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Decommissioning coal seam gas wells

Final Report of GISERA Project S.9: Decommissioning CSG wells

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Acknowledgments

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Executive summary

This report is the final output from CSIRO's GISERA Decommissioning CSG wells project. The project was conducted during 2017 by a research team combining geological, technical and social science expertise in response to a need identified by stakeholders to consider effective and socially acceptable decommissioning processes for coal seam gas (CSG) wells. The project addressed three objectives:

1. review regulatory frameworks
2. explore the characteristics of successful decommissioning from different viewpoints
3. develop policy options for government, industry and local stakeholders.

Review of regulatory frameworks

The report finds that the regulatory frameworks for the rehabilitation of CSG projects are similar in Queensland and NSW, with the main differences primarily procedural in nature. Both have rehabilitation conditions linked to the authorities granted for exploration or production of a CSG resource. In Queensland these conditions are in a separate environmental authority associated with the resource authority, while in NSW the conditions are included within the resource authority. In both cases, the conditions are determined based on an assessment of the potential environmental impacts. The level of assessment is commensurate with the level of activity, with petroleum production requiring a full environmental impact statement in both states, while exploration activities require a lower level assessment. The regulators in both states require authority holders to pay a deposit that would cover the full costs of rehabilitation. This is seen as important assurance for the states to protect themselves against an authority holder defaulting on their obligations.

Rehabilitation and decommissioning of CSG wells has two components – above ground and below ground. Both states have a code of practice that covers CSG well construction and abandonment. The Queensland code is called up in legislation, while the NSW code is referred to within the conditions attached to resource authorities. Both codes require CSG wells to be fully cemented from the production horizon to the surface, and for the top 1.5 metres of the well to be removed and the well buried. The requirements for surface rehabilitation are also similar for both states, with a general requirement to return disturbed areas to a safe and stable condition, fit for an agreed land use and in a condition that is similar or better than those that existed before the activities.

Consultation with the landholder is important in both jurisdictions. There are provisions for the transfer of some infrastructure to the landholder, with their agreement. The landholder does not have the right to determine whether rehabilitation has been properly completed – that power lies with the regulator. However, the regulator in both states does require the landholder to be consulted and appears to place considerable weight on their point of view.

Characteristics of successful decommissioning

The second objective of the project was to bring together industry, regulators and local representatives to discuss the characteristics of successful decommissioning and to explore areas of overlap and difference between the perspectives of diverse stakeholders. Three workshops were conducted, one each in Camden, NSW; Chinchilla, Queensland; and Narrabri, NSW, representing different phases of the industry. The sequence of the workshops represented working backwards from the closure phase (Camden), where effective and responsible decommissioning is front and centre of industry activity. The group discussed the procedures of decommissioning and processes for rehabilitation in a context where land use has changed from the time when the industry was established.

The Chinchilla workshop corresponded to the operations phase of the industry, where the focus of rehabilitation was most strongly concerned with relinquishing unproductive wells along the way, in addition to decommissioning any wells that experienced unforeseen technical difficulties during installation. The discussion also included broader principles for end-of-life planning. These included hypothetical questions, such as 'What does 'in perpetuity' mean in practice?' and 'What procedures are in place to ensure the long term integrity of the wells?'. The workshop also included practical questions about the logistics of decommissioning and how specific risks are managed.

The Narrabri workshop focused on the exploration and feasibility phases of the industry and the importance of considering decommissioning at this early stage. Considering the number of exploration wells, decommissioning is an issue independent of whether or not the industry is given approval to proceed to full production. For local stakeholders, confidence in the ability to safely and effectively decommission future wells is a component of their questions about whether the industry should go ahead. Local stakeholders expressed specific concerns about perceived environmental risks and how the industry would respond to those.

Across all of the workshops, industry and government regulators expressed strong confidence in the code of practice for each state and felt that each code was clearly articulated and consistent with international best practices. Local stakeholders tended not to share this view and generally found the codes of practices difficult to understand or open to interpretation. When implemented correctly, government regulators and industry participants were confident that decommissioned wells would not result in legacy problems and would not require subsequent monitoring or further action. By contrast, local stakeholders tended to lack confidence in the codes of practices and, in some cases, queried technical specifications of decommissioning procedures.

A common theme among local participants in all workshops was a concern over potential legacy effects, with many participants expressing a need for ongoing monitoring to identify and resolve potential future problems. Another common theme among local stakeholders was a perceived lack of oversight. Local stakeholders noted the absence of an impartial review process if the code of practice resulted in problems for potentially unforeseen reasons. The issue of transparency was also raised at each of the workshops. Industry participants explained that they submit extensive records to regulators throughout the decommissioning process. However, local stakeholders felt that this information was inaccessible to them. In part, this lack of transparency was seen as a logistical issue – records were difficult to access or slow to be updated. In addition, the information that was available was difficult to interpret for local stakeholders, which added to the uncertainty and decreased confidence in decommissioning processes.

Differing views about the code of practice in each state and concerns about transparency and oversight reiterated a distinction between, on one hand, a high level of overlap between government and industry, and, on the other hand, uncertainty among local stakeholders. This distinction was reduced when it came to focusing on the ultimate goals of decommissioning. With very few exceptions, the views of most participants from a wide range of local, industry and regulatory backgrounds in each location reflected a high degree of alignment about the end point of successful decommissioning: that the sites of decommissioned wells would be barely noticeable as having had past CSG activity and there are no concerns about legacy effects.

Policy options for government, industry and local stakeholders

The third objective of the report was to develop policy options for government, industry and local stakeholders. Policy considerations included:

- the role of regulatory oversight
- information accessibility, transparency and reporting.

The role of oversight is a key issue for consideration in future reviews of the code of practice in each state. While it is outside the scope of this project to provide a detailed review of broader oversight procedures across the Australian governance system, there are precedents for oversight roles regarding retail gas suppliers and other utilities, for example. Specifically, governments may consider reviewing existing oversight provisions in relation to local stakeholders' desire for independent assessment of well decommissioning activities and mechanisms for raising grievances, as detailed in this report.

Accessibility and transparency of information and reporting is an additional area of importance. Specifically, governments may consider a review of the publicly available information on well decommissioning and the timeframe in which it is made available, as well as the ability of local stakeholders to make sense of reported information. A further option is for industry to provide plain English summaries of important decommissioning reports. Many of the concerns raised by local stakeholders during the workshops stemmed from a misunderstanding of the procedures for decommissioning wells or a lack of information about logistics. In the absence of complete information, several local stakeholders made assumptions about practices that turned out to be incorrect. Clear and accurate information about technical procedures would help to reduce uncertainty for local stakeholders and minimise angst based on misunderstandings.

Part I CSG well decommissioning practices

1 The life of a well

Wells are a fundamental component of CSG developments. CSG is extracted from coal seams that lie at depths from several hundred metres to around one and a half kilometres. A *well* is a hole drilled from the surface to access the coal seam at depth. It consists of a *wellbore* (the hole itself) and the components placed in the wellbore to maintain its integrity and for the intended purpose. The diameter of a wellbore is around 150 to 250 millimetres.

Wells are used during exploration and production phases of a CSG development. Exploration wells are drilled to define and characterise a CSG resource, and may be *suspended* or *abandoned* shortly after drilling, or may be converted into production wells. Production wells are drilled to allow the production of gas from the coal seam. For CSG production, wells are constructed to provide a pathway for fluid (water and gas) to flow to the surface in a controlled manner (see Box 1).

Box 1: Water and gas movement in the subsurface

CSG resources form in sedimentary basins that consist of layers of sedimentary rock. The gas resource is in a coal seam and the overlying layers of rock are referred to as the overburden. The overburden has layers that are permeable (which allow fluid to flow through them) or impermeable (which form a barrier to fluid movement). Some of the permeable layers may be aquifers, containing water that is used for agriculture or domestic purposes, whereas others may contain salty water. Gas may also be present in some overburden layers.

For fluids to move in the subsurface, there needs to be a driving force. For CSG resources, pore pressures and gas buoyancy are the driving forces. The pore pressure refers to the pressure of the fluids in the rock. In most CSG resources, the pore pressure at any particular depth is equal to the weight of a column of water extending to the surface, which is referred to as the hydrostatic pressure.

When water in rock layers is at hydrostatic pressure, there is no driving force for the water to flow vertically. If a well is drilled into a water-bearing layer that is at hydrostatic pressure, water would only flow up the well with the aid of a pump. In some geological settings, the pore pressure is higher than the hydrostatic pressure, resulting in overpressures. Overpressures can only occur where there are impermeable layers preventing the vertical flow of water, otherwise the water would flow upwards to equalise back to hydrostatic pressure. If a well is drilled into an over-pressured layer, the water will flow up the well unassisted. A common example of this scenario is the artesian water wells drilled into the Great Artesian Basin.

CSG is predominantly methane, which has a much lower density than water. Buoyancy will drive natural gas to move upwards and gas resources can only exist if the gas is trapped in the subsurface, otherwise it would have leaked out through geological time. The gas may be trapped below impermeable layers of rock, or by adsorption onto organic-rich rocks like coal. To extract the gas, a well must be drilled to provide a pathway for the gas to flow to the surface. In CSG resources, where gas is adsorbed onto the coal, the pore pressures need to be lowered (by pumping out some of the water) to release the gas.

The rate at which fluids or gas can move in the subsurface is affected by the permeability and size of the flow pathway. The higher the permeability, or the larger the pathway, the greater the rate of flow for a given driving force (overpressure or buoyancy). Friction and surface roughness of the pathway reduce the flow rate; therefore, fluid and gas flow rate will be lower over longer pathways.

The life of a production well may extend over several decades. In addition to exploration and production wells, a CSG development may also drill wells for monitoring of groundwater levels and other parameters, access to water or for the reinjection of water.

The maintenance of the well is provided through well integrity management practices, which are a focus for industry and regulators (see Box 2). Although the design of each well will depend on its intended use and the local geological conditions, the general life cycle for all wells is similar.

Box 2: Well Integrity

Well integrity is a focus for industry and regulators in ensuring the safe and effective management of wells throughout their life, including post abandonment, and is covered by international standards (Standards Norway, 2013; International Organization for Standardization, 2017). Well integrity is the quality of a well that prevents the unintended flow of fluid (gas or water for CSG well) into or out of the well, to the surface or between rock layers in the subsurface. A loss of well integrity could impact the safety of people working on or near the well or the environment.

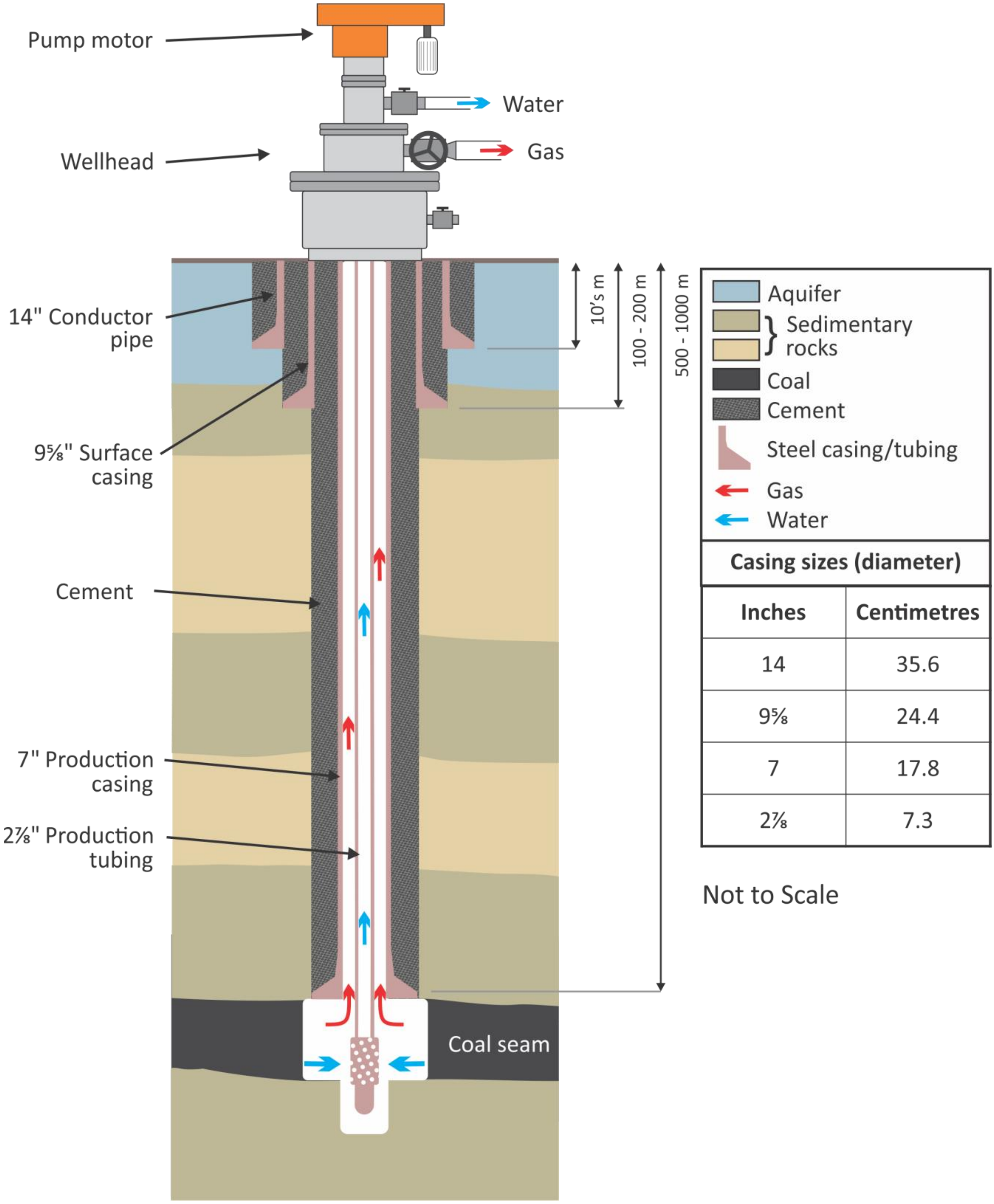
Well integrity establishes barriers that prevent unintended fluid flows as well as pathways for flow that can be controlled. The methods of creating well integrity vary throughout a well's life, but include cementing casing into the well and using equipment that allows the flow of gas and water to the surface to be controlled, such as the wellhead. The casing and cement act together to prevent any movement of gas and water along the outside of the well, while allowing a pathway for controlled flow along the inside of the well. At post abandonment, a well with good well integrity will not be a pathway for the flow of gas or water along the well.

1.1 Site preparation

The first stage in the life cycle of a well once a location has been selected is to prepare a *well pad* for drilling. Well pads are typically 1 to 1.5 hectares in area and provide the working area for drilling operations. They are usually prepared using earthworks machinery to level the site and clear vegetation. Aggregate may be laid down to allow all-weather access and operations of the drill rig. Topsoil is stockpiled at the site so that it can be put back in place during rehabilitation of the site. The well pad may have one or two sumps to store water, catch drill cuttings and hold drilling mud during operations. These sumps have a capacity of around 100,000 litres. The well may also have a flare pit to contain ground flares that allow for the controlled burning of gas from the well.

1.2 Drilling

The next stage of the life cycle of a well is the drilling itself. This stage involves the mobilisation of the drilling rig and associated equipment to the site, the drilling of the well, completion of the well and demobilisation of the drilling equipment. The drilling technologies used in CSG exploration and development have evolved from those used in drilling for conventional petroleum resources and for exploration for coal mining. The drilling rigs used are typically smaller than those typically used for conventional petroleum wells as the target coal seams are at shallow depths compared to conventional petroleum resources. The rigs may be mounted on a single truck or be transported using several semi-trailers. The drilling stage occurs over several days to several weeks, depending on the depth and design of the well.



Casing sizes (diameter)	
Inches	**Centimetres**
14	35.6
9⅝	24.4
7	17.8
2⅞	7.3

Figure 1: Typical completion of a vertical CSG well (not to scale)

Drilling fluids are an important component of the drilling process. These fluids typically comprise water with additives that modify the friction between the drill rods and the wellbore walls, increase density and viscosity of the fluid to aid in the removal of cuttings, and decrease the reactivity of the drilling fluid with the formations being drilled. The additives include:

- salts (typically potassium chloride or potassium sulphate) to limit damage to the formation being drilled and increase the density of the drilling fluid

- clays (primarily bentonite) to increase the viscosity of the drilling fluid and to reduce loss of drilling fluid into the formations being drilled
- polymers to increase viscosity and provide lubrication.

The amount of drilling fluid required for a well will be around 50,000 litres, although this will vary depending on the diameter and depth of the well and the characteristics of the formations the well intersects.

An 800-metre deep CSG well will produce around 50 cubic metres of drill cuttings (rock removed from the hole). Drill cuttings have traditionally been captured in drilling sumps or pits. However, pitless drilling techniques may be deployed to provide better management of the drilling fluid and cuttings.

Wells are drilled in stages, with each stage cased with steel casing (see Box 3) before drilling proceeds to the next stage, using a smaller diameter drill bit. Figure 1 shows the general layout and nomenclature for casing used in CSG wells, showing how the diameter of the well decreases with depth, as successive casing telescopes inside the previous casing strings. The casing is cemented into the well (Figure 3) to provide additional strength to the well and create a seal between the casing and the surrounding rock. The cement is pumped down the centre of the casing so that flows occur around the bottom of the casing and up the annulus between the casing and the surrounding rock layers. Cementing practices, such as the use of top and bottom plugs, prevent the cement from mixing with fluid in the well (Figure 2).

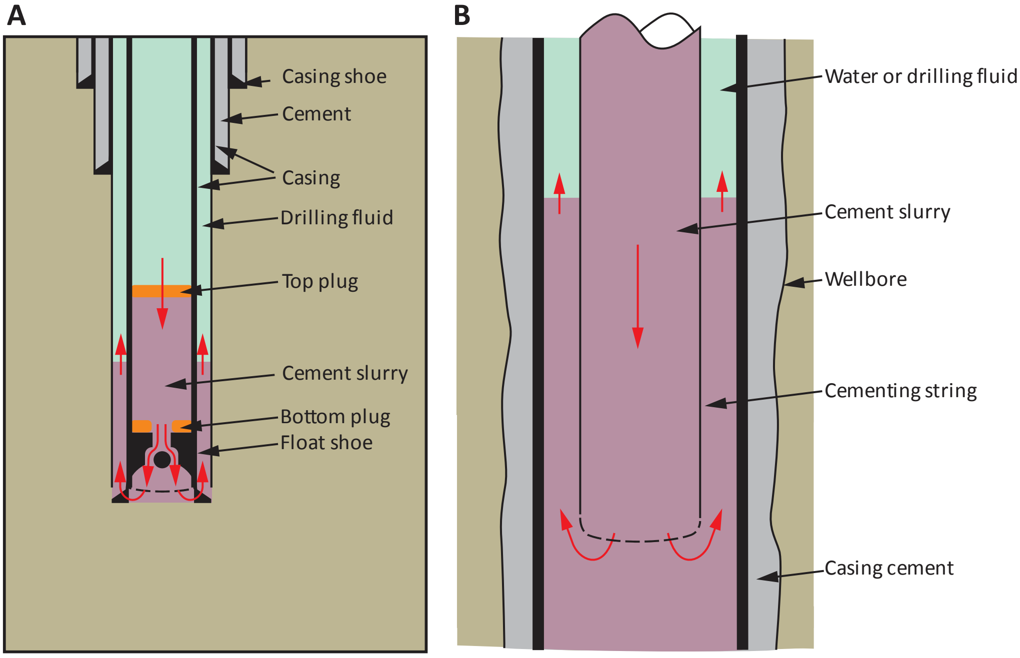


Figure 2: Cementing operations in a well. Panel A shows cementing of casing and panel B shows the placement of cement plug inside casing for abandonment

The casing and cement act as a system to provide well integrity, isolating shallow formations from drilling muds during drilling of deeper formations, providing well control, preventing well collapse and isolating shallow aquifers from gas-bearing formations. The casing is left in the well at the completion of drilling.

As shown in Figure 1, there are several different size casing strings present in a typical CSG well. Initially the largest diameter '14 inch conductor' casing is inserted and grouted to a depth of 6 to 10 metres to isolate the well from loose soil and rock near the surface. The next (slightly smaller) stage of the borehole is drilled through the centre of the conductor casing past the shallow aquifers. In Figure 1 this is shown to have a depth of around 140 metres. A 9⅝ inch casing string is cemented into this section with cement extending to the surface (shown as 'cement to surface' in Figure 1). The next stage is known as the production hole and is drilled though the centre of the 9⅝ inch casing to a final depth of the top of the target coal seam. A 7 inch casing string is cemented to the surface in this example.

Box 3: Casing and cement in CSG wells

Well casing provides the structural integrity for the well and a channel for fluid flow. Casing is made up of a series of hollow steel pipes that are joined together with threaded connections as they are lowered into the well.

Engineers select the casing from a range of internationally standardised products that vary in the type of steel alloy, casing diameter, wall thickness, construction material and surface finish. The casing design is selected based on the characteristics of the local geology, the well design and any anticipated treatments (such as hydraulic fracturing). Casing needs to be strong enough to resist pressures both from the external rock formations and from activities such as circulation of drilling mud and pumping of hydraulic fracturing fluids. The selected casing also needs to be resistant to corrosion from substances and fluids encountered in the local geology and in drilling and operating conditions.

Cement effectively acts to both fill the space between the outside of the casing pipe and the surrounding rock and to 'glue' the casing in place. Cement is an engineered product designed in such a way to resist mechanical and chemical failure throughout the life of the well. Once set, cement has a high compressive strength, low permeability and long life under the conditions encountered in CSG wells. Portland cement is the principal ingredient and additives are used to create a cement mix that is suitable for the local geology and well-specific engineering requirements. Design and performance validation of the cement is achieved through laboratory testing at the conditions encountered in the well.

It is important to note the distinction between the steel casing and cement products used in oil and gas wells and the steel and concrete products used in construction and other applications. Steel casing is engineered and treated in such a way to ensure performance over the life of an oil and gas well. While Portland cement is also the primary component (binding agent) of industrial concrete, oilfield cement does not have a mixture of cement, gravel and sand; rather, it is mixed with specialist additives to achieve the desired performance.

The oil and gas industry is heavily reliant on international standards to ensure satisfactory performance of well casing and cement products. The International Association of Oil and Gas Producers (2016) provides an overview of international standards and guidelines relating to well construction and operations, which covers all aspects of casing and cement performance and testing.

1.3 Completion

The next stage in the life cycle of a well after drilling has finished will depend on the purpose of the well. The well may be *completed* as a production well, where equipment is installed in the well to enable safe and efficient production of gas, suspended, or plugged and abandoned. When a well is completed or suspended, a *wellhead* (Figure 1) is installed at the top of the well to provide an interface with the well, allowing the well to be closed off (when suspended) or connected to other surface infrastructure such as pumps and gas–water separators when the well is in production.

1.4 Decommissioning and rehabilitation

The decommissioning of a CSG well involves two components: rehabilitation of surface disturbance associated with the well (the well pad) and plugging and abandonment of the well.

Rehabilitation of CSG wells can begin as soon as drilling of the well is completed and the drill rig leaves the well pad. The drilling fluids and drill cuttings are disposed of and any drill sumps or flare pits are backfilled. Drill cuttings may be disposed of on site using the mix-bury-cover method, or they may be taken to a waste handling facility. The well pad can also be rehabilitated as far as practical, leaving a smaller area around the wellhead for surface infrastructure.

Once a well is no longer required, the well will be *plugged and abandoned,* which typically involves removing any well completion hardware from the well (such as production tubulars), testing the integrity of the casing and cement installed during drilling and filling the well with cement to prevent gas or water from travelling up or down the well. The wellhead and the top 1 to 2 metres of the casing below the ground surface will be removed, and a cement cap is placed over the well. The remainder of the well pad is also rehabilitated.

1.4.1 Plugging and abandonment practices

Abandonment aims to plug the well in perpetuity, preventing any movement of gas or water between rock layers in the subsurface or to the surface. Effective abandonment requires that all potential pathways for gas or water flow are blocked, and it relies on the integrity of the casing-cement-rock as a system as well as plugs placed within the casing. Figure 3 shows potential leakage pathways from abandoned wells. Well abandonment practices are designed to eliminate these pathways.

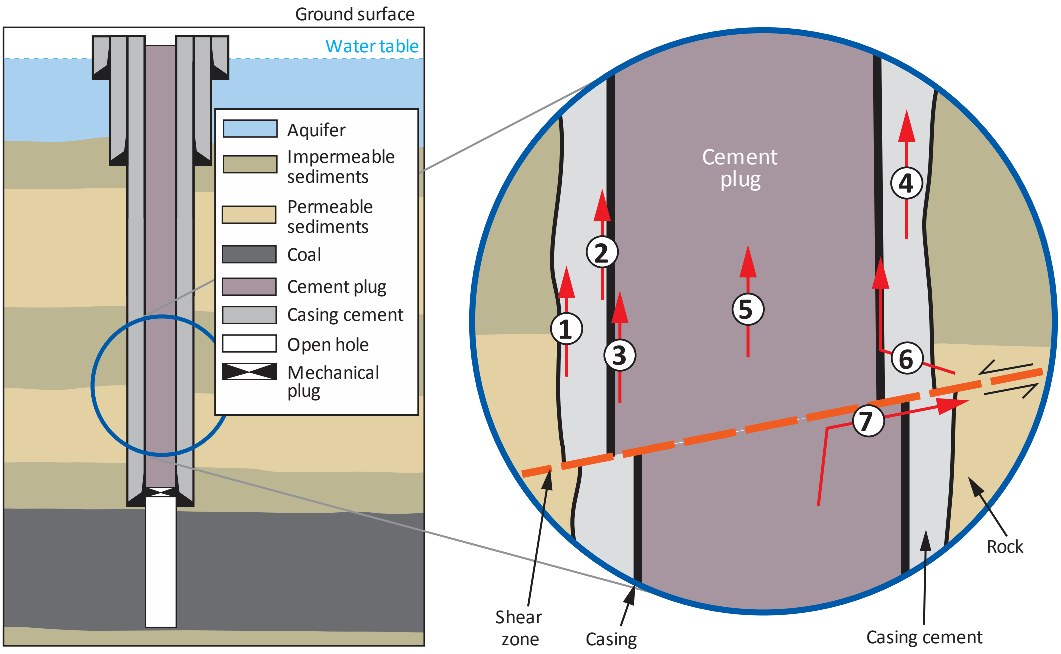


Figure 3: Pathways for fluid leakage in a cemented wellbore: 1) between cement and surrounding rock formations, 2) between casing and surrounding cement, 3) between cement plug and casing, 4) through the cement between casing and rock formation, 5) through cement plug, 6) across the cement outside the casing and then along the casing, and 7) along a shear through a wellbore

Source: After Davies et al. (2014)

Well integrity management throughout the life of the well is important for effective abandonment as it ensures that there is no pathway in the casing-cement-rock system (pathways 1, 2 and 4 in Figure 3). Properly designed casing and cement when the well is drilled is the starting point for effective well abandonment. The integrity of the casing-cement-rock system can verified in several ways, including:

- confirmation that cement has reached the surface for fully cemented casing strings

- pressure testing of the casing string
- cement bond logs (CBL) that use sonic methods to test the bond between the casing and cement and the rock and cement
- electromagnetic logging tools that test the integrity of the casing by detecting changes in thickness that may be caused by corrosion or erosion
- acoustic tools that 'listen' for fluid movement behind the casing
- calliper logs that test for deformation of the casing, indicating damage caused by stress around the well
- monitoring of annular pressures in the casing (the space between casing strings)
- monitoring for gas leaks at the surface
- review of the operation of the well throughout its life.

Not all of these techniques are applied on every well. They are only used where there are concerns about the well integrity at the end of the well's life. If any issues in the integrity of the casing-cement-rock system are detected, they may need to be remediated before abandonment can progress. These include a cement squeeze, where the casing is perforated to allow cement to be pumped in to the annular space between the casing and formation. Swellable liners can also be used to line the casing.

In addition to testing the well's integrity, any hardware in the well that can be removed is taken out of the well (pumps, production tubing) and the inside of the casing is cleaned. Cleaning, through the use of physical methods (wipers) or flushing with fluids, removes any build up of material on the inside of the well that may affect the bond of cement with the inside of the casing.

Once the well integrity of the casing-cement-rock system is confirmed, the equipment is removed and the well is cleaned, the inside of the well can be plugged. This is done using mechanical and cement plugs. A mechanical plug creates a seal that the cement can be placed on top of while it cures – the cement plug then forms the seal within the casing. Cementing the inside of the well uses similar cements to those used in the casing-cement-rock system (Box 3). The cement plugs will be placed to isolate permeable layers of rock from each other. This can be done by placing cement across the boundary between an impermeable layer and the overlying permeable layer (or aquifer), or by fully cementing the inside of the well. The cement is placed in the well using a cementing string (a tube) to avoid the cement mixing with water in the well (Figure 2B).

Mechanical plugs can be tested by pressure testing. Cement plugs can also be tested by pressure testing, but can also be tested by tagging the top of the cement plug with the drill string and applying a certain weight to confirm that the cement has properly cured. To provide long-term integrity, the cement (or other barrier material) must:[1]

- not shrink
- be able to withstand the stresses in the wellbore
- be impermeable
- be impervious to chemical attack from formation fluids and gases

[1] NORSOK D-010. p96

- be able to bond with steel casing and rock
- not cause damage to the casing.

The final stage in well abandonment is to remove all surface equipment and to cut the casing off at a depth below the surface so that it will not impact on other land users. Once a well has been abandoned, there is little prospect of re-entering the well for any purpose. Monitoring for gas flow at the surface may be conducted after the well has been abandoned to confirm that plugs have been properly set in the well.

There must be a driving force and a pathway for water and gas to flow in the subsurface (see Box 1). CSG resources have low driving forces as they are not usually over-pressured and the gas is adsorbed onto the coal. The possible pathways shown in Figure 3 will all have a small cross-sectional area and significant lengths for gas or water to flow to the surface or between formations. Should abandonment not be successful, the combination of low driving force and long flow pathways will limit the flow rates of gas and water.

2 Regulatory framework for well decommissioning

In Australia, the state governments own the rights to onshore petroleum resources and grant 'authorities' to an entity (a person or corporation) to explore for and develop these resources. The regulatory frameworks in each state cover the licencing of access to the state's resources; environmental and planning requirements; operational requirements, including health and safety; and royalty or taxation regimes for resource development. The regulatory frameworks also provide a mechanism under which the resource developer can enter the land that overlies that resource, and the obligations that they must follow when doing so.

This section outlines the regulatory framework that applies to CSG exploration and production in Queensland and NSW, with a particular focus on the drilling, operation and decommissioning of wells.

2.1 An overview of regulatory mechanisms

Although there is no commonly accepted definition for regulation (Orbach, 2012), it is generally understood to include any laws or other government-endorsed 'rules' where there is an expectation of compliance. Regulatory mechanisms include primary legislation, subordinate legislation, administrative decisions or discretions, and quasi-regulations. Figure 4 shows the hierarchy of these mechanisms. The regulatory mechanisms can prevent activities, or require certain activities to be undertaken, as well as stipulate activities to be performed in a certain way (Queensland Competition Authority 2014).

The regulation of CSG development is a subset of the overall regulation of petroleum activities. In Queensland and NSW there is a regulatory framework that is directed at petroleum activities, with specific legislation that sets out the process for granting authorities, the safe conduct of the activities and the royalty arrangements that apply when petroleum (oil or gas) is produced. Authorities are initially granted for exploration to allow the authority holder to explore for resources, with a separate authority required for the production of petroleum resources.

Petroleum activities are also covered by a range of regulatory mechanisms that cover the environment, water resources, occupational health and safety, waste management, Indigenous land rights and regional planning. There is also Commonwealth legislation that addresses projects with the potential for significant environmental impact, as well as native title, management of water (in catchments of the Murray-Darling Basin) and industrial chemical use (Table 1).

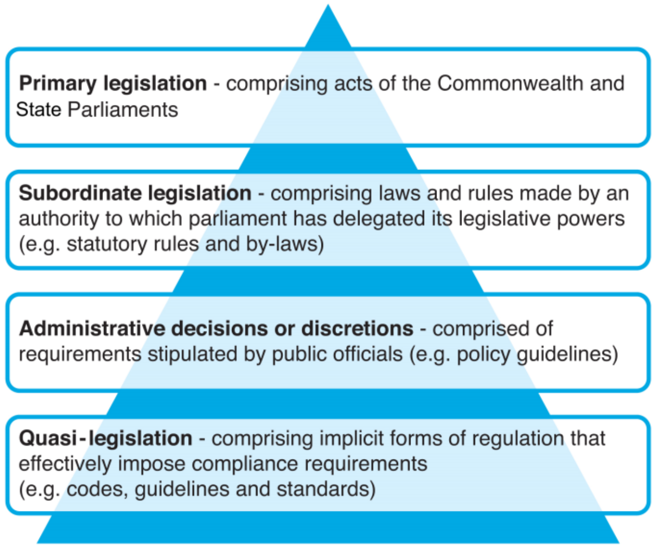


Figure 4: Overview of the hierarchy of regulatory mechanisms

Modified from Queensland Competition Authority (2014).

Table 1: Key Commonwealth legislation relating to the development of petroleum resources

Legislation	Description	Administering department
***Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)**	Protection and management of nationally and internationally important flora, fauna, ecological communities and heritage places. It has a specific trigger related to water resources in relation to coal seam gas (CSG) development.	Department of the Environment and Energy
***Water Act 2007* (Water Act)**	Management of water within the Murray-Darling Basin	Department of Agriculture and Water Resources
***Native Title Act 1993* (NT Act)**	Recognition and protection of native title and the requirements for Indigenous land use agreements	Attorney-General's Department, Department of the Prime Minister and Cabinet (Indigenous Affairs)
***Industrial Chemicals (Notification and Assessment) Act 1989* (IC Act)**	Notification and assessment of the use of industrial chemicals within Australia	Department of Health (through the National Industrial Chemicals Notification and Assessment Scheme)

2.2 Overview of regulatory pathway for petroleum projects in Queensland

The high-level process that all petroleum resource projects must follow in Queensland as of December 2017 is:

- The process for awarding authorities for petroleum activities in Queensland is regulated under the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act), and administered by the Queensland Department of Natural Resources and Mines. For exploration activities, the project proponent applies for an authority to prospect (ATP)[2] through a tender process. The project proponent must submit an initial work program as part of the tender process. The holder of an ATP, or any other form of authority, is also referred to as the 'authority holder'. An applicant for an ATP must obtain an environmental authority (EA) under the *Environmental Protection Act 1994* (EP Act) from the Queensland Department of Environment and Heritage Protection before the ATP can be granted. This is a requirement of the P&G Act for the award of the ATP. The requirements for the EA are discussed further in Section 2.2.1.
- If the holder of an ATP discovers petroleum resources in their lease that they consider to be commercially viable, the applicant can apply for a petroleum lease (PL). This process is regulated through the P&G Act. The project proponent must submit an initial development program as part of their application. An applicant for a PL must obtain an EA or amend an existing EA for the development before the authority can be granted.
    - The project may require an environmental impact statement (EIS) to be prepared by the project proponent before the EA can be granted. This requirement can be triggered under the EP Act or by the Queensland Coordinator-General if the project is deemed to be a 'coordinated project' under the requirements of the *State Development and Public Works Organisation Act 1971* (SDPWO Act). A coordinated project is one that has been identified by the Coordinator-General as requiring a rigorous impact assessment involving whole-of-government coordination.

The holder of an authority, either an ATP or a PL, must operate in accordance with the conditions of their PL and their EA (which include requirements for the rehabilitation of the lease prior to relinquishment). They must also meet the requirements of all other state legislation relevant to their activities. Table 2 outlines some of this legislation. The advanced stage of development of the CSG sector in Queensland is reflected by specific provisions of the P&G Act, EP Act and *Environmental Protection Regulations 2008* (EP Reg). There are also policies, guidelines and approvals related to CSG, primarily focused around management of water.

The Queensland Department of Natural Resources and Mines has developed a code of practice for the construction and abandonment of CSG wells in Queensland (Queensland Department of Natural Resources and Mines, 2017). This code sets out minimum standards for the construction and abandonment of wells drilled as part of CSG activities. The code is called up in legislation and authority holders are obligated to comply with the code.

When an authority holder is applying for a PL the project may trigger the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) if it was going to impact on an area of significant national environmental value. The EPBC Act contains specific triggers related to CSG and coal mining.

[2] There are several authority types for petroleum activities in Queensland. This section has focused on the authorities related to exploration and production of CSG. A complete list of authorities is provided in the appendix.

Table 2: Key Queensland legislation relating to the development of petroleum resources in Queensland.

This is not an exhaustive list of all legislation that may apply to CSG projects.

Legislation	Description	Administering department
Queensland key legislation		
Petroleum Act 1923	Regulates certain petroleum and natural gas activities. The *Petroleum and Gas (Production and Safety) Act 2004* supersedes this act, but an amended version of the *Petroleum Act 1923* was retained so that existing permit holders existing rights were not lost.	Department of Natural Resources and Mines
***Petroleum and Gas (Production and Safety) Act 2004* (P&G Act)**	Regulates petroleum and gas exploration tenure, safety, production and pipelines	Department of Natural Resources and Mines
***Mineral and Energy Resources (Common Provisions) Act 2014* (MERCP Act)**	Regulates land access for mineral and energy resource authority holders. Commenced on 27 September 2016.	Department of Natural Resources and Mines
***Environmental Protection Act 1994* (EP Act)**	Regulates activities to avoid, minimise or mitigate impacts on the environment, and to protect Queensland's heritage places	Department of Environment and Heritage Protection
***State Development and Public Works Organisation Act 1971* (SDPWO Act)**	Facilitates timely, coordinated and environmentally responsible development. Provides ability for Queensland's Coordinator-General to declare a project a 'coordinated project'. Coordinated projects require an environmental impact statement and a high level of public input.	Department of State Development
Queensland – other relevant legislation		
***Environmental Offsets Act 2014* (EO Act)**	Regulates the requirements and management of environmental offsets in response to activities that cause a significant residual impact on prescribed environmental matters	Department of Environment and Heritage Protection
***Water Act 2000* (Water Act)**	Regulates the sustainable management of Queensland's water resources, water supply and the impacts on groundwater caused by the extraction of groundwater by the resources sector	Department of Natural Resources and Mines; Department of Environment and Heritage Protection; Department of Energy and Water Supply
***Water Supply (Safety and Reliability) Act 2008* (WS Act)**	Regulates interactions and direct impacts associated with drinking water supply	Department of Energy and Water Supply; Department of Health
***Waste Reduction and Recycling Act 2011* (Waste Act)**	Regulates the production, reuse and disposal of waste materials	Department of Environment and Heritage Protection
***Regional Planning Interests Act 2014* (RPI Act)**	Identifies and protects areas of Queensland that are of regional interest and resolves potential land use conflicts. The RPI Act protects living areas in regional communities, high-quality agricultural areas from dislocation, strategic cropping land, and regionally important environmental areas.	Department of Infrastructure, Local Government and Planning

Legislation	Description	Administering department
Public Health Act 2005 **(PH Act)**	Protects and promotes the health of the Queensland public. Allows for public health orders to be issued that require the removal or reduction of the risk to public health from a public health risk, or to prevent that risk from recurring. Allows for the investigation of health complaints.	Department of Health
Gasfields Commission Act 2013 **(GFC Act)**	Establishes the Gasfields Commission, an independent statutory body with powers to review legislation and regulation, obtain and disseminate factual information, advise on coexistence issues, convene parties to resolve issues and make recommendations to government and industry.	The commission is independent, but administrative matters are handled by the Department of State Development

2.2.1 Environmental authorities

EAs are required for all environmentally relevant activities (ERA) in Queensland. ERAs are defined in the EP Act or prescribed in the EP Reg that include industrial, resource and intensive agricultural activities where contaminants may be released to the environment. Petroleum activities are ERAs as they are resource developments. The P&G Act also requires an EA to be granted before a petroleum authority (such as an ATP or PL) can be granted.

An EA is a critical component in the regulation of petroleum activities, setting out the environmental conditions that those activities must comply with. EAs are administered under the EP Act and are supported by a range of other regulatory instruments including the *Environmental Protection Regulation 2008* (EP Reg), policies (*Environmental Protection (Air) Policy 2008*, *Environmental Protection (Noise) Policy 2008*, and *Environmental Protection (Water) Policy 2009*), guidelines, procedures and eligibility criteria. These other regulatory mechanisms provide guidance on what needs to be included in an application for an EA, the level of performance required to be met under an EA, approaches to management of impacts that would be deemed acceptable for an EA, as well as providing model conditions for an EA. An EA covers aspects of activities, including:

- general environmental protection
- waste management
- protection of acoustic values
- protection of air values
- protection of land values
- protection of biodiversity values
- protection of water values
- rehabilitation
- well construction, maintenance and stimulation activities
- dams.

Three types of EA applications can be made, depending on whether the activity is an eligible ERA and can comply with the standard conditions for that activity. For petroleum activities, only exploration, survey and pipeline activities have eligibility criteria and standard conditions. All other petroleum activities are ineligible ERAs. The three types of EA applications are:

- standard application, where the activities meet eligibility criteria and are able to comply with all of the standard conditions for that activity. For petroleum activities, this would only apply for the exploration stage
- variation application, where the activities meet eligibility criteria and one or more of the standard conditions for that activity need to be changed. For petroleum activities, this would only apply for the exploration stage
- site-specific application, where a standard or variation application cannot be made. A site-specific application would need to be accompanied by a work plan that provides detailed information about the proposed activities and their potential environmental impacts. A site-specific application is also likely to require an EIS.

The mandatory regulatory requirements for an application to comply with the purposes of the EP Act are outlined in the guideline *Application requirements for petroleum activities* (Queensland Department of Environment and Heritage Protection, 2013). There is also a guideline for streamlined model conditions for petroleum activities (Queensland Department of Environment and Heritage Protection, 2016). An EA application should:

- identify the environmental values in locations where the proposed petroleum activities will be undertaken and the potential impact of the proposed activities on those values
- identify the risks to and impacts on environmental values caused by the activities within the project area and that extend beyond to surrounding areas including regional and cumulative impacts. As well as providing these risks and impacts, the authority holder would also be required to provide background information and raw data used in the assessment
- describe the management practices that will be used to control the risks of impacts on environmental values. The environmental protection commitments in the management plan should describe the incremental protection objectives and any performance indicators, the standards they will be assessed against and the control strategies that will be used to ensure the objectives are achieved. Management plans for different environmental values (for example, a noise management plan), as well as risk assessments and management plans for key activities (for example, risk assessment and management plan for hydraulic fracturing) may also be required
- where a variation application is made, the EA application must include a plan of operations that has information about the location of the activities, the actions that will be taken by the authority holder to comply with the conditions of the EA, the rehabilitation program and the proposed amount of financial assurance.

In summary, the EA for a petroleum project becomes the main regulatory instrument for setting the environmental approvals and conditions for a petroleum activity. The information required for an EA application (information about how the environmental risks will be managed, such as an EIS, environmental management plan and risk assessments related to specific components of the activities) provides the assessment of potential impacts of the activity. The EA sets out the outcomes of the proposed management approaches for these impacts.

2.2.2 Queensland well decommissioning regulation

The decommissioning and abandonment of CSG wells has two main components: surface expression of the well along with associated infrastructure and the well itself.

Surface disturbance

The EP Act requires environmental objectives that set the criteria for environmental management under the Act. The environmental objectives are listed in Schedule 5, Part 3, Table 1 of the EP Reg. The environmental objective for land states that

> *"The activity is operated in a way that protects the environmental values of land including soils, subsoils, landforms and associated flora and fauna."*

The performance outcomes for this objective include requirements for rehabilitation:

> *'(b) areas disturbed will be rehabilitated or restored to achieve sites that are—*
> *(i) safe to humans and wildlife; and*
> *(ii) non-polluting; and*
> *(iii) stable; and*
> *(iv) able to sustain an appropriate land use after rehabilitation or restoration;'*

The application requirements for an EA (Queensland Department of Environment and Heritage Protection 2013) require that an application for an EA

> *'…must include details of how the land, which is the subject of the application, will be rehabilitated after each relevant activity ceases. This includes details of how any land that will be contaminated or disturbed by the proposed activity will be remediated or rehabilitated to reinstate environmental values and ensure that the land is suitable for intended future uses. (p.44)'*

The requirements also outline a rehabilitation hierarchy, in order of preference:

> *'1. Reinstating a native ecosystem as similar as possible to the original ecosystem as the preferred option.*
> *2. Establishing an alternative outcome with a higher environmental value than the previous land use.*
> *3. Reinstating the previous land use (e.g. grazing or cropping).'*

The requirements indicate that rehabilitation must be conducted progressively as areas become available. Section 560 of the P&G Act requires the authority holder to remove all surface equipment and improvements before they can relinquish a petroleum authority unless the landowner otherwise agrees. The EP Act requires the decommissioning and rehabilitation of all infrastructure unless it is permanent.

These requirements articulate the objectives and goals of rehabilitation that the authority holder must achieve. The authority holder must demonstrate how these objectives will be met in the EA application and the granted EA will include final rehabilitation criteria. Upon completion of rehabilitation activities, the authority holder must submit a rehabilitation report (according to s.264 of the EP Act) that describes how the final rehabilitation criteria have been met and an environmental risk assessment. The administering authority (the Department of Environment and Heritage Protection) will assess the rehabilitation report and will only approve the surrender of the EA when it is satisfied that the final rehabilitation criteria have been met. The authority holder remains liable until the EA and relevant petroleum authority are surrendered. These authorities must be surrendered together.

The well

Section 292 of the P&G Act requires that the authority holder must decommission a well while they still hold a petroleum authority over the land on which the well is located. The code of practice for the construction and abandonment of CSG wells in Queensland (Queensland Department of Natural Resources and Mines, 2017) outlines how CSG wells must be abandoned, and must be considered in conjunction with legislative requirements (i.e. Schedule 3 and s.69 and 70 of the P&G Reg). The third version of the code of practice, released in 2017, has significantly revised well abandonment requirements compared to the second edition (Queensland Department of Natural Resources and Mines, 2013). The requirement to fully cement the innermost casing string to the surface has been removed and replaced with minimum abandonment plug requirements that are dependent on the configuration of the well. The code outlines the following principles for well abandonment:

> *'CSG well abandonment must ensure the environmentally sound and safe isolation of the well, protection of groundwater resources, isolation of the productive formations from other formations, and the proper removal of surface equipment.*
>
> *The outcomes of well abandonment are to:*
> - *isolate groundwater aquifers within the well from each other and hydrocarbon zones.*
> - *isolate hydrocarbon zones within the well from each other unless commingling is permitted.*
> - *ensure there is no pressure or flow of hydrocarbons or fluids at surface both internally in the well and externally behind all casing strings.*
> - *recover/remove surface equipment so as to not adversely interfere with the normal activities of the owner of the land on which the well or bore is located. (p.20-21)'*

The code's mandatory requirements for well abandonment include:

- a requirement to seal and fill the well to prevent any leakage of gas and/or water
- that cement must be used as the primary sealing material as well as testing requirements for cement
- the operator must confirm the absence of pressure/flow externally behind all casing strings prior to abandonment
- that there is a minimum of two adjacent cement barriers across all formations above the uppermost hydrocarbon production zone
- that the operator must conform the absence of pressure/flow within the well and behind all casing strings prior to surface abandonment
- that the wellhead be removed and the casing cut at a depth greater than 1.5 metres below the surface.

The Department of Natural Resources and Mines must be notified within 10 days of the abandonment of a well, and a well abandonment report containing complete and accurate records of the entire abandonment procedure must be submitted within 2 months of abandonment. The code also sets out requirements for the construction of wells that aim to ensure the long-term integrity of the well, particularly for the casing and cementing of casing in the well.

Landholder's rights

If the land on which the well is located is privately owned, then the landowner has some rights in relation to decommissioning and rehabilitation. The rehabilitation report must include a landowner statement where the landowner can state their level of satisfaction with the rehabilitation. Any agreement between the authority holder and the landowner for the transfer of ownership of any infrastructure or disturbed land must be included with the landowner statement. The administering authority will take the landowner statement into consideration when certifying that the rehabilitation has been completed.

The P&G Act (Chapter 2, Division 3) also allows the ownership of wells to be transferred to the landowner. This would only occur for water wells or water monitoring wells.

2.2.3 Financial assurance

The holder of an EA for petroleum activities that result in significantly disturbed land must lodge financial assurance (FA). FA is a type of financial security provided to the Queensland Government that covers expenses incurred in taking action to prevent or minimise environmental harm or rehabilitate the environment should the holder fail to meet their environmental obligations as set out in the EA (Department of Environment and Heritage Protection, 2016). The requirement for providing FA is a condition of an EA under the EP Act. The amount of FA is calculated according to a range of factors, including the scale/area of disturbance, the original land use and the costs of rehabilitating or restoring the disturbed land area. The authority holder proposes the amount of FA to the administering authority (Department of Environment and Heritage Protection) who decides whether that amount is appropriate. The authority holder must lodge the FA prior to commencing activities.

The amount of FA can be amended throughout the life of a project. It may increase or decrease in line with changes to the amount of land that has been disturbed or rehabilitated. The EA holder must apply to have the amount of FA amended and may apply for the return of the FA when they transfer or surrender the EA. The FA will only be returned when the administering authority is satisfied that the EA holder has complied with all the conditions of their EA and that there is no ongoing liability to the Queensland Government.

2.3 Overview of regulatory pathway for petroleum projects in NSW

The New South Wales Government (NSW Government) has been reforming its regulatory framework for gas development in line with the NSW Gas Plan (NSW Government, 2014) that was developed in response to the Independent Review of Coal Seam Gas Activities in NSW (O'Kane, 2014). The high-level process that all petroleum resource projects must follow in NSW as of December 2017 is:

- The process for awarding authorities for petroleum activities in NSW is regulated through *Petroleum (Onshore) Act 1991* (PO Act) and administered by the Division of Resources and Energy, Department of Planning and Environment. For exploration activities, the project proponent applies for a petroleum exploration licence (PEL)[3] through a tender process. A successful applicant will then need to submit a work plan and, if the planned activities are not low intensity with minimal environmental impact, a review of environmental factors (REF) for approval. Drilling is not considered a low intensity exploration activity. If granted, the approval will include licence conditions that include environmental aspects. The authority holder must hold an environment protection licence (EPL) issued by the NSW Environmental Protection Agency (EPA) under the *Protection of the Environment Operations Act 1997* (POEO Act).
- If the holder of a PEL discovers petroleum resources in their licence area that they consider to be commercially viable, the applicant can apply for a petroleum production licence (PPL). A petroleum production development is considered a State Significant Development and requires development consent from the Minister for Planning under the Environmental Planning and Assessment Act 1979 (EPA Act). The approval process requires an environmental impact statement (EIS) to be prepared by the applicant. This process is administered by the Department of Planning and Environment with input from other government agencies. Development consent will include conditions that include environmental aspects.

[3] There are several authority types for petroleum activities in NSW. This section has focused on the authorities related to exploration and production of CSG. A complete list of authorities is provided in the appendix.

The NSW EPA regulates the CSG industry in NSW for all matters except those related to workplace health and safety, which are regulated by the Division of Resources and Energy.

The holder of an authority, either PEL or PPL with development consent, must operate in accordance with the conditions of their authority, which include requirements for rehabilitation prior to relinquishment. They must also meet the requirements of all other state legislation relevant to their activities. Table 3 outlines some of this legislation.

The Division of Resources and Energy, NSW Department of Planning and Environment has developed a code of practice for the construction and abandonment of CSG wells in NSW (NSW Department of Trade and Investment 2012). This code sets out minimum standards for the construction and abandonment of wells drilled as part of CSG activities. The code is referred to in the conditions attached to PELs and PPLs.

When an authority holder applies for a PPL the project may trigger the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) if it was deemed to impact on an area of significant national environmental value. The EPBC Act contains specific triggers related to CSG and coal mining.

Table 3: Key NSW legislation relating to the development of petroleum resources in NSW

This is not an exhaustive list of all legislation that may apply to CSG projects.

Legislation	Description	Administering department
NSW key legislation		
***Petroleum (Onshore) Act 1991* (PO Act)**	Regulates petroleum and gas exploration tenure, safety, production and pipelines	Division of Resources and Energy, Department of Planning and Environment; Environmental Protection Agency
Environmental Planning and Assessment Act 1979 (EPA Act)	Regulates environmental planning and assessment in NSW. Sets out the process for planning approvals and assessment of environmental impacts for all developments.	Department of Planning and Environment
Protection of the Environment Operations Act 1997 (POEO Act)	Provides a regulatory framework for the protection, restoration and enhancement of the quality of the environment in NSW	Department of Planning and Environment
NSW – other relevant legislation		
Water Act 1912	Regulates water use in NSW, being phased out and replaced by the Water Management Act 2000.	Department of Primary Industries
Water Management Act 2000	Regulates the sustainable management of NSW's water resources, licenses the extraction of groundwater by the resources sector	Department of Primary Industries
Pipelines Act 1967	Regulates the licencing of gas pipelines and the safety and integrity of the pipelines once they are licensed	Division of Resources and Energy, Department of Planning and Environment
Gas Supply Act 1996	Regulates gas distribution (reticulated gas networks) and the efficient use of gas	Division of Resources and Energy, Department of Planning and Environment
Protection of the Environment Administration Act 1997	Establishes the Environmental Protection Agency, and sets out the objectives of the agency	Environmental Protection Agency, Department of Planning and Environment

Legislation	Description	Administering department
Contaminated Land Management Act 1997	Allows for management and regulation of contamination of land	Environmental Protection Agency, Department of Planning and Environment
National Parks and Wildlife Act 1974	Regulates the care, control and management of all national parks, historic sites, nature reserves, reserves, Aboriginal areas, state game reserves and conservation areas in NSW. Regulates the protection and care of native fauna and flora, and Aboriginal places and objects.	Office of Environment & Heritage, Department of Planning and Environment
Heritage Act 1977	Regulates the management of NSW's environmental, cultural and Aboriginal heritage	Office of Environment & Heritage, Department of Planning and Environment
Environmentally Hazardous Chemicals Act 1985	Regulates the use of environmentally hazardous chemicals throughout their life cycle	Department of Planning and Environment
Waste Avoidance and Resource Recovery Act 2001	Regulates the production, reuse and disposal of waste materials in NSW	Environmental Protection Agency, Department of Planning and Environment
Public Health Act 2010	Regulation to protect and promote the health of the NSW public and control risks to public health	Department of Health

2.3.1 Environmental conditions for NSW petroleum authorities

The licence or development consent conditions for a petroleum activity include the environmental conditions that those activities must comply with. The process for setting these conditions is different for the exploration and production stages.

The requirement to get an activity approval for petroleum exploration activities is set out in the PO Act. The process for approving exploration activities from an environmental perspective follows the requirements of Part 5 (Environmental Assessment) of the EPA Act (NSW Department of Planning and Environment, 2015b). All applications for activity approvals for petroleum exploration, except for those with minimal environmental impact such as surface geological mapping, will require the submission of a work plan and a review of environmental factors (REF).

The REF documents how the activities are likely to impact the environment. The required contents of an REF are set out in *ESG2: Guideline for preparing a Review of Environmental Factors* (NSW Department of Planning and Environment 2015a), which include:

- a description of the proposed activities and management strategies to mitigate against environmental impacts and to consult with other stakeholders
- a description of the existing environment, including flora and fauna, groundwater and surface water resources, Aboriginal and historic or natural heritage
- an assessment of the impacts on the environment, including cumulative impacts, in the following areas:
    - air impacts
    - water impacts
    - soil and stability impacts

    - noise and vibration impacts
    - other physical or pollution impacts
    - biological impacts (including flora and fauna, ecology and biosecurity)
    - resource use impacts (impacts on community resources such as shared infrastructure and on other natural resources)
    - community impacts (social, cultural, heritage, economic, land use, transportation and aesthetic impacts)
- a summary and conclusions.

The Department of Planning and Environment will conduct an environmental impact assessment based on the material provided in the REF for consideration by the determining authority, who may grant or refuse the application. An approval for the activities contains the environmental conditions that the activities must comply with, which are based on the commitments made in the REF. If the determining authority concludes that the activities may significantly affect the environment, then an EIS must be prepared. A species impact statement is required for any activity likely to significantly impact on a threatened species. The determining authority sets out the requirements for an environmental assessment conducted in an EIS, as well as the process for preparing and exhibiting the EIS. The approving authority then assesses the EIS.

Petroleum production in NSW is considered a state significant development (SSD) under the *State Environmental Planning Policy (State and Regional Development) 2011*, a policy under the EPA Act. The process for assessing and determining an application for a SSD has the following steps:

1. The applicant submits a preliminary environmental assessment and requests the Secretary of the Department of Planning and Environment to provide environmental assessment requirements (SEARs) for the proposed development. The SEARs outlines the information that must be contained in an EIS for the project.
2. The applicant prepares the EIS in accordance with the SEARs. The EIS will contain a full description of the development and the site, the objectives of the development, analysis of any feasible alternatives, the impacts of the development and measures to medicate these impacts and other required approvals. During the preparation of the EIS the applicant must also consult with relevant state and local authorities and the local community. The EIS must include details and outcomes of this consultation.
3. The applicant submits the development application and EIS, which are then exhibited by the Department of Planning and Environment for public comment. The applicant then responds to submissions made by other stakeholders.
4. The Department of Planning and Environment will then assess the application and EIS, and publish their assessment.
5. The application is determined by the Planning Assessment Commission (PAC) or senior staff in the Department of Planning and Environment. The PAC is likely to make a determination for petroleum production developments due to their size and high level of community concern. The PAC process includes a review and public hearing. The PAC will publish a review report and the applicant will have an opportunity to respond.
6. The PAC will then make a determination either to approve the developments with or without conditions or refuse the application. The conditions on an approval include the required environmental performance for the development.

In addition to the development approval, the authority holder must hold an EPL issued by the NSW EPA under the POEO Act. These licences relate to pollution prevention and monitoring and waste reduction. Licences are applied to facilities (for example, a water treatment facility as part of a CSG development).

In summary, the NSW system for licensing exploration or providing development consent for petroleum production includes the conditions for environmental performance within the licence or consent. These conditions are the main regulatory instrument for setting the environmental standards for a petroleum activity.

2.3.2 NSW well decommissioning regulation

The decommissioning and abandonment of CSG wells has two main components: surface expression of the well, along with associated infrastructure, and the well itself.

Surface disturbance

The *Exploration code of practice: rehabilitation* (NSW Department of Planning and Environment, 2015d) will be a condition of all PELs issued or renewed from 1 July 2015. This code requires rehabilitation planning and practices to be integrated throughout all phases of an exploration program, with an emphasis on prevention and minimisation of disturbance in the first place. The code states that

> *'The final condition should be as good or better than as it existed prior to exploration activities, or one that allows the proposed final land use(s) to be sustained. (p. 3)'*

The authority holder must develop a rehabilitation management plan (RMP) that describes the exploration activities that will be undertaken, a risk assessment for rehabilitation activities, baseline information on existing land use, photographs of the work sites, final land use goals for land that has been disturbed by the activities, rehabilitation objectives and completion criteria developed in consultation with relevant landholders, a description of the rehabilitation methods that may be used, the schedule for rehabilitation activities, monitoring and care and maintenance activities post-rehabilitation and any other measures identified by the risk assessment. Rehabilitation must commence as soon as practical following completion of exploration activities at a site.

An annual activity report that includes an annual environmental and rehabilitation compliance report must be submitted every year by the authority holder, as outlined in *ESG4: Guideline for preparing an Environmental and Rehabilitation Compliance Report* (NSW Department of Planning and Environment, 2016; NSW Department of Trade and Investment, 2012). This report will include the status of exploration activities and associated rehabilitation since the grant of the title.

Part 3 of the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* sets out matters that must be considered prior to granting development consent for petroleum production. These matters must be addressed in the EIS for petroleum production. The requirements for rehabilitation are:

> ***'17 Rehabilitation***
>
> *(1) Before granting consent for development for the purposes of mining, petroleum production or extractive industry, the consent authority must consider whether or not the consent should be issued subject to conditions aimed at ensuring the rehabilitation of land that will be affected by the development.*
>
> *(2) In particular, the consent authority must consider whether conditions of the consent should:*
>
> *(a) require the preparation of a plan that identifies the proposed end use and landform of the land once rehabilitated, or*
>
> *(b) require waste generated by the development or the rehabilitation to be dealt with appropriately, or*

> (c) *require any soil contaminated as a result of the development to be remediated in accordance with relevant guidelines (including guidelines under section 145C of the Act and the Contaminated Land Management Act 1997), or*
> (d) *require steps to be taken to ensure that the state of the land, while being rehabilitated and at the completion of the rehabilitation, does not jeopardize public safety.'*

The conditions that form part of the approval for a PPL include requirements for a rehabilitation and environmental management process (REMP). This includes a petroleum operations plan (POP), submitted prior to beginning any operations and an environmental management report (EMR). For rehabilitation, the REMP identifies the significant rehabilitation and environmental aspects of the operation, and the detailed planning for monitoring rehabilitation progress and success. The REMP will also set out the authority holder's reporting requirements to government agencies on environmental matters.

The well

The code of practice for CSG well integrity in NSW (NSW Department of Trade and Investment, 2012) sets out the requirements for abandoning CSG wells. Authority holders must comply with the code under the conditions for PELs and PPLs issued or renewed since 2012. The code states that the principle applied to the decommissioning of wells is that:

> *'CSG well abandonment must ensure the environmentally sound and safe isolation of the well, protection of groundwater resources, isolation of the productive formations from other formations, and the proper removal of surface equipment.*
>
> *Titleholders are responsible for the well until the department is satisfied that the titleholder can demonstrate that the well is safe and non-polluting.*
>
> *The outcomes of well abandonment are to:*
> - *maintain isolation of beneficial aquifers within the well from each other and hydrocarbon zones;*
> - *maintain isolation of hydrocarbon zones within the well from each other, from aquifers, water bearing zones or from zones of different pressure;*
> - *minimize risk to possible future coal mining*
> - *isolate the surface casing or production casing from open hole;*
> - *place a surface cement plug in the top of the casing; and recover/remove the wellhead. (p.23-24)'*

The code's mandatory requirements for well decommissioning include:

- The Division of Resources and Energy within the Department of Planning and Environment must give prior approval for the abandonment of a well.
- The well must be sealed by filling the near-vertical section from total depth to the top with cement, or similar method approved by the regulator.
- The well must be abandoned in a manner that prevents any leak of gas and/or water.
- The well must be sealed with cement. The code stipulates the minimum strength for the cement and a process for placing the cement in plugs of up to 200 metres in length at a time.
- The wellhead must be removed and casing cut at a depth of at least 1.5 metres below the surface, and a marker plate must be installed to identify the well.

The code also sets out requirements for the construction of wells that aims to ensure the long-term integrity of the well, particularly in terms of the casing and cementing of casing in the well. In addition to the requirements of the code, additional conditions may be placed on the authority holder. One such condition is the requirement to remove steel casing from the vertical section of a well that crosses a mineable coal seam.

Landholder rights

The NSW regulatory framework for CSG development requires consultation with landholders throughout the process. The *Exploration guideline: petroleum land access* (NSW Department of Planning and Environment, 2015c) provides guidelines for this process during exploration. The guideline requires the authority holder and landholder to agree on the intended final use goal for the areas that are disturbed, discuss the landholder's preferences or identify problems prior to rehabilitation, rehabilitate the land in consultation with the landholder and use all reasonable endeavours to obtain the landholder's sign-off on the rehabilitation. If agreed with the landholder and if it is lawful, infrastructure may be left in place for the landholder. The RMP, as required by the *Exploration code of practice: rehabilitation* (NSW Department of Planning and Environment, 2015d), will document the rehabilitation objectives and completion criteria developed in consultation with relevant landholders.

The SSD evaluation process for PPLs also requires consultation with landholders. The conditions of a development approval for petroleum production set out these requirements.

Wells may be converted in to water wells and ownership transferred with approval from the regulator.

2.3.3 Rehabilitation security deposits

Under the PO Act, the relevant Minister may require the authority holder to lodge a rehabilitation security deposit. This is included as a condition on petroleum titles in NSW. The deposit amount must be sufficient to cover the government's full costs in undertaking rehabilitation in the event of default by the authority holder. The deposit amount is adjusted according to the level of activity and the anticipated costs of rehabilitation, and will increase as a project is developed and may decrease as rehabilitation progresses.

The authority holder is required to submit a rehabilitation cost estimate (RCE) prepared in accordance with the *Rehabilitation cost estimate guidelines* (NSW Department of Planning and Environment, 2017). The Division of Resources and Energy in the Department of Planning and Environment reviews the RCE and will reject it and require it to be resubmitted if they deem it to be inadequate. The authority holder must submit a RCE whenever a potential change in rehabilitation liabilities occurs. The amount of security may also be reviewed when the authority is renewed or transferred, after an environmental incident, or at the request of the authority holder.

Rehabilitation security deposits will be released when the authority holder satisfactorily demonstrates to the regulator that they have met the relevant rehabilitation completion criteria. The amount of security may be reduced if the authority holder can demonstrate that they have progressively rehabilitated part of the site.

2.4 International regulations

This section discusses decommissioning practices and regulation in North American jurisdictions with established large-scale CSG (also known as coalbed methane, or CBM) activity comparable to that of Australia. While many countries are prospective for CSG, large-scale CSG development has only been undertaken in the United States of America, Canada, China and Australia. CSG development in China has been dominated by coal mine methane (CMM), where the gas is produced in association with coal mining. Although CSG development is increasing in China, the focus is on jurisdictions that have mature CSG industries as these provide the best insight for Australia. This review focuses on key themes around land access, well abandonment procedures and financial assurances for well abandonment. For the purposes of this report, regulation relevant to individual wells, not overarching regulatory requirements that might apply if the well is part of a large project, is considered. The following discussion concentrates on current regulatory practices. In most cases the regulation applies to all gas wells within the given jurisdiction with no distinction made between CSG and other gas resources (exceptions to this case are noted).

There is a lack of peer-reviewed scientific literature on the effectiveness of these regulatory frameworks in ensuring wells are decommissioned appropriately. Well decommissioning methods do not appear to have had much attention from the research community. There is some literature on leakage rates from abandoned onshore oil and gas wells (Kang et al., 2014; Kang et al., 2016; Boothroyd et al., 2016; Townsend-Small et al., 2016); however, the well abandonment method is rarely discussed.

2.4.1 United States

CSG has been exploited for over 40 years in the United States, with most production coming from Colorado, New Mexico, Wyoming, Virginia, Alabama, Oklahoma and Utah. Production peaked in 2008 at 57 billion cubic metres (bcm) and has declined by half over the last decade (EIA, 2018). By comparison, Queensland's CSG production was 36 bcm in 2016–2017.

Regulation of oil and gas development in the United States is dependent on the owner of the surface rights of the land (Cogan and Cogan, 2018; James and Pulman, 2018). Oil and gas exploration and production on land that is owned and managed by the federal government is regulated by the federal Bureau of Land Management (BLM). There are also federal laws on environmental impacts that are not specific to any particular industry to which oil and gas operations must comply, most notably the *National Environmental Policy Act* (NEPA). There is some overlap with state laws in this regard. Where the land is state or privately owned, regulation of oil and gas activities is carried out by the relevant state government. Some local governments (municipalities and counties) also regulate oil and gas activities.

This review has looked at regulations in Alabama, Colorado, New Mexico and Wyoming as these states have significantly highly levels of activity than Utah, Virginia and Oklahoma. In each of the jurisdictions reviewed, regulation of the oil and gas industry is conducted through a board or commission whose powers are established through statutes:

- Alabama: State Oil and Gas Board of Alabama (OGBA)
- Colorado: Colorado Oil and Gas Conservation Commission (COGCC)
- New Mexico: Oil Conservation Division (NMOCD)
- Wyoming: Wyoming Oil and Gas Conservation Commission (WOGCC).

The regulation of CSG activities is mostly included within the overall regulation of oil and gas in all the jurisdictions reviewed. There are specific aspects of CSG development that are treated separately in some states, the most notable being Alabama, which has specific requirements around well construction and abandonment for CSG wells.

Tenure and land access

In contrast to the state ownership of oil and gas in Australia, access rights for oil and gas resources reside with the owner of the surface rights in the United States (Cogan and Cogan, 2018; James and Pullman, 2018). This may be the federal or relevant state government, or private owners. Rights to resources may be transferred to a third party by sale or lease and granting access to oil and gas resources also implies rights to access and use the surface to produce the resource (Lucas and Fraser, 2016). Surface rehabilitation requirements are negotiated directly between the landholder and the oil and gas developer, although the regulator of the relevant jurisdiction will also have requirements for long-term environmental impacts.

A greater proportion of the rights in the gas producing states located in the western half of the United States (for example, Colorado, Wyoming, New Mexico) are federal or state owned in comparison with those in the east.

Well decommissioning and surface reclamation requirements

The requirements for well decommissioning vary across the various jurisdictions in the United States. A review of all jurisdictions is beyond the scope of this report; instead, the key aspects of federal jurisdiction through the BLM, along with the regulations in the states of Alabama, Colorado, New Mexico and Wyoming that have mature CSG industries, are described.

For most of the jurisdictions reviewed, well abandonment and surface rehabilitation must be considered as part of the process of gaining approval for drilling of the well, or as part of negotiations with the surface owner for access.

All jurisdictions require that the operator apply for approval from the regulator prior to the commencement of abandonment. The applications set out all aspects of the proposed abandonment operation. For example, the Colorado regulations (Rule 311, COGCC, 2016) require that:

> *'Notice of Intent to Abandon shall be completed and attachments included to fully describe the proposed abandonment operations. This includes the proposed depths of mechanical plugs and casing cuts; the proposed depths and volumes of all cement plugs; the amount, size and depth of casing and junk to be left in the well; the volume, weight, and type of fluid to be left in the wellbore between cement or mechanical plugs; and the nature and quantities of any other materials to be used in the plugging. The operator shall provide a current wellbore diagram and a wellbore diagram showing the proposed plugging procedure…'*

The Wyoming regulations require that (from Chapter 3, Section 15 of WOGCC, n.d.):

> *'Before beginning abandonment work on any well, stratigraphic test, core hole, dry hole, or other exploratory hole, a Notice of Intent to Abandon (Form 4) shall be filed with the Supervisor and approval obtained as to method of abandonment before the work is started. The notice must show the reason for abandonment, and must give a detailed statement of proposed work including such information as kind, location, and length of plugs (by depths), and plans for mudding, cementing, shooting, testing, and removing casing, as well as any other pertinent information.'*

At the completion of abandonment operations, all jurisdictions require that a well abandonment report be submitted to the regulator in a prescribed format. With the exception of New Mexico and Wyoming, the jurisdictions reviewed had prescriptive requirements for well abandonment. For example, the BLM sets minimum standards for plugging of wells (from Section III, G, BLM, 1988), including:

> *'2. Cased Hole. A cement plug shall be placed opposite all open perforation and extend to a minimum of 50 feet below (except as limited by TD or PBTD) to 50 feet above the perforated interval. All cement plugs, except the surface plug, shall have sufficient slurry volume to fill 100 feet of hole, plus an additional 10 percent of slurry for each 1,000 feet of depth. In lieu of the cement plug, a bridge plug is acceptable, provided:*
>
> *i. The bridge plug is set within 50 feet to 100 feet above the open perforations;*
>
> *ii. The perforations are isolated from any open hole below; and*
>
> *iii. The bridge plug is capped with 50 feet of cement. If a bailer is used to cap this plug, 35 feet of cement shall be sufficient.'*

Alabama is the only jurisdiction with abandonment requirements explicitly for CSG (referred to as coalbed methane, or CBM in the United States). These requirements are similar to those for other oil and gas wells. An example of the abandonment requirements from Alabama is (from 400-3-4-.14., OGBA, n.d.):

'(1) - Cased Hole Completions.

(a) Perforated Wells. A perforated well shall be plugged by one of the following methods:

1. *A permanent-type bridge plug shall be placed above the uppermost perforation or injection zone and a cement, concrete or grout plug not less than one hundred (100) feet in length shall be placed atop the bridge plug.*
2. *A permanent-type bridge plug shall be placed above the uppermost perforation or injection zone and at least fifty (50) feet below the surface casing shoe, and the well shall be filled from the bridge plug to land surface with cement, concrete, or grout.*

(b) Unperforated Wells. An unperforated well shall be plugged by one of the following methods:

1. *If records indicate production casing has been cemented, a permanent-type bridge plug shall be placed inside production casing at a depth of at least two hundred (200) feet, and the well shall be filled from the bridge plug to land surface with cement, concrete, or grout.*
2. *If records do not indicate production casing has been cemented, freshwater shall be pumped into the well to establish circulation, whenever possible. The amount of cement calculated to fill the production casing and its annulus shall, whenever possible, be pumped down that casing. After a minimum of twenty-four (24) hours, the top of the cement in the casing shall be verified by tagging or pressure testing.*
3. *Other plugs consisting of cement, concrete or grout shall be set if deemed necessary by the Supervisor.'*

For New Mexico and Wyoming, the abandonment requirements are objective based and they appear to be assessed based on the application for abandonment. An example of the objective-based requirements from New Mexico (19.15.25.10 of NMOCD, n.d.) is:

'A. Before an operator abandons a well, the operator shall plug the well in a manner that permanently confines all oil, gas and water in the separate strata in which they are originally found. The operator may accomplish this by using mud-laden fluid, cement and plugs singly or in combination as approved by the division on the notice of intention to plug.'

All jurisdictions have requirements for rehabilitation (referred to as 'reclamation' in North America) of the drill site. These include a timeframe by which reclamation must be completed (typically 12 months after the well has been abandoned, although some jurisdictions make allowances for seasons), and the land is returned to its original condition. There are allowances for the surface owner to negotiate for a different land use.

New Mexico and Wyoming have prescriptive requirements around the life cycle of pits, whether they are used for drilling or other purposes, including for reclamation.

Financial assurance and orphaned wells

All jurisdictions require financial assurance (generally referred to as 'bonds' in the United States) to be lodged prior to drilling commencing, and this is held by the regulator until the well has been properly abandoned and the surface reclaimed (Davis, 2015). The amount of financial assurance or bond varies across jurisdictions and it is generally calculated to cover the costs of completing the decommissioning process should the operator default on their obligations. However, the adequacy of these bonds has been questioned in a recent study (Ho et al., 2018). The bond is released once the well has been decommissioned to the satisfaction of the regulator. For example, the Colorado regulations (Rule 709, COGCC, 2016) state:

'All financial assurance provided to the Commission pursuant to this Series shall remain in-place until such time as the Director determines an operator has complied with the statutory obligations described herein, or until such time as the Director determines that a successor-in-interest has filed satisfactory replacement financial assurance, at which time the Director shall provide written approval for release of such financial assurance. Whenever an operator fails to fulfil any statutory obligation described herein, and the Commission undertakes to expend funds to remedy the situation, the Director shall make application to the Commission for an order calling or foreclosing the operator's financial assurance.'

In addition to financial assurance, all the jurisdictions reviewed have also established funding mechanisms for 'orphaned' wells. These are wells for which the operator is not able to complete decommissioning, usually because of bankruptcy (Ho et al., 2018). Orphaned wells have increased over recent years due to the addition of low cost gas to the North American market, and due to insufficient financial assurance or bonds to cover the costs of well decommissioning. Bleizeffer (2011) provides an example of the decline in the CSG industry in Wyoming. Walsh (2017) reports that as of May 2017, there were 4149 orphaned gas wells in Wyoming. This legacy is acerbated by the surface and resource ownership rights in Wyoming, which resulted in numerous small operators.

Orphaned well funds are raised through a combination of direct fees and levies on oil and gas production (Ho et al., 2018). There have been recent efforts to increase the size of orphaned well funds in several states through levies on industry (API, 2018).

2.4.2 Canada

Alberta is the only province in Canada with large-scale CSG activities, which are regulated by the Alberta Energy Regulator (AER). The AER replaced the Energy Resources Conservation Board (ERCB) in 2013. Alberta produced 6.5 bcm of CSG in 2016 (AER, 2018), although production has declined in recent years. The regulation of oil and gas activities in Alberta is highly prescriptive. In addition to primary legislation, subordinate legislation in the form of rules and directives put in place by the AER (or its predecessor, the ERCB) sets out specific requirements for oil and gas activities. CSG activities are regulated as for other oil and gas activities.

Tenure and land access

Oil and gas rights in approximately 81% of Alberta are owned by the provincial Crown, with the remainder owned by the federal Crown within national parks and Indian reserves (Alberta Government, 2017). There are also some historical freehold rights that were granted prior to 1887. This is similar to the resource ownership rights in Australia. The AER administers the licencing of these rights to explorers and producers. Licencing of oil and gas resource rights in Alberta has the ability to separate resources at different depths (zones) and to license these zones in separate leases.

Oil and gas right holders must negotiate a private surface agreement with the landholder. These agreements include a description of the oil and gas infrastructure that will be developed, compensation, access arrangements and rehabilitation arrangements.

Well abandonment requirements

Overarching well abandonment requirements are set out in the *Oil and Gas Conservation Act*, with detailed requirements in Directive 20, Well Abandonment (AER, 2016a). Directive 20 states that:

'The objective of a well abandonment is to cover all non-saline groundwater (water with total dissolved solids [TDS] less than 4000 milligrams per litre [mg/l]) and to isolate or cover all porous zones.'

Operators are only required to apply for approval for non-routine abandonment operations, and provide notification to the AER prior to routine abandonments. Examples of non-routine abandonment include abandonment of wells associated with in situ coal gasification, wells that have a wellbore problem and wells where cement does not cover all non-saline groundwater zones. Well abandonment reports must be submitted to the regulator on completion of well abandonment operations.

Directive 20 (AER, 2016a) prescribes the requirements for abandoning wells in some detail. These requirements include:

- evaluation of the cement behind casing before abandonment
- requirement of cement plugs to cover all non-saline groundwater to the base of groundwater protection (BGWP)
- minimum length of cement plugs (depth dependent)
- requirement to isolate all porous zones, including a definition of porous zones based on rock type.

There is also a requirement for post-abandonment monitoring of the well to ensure that the abandonment has been successful and that there is no migration of gas up the well outside of the casing, through casing annuli or through the inner casing. The method for conducting this monitoring is also prescribed. Surface abandonment cannot be completed until this testing has verified that there are no problems with the plugging of the well.

Surface abandonment requirements are also prescribed in Directive 20 (AER, 2016a). Cutting off the casing immediately below the surface is mandated, with the depth dependent on land use and well location. If the well is in an area where surface mining may be carried out, a 15 metre plug must be installed in the well below the intended depth of strip mining and the casing must be cut at intervals approved by the mining operator. A cap must be installed at the top of the casing.

Surface rehabilitation (or reclamation) requirements are set out in the *Environmental Protection and Enhancement Act* (EPEA) and the *Conservation and Reclamation Regulation* (CRR). The AER is responsible for ensuring that land used for energy resource activities is reclaimed in an environmentally sound manner. Rehabilitation must return disturbed land to an 'equivalent land capability'. Specified Enactment Direction 002 (AER, 2016b) sets out the obligations on the operator to obtain a reclamation certificate to demonstrate that they have completed rehabilitation of the site. The landholder must be notified that the operator has completed rehabilitation and is able to lodge an objection, and a dispute resolution process is also in place. Progressive rehabilitation is also allowed.

Specified Enactment Direction 002 (AER, 2016b) describes how a site rehabilitation would be assessed and specifies all the information that must be contained in an application for a reclamation certificate, including:

- environmental site assessment requirements. An ESA is an investigation to determine the environmental condition of a site
- a description of the level of disturbance
- topography relative to adjacent land
- revegetation approach, and whether fertilizers or herbicides were used
- a description of the vegetation surrounding the site and on the site
- a listing of any facilities that will remain in place
- whether a flare pit was used, and if so, sampling from the pit is required
- information on any spills or releases of fluids.

Financial assurance and orphaned wells

The AER collects security deposits in accordance with the *Oil and Gas Conservation Rules (Alberta Regulation 151/1971)*. The security deposit is intended to offset potential suspension, abandonment, remediation and reclamation costs. The security deposit may be returned to the operator once they have met all of their obligations, including well abandonment and surface rehabilitation.

Alberta has a unique approach to orphaned wells (and other infrastructure issues). The Orphan Well Association (OWA) (http://www.orphanwell.ca/) is a non-profit organization whose mandate is to manage the abandonment of orphaned upstream oil and gas facilities, including wells and pipelines, and the remediation and reclamation of their associated sites. The OWA is funded by a levy collected by the AER from operators. In the 2017–2018 fiscal year, the AER collected $30 million Canadian in levies for the OWA (AER, 2017). The OWA has 1391 orphaned wells in its inventory, and spent over $12 million Canadian abandoning 232 wells in the 2016–2017 financial year (OWA, 2017).

3 Summary

The regulatory frameworks for the rehabilitation of CSG projects in the United States and Canada are similar to Queensland and NSW, with the main differences primarily procedural in nature. Both have rehabilitation conditions linked to the authorities granted for exploration or production of a CSG resource. In Queensland these conditions are in a separate environmental authority associated with the resource authority, while in NSW the conditions are included within the resource authority. In both cases, the conditions are determined based on an assessment of the potential environmental impacts. The level of assessment is commensurate with the level of activity, with petroleum production requiring a full environmental impact statement in both states, whereas exploration activities require a lower level assessment. The regulators in both states require authority holders to pay a deposit that would cover the full costs of rehabilitation. This is seen as important assurance for the states as protection against an authority holder defaulting on their obligations.

Rehabilitation and decommissioning of CSG wells has two components – above ground and below ground. Both states have a code of practice that covers CSG well construction and abandonment. The Queensland code is called up in legislation, whereas the NSW code is referred to within the conditions attached to resource authorities. The NSW code requires CSG wells to be fully cemented from the production horizon to the surface. The Queensland code sets minimum requirements for cement plugs according to the well configuration. Both codes require for the top 1.5 metres of the well to be removed and the well buried. The requirements for surface rehabilitation is also similar in both states, with a general requirement to return disturbed areas to a safe and stable condition, fit for an agreed land use and in a condition that is similar or better than those that existed before the activities.

Consultation with the landholder is important in both jurisdictions. There are provisions for the transfer of some infrastructure to the landholder, with their agreement. The landholder does not have the right to determine whether rehabilitation has been properly completed, that power lies with the regulator. However, the regulators in both states require the landholder to be consulted and appear to place some weight on their point of view.

International regulatory frameworks are similar to those of Queensland and NSW. All jurisdictions require approval prior to abandonment of wells, with the exception of Alberta, Canada, which only requires approval for ‘non-routine’ abandonment. Most jurisdictions reviewed had prescriptive requirements for abandonment, however, the level of prescription varied. All jurisdictions use some form of financial assurance. Orphaned wells is a significant issue in all overseas jurisdictions reviewed, and orphaned well funds and programs have been established to address this liability.

Part II Stakeholder Workshops

4 Workshop method

To consider how the CSG industry and regulators are responding to evolving best practices and to community expectations regarding decommissioning, three workshops were held involving industry, government and local residents.

4.1 Locations

The workshops were conducted across three regions over a 3 month period:

- Camden (Macarthur region): June 2017
- Chinchilla (Surat Basin): August 2017
- Narrabri: September 2017.

These regions were selected to explore any similarities or differences between the different regulatory environments of Queensland and NSW, and the varying stages of CSG development in each location. Given the size of the region and high level of CSG activity, two workshops were initially scheduled for the Surat Basin: Chinchilla and Roma. However, the level of participant response was too low for the workshop in Roma to proceed.

Camden, (Macarthur region) NSW – Production winding down

The CSG industry in the Macarthur region, operated by AGL, has commenced decommissioning, with plans to progressively decommission wells and rehabilitate sites at the Camden Gas Project prior to ceasing production in 2023 (AGL, 2017). Formerly a rural area when the gas industry was established, the Macarthur region continues to experience urban expansion as the fringe of the greater Sydney area expands.

Chinchilla (Surat Basin), Queensland – Production at high levels

CSG development has expanded rapidly in recent years in the Surat Basin in Queensland, and is expected to continue for several decades (Office of the Chief Economist, 2015; Measham and Fleming, 2014). There are several major projects in the area with operators that include Santos, Shell and Origin. Decommissioning has commenced in the Surat Basin particularly for exploration wells, poorly producing wells, wells with integrity issues and water bores. Decommissioning of productive wells coming to the end of their life is expected to proceed from mid-2018. Chinchilla is an important regional centre and hub of CSG activity within the Surat Basin.

Narrabri, NSW – Proposed development

CSG development is in the proposal stage in the Narrabri region (with exploration wells already in place). The environmental impact statement for the Santos project is currently being assessed by the state and Commonwealth governments. Narrabri Shire is located in North West, NSW and is dominated by agricultural activities. There has been some decommissioning of exploration wells within the Narrabri region.

4.2 Workshop participants

Workshop invitees included representatives from industry operators in each region, state government, local government and members of the local communities. Those attending from industry tended to be involved in the technical and environmental aspects of the decommissioning process.

Given the research topic focused on a very specific stage and process of CSG development, recruitment of local stakeholders was targeted towards members of CSG project community consultative committees (including local government representatives), landholders and other known interest groups. The purpose was to capture local perspectives informed by some understanding of CSG development, which would enable discussion on a specific aspect of this topic. However, participation rates for this stakeholder group were lower in the Camden and Narrabri workshops compared with the Surat (Table 4). One of the local representatives in Camden was unable to attend the workshop in person and took part in a post-workshop interview instead.

The variable participation of local stakeholders between workshops is acknowledged as a limitation of this study. Furthermore, the workshops lacked participation from landholders who had actually experienced or would soon experience CSG well decommissioning on their properties. This may have inhibited the study's potential to uncover a more comprehensive range of perspectives.

Table 4 summarises the level of stakeholder participation at each workshop.

Table 4 Stakeholder participation at workshops

WORKSHOP	INDUSTRY	STATE GOVERNMENT	LOCAL STAKEHOLDERS*	TOTAL	CSIRO RESEARCHERS
Camden	4	1	3	8	3
Chinchilla (Surat Basin)	4	4	12	20	4
Narrabri	2	3	2	7	4
Total	12	8	16	35	–

*Local stakeholders comprise members from community consultative committees (CCCs) in each location. CCCs include local government representatives as well as advocacy groups.

4.3 Workshop format

The workshops brought together different stakeholder groups as it was considered important that stakeholders could respond and reply to the contributions made by each other to the discussion. For example, industry and regulators were able to directly clarify any queries from the local stakeholders about the decommissioning process, and industry and government could respond to the different technical and regulatory aspects of their responsibilities. This format allowed the researchers to build a more in-depth understanding of different perspectives and of the interactions of the stakeholders throughout the decommissioning process.

Each workshop followed a similar format and flow, commencing with project background, research ethics information and brief introductions from participants. This was followed by a brief overview and presentation by a member of the research team on the decommissioning process to ensure participants were familiar with the topic. The presentation outlined both the technical and regulatory aspects of CSG well decommissioning, including differences between the NSW and Queensland contexts.

Discussion, facilitated by a member of the research team, followed the presentation. The discussion was somewhat structured and guided by a set of key questions. During the discussion, the facilitator asked follow-up questions to further explore and clarify the issues.

The workshop format overview entailed:

- project background
- presentation - technical overview of decommissioning and regulatory context
- facilitated group discussion
  - How is industry responding?
  - How are regulators responding?
  - What are the expectations, preferences and concerns of local residents with regard to decommissioning?
  - What does successful decommissioning look like?
  - What has worked well?
  - Areas for improvement?
  - To what extent do the views of industry, government and residents align?

The workshops and interview were not audio-recorded; however, detailed notes capturing the discussions were taken by the research team and debrief sessions were held shortly after the workshops were recorded to capture the researchers' immediate insights and reflections. These sources combined provided an appropriate level of detail to ascertain the key concerns about CSG well decommissioning.

The workshop activities were conducted in accordance with National Statement on Ethical Conduct in Human Research and granted ethics approval by the CSIRO Social Science Human Research Ethics Committee (Approval number: 032/17).

5 Workshop insights

This section outlines the main issues and concerns identified from each workshop, followed by a consolidated summary of the key themes from the stakeholder discussions.

5.1 Camden

The role of landholders

Landholder involvement in the decommissioning process was raised in a range of contexts during the Camden workshop. Landholders were considered by industry and regulators to play an important role as decommissioning and rehabilitation must be completed to the landholders' satisfaction. Without landholder satisfaction regulators will not provide final sign-off on rehabilitation. The decommissioning that takes place is site specific and is guided by the agreement between landholders and the industry in terms of what condition the land needs to be rehabilitated to and whether the landholder wishes any infrastructure to be left in place for future use. However, concerns were raised about what might occur if a landholder and industry could not agree on reasonable terms for rehabilitation, and what landholder terms may or may not be considered reasonable. It was determined that this situation had not yet occurred and formal procedures were not in place to handle such grievances. Concerns were also raised about whether a landholder may have sufficient knowledge and understanding of the decommissioning process to determine whether they are indeed satisfied with the outcome on their property, and that landholders may benefit from access to independent expertise on the matter.

Future responsibility

Further concerns were raised about the role of landholders and who would be responsible for addressing any future issues should they arise after regulatory authorities had approved the outcome of decommissioning activities. In particular, concern was expressed about landholders being burdened by impacts in the future and taxpayers being held financially responsible if something goes wrong. Some participants expressed the view that the company involved has responsibility to finance any required remediation works, that ongoing monitoring of decommissioned wells was important to ensure any problems could be addressed and that the EPA should be responsible for such.

Close proximity to urban areas

The Macarthur region is in a somewhat unique position given that CSG activities are located in close proximity to urban areas. This gave rise to several concerns. Local council representatives raised concerns about potential impacts on nearby residents while decommissioning activities were taking place, such as noise and general disruption. It was deemed important that residents are notified and informed about these activities and their expected duration. Another issue of concern to residents was well integrity and the management of any legacy effects such as potential gas leakage and the potential impact on the environment and surrounding residents.

Future land use

Somewhat related to urban proximity issues, considerable discussion centred on future land use of decommissioned and rehabilitated CSG well sites. Representatives from local councils spoke of the high likelihood that rehabilitated well areas would have urban uses in the future, and that current landholders would want to retain the ability and opportunity to rezone and subdivide their properties, as this has already occurred for decommissioned well sites. Further to this, council representatives emphasised that decommissioning activities should not affect land values and resale potential. Flexible options for future land use were also considered important for decommissioned CSG well sites located on council-owned land, as intended purposes can change with political cycles and changing decision-makers. Regulators and industry representatives acknowledged that future land uses would always be limited by factors such as planning permissions, and environmental and geological characteristics of the location, irrespective of historical CSG activities. Industry representatives stated that they work with the landowner and developer to accommodate future known land uses at the time of well decommissioning and that this has been completed on several occasions.

5.2 Chinchilla

Code of practice and regulatory concerns

The workshop discussion provided clear indication from the industry representatives that there was a strong reliance on and confidence in the Queensland code of practice (NSW Department of Trade and Investment, 2012) to guide decommissioning activities. State government representatives also stated support for the code. Although the code was well understood by industry and the regulator, local stakeholders had concerns that the practices lacked clarity and were difficult to interpret. Some had misunderstandings about the decommissioning process, such as the impression wells were filled with mud and capped with cement. Furthermore, although decommissioning and rehabilitation activities were to last in perpetuity, it was acknowledged that this terminology lacked a clear definition. Concerns were also expressed on whether resolution processes for resolving any issues existed within the current regulatory framework. Industry and government representatives confirmed such a mechanism was not part of current frameworks.

Legacy issues

The workshop discussion touched on a range of issues related to the legacy of decommissioning and rehabilitation activities. There was some unease about future impacts, with local stakeholders feeling there was a high level of uncertainty around legacy issues. The regulator stated that decommissioned wells were considered low risk following completion and approval. Local stakeholders did not want problems to arise that future generations would then have to deal with. There was also specific mention of potential future impacts to water supply, particularly to the Great Artesian Basin. Concern was also expressed about the resulting agricultural productivity level of CSG wells sites following decommissioning and rehabilitation. It was felt that the land should be returned to its previous state or to a higher level of productivity. Participants with properties nearby or adjacent to those with well sites were also concerned about the impact on property values; for example, due to issues that are detrimental to properties in the future.

State government representatives indicated that responsibility for monitoring post-decommissioning and remediating any legacy issues, should they arise, should belong to the state government. However, they also stressed the importance of having sufficient resources to undertake this role adequately.

Provision of information

Several aspects on the provision of information were raised during the workshop discussion. Local stakeholders expressed concerns about accessibility and transparency of the information provided on well decommissioning. Reference was made to QDEX (Queensland Government database of geospatial data and statutory reporting) and the difficulty encountered when trying to access information. There were also concerns about the timeliness of reporting, particularly around the length of time taken for well completion and well abandonment reports to be made publicly available. State government representatives acknowledged there was a lack of clarity on when information became publicly available on QDEX after submission. Local stakeholders also felt that much of the reporting and information was too lengthy and technical to decipher. In addition, some felt it would be beneficial to have a consistent and reliable point of contact to direct queries and concerns.

5.3 Narrabri

Code of practice and regulatory concerns

Similar to the views expressed in the Surat Basin, the industry representatives in the Narrabri workshop indicated they were very much guided by and reliant on the NSW code of practice (NSW Department of Trade and Investment, 2012). They also expressed confidence in the decommissioning practices it outlines and believed what was required of them was very clear. Regulators explained the practices had been based on industry experiences from around the world and improved upon the practices in other Australian jurisdictions. It was also emphasised that the code would be reviewed and updated on an ongoing basis. Concerns about the code included a perceived lack of clarity on the process, stemming from attempts to gain a more detailed understanding on specific processes from the document. Other regulatory concerns of local stakeholders centred on inclusion of details and consistency around penalties for any breaches.

Technical issues

Discussion around the code led to queries about specific technical details of decommissioning processes. There were concerns that ‘scraping’ was inadequate and posed a risk to the cement-casing bond, and that sulphate reducing bacteria caused degradation of casing. In addition, they raised the issue of compromised cement bonding due to cement contact with water during the cementing process. The participants felt details about this process were not sufficiently clarified in the code and available decommissioning records. Industry representatives explained that the water was displaced through the cementing process so that the cement bond was not compromised. They further explained that testing is conducted as required by the code of practice to ensure integrity of the cement barrier.

The use of wireline logging for wellbore integrity was discussed. Industry representatives confirmed that wireline logging was not conducted for every wellbore, rather a determination was made if wireline logging was required based on the properties of the well properties.

A concern of cross-site contamination through machinery movement was discussed and washing of machinery between sites was suggested by a local stakeholder.

A question was raised in the Narrabri workshop as to how decommissioned wells may be affected by bushfires. Workshop participants felt that risk of bushfires affecting decommissioned wells was very low because decommissioned wells are sealed below the soil surface.

Monitoring

Another concern raised by communities focused on monitoring post-decommissioning, specifically what checks were conducted after wells had been plugged and abandoned, how long should monitoring occur and who should bear the cost. State government representatives indicated that checks included 'bubble tests' post cementing and final cement tests at the end of abandonment. If test results are satisfactory, then the decommissioned well is considered to be low risk. Local stakeholders expressed uncertainty about the potential for future failures and emphasised the importance of ongoing monitoring. Community members referred to examples such as cement cracking over time in slabs and driveways. They also sought reassurance in the form of monitoring and insurance funds to repair potential damage should wells leak in the future. One participant also raised several specific suggestions for ongoing monitoring, including aquifer flow, presence of bacteria, and soil pH. The pH of the soil was identified as important for the growth of local plant species, such as cypress.

5.4 Cross-cutting themes

Oversight and independent assessment

The results from this research reiterate the observation that developing appropriate governance systems is a crucial component of effectively managing the unconventional gas sector (Measham et al., 2016). In each of the workshops, the topic of oversight was discussed. Residents expressed the need for some mechanism for independent assessment of decommissioned wells and the resulting implications of any potential problems. In Camden, participants noted that landholders had been satisfied with rehabilitation to date and were not aware of any observed discrepancies over rehabilitation processes. However, a hypothetical question was asked about what would happen if landholders and gas companies failed to agree on reasonable terms for rehabilitation in the future. Would there be an opportunity to appeal to some kind of ombudsman or similar role? Participants felt that current procedures may need review in order to reconcile potential differences in terms of acceptable rehabilitation in the future. In Narrabri, participants felt that these issues were not sufficiently clear when it came to independent assessment, and any potential penalties that may result from breaches of the code of practice. In the Surat Basin workshop, related concerns were raised; however, in addition to a mechanism to appeal regarding potential grievances, Surat residents would feel more confidence if there was more pro-active checking of wells by independent assessors at the point of declaring that a well had been successfully decommissioned.

Legacy effects and monitoring

In each workshop, legacy effects were acknowledged as a crucial component of successful decommissioning, as has been recognised more widely in scientific literature on unconventional gas (Boothroyd et al. 2016; Vidic et al 2013). In the Macarthur region, where many wells have already been decommissioned and returned to previous land uses, or in some cases, converted into new land uses, legacy effects were strongly connected with proximity to urban populations. The focus was on the cement and near-term potential implications i.e. ensuring that current and future residents would remain safeguarded against any potential leakage, if for example, changing land uses involved extensive excavation to install foundations in buildings. This issue was mostly considered to be comparable with other types of developments in urban areas, whereby future land users need to be cautious when it comes to any action that may disturb infrastructure on any given site. In the Camden workshop, industry participants clarified that in some cases excavating and cutting off decommissioned wells at lower depth was an option that had already been taken up by landholders to facilitate future land uses where appropriate. In the Surat Basin, there was a stronger emphasis on groundwater and significant water sources such as the Great Artesian Basin. The Surat Basin workshop tended to take a long-term view when it came to legacy issues and considered the need to safeguard future generations. Regulators in Queensland emphasised that the state is ultimately responsible for remediating any potential problems that may occur. In both Surat and Narrabri, residents expressed the need for ongoing monitoring of decommissioned wells to ensure that they were not leaking and to respond to any well integrity problems that could occur post decommissioning. Regulators and industry representatives acknowledged that residents had concerns, however, they also had strong confidence in the plugging and abandonment process and deemed the risk of future leaking to be very low.

Transparency and accessibility of information

Access to transparent information is a recognised dimension of social licence (Prno and Scott Slocombe, 2012; Zhang et al., 2018). Concerns about the transparency and accessibility of information about CSG well decommissioning were apparent across each workshop location. In the Camden workshop, industry participants emphasised that fact sheets are readily available along with phone numbers and email details for contact. However, a concern was raised that information on the decommissioning process was hard to find and difficult to understand from a layperson's point of view. In the Surat Basin, emphasis was placed on the provision of information through government-managed platforms and the perception that the information lacked clarity and was not provided in an open and transparent manner due to the long delays before reporting became publicly accessible. The regulators in Queensland also recognised this was an issue, and admitted some lack of awareness about the length of time taken for records to appear on QDEX. Participants in the Chinchilla workshop found the technical and lengthy nature of the information an inhibiting factor in gaining a satisfactory understanding of CSG well decommissioning activities. In Narrabri, the theme of transparency and accessibility of information surfaced in discussions around the code of practice. Participants found the code lacked clarity about the decommissioning process despite attempts to engage with it.

Extent of stakeholder alignment

Understanding the alignment of values is an important part of understanding the CSG industry (Colvin et al., 2015; Huth et al., 2017). Across the workshops a theme centred on stakeholder alignment emerged, with industry and regulators tending to align, while local perspectives were somewhat disparate from these groups. The alignment of industry and regulators was apparent in all three workshops with regards to their perceptions of the code of practice. Coming from a perspective with significant knowledge and understanding, both groups expressed a strong reliance on and confidence in the code of practice in each state to guide completion of decommissioning activities to a high standard. However, the local stakeholders expressed uncertainty and misgivings towards the code, with some reflection of an understandably less comprehensive knowledge base. In Camden, one participant was reluctant to place their trust in the procedures and oversight of industry and government. In the Surat Basin, participants wanted greater clarification of the process and terminology in the code and questioned the lack of grievance procedure. Similarly in Narrabri, concerns were raised about the difficulty in determining certain details of the decommissioning process from the code, and the absence of a mechanism for resolving disputes.

The disparity between views was apparent to varying extents in discussions on what the outcomes of successful decommissioning should be or look like. Industry and regulator representatives in Camden were strongly aligned with the view that decommissioning should meet all technical and licencing requirements, while meeting the landholders' expectations and gaining satisfaction. The local government representatives further added that the process should result in there being minimal evidence that the industry had operated there and that residents were thoroughly engaged in the process. Again, in the Surat Basin, industry and regulators were aligned, believing decommissioning should maintain well integrity into the future; have minimal impact on the surface environment; be conducted according to time, scope and budget requirements; and be to the landholders' satisfaction. Local stakeholders agreed with these outcomes, however, added that it would take some years for desired environmental outcomes to be attained, and had further expectations of there being a framework in place to resolve issues if they arose. In Narrabri, industry and regulators agreed that successful decommissioning would meet the requirements of the code and the landholders' expectations, with healthy outcomes for the environment and society. Local stakeholders in Narrabri felt their views diverged somewhat from those of industry and government, with the expectation that decommissioning should leave any given site in a way that it appears untouched and that no environmental damage has occurred. They also felt the process should include specific ongoing measures for monitoring.

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Part III Summary and policy options

6 Summary and policy options

One of the objectives of this report is to develop policy options for government, industry and local stakeholders that will address the concerns of all stakeholders on the efficient and effective decommissioning of wells and well pads. The following policy options are based on the outcomes of the workshops, and the review of the regulatory frameworks in Queensland and NSW and literature on well decommissioning practices in other jurisdictions. Some of these options relate to broader themes around the conduct of CSG activities (and resource development in general) and the perceptions of the various stakeholder groups. The term ‘policy’ is applied its broadest definition as a ‘course or principle of action by an organisation or individual’ and includes aspects of regulatory and industry practice.

6.1 Well decommissioning process

This study has found broad agreement between stakeholders that the outcome of successful well decommissioning is that there should be no legacy issues arising from the abandoned well or well pad, in perpetuity. The current regulatory frameworks in Queensland and NSW and industry practice are aimed at achieving this outcome. However, there was misalignment in the confidence that different stakeholders had in the well abandonment processes and their ability to achieve this outcome. Government and industry expressed a high level of confidence in the regulatory requirements outlined in the codes of practice in each state and in the current practices employed by industry in complying with the codes. The opinion of government and industry representatives was that the risk of legacy effects was low. Local stakeholders had less confidence in the process, which may partly be due to having a lower understanding of the engineering aspects of the well abandonment process. There was a strong desire from local stakeholders for long-term monitoring and oversight to demonstrate that abandonment has been conducted successfully. This contrasts with the industry and government perspective that well abandonment is final and that ongoing monitoring is generally not required.

Policy Option 1

Government and industry should consider providing more information to the public about the well abandonment process in a range of formats (fact sheets and video) with the aim of improving broader understanding. This information should be easily accessible and describe:

- **how well integrity is maintained throughout the well life cycle and is verified prior to abandonment**
- **the abandonment process, including key operations such as the removal of completions, cleaning of the well, placement of cement, and verification of cement plugs**
- **the materials used in wells, including cement and casing, and their durability in the subsurface environment**
- **how abandoned wells are monitored and the results of monitoring, if recommendation 2 is adopted.**

6.2 Monitoring of abandoned wells

The demand for monitoring of abandoned wells to increase confidence in the abandonment process has been highlighted in other studies. The *Northern Territory Hydraulic Fracturing Inquiry* (NT Hydraulic Fracturing Inquiry, 2018) has recommended that that the Northern Territory Government implement a program of ongoing monitoring of abandoned shale gas wells. This recommendation was based on the inquiry finding that there is very little information available worldwide on the integrity of abandoned shale gas wells. The limited literature on oil and gas well integrity post-abandonment does indicate that some proportion of wells may leak methane (Kang et al., 2016; Townsend-Small et al., 2016). CSG wells can be considered to be a subset of oil and gas wells with relatively benign reservoir conditions (low pressures and temperatures) and shallow depth compared to other oil and gas wells. There are insufficient monitoring data from abandoned CSG wells in Australia, with only a handful of wells analysed, to allow any conclusions to be drawn (Day et al., 2014; Day et al., 2016). The surface expression of physical failures in abandoned wells is considered likely to take the form of methane leakage at the surface. If present, these leaks could be detected through the use of surface flux chambers or other monitoring technologies. Well integrity failures in abandoned wells that allow communication between formations in the subsurface are more difficult to monitor. Potential options for monitoring of subsurface fluid/gas movement along abandoned CSG wells may include, monitoring of offset wells for changes in groundwater chemistry, distributed acoustic sensing to listen for fluid movement or pressure sensors placed within the abandoned well as part of the well abandonment process. However, these techniques may have limited effectiveness if flow rates are low and changes to water chemistry are small. At the time of writing, most CSG wells in Queensland are at the start of their life and abandonment is a long way off. This provides an opportunity for the results of monitoring to provide confidence in future abandonment activities, and should any potential issues be identified, for improved processes to be developed. There is also an opportunity to conduct monitoring of wells abandoned in the Macarthur, Gloucester and Narrabri regions in NSW before any new developments commence.

Policy Option 2

Government and industry should consider instigating a program of monitoring abandoned wells. This will likely require some research into appropriate monitoring methods. Monitoring results should be made publicly available.

6.3 Regulation of the decommissioning process

Local stakeholders expressed a desire for the regulator to be more accessible to local stakeholders and provide additional information on their procedures related to compliance, monitoring and review in a format that was easily understandable by people without an oil and gas background. Another commonly expressed view was that it was unclear who was responsible for management and remediation of decommissioned wells post abandonment. Local stakeholders expressed a desire for clarity on who was responsible for decommissioned wells and what that responsibility would entail, when responsibility would be transferred between industry and government, and who would be responsible for further remediation should issues arise.

Policy Option 3

Government should consider publishing fact sheets that outline the following:

- **summary of the regulation of the abandonment and rehabilitation process**
- **who is responsible for issues arising from wells and well pads**
- **the process of achieving final signoff of successful decommissioning**
- **when and to who the ownership of the abandoned wells transfers**
- **what would happen if there is a long-term problem.**

Policy Option 4

Government should consider improving the mechanisms provided for public enquires, questions and complaints related to decommissioning, and clearly communicate these processes. For example, decommissioning could be included as one of the issues in the Queensland DNRM's CSG Complaints Form (https://www.dnrm.qld.gov.au/business/mining/csg-complaints-form).

Policy Option 5

That consideration be given to improving processes for government and industry to listen to the concerns of stakeholders by providing a consistent point of contact.

6.4 Existing communication platforms

Although well completion reports and abandonment reports are publicly available in both Queensland and NSW through the QDEX and DIGS systems respectively, the local stakeholders indicated they were difficult to locate, access and comprehend. There is also a lack of clarity about the timeframe in which these reports are made publicly available.

Policy Option 6

Government should consider requiring industry to provide plain English summaries of well completion and decommissioning reports in a common format. Information on these reporting requirements (including timing and location of the reports and how to access them) should be provided by the government to local stakeholders.

Appendix A Resource authorities/licences in Queensland and NSW

Queensland[a]		NSW[b]	
Title	**Description**	**Title**	**Description**
Authority to prospect	A resource authority that allows the holder to conduct exploration for petroleum, oil, coal seam gas and natural gas	**Petroleum exploration licence**	A resource authority that allows the holder to conduct exploration for petroleum, oil, coal seam gas and natural gas
Data acquisition authority	A resource authority that allows the holder to conduct limited geophysical survey activities and collect data in areas immediately adjacent to their authority to prospect	**Petroleum special prospecting authority**	A resource authority that allows the holder to conduct desktop surveys or other low impact scientific investigations over the tenement
Water monitoring authority	A resource authority that allows the holder to monitor conduct activities outside of an authority to prospect or petroleum lease so that they can comply with their water management obligations	–	–
Potential commercial area	A resource authority that allows the holder to evaluate the potential production and market opportunities for the resource	**Petroleum assessment lease**	A resource authority that allows the holder to evaluate the potential production and market opportunities for the resource
Petroleum facility licence	A resource authority that allows the holder to operate a petroleum facility, such as a gas processing facility	–	–
Petroleum lease	A resource authority that allows the holder to explore for, develop and produce petroleum (gas and oil) in Queensland	**Petroleum production lease**	A resource authority that allows the holder to explore for, develop and produce petroleum
Petroleum pipeline licence	A resource authority that allows the holder to construct and operate a petroleum pipeline	**Pipeline licence**	A resource authority that allows the holder to construct and operate a cross-country pipeline
Petroleum survey licence	A resource authority that allows the holder to enter land to survey the proposed route for a pipeline or petroleum facility	**Authority to survey**	A resource authority that allows the holder to enter land to survey the proposed route for a pipeline

[a]Queensland authorities are issued under the *Petroleum and Gas (Production and Safety) Act 2004.*
[b]NSW authorities are issued under the *Petroleum (Onshore) Act 1991*.

Shortened Forms

AER	Alberta Energy Regulator
ATP	Authority to prospect (Queensland)
bcm	Billion cubic metres
BLM	Bureau of Land Management (USA)
CBL	Cement bond log
CBM	Coal bed methane
CMM	Coal mine methane
COGCC	Colorado Oil and Gas Conservation Commission
CSG	Coal seam gas
EA	Environmental authority (Queensland)
EIS	Environmental impact statement
EMR	Environmental management report (NSW)
EP Act	*Environmental Protection Act 1994* (Queensland)
EP Reg	*Environmental Protection Regulations 2008* (Queensland)
EPA	Environmental Protection Agency (NSW)
EPA Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ERA	Environmentally relevant activities
ERCB	Energy Resources Conservation Board (Alberta)
FA	Financial assurance
IC Act	*Industrial Chemicals (Notification and Assessment) Act 1989* (Commonwealth)
NEPA	*National Environmental Policy Act* (USA)
NMOCD	Oil Conservation Division (New Mexico)
NT Act	*Native Title Act 1993* (Commonwealth)
OGBA	State Oil and Gas Board of Alabama
OWA	Orphan Well Association (Alberta)
P&G Act	*Petroleum and Gas (Production and Safety) Act 2004* (Queensland)
PAC	Planning Assessment Commission (NSW)
PEL	Petroleum exploration licence (NSW)
PL	Petroleum lease (Queensland)

PO Act	*Petroleum (Onshore) Act 1991* (NSW)
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
POP	Petroleum operations plan (NSW)
PPL	Petroleum production licence (NSW)
RCE	Rehabilitation cost estimate (NSW)
REF	Review of environmental factors (NSW)
REMP	Rehabilitation and environmental management process (NSW)
RMP	Rehabilitation management plan (NSW)
SDPWO Act	*State Development and Public Works Organisation Act 1971* (Queensland)
SEAR	Secretary’s environmental assessment requirements (NSW)
SSD	State significant development (NSW)
Water Act	*Water Act 2007* (Commonwealth)
WOGCC	Wyoming Oil and Gas Conservation Commission

Glossary

Appraisal well	A petroleum well drilled to test the potential of one or more natural underground reservoirs for producing or storing petroleum.
Aquifer	An identifiable stratigraphic formation that has the potential to produce useful flows of water and may include formations where, due to hydraulic fracturing activity, a changed hydraulic conductivity allows such water flows.
Aquitard	A saturated geological unit that is less permeable than an aquifer and incapable of transmitting useful quantities of water. Aquitards often form a confining layer over an artesian aquifer.
Annulus	The gap between tubing and casing or between two casing strings or between the casing and the wellbore. The annulus between the tubing and casing is the primary path for producing gas from CSG wells.
Authority holder	The entity that holds a resource authority for PO Activities. Authorities include authority to prospect, petroleum licence, petroleum facilities licence, and petroleum pipeline licence. The authority allows the authority holder to conduct the authorised activities as well as setting out obligations.
Biodiversity	Variety of life forms including the different plants, animals and microorganisms, the genes they contain and the ecosystems they form. Biodiversity is usually considered at three levels: genetic, species and ecosystem.
Block	A sub-division of land used to define the location and size of petroleum and gas authorities in Queensland. A block is defined in the Petroleum and Gas (Production and Safety) Act as an area five minutes in latitude by five minutes in longitude.
Bore	Generally refers to a narrow, artificially constructed hole drilled to intercept, collect or store water from an aquifer, or to passively observe or collect groundwater information. Also known as a borehole, drill holes or piezometer.
Casing strings	Steel pipe used to line a well and support the rock. Casing extends to the surface and is sealed by a cement sheath between the casing and the rock. Often multiple casings are used to provide additional barriers between the formation and well.
Cement testing	Cement testing procedures are specified in codes of practices to assess the properties of cement used in the CSG industry such as slurry density and compressive strength.
Coal seam gas	A form of natural gas (generally 95 to 97% pure methane, CH_4) extracted from coal seams, typically at depths of 300 to 1000 m. Also called coal seam methane (CSM) or coalbed methane (CBM).
Development well	A petroleum well which produces or stores petroleum.
Decommissioning	The process to remove a well or other infrastructure from service.
De-watering	The lowering of static groundwater levels through complete extraction of all readily available groundwater, usually by means of pumping from one or several groundwater bores.
Drawdown	A lowering of the water table of an unconfined aquifer or of the potentiometric surface of a confined aquifer, typically caused by groundwater extraction.
Drill cuttings	Fragments of rock 'cut' by the drill bit during drilling.
Drilling fluids	Fluids that are pumped down the wellbore to lubricate the drill bit, carry rock cuttings back up to the surface, control pressure, stabilise the well and for other specific purposes. Also known as drilling muds.

Environmental authority	An environmental authority in Queensland issued by the administering authority under Chapter 5 of the *Environmental Protection Act 1994*.
Environmental impact statement	A document(s) describing a proposed development or activity and assessing the possible, probable, or certain effects of that proposed development on the environment and other potential environmental values. In Queensland, the requirements for an EIS are regulated by the *Environmental Protection Act 1994*. In NSW, the requirements for an EIS are regulated under the *Environmental Planning and Assessment Act 1979*.
Exploration well	A petroleum well that is drilled to test for the presence of petroleum or natural underground reservoirs suitable for storing petroleum, or to obtain stratigraphic information for the purpose of exploring for petroleum.
Flaring	Burning of gas that cannot be used commercially or economically piped for use elsewhere or gas that needs to be released for safety reasons. Associated flare pits dug into the earth contain fluids produced from flaring as well as produced water. See also venting.
Flowback water	The volume of fluid that is pumped back to the surface following hydraulic fracturing operations. It typically contains fracturing fluid, water used to flush the fracturing fluid out of the wellbore, and some formation water from geological formations surrounding the fracturing zone.
Formation water	Naturally occurring groundwater that is within the shale formation.
Fugitive emissions	In the natural gas industry, fugitive emissions are considered to include all greenhouse gas emissions from exploration, production, processing, transport and distribution of natural gas, except those from fuel combustion. Emissions from flaring of natural gas are also considered to be fugitive emissions.
Horizontal drilling	Drilling of well in a horizontal or near-horizontal plane, usually within the target formation. Requires the use of directional drilling techniques that allow the deviation of the well on to a desired trajectory. Horizontal wells typically penetrate a greater length of the reservoir than a vertical well, significantly improving production while minimising the surface footprint of drilling activities.
Hydraulic fracturing	Also known as ‘fracking’, ‘fraccing’ or ‘fracture simulation’, is one process by which hydrocarbon (oil and gas) bearing geological formations are ‘stimulated’ to enhance the flow of hydrocarbons and other fluids towards the well. In most cases hydraulic fracturing is undertaken where the permeability of the formation is initially insufficient to support sustained flow of gas. The hydraulic fracturing process involves the injection of fluids, proppant and additives under high pressure into a geological formation to create a conductive fracture. The fracture extends from the well into the production interval, creating a pathway through which gas is transported to the well.
Impact	The difference between what would happen as a result of activities and processes and what would happen without them. Impacts may be changes that occur to the natural environment, community or economy. Impacts can be a direct or indirect result of activities, or a cumulative result of multiple activities or processes.
Mix-bury-cover	A method for on-site disposal of solid waste from drilling activities where the material is mixed with subsoil, then buried and covered with topsoil. Details of the requirements to use this methodology vary across jurisdictions.
Openhole	An un-cased section of a well.
Packer	A device that can be run into a well with a small initial outside diameter and then expanded to seal the wellbore. Used to isolate zones within a well in applications such as multi-stage hydraulic fracturing.
Perforation	A channel through the casing and cement in a well to allow fluid to flow between the well and the reservoir (hydraulic fracturing fluids in to the reservoir or gas and oil in to the well). The most common method uses perforating guns equipped with shaped explosive charges that produce a jet.
Permeability	The measure of the ability of a rock, soil or sediment to yield or transmit a fluid. The magnitude of permeability depends largely on the porosity and the interconnectivity of pores and spaces in the ground.

Plug	A device or material placed within a well to prevent vertical movement of fluids. May be a mechanical device or cement.
Plugged and abandoned	A permanently closed well, with plugs inserted to isolate sensitive formations and aquifers and surface infrastructure removed.
Porosity	The proportion of the volume of rock consisting of pores, usually expressed as a percentage of the total rock or soil mass.
Produced gas	Gas brought to the surface via a well.
Produced water	Water brought to the surface via a well.
Production zone	The section from well from which fluids or gas are produced.
Reservoir	A geological formation with adequate porosity, fractures or joints that can store hydrocarbons.
Rotary mud drilling	A drilling method where the drill bit is rotated to cut the rock and a drilling mud (or drilling fluid) used to lubricate the drill bit and lift cuttings from the well.
State significant development	Development in NSW that is deemed to have State significance due to the size, economic value or potential impacts. All petroleum production developments in NSW are considered to be State significant development.
Tenement	An area of land held by an authority holder. May be an authority to prospect, a petroleum lease, a petroleum facilities lease or a petroleum pipeline lease.
Venting	Release to atmosphere of gas that cannot be used commercially or economically piped for use elsewhere or gas that needs to be released for safety reasons.
Well	A hole drilled into the earth from which petroleum or other fluids can be produced.
Wellhead	The surface infrastructure that controls pressure and access at the top of a well.
Well pad	The area that has been prepared to allow for a drilling rig to work.
Workover	The restoration or stimulation of a production well to restore, prolong or enhance the production of oil and/or gas.

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