Briefing Note

# Coal seam gas water storage ponds: managing risk

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## Key facts

- Natural gas in coal seams (coal seam gas, or CSG) is held in place by groundwater pressure.
- Pumping groundwater to the surface via wells relieves this pressure, allowing gas to flow and be collected. The "produced" water must be collected and stored before treatment and re-use or disposal.
- Storage ponds and tanks are designed to minimise the risk of leakage of the produced water to the environment, and prevent public access.
- Like all groundwater, produced water from coal seams contains varying levels of natural salts, minerals, and other geogenic material. Sectors other than the CSG industry also extract groundwater from coal seams for stock, domestic, urban and other uses.
- Government oversight and the industry's track record demonstrate that produced water, including water produced from hydraulically fractured wells, does not pose a significant risk to the public or environment under existing regulatory controls and standards.
- Some of the chemicals used for hydraulic fracturing are locked in the coal seam as fracturing takes place and do not return to surface. Those that do return tend to dissociate or breakdown such that only the daughter products are returned to surface, and these are highly diluted in the produced groundwater.
- There has been no systemic contamination of waterbodies from leaking ponds; no reported incidents of people swimming in CSG ponds; and no reported incidents of people drinking water from CSG ponds.

## Introduction

This case study focuses on the regulations and best industry practice for controlling and limiting leakages from water storage ponds, as well as the measures in place to prevent the public from drinking or swimming in these ponds.

It discusses how water storage ponds are designed and constructed, the relevant legislative controls and risk management systems in place to minimise risks to health and the environment, and illustrates how these work in practice.

This case study contributed to the National CSG Chemicals Risk Assessment by developing the conceptual and numerical site models used in exposure assessment, specifically in developing predicted exposure concentrations and residual risk ratings, which account for controls and their effectiveness.

## Background

Groundwater from coal seams has been used in Australia for a variety of purposes for many years. In Queensland's Walloons Coal Measures in, from which most CSG is produced, more than 2,000 non-petroleum industry bores extract almost 17 billion litres of water each year – predominantly for agriculture, stock and domestic uses.

In some areas, groundwater from coal seams is suitable for these uses without treatment. But, like all groundwater, water from coal seams contains various dissolved natural salts and minerals, and can be mildly salty or "brackish" to salty [1], [2]. The higher the concentrations of salts and minerals, the more likely it is that water would require desalination treatment or blending with fresher (less saline) water before it is suitable for agricultural and domestic uses.

Groundwater is also extracted by the petroleum industry in order to produce natural gas from coal seams as the gas is held in place by groundwater pressure. In some areas hydraulic fracturing is necessary to enable a more effective flow of gas. The fracturing process increases the productivity of the well and means fewer wells are needed in order to produce the same amount of gas.

There are specific regulatory requirements that apply to the management and storage of groundwater produced by the CSG industry, which is termed "produced water", and specific requirements for wells that have been hydraulically fractured. This regulation may vary in its detail from state to state but the overall objective is the same in all jurisdictions – to ensure that risk to the environment and human health is minimised and at acceptable levels.

It should also be noted that while the objectives of regulation and industry practice are similar, in practice there are a variety of project configurations and methods for managing water. This is because water production varies according to geology, and the most effective means for managing water can also vary from location to location.

For example, where water production is low, above or below-ground tanks may be used instead of water storage ponds, and project configurations may also involve produced water flowing directly to a water treatment plant.

Ponds are used for a number of different purposes in the industry, and they may therefore be built according to different standards. To illustrate, small ponds or tanks may be used in the short-term during the initial well construction and/or hydraulic fracturing process; larger ponds may be used to aggregate water from multiple wells, and a number of large ponds may be used to store water of different quality at water treatment facilities. The operational and regulatory requirements for each of these types of pond vary.

In all cases, the management of water produced by the CSG industry involves detailed assessment of a broad range of water management options with design tailored to each project.

## Controls and regulations around pond design and access

As noted, the specific regulation in place for CSG ponds varies on a state-by-state basis. However, regulation in the two states that host CSG production (Queensland and NSW) is consistent in that they specify engineering standards. Figure 1 below is based on the Queensland regulatory system and outlines each stage of design, approval and operation of CSG ponds.

**Figure 1. Summary of the Current Environmental Controls around Pond Design, Approval and Operation**


[a] In Queensland the design requirments include consideration of the following legislation, statutory approvals, guidelines and manuals [3], [4]:

- *Environmental Protection Act 1994*
- Activity based Environmental authorities and development approvals
- *Guideline: Structures which are dams or levees constructed as part of environmentally relevant activities (EM634)*
- *Manual for Assessing Hazard Consequence and Hydraulic Performance of Structures (EM635)*

[b] Designs are assessed for threats to human life and the environment and associated consequences. Based on the risk and consequence category each design is required to meet performance criteria.
[c] Authorisation is provided by the administering authority. In Queensland this is the Department of Environment and Heritage Protection and in NSW this is the Dam Safety Committee.
[d] Suitably Qualified and experienced designers are a key feature of approval and construction phases. For example in Queensland the construction is typically certified by a Registered Professional Engineer of Queensland.

If the CSG operator was in NSW, a very similar process would be used to design a pond, and the NSW Dam Safety Committee would review all design and construction certification reports alongside the government regulating bodies.

The key documents regulating pond construction are public documents and easily accessible, but are relatively complex as they relate to engineering construction. A detailed discussion of their contents is outside the scope of this case study.

However, these documents work together to establish a very high standard for the construction of ponds in the CSG industry, with engineering complexity increasing commensurate with the risk/consequence of failure. The effect of the regulation is that ponds constructed by the CSG industry are of a considerably higher standard than ponds containing water of the same or similar quality that may be used outside of the CSG industry.

For example, CSG ponds that hold water returned from wells that have been hydraulically fractured must be designed with a floor and sides of material that will ensure the contents are kept within the bounds of the containment system during the pond's operational life, and in some cases, a double lining system may be used. CSG ponds are often required to have a system that enables the detection of any leaks through either the floor or sides of the dam, and this further reduces the risk that leaks will impact soil or groundwater.

Seepage or groundwater monitoring bores may also be required in the vicinity of some dams as an additional protection measure.

The evidence is that these measures to manage and mitigate risk are working and there has been no reported systemic contamination of waterbodies from leaking produced water ponds.

**Figure 1. CSG ponds using geosynthetic liner system**

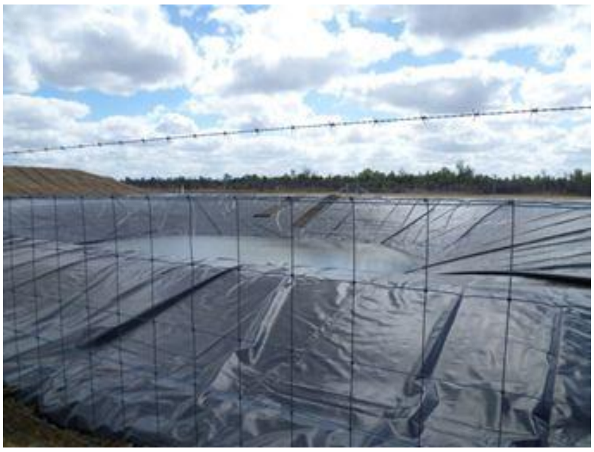
## Access control

Protection of wildlife and people from accidently or unlawfully entering the pond is another key requirement of water storage pond management. As well as human health and environmental protection objectives, there are clear operational reasons for restricting access to ponds, as ingress of wildlife could cause damage to the lining system and reduce its effectiveness.

Animal-proof fencing and security systems are therefore typically built around the pond exterior.

These fences are similar to tall security fencing systems and are intended to limit wildlife and non-authorised people from entering the site.

**Figure 3: CSG pond under construction with fence and liner**



## What would happen if someone swam in a pond containing CSG water?

Notwithstanding the above controls to restrict entry to the pond area, if a person was to gain access to a CSG pond, it is highly unlikely that there would be adverse health impacts.

Industry and government have assessed what would happen in a hypothetical, and very conservative (i.e. highly unlikely) exposure scenario whereby a child accesses and swims regularly in a water storage pond containing water from a hydraulically fractured well. [5]

The risk assessment assumed that the child was able to breach the access controls on a typical pond, and swim for 30 minutes (similar to lap swimming), swallowing 50 mL water of pond water during that time, for 20 days each year over a 10 year period. The assessment then examined scenarios where the pond water contained 20% produced water from a fractured well (mixed with other coal seam water), 80% water from a fractured well, or 100% water from a fractured well.

It should be noted that these are unrealistic assumptions. For example, water from fractured wells is not held in ponds for 10 years. It is also highly unlikely that a child would gain access, unnoticed, to a pond on a regular basis over such an extended period of time.

Nevertheless, the risk assessment results indicate that even this was to occur, the risk of adverse health effects is low or negligible.

## Water from coal seams and hydraulic fracturing

Approximately 20-40% of CSG wells are expected to require hydraulic fracturing over the long term [6]. However, to date just over 6% of the active CSG wells in Australia have employed the process[1].

The constituents of hydraulic fracturing fluids vary and depend on a number of factors, including local geology. While a total over 100 chemicals have been used at various times in Australia, relatively few chemicals (typically less than 10) are used in any given well.

Depending on the hydraulic fracturing fluid system used, chemicals would normally make up between 0.04% to 1.5% of the fracturing fluid by volume, the remainder being water and sand [6].

The chemicals used in hydraulic fracturing fluids, as with all industrial chemicals used in Australia, are listed on the Australian Inventory of Chemical Substances (AICS) or have been notified to the National Industrial Chemical Notification Assessment Scheme (NICNAS) [7].

CSG operators typically provide on their websites indicative lists of chemicals that may be used (e.g., [8], [9], [10]), and landholders are provided with details of the specific chemicals used on their property. The chemicals employed for hydraulic fracturing are also used for a variety of agricultural, pharmaceutical, food production, construction, domestic and other industrial purposes.

Just like for the water produced by the CSG industry, there are a number of methods used to manage hydraulic fracturing fluid, and the objective is the same - to ensure that risk to the environment and human health, including the petroleum industry workforce, are at minimal and acceptable levels.

Where hydraulic fracturing is used at locations remote from water treatment infrastructure, the fluid may be stored on site in lined ponds prior to being trucked to a separate facility, or the water may be piped for aggregation in larger ponds, or piped to a water treatment facility.

[1] http://www.appea.com.au/wp-content/uploads/2015/08/Q2-2015-Total-CSG-Industry-Data_Final.pdf

Once pumped into the coal seam, some of the chemicals used in hydraulic fracturing adsorb (bond at a molecular level) to the coal, and are not returned to the surface. Other chemicals dissociate (split into smaller ions, or molecules) or break down.

Monitoring of pond water by CSG operators is designed to detect the breakdown products of hydraulic fracturing fluids, or other indicator species, as the original chemicals will have been degraded and diluted to the point where they are largely undetectable.

In the context of a project producing gas, not all wells will be hydraulically stimulated, and wells that have been stimulated will be in varying stages of production. The result is that the chemicals used in hydraulic fracturing fluid, which are already diluted, are diluted further in the water contained in the coal seam and then diluted again with a much larger volume of water when the water from the network of production wells is aggregated for treatment. The dilution and degradation of the chemicals is one reason why the risk associated with storage of water produced from hydraulically fractured wells is so low.

Pond monitoring data collected by regulatory bodies in Australia shows the range of naturally occurring salts, minerals, and occasionally hydrocarbons (given that coal seams are hydrocarbon reservoirs) that can be present in produced waters [11]. These results are consistent with the findings of CSG operators at water storage ponds.

## Hypothetical water storage pond scenario

This section sets out an indicative hypothetical scenario of how water is managed within the CSG industry.

Under this scenario a production well is hydraulically fractured. The fracturing fluid is created by adding guar gum to thicken water so that it can carry more sand into the coal seam. Once the sand has been delivered into the coal seam, a “breaker” is used so that the fluid becomes less viscous (i.e., less thick) so that the fluid can be extracted, while the sand remains within the coal seam.

Other chemicals are used to prevent corrosion within the well bore, and to prevent bacterial growth (for example, in the guar gum).

The landholder and the government will be provided with details of the chemicals being used by the CSG operator.

Some of the chemicals used in the fracturing fluid will break down in the coal seam, some will chemically bond to the coal, and some will return to the surface when pumping commences after the fracturing is completed.

The chemicals used to produce the fracturing fluid typically make up 1% of the fluid by volume and are further diluted by the water in the coal seam.

The chemicals and breakdown products that remain underground are highly unlikely to move away from the initial injection point as water and gas is being extracted from the well, meaning that fluid and gas is moving towards, rather than away from, the well. This natural breakdown, adsorption, and dilution of the chemicals reduces their environmental and health risks to very low levels.

The water produced from the well is then piped to a water aggregation pond, which collects water produced from 100 wells. Forty percent of these other wells have been fractured, so the breakdown products of the fracture fluid are further diluted in the produced water stored in this pond. This additional dilution of the fracturing fluid means that by this stage of the process it will difficult to detect the chemicals and by-products of the fracturing process.

Notwithstanding that the returned fracturing fluid is now highly diluted, risk is reduced further by the design and construction of the storage pond. As discussed above, the storage pond will be fully-lined with a leak detection system, and access to the pond will be controlled.

As it is standard practice in the CSG industry to beneficially re-use produced water, the water in this scenario will be treated for further use. Water from the CSG industry is used to augment river flow, for agricultural use (e.g., crop irrigation, livestock watering), on-site re-use during CSG development or operational activities (e.g., dust control, drilling water, fire protection), industrial use by existing or new users of water and potable use (i.e., augmentation of drinking water supplies) [12]. In each case, there is a defined water quality standard set by government and water from the CSG industry is treated to meet or exceed the applicable standard.

## Effectiveness of the controls

The effectiveness of controls on CSG ponds can be assessed by looking at operational records for ponds. As CSG ponds are controlled facilities, operated under licences, CSG operators are required to report incidents relating to ponds. Based on company records and public records:

- No systemic contamination of water bodies, groundwater dependent ecosystems and water supply bores from leaking ponds has been reported.
- No incidents of people swimming in CSG ponds have been reported.
- No reported incidents of people drinking water from CSG ponds have been reported.

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