be needed to identify the range of compounds potentially released, along with potential exposure pathways, within a Victorian context.

4.4.4 Potential human health risks resulting from chemicals

Chemical use in onshore unconventional gas activities may include the use of chemicals in hydraulic fracturing fluids, drilling muds, and other processes. Chemicals may also be released from geological stores as a result of extraction processes.

Hydraulic fracturing and proprietary chemicals

While there is general information available in the published literature relating to the classes of chemicals commonly used in hydraulic fracturing fluids, numerous reports highlight that the chemical composition of hydraulic fracturing fluids has typically been classified as proprietary. Past practice has been for DELWP to require a proponent to provide information to DELWP on the chemicals used in hydraulic fracturing.

The lack of disclosure of such chemicals has limited the opportunity for research into potential public health impacts from unconventional gas activities and comprehensive human health risk assessments. Human
health risk assessments are used to develop appropriate health guidelines, which could in turn be incorporated into relevant legislative approval processes.

In June 2015, the United States Environment Protection Agency published an Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. The report emphasizes the paucity of data regarding chemicals used in hydraulic fracturing, the physiochemical properties for hydraulic fracturing fluids and their associated toxicological properties.

The US EPA report highlights that more than 70% of disclosures to its national hydraulic fracturing chemical registry contained at least one chemical designated as ‘confidential business information’, or proprietary. In addition, of the 1,076 chemicals compiled by the USEPA, measured or estimated physicochemical properties could be obtained for 453 of these chemicals.

Further, the report highlights that data was only available to determine human health toxicological endpoints for a very small fraction of these chemicals (i.e. health endpoints could only be determined for 8% of the chemicals, or 90 of the 1,076 chemicals). Of the chemicals that had values available, the health endpoints associated with those values ‘include the potential for carcinogenesis, immune system effects, changes in body weight, changes in blood chemistry, cardiotoxicity, neurotoxicity, liver and kidney toxicity, and reproductive and developmental toxicity.’

**National assessment of chemicals associated with coal seam gas extraction in Australia**

The Commonwealth Government has provided funding for a national assessment of chemicals associated with coal seam gas extraction on advice from the IESC. This national assessment is being led by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the Australian Government Department of Environment and Geoscience Australia.

The study includes the examination of adverse health effects of chemicals used in drilling and hydraulic fracturing for coal seam gas in Australia. The project commenced in July 2012 and final results are expected later in 2015.

Past practice has been that the proponent must disclose the proposed use of all chemicals to be used in hydraulic fracturing.

**Naturally occurring radioactive chemicals**

There is potential for naturally occurring radioactive materials (NORM) to be concentrated during the operational extraction of gas from hydraulic fracturing techniques, such as the accumulation of NORM ‘scales’, similar to those identified with current oil and gas sector extraction. It is possible to manage such NORM material so as to minimize exposure to workers, the public and the environment and subsequent waste disposal with sensible planning and awareness. This may need to be regulated through the Radiation Act 2005, depending on the composition of the material.

**4.4.5 Potential risks resulting from noise**

Noise impacts may result from onshore unconventional gas activities, for example from pumping stations or compressors, which may in turn impact on public health and wellbeing. In Victoria, there have been noise complaints in the past from members of the public in relation to onshore gas exploration activities. The proximity of any potential development(s) to residences would be a factor for this risk.
4.5 Mitigations and residual risk

The Petroleum Act requires a titleholder to identify all the risks and the mitigation measures to control these risks (section 161). These risks and controls have to be included in the operation plan which has to be assessed and approved by the Minister prior to the titleholder undertaking the petroleum operation.

Each stage of the lifecycle of the petroleum operation requires an operation plan, so that the risks and controls for each are identified and assessed prior to being approved. An implementation strategy is required to be developed in the Environmental Plan (required in the Operation Plan) (regulation 11).

The MRSD Act prohibits all work (other than low impact exploration) unless an approved work plan is in place. Risk-based work plans are due to be introduced from 1 January 2016, as per the Government response to the report of the Hazelwood mine fire inquiry and the Government response to the EDIC Inquiry into greenfields mineral exploration and development in Victoria.

The effectiveness of current risk management practices and opportunities to improve the regulatory framework are discussed in Chapter 7.
5 Coexistence with existing land and water uses

Key points:

Many rural and regional communities rely on the agricultural productivity of the land. The Victorian agricultural sector generated a gross value of food and fibre production of $12.68 billion in 2013-14 from approximately 12 million hectares of agricultural land across the whole State (Australian Bureau of Statistics, 2015). This comprises approximately 3 per cent of the nation’s agricultural land and includes many of the nation’s most productive land areas. The potential impacts of developing onshore unconventional gas, and the coexistence with existing land and water use, raise concerns for some landholders, traditional owners and community groups, which require careful consideration.

Onshore unconventional gas production can have positive impacts on regional economies. Studies of Queensland’s experience found rural decline was reversed, and communities with coal seam gas industry experienced growth in youth population, increased education levels and increases to family incomes. The potential for these positive impacts would need to be assessed in the Victorian context.

There are important potable drinking water supplies sourced from groundwater in areas that are prospective for unconventional gas that may be impacted by an exploration or development industry.

There are a range of rights and obligations associated with exploration and development. Unconventional gas resources are Crown-owned under the MRSD Act or the Petroleum Act and water resources are regulated under the Water Act. Land access for exploration and development is regulated under MRSD Act or the Petroleum Act, and the MRSD Act contains protections for agricultural land when mining is proposed. As well as state and federal legislation relating to traditional owner settlements and native title, traditional owners have responsibilities under traditional law and custom to care for their country.

The Victorian planning system has a range of mechanisms that could be applied to assessing competing land use needs in areas of proposed unconventional gas development. A preliminary assessment indicates a close alignment between the national Multiple Land Use Framework developed to support consideration of minerals and petroleum resource development, and the Victorian planning system in terms of objectives, design features and processes.

Acknowledging the information asymmetry between landholders and potential resource development companies, jurisdictions across Australia, including Victoria, have prepared land access legislation and guidance tools to facilitate land access and address the information asymmetry between landowners and gas industry proponents.

Victoria’s economic growth—and that of many rural and regional communities—relies on the productive potential and output of agricultural land. While a wide range of parties might expect to benefit from onshore unconventional gas exploration and development, the potential economic benefits of unconventional gas development will need to be weighed against the potential impacts on natural resources important to agricultural productivity and other land and water users, including the environment.

Onshore unconventional gas production can have positive impacts on regional economies. Studies of Queensland’s experience found rural decline was reversed, and communities with coal seam gas industry
experienced growth in youth population, increased education levels and increases to family incomes (see section 5.5).

Traditional owners, landholders and community groups have expressed concerns regarding land access for onshore gas exploration. Some of these concerns relate to the potential impacts raised in the previous chapter; another set of concerns is the impact of gas wells and other related infrastructure on existing agricultural activities, particularly on intensively-cropped land. Further concerns expressed by traditional owners arise from their responsibility to care for country under traditional law and custom.

Victoria’s planning and earth resources legislative regimes are based (to varying degrees) on the principles of ecologically sustainable development, multiple and sequential land use and net community benefit. These principles will be critical factors in future decisions regarding onshore unconventional gas exploration and development.

5.1 Coexistence of agriculture and earth resources

5.1.1 Water access
The maximum allowable extraction volumes for many water resources have been capped, through either a permissible consumptive volume or a sustainable diversion limit. Where water resources have been fully allocated, no further water entitlement may be issued. Any person or business wanting access to water would need to purchase an entitlement or entitlements for the volume they require.

The majority of licences are used in agriculture. The availability of a licence on land typically has a positive influence on property values. Transfer of a licence could have an impact on the value of agricultural land and result in a decrease in agricultural output, which could have wider implications for local and regional economies.

Potable water supply
The potential for impacts of unconventional gas development on water quality access are relevant when considering potable drinking water. There are potable drinking water supplies sourced from groundwater aquifers in areas that are prospective for gas. Examples include the Dilwyn Formation, accessed by the Barwon Down Groundwater borefield, which can supply up to 70% of the water demand of Greater Geelong and the Eastern View formation, which also supplies water to Geelong.

5.2 Legal rights of property owners

5.2.1 Crown stewardship of earth resources
Rights to all naturally occurring petroleum, including unconventional gas, are vested in the Crown, which relies on the private sector to develop those resources through a licensing system. In Victoria’s onshore areas, the MRSD Act and the Petroleum Act provide for the transfer of rights to these resources to explorers through licensing regimes. Property owners also retain rights with regard to access to their land and appropriate compensation.

The development of resources is managed through a whole of government regulatory framework. The risks to the resource itself, workers and the broader environment (including public safety, infrastructure and human health) establish the case for government oversight to ensure the State, its natural assets and its citizens are protected from harm during petroleum exploration and recovery. With regard to coexistence, the regulatory framework considers new land uses based on their contribution to the best use of the land, potential adverse impacts on existing uses and the overall benefit to current and future Victorians.
Licences can be held without ownership of the land, and generally privately owned land will have an existing productive land use that may be impacted by resources operations. Unlike other resources, such as gold or coal mining, which tends to have a small number of larger operations that displace the existing land use, unconventional gas has a generally large number of small-scale operations that operate next to existing agricultural or other land uses. All access to private land for exploration and mining activity is subject to written consent and/or compensation to the landholder prior to activities commencing.

5.2.2 Traditional Owners and Native Title

Traditional owners have a responsibility under their traditional law and custom to care for their country, which they see as inextricably linked to their identity, culture and wellbeing.

Victorian traditional owners tend to have a lower tolerance for risk than other land owners where an activity may have a detrimental impact on the health of their traditional country. Traditional owners therefore typically seek development that is consistent with their duty to care for their country.

Where the risk of a particular activity (for example, hydraulic fracturing) is considered to be inconclusive or unknown, a traditional owner group may err on the side of caution is likely to be conservative about allowing that activity to occur on their country. Consenting to an activity that may have a serious or long-term detrimental impact on sustainable environmental systems is incompatible with a traditional owner’s duty to care for their country for future generations.

The Native Title Act 1993 (Cth)

The Native Title Act 1993 (Cth) (Native Title Act) provides a process through which Aboriginal people can make a claim for a Federal Court determination that recognises their native title rights and interests in their land and waters. To date, there have been four positive determinations of native title in Victoria.

It is particularly important that the State acts to ensure that native title holders are able to enjoy fully their rights and interests (Preamble to the Native Title Act). To this end, native title claimants and holders have procedural rights (e.g. consultation, negotiation, consent) for activities that affect native title rights and interests (Part 2, Division 3).

Applicants for an exploration or mining licence are required to negotiate in good faith with a view to securing the agreement of the native title parties to the granting of the licence (section 25). Such negotiations may result in the traditional owner group requesting information about the proposed exploration activities and obtaining conditions through an agreement with the licence applicant (section 31(1)(b)).

If after six months no agreement has been reached in relation to the activity, a negotiation party may apply to the National Native Title Tribunal for a determination about whether or not the activity may proceed or whether it may proceed subject to certain conditions (section 35(1)).

The State can point to a history of constructive relationships between native title groups and the mining sector. There have been 75 ‘section 31 mining agreements’ that allow mining to proceed and an additional...
28 Indigenous Land Use Agreements for mining and exploration⁸. Twelve disputes in Victoria have required arbitration⁹.

**Exploration and Mining licences**

There have been recent indications that native title groups may oppose exploration and mining licences where hydraulic fracturing is a potential activity.

The State notifies native title parties when it intends to confer mining rights, including an exploration licence (section 29). When a company makes an application for an exploration licence, it may not know what exploration activities will follow.

The licence holder may carry out activities that fall within the definition of low impact exploration (Department of Economic Development, Jobs, Transport and Resources, 2014). Importantly, low impact exploration means exploration that does not involve taking water from an aquifer, hydraulic fracturing, or excavation using heavy earth moving equipment (Department of Economic Development, Jobs, Transport and Resources, 2014).

A licensee wishing to undertake hydraulic fracturing under a licence is required to lodge a work plan or operations plan with the State. However, no procedural rights are invoked under the Native Title Act at this stage in the approvals process.

Because the approval of an exploration licence rather than the approval of the operation plan or work plan invokes the future acts regime of the Native Title Act, there is a risk that native title holders may decide to withhold consent to licence grants in order to ‘screen out’ hydraulic fracturing.

If this approach were pursued by native title holders, it could slow down the issue of exploration licences targeting resources other than unconventional gas. While National Native Title Tribunal precedents suggest that most licence grants ultimately succeed¹⁰ such disputes can take years and significant resources to resolve and inhibit critical relationship building between the mining company and the native title group.

**Traditional Owner Settlement Act 2010 (Vic)**

The Victorian Government has developed an alternative system for recognising the rights of traditional owner groups. The Traditional Owner Settlement Act 2010 (Vic) (Traditional Owner Settlement Act) allows the State and traditional owner groups to enter into comprehensive agreements that recognise a group’s relationship to the land and provide the group with certain rights over Crown land.

The State relies on the Traditional Owner Settlement Act to comprehensively resolve native title and compensation claims and to provide a broad suite of beneficial outcomes for traditional owners, including enhanced economic development. To date, there have been two settlements under the Traditional Owner Settlement Act.

A settlement pursuant to the Traditional Owner Settlement Act may include a Land Use Activity Agreement (Part 4). Such an agreement applies to any person, including a State agency or a corporation, wanting to undertake activities on Crown land subject to a settlement. There is one Land Use Activity Agreement in place between the State Government and the Dja Dja Wurrung traditional owner group that commenced on

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⁸ National Native Title Tribunal combined statistics for Indigenous Land Use Agreements in Victoria for mining, petroleum and/or exploration, as at 17 June 2015.

⁹ Future act determinations, National Native Title Tribunal, 17 June 2015.

¹⁰ Across Australia there have only been three National Native Title Tribunal determinations that the future act cannot be done. This represents 3.4 per cent of all relevant future act determinations.
25 October 2013. Up to four new Land Use Activity Agreements may commence over the next three years in central Victoria, Gippsland and south-western Victoria.

A Land Use Activity Agreement provides a right to negotiate for mining licences (similar to the Native Title Act) and a fast tracked pre-approval process for exploration licences (‘standard conditions’) (section 31(3) and 31(3A)). State agencies, industry representatives and traditional owner representatives collaboratively developed the standard conditions in 2009–2010. At the time, unconventional gas production was not a significant issue for traditional owners; nor did it have a high profile in Victoria.

**Hydraulic fracturing and unconventional gas**

Negative views on hydraulic fracturing held by increasing numbers of traditional owner groups may influence their willingness to enter into a settlement under the Traditional Owner Settlement Act.

If a licence applicant accepts the standard conditions, the traditional owner group has no right to withhold consent as a way of ‘screening out’ exploration activities that it regards as carrying an unacceptable risk of environmental damage.

Due to concerns about hydraulic fracturing, some traditional owners have expressed dissatisfaction with the standard conditions component of Victoria’s alternative settlement framework, requesting that all exploration or prospecting licence grants be subject to a right to negotiate.

A number of traditional owners perceive the right to negotiate under the Native Title Act provides them with a better means of carrying out their duty to care for country. Traditional owner groups may consider that the only way to oppose hydraulic fracturing under an exploration licence is to reject a settlement under the Traditional Owner Settlement Act. Groups may instead seek native title determinations through the Federal Court.

In the absence of a settlement under the Traditional Owner Settlement Act, the default regime for all exploration licences is the right to negotiate process under the Native Title Act.

**Implications for local and regional development, investment and jobs**

In addition to resolving native title and compensation claims, the purpose of the Traditional Owner Settlement Act is to advance reconciliation and promote good relations between the State and traditional owner groups (section 1). Settlements under the Traditional Owner Settlement Act provide opportunities for economic development and assist aspirations for self-determination.

It is desirable that a mechanism be found that both resolves the concerns of traditional owners about unconventional gas production and enables the benefits of the Traditional Owner Settlement Act for all parties to be realised.

**5.2.3 Rights of private property owners**

In Victoria, access to land in Victoria to explore for and produce most types of petroleum, including shale, tight and conventional gas, is regulated under the Petroleum Act. Access to land for coal seam gas is regulated under the MRSD Act as it is a hydrocarbon contained in coal.

Prior to commencement of any mineral or petroleum operation on private land either the written consent of the landholder must be obtained or a registered compensation agreement with the landholder must be made. Landholder consent is binding on all subsequent landholders and a compensation agreement remains with the land.

Where the parties cannot agree to access arrangements (with or without compensation), either party can take the matter to the Victorian Civil and Administrative Tribunal (VCAT) or can seek to take the matter to the
Supreme Court. VCAT’s primary role is to determine the amount of compensation to be paid to the landholder. VCAT does not have the right to refuse access.

Compensation can be sought for any loss or damage as a result of mineral or petroleum operations as prescribed under section 85 of the MRSD Act and section 129 of the Petroleum Act, including:

- deprivation of possession of the whole or any part of the surface land
- damage to the surface of the land
- damage to any improvements on the land
- severance of the land from other land of the owner or occupier
- loss of amenity, including recreation and conservation values
- loss of opportunity to make any planned improvement on the land
- any decreased in the market value of the owner or occupier’s interest in the land
- loss of opportunity to use tailings disposed of with the consent of the Minister
- reasonable incidental expenses incurred in obtaining and moving to replacement land, if required
- intangible and non-pecuniary disadvantages not otherwise compensable (additional 10%).

The Mining Warden in Victoria is also appointed under the MRSD Act and operates as an independent statutory office holder. The Mining Warden can investigate or attempt to mediate or arbitrate to assist in settling disputes.

The Mining Warden does not have jurisdiction to determine compensation disputes, rather this is a matter for VCAT. However, VCAT’s practice is to not hear compensation matters until the Mining Warden has first considered the matter and mediation or voluntary arbitration has been attempted.

The MRSD Act also has provisions that aim to protect agricultural land:

- Section 26A, in which applications for mining or prospecting licences on agricultural land require a statement of economic significance which assesses the benefits to Victoria, including employment and revenue considerations.
- Section 26B, in which the Minister must excise agricultural land from a licence on application of by the landholder where it can be shown that agricultural activities would be more economically beneficial.
- Section 40, in which, if the licence is a mining licence or a prospecting licence under which mining activities are proposed to be carried out, there must be a work plan that includes a rehabilitation plan for the area of land covered by the licence.

A previous example of resources developed to support landholders in dealing with earth resources exploration and development on their land is the 2008 Guide for Private Landowners regarding Exploration and Mining on Private Land developed in partnership between the MCA and the VFF.

Farmers have biosecurity and land management responsibilities as part of running their businesses. For coexistence to be successful, mining companies should meet the same standards as farmers regarding biosecurity and land management obligations.

5.3 Multiple land use
The Planning and Environment Act 1987 (Vic) provides the framework for planning schemes which regulate the use and development of land through standardised planning provisions to achieve the objectives and policies set out under the Act and the scheme. One way they do this is by requiring that certain types of use or development can only be carried out if a planning permit is granted. It also provides mechanisms for third party involvement and dispute resolution regarding land use and development decisions.
The use of land for earth and energy resources industry exploration does not require a planning permit under provisions of the MRSD Act (section 43(3)) and the Petroleum Act (Section 118). For projects where the Minister for Planning determines an Environment Effects Statement (EES) is to be prepared for that project (and an Assessment is issued under the Environment Effects Act to the MRSD Act decision maker), separate application for a planning permit is not necessary as planning issues are addressed through the EES assessment process (Victorian Planning Provisions, clause 52.08).

The Land Access Working Group, under the then Standing Council on Energy and Resources (now the COAG Energy Council), was tasked with developing a nationally consistent methodology to help resolve land use tensions and conflicts with respect to consideration of minerals and petroleum resource development. The resulting Multiple Land Use Framework (MLUF) was finalised and endorsed in December 2014 as guidance material for all jurisdictions (Standing Council on Energy and Resources, 2013b). The previous Government’s response to the Economic Development and Infrastructure Committee (EDIC) Inquiry into Greenfield Mineral Exploration in Victoria included a commitment to assess the Victorian planning framework against the eight guiding principles of the MLUF.

The Department of Transport, Planning and Local Infrastructure (now DELWP) prepared a preliminary assessment that found a close alignment between the MLUF and the Victorian planning system in terms of objectives, design features and processes.

The EDIC report recommends the development of a state-wide integrated, strategic land use policy framework to better manage ‘competing land uses’ in Victoria. Since that report was released, eight Regional Growth Plans (RGPs) covering the whole state have been completed and implemented into the State Planning Policy Framework and all planning schemes. The RGPs aid future strategic planning by identifying important resources and the direction of future settlement growth.

The need for a centralised, regional or State level strategic framework specifically in relation to unconventional gas is yet to be determined. The Gippsland RGP, which includes consideration of significant coal and gas resources in the region, noted that exploration is at an early stage and the potential for commercial extraction of gas is not known (p31). The RGP recognises the importance of being able to develop new earth resources industries in a way that is environmentally sustainable and compatible with existing and developing industries (Victorian Government, 2014b).

5.4 Experiences in other jurisdictions

The challenges and opportunities associated with land access for earth resource development are not unique to Victoria. Other jurisdictions have implemented a range of approaches to land access, multiple land use and coexistence. The current Parliamentary Inquiry could consider how the experiences of other jurisdictions may (or may not) be applicable in the Victorian context when considering a framework for the effective coexistence of agricultural land and an unconventional gas industry.

5.4.1 Commonwealth

In 2013, noting the limited guidance available for landholders to assist in negotiating conditions of arrangements, the Commonwealth Government Rural Industries Research and Development Corporation prepared the Principles for Negotiating Appropriate Co-existence Arrangements for Agricultural Landholders. The report documents best practice for co-existence; and provides a checklist for farmers needing to accommodate a new land use on their land. It examined particular case studies, one of which was coal seam gas in the Surat Basin in Queensland and includes learnings specific to unconventional gas.
5.4.2 New South Wales

New South Wales has adopted a ‘Strategic Regional Land Use Policy’ to provide protection of valuable agricultural land and water resources, in conjunction with development of mining and coal seam gas across the state (New South Wales Planning and Environment, 2014).

As in Victoria, landholders in New South Wales are entitled to compensation for any compensable loss suffered as a result of operations under an exploration or mining licence and an arbitrator can direct the amount of compensation to be paid under a Land Access Agreement.


Independent Review – NSW Chief Scientist & Engineer

Commissioned in 2013, the NSW Chief Scientist and Engineer conducted an independent review of Coal Seam Gas activities in NSW. The final report made 16 recommendations, two of which are of particular relevance to coexistence with other land uses.

Recommendation 1 was that government make a clear public statement regarding its intention to develop a regime for coal seam gas extraction including ‘…a fair system for managing land access and compensation’.

Recommendation 3 was that government investigate measures for affected communities to have ‘fair and appropriate’ land access and compensation arrangements, extending to compensation for impacted local residents other than landholders and funding for local councils to maintain infrastructure impacted by coal seam gas activities.

5.4.3 Queensland

Queensland reformed its land access regime in response to the rapid emergence of the coal seam gas industry. Resource industry licence holders are required to comply with the Land Access Code 2010. The Code outlines consultation obligations and aims to ensure landholders are fairly compensated for activities on their land, and those activities have a minimal impact on existing land uses.

The Gasfields Commission Queensland has prepared a landholder guide for land access negotiations specific to coal seam gas issues and AgForce is supporting agricultural landholders by offering landholder negotiation workshops to prepare landholders for their dealings with coal seam gas operators (Gasfields Commission Queensland, 2014).

Unconventional gas industry operators are also required to prepare a Social Impact Statement as part of the approvals process for the Environmental Impact Statement prior to commencing any activity. The Social Impact Statement includes specific plans for the management of workforce pressures and impacts on housing affordability and accommodation.

5.4.4 South Australia

The South Australian Government has published a range of guidelines and factsheets to provide information to landholders and the resources industry on land access and coexistence, in part based on applying the MLUF principles to their own context. A key document for landowners, updated in 2014, is the Guidelines: Landowner rights and access arrangements in relation to mineral exploration and mining in South Australia, which aims to ensure landowners are aware of their rights and considerations in relation to having exploration activities or an operating mine on (or near) their land.
For resource companies, the South Australian Chamber of Mines and Energy (SACOME) published the *Code of Practice for Community and Stakeholder Engagement*, which provides guidelines for best practice in ensuring that the wider community and all stakeholders are informed about mining activities that may affect them.

### 5.5 Impacts on local and regional development

Onshore unconventional gas development would result in both opportunities and challenges for regional Victorian communities from social, economic and environmental perspectives. To date, there is very little research published with respect to the potential net economic impacts of onshore gas development in regional Victoria and whether potential benefits outweigh possible negative impacts on regional communities.

The nature and magnitude of economic impacts associated with onshore gas projects would be expected to vary depending on the where the development is located and scale of each project. Existing onshore gas projects elsewhere in Australia provide a starting point to identify the broad range of economic impacts that could result from onshore gas development in Victoria, and could be used as a guide to understanding the likely magnitude of these impacts with respect to onshore gas development in regional Victoria. Examples of previous investigations include Fleming and Measham (2014) and The Australia Institute (2014). Potential areas of economic and social impact are summarised in Table 3.

**Table 3 – potential impacts for local and regional development**

<table>
<thead>
<tr>
<th>Positive impacts</th>
<th>Adverse impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Investment potential – the magnitude and nature of private sector investment that may be generated as a result of bringing infrastructure and investment to rural and regional districts, and the role of projects in strengthening and diversifying regional economies.</td>
<td>• Potential impacts on agriculture and agricultural products.</td>
</tr>
<tr>
<td>• Employment and skills development opportunities – local employment and skills development across the value chain, the quantum of direct jobs, flow-on benefits to local businesses contracted to provide goods or services to the industry, or to businesses meeting the needs of new residents.</td>
<td>• The affordability and availability of land, housing and accommodation arising from changes in population due to new projects.</td>
</tr>
<tr>
<td>• Local infrastructure improvements – opportunities to build capacity for long term growth, like roads, accommodation, community facilities and airports.</td>
<td>• Constraints on the capacity of regional infrastructure (e.g. roads and telecommunications infrastructure) to deal with new industry.</td>
</tr>
<tr>
<td></td>
<td>• Resource constraints for existing regional industries, including food and agriculture, arising from these industries competing for resources with an unconventional gas industry.</td>
</tr>
</tbody>
</table>
Positive impacts

- Indirect industry development – nature and magnitude of indirect industry development opportunities, including in water desalination, recycling projects and transport, manufacturing and service industries that support onshore gas infrastructure developments.
- Natural gas availability and affordability – potential for greater availability and affordability of gas to encourage new businesses or make existing businesses more competitive.

Adverse impacts

- The viability of local businesses that may be affected by competition for resources and increased wages.
- Demand for health services and increased demand on medical facilities.
- Uncertainty for landowners and community members.

5.5.1 Queensland

The rapid development of coal seam gas in south east Queensland over the last decade has resulted in substantial economic and social change in rural agricultural areas. A body of research into the experiences of Queensland has emerged, providing insights into impacts of unconventional gas development (see for example de Rijke, 2013).

Gas Industry Social and Environmental Research Alliance

The social and economic impacts of the unconventional gas industry on regional and local communities in Queensland is being explored by the Gas Industry Social and Environmental Research Alliance (GISERA), jointly founded by the CSIRO, Australia Pacific LNG Pty Ltd and QGC.

Studies conducted found examples of rural decline being reversed in communities with coal seam gas industry including growth in youth population (particularly in young women), increased education levels (particularly of young men) and increases to family incomes (Measham and Fleming, 2014).

Regarding employment, GISERA studies have shown that for each gas industry job created there were two additional jobs created in the related construction and professional services sectors. Conversely, for each new gas job there was a reduction of 1.7 jobs in the agriculture sector (Fleming and Measham, 2014).

GISERA also commissioned a literature review of the experience of rural communities with extractive resources industries (Measham and Fleming, 2013). It reported that the increase in labour demand caused by an energy resources boom has three direct economic effects:

1. Local wages increase as more labour is demanded.
2. Increased demand for local goods and services (including housing and accommodation) is likely due to increased disposable income.
3. A movement of labour away from agriculture/manufacturing (tradable goods) to the resources sector is likely as tradable goods employers are unable to compete with resource wages.

The impact of these effects varied in degree according to at least six variables, with no specific variable emerging as a sole indicator of social and economic impacts such as housing affordability. The variables were community mining history, labour force skills, weight of manufacturing, integration of the local economy into the regional and national economy, multifunctional or diverse economies and housing market flexibility.
5.6 Community and stakeholder perceptions

5.6.1 Literature review of community concerns

In partnership with the former Victorian Department of State Development, Business and Innovation, the CSIRO undertook a literature review of societal concerns related to onshore gas development (Walton et al., 2015). The report drew on literature on literature on coal seam gas development in Australia and shale gas development in Northern America. The review focused primarily on issues raised by communities directly affected by gas development, but includes some discussion of concerns expressed by wider community members.

The report highlights six key areas of concern for communities and society:

- water quality and availability
- human health
- impacts on landholders (e.g. noise, dust, increased labour costs, decline in property value)
- local infrastructure and facilities (e.g., housing affordability, and traffic)
- economic changes (e.g. regulatory compliance burden, workforce pressures and wage increases)
- community and social fabric changes (e.g. change from rural to rural and industrial environments).

The review highlights that it cannot be assumed that Victorian communities would react in the same way as those examined in the literature. State-specific differences, the current absence of a Victorian unconventional gas industry, and a change in the political environment around unconventional gas emphasise the need for specific studies of Victorian community perceptions to allow considered planning and gathering of independent scientific knowledge to avoid negative consequences and maximise benefits of any potential industry.

5.6.2 Community perceptions of unconventional gas in Victoria

A community and stakeholder engagement program was conducted by an independent facilitator, the Primary Agency, under the guidance of the previous Victorian Government. Community views on onshore gas in Victoria were reported as comprising of three cohorts: supportive, not supportive and undecided/don't know. The results from the quantitative survey component program reported the level of support for the onshore gas industry in Victoria is about 29 per cent, opposition about 27 per cent, undecided about 35 per cent, and nine per cent said they don’t know. For questions of coexistence, the level of opposition to an onshore gas industry is higher in the areas most prospective for onshore gas than metropolitan areas (46 per cent). In these areas networks of organised community groups have formed opposing the development of onshore gas and or coal. A number of local councils in these areas have reflected the concern in their communities by declaring themselves ‘gasfield free’.

The supportive group generally focussed on economic, state, national and global considerations, and held the view that the benefits of a well-managed onshore gas industry would outweigh the costs.

The not supportive group generally held the view that the industry will change the landscape, natural resource base, structure of the economy and community character for the worse, based on previous experience and case studies from other areas with an onshore gas industry. Further, the benefits and costs are not seen to be distributed equitably, with the benefits accruing mainly outside the region, while the costs are mainly borne inside the region.

The undecided group saw some merit in the perspectives emerging from the two polarised groupings within their community. They recognised some of the knowledge deficiencies and often turned to authorities, such as scientific and government agencies, to seek more information. Some within this undecided grouping had an open but conditional stance on the development of the onshore natural gas industry in Victoria. They
focussed on how the industry might be allowed to develop and the controls that would be necessary to mitigate risks.

5.6.3 Landholder perceptions of coexistence in Queensland

The CSIRO conducted a study of farmers’ perceptions of coexistence between agriculture and large scale coal seam gas development in the Surat Basin in southern Queensland (Huth et al. 2014). The lessons regarding farmers’ perceptions of coexistence with coal seam gas development cross a diverse range of problem areas. Some conclusions from the study:

- Farmers feel that acceptable economic benefit from coal seam gas compensation payments could be possible if fair and equitable processes could be developed and concerns for environmental impacts addressed.
- Environmental impacts are a large area of concern for farmers. Impacts on ground and surface waters are a primary concern. A collection of issues regarding atmospheric pollution (dust, light, noise) has a significant impact on many aspects of farmer’s lives. The impact of significantly increased traffic, both on and off the farm, should be addressed.
- Science, coal seam gas and agricultural industry groups will need to work closely with farmers to develop understanding of these emerging issues and to develop solutions that are timely and relevant. Solutions may need to include formalised processes incorporating scientific knowledge to assist farmers make decisions.

The engagement with farmers by the study highlighted farmer’s perceptions that farm aesthetics and place identity are not well understood by company staff with non-rural backgrounds. These differences in landscape interpretation caused considerable frustration, and the farmers felt this led to impacts on mental health and wellbeing. The report identifies that farmers feel a change of culture in the coal seam gas industry is required to improve engagement between the agriculture and resources industries.

Similar to the ‘not supportive’ group in the Victorian engagement program, the study found that farmers negative perceptions related to potential damage to the environment.
6 Contribution to Victoria’s energy mix

Key points:

Exploration of onshore unconventional gas types is at an early stage and Victoria has no unconventional gas reserves.

The extent to which onshore unconventional gas can contribute to Victoria’s energy mix is unknown and without further exploration the contribution will remain zero.

The activities required along the gas supply chain and community acceptance are key factors that will impact the competitiveness and affordability of unconventional gas.

In the absence of an accurate estimate of commercially recoverable unconventional gas, no definitive conclusions may be drawn regarding Victoria’s emissions profile or the implications for climate change.

Victoria has the largest residential gas demand of any Australian state, equivalent to two-thirds of all residential gas consumption in Australia. The Essential Services Commission (2014) reports 77 per cent of Victorian households receive gas via the pipeline distribution network and many other households use bottled gas where mains gas is unavailable, or to supplement to mains gas supply. The main household uses of gas are in cooking appliances (ovens, cooktops and barbeques), gas heaters, ducted heating units and hot water systems.

Many businesses rely on gas as an energy source or feedstock in the manufacture of a range of products including basic chemicals, plastics, pharmaceuticals, fertilisers, paints, pesticides and cosmetics.

Victoria is a net exporter of gas sourced from offshore areas in adjacent Commonwealth waters.

There is no onshore unconventional gas production in Victoria and no unconventional gas reserves have been declared. Exploration is at an early stage so it is unknown whether the State has any commercially viable resources of gas onshore. There has been a discovery of potential tight gas in Victoria, but the commerciality of this is yet to be determined.

The COAG Energy Council prepares an annual report on Australia’s unconventional reserves, resources, production, forecasts and drilling rates through its Upstream Petroleum and Resources Working Group. The most recent report was released in November 2014. The report notes Victoria’s Reserves/Resources as presented in Table 4.
Table 4 – Victoria’s unconventional gas reserves. The estimates are based on figures given in Lakes Oil N.L. announcements to the Australian Stock Exchange (10 August 2010 and 1 July 2009).

1P reserves’ = proven reserves (both proved developed reserves + proved undeveloped reserves); ‘2P reserves’ = 1P (proven reserves) + probable reserves; ‘3P reserves’ = the sum of 2P (proven reserves + probable reserves) + possible reserves.

Without an accurate estimate of commercially recoverable gas, it is not possible to determine what contribution unconventional gas could make to Victoria’s energy mix. The situation is further complicated by uncertainty about the time it would take to get any gas to market, as there is typically a lead-time from discovery to production. Generally, a minimum of five to seven years is required to bring discovered gas into commercial production. The exception to this may be where existing operators are able to use existing infrastructure and commence production in less time, noting that Environment Effects Statement processes alone can take up to three years. Even with a change in current policy, onshore unconventional gas is unlikely to be part of Victoria’s energy mix for at least the next five to seven years. Currently, relatively low international energy prices may have reduced the commercial incentive for new gas development.

6.1 Factors impacting competitiveness and affordability of unconventional gas

Australia’s gas supply chain (Figure 6) illustrates the process to deliver resources to the end use market. All links in the supply chain have associated costs and other factors that impact the competitiveness and affordability of unconventional gas as a contributor to the supply chain. These factors have been discussed in several Australian studies. Community acceptance of an onshore unconventional gas industry might also affect competitiveness and affordability of unconventional gas.
6.1.1 Exploration and discovery

Information and knowledge of potential resources are fundamental for efficient investment. The Roadmap for oil and gas projects in South Australia notes ‘Ready access to data reduces critical uncertainties, enabling investment decision making that forms the basis for efficient and effective exploration’ (Department for Manufacturing, Innovation, Trade, Resources and Energy, 2012). Industry exploration also generates information. Victoria’s regulatory framework mandates that exploration data is provided to the Government so that it can be used to enhance the understanding of the underlying geology. Previous data collected during exploration programs may be re-used later on, for example petroleum exploration data is valuable in assessing carbon storage and geothermal potential. Industry exploration data are also made publicly accessible under certain time frames or conditions, as discussed in chapter 7.

Government geoscience programs are important to attract investment in mineral and petroleum exploration and development. Typical work programs include regional geological investigations, 3D modelling and interpretation of the underlying geology. The generation of pre-competitive geoscience information is a clear role for government, as discussed in chapter 7.

6.1.2 Development and production

According to the data in the Australian Gas Resource Assessment (2012), the cost of new gas developments increased sharply in Australia between 2004 and 2008. Gas reserves are becoming more expensive to find and extract and it is becoming increasingly costly to develop unconventional gas resources. The Eastern Australian Domestic Gas Market Study reported the average cost of development for new unconventional and coal seam gas was approaching $5/GJ in 2013 and continuing to rise.
The timeframe for development and the size of the project can affect the competitiveness and affordability of unconventional gas in Victoria. Nearly half of gas-producing projects in Australia were completed within five years of initial discovery, as shown in Figure 7.

![Figure 7: Development time for gas producing projects in Australia (Geoscience Australia and ABARE, 2010).](image)

While the cost of developing a resource in a specific area will have locational specific costs, it will also be a function of key inputs such as labour, equipment, contracting services and raw materials. New gas developments compete with existing developments for labour and materials and there are observations that these costs are rapidly increasing (Energy Quest, 2014). There have also been significant delays to recently completed projects.

With the rapid increase in cost of developing new gas resources over the last several years, it is unclear if onshore unconventional gas development would be cost competitive with existing sources of conventional gas supply within Victoria.

### 6.1.3 Processing, transport and storage

The *Eastern Australian Domestic Gas Market Study* noted that ‘while transportation, processing and storage costs are a lower proportion of delivered gas prices than production costs, they have the potential to affect long-term gas supply outcomes by limiting the competitiveness of primary contracts for gas supply and the efficiency of spot and forward pricing markets’.

If potential unconventional gas resources are located close to existing infrastructure such as gas processing facilities and pipelines and they are able to access this infrastructure, this may cut down the long lead-time from discovery of gas to production and reduce the cost of delivering gas to market. Under these circumstances, it is likely to take approximately five to seven years to get the gas to market. However, it is not possible to conclude whether onshore unconventional gas will be cost competitive with gas from the Gippsland basin.

The *Gas Market Taskforce Final Report and Recommendations* noted some commercial gas customers had difficulty in negotiating with ‘Victorian gas transmission and distribution owners for access to related services, such as a connection or upgrade of pipeline assets’, causing delays and impost on business.
6.1.4 Community acceptance

Community acceptance is another factor that might impact competitiveness and affordability of unconventional gas in Victoria. The Eastern Australian Domestic Gas Market Study highlighted the importance of communities being engaged and supportive of coal seam gas operations, without which the industry will struggle to maintain its social licence to operate.

6.2 Effect of Victorian unconventional gas on domestic gas prices

As a general economic principle, increasing supply of a good into a market is expected to create downward pressure on its price. With the start of LNG exports from Queensland, Victorian gas is now part of an international market and increases in Victorian supply would not be expected to have much impact on world supply; the price of gas in Victoria is instead being driven by the international LNG price.

With international LNG export prices having a considerable influence on prices within Eastern Australia (Productivity Commission, Examining Barriers to More Efficient Gas Markets, page 51); Victorian domestic gas prices are expected to converge to an export parity price, which is calculated as the international price less the costs of liquefying and shipping the gas (referred to as the netback price). However, the Eastern Australian Domestic Gas Market Study conducted by the Commonwealth Department of Industry notes that in this period of transition, there is a risk that prices may exceed export parity. This could be a result of insufficient information available to the market, and could be sustained given the existence of market power among the large gas producers in Victoria.

For onshore gas to make a difference to the price paid by Victorian users (reduce the price) it would need to be produced in sufficient quantity to influence the international LNG price. It would also require sufficient long-term contracts to underwrite a project and be deliverable to the international market.

A key consideration for whether onshore gas can influence the price in Victoria is the competitiveness of the Eastern Australian gas market. While this is currently the subject of an inquiry by the Australian Competition and Consumer Commission (ACCC), observations can be made about the potential influence of existing market structures on future gas prices. For example, the Eastern Australian gas market currently has a small number of suppliers. Many of these are vertically integrated and/or a party to joint venture and marketing arrangements, which has the effect of further increasing market concentration. The Productivity Commission (2015) found there are also large barriers to entry, due to large sunk costs and long investment lags, which can further diminish competition.

This indicates the importance of diversity of supply, and suggests that if incumbents control new supply, the new supply may not enhance competition and is unlikely to influence the price paid by Victorian gas users. Victorian gas users are largely likely to be price-takers and it is unclear if increasing supply in Victoria will reduce gas prices.

6.2.5 Other considerations

There is a lack of reliable information on existing contracted future gas price, which has implications for those commercial users whose businesses are sensitive to gas prices. Contract prices are confidential and there is no Australian futures/forward market, which makes it difficult to forecast gas prices.

In 2013, DEDJTR engaged SKM MMA, a private company providing advice and modelling of energy markets, to model wholesale and retail gas prices. SKM MMA’s modelling results (as shown in table 5 below) indicate that wholesale gas prices are expected to increase from the current level of $4.50/GJ to between $6.50/GJ and $8.00/GJ by 2022. Wholesale gas prices account for close to 30 per cent of a residential bill. Retail contracts are relatively short term and are therefore sensitive to wholesale cost rises. This results in retail prices rising from approximately $18/GJ in 2013 to between $22/GJ and $26/GJ by 2015.
Australian gas exports to Japan have traditionally been referenced to the benchmark oil price because the early use of gas in Japan was as a substitute for oil. SKM MMA reported that some of the new LNG contracts link the gas price to international oil prices. For these contracts, the LNG contract price is primarily a function of the Japan Crude Cocktail (JCC). The JCC price is derived from a range of factors including the Brent Crude price (the benchmark for prices of oil worldwide). In practice this means that a higher (lower) JCC price will translate to a higher (lower) LNG price. SKM MMA estimated LNG netback prices for low, medium, and high JCC price scenarios (see Table 5).

Table 5 - Potential LNG netback values at Gladstone (SKM MMA, 2013).

<table>
<thead>
<tr>
<th></th>
<th>Low Scenario</th>
<th>Medium Scenario</th>
<th>High Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan Crude Cocktail price ($US/oil barrel)</td>
<td>$75.00</td>
<td>$105.00</td>
<td>$140.00</td>
</tr>
<tr>
<td>Exchange rate ($US/$A)</td>
<td>$0.80</td>
<td>$0.90</td>
<td>$1.00</td>
</tr>
<tr>
<td>LNG delivered value ($A/GJ)</td>
<td>$13.33</td>
<td>$16.59</td>
<td>$19.91</td>
</tr>
<tr>
<td>LNG Netback value ($A/GJ)</td>
<td>$6.48</td>
<td>$9.74</td>
<td>$13.06</td>
</tr>
</tbody>
</table>

The JCC price was US$79.07 a barrel in December 2014 which would indicate a current LNG netback price of approximately $A6.50 /GJ. It has since fallen to $49.42 a barrel in February 2015, the lowest since April 2009 (Reuters, March 2015). However, LNG contracts tend to have price renegotiation trigger points that occur under circumstances such as low or high oil prices and this means that it is difficult to infer a LNG netback price.

In terms of supply, the US and Russia are expected to significantly increase LNG exports over the coming years. This may potentially indicate that the global LNG market will be oversupplied. If this occurs, any new onshore gas development will need to be at very low cost by global standards, to proceed.

The development of further unconventional gas supplies may also have a dampening effect on the global LNG price. There is a possibility of an emergence of unconventional oil and gas in Asia. With growing demand for energy, substantial reserves of unconventional gas, and acquisition of North American shale assets may suggest that an Asian shale gas industry will eventually emerge. This is however dependent on factors such as technological and commercial viability, environmental and social concerns, and government policy (PwC, 2013).

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11 ABC News 1 December 2014, China gas squeeze: demand may fall as supply ramps up <www.abc.net.au/news/2014-12-01/china-gas-squeeze-demand-may-fall-as-supply-ramps-up/5930272>
7 Knowledge gaps and policy and regulatory safeguards

Key points:

Some risks and impacts associated with onshore unconventional gas are generally well understood from a range of credible reports, while others are relatively poorly understood.

Knowledge gaps include the prospectivity for onshore unconventional gas in Victoria, a full understanding of the geological formations in the Gippsland sedimentary basin and its chemical composition, as well as human health and environmental impacts as they may relate to individual unconventional gas projects.

It is only possible to assess particular risks and impacts for an individual project once a resource is proven and the implications of development of that project become measurable. It is at this point that a more informed assessment of the benefits and costs of developing a potential commercial resource could be assessed against the risks and impacts.

Additional work would be necessary to improve the state of knowledge and the associated regulatory safeguards for onshore unconventional gas in Victoria.

The results of the community and stakeholder engagement program note that those who are supportive of onshore gas development qualify their support with the caveat of ‘a well-managed industry’.

7.1 Key knowledge gaps

Most of this section focusses on biophysical knowledge gaps. Knowledge gaps relating to features and assets in the regional landscape are discussed at the end of this section.

7.1.1 Water science knowledge gaps

Regional groundwater modelling provides a starting point upon which to make decisions on potential onshore gas development. Further scientific work would help to address knowledge gaps and confirm key assumptions to inform the regulatory framework for any permitted unconventional gas activity.

Regional groundwater modelling and assessment

The onshore natural gas water science studies assessment framework is based on the “hazard-pathway-receptor” model to assess impacts on the receptors (water resources) from possible future onshore gas development. A review of relevant Australian and international literature, which looked at risk from gas development, was completed prior to developing the water science studies impact assessments.

For aquifer depressurisation, modelling and analysis was used to assess the potential impacts on groundwater levels and by inference the potential impacts on water users and ecosystems. This approach was taken because relevant region-specific data was not available for a quantitative risk assessment and the available data was suitable for impact assessment.

For chemical contamination of groundwater from hydraulic fracturing fluids, induced seismicity and land subsidence, a qualitative risk assessment approach was used to assess the potential risks to water users
and ecosystems, as the necessary region-specific data for a quantitative risk assessment or impact assessment approach was not available.

**Further scientific work arising from water science studies**

A preliminary list of knowledge gaps has been developed in completing the onshore natural gas water science studies (DELWP and GSV, 2015c, 2015d). These include:

- Permeability of seal rocks
- Delineation of potential gas resources
- Compaction and consolidation parameters
- Relationship between groundwater drawdown and river flows
- Connection of ecosystems to groundwater.

**Permeability of seal rocks**

In the Otway region and the Gippsland region, the seal rocks (rocks which overlie the gas reservoirs and keep the gas in place) also act to separate the gas reservoirs from the overlying water resource aquifers. However, relatively few field tests data have been undertaken in Victoria on the properties of the seal rocks as they relate to groundwater movement (permeability). Collection of such data would improve the assessment of potential impacts and risks. In this study, a relatively high permeability (and therefore high degree of hydraulic connection between gas reservoirs and aquifers) has been adopted; it is possible however that less connection exists over much of the study area, resulting in lower potential impacts and risks.

**Gas/water drawdown estimates**

The potential impacts on water users and ecosystems have been inferred based on assessments of declines in groundwater levels due to depressurisation of gas reservoirs associated with gas extraction. For the assessments, conservative values were used to predict groundwater declines in the hypothetical gas production zones which ignored the effect of gas in the gas reservoirs. The assessments could be improved by preparing a better estimate of groundwater declines as a result of combined gas extraction and existing groundwater use.

**Definition of potential gas resources**

The geological understanding associated with unconventional gas resources in the Otway region and Gippsland regions is immature. Although it is possible to make indicative estimates about potential host gas-bearing formations and their extent, whether or not gas is present, and then present in economically recoverable volumes is unknown. Better definition of the resource potential and the potential extent of development would improve the assessment of potential impacts and risks to water resources.

**Compaction and consolidation parameters**

The risk of land subsidence is evaluated based on parameters for compaction. These parameters are known at only one location (Barwon Downs in the Otway region). Improved assessment of the risk of subsidence could be made if more data on the compaction of aquitards was available, in particular for the Gippsland region.

**Relationship between groundwater drawdown and river flows**

For the assessment of the potential impact on surface water users this has been assessed by inferring impact to the existing depth to watertable from the predicted drawdown. To improve this, better descriptions of the relationship between groundwater drawdown and river flow could be developed. For example, if major river reaches were to have a drawdown sensitivity assigned to flow, then the groundwater drawdown estimates could be more readily assessed in terms of the impact on surface water availability. The current study infers that in all areas groundwater drawdown will lower surface water availability where the watertable
is shallow. This may not be the case in all areas because of the nature of the surface water systems. Better understanding of the link between groundwater drawdown and surface water flow could improve the assessment of potential impacts. This could enable a more targeted assessment to be made.

Connection of ecosystems to groundwater
The potential impact to surface water ecosystems has been assessed by inferring impact to the existing depth to watertable from the predicted drawdown. This may or may not reflect the sensitivity of a groundwater dependent ecosystem to drawdown. The assessment could be improved if a better understanding of the response to groundwater drawdown for different surface water ecosystems was available for the Gippsland region. This could enable a more targeted assessment to be made.

7.1.2 Hydraulic fracturing knowledge gaps

Potential for hydraulic fracturing to be required in Victoria
Hydraulic fracturing involves some specific risks, including those arising from chemical use, as discussed in chapter 4. Additionally, BTEX chemicals can occur naturally in sedimentary formations containing hydrocarbons. It is important to know whether hydraulic fracturing would be needed to develop unconventional gas, to inform regulation about its use to minimise any potential risks.

Hydraulic fracturing may be required if development of tight and shale gas were to be allowed in the Gippsland region and tight, shale and coal seam gas in the Otway region, in order to increase rock permeability and hence gas production. If fracturing is needed, typical fracture propagation distances in these rocks are likely to be in the order of tens of metres (DELWP and GSV, 2015a, 2015b). However, it is unknown whether commercial development of tight, shale or coal seam gas target rocks in the Gippsland and Otway regions requires hydraulic fracturing, as there has been no commercial production of unconventional gas in these areas.

Hydraulic fracturing is unlikely to be required if development of coal seam gas (from brown coal seams) were permitted in the Gippsland region. The geomechanical properties of the coal seams are unlikely to be suitable for hydraulic fracturing. Horizontal drilling techniques could be implemented, which can negate the need for hydraulic fracturing in many cases in coal seam gas development (DELWP and GSV, 2015a) and in tight or shale gas. Horizontal and deviated wells are drilled so that the well is oriented along the target rock unit. In this way the area of contact between the well and the target rock formation is increased, allowing greater access to hydrocarbons in the rock. A horizontal well can also be fractured to improve the rate of production of the well.

If development of coal seam gas from black coals in South Gippsland was to occur, then hydraulic fracturing may be required. However, the assessment by Goldie Divko (2015a) found the ‘prospectivity of coal seam gas from black coals in Gippsland appears poor on the basis of current information’ and that ‘there is no data available for most of the area where black coals may be found and evaluation of the prospectivity is therefore difficult’.
Composition of hydraulic fracturing fluids
The USEPA describes hydraulic fracturing fluids in terms of three parts: (1) the base fluid, which is the largest constituent by volume, (2) the additives, which can be a single chemical or a mixture of chemicals, and (3) the proppant. Box 1 (below) provides an overview of chemical classes commonly used in hydraulic fracturing fluids.

Box 1 - Chemical classes commonly used in hydraulic fracturing fluids
The United States EPA has compiled a list of 1,076 chemicals known to be have been used in the hydraulic fracturing process. The chemicals used in hydraulic fracturing fall into different chemical classes and include both organic and inorganic chemicals. The chemical classes of commonly used hydraulic fracturing chemicals include:

- Acids (e.g., hydrochloric acid, peroxydisulfuric acid, acetic acid, citric acid).
- Alcohols (e.g., methanol, isopropanol, ethylene glycol, propargyl alcohol, ethanol).
- Aromatic hydrocarbons (e.g., benzene, naphthalene, heavy aromatic petroleum solvent naphtha).
- Bases (e.g., sodium hydroxide, potassium hydroxide).
- Hydrocarbon mixtures (e.g., petroleum distillates).
- Polysaccharides (e.g., guar gum).
- Surfactants (e.g., poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy, 2-butoxyethanol).
- Salts (e.g., sodium chlorite, dipotassium carbonate).

While there is general information available in the published literature relating to the classes of chemicals commonly used in hydraulic fracturing fluids, there is little data regarding chemicals used in hydraulic fracturing, the physiochemical properties for hydraulic fracturing fluids and their associated toxicological properties (both in terms of individual chemicals and as mixtures). These issues are highlighted in published reports and are also the focus of current research (see Chapter 4).

Another knowledge gap is the potential to mobilise geogenic chemicals. These are chemicals that naturally occur underground and may be mobilised as a consequence of hydraulic fracturing or other activities that may change the chemical regime in the subsurface.

Induced seismicity
The water science studies found that the potential for induced seismicity from hydraulic fracturing is low for all onshore gas types in the Otway region and low for tight and shale gas in Gippsland, noting that hydraulic fracturing is not expected to be required for coal seam gas in Gippsland. Further investigations may be warranted in the event specific projects were proposed, to build on the understanding gained through the water science studies.

7.1.3 Human health knowledge gaps
There are significant knowledge gaps relating to public health risks relating from onshore unconventional has activities. As mentioned previously, the only known research project being conducted at a national level which is focussed on human health is the national assessment of chemicals associated with coal seam gas extraction. While this study is an important first step, there are other significant knowledge gaps relating to human health impacts, including:

- Air emissions or releases associated with chemicals other than those used in coal seam gas extraction at or near the working sites
- Assessments of chemicals needed to support site infrastructure operations such as fuels (petrol, diesel) and oils for machine and plant operation, transport, building services and construction purposes
• Human health risk assessment of geogenic chemicals (contaminants that naturally occur underground and may be mobilised as a consequence of hydraulic fracturing)
• Chemical contamination of deeper groundwater
• Impact of mixtures of chemicals on human health
• Effectiveness of treatments of produced water to remove contaminants
• Treatments to remove impurities from natural gas before it can be used as a fuel.

Addressing these knowledge gaps will be important to provide surety to Government and the community that potential public health impacts can be appropriately managed.

7.1.4 Exploration and direct sampling generates knowledge

As discussed earlier (section 5.2.1), the Crown allows the private sector to develop its earth resources through a licensing system. The role of government has traditionally been to provide pre-competitive information and incentives for explorers to invest in a particular jurisdiction, such as co-funded drilling initiatives, and then collect royalties and rent from companies once they are in production.

Pre-competitive information enables commercial explorers to target potential mineral and energy resources, and also informs the design of the regulatory framework to manage anticipated risks. Commercial exploration (such as direct sampling) under strict licence conditions generates additional, site-specific data that companies use to inform future investment, as well as risk assessment and control and the setting of operation-specific performance standards.

7.1.5 Landscape, social and economic knowledge gaps

Other knowledge gaps include features and assets across prospective areas such as significant farmland, significant landscape and built heritage and Aboriginal cultural heritage values.

In terms of landscape studies, DELWP is in the final stages of completing regional landscape studies of all regional Victoria, except eastern Victoria (Department of Transport, Planning and Local Infrastructure, 2014). A comprehensive landscape assessment would better inform land use decision making, and help ensure landscapes of importance are adequately protected and managed into the future. Similar work is also available for the coastal hinterland, completed in 2006 by the former Department of Sustainability and Environment.

Detailed understanding of net social and economic opportunities and vulnerabilities (as discussed in chapter 5) is not yet available.

7.2 Current regulatory controls

The current body of legislation, regulations, codes of practice and operational guidelines are designed to provide safeguards to ensure that:

• Adverse impacts on water resources are minimised
• Resources are developed in ways that minimise adverse impacts on the environment and the community (including impacts on individuals and public safety)
• Community consultation is effective with appropriate access to information
• Compensation is required for the use of private land for exploration or production
• Conditions in licences and approvals are enforced
• Land that has been accessed is rehabilitated
• Dispute resolution processes are effective.
7.2.1 Coal seam gas
Earth Resources Regulation grants exploration and mining licences and sets conditions to ensure compliance with the MRSD Act. Coal seam gas is regulated under the MRSD Act on the basis that it is produced from coal seams and this arrangement seeks to avoid issues of resource rights conflict. However, in some places the geological units that have been targeted for coal seam gas under the act have also been targeted for tight gas (e.g. Otway region) under the Petroleum Act.

Exploration and mining activities are regulated through an approved work plan. The work plan details the activities to be carried out on the site and how the surrounding environment must be protected. An exploration work plan includes descriptions of the work to be carried out, how the site is to be rehabilitated, consultation arrangements, and how the site will be monitored, including details of environmental monitoring. A mining work plan is more detailed and includes geological information, rehabilitation plan, environmental monitoring plan and a community engagement plan.

During operations, Earth Resources Regulation and EPA have powers and responsibilities to monitor and enforce compliance with environmental standards, relevant State Environment Protection Policies and conditions in any work plan or EPA licence respectively. Licensed sites are regularly inspected to ensure that the commitments set out in the work plan are being met and enforcement action is undertaken where required.

7.2.2 Tight gas and shale gas
The Petroleum Act grants rights to target any and all hydrocarbons in the licence area and does not specify whether those hydrocarbons must be contained in conventional or unconventional reservoirs.

Earth Resources Regulation regulates onshore petroleum exploration and development activities, including shale, tight and conventional gas under the Petroleum Act. It manages licensing, consents, approvals and other issues such as consultation, rehabilitation, royalties and enforcement.

Once a petroleum licence is granted, the holder cannot undertake operations until an operation plan is submitted and approved which is for the specific petroleum activity. The operation plan addresses the proposed activities, risk assessments and management commitments, well operation plans (where relevant) and environment management plans that include consultation.

An environment management plan includes a description of the activity and the purpose of the activity in relation to the target resource, performance objectives and standards, risk assessment and management, implementation strategy, responsibility for compliance, documentation of training and competencies, monitoring, evaluation and audit documentation, consultation and continuous improvement.

The philosophy of compliance activities is to audit the activity against the operation plan at least once, possibly two or three times depending on the duration of the activity. In addition, the Department inspects the activity numerous times reviewing compliance with some or all of the operation plan and in relation to finding from audits. Inspections are done both by notification and by surprise when inspectors are in the area.

7.2.3 Regulation of hydraulic fracturing
Mineral Resources (Sustainable Development) Act 1990
For coal seam gas, hydraulic fracturing is regulated under Schedule 15 of the Mineral Resources (Sustainable Development) (Mineral Industries) Regulations 2013; a work plan must contain a description of the extractive methods to be used. This includes a description of the proposed mineral processing and extraction activities. These plans must include an environmental management plan which identifies key
environmental risks, including background data and baseline studies and detail how they would be mitigated and will include:

- a proposal for management of waste
- a proposed monitoring program
- a description of the plant and equipment to be used
- a description of the physical, chemical or biological processes to be employed
- details of the chemical reagents, additives or bi-products associated with the processes
- approximate throughputs and rates for material input, mineral production, waste production and reagent use.

Injection of fluids used in hydraulic fracturing is subject to risk assessment under the MRSD Act. Licence holders would be required to provide appropriate evidence about hydraulic fracturing, the risks around it and how these risks would be eliminated or mitigated.

**Petroleum Act 1998**

Petroleum activities are defined in section 4 of the Petroleum Act. Petroleum operations include any activity relating to petroleum exploration or production, including drilling wells, hydraulic fracturing, conducting production tests, or seismic surveying.

The Petroleum Act is objective based. It specifically requires all risks (includes safety, integrity and environmental) and controls to be identified and activities to be undertaken in accordance with an approved plan (section 161). The Petroleum Regulations require that an implementation strategy for the environment management plan must be developed (regulation 11) and plans must be modified if risks change.

Petroleum operations can only be undertaken if an Operation Plan is accepted by the Minister (or delegate)(section 161). An Operation Plan must contain other information identified for the activity (regulation 6(1)(a)). This includes an Environment Management Plan for all activities and Well Operation Management Plan for all well activities.

The Well Operation Management Plan must include the philosophy and criteria for design, construction and operation of the well including why hydraulic fracturing may be necessary and exactly how this will be done and by whom. It needs to explain methods for protecting aquifers such as well casing, cementing, logging, checking, verify–repeat (regulation 13(f)(iii)).

The Environment Management Plan includes a description of the activity and the purpose of the activity in relation to the target resource. This description must include a justification that is considered acceptable by Earth Resources Regulation. It also includes mapping to show the proposed location, environmental sensitivities, cadastral boundaries, sensitive receptors, water courses including potable water aquifers and any other local features that may be at risk because of the operation.

The Petroleum Act requires that titleholders submit rehabilitation bonds for surface rehabilitation works (section 172) and to hold insurance for the clean-up of pollution prior to undertaking any activities (section 171).

### 7.2.4 Chemical use

A ban on the addition of BTEX (the hydrocarbons benzene, toluene, ethyl-benzene and xylene) in hydraulic fracturing fluids has been legislated, though there is no commencement date for this while the moratorium is in place.
7.2.5 Water management and monitoring

Coal seam gas production requires the extraction of large volumes of water. This is to depressurise the rock resource, which allows the trapped gas to become mobile and be extracted (with the water). As coal seams are typically shallow, the extraction of large volumes of water may have impacts upon the local hydrogeological system. Petroleum production for tight or shale gas does not require water extraction to mobilise the hydrocarbon, as separation of hydrocarbon from water in the extraction phase is part of well design.

Under the Water Act, extraction or potential access to water is treated in the same way, irrespective of whether the purpose is irrigation, mining, water bottling or another use. Water co-produced with petroleum under the Petroleum Act is exempt from having a take and use licence as it has been determined as not part of an aquifer (the Petroleum Act S166(d)(ii) specifically requires sources of water to be kept separate from petroleum and water in the petroleum is not considered a source of water). However, water co-produced with coal seam gas under the MRSD Act is not exempt from needing a take and use licence.

With the exception of domestic and stock use, and co-produced water under the Petroleum Act, a water entitlement (either a water share or a section 51 'take and use' licence) is required for to extract water from a waterway, groundwater, spring, soak or dam (unless supplied from a roof, or other source for which an entitlement is held).

A licence under section 67 of the Water Act (commonly referred to as a works licence) is required for the construction and operation of works. ‘Works’ is defined broadly in the Water Act and includes dams, bores, pipes and machinery – whether on, above or under land.

Before either the issue or transfer of a take and use licence or works licence, the Water Act requires that a range of matters must be considered by the Minister (or his or her delegate). These include the existing and projected availability of water in the area, as well as any adverse effect that the allocation or use is likely to have on existing authorised uses of water, a waterway or aquifer and environmental protection.

State Environment Protection Polices (SEPPs), established under the Environment Protection Act 1970, provide a legal tool for documenting environmental standards for water quality (see 7.3.2 for more information). Victoria’s State Environment Protection Policy (Groundwaters of Victoria) (SEPP Groundwaters) establishes a comprehensive framework for the protection of all groundwater in Victoria. It focuses on water quality and environmental protection.

The Environment Protection (Scheduled Premises and Exemptions) Regulation 2007 (SPER) partially covers coal seam gas extraction under the Category CO1 (extractive industries and mining). Any discharge of wastewater to groundwater or surface water as a result of CSG extraction will trigger an EPA works approval requirement under the SPER, just like any other mining proposal. However, premises carrying out mining or extractive industries (including CSG) where discharges of waste are solely to the ground and are regulated by the Mineral Resources (Sustainable Development) Act 1990 are exempted from the SPER. The SPER does not explicitly cover the activity of hydraulic fracking, however, as with other CSG activities, fracking may be captured under CO1 where it will result in a discharge of wastewater to groundwater or surface water.

7.2.6 Human health

Health of the public is one of the objectives of the MRSD Act (section 2(1)b(vii)). The Petroleum Act seeks to ensure that impacts on individuals will be minimised as far as is practicable (section 23(2)(b)), and operation plans must identify and minimise risks to any member of the public (section 161). Comprehensive assessment and mitigation of health risks will be important aspects of regulatory approval processes for unconventional gas applications.
7.2.7 Broader consideration of environment, social and economic impacts

Unconventional gas projects would most likely be subject to assessment under the Environment Effects Act 1978, which applies consideration of environment, social and economic impacts. A full Environmental Impact Assessment process involves an independent panel process with extensive public input.

The Environment Effects Act 1978 provides a framework for risk based assessment of the potential impacts of proposals of all sorts to inform any approval decisions that may be required under a variety of legislation relevant to the project under assessment. There is capacity for guidelines to specify particular matters that should be assessed, where an assessment is necessary.

The recently adopted EPBC Commonwealth-Victoria Bilateral (Assessment) Agreement has underscored earlier agreements by the Victorian Government to adopt the National Partnership Agreement on Coal Seam Gas and Large Scale Coal Mining. This will trigger an EES referral.

7.3 Opportunities to improve regulatory safeguards

The results of the community and stakeholder engagement program note that those who are supportive of onshore gas development qualify their support with the caveat of ‘a well-managed industry’. While the current regulatory framework provides a range of important controls and safeguards, there are opportunities for improvement, identified from comparisons of Victoria’s regulatory framework, national and international initiatives and the approaches of other jurisdictions.

However, even a high functioning regulatory framework cannot mitigate all risks. This is important for industries such as onshore unconventional gas, given that the risk of an adverse event may have significant local consequences.

7.3.1 Improving consistency of regulation across unconventional gas types

The MRSD Act and Petroleum Act have been developed to regulate the different technologies used and activities undertaken in conventional mineral and petroleum exploration and production. This has resulted in some inconsistencies when regulating different types of unconventional gas.

The objectives of the MRSD Act explicitly include sustainable development, whereas the Petroleum Act seeks to have regard to economic, social and environmental interests. However, it is the specific sections within each act that apply the principles and achieve the outcomes. In terms of managing risk, both acts seek to minimise adverse impacts of activity on the environment, community (individuals and public amenity) and public safety, though again there are differences in application in each act.

The Petroleum Act specifically identifies well operation and testing as activities which require operation plan approval. In comparison, the MRSD Act does not have any specific provisions for wells, which means that coal seam gas wells are regulated under general risk management provisions within the MRSD Act.

Rights to explore and produce are allocated differently under the two resource acts. Allocation of petroleum licences is by competitive tender, whereas applications for licences under the MRSD Act are over-the-counter, as described in chapter 2.

The MRSD Act contains different consultation requirements than the Petroleum Act. The MRSD Act contains a duty to consult with the community (section 39A) and requires work plans to contain a plan for consulting with the community. In comparison, the Petroleum Act requires that appropriate consultation for the life of the operation about the authority holder’s environmental performance with relevant State and Commonwealth agencies and other relevant interested people and organisations.
Royalties on gas from coal seams are different than royalties on gas from conventional, tight or shale gas. Under the MRSD Act, coal seam gas is subject to a royalty of 2.75 per cent of the net market value, whereas under the Petroleum Act, conventional and other unconventional gas is subject to a 10 per cent royalty on value of petroleum at the wellhead. This inconsistency might affect industry incentives to explore for and produce types of gas.

Where mining is proposed on agricultural land under the MRSD Act, the licence holder must prepare a statement of economic significance to establish whether the value of the mineral resource is more or less than its agricultural worth (section 26A). The content and methodology of the statement are not prescribed. This statement must be made within six months of the granting of the licence (or lodging of a work plan) and a copy must be provided to the landholder. The Petroleum Act does not impose this requirement; if tight or shale gas operations were contemplated in future, the larger landscape footprint of these kinds of development may warrant a similar approach for agricultural land.

Exploration and production data from petroleum projects is released after two years, and interpretive information after five years, in the interests of providing public good information. There is a formal notification process related to release of interpretive information. In comparison, information about minerals and extractives under the MRSD Act is confidential until the licence expires. Release of data about exploration for coal seam gas could inform regulatory and production decisions about unconventional gas exploration and production.

An assessment of Victoria’s regulatory framework against the 18 leading practices in the National Harmonised Regulatory Framework for natural gas from coal seams identifies areas where improvements could be made to ensure Victoria meets the leading practices fully (Appendix 2). The Petroleum Act meets more of the leading practices than the MRSD Act, especially around requirements for environment management plans.

### 7.3.2 Regulatory safeguards for water and the environment

On the basis of the water science studies covered elsewhere in this submission, it is likely that any significant impact on water resources and the environment would come from exploration and development of coal seam gas from brown coal in Gippsland rather than from other forms of unconventional gas (noting, however, the need for access to substantial water resources used in hydraulic fracturing for the production of shale and tight gas). In Gippsland, brown coal seams and the aquifers are interconnected and there are potential water impacts to be managed.

**Coal seam gas from Gippsland brown coals**

*Water licensing - exploration phase*

In the exploration phase the groundwater yield or the amount of groundwater taken is small. The impacts of this water use will be minimal. They can be managed under the *Water Act 1989* under which an applicant may apply for or transfer a take and use licence and apply for a works licence. The matters spelt out in the Act must be considered before any licence is issued. These include potential effects on the resource, existing authorised uses and the environment.

*Water licensing - development phase*

In the development phase of coal seam gas from brown coal in Gippsland, there could be significant impacts from water extraction and depressurisation of surrounding aquifers and would require the development of particular conditions to be applied to the take and use and works licences. The conditions could include: mitigation strategies; requirement to make alternative supply available to licence holders or other users who are adversely affected; and monitoring and reporting requirements.
**Subsidence**

The risk of subsidence is moderate to high in relation to coal seam gas in Gippsland. To deal with this, a condition should be included in any licence issued to require the holder to obtain lithological samples during bore construction for testing and modelling of geotechnical properties. If subsidence is confirmed to be a high risk, appropriate conditions can be included on the take and use licence to manage the subsidence risk associated with water extraction.

**Hydraulic Fracturing**

Hydraulic fracturing is not expected to be required for coal seam gas extraction from brown coals in Gippsland.

**Underground disposal of produced water**

Water extracted to produce coal seam gas is called ‘co-produced water’. There will be potentially large quantities of co-produced water to be managed from coal seam gas development in Gippsland. Disposal underground of produced water is one management option. Underground disposal would have to occur at a significant lateral distance and/or vertical depth beyond production wells. Underground disposal would be authorised under section 76 of the Water Act in consultation with the EPA. There is a potential risk that the disposal of large volumes of produced water could induce seismicity (earth tremors). This risk would need to be assessed as part of the section 76 approval.

**Dam storage of produced water**

Large dams fitting the criteria for wall height and/or volume under section 67 of the Water Act would require a licence for construction and operation. Dams meeting these criteria are classed as hazardous, must comply with ANCOLD guidelines and an emergency management plan must be in place in the event of any weakness in the structure posing a threat to property or life. The use of dams to store large quantities of produced water would be the least preferred management option for produced water especially in higher rainfall and cool climate areas such as Gippsland or the Otway region.

**Tight gas, shale gas and conventional gas**

**Water licensing**

The groundwater yield for tight and shale gas in both the exploration and development phase is negligible and potential impacts are low. Therefore, any potential impacts could be managed by the imposition of conditions similar to those imposed upon other industries that effect groundwater.

**Subsidence**

The risk of subsidence from tight and shale gas development is low.

**Hydraulic fracturing**

Hydraulic fracturing may be required for tight and shale gas development.

Hydraulic fracturing involves the injection of water and sand (typically 98%), and chemicals additives (typically 2%) under high pressure into a bore hole (well) causing fractures to improve the permeability of rock formations and hence gas production.

Potential impacts to groundwater users, surface water users and ecosystems as result of hydraulic fracturing operations primarily relate to chemical contamination of groundwater from hydraulic fracturing fluids. Chemical contamination of groundwater from hydraulic fracturing fluids can occur where the fracture propagation extends further than intended and creates a direct connection to an aquifer. The chemical additives used in hydraulic fracturing fluid vary, depending on the application, the nature of the rock formation, the developer and, in some cases, legislation and regulations applicable to the state or territory. Many of the classes of chemicals are commonly used in other industries, including chemicals used in swimming pool additives, disinfectants and detergents. However there is little data about the actual
chemicals that are or may be used. There is a ban in Victoria on the addition of BTEX (benzene, toluene, ethyl-benzene and xylene) to hydraulic fracturing fluids.

As hydraulic fracturing used for the production of shale and tight gas would be carried out at great depth, it would be unlikely to have any significant impact on aquifers that are accessed by existing users. There could be a low risk of fracturing causing aquifer connection which could be managed by including conditions to require (i) a set-back distance from the base of the aquifer and (ii) surface or down-hole seismic monitoring.

Hydraulic fracturing as part of the bore construction process could be managed by conditions imposed by the regulator under the applicable petroleum regulations in consultation with the Department of Environment, Land, Water and Planning rather than under the Water Act.

State Environment Protection Policies and Scheduled Premises Regulations
State Environment Protection Policies (SEPPs), established under the Environment Protection Act 1970, provide a legal tool for documenting environmental standards for water quality. Currently the SEPP (Waters of Victoria) and SEPP (Groundwaters of Victoria) set environmental standards, known as environmental objectives and indicators. Environmental objectives and indicators are the water quality levels required to protect a range of agreed values and uses (Beneficial uses) of Victorian waters. They are set at a range of geographic scales for rivers, streams, estuaries, marine environments and groundwater.

The SEPP may be useful in defining beneficial uses in areas under consideration of unconventional gas development. Depending on the use, the performance standards could be set with reference to relevant nationally agreed health or environmental guideline values.

The environmental objectives and indicators can be used as a basis for when assessing and approving of works approvals or licences for managing environmental risks and/or discharge of waste to the environment or issuing a notice (under Environment Protection Act 1970). An activity must be established under the Environment Protection (Scheduled Premises and Exemptions) Regulation 2007 (SPER) to be a licensable activity.

SEPP (Waters of Victoria) and SEPP (Groundwaters of Victoria) are currently under review via the SEPP (Waters) Review, which is being led by DELWP with the support of EPA. In addition to the SEPP (Waters) Review, the SPER is also due for review as the regulations sunset in mid-2017. Together, these reviews may provide an opportunity to clarify, streamline and possibly strengthen the regulatory framework, standards and policy direction as they apply to onshore unconventional gas.

7.3.3 Regulatory safeguards for human health
Approvals processes that adequately incorporate risk to public health provide assurances to regulators, other decision makers and the public that risks from these new technologies and industry will be appropriately managed. Additional safeguards for human health could include:

- Full disclosure of chemicals used in natural gas production to support comprehensive health risk assessments.
- Mechanisms to ensure that funds are available for necessary remediation, health risk assessment and management works that might be required to address public health risks during and beyond the life of a project.
- Revised community consultation requirements that licensees be responsive in considering mitigation options raised by residents.

All relevant regulators and decision makers need the required expertise for assessing risks to public health when approving work plans to ensure mines can operate with no undue impact to the health of the
community. Further, as discussed in Chapter 4, appropriate health guidelines would support effective oversight of unconventional gas exploration and development.

### 7.3.4 Other opportunities to manage environmental risks

Several reports provide a analysis of treatment options for the environmental risks associated with unconventional gas, for example the 2014 report of the NSW Chief Scientist and Engineer.

Under the National Partnership Agreement on Coal Seam Gas and Large Scale Coal Mining, Victoria has agreed to refer coal seam gas and coal mining developments that are likely to have a significant impact on water resources to the IESC for advice. On receiving an application that has been referred to the IESC, decision makers must take into account this advice in a transparent manner.

The Victorian Protocol under the National Partnership Agreement specifies that “decision-makers under the MRSD Act and Environment Protection Act 1970 (Vic) are to have regard to advice from the IESC to either the Minister for Planning or to DPCD” (now DELWP).

The protocol also specifies:

- a. Advice will be sought from the IESC for any project proposing to extract coal seam gas or to develop or to expand a coal mine that requires an EES under the Environment Effects Act 1978 and that
- b. Project proposals that could significantly affect the beneficial uses of water resources in a regional or State context, must be referred to the Minister for a decision on the need for an EES.
8 Other reviews and inquiries

There is a substantial body of national and international work on unconventional gas issues across the economic, social and environmental spheres. This section presents a summary table of key studies and findings by other jurisdictions on the management of exploration, extraction, production and rehabilitation of unconventional gas and related industries and risks. The list is not exhaustive, but is provided as an aid to further research.

Despite differences between jurisdictions, there may be sufficient similarity in economic, social and institutional structures and conditions to enable application of lessons learned to the Victorian context.

8.1 Summary of domestic and international reviews and inquiries

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<th>Report</th>
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<td><strong>National</strong></td>
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<td><em>Examining Barriers to More Efficient Gas Markets – Research Paper</em> (March 2015) Productivity Commission (Commonwealth)</td>
<td>Examines issues relating to different stages of the gas supply chain in the eastern Australian gas market, against the backdrop of integration with the Asia-Pacific market. The opening of the export market is creating significant disruption for market participants and is expected to lead to material costs for some gas users, including through higher prices. The gas industry faces resistance from sections of the community, partly due to the poor early record of some companies in dealing with landholders and local communities. Some gas companies have increased their engagement efforts recently.</td>
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<td><strong>Domestic Gas Strategy (2015)</strong> Department of Industry (Commonwealth)</td>
<td>The strategy articulates the Australian Government’s role, and expectations of State and Territory governments (the States) and industry, in developing unconventional gas. The dominant issue that underlies the discussion, analysis and range of policy options presented in this study is the transition of the eastern gas market from being solely domestic to one that is export linked. The scale and duration of this change is likely to have profound effects on market participants. These effects will be exacerbated if impediments to supply or other constraints are imposed on the market’s ability to respond to the challenge of future market dynamics.</td>
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<td><em>National assessment of chemicals associated with coal seam gas in Australia</em> (Expected release in 2015) National Industrial Chemicals Notification and Assessment Scheme (NICNAS)</td>
<td>This project commenced in July 2012 and is expected to be completed in 2015. The project examines human health and environmental risks from chemicals used in drilling and hydraulic fracturing for coal seam gas extraction in Australia.</td>
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<td><strong>ACCC inquiry into Eastern and Southern Australian wholesale gas prices</strong>&lt;br&gt;(2015)</td>
<td>The Australian Government has directed the ACCC to commence a 12 month public inquiry into the competitiveness of wholesale gas prices in Eastern and Southern Australia. &lt;br&gt;The ACCC will consider competition levels in the East Coast upstream gas market - at producer, processor, pipeline, and wholesale levels of the market.</td>
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<td><strong>ASX and AEMO launch Wallumbilla Gas Futures</strong>&lt;br&gt;(2015)</td>
<td>Establishment of a gas futures market to assist the gas industry and move towards increased transparency and competition in Australia’s eastern and south eastern gas markets. &lt;br&gt;Participants will be able to use the Wallumbilla Gas Supply Hub Benchmark price as a basis price for their gas contracts.</td>
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<td><strong>East Coast Wholesale Gas Market and Pipeline Frameworks Review</strong>&lt;br&gt;(2015)</td>
<td>The COAG Energy Council has directed the Australian Energy Market Commission to review the design, function and roles of facilitated gas markets and gas transportation arrangements on the east coast of Australia. &lt;br&gt;Draft report presents six initiatives to improve the market and identifies complex and interlinked issues for more detailed consideration. Most of the initiatives focus on information access.</td>
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<td><strong>Fracking the future - Busting industry myths about coal seam gas</strong>&lt;br&gt;(2014)</td>
<td>This paper asserts the gas industry exaggerates the economic benefits of coal seam gas development, there is little to be gained from rushing exploration for coal seam gas and more work needs to be done to assess the health and environmental risks.</td>
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<td><strong>Gas at the crossroads - Australia's hard choice</strong>&lt;br&gt;(2014)</td>
<td>Independent commentary on gas policy which asserts that governments should remove barriers to efficient market operation and resist community pressure to keep gas affordable.</td>
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<td><strong>National Harmonised Regulatory Framework for natural gas from coal seams (2013)</strong>&lt;br&gt;Standing Council on Energy and Resources (COAG Energy Council)</td>
<td>Defines 18 leading practices for regulating coal seam gas operations in the areas of well integrity, water management and monitoring, hydraulic fracturing and chemical use. All jurisdictions report to COAG Energy Council on progress to implement the framework. Victoria is not amending its legislation prior to a decision on the moratorium.</td>
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<td><strong>Eastern Australian Domestic Gas Market Study (2013)</strong>&lt;br&gt;Department of Industry (Commonwealth), Bureau of Resources and Energy Economics</td>
<td>The study was designed to help address information gaps and inform debate on strategy for gas policy. Outlines options for governments to address gas supply constraints and facilitate well-functioning and transparent markets.</td>
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<td><strong>Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development research projects (2013)</strong>&lt;br&gt;Commonwealth Government</td>
<td>The IESC provides scientific advice to decision makers on the impact that coal seam gas and large coal mining development may have on Australia’s water resources. The research aims to strengthen the science underpinning regulatory decisions, including by informing the advice the IESC provides to regulators. It focuses on areas of high risk and where there are identified knowledge gaps, and aims to address issues of national significance within three years.</td>
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<td><strong>Bioregional Assessments (2013)</strong>&lt;br&gt;CSIRO, Department of the Environment (Cth), and Geoscience Australia</td>
<td>The purpose of a bioregional assessment is to define, characterise and explain conceptual models that establish causal pathways describing the chain of interactions and events connecting depressurisation and dewatering of coal seams at depth with impacts on anthropogenic and ecological receptors located at depth or the surface. Gippsland is one of six areas where bioregional assessments are being conducted in Australia.</td>
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<td><strong>Securing Australia’s Future – Engineering energy: unconventional gas production (2013)</strong>&lt;br&gt;Australian Council of Learned Academies</td>
<td>The discovery of large shale gas resources and the exploitation of shale gas (and shale oil) reserves have transformed the energy market in North America and have the potential to have a major impact on global gas supplies. Although the most prospective Australian shale gas basins are located inland, in sparsely populated areas, it is likely that some shale gas resources will also be found in more densely populated parts of Queensland, NSW, Victoria and Western Australia and the presence of existing gas infrastructure there, could mean that it may be economic to develop shale gas in these areas as long as social and environmental issues are appropriately addressed.</td>
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<td><strong>Framework for assessing potential local and cumulative effects of mining on groundwater resources – project summary report (October 2011)</strong> National Water Commission, Sinclair Knight Merz, Sustainable Minerals Institute</td>
<td>The mining risk framework proposes a risk-based approach to managing cumulative groundwater affecting activities of mine operators and identifies issues to be considered when undertaking a cumulative effects assessment of mining on groundwater resources.</td>
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<td><strong>An analysis of coal seam gas production and natural resource management in Australia – Issues and ways forward (October 2012)</strong> John Williams Scientific Services for the Australian Council of Environmental Deans and Directors</td>
<td>Literature-based review and analysis of coal seam gas production, from the perspectives of government, industry and community. Examines the science and engineering of coal seam gas production in Australia and overseas and potential impacts of the industry on natural resource management issues in the Australian landscape. Also looks at social, economic and community development issues associated with expansion of the industry in Queensland and NSW.</td>
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<td><strong>Victoria</strong></td>
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<td><strong>Unconventional gas: managing risks and impacts (third quarter 2015)</strong> Victorian Auditor-General’s office</td>
<td>This audit is being undertaken to inform Parliament about Victoria’s preparedness to effectively respond to emerging risks and challenges. This will include examining recent activities and approaches to manage the risks and impacts associated with unconventional gas exploration and production. The audit will determine whether Victoria is well-placed to effectively respond to potential environmental and community risks and impacts in the event that unconventional gas activities proceed in this state.</td>
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<td>Report on community and stakeholder attitudes to onshore natural gas in Victoria (April 2015)</td>
<td>The Primary Agency was engaged as an independent facilitator to conduct a community and stakeholder consultation process to discuss and seek community input on issues surrounding the potential of an onshore gas industry in Victoria. The final report of the community and stakeholder engagement program presented the results in terms of the views expressed by three defined groups: supportive, not supportive and undecided/don’t know.</td>
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<td>Report of the Gas Market Taskforce (September 2013)</td>
<td>The Gas Market Taskforce was established in December 2012 to provide policy options to the Victorian Government on improving the operation and efficiency of the eastern Australian gas market, suggesting ways of facilitating market transparency and transmission capability, and increasing gas supply to meet rising demand at competitive prices. The eight member Taskforce was chaired by former Commonwealth Minister, the Hon. Peter Reith. The Report makes 19 recommendations including lifting the holds on fracking and the approval of new Coal Seam Gas exploration licences. The Report also details recommendations to ensure the application of the highest standards of regulatory and scientific oversight of the gas industry.</td>
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<td>New South Wales</td>
<td>The NSW Gas Plan is about securing gas supplies for NSW households and businesses by establishing a safe, sustainable industry. In developing the Gas Plan, the Government is acting upon the independent advice of the NSW Chief Scientist and Engineer, Professor Mary O’Kane, as set out in the Final Report of the Independent Review of Coal Seam Gas Activities in NSW. This report represents 19 months of work reviewing the coal seam gas industry. The final conclusion of this work is that the risks of gas development can be effectively managed with the right regulation, engineering solutions, and ongoing monitoring and research. The Plan accepts all of Professor O’Kane's recommendations.</td>
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<td>NSW Gas Plan (2014) NSW Government</td>
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Parliamentary Inquiry into unconventional gas in Victoria – Victorian interdepartmental submission 68
| **Independent review of coal seam gas activities in New South Wales (2014)**  
NSW Chief Scientist and Engineer, Professor Mary O’Kane | In November 2013 the NSW Government implemented a hold on exploration and extraction of coal seam gas in ‘Special Area’ zones in the Sydney drinking water catchment, pending an investigation into potential impacts by the NSW Chief Scientist and Engineer.  
In September 2014 the NSW Chief Scientist and Engineer published her independent review of coal seam gas activities in NSW. |
| **NSW Government response - NSW Legislative Council General Purpose Standing Committee - Inquiry into Coal Seam Gas (May 2012)**  
New South Wales Parliament - Legislative Council | A key theme throughout this report is the level of uncertainty surrounding the potential impacts of the coal seam gas industry.  
The Inquiry concludes more data needs to be gathered to assess the potential impacts of the coal seam gas industry. In order to do this exploration should proceed. While exploration and drilling are of great concern to many community members, they are unavoidable if we are to assess whether it is safe for the industry to proceed to production. |
| **On measuring the cumulative impacts of activities which impact ground and surface water in the Sydney Water Catchment (2014)**  
NSW Government | The Report assesses the cumulative impacts of several activities, for example a longwall mine or a new coal seam gas well, occurring simultaneously in the Sydney Water Catchment.  
The assessment was broken down into cumulative impact issues associated with water quality, water quantity and whole-of-catchment issues. |
| **Coal Seam Gas Review: a series of technical information papers on specific sets of issues related to the coal seam gas industry (2013)**  
NSW Government Chief Scientist and Engineer | A series of technical information papers on specific sets of issues related to the coal seam gas industry and operations was commissioned by the Review. The papers form a key component of the Review as both an information source and assisting in developing reports and informing compliance activities.  
Chief Scientist and Engineer, Professor O’Kane published a number of issues-based reports and information papers during her 19-month review of coal seam gas activities in NSW. |
| **Coal Seam Gas Review: Life Cycle of Coal Seam Gas Projects (2013)**  
Professor Peter J Cook, NSW Government | In order to address a number of key issues relating to coal seam gas in New South Wales, the Office of the Chief Scientist and Engineer requested a report covering the following areas  
The coal seam gas project life cycle including:  
- exploration  
- assessment (including pilot well testing)  
- production  
- suspension, Closure and Abandonment  
- storage, processing and transport of gas. |
### Northern Territory

Dr Allan Hawke AC for the Northern Territory Government  
On 26 February 2015 the NT Government released the Report of the Inquiry into Hydraulic Fracturing in the Northern Territory. The report concluded that hydraulic fracturing could take place safely in the Northern Territory provided the appropriate regulatory and monitoring regime was in place, and that there is no justification for a moratorium on hydraulic fracturing. The Report also identified widespread community concerns about fracking.

In response the NT Government acknowledged the community concerns and has announced steps to ensure current exploration activities continue to be safely managed while a best-practice regulatory model in line with community expectations is developed.

### Queensland

**A framework for the next generation of onshore oil and natural gas in Queensland** (2014)  
Queensland Government  
The framework provides an overview of Queensland’s regulation of the deep gas and oil industry and highlights 12 recommendations that respond to policy issues to encourage ongoing investment in the industry in an environmentally and socially responsible way.

**Groundwater risks associated with coal seam gas development in the Surat and southern Bowen Basins** (2013)  
Department of Natural Resources and Mines, Worley Parsons  
Identified key risk factors for the Surat and southern Bowen basin groundwater systems associated with the emerging coal seam gas industry and developed a methodology for the risk assessment.

The risk assessment is based on the widely used source pathway and receptor principle with the adopted hybrid Groundwater Model and Multi Criteria Analysis methodology overlaying the different risk attributes using Geographic Information System.

Queensland Water Commission  
The Underground Water Impact Report is the legally enforceable instrument to implement the baseline assessment and ‘make good’ provisions for the Surat Cumulative Management Area under the Queensland Water Act 2000. The report contains a regional groundwater model to predict immediate & long term impacts, a water monitoring strategy and a spring impact management strategy, and defines the rules for determining responsible tenure holders and their obligations to ‘make good’ on impairment of private bore water supply.

### South Australia

**Inquiry into Unconventional Gas (Fracking)** (2015)  
South Australian Government submission  
The Natural Resources Committee of the SA Parliament is conducting an inquiry into Unconventional Gas (Fracking).

The South Australian Government submission to the inquiry asserts deep natural gas in the South East could be exploited using fracture stimulation technology without significant or unacceptable controlled risks to the environment, people or enterprises and would deliver significant benefits to the South Australian community.
| **Assessment of Vulnerability of Water Assets to Hydrological Change Cause by Coal Seam Gas and Large Coal Mining Development in South Australia**  
(February 2014)  
Department of Environment, Water and Natural Resources, Auricht Projects Pty Ltd | A foundational activity contributing to a knowledge and information platform supporting improved management of water resources in South Australia. |
|---|---|
| **Groundwater assessments of the Arckaringa and Pedirka Basins**  
(2013)  
Department of Environment, Water and Natural Resources | Targeted groundwater assessment projects of the Arckaringa Basin and Pedirka Basin, in recognition of coal mining development potential, data scarcity and water resource significance. The report focus is on hydrogeological considerations. |
| **Tasmania** | |
| **Government Policy on Hydraulic Fracturing (Fracking) in Tasmania**  
(2015)  
Tasmanian Government | On 26 February 2015 the Tasmanian Government released a policy statement detailing its intent to maintain a moratorium on the use of hydraulic fracturing for the purposes of hydrocarbon resource extraction until March 2020. The statement was in response to a review by the Department of Primary Industries, Parks, Water and Environment into fracking in Tasmania. The Review was conducted in collaboration with the EPA Division and AgriGrowth Tasmania within the Department, and with Mineral Resources Tasmania in the Department of State Growth. |
### United States of America

**EPA's Study of Hydraulic Fracturing for Oil and Gas and Its Potential Impact on Drinking Water Resources**  
(June 2015)  
US EPA

The USEPA issued a draft assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources (USEPA 2015). The scope of the assessment included water acquisition for hydraulic fracturing fluids, chemical mixing at the well site to create hydraulic fracturing fluids, well injection of hydraulic fracturing fluids, the collection of hydraulic fracturing wastewater and wastewater treatment and disposal.

The draft report concluded that no evidence could be found of widespread, systemic impacts on drinking water resources, but that potential vulnerabilities in the water lifecycle exist which could impact drinking water. The report identifies potential vulnerabilities to drinking water resources (not all of which are unique to hydraulic fracturing) including:

- water withdrawals in areas with low water availability;
- hydraulic fracturing conducted directly into formations containing drinking water resources;
- inadequately cased or cemented wells resulting in below ground migration of gases and liquids;
- inadequately treated wastewater discharged into drinking water resources;
- and spills of hydraulic fluids and hydraulic fracturing wastewater, including flowback and produced water.

### United Kingdom

**Shale Gas and Groundwater** *(date unknown)*  
British Geological Survey

Research projects on the potential impacts on groundwater from possible shale gas development in the UK.

A national survey of baseline methane concentrations in ground waters across the UK.

Mapping the spatial relationships between potential shale gas source rocks and overlying aquifers.

**The Royal Society Shale gas extraction in the UK: a review of hydraulic fracturing, The Royal Society and the Royal Academy of Engineering**  
(2012)  
Stanford University

The UK Government’s Chief Scientific Adviser, asked the Royal Society and the Royal Academy of Engineering to review the scientific and engineering evidence and consider whether the risks associated with hydraulic fracturing as a means to extract shale gas could be managed effectively in the UK.

The key findings of this review include:

- health, safety and environmental risks can be managed effectively in the UK. Operational best practices must be implemented and enforced through strong regulation, and
- fracture propagation is an unlikely cause of contamination - The risk of fractures propagating to reach overlying aquifers is very low provided that shale gas extraction takes place at depths of many hundreds of metres or several kilometre.
Bibliography


Alberta Energy Regulator undated, Play-based regulation: piloting a new approach to oil and gas regulation. <www.aer.ca/documents/About-Us/PBR_Brochure.PDF>


Department for Manufacturing, Innovation, Trade, Resources and Energy 2012, *Roadmap for oil and gas projects in South Australia,* South Australia.


Department of Environment, Land, Water and Planning (DELWP) and Geological Survey of Victoria (GSV) 2015a, *Onshore natural gas water science studies — Gippsland region assessment of potential impacts on


Dr Barry Drummond, background paper on seismicity for NSW Chief Scientist and Engineer http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0019/32761/Background-Paper-on-Seismicity_Dr-Barry-Drummond.pdf


Energy Quest 2014, *Oil and gas industry cost trends*, November.


Geoscience Australia, Australian Mines Atlas,  


Media release by the Minister for Energy and Resources ‘Onshore gas exploration on hold as consultation continues’, 28 May 2014.


New South Wales Government 2014b, *On measuring the cumulative impacts of activities which impact ground and surface water in the Sydney Water Catchment*. 

Parliamentary Inquiry into unconventional gas in Victoria – Victorian interdepartmental submission
Parliamentary Inquiry into unconventional gas in Victoria – Victorian interdepartmental submission


Western Australian Government 2010, *Coastal Eutrophication Risk Assessment Tool* -

# Glossary of terms and abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>ACCC</td>
<td>Australian Competition and Consumer Commission</td>
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<tr>
<td>ANCOLD</td>
<td>Australian National Committee on Large Dams</td>
</tr>
<tr>
<td>Aquifer</td>
<td>Rock or soil that readily transmits water</td>
</tr>
<tr>
<td>Aquifer</td>
<td>depressurisation Reduction in aquifer pore water and gas pressure (e.g. due to extraction of groundwater and gas)</td>
</tr>
<tr>
<td>Basin</td>
<td>A geological depression filled with sediments.</td>
</tr>
<tr>
<td>Bcf</td>
<td>Abbreviation for billion cubic feet, a unit of measurement for large volumes of natural gas.</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.</td>
</tr>
<tr>
<td>Black coal</td>
<td>A carbon-rich sedimentary rock that forms from the remains of plants deposited as peat in swampy environments. Black coal is older in age and of greater hardness and energy content than brown coal.</td>
</tr>
<tr>
<td>Bore / borehole</td>
<td>‘Bore’ and ‘borehole’ generally refer to a hole drilled in the ground with a drilling rig for the purpose of geological or hydrogeological investigation or groundwater extraction. ‘Well’ generally refers to a hole drilled in the ground with a drilling rig for the purpose of oil or gas exploration or extraction.</td>
</tr>
<tr>
<td>Brown coal</td>
<td>A carbon-rich sedimentary rock that forms from the remains of plants deposited as peat in swampy environments. Brown coal is younger in age and of lower hardness and energy content than black coal.</td>
</tr>
<tr>
<td>BTEX</td>
<td>Collective term for the hydrocarbon compounds benzene, toluene, ethyl-benzene and xylene (which can be naturally occurring, for example in crude oil, and at background concentrations in groundwater in the vicinity of natural gas and petroleum deposits).</td>
</tr>
<tr>
<td>Compaction</td>
<td>The physical process by which sediments are consolidated. As layers of sediment accumulate, the ever increasing overburden pressure during burial causes compaction of the sediments, loss of pore fluids and formation of rock as grains are welded or cemented together.</td>
</tr>
<tr>
<td>CSG</td>
<td>Coal Seam Gas</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organisation</td>
</tr>
<tr>
<td>DEDJTR</td>
<td>Department of Economic Development, Jobs, Transport and Resources</td>
</tr>
<tr>
<td>DELWP</td>
<td>Department of Environment, Land, Water and Planning</td>
</tr>
<tr>
<td>Drilling (core)</td>
<td>Undertaken to recover rock-core samples and below-ground tests at depths of up to 4000 metres. Core drilling uses a rotating, ring-shaped drill-bit to recover a continuous rock-core. Geologists use the core samples for a range of analyses, geological modelling and interpretation.</td>
</tr>
<tr>
<td>EDIC</td>
<td>Economic Development and Infrastructure Committee</td>
</tr>
<tr>
<td>EMP</td>
<td>Environment management plan</td>
</tr>
</tbody>
</table>

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Cook et al 2013
Schlumberger 2015 <www.glossary.oilfield.slb.com/>
IUCN 2015 <iucn.org/iyb/about/>
<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
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</thead>
<tbody>
<tr>
<td>EPA</td>
<td>Environment Protection Authority</td>
</tr>
<tr>
<td>Ex ante</td>
<td>A phrase meaning ‘before the event’, often used to indicate a forecast or intention.</td>
</tr>
<tr>
<td>Exploration</td>
<td>The phase of operations in which a company searches for oil or gas by carrying out detailed geological and geophysical surveys followed up where appropriate by exploratory drilling in the most prospective locations.</td>
</tr>
<tr>
<td>Export parity price</td>
<td>The price that a producer gets or can expect to get for its product if exported, equal to the freight on board price minus the costs of getting the product from the farm or factory to the border.</td>
</tr>
<tr>
<td>Fault</td>
<td>A break or planar surface in a brittle rock across which there is an observable displacement.</td>
</tr>
<tr>
<td>Fugitive emissions</td>
<td>Emissions of gases or vapors from pressurised equipment due to leaks and other unintended or irregular releases.</td>
</tr>
<tr>
<td>Gas treatment and transmission</td>
<td>Includes gas processing plants, compressors, and pipelines for collection and delivery of gas to markets.</td>
</tr>
<tr>
<td>Geophysical data collection</td>
<td>Gravity or seismic surveys is common, providing valuable information about the subsurface geology. Other geophysics techniques also used include electrical, electromagnetic and magnetic surveys to map the subsurface and better understand the buried geology where gas accumulations might be found.</td>
</tr>
<tr>
<td>Geogenic</td>
<td>Naturally occurring chemicals formed by geological processes within the Earth.</td>
</tr>
<tr>
<td>GISERA</td>
<td>Gas Industry Social and Environmental Research Alliance</td>
</tr>
<tr>
<td>GSV</td>
<td>Geological Survey of Victoria</td>
</tr>
<tr>
<td>Gravity survey</td>
<td>A gravity survey measures small gravity variations at individual points on the ground. Rock density varies with rock type (for instance, sandstone density is different to granite) and this affects the Earth's overall gravity field located near the rock. This small effect can be measured at the surface with a gravity meter – a sensitive weight measuring instrument. This survey will result in a gravity variation map, and estimated positions and depths to rock features of different density.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>Water found underground in the pores and fissures of soil and rock.</td>
</tr>
<tr>
<td>Habitat fragmentation</td>
<td>The process by which habitat loss results in the division of large, continuous habitats into smaller, more isolated remnants.</td>
</tr>
<tr>
<td>Hydraulic fracturing</td>
<td>Used to increase gas production from low permeability rocks. The process involves creating fractures or opening existing natural fractures in deep rock formations through injecting fluid, sand (proppant) and potentially, chemical additives at high pressure.</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>A naturally occurring organic compound comprising hydrogen and carbon. Petroleum is a complex mixture of hydrocarbons. The most common hydrocarbons are natural gas, oil and coal.</td>
</tr>
<tr>
<td>Hydrogeology</td>
<td>The area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the earth's crust (commonly in aquifers).</td>
</tr>
<tr>
<td>IESC</td>
<td>Independent Expert Scientific Committee for coal seam gas and large coal mining development</td>
</tr>
<tr>
<td>Induced seismicity</td>
<td>Refers to typically minor earthquakes and tremors that are caused by human activity that alters the stresses and strains on the Earth's crust. Most induced seismicity is of a low magnitude.</td>
</tr>
<tr>
<td>Information asymmetry</td>
<td>Where considering decisions around contracts or transactions, one party has more or better information than the other, resulting in an imbalance of power in negotiations.</td>
</tr>
<tr>
<td>JCC</td>
<td>Japan Crude Cocktail</td>
</tr>
<tr>
<td>Land subsidence</td>
<td>A lowering of the ground surface in an area, for example due to excessive withdrawal of groundwater causing soil or rock to compact.</td>
</tr>
<tr>
<td>Lithology</td>
<td>The macroscopic nature of the mineral content, grain size, texture and color of rocks.</td>
</tr>
<tr>
<td>LNG</td>
<td>Liquefied Natural Gas</td>
</tr>
<tr>
<td>Macerals</td>
<td>A microscopic constituent of coal.</td>
</tr>
<tr>
<td>MCA</td>
<td>Minerals Council of Australia</td>
</tr>
<tr>
<td>Term</td>
<td>Explanation</td>
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<tr>
<td>Mineralogy</td>
<td>The area of geology that deals with the chemistry, crystal structure, and physical (including optical) properties of minerals.</td>
</tr>
<tr>
<td>MLUF</td>
<td>Multiple Land Use Framework</td>
</tr>
<tr>
<td>MRSD Act</td>
<td><em>Mineral Resources (Sustainable Development) Act 1990</em></td>
</tr>
<tr>
<td>NWI</td>
<td>National Water Initiative</td>
</tr>
<tr>
<td>Native Title Act</td>
<td><em>Native Title Act 1993 (Commonwealth)</em></td>
</tr>
<tr>
<td>Permissible Consumptive Volume</td>
<td>A cap on the total volume of water that may be taken in and area or water system</td>
</tr>
<tr>
<td>Permeability</td>
<td>The degree to which gas or fluids can move through a rock.</td>
</tr>
<tr>
<td>Petajoules</td>
<td>A unit of energy, work or heat equal to 1015 joules.</td>
</tr>
<tr>
<td>Petroleum Act</td>
<td><em>Petroleum Act 1998</em></td>
</tr>
<tr>
<td>Play</td>
<td>An area in which hydrocarbon accumulations or prospects of a given type occur (e.g. shale gas play).</td>
</tr>
<tr>
<td>Porosity</td>
<td>The amount of pore space (voids) in between the grains in a rock available for air, water, other fluids or gas to be stored.</td>
</tr>
<tr>
<td>Possible reserve</td>
<td>An element of ‘unproven’ reserves, possible reserves are an estimate of oil or gas reserves that may be present for extraction.</td>
</tr>
<tr>
<td>Probable reserve</td>
<td>An element of ‘unproven’ reserves, probable reserves are those assessed to have a 50% chance of being present.</td>
</tr>
<tr>
<td>Produced water</td>
<td>Produced water is typically a combination of water from the geological formation and hydraulic fracturing fluid ‘produced’ as a result of unconventional gas extraction activities.</td>
</tr>
<tr>
<td>Production</td>
<td>The phase of bringing well fluids to the surface and separating then and storing, gauging and otherwise preparing the product for transportation.</td>
</tr>
<tr>
<td>Prospective resources</td>
<td>Petroleum that is potentially recoverable from undiscovered accumulations.</td>
</tr>
<tr>
<td>Prospectivity</td>
<td>An assessment, whether qualitative or quantitative, of the potential for prospective gas resources.</td>
</tr>
<tr>
<td>Proven reserve</td>
<td>Quantity of energy sources estimated with reasonable certainty, from the analysis of geologic and engineering data, to be recoverable from well-established or known reservoirs with the existing equipment and under the existing operating conditions</td>
</tr>
<tr>
<td>RDV</td>
<td>Regional Development Victoria</td>
</tr>
<tr>
<td>Reservoir</td>
<td>A rock or geological formation that may hold petroleum within the pore spaces in the rock.</td>
</tr>
<tr>
<td>RGP</td>
<td>Regional Growth Plan</td>
</tr>
<tr>
<td>Rural Decline</td>
<td>The general decrease in economic activity and employment in a rural region. Consists of factors such as migration (particularly youth) away from rural regions, the resulting loss in human capital and increasing rural poverty due to low rural incomes compared to urban areas.</td>
</tr>
<tr>
<td>SCER</td>
<td>Standing Council on Energy and Resources</td>
</tr>
<tr>
<td>Seal</td>
<td>An impermeable rock that forms a barrier or cap above reservoir rocks such that fluids cannot migrate beyond the reservoir.</td>
</tr>
<tr>
<td>Sedimentary sequence</td>
<td>The sequence of layers (strata) in sedimentary rock.</td>
</tr>
<tr>
<td>SEPP</td>
<td><em>State Environment Protection Policy</em></td>
</tr>
<tr>
<td>Seismic survey</td>
<td>A survey of underground geology using the same principle as medical ultrasound scanning, but on a larger scale. Vibrating plates are pressed to the ground to generate sound waves, and the echoes are recorded to generate cross-sectional images of the earth.</td>
</tr>
<tr>
<td>Shale gas</td>
<td>Natural gas produced from gas shale formations.</td>
</tr>
<tr>
<td>Term</td>
<td>Explanation</td>
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<td>-------------------------------</td>
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</tr>
<tr>
<td>Gas shale</td>
<td>A unit of shale rock that produces natural gas. A shale that is thermally mature enough and has sufficient gas content to produce economic quantities of natural gas.</td>
</tr>
<tr>
<td>Social licence to operate</td>
<td>The ongoing approval or acceptance of the local community and other stakeholders for a project or the operation of an industry.</td>
</tr>
<tr>
<td>Soil hydrocarbon surveys</td>
<td>Collects information on hydrocarbon concentrations in shallow soils (typically less than one metre depth), which is used to interpret potential hydrocarbon pathways in the subsurface. The test involves placing modules in the ground for several weeks. The modules are then recovered and sent to a laboratory for analysis.</td>
</tr>
<tr>
<td>Source rock</td>
<td>A rock rich in organic matter, which, if heated sufficiently, will generate oil or gas.</td>
</tr>
<tr>
<td>SPER</td>
<td>Environment Protection (Scheduled Premises and Exemptions) Regulation 2007</td>
</tr>
<tr>
<td>Sunk costs</td>
<td>Costs that have already been expended and are largely (or entirely) unable to be retrieved, so should be considered irrelevant to future decision making.</td>
</tr>
<tr>
<td>SDL</td>
<td>Sustainable Diversion Limit. The sustainable diversion limit is the amount of surface water that can be taken for town water supplies, industry, agriculture and other human or ‘consumptive’ uses.</td>
</tr>
<tr>
<td>Strata</td>
<td>Layers of sedimentary rock.</td>
</tr>
<tr>
<td>Tight gas</td>
<td>Gas produced from a relatively impermeable reservoir rock. The term is generally used for reservoirs other than shales.</td>
</tr>
<tr>
<td>Traditional Owner Settlement Act</td>
<td>Traditional Owner Settlement Act 2010 (Victoria)</td>
</tr>
<tr>
<td>Trap</td>
<td>Any barrier to the upward movement of oil or gas, allowing either or both to accumulate.</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>VCAT</td>
<td>Victorian Civil and Administrative Tribunal</td>
</tr>
<tr>
<td>Venting</td>
<td>The controlled release of unburned gases directly into the atmosphere. Typically to allow safe disposal of gases in an emergency situation where those gases cannot be stored.</td>
</tr>
<tr>
<td>Vertical integration</td>
<td>An arrangement by which elements of a supply chain of a company is owned by that company.</td>
</tr>
<tr>
<td>VFF</td>
<td>Victorian Farmers Federation</td>
</tr>
<tr>
<td>Viticulture</td>
<td>The science, production and study of grapes (for example for winemaking).</td>
</tr>
<tr>
<td>Well</td>
<td>See bore/borehole</td>
</tr>
<tr>
<td>WOMP</td>
<td>Well operation management plan.</td>
</tr>
</tbody>
</table>
Appendix 1

COAG principles of best practice regulation

COAG has agreed that all governments will ensure that regulatory processes in their jurisdiction are consistent with the following principles:

1. Establishing a case for action before addressing a problem.
2. A range of feasible policy options must be considered, including self-regulatory, co-regulatory and non-regulatory approaches, and their benefits and costs assessed.
3. Adopting the option that generates the greatest net benefit for the community.
4. In accordance with the Competition Principles Agreement, legislation should not restrict competition unless it can be demonstrated that:
   a. the benefits of the restrictions to the community as a whole outweigh the costs, and
   b. the objectives of the regulation can only be achieved by restricting competition.
5. Providing effective guidance to relevant regulators and regulated parties in order to ensure that the policy intent and expected compliance requirements of the regulation are clear.
6. Ensuring that regulation remains relevant and effective over time.
7. Consulting effectively with affected key stakeholders at all stages of the regulatory cycle.
8. Government action should be effective and proportional to the issue being addressed.
Appendix 2

A preliminary assessment of Victoria’s regulatory framework against the leading practices of the National Harmonised Regulatory Framework

For each leading practice that Victoria does not fully meet, comments are provided about the current situation and the interim and longer term changes that could be implemented to achieve these leading practices within the current regulatory regime.

Leading Practice 1 – Undertake comprehensive environmental impact assessment, including rigorous chemical, health and safety and water risk assessments

Victorian regulation meets this leading practice via the Environment Effects Statement process.

Leading Practice 2 - Develop and implement comprehensive environmental management plans which demonstrate that environmental impacts and risks will be as low as reasonably practicable

Assessment of work plans currently provides for the general matters articulated in LP 2, but this process does not specifically consider the risks particular to coal seam gas or hydraulic fracturing operations.

- Coal seam gas exploration: there is no specific requirement for an Environmental Management Plan (EMP) at this stage and requirements don’t cover hydraulic fracturing.
- Coal seam gas development: the Mineral Regulations require an EMP as part of the work plan, but don’t specifically cover ‘risks’ and hydraulic fracturing.
- Shale/tight gas (Petroleum Act): requires operation plans and identification of risks to the environment and management of these. The Petroleum Regulations specifically require an EMP be included in the operation plan, whether for exploration or development. EMP requirements do not specifically refer to hydraulic fracturing.

Interim reform could impose conditions on exploration and retention licences requiring the preparation of an EMP as part of a work plan.

Long term reform under the current regulatory regime could:

- Amend the Legislation (MRSD Act and Petroleum Acts as required, ensuring consistency) to define coal seam gas and to require an EMP for all coal seam gas mining work plans.
- Amend the respective Mineral and Petroleum Regulations (or both) to specify EMP requirements for coal seam gas mining/development where hydraulic fracturing is involved, including an up-front risk assessment and risk management, and require full disclosure of chemicals used.
- Develop new coal seam gas Work Plan Guidelines that explain the expectations set out in the Regulations and include best practice for operations and hydraulic fracturing and expectations for exploration and development stages.
Leading Practice 3 - Apply a hierarchy of risk control measures to all aspects of the coal seam gas project

While Victoria broadly meets this leading practice, a partial gap exists under the MRSD Act in that there is no EMP required for coal seam gas exploration and no well operation management plan (WOMP) is required for coal seam gas operations (as is the case for Petroleum Regulations).

Interim and long term reform would be as for Leading Practice 2.

Leading Practice 4 - Verify key system elements, including well design, water management and hydraulic fracturing processes, by a suitably qualified and authorised person

The MRSD Act and Mineral Regulations do not explicitly require the proponent to outline the skills, experiences, accreditation and qualifications of their personnel or contractors.

Petroleum Act and Regulations do not specifically provide for verification, though there are requirements for an applicant to provide information about technical qualifications etc. An EMP requires an implementation plan, including a clear chain of command, roles and responsibilities etc.

Guidelines (Work Plan Guidelines for a Mining Licence) do not outline what is an acceptable level of competency for an operator or contractor to perform well drilling and hydraulic fracturing processes based upon a risk assessment.

Reforms could include placing a condition on all coal seam gas licences and petroleum titles to require a suitably qualified person to verify key system elements.

Licensing of infrastructure through works licences and disposal of matter underground under the Water Act 1989. This includes bores and licence conditions relating to the construction of the bore, and skills and qualifications of the person undertaking the work.

Leading Practice 5 - Apply strong governance, robust safety practices and high design, construction, operation, maintenance and decommissioning standards for well development

There are currently no requirements for a WOMP for coal seam gas operations under the MRSD Act or Mineral Regulations. The requirement does exist under the Petroleum Act.

An interim reform would be to require best practice well development standards via condition on all coal seam gas licences and implement via the existing work plan process.

Long term reform would mirror the Petroleum Act Requirement for a WOMP in the MRSD Act, and prescribe WOMP requirements in the Mineral Regulations, supported by guidelines.

All water bores are required meet the “Minimum Construction Requirements for Water Bores in Australia”.

Leading Practice 6 - Require independent supervision of well construction

There is no explicit requirement for independent supervision of well construction under the MRSD Act or Petroleum Act, however this is likely to be standard industry practice.

An interim reform could be to require verification of well design and independent supervision of construction via a condition on the licence.
Long term reform could include a requirement for verification of well design and independent supervision of construction as part of the WOMP in the Mineral and Petroleum Regulations, and provide supporting information in guidelines.

The Rural Water Corporations are responsible for compliance of water bore construction.

**Leading Practice 7 - Ensure the provision and installation of blowout preventers informed by a risk assessment**

This requirement is not specifically contemplated by the MRSD Act, which was developed to legislate for traditional minerals exploration. However, there is a standard licence condition (20.4) applied to require blowout preventers for coal seam gas exploration. The Petroleum Act and Regulations does not explicitly require blowout preventers. This ‘gap’ relates specifically to ‘informed by a risk assessment’.

An interim reform could be to place conditions on licences that blow out preventers are required if their need is determined by a risk assessment, and to ensure that these are reflected in work plans for coal seam gas or WOMPs for Petroleum licences.

Long term reform could develop guidelines that explain what is required in a risk assessment and when blow out preventers are required.

**Leading Practice 8 - Use baseline and ongoing monitoring for all vulnerable water resources**

The current water licensing framework enables requirements to be imposed for baseline and ongoing monitoring. For clarity, in the short term it would be possible to place conditions on licences to require ongoing monitoring of surface and groundwater resources to establish a baseline and then any impacts, including monitoring post closure.

Long term reform could amend the regulations and develop guidelines around the requirement for ongoing monitoring of surface and groundwater resources to establish a baseline and then any impacts, including monitoring post closure.

**Leading Practice 9 - Manage cumulative impacts on water through regional-scale assessments**

Victorian regulation meets this leading practice.

Long term improvements could include storing and continuously updating data from water monitoring to enable regional scale water models and assessment of cumulative impacts. In addition, a task group could be established to regularly assess data from water monitoring, discuss assessments and develop responses to the management of cumulative impacts.

**Leading Practice 10 - Ensure co-produced water volumes are accounted for and managed**

Victorian regulation meets this leading practice.
Leading Practice 11 - Maximise the recycling of co-produced water for beneficial use, including managed aquifer recharge and virtual reinjection

Victorian regulation meets this leading practice.

Leading Practice 12 - Require a geological assessment as part of well development and hydraulic fracturing planning processes

There is no requirement for geological assessments as part of work plan (or well operation management plan) that would ensure all risks around dewatering or hydraulic fracturing processes take into account the unique geology for a given operation.

Interim reform could include a condition on all coal seam gas licences and petroleum titles to require geological assessments, and to stipulate that preparation and subsequent review of the assessment would need to be conducted by suitably qualified persons.

Long term reform could amend the Regulations and develop new guidelines to require geological assessments. Preparation and subsequent review of the assessment would need to be conducted by suitably qualified persons.

Leading Practice 13 - Require process monitoring and quality control during hydraulic fracturing activity

There are currently no specific requirements or guidance related to hydraulic fracturing.

Interim reform could impose conditions on all licences requiring the preparation of an EMP and WOMP that includes consideration of hydraulic fracturing.

Long term reform could:

- Define hydraulic fracturing in the legislation.
- Specify requirements for hydraulic fracturing in the legislation and include in the requirements for EMP and/or WOMP as specified in guidelines.

Leading Practice 14 - Handle, manage, store and transport chemicals in accordance with Australian legislation, codes and standards

Victorian regulation meets this leading practice.

Leading Practice 15 - Minimise chemical use and use environmentally benign alternatives

Victorian regulation meets this leading practice.
Leading Practice 16 - Minimise the time between cessation of hydraulic fracturing and flow back, and maximise the rate of recovery of fracturing fluids

There are no currently no specific requirements or guidance related to hydraulic fracturing.

Interim reform could impose conditions on licences requiring the preparation of an EMP and WOMP to include this requirement.

Long term reform could include this requirement in the EMP and WOMP requirements, as specified in guidelines.

Leading Practice 17 - Increase transparency in chemical assessment processes and require full disclosure of chemicals used in coal seam gas activities by the operator

There is currently no requirement for the full or public disclosure of chemicals under the MRSD Act or Petroleum Act. Full disclosure is required for an EPA works approval or Research, Development and Demonstration (RD&D) approval. Consideration of this would be required in an application made under the Water Act 1989.

Interim reform could impose conditions on licences requiring full chemical disclosure.

Long term reform could prescribe a requirement in the Regulations to fully disclose chemicals so that regulators are able to adequately and appropriately assess and condition projects to minimise or prevent environmental impacts and community members can be informed about the chemicals approved for use in operations.

Leading Practice 18 - Undertake assessments of the combined effects of chemical mixtures, in line with Australian legislation and internationally accepted testing methodologies

There is currently no robust linked together process for assessing cumulative impacts of chemicals.

As an interim reform for the development stage could be to rely on the EES process and referral to the IESC.

Long term reform could require EMPs to include longer term assessment of likely impacts of chemical use, which could interact with the ongoing monitoring requirements on the operator to provide a good indication of likely cumulative impacts, which can then be managed. The definition of ‘longer term’ would need careful consideration, to understand if it would extend beyond the term of a licence, which would raise questions of how to enforce such a condition. Consideration would also be needed of whether likely impacts should be limited to use of chemicals by the individual operator.
Appendix 3

Otway Basin production history

The Port Campbell Embayment has a working petroleum system that has been proven through the discovery and recovery of around 89 billion cubic feet of gas\(^\text{13}\). Further discoveries, although small relative to those encountered offshore, are possible in the area. Gas remains in place in the Grumby and Langley fields due to the high CO\(_2\) content – 53% and 66% respectively\(^\text{14}\); methane remains in place in the Lavers Field. The depleted Iona, North Paaratte and Wallaby Creek gas fields, to the north and northeast of Port Campbell, operate as a gas storage facility, taking gas piped from offshore production and storing it prior to release to consumers.

Table 6 - Port Campbell Embayment gas production history

<table>
<thead>
<tr>
<th>Production Licence number</th>
<th>Gas Field/well</th>
<th>Date of discovery</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPL1</td>
<td>North Paaratte Field</td>
<td>Oct 1979, Mar 1981</td>
<td>Both fields produced; now used for underground gas storage</td>
</tr>
<tr>
<td></td>
<td>Wallaby Creek</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPL2</td>
<td>Iona Field</td>
<td>Mar 1989</td>
<td>Produced; now used for underground gas storage</td>
</tr>
<tr>
<td>PPL3</td>
<td>Boggy Creek – CO(_2)</td>
<td>Jan 1992</td>
<td>Remains in production</td>
</tr>
<tr>
<td>PPL4</td>
<td>Mylor-1</td>
<td>Jun 1994, Apr 1997</td>
<td>Produced, Produced</td>
</tr>
<tr>
<td></td>
<td>Fenton Creek-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPL5</td>
<td>Penryn Gas Field</td>
<td>Jan 2000</td>
<td>Produced</td>
</tr>
<tr>
<td>PPL6</td>
<td>McIntee-1</td>
<td>2001</td>
<td>Produced</td>
</tr>
<tr>
<td>PPL7</td>
<td>Tregony Gas Field</td>
<td>2001</td>
<td>Produced</td>
</tr>
<tr>
<td></td>
<td>Dunbar-1</td>
<td></td>
<td>Produced</td>
</tr>
<tr>
<td></td>
<td>Langley Field</td>
<td></td>
<td>Produced</td>
</tr>
<tr>
<td></td>
<td>Skull Creek-1</td>
<td></td>
<td>Produced</td>
</tr>
<tr>
<td></td>
<td>Wild Dog Road-1</td>
<td></td>
<td>Produced</td>
</tr>
<tr>
<td>PPL9</td>
<td>Lavers-1</td>
<td>May 2001</td>
<td>Not produced</td>
</tr>
<tr>
<td>PPL10</td>
<td>Croft-1</td>
<td>April 2001</td>
<td>Produced</td>
</tr>
<tr>
<td>PPL11</td>
<td>Buttress-1– CO(_2)</td>
<td>2001</td>
<td>Production well for CO2CRC pilot</td>
</tr>
<tr>
<td>PPL12</td>
<td>Seamer Gas Field</td>
<td>Dec 2002</td>
<td>Produced</td>
</tr>
<tr>
<td>PPL13</td>
<td>Naylor</td>
<td>2001</td>
<td>Produced; now used as CO2CRC CO(_2) storage</td>
</tr>
</tbody>
</table>

\(^{13}\) Department of Primary Industries 2007, *Victoria’s Minerals, Petroleum and Extractive Industries 2005/06 Statistical Review*. Department of Primary Industries.

Appendix 4

Summary of the findings of the water science studies\textsuperscript{15}

This appendix presents a summary of the onshore gas water science studies. These studies provide the Victorian Government and community with technical information about potential water-related issues and impacts that may arise as a consequence of the development of an onshore gas industry in Victoria.

The Gippsland and Otway regions were the focus of these studies. This is because these two regions are thought to be the most prospective areas in Victoria for onshore gas development. At present there is no active onshore gas development in Victoria.

The purpose of the water science studies on onshore gas is to provide an initial screening analysis of the potential impacts of possible onshore gas exploration and development on water users and ecosystems. The studies assess the potential impacts of aquifer depressurisation (i.e. groundwater level decline), chemical contamination of groundwater from hydraulic fracturing fluids, induced seismicity, and land subsidence.

Gas extraction depressurises the gas-bearing formation and may cause a decline in groundwater level, which could impact water users and ecosystems. Groundwater level decline may also cause land subsidence.

Hydraulic fracturing can increase gas yield, but may unintentionally contaminate water supplies with hydraulic fracturing fluids and induce seismicity (earthquakes).

The studies apply a causal pathway approach, describing where gas might be, where water resources are, the physical connection between the gas and water resources, and utilising modelling and analysis to infer impacts on water users and ecosystems.

The studies were conducted by the Department of Environment, Land, Water and Planning and the Geological Survey of Victoria (part of the Department of Economic Development, Jobs, Transport and Resources). An essential part of the water science studies was the engagement of a scientific review panel, which provided an independent peer review of the studies, ensuring the rigour of the significant body of technical work that was undertaken.

The studies have used the best available information, although noting that there are known gaps in the geological and hydrogeological data sets. Because of these gaps the impact assessment is conservative; that is, the results are likely to estimate higher impacts than may eventuate if development did occur.

There are issues that are beyond the scope of these water science studies. These include treatment and disposal of co-produced water, water use for fracturing and gas production, and non-water resource issues such as amenity, air quality, fugitive gas emissions, on-site chemical management and bore integrity. Therefore, the findings that follow should be considered only with respect to the topics addressed.

\textsuperscript{15} DELWP and GSV 2015c, \textit{Gippsland region synthesis report} and DELWP and GSV 2015d, \textit{Otway region synthesis report}. 
Findings for the Otway region

Overall, the potential for impacts on water users and ecosystems from possible onshore gas developments in the Otway region was found to be low. Specific findings are summarised below and in Tables 1 and 2.

- The potential for impacts on groundwater users from aquifer depressurisation for gas development is low, as inferred from a predicted decline in the water table of less than 2 m and a predicted decline in deep groundwater levels of less than 10 m.

- The potential for impacts on groundwater quality from aquifer depressurisation for gas development is inferred as low, based on the predicted changes to groundwater pressure gradients being within historical ranges.

- The potential for impacts on surface water users and ecosystems as a result of reduced stream flow or changes in surface water quality caused by aquifer depressurisation is inferred as low, because the predicted changes to groundwater levels are within historical ranges.

- The potential for chemical contamination of groundwater from hydraulic fracturing fluids is low, based on a review of national and international literature with consideration of the particular geological conditions of the Otway region and the fact that the addition of BTEX chemicals to hydraulic fracturing fluids is banned under Victorian law.

- The potential for induced seismicity is low, based on a review of national and international literature with consideration of the particular geological conditions of the Otway region.

- The potential for land subsidence is low, based on the predicted changes to groundwater levels.

Table 1 - The potential impacts associated with aquifer depressurisation for each gas scenario.

<table>
<thead>
<tr>
<th>Gas type</th>
<th>Impacts on users</th>
<th>Groundwater users</th>
<th>Surface water users</th>
<th>Ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Tight gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Shale gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Coal seam gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
Table 2 - The potential impacts associated with hydraulic fracturing, induced seismicity and land subsidence for each gas scenario.

<table>
<thead>
<tr>
<th>Gas type</th>
<th>Chemical contamination of groundwater from hydraulic fracturing fluids</th>
<th>Induced seismicity</th>
<th>Land subsidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundwater users</td>
<td>Surface water users</td>
<td>Ecosystems</td>
</tr>
<tr>
<td>Conventional gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Tight gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Shale gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Coal seam gas</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Findings for the Gippsland region

Overall, the potential for impacts on water users and ecosystems from possible onshore natural gas developments in Gippsland was found to be low for tight and shale gas (with some exceptions) and moderate to high for coal seam gas.

The specific findings are summarised below and in Tables 3 to 6.

**Tight and shale gas**

- The potential for impacts on groundwater users from aquifer depressurisation for tight and shale gas development is low, as inferred from a predicted decline in the watertable of less than 2 m and a predicted decline in deep groundwater levels of less than 10 m.

- The potential for impacts on groundwater quality from aquifer depressurisation for tight and shale gas development is inferred as low, based on the predicted changes to groundwater pressure gradients being within historical ranges.

- The potential for impacts on surface water users as a result of reduced stream flow or changes in surface water quality due to aquifer depressurisation is generally low, with the exception of localised areas of moderate (as inferred from a predicted decline in watertable of greater than 0.1 and less or equal to 2.0 m) to high potential impact (as inferred from a greater than 2.0 m predicted decline in watertable) in the central Latrobe Valley region. This is inferred, based on the predicted changes to groundwater levels. However, the areas of moderate to high potential impact could be reduced to low with implementation of one or more of the mitigation strategies outlined in this report.

- The potential for impacts on ecosystems as a result of reduced stream flow caused by aquifer depressurisation is generally low, with the exception of localised areas of moderate to high potential impact in the central Latrobe Valley region. This assessment is inferred from the predicted changes to groundwater levels. Applying effective mitigation in these localised areas may have technical and financial limitations if the potential impact is moderate to high.

- The potential for chemical contamination of groundwater from hydraulic fracturing fluids is low for tight and shale gas development, based on a review of national and international literature, the particular geological conditions of the Gippsland region, and the fact that the addition of BTEX chemicals to hydraulic fracturing fluids is banned under Victorian law.
• The potential for induced seismicity is low for tight and shale gas development, based on a review of national and international literature with consideration of the particular geological conditions of the Gippsland region.

• The potential for land subsidence is low for tight and shale development, based on the predicted changes to groundwater levels.

**Coal seam gas**

• The potential for impacts on groundwater users from aquifer depressurisation as a result of coal seam gas development is moderate to high (e.g. greater than 15 m decline in the watertable), based on the distance to the prospective development area and the predicted changes to groundwater levels. The impact could be reduced to low by implementing one or more of the mitigation strategies outlined in this report.

• The potential for impacts on groundwater quality from aquifer depressurisation for coal seam gas development is inferred as moderate, based on predicted depressurisation which is moderate to high. There are possible technical and financial implications to applying effective mitigation to reduce this impact.

• The potential for impacts on surface water users as a result of reduced stream flow or changes in surface water quality caused by aquifer depressurisation is moderate to high, depending on proximity to a proposed natural gas development. This is inferred from the predicted changes to groundwater levels. However, this can be reduced to low by implementing one or more of the mitigation strategies outlined in this report.

• The potential for impacts on ecosystems as a result of reduced stream flow or changes in surface water quality caused by aquifer depressurisation is moderate to high, depending on proximity to the proposed natural gas development. This is inferred from the predicted changes to groundwater levels. There are possible technical and financial constraints on applying effective mitigation to reduce this impact.

• Hydraulic fracturing is not expected to be required for the development of coal seam gas, and therefore would not have any potential impact in this region.

• The potential for induced seismicity is low for coal seam gas development, based on a review of national and international literature with consideration of the particular geological conditions of the Gippsland region.

The potential for land subsidence is moderate for coal seam gas development, based on the predicted changes to groundwater levels. There are possible technical and financial limitations to applying effective mitigation to reduce this impact from moderate to low.

**Table 3 - The potential for impacts associated with aquifer depressurisation for each natural gas scenario without any mitigation measures applied.**

<table>
<thead>
<tr>
<th>Natural gas type</th>
<th>Impacts on users</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundwater users</td>
</tr>
<tr>
<td>Tight and shale</td>
<td>Low</td>
</tr>
<tr>
<td>Coal seam gas (brown coal)</td>
<td>High</td>
</tr>
</tbody>
</table>

*Localised areas of moderate to high potential impact in the central Latrobe Valley region
Table 4 - The potential for impacts associated with hydraulic fracturing, induced seismicity and land subsidence for each natural gas scenario, without mitigation measures applied.

<table>
<thead>
<tr>
<th>Natural gas type</th>
<th>Chemical contamination of groundwater from hydraulic fracturing fluids</th>
<th>Induced seismicity</th>
<th>Land subsidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundwater users</td>
<td>Surface water users</td>
<td>Ecosystems</td>
</tr>
<tr>
<td>Tight and shale</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Coal seam gas</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 5 - The potential for impacts of aquifer depressurisation for each natural gas scenario following mitigation measures.

<table>
<thead>
<tr>
<th>Natural gas type</th>
<th>Impacts on users</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundwater users</td>
</tr>
<tr>
<td>Tight and shale</td>
<td>Low</td>
</tr>
<tr>
<td>Coal seam gas (brown coal)</td>
<td>Low</td>
</tr>
</tbody>
</table>

*Localised areas of moderate to high impact in the central Latrobe Valley region

Table 6 - The potential for chemical contamination of groundwater from hydraulic fracturing fluids, induced seismicity and land subsidence for each natural gas scenario following mitigation measures.

<table>
<thead>
<tr>
<th>Natural gas type</th>
<th>Chemical contamination of groundwater from hydraulic fracturing fluids</th>
<th>Induced seismicity</th>
<th>Land subsidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groundwater users</td>
<td>Surface water users</td>
<td>Ecosystems</td>
</tr>
<tr>
<td>Tight and shale</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Coal seam gas (brown coal)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>