Gas and Oil in Unconventional Reservoirs in the South East of South Australia

Version 25/10/16

Government of South Australia
Department of State Development

KEY POINTS

1. There has been no fracture stimulation (commonly referred to as "fracking") to date in the South East of South Australia, nor has there been any proposal made to government for fracture stimulation in this region of the State.

2. The existing regulatory framework for the upstream petroleum industry in South Australia, administered by the Department of State Development (DSD) through the *Petroleum and Geothermal Energy Act, 2000* (PGE Act), continues to ensure the protection of natural, social and economic environments, including public health.

3. DSD regulates in close consultation and under existing administrative arrangements with the Department of Environment, Water and Natural Resources (DEWNR), the Environment Protection Authority (EPA), Primary Industries and Regions SA (PIRSA), SA Health and SafeWork SA.

4. Fracture stimulation will not be permitted in the South East of South Australia unless a proponent can demonstrate to DSD that:
   - All risks that will adversely affect other users of the land will be avoided; and
   - All concerns from potentially affected stakeholders (including land owners, enterprises, cultural heritage and native title groups, community groups, and other government departments) have been adequately addressed under the consultation requirements in the PGE Act.

5. The most recent (2014) exploration drilling for gas in unconventional reservoirs in the South East entailed low risk operations as demonstrated by conventional drilling that has occurred in the region over the last 100 years (to date over 100 petroleum wells have been drilled in the South Australian Otway Basin).

6. Shallow coal seam gas (CSG) is not the target of exploration drilling in the South East. The potential unconventional reservoirs in the South East are in shale that is greater than 2,500 metres below surface.

7. Fracture stimulation has been demonstrated to be safe and without harm to social, natural or economic environments in more than 800 wells in the Cooper Basin of South Australia.

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SOUTH AUSTRALIA

Government of South Australia
Department of State Development

FREQUENTLY ASKED QUESTIONS

Contents

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1. Has fracture stimulation (fracking) been proposed for the South East of South Australia?

No, at this point in time the potential for gas or oil in unconventional reservoirs (defined in Appendix 1) in the South East has yet to be determined. The exploration drilling undertaken by Beach Energy near Penola is seeking to determine whether any such resource is present. This was the first stage of the exploration phase and comprises of nothing more than drilling operations for conventional reservoirs which are low risk, as demonstrated by the thousands of such wells drilled here in South Australia including over 100 petroleum wells already drilled in the South East over the last century. For a map of oil and gas wells drilled in the South East since 1910 refer to Appendix 2 at the end of this information sheet.

The potential risks relating to the drilling and well operations stage of Beach Energy's exploration program have been adequately addressed through the environmental assessment and approval process under the *Petroleum and Geothermal Energy Act 2000* (the PGE Act) culminating in the publicly disclosed Environmental Impact Report (EIR) and approved Statement of Environmental Objectives (SEO). Included are hyperlinks to these documents on the petroleum pages of the State Government's websites[1].

2. Are aquifers protected?

The objectives of the PGE Act and its Regulations are to ensure that all risks to the health and safety of the community and to the environment are either completely avoided, or managed and reduced to a level that is as low as reasonably practicable and acceptable to the community. Furthermore, under the PGE Act it is an offence for any regulated activity, in this case drilling and well operations, to cause, amongst other things, contamination of underground aquifers.

In the event that a potential gas or oil resource is discovered through this current drilling program, the next stage may require the company to undertake fracture stimulation activities to determine whether the discovered resource can flow at commercial quantities. In the event that the company proposes fracture stimulation, under the PGE Act a comprehensive and extensive public consultation process will need to be undertaken demonstrating how all risks to aquifers are addressed to as low as reasonably practicable. Only at such time that community concerns have been adequately addressed and all significant risks are effectively managed to protect: (1) the natural environment (including the precious water resources of this region); (2) social environments; and (3) enterprises that are also land users – does the government then consider granting approval. Again, as with drilling and well operations, it is an offence for any such activity, including fracture, stimulation to cause aquifer contamination and adversely impact on land owners.

The following extract from the Beach Energy approved SEO for the exploration in shale and tight gas in the Cooper Basin[2] illustrates typical SEO provisions for groundwater protection

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[1] Beach Energy Drilling, Completion and Initial Production Testing - EIR
http://www.pir.sa.gov.au/__data/assets/pdf_file/0015/214053/A397B-Otway_Basin_Drilling_EIR-Rev2.pdf
Beach Energy Drilling, Completion and Initial Production Testing - SEO
http://www.pir.sa.gov.au/__data/assets/pdf_file/0016/214054/A397B-Otway_Basin_Drilling_SEO-Rev2.pdf
For general information regarding petroleum – go to:
http://www.petroleum.statedevelopment.sa.gov.au/home

[2] Beach Energy Fracture Stimulation in the Nappamerri Trough, Cooper Basin - SEO
http://www.petroleum.statedevelopment.sa.gov.au/__data/assets/pdf_file/0019/175051/Cooper_Basin_Shale_Gas_Fracture_Stimulation_SEO-Rev1.pdf

from drilling and fracture stimulation operations in accordance with the PGE Act. In this case, the two clear regulatory objectives are:

- Avoiding aquifer contamination (objective 1); and
- Avoiding impacts on other water users (objective 2).

Table 1

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved
1. Avoid aquifer contamination.	No undesired flow between geological units or to surface. No contamination of aquifers as a result of fracture stimulation operations.	<u>Well Integrity</u> Casing and wellhead designed to meet pressure, temperature, operational stresses and loads. Well pressure tested prior to fracture stimulation. Monitoring programs implemented (e.g. through well logs, pressure measurements, casing integrity measurements and corrosion monitoring programs) to assess condition of casing and cross-flow behind casing. <u>Fracture Stimulation Planning and Monitoring</u> Assessment of geological and geomechanical settings undertaken during design of fracture stimulation treatments to avoid growth into undesired strata. Trip systems installed to shut off stimulation pumping units if pre-set operational maximum pressure is reached. Injection pressures monitored and compared to expected fracture initiation pressure. If initiation pressure is significantly lower, injection is stopped and casing integrity is assessed. Investigation undertaken if unexpected water flows occur during production testing, to determine source (e.g. may indicate communication with aquifer). Microseismic monitoring to be used to monitor height growth, if required, due to thinning of geological strata or evidence of unsuitable geomechanical conditions.
2. Minimise impacts of groundwater use.	No reasonable stakeholder complaints left unresolved. No impact on groundwater dependent ecosystems resulting from extraction of groundwater.	Potential impacts to existing bores assessed where new water bores are to be drilled within 5 kilometres of existing water bores. Options to access deeper aquifer sands and to undertake monitoring of existing bores (where applicable) investigated to confirm that water extraction does not impact adversely on existing users. Water extraction for fracture stimulation in accordance with licensing and water allocation plan where applicable. Options for alternative water supplies investigated / used where feasible (e.g. produced formation water, recycling, reuse). Extraction of large volumes of water from aquifers that provide base-flow to nearby waterholes (e.g. aquifers in sandy sequences underlying and adjacent to the Cooper Creek) avoided. For water bores proposed in close proximity to waterholes - location, depth and aquifer properties assessed and, where necessary, deeper intervals targeted or water wells relocated (where appropriate). Requirement for monitoring bore near the waterhole addressed.

It is important to know that shallow aquifers that are essential to people and valuable enterprises in the South East are separated from the deep gas resources by thousands of metres of sealing rock, which prevents natural upwards migration of fluids and gases.

Prior to any well operations being undertaken such as fracture stimulation, appropriate baseline studies must be undertaken. As part of these baseline studies the existing overall health of the environment needs to be evaluated. In relation to the South East region, the current widespread impacts on the shallow unconfined aquifers (Gambier Limestone) from

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longstanding industries and poor agricultural practices[3] will need to be identified and accounted for.

Furthermore, in the Otway Basin, methane gas present in shallow aquifers is a natural occurrence as was found from government sampling results from water bores in the region back in 1993[4]. In January 1993, 15 water bores were sampled in the South East for headspace gas analysis of which 7 provided sufficient hydrocarbons for compositional analysis. Methane values ranged from 25% to 92% of the total gas for these bores with nitrogen and oxygen accounting for the remainder of the gas with varying levels of carbon dioxide. Six samples taken from the 7 bores were analysed for stable carbon isotopic composition for methane and carbon dioxide to provide an estimate of the ratio of biogenic to thermogenic gas. With the exception of one sample, all gases were of bacterial origin although associated CO_2 was clearly thermogenic, possibly derived from a volcanic source.

Therefore in the case of the South East, in order to satisfy Objective 1 above, ensuring protection of the surface aquifers entails protection from both potential cross-flow from deep hydrocarbon reservoirs and any potential cross-flow between the polluted unconfined aquifer and the more pristine deeper confined Dilwyn aquifer.

3. How does the activity in the South East differ to Coal Seam Gas (CSG)?

Unconventional reservoirs in Queensland and NSW are all related to shallow coal seam gas (CSG). In South Australia however, there are currently no industry project proposals for developing shallow CSG. Shallow CSG is very different to the deep gas resources that are being developed in South Australia and poses different potential risks. In general, shallow CSG resources may be near shallow, multiple use water resources generally at depths less than 1,000 metres below surface, while deep gas in South Australia includes targets generally at depths greater than 2,000 metres below surface. The shallow potable aquifers of the Gambier Limestone and Dilwyn Formation in the South East of South Australia are generally at depths no more than 500 metres below surface.

In addition, fewer wells and pipelines are required to produce from high pressure, deep gas resources, compared to requirements to produce from low pressure, shallow CSG. Multiple wells can be drilled from a single pad into a deep gas resource, greatly reducing surface footprint.

[3] The South Australian Environment Protection Authority (EPA) state on their website that "*Groundwater contamination of the unconfined aquifer is the result of either point source contamination (e.g. spills from copper-chrome-arsenate wood preservation industries) or diffuse source contamination. Point source contamination is due to the historical disposal of wastes into the aquifer by industries such as dairying, timber mills, gasworks, cheese factories, abattoirs and septic disposa*l. *The Environment Protection Act 1993 now prohibits disposal of waste into the aquifer. Inappropriate pesticide use has resulted in groundwater contamination, to the extent that organochlorine and triazine pesticides have been detected in groundwater in parts of the region. Diffuse source contamination of the unconfined aquifer is due to agricultural activity and forestry. Diffuse nitrate pollution has had the largest effect on the aquifer with increasing nitrate levels being observed in groundwater south of Mount Gambier and in the Coonawarra area. Pesticides have also been detected in limited testing of groundwater in the lower South East.*": http://www.epa.sa.gov.au/environmental_info/water_quality/programs/south_east_groundwater

For the most recent EPA groundwater monitoring report for the South East see: http://www.epa.sa.gov.au/reports_water/se_creeks-ecosystem-2014

[4] https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/RB9500017.pdf

4. What legislation is all gas and oil development regulated under?

In South Australia, all oil and gas exploration and production activities are regulated under the *Petroleum and Geothermal Energy Act 2000* (PGE Act) and associated Regulations. This Act and its Regulations can be readily accessed through the South Australian legislation website[5].

All activities regulated under the PGE Act are also subject to the provisions of other state environmental regulation such as the *National Parks and Wildlife Act 1972*; the *Natural Resources Management (NRM) Act 2004*; the *Work, Health and Safety Act 2012*; and the *Environment Protection Act 1993*. This in turn creates another layer of protection in addition to the best practice regulatory regime under the PGE Act. The PGE Act forms the one window to government for the industry whereby, through the SEO as a regulatory instrument under the Act, the requirements of other relevant pieces of legislation are incorporated into the Department of State Development's Energy Resources Division (DSD-ERD) approval and compliance monitoring processes.

South Australia's petroleum exploration, development, production, transport and processing in both the Cooper Basin (in the Far North) and the Otway Basin (in the South East) of the State have for decades been managed in ways that reduce risks to as low as reasonably practicable, without any significant impacts on social, natural and economic environments. This has established the environmentally sustainable development credentials of the upstream petroleum industry in the state.

5. Is fracture stimulation new to South Australia?

Fracture stimulation has been safely used in wells drilled in both conventional and unconventional reservoirs in South Australia since 1969, regulated under the PGE Act and its predecessor – the *Petroleum Act 1940*. To date over 800 wells have been fracture stimulated in the deep sandstone reservoirs of the Cooper Basin, South Australia with no evidence of adverse impacts on aquifers within the Great Artesian Basin and other shallower aquifers.

6. How important is well and cement integrity?

As detailed under question 2, the containment of fluid and pressure during well operations is critical for the protection of groundwater and the achievement of SEO objectives. Well integrity plays a significant role in ensuring pressure and fluid containment during well operations, including fracture stimulation activities, and industry standards are followed to ensure fracture stimulation fluid and any oil or gas production is contained within the reservoir rock and well bore.

The Information Paper[6] on Abandoned wells from the NSW Chief Scientist's Independent Review of Coal Seam Gas Activities in NSW states that:

"Cement is a critical component of well construction and thus cementing is a fully designed and engineered process. Cement is used in casing at the time of well construction, in addition

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[5] www.legislation.sa.gov.au

[6] NSW Chief Scientist and Engineer, Independent Review of Coal Seam Gas Activities in NSW, Information Paper: Abandoned wells, September 2014, available at http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0009/56925/141002-Final-Abandoned-Well-report.pdf.

to plugging at the time of well abandonment, and less commonly to address production or perforation issues. Cement used for plugging has the purpose of providing zonal isolation, preventing fluid from flowing within the well. Cementing a well casing has two main purposes: to provide zonal isolation between formations and to provide structural support to the well. According to the API, "cement is fundamental in maintaining integrity throughout the life of the well".[7]

"Cementing practice and design has decades of research to underpin it. Special formulations and additives are available to customise cement to individual well conditions, including increased resistance to gas migration, naturally occurring chemical ions, low pH environments, carbon dioxide (CO_2), high temperatures, sulphate, and mineral acids.[8] *Designs may call for using different cements for casing than for plugging a well. Poor cement jobs, which may result in well integrity failure and potential leaks, are influenced by three main problems: failure to bring the cement top high enough, failure to surround the casing completely with cement, and gas migration in the cement during cement setting. All of these problems can be mitigated through proper cement design and competent execution. "Cement is a strong, durable, very long-lasting barrier as long as it is mixed and placed properly".*[9]*"*

Wells are designed to have layers of steel casing and engineered cement that form a continuous barrier between the well and surrounding rock. Casing and cement are pressure tested for leak-tightness prior to taking further steps in well construction. Cement integrity evaluation tools are used to assess the cement bond to confirm long term integrity of the well construction. This process the subject of continuous innovation by industry, is heavily regulated by DSD-ERD and requires that operators adhere to the highest well design standards, including ongoing monitoring of the integrity of each barrier (casing strings) within the well bore. The requirements of DSD-ERD are consistent with and in many cases exceed globally recognised best industry practice[10].

The importance of well integrity as a barrier for containment is highlighted by one study[11] that assessed water samples from drinking water bores overlying the Marcellus and Barnett shales in the US. While most samples were found to be gas-rich from natural processes, there were cases where fugitive gas contamination was identified due to an increase in gas contamination over time. Where fugitive gas contamination occurred it was found that leakage was due to poor well integrity (i.e. issues with casing or cement). The data in the study rules out that fracture stimulation or horizontal drilling has created a conduit to connect the deep shale formations to surface aquifers.

[7] API. (2009). *Hydraulic fracturing operations – well construction and integrity guidelines. API Guidance Document HF 1:* American Petroleum Institute Publishing. Retrieved from http://www.api.org/policy-and-issues/policyitems/hf/api_hf1_hydraulic_fracturing_operations.aspx.

[8] King, George. (2012). *Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells.* Paper presented at the SPE Hydraulic Fracturing Technology Conference.

[9] Ibid.

[10] Guideline for world recognized best practice for well construction and integrity management http://www.shalegas.energy.gov/resources/HF1.pdf

[11] Darrah, T. H., Vengosh, A., Jackson, R. B., Warner, N. R., Poreda, R. J., Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales, PNAS 2014 http://www.pnas.org/content/early/2014/09/12/1322107111

Furthermore, the New York State Department of Environmental Conservation in their draft Environmental Impact Statement[12] for horizontal drilling and fracture stimulation demonstrates through their own research that "*no significant adverse impact to water resources is likely to occur due to underground vertical migration of fracturing fluids through the shale formations.*"

7. Is there any risk of casing and/or cement failure?

Like most life experiences there is no such thing as zero risk. For example - our use of motor vehicles is made as safe as practical, to meet community expectations for net outcomes. While *"the probability of well failure is low for a single well if it is designed, constructed and abandoned according to best practice",*[13] throughout the history of well construction and operations, there have been documented failures of casing and cement behind casing. However, in all documented cases the failures have mainly been attributed to historic well construction practices that have led to poor coverage of cement (preventable mishaps) within the annulus or annuli between various casing strings. Where industry best practice is applied, "*worldwide industry experience in both conventional and unconventional petroleum resources suggests that well integrity failures are low for both active and abandoned wells*".[14]

As demonstrated in Table 2 below, in a case of over 200,000 wells in the United States the frequency and likelihood of casing failures is extremely low compared to other risks faced by society in general.

Table 2 - Likelihood of well casing failure compared to general risks faced by society

Risk	Life time odds
Heart attack[2]	$2x10^{-1}$ (1 in 5)
Car accident leading to serious injury or death[1]	$1x10^{-2}$ to $7x10^{-3}$ (1 in 10)
Casing failure leading to aquifer contamination[3]	$4x10^{-5}$ (1 in 25,000)
Airplane accidents[1]	$2x10^{-5}$ (1 in 50,000)
Shark Attack[2]	$1.6x10^{-5}$ (1 in 60,000)

[1] Bandolier: Evidence based thinking about health care.
[2] 31st October 2007: New York Times Health and Science
[3] October 2013: Environmental Risk Arising From Well Construction Failure: Difference Between Barrier and Well Failure, and Estimates of Failure Frequency Across Common Well Types, Locations and Well Age: SPE 166142, Table 8. p.13

It has been demonstrated in the petroleum industry that, where deficient cement coverage in wells has been detected behind casing, with and without any risks of cross-flow (between

[12] New York State Department of Environmental Conservation – Preliminary Revised Draft, Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program – September 30, 2009 – http://www.dec.ny.gov/data/dmn/ogprdsgeisfull.pdf
[13] Royal Society, & Royal Academy of Engineering. (2012). Shale gas extraction in the UK: a review of hydraulic fracturing. London: The Royal Society and the Royal Academy of Engineering.
[14] Davies, S. Almond, R. S. Ward, R. B. Jackson, C. Adams, F. Worrall, L. G. Herringshaw, J. G. Gluyas. (2014). Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. *Marine and Petroleum Geology, 56*, 239-254.

rocks at different levels), remedial action can be taken effectively. There have been cases where remedial work known as cement squeezing has successfully isolated the zones behind exposed casing. In the very rare cases where hydrocarbon has entered aquifers, decontamination can be successfully achieved.

The high well failure rates often quoted by Tony Ingraffea in the order of 40% to 60% do not represent a failure that has led to a loss of containment. The main source of data that Tony Ingraffea has referenced as examples of high well failure rates is from an article[15] in Oilfield Review that analyses instances known as sustained casing pressure (SCP). SCP does not mean a well has lost containment. SCP only refers to the build-up of pressure in one or more annuli within the well and is detected through ongoing pressure monitoring.

In South Australia, licensees are required to report well casing pressure monitoring to DSD-ERD on a regular basis, demonstrating the integrity of all casing strings including the internal tubing through which gas is produced. Licensees also must demonstrate the risk level of any wells found to have abnormal pressure readings and submit activity notifications for remedial action that may be required on wells with an unacceptable risk rating.

8. What monitoring is undertaken to prove well and cement integrity?

Through the SEO process, fit for purpose monitoring requirements are imposed on licensees to demonstrate compliance with the regulatory requirements. In terms of well integrity, to ensure protection of potable aquifers and hence other land users' access to that water, the SEO requires that background sampling and analysis of aquifers are undertaken before drilling activities commence. Regular ongoing sampling is then undertaken at appropriate intervals to demonstrate that no contamination is occurring.

Furthermore, prior to the completion of the well, the SEO requires the licensee to demonstrate that cement integrity behind the casing is adequate and meets relevant industry requirements. This is most often achieved through the use of sonic cement bond log tools being run in the hole which measure the cement coverage behind the casing and more importantly the integrity of the cement bond. In addition, a relentless pursuit of evermore efficient and effective technologies and methodologies is evidenced within the upstream petroleum sector. Edible fracture stimulation fluids and cements that can self-heal behind-pipe potential for cross-flow are two such recent innovations

9. How long do abandoned wells last for?

The Information Paper on Abandoned wells from the NSW Chief Scientist's Independent Review of Coal Seam Gas Activities in NSW notes the following about abandoned wells:[16]

"While little data exists about the long-term durability (100 – 1000 years) of abandoned petroleum wells, other studies have been undertaken into the degradation of comparable wells that suggest sound integrity over a 1,000+ year period. Yamaguchi (et al) (2013) investigated the long-term corrosion behaviour of cement in abandoned wells under CO_2 geological storage conditions by simulating the geochemical reactions between the cement

[15] https://www.slb.com/~/media/Files/resources/oilfield_review/ors03/aut03/p62_76.ashx

[16] NSW Chief Scientist and Engineer, Independent Review of Coal Seam Gas Activities in NSW, Information Paper: Abandoned wells, September 2014, available at http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0009/56925/141002-Final-Abandoned-Well-report.pdf.

seals over a simulated period of 1,000 years.[17] *While alteration of the cement seals was found after a period of time, the alteration length after 1,000 years was approximately one meter, leading to the conclusion that cement would be able to isolate* CO_2 *and upper aquifers over the long-term.*

"Cement plug integrity in CO_2 *subsurface storage was also looked at by Van der Kuip, Benefictus, Wildgust & Aiken (2011). Using estimates for degradation after 10,000 years they likewise came to similar conclusions stating that "mechanical integrity of cement plugs and the quality of its placement probably is of more significance than chemical degradation of properly placed abandonment plugs".*[18]

"It is important to note in the foregoing, that the literature on corrosion and cement degradation considers CO_2 *stored at high pressure to be more aggressive than methane*[19]*. Therefore, a conclusion can be drawn that if wells are properly designed, installed and maintained, the risk of long-term leakage from CSG wells from both the casing and cement can be considered to be minimal, although there is scope for additional research specifically to assess the impact of abandoned CSG wells over extended timeframes."*

Although CSG is not the target of unconventional exploration in the South East, the same conclusion can be drawn that the long-term abandonment of unconventional wells would be in a downhole environment that is of lower pressure (as gas has been depleted from the unconventional reservoir) and less aggressive (methane is not as reactive as CO_2).

10. Are land and surface waters protected from contamination?

As with groundwater contamination, the mitigation of any potential contamination of land and soil from spills, whether the contaminant is hydrocarbon or produced water, is explicitly addressed through the SEO. Table 3 below provides an extract from a standard SEO and illustrates typical provisions for protecting land and surface waters in accordance with the PGE Act.

11. What volume of water is required?

PGE Act Petroleum Exploration or Production Licence holders are required to provide for their water requirements within the framework of the NRM Act, like all other water users. This legislation requires that any water use is undertaken in accordance with principles set out in the relevant Regional Natural Resource Management (NRM) Plan and the relevant Water Allocation Plan (WAP).

A WAP is a legal document that sets out the rules for managing, taking and using prescribed water. WAPs seek to provide security and equity between water users while balancing the capacity of the region's water resources and the needs of the environment.

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[17] Yamaguchi, K, Shimoda, S, Kato, H , Stenhouse, MJ, Zhou, W, Papafotiou, A, Yamashita, Y, Miyashiro, K, & Saito, S. (2013). The long-term corrosion behaviour of abandoned wells under CO_2 geological storage conditions: (3) Assessment of long-term (1,000- year) performance of abandoned wells for geological CO_2 storage Energy Procedia,

[18] Van der Kuip, M D C, Benedictus, T, Wildgust, N, & Aiken, T. (2011). High-level integrity assessment of abandoned wells. Energy Procedia, 4, 5320-5326.

[19] Popoola, L K, Grema, A S, Latinwo, G K, Gutti, B, & Balogun, A S. (2013). Corrosion problems during oil and gas production and its mitigation. International Journal of Industrial Chemistry, 4(35).

The Coonawarra is within the Lower Limestone Coast Prescribed Wells Area. The Lower Limestone Coast WAP[20] was approved by the Hon. Ian Hunter MLC, Minister for Sustainability, Environment and Conservation on 26 November 2013.

Volumes of water required to be taken for petroleum exploration are minimal and will not impact on the availability of water for other users. An exploration well has a 'one-off' requirement of 1 to 2 megalitres of water in total, depending on the depth of the drill. The water is used mostly for making up fluid (mud) used in the well drilling and cement used in the well casing process. For these reasons, the taking of water for petroleum exploration anywhere in the State is authorised without a licence, under section 128 of the NRM Act. In the case of fracture stimulation activities, about 1 megalitre per stimulation stage (i.e. fracture stimulated zone) is required. Typically in Australia, a single, vertical exploration well program for fracture stimulation entails an average of 4 stages (thus, 4 megalitres of water). More stages are typical in horizontal production wells. For example, a US horizontal shale well on average will use ~15 megalitres of water[21].

For the purposes of petroleum production, the Lower Limestone Coast WAP, (Principles 215-217, p137) states that co-produced water (water that is taken from the target formation as a by-product of petroleum extraction) can be allocated above the sustainable extraction limit.

[20] For further information visit:
http://www.senrm.sa.gov.au/Water/TheLowerLimestoneCoastWAP/AdoptedLLCWAPinformation.aspx
[21] Engineering Energy: Unconventional Gas Production, Final Report: ACOLA, pg. 58
http://acola.org.au/PDF/SAF06FINAL/Final%20Report%20Engineering%20Energy%20June%202013.pdf

Table 3

- o Avoiding contamination of surface water and shallow groundwater (Objective 3); and
- o Avoiding contamination to soil (Objective 4).

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved
3. Avoid contamination of surface water and shallow groundwater.	No leaks / spills outside of areas designed to contain them. No overflow or escape of flow-back fluids from temporary ponds. No water (surface or groundwater) contamination as a result of fracture stimulation operations.	Pond Location: Well sites and pond locations selected to ensure that consequences of a potential pond failure are minimised (e.g. ponds not located in close proximity to the Cooper Creek channel or other significant watercourses such that failure would result in direct release to these watercourses). Well leases located on higher ground as far as practicable. Where well leases have potential for infrequent flooding, measures undertaken to ensure ponds are not vulnerable to flooding (e.g. ponds on higher ground, construction of higher pond walls, removal of flow-back fluids off-site either during testing or at completion of operations). Pond Integrity: Flow-back fluids securely contained in ponds lined with UV stabilised material. Ponds with above-ground walls / bunds to prevent surface runoff into ponds. Quality control on pond construction and liner installation to minimise risk of compromised liner integrity. Maximum pond fill level not exceeded (allow for rain events and wave effects). Water balance method used for leak detection (incorporating inflow, evaporation, fluid levels and measurement uncertainty). Pond operation monitored (e.g. pond wall integrity) and repair / remediation and / or decommissioning / rehabilitation undertaken where appropriate (e.g. if leak evident, recover excess fluid where practicable, repair or decommission / rehabilitate pond). Monitoring: Program established to monitor shallow aquifers that are accessed by regional stakeholders. Monitoring of Cooper Creek levels at gauging stations upstream of the Nappamerri Trough (e.g. Durham Downs, Windorah, Stonehenge and Blackall) to enable implementation of flood response procedures if flood fronts are identified that are likely to impact on well operability and pond integrity.
4. Minimise disturbance and avoid contamination to soil.	No overflow or escape of fluids from temporary ponds. No soil contamination as a result of fracture stimulation and flow-back operations. Fuel and Chemical Storage and Handling No spills / leaks outside of areas designed to contain them. Level of hydrocarbon and other contaminants continually decreasing for in situ remediation of spills. Also refer to Objective 12 for remediation of contaminated sites.	Routine inspections of storage ponds, general lease area and equipment. Flow-back lines from wellhead rated and pressure tested to appropriate pressure and emergency shut-down system installed on well-head. Spills / leaks cleaned up and remediated. Flare pit cleaned up and remediated as required following completion of operations. Refer to Objective 3 for criteria related to pond integrity. Refer to Objective 9 for pressure integrity of fracture stimulation pumping equipment. Fuel and Chemical Storage and Handling: All fuel, oil and chemical storage, handling and secondary containment in accordance with the appropriate standards and guidelines e.g. Australian Standard AS 1940, EPA guideline *080/07Bunding and Spill Management* and product MSDSs. Refuelling undertaken with appropriate drip capture systems. Spill response equipment maintained on site. Spills or leaks immediately reported and clean up actions initiated. Spill Response / Contingency Planning: Results of emergency response procedures carried out in accordance with Regulation 31 show that emergency response plan in place in the event of a spill is adequate and any necessary remedial action needed to the plan is undertaken promptly. Personnel trained in correct procedures for use of materials, including refuelling and clean-up procedures.

12. What chemicals are used in fracture stimulation?

Any chemicals used in fracture stimulation are at very low concentration by volume in the hydraulic fracturing water (average 0.1 to 0.5%). Table 1 includes other common uses for the chemicals used in fracture stimulation fluids, but this should not be taken to mean that all of these chemicals are perfectly safe without proper storage and handling in a concentrated form. A comprehensive on-site chemical safety management plan (addressing transport, storage, use and waste) is required to be approved by the regulators before any proposed fracture stimulation would be approved to prevent impacts to workers, the public and the environment. This would include consideration of all chemicals to be used and their potential cumulative toxicity, as for the use of potentially hazardous substances by any industry.

Table 4 - Typical chemicals found in fracture stimulation fluids – *source: US Department of Energy, Modern Shale Gas Development is the United States: A Primer (p63)*

Additive Type	Main Compound(s)	Purpose	Common Use of Main Compound
Diluted Acid (15%)	Hydrochloric acid or muriatic acid	Help dissolve minerals and initiate cracks in the rock	Swimming pool chemical and cleaner
Biocide	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive byproducts	Disinfectant; sterilize medical and dental equipment
Breaker	Ammonium persulfate	Allows a delayed break down of the gel polymer chains	Bleaching agent in detergent and hair cosmetics, manufacture of household plastics
Corrosion inhibitor	N, n-dimethyl formamide	Prevents the corrosion of the pipe	Used in pharmaceuticals, Acrylic fibers, plastics
Crosslinker	Borate salts	Maintains fluid viscosity as temperature increases	Laundry detergents, hand soaps, and cosmetics
Friction reducer	Polyacrylamide	Minimizes friction between the fluid and the pipe	Water treatment, soil conditioner
	Mineral oil		Make up remover, laxatives, candy
Gel	Guar gum or hydroxyethyl	Thickens the water in order to suspend the sand	Cosmetics, toothpaste, sauces, baked goods, ice cream
Iron control	Citric acid	Prevents precipitation of metal oxides	Food additive, flavouring in food and beverages; lemon juice ~7% Citric Acid
KCl	Potassium chloride	Creates a brine carrier fluid	Low sodium table salt substitute
Oxygen Scavenger	Ammonium bisulfite	Removes oxygen from the water to protect the pipe from corrosion	Cosmetics, food and beverage processing, water treatment
pH Adjusting Agent	Sodium or potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Washing soda, detergents, soap, water softener, glass and ceramics
Proppant	Silica, quartz sand	Allows the fractures to remain open so the gas can escape	Drinking water filtration, play sand, concrete, brick mortar
Scale inhibitor	Ethylene glycol	Prevents scale deposits in the pipe	Automotive antifreeze, household cleansers, and de-icing agent
Surfactant	Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, and hair color

In all cases with good well design, construction and maintenance, the risk of significant (i.e. has an impact on landowners) crossflow between the stimulated reservoir and aquifers can be avoided. In addition, with good work practices all chemicals will also be contained at the surface and disposed of appropriately.

13. How are health impacts addressed?

The objectives of the PGE Act and its Regulations are to ensure that all risks to the health and safety of the community and to the environment are either completely avoided, or managed and reduced to a level that is as low as reasonably practicable and acceptable to the community. Potential health impacts to both employees and adjacent communities must be managed effectively and the SEO process seeks to adequately address such risks prior to any approval being granted. This has been a topic of great debate internationally, and one study[22] recently released in the UK by the Public Health Department concluded that any such risks are manageable through proven well construction and fracture stimulation design and appropriate monitoring. The review was commissioned in 2012 in response to public concern regarding fracking and the project was conducted by Public Health England's Centre for Radiation, Chemical and Environmental Hazards. The review focused on the public health impact of direct emissions of chemicals and radioactive material from the extraction of shale gas and was released as a draft for comment in October 2013. Concerns are generally consistent with those raised regularly in the debate on unconventional reservoir development:

1. Pollution of drinking water supplies
2. Air pollution
3. Community disruption during shale gas production
4. Supply and safe storage of chemicals used in fracking
5. Cumulative adverse impact on communities

   Additional concerns identified in the UK report were:

6. Radionuclides dissolved in water, including NORM and radon, which can be released underground from rocks and become dissolved in the fracking fluid
7. Radioactive tracers if they are used to monitor the fracking process (IAEA 2003)
8. Contamination arising from waste water

The UK report examines these factors and concludes that all can be managed to as low as reasonably practicable through robust and effective regulation, of the kind we have in South Australia. The following extract[23] from the Executive Summary of the report is of particular relevance:

"The currently available evidence indicates that the potential risks to public health from exposure to the emissions associated with shale gas extraction are low if the operations are properly run and regulated. Most evidence suggests that contamination of groundwater, if it occurs, is most likely to be caused by leakage through the vertical borehole. Contamination of groundwater from the underground fracking process itself (i.e. the fracturing of the shale) is unlikely. However, surface spills, of fracking fluids or waste water, may affect groundwater; and emissions to air also have the potential to impact on health.

Where potential risks have been identified in the literature, the reported problems are typically a result of operational failure and a poor regulatory environment. Therefore, good on-site management and appropriate regulation of all aspects including exploratory drilling, gas capture, use and storage of fracking fluid, and post operations decommissioning are essential to minimise the risk to the environment and public health."

Furthermore, a recent report from the Nova Scotia Independent Panel on Hydraulic Fracturing states that *"there is currently no evidence of catastrophic threats to public health in the short-to-medium term that would necessitate the banning of hydraulic fracturing outright.* [24]*"*

The following extract from a standard SEO illustrates typical provisions for addressing health and safety risks in accordance with the PGE Act.

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[22] Report available at https://www.gov.uk/government/news/shale-gas-extraction-emissions-are-a-low-risk-to-public-health

[23] Refer Executive Summary, page iv

[24] Wheeler, David, et al. (2014). Report of the Nova Scotia Independent Review Panel on Hydraulic Fracturing - http://energy.novascotia.ca/sites/default/files/Report%20of%20the%20Nova%20Scotia%20Independent%20Panel%20on%20Hydraulic%20Fracturing.pdf

Table 5

Environmental Objectives	Assessment Criteria	Guide to How Objectives Can be Achieved
8. Minimise air pollution and greenhouse gas emissions.	No reasonable stakeholder complaint left unresolved. No unplanned gas releases. Well production diverted to flare as soon as practicable. Well testing curtailed when test objectives are satisfied.	Equipment operated and maintained in accordance with manufacturer specifications. Well flow-back diverted to separator as soon as practicable to minimise gas not being recovered and sent to flare. Flaring during production testing kept to minimum length of time necessary to establish resource and production parameters. Options to connect to gathering network investigated once initial testing is complete and longer term testing is required for reserve definition. Dust control measures (e.g. water spraying) implemented if dust generation becomes a problem e.g. near sensitive sites. Appropriate emergency response procedures are in place for the case of a gas leak. Monitoring of well parameters during testing operations to check for fugitive emissions at the wellbore.
9. Minimise risks to the safety of the public, employees and other third parties.	Reasonable measures implemented to ensure no injuries or health risks as a result of the activities.	<u>Fracture Stimulation Activity</u> All employees and contractor personnel complete a safety induction prior to commencement of work in the field. All employees and contractor personnel undertake a regular refresher induction. Signage in place to warn third parties of access restrictions to operational areas, with particular warnings when potentially dangerous operations are being undertaken. Contractor equipment has valid certifications, is properly secured and pressure tested prior to commencement of stimulation at each site and trip systems are installed to shut off stimulation pumping units if pre-set operational maximum pressure is reached. All appropriate PPE (personnel protective equipment) is issued and available as required in accordance with company operating requirements and applicable standards. Monitoring undertaken to confirm / ensure that levels of radioactivity are within acceptable limits. Safety management plans prepared as required for the activity. Permit to work systems in place for staff and contractors as required. Effective Emergency Response Plan (ERP) and procedures are in place. Traffic and journey management procedures followed. <u>General Area</u> Speed restrictions and appropriate signage to reduce speed and increase awareness of hazards for public, employees and third parties. Fire and Emergency Services Act requirements complied with (e.g. permits for ‘hot work’ on total fire ban days). Fire-fighting equipment available as appropriate for location and use.

14. Has there been any evidence of adverse impacts of such activities?

There is no evidence to date that suggests fracture stimulation activities here in Australia have led to any serious environmental contamination, harm to the surface and subsurface environments, or impacts to human health.

In North America there have been cases before the courts relating to incidents of contamination and in some cases alleged harm to human health as a result of petroleum related activities, including one case[25] from fracture stimulation. Notwithstanding some of these cases have been disputed and/or subject to appeal, through good regulation ensuring implementation of recognised good industry practice, such incidents are avoidable. Studies and reviews undertaken have shown the risks associated with unconventional reservoir development are low through implementation of: proven well construction and fracture stimulation design; chemical storage; and monitoring techniques. The study referenced above[22] undertaken by the Public Health England agency within the United Kingdom Health Department demonstrates this assertion.

15. What are the greenhouse gas emissions of shale gas extraction?

On 9th of September 2013, the UK Department of Energy and Climate Change (DECC) released its report[26] on the potential greenhouse gas (GHG) emissions from extraction and use of shale gas.

In relation to overall GHG emissions associated with shale gas, the report concludes that:

- Through adoption of appropriate industry recognised techniques, in particular those referred to as “green completions”, GHG emissions from shale gas extractions represent only a small proportion of the total carbon footprint of shale gas dominated by CO_2 emissions associated with its combustion.
- The carbon footprint of shale gas extraction and use is likely to be in the range 200 – 253g CO_2e per kWh[27] of chemical energy, which makes shale gas’s overall carbon footprint comparable to gas extracted from conventional sources (199 – 207g CO_2e/kWh(th)[28]), and lower than the carbon footprint of Liquefied Natural Gas (233 – 270g CO_2e/kWh(th)).
- When shale gas is used for electricity generation, its carbon footprint is likely to be in the range 423 – 535 g CO_2e/kWh(e), which is significantly lower than the carbon footprint of coal (837 – 1130 g CO_2e/kWh(e)).

Therefore using natural gas as thermal fuel in preference to coal to generate power is a means to mitigate GHG emissions. Evidence from the USA over the last few years shows that shale gas production has significantly reduced that country’s GHG emissions because less coal is being burnt to generate electricity. This is a major environmental dividend resulting from exploration and production of shale gas. Furthermore, natural gas has been supplied to South Australian homes, businesses and industry for decades.

[25] http://www.nytimes.com/interactive/us/drilling-down-documents-7.html?_r=0#document/p1/a27935
[26] https://www.gov.uk/government/publications/potential-greenhouse-gas-emissions-associated-with-shale-gas-production-and-use
[27] Carbon dioxide equivalent per kilowatt-hour
[28] Carbon dioxide equivalent per kilowatt-hour thermal

16. Is venting of methane allowed?

In South Australia, the adoption of key aspects of "green completions", in particular the requirement to flare and not vent gas during flow back and well testing stages, has always been a requirement under the PGE Act. In August 2012, consistent with requirements in Australia, the US Environmental Protection Agency published its new emission performance standard banning venting of gas directly to atmosphere during well testing operations. The rule states: "where it is not feasible to store gas, re-inject, use as on-site fuel or if emissions cannot be directed to a flow line, then the emissions must be directed to flare permitting it is safe to do so."

In South Australia, DSD-ERD has always supported this approach in its approvals and has not permitted, other than in the case of an emergency or in a controlled operational situation (for example, during maintenance of a high pressure gas pipeline) the venting of natural gas (or any petroleum). It has always been a requirement that natural gas be flared where it could not be either used for fuel, injection or directed into a flow line. The USA, through the adoption of this rule in August 2012, have brought themselves into line with what we in South Australia always considered to be a minimum requirement.

17. What are the key aspects of the regulatory framework?

Fracture stimulation is just one technology already well regulated under the PGE Act that has been performed in this state safely, and without harm, over the last 40 years. Therefore, in the case that fracture stimulation is considered for the South East, the existing regulatory framework is sufficient to ensure that all concerns and issues raised by the community are addressed to an acceptable level prior to any approval being granted.

The objectives of the PGE Act and its Regulations are to ensure that all risks to the health and safety of the community and to the environment are either completely avoided, or managed and reduced to a level that is as low as reasonably practicable and acceptable to the community. Regulated activities under the PGE Act cannot be carried out unless there is an approved SEO in place, prepared on the basis of an EIR. The EIR identifies all potential risks relating to the activity and describes the appropriate risk mitigation strategies. The SEO identifies the environmental objectives to be achieved and the criteria to be used to assess achievement of the objectives. These documents are required to be developed by the proponent through a consultative process involving potentially affected stakeholders, and are assessed by DSD-ERD through a further consultative process as required by the PGE Act and its Regulations. The extent of DSD-ERD's consultation is determined on the basis of an environmental significance assessment undertaken in consultation with other Government agencies, discussed further under question 20.

The PGE Act forms one window to government for the industry whereby the SEO incorporates the requirements of other pieces of relevant legislation (for example the *National Parks and Wildlife Act 1972*; the *Natural Resource Management Act 2004*; the *Work, Health and Safety Act 2012*; and the *Environment Protection Act 1993*) and these are in turn incorporated into the DSD-ERD approval and compliance monitoring processes. EIRs and approved SEOs are public documents available on the DSD-ERD website[29].

[29] http://www.petroleum.statedevelopment.sa.gov.au/environment/register/seo,_eir_and_esa_reports

In the case of fracture stimulation, the EIR and SEO must address risks associated with fracture stimulation fluid and petroleum cross-flow. This is detailed further under questions 2, 10 and 13. The sustainable use of water for such activities must be also addressed in the EIR and SEO.

18. Do such activities alienate other land users, in particular agriculture?

The development of an EIR and SEO in accordance with the PGE Act requirements provides all potentially affected stakeholders (including farmers) with the right to be consulted and to raise any issues and concerns (including those associated with other uses of the land) well ahead of land access. In addition, the required notice of entry to land process provides ample opportunity for landowners (which incorporates many land users) to negotiate proper land access conditions and any commercial terms for such access, including compensation for: any deprivation or impairment of the use and enjoyment of the land; damage to the land; disturbance to business or other activity lawfully conducted on the land; and any consequential loss incurred as a result of the entry to land.

The notice of entry to land process provides the landowner with rights to dispute entry and to seek resolution on terms of entry through the Minister acting as a mediator (and by policy, through the appointment of a knowledgeable, independent and highly regarded person). As a last resort, failing to have this resolved to the satisfaction of both parties, the matter may be referred to the Warden's Court.

The obligations for PGE Act licence holders to compensate landowners underpin the position of power given to landowners (including farmers) under the PGE Act.

19. Will unconventional reservoir exploitation impede renewable energy?

The South Australian Government is a strong supporter of renewable energy[30], as it will make a valuable contribution to reducing greenhouse gas emissions and ensure a sustainable economic future for all South Australians.

The South Australian Government's commitment is demonstrated by the incorporation of a renewable energy target into South Australia's Strategic Plan. The original target sought to support development of renewable energy so that it comprised 20% of the State's electricity production by 2014. As the target was exceeded during 2010/11, the State established a new target of 50% of the State's electricity production from renewable energy sources by 2025. In 2014/15, renewable energy was responsible for approximately 41% of South Australia's total energy production. Wind energy currently provides the bulk of renewable energy generation in the State. South Australia's sixteen wind farms have a total installed capacity of 1,473 MW representing approximately 37% of the nation's total.

In October 2013, the South Australian Government further demonstrated its support by committing to an investment target of $10 billion in low carbon generation by 2025. This is in order to support a renewed economic development focus, and to further support South Australia's ongoing push for increased renewable energy generation. Some of the initiatives that the Government has developed to support renewable energy generation in South Australia include the Solar Feed-in Scheme; improving access to pastoral land; streamlined planning and approvals processes; and targeted grants.

[30] www.renewablessa.sa.gov.au

The South Australian Government is working to widen the area that renewable energy investors have access to for the development of projects. Recently, a Bill was introduced into South Australia's Parliament to amend the *Pastoral Land Management and Conservation Act 1989* in an effort to provide renewable energy investors with access to 40 percent of South Australia's land mass that is Crown Land subject to pastoral leases. If successful, the Bill will make it possible for a wind farm developer to apply for a licence to build and operate a wind farm on pastoral lease land. This would mean a wind farm development can co-exist with pastoral activities in the same way as occurs on freehold farming land. The Bill also expedites access to pastoral land for solar energy projects.

The South Australian Government has also demonstrated a willingness to financially assist developers with establishing a case for developing large-scale projects, particularly if they have the potential to boost economic and community development within regional areas. This has been demonstrated by the contribution of a $130,000 grant from the South Australian Government's Enterprise Zone Fund to assist with Alinta Energy's plan to undertake a full feasibility and technological analysis to assess the viability of large-scale solar thermal generation in Port Augusta.

Notwithstanding the demonstrable support the South Australian Government has for renewable energy, until there is an economically viable renewable energy solution to the problem of intermittent generation, gas and brown coal generation will continue to play an important role in maintaining the stability of the electricity network.

20. How does DSD - ERD manage a conflict of interest between the promotional and regulatory roles of Government?

Any potential for such conflict at DSD-ERD is addressed through the open and transparent regulatory processes. Segregating the promotional and regulatory roles within government is neither the most effective nor the most efficient way to manage the risk of regulatory capture. Transparency and openness enables regulatory competence, retaining knowledge and lower costs to the public through more efficient and more effective regulation by more competent people than is enabled by the segregation of duties.

The regulatory philosophy of the PGE Act is premised on a number of key principles, two of which pertain to the need to avoid potential for regulatory capture, being “openness” and “transparency”.

Openness Principle: All regulatory objectives pertaining to the conduct of activities regulated under the PGE Act are developed, assessed and approved through comprehensive and extensive stakeholder consultation processes.

That is, the EIR and SEO documents are prepared by the proponent through community consultation where a clear description of the proposed activities and their associated mitigated risks are provided to enable the community to reach an informed decision on both the level of severity and acceptability of such risks. In response, the proponent is required to address any community concerns and issues in the EIR and ensure that relevant measurable objectives are detailed in the SEO that demonstrate how these risks will be monitored and controlled, prior to submitting to the regulator for assessment and approval consideration. Furthermore, in keeping with this openness principle, DSD-ERD as the lead regulator is required through statutory requirement (Regulation 12(4) under PGE Regulations 2000) to assess these documents in consultation with the Department of Environment, Water, and Natural Resources (DEWNR), the Environment Protection Authority (EPA), the Department of Planning, Transport and Infrastructure (DPTI) and Safe Work SA as relevant. This mandated engagement with these agencies is conducted through individual Administrative Arrangements publicly available on DSD-ERD's website[31].

Transparency Principle: All approval, compliance monitoring and enforcement documents are available for stakeholders to review and scrutinise. This is achieved through the following:

1. EIR and SEO Assessments:

In addition to the public disclosure of the EIR and approved SEO, the environmental significance assessment (ESA) undertaken by DSD-ERD in consultation with other government agencies is also available on DSD-ERD's website[32].

2. Annual Compliance Reports:

Since 2006, on an annual basis DSD-ERD publishes and tables in the Parliament of South Australia its annual compliance report detailing all regulatory surveillance and approval activities undertaken by DSD-ERD over the previous calendar year, all enforcement actions taken in accordance with its compliance policy and all serious incidents may have occurred including subsequent corrective actions. These reports are publicly available on DSD-ERD's website[33], and provide an excellent demonstration of how the department transparently reveals industry compliance. This constitutes regulatory best practice addressing any notion or perception of regulatory capture.

3. Company Annual Compliance Reports:

Further to DSD-ERD's annual compliance reports, the PGE Act requires all licensees to submit for public disclosure its own compliance report against the regulatory requirements and SEO criteria. These reports are received and reviewed by DSD-ERD annually and published on its website[34].

21. What is the role of DSD-ERD as Regulator in all of this?

The role of the regulators who administer the PGE Act and relevant co-regulations is to provide assurance to the community that the design and execution of regulated activities will achieve the approved objectives of the relevant SEO. The aim of the Ministers for all forms of relevant co-regulation, and the aim of all of PGE Act processes and people are to foster the utmost trust that the robust co-regulatory processes combine to provide necessary safe guards from any potential risks associated with activities regulated under the PGE Act, including all unconventional operations.

Any and all approvals for the development of South Australia's natural energy and mineral resources will always be informed by competent and trusted regulators using the best available science and engineering information so that only environmentally sustainable projects are provided with land access. In other words, where a project cannot demonstrate that it can be undertaken in manner which will comply with the regulatory requirements, that is to be environmentally sustainable, then approval will not be granted. For example, in the case of fracture stimulation where a proponent is unable to demonstrate that the undertaking of this activity will avoid contamination of adjacent aquifers, approval will not be granted.

[31] http://www.petroleum.statedevelopment.sa.gov.au/legislation/regulation/admin_arrangements
[32] http://www.petroleum.statedevelopment.sa.gov.au/environment/register/seo,_eir_and_esa_reports
[33] http://www.petroleum.statedevelopment.sa.gov.au/legislation/compliance/petroleum_act_annual_compliance_report
[34] http://www.petroleum.statedevelopment.sa.gov.au/legislation/company_annual_reports

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22. What is the benefit to the South East Community in allowing unconventional reservoir development to proceed?

Natural gas remains a critical form of energy for thousands of Australian families, businesses (including agriculture) and industry – whether through direct gas supply, or via electricity generated from natural gas or as feedstock for fertiliser and other products widely required for Australian enterprises. In 2014-15, 37% of the State's electricity was generated from natural gas[35].

The magnitude of economic benefits from any unconventional reservoir development in the South East to the regional community and the state overall in terms of industry development, employment, infrastructure development, royalty and security of energy supply is difficult to ascertain at this point in time. It will ultimately depend on the total size of any commercial discoveries. As an example of the benefits realised through the conventional Katnook gas field discoveries in the region made in the 1980s and 90s, the total gas production was over 66.31 billion cubic feet of natural gas and 432,782 barrels of gas liquids (condensate) over a 30 year period equating to $163.3 Million from total gas sales and $17.9 Million from total condensate sales. Total royalty paid to the state of South Australia amounted to $11.77 Million. Furthermore, these discoveries resulted in the gas pipeline network feeding the Ladbroke Grove and Snuggery power plants, Safries Chip factory (which is now being re-purposed), Kimberley-Clark paper mill and the town of Mount Gambier with natural gas. Once these local fields commenced decommissioning around 2005, gas supply continued through this infrastructure with gas delivered through the South East South Australia pipeline connected to the SEAGas pipeline delivering offshore Otway Basin gas to South Australia.

In terms of the potential benefits that any large commercial unconventional reservoir development could deliver, one can draw from the US experience, a 2014 IHS study undertaken to better understand and quantify the economic contributions associated with unconventional reservoir development have concluded that[36];

- Natural gas production increased 27 percent between 2007 and 2013. Estimates of recoverable natural gas reserves have more than doubled since 2005. U.S. oil production has increased 3.3 million barrels per day since 2008 – a 66 percent increase. This increase alone is larger than the output of 11 of 12 OPEC countries.
- By 2012, the unconventional activity was already supporting more than 2.1 million jobs across a vast supply chain. About 60 percent of these jobs – 1.3 million – were from shale gas activity; the rest from tight oil.
- The total number of jobs supported is expected to rise to 3.3 million by 2020 – with 1.8 of those jobs from shale gas.
- In 2012, this revolution added $74 billion to federal and state government revenues. IHS projects the number to rise to about $125 billion by 2020. Between 2012 and 2035, unconventional activity is expected to generate nearly $1.6 trillion in cumulative government revenues.
- Today, natural gas in unconventional reservoirs accounts for nearly 67 percent of total U.S. lower-48 natural gas productive capacity and is projected to rise to nearly 75 percent by the end of the decade. US Lower 48 resources are sufficient to supply current consumption rates for over 100 years.

[35] http://www.aemo.com.au/Electricity/Planning/South-Australian-Advisory-Functions/South-Australian-Electricity-Report

[36] IHS Vice Chairman Dr. Daniel Yergin Testimony to the Joint Economic Committee of the United States, on the economic benefits of U.S. natural gas production, WASHINGTON, D.C. (June 24, 2014)

- Owing to the long supply chains, the job impacts are being experienced across the United States, including in states without significant shale gas or tight oil activity. More than a quarter of all jobs associated with the unconventional revolution are found in states with no appreciable unconventional activity.
- The unconventional revolution increased average household disposable income in 2012 by $1,200 – a number that will grow to $2,700 by 2020 – as a result of savings on utilities and lower costs for goods and services as producers and retailers enjoy lower energy costs.

The abundance of oil and gas that has been brought to market has also brought the price of oil and gas down in the USA (since late 2014). The abundance of supply from shale resources has driven the price of oil and gas to (near) real historical lows in the USA in late 2015. This has great benefits for the USA's economy.

The Australian Council of Learned Academies (ACOLA)[37] Report notes that economic diversification that leverages energy projects is the greatest way of contributing to the long-term wellbeing of a region, though a strategic approach to regional development is vital. The Western Australian onshore gas industry is now considering how to make the most of the local benefits from shale gas production through incentives for regional contractors, farm-friendly working conditions, community development programs and fair compensation payments. In the case of the South East, similar initiatives can also be considered.

23. Can landowners object to land entry for oil and gas exploration?

In South Australia, individual land owners have rights under the PGE Act, Part 10, sections 60 to 64, to object to entry and to negotiate any authorised entry and/or compensation.

Notwithstanding this, there is no law in South Australia or Australia, constitutional or otherwise that would preclude responsible development in the public interest. The reason being, the Crown that is the overall community, in South Australia is the owner of the mineral rights including oil and gas, not an individual land owner. Therefore as the owner of those rights, the Crown reserves the right to ensure the general public interest is in no way disadvantaged through vexatious and unreasonable demands from some sectors of the community. However, the government must also in exercising that right ensure that any proposed development delivers net beneficial outcomes, that is, maximise the benefits of projects such as GSP, jobs, royalties, security of energy supply and industry development and minimise any detrimental risks associated with such projects to an acceptable level addressing community concerns. It's for this reason that legislation such as the PGE Act exist.

24. How many wells would be needed to exploit any unconventional reservoir?

The number of wells required depends very much on the size of any resource discovered and the commercial flow rates that can be achieved from each well. In simple terms, the lower the productivity of each well the more wells required to extract the resource. However, taking into account the cost of drilling and completing wells and the value of the resource being exploited, there would be a maximum number of wells that could be drilled at any given time before the project becomes commercially uneconomic.

Furthermore, given the size of the gas markets to which natural gas produced in the onshore South Australian Otway Basin are likely to be competitive – if an early well or three are successful in delineating unconventional rock-reservoirs that can flow at economic rates –

[37] http://www.acola.org.au/PDF/SAF06FINAL/Final%20Report%20Engineering%20Energy%20June%202013.pdf

then we could envisage possibly tens of development wells to follow –drilled from multi-well pads - with an aggregate surface foot-print similar to what locals have experienced for decades in the South East of our State. We do not envisage gas market growth in the foreseeable future in South East Australia to drive the development of deep gas resources in the Otway Basin to anything approaching thousands of wells quoted in the local media.

25. Is there a need for a prescribed separation distance between petroleum activities and other land uses and users?

The need for prescribed separation distances of petroleum activities from other land uses such as areas of tourism, dwellings and townships is addressed through the environmental impact assessment process under the PGE Act. It is worth pointing out that only after potential risks to social, natural and economic environments during all phases of petroleum operations (including drilling) are robustly addressed, and effective risk mitigation strategies and controls (including separation distances where appropriate) are required to be implemented, are any upstream petroleum operations approved pursuant to the PGE Act.

Being a risk-based regulatory framework, one of the PGE Act's essential features is that the level of stringency of the required controls need to be commensurate to the severity of the risk at hand. That is, through the environment impact assessment as detailed in the Environmental Impact Report (EIR), it would be determined whether through design, operational control or simply an appropriately determined separation distance that a particular threat to social, economic and/or natural aspects of the surrounding environment can be best managed. If any particular activity cannot be practically managed to meet community expectations for net outcomes – then such activities will not be approved for undertaking.

The PGE Act assessment process entails consultation with potentially affected people and enterprises in developing Environmental Impact Reports (EIRs) and Statements of Environmental Objectives (SEOs). It is through this process that any justification for separation distances to protect features of the environment such as townships, dwellings or other land uses can and needs to be addressed.

26. Can fracture stimulation cause earthquakes?

There is a thorough understanding of the microseismic activity associated with fracture stimulation in the petroleum industry. Fracture stimulation operations generate microseismic events that can be recorded with sensitive listening tools and analysed with established scientific methods. There has been no cases of injuries or damage as a result of the very low level of seismicity related to fracture stimulation[38].

The results from one study[39], which assessed thousands of fracture treatments in US shale plays, showed that the largest microseismic event recorded had a measured magnitude of approximately 0.8. This is approximately 2000 times less energy than a magnitude 3.0 earthquake. The magnitude 3.0 earthquake is commonly used to describe deep earthquakes that can be felt at the surface, but still much smaller than an earthquake that could be damaging or harmful.

[38] http://nlhfrp.ca/wp-content/uploads/2015/01/HF-and-Seismic-Activity-Report-v2.pdf

[39] Warpinski, N. R., Du, J., & Zimmer, U. (2012, January 1), Measurements of Hydraulic-Fracture-Induced Seismicity in Gas Shales, Society of Petroleum Engineers

Any further queries?

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This FAQ can be downloaded online at the following location:
http://www.petroleum.statedevelopment.sa.gov.au/prospectivity/basin_and_province_information/unconventional_gas/frequently_asked_questions

Appendix 1: Definition of Unconventional Reservoirs

To understand what unconventional reservoirs are, it is worth first defining the meaning of conventional reservoirs. From one published definition[40], natural gas (and oil) is trapped in porous and permeable (conventional) reservoir rocks, such as sandstones, in favourable geological structures or traps, such as anticlines, and within sedimentary basins, illustrated in Figure 1 below. Porosity is the space between the grains that make up a reservoir rock, in which fluids such as water or gas occur. The higher the porosity, the greater the quantity of a fluid, whether water or hydrocarbons, that can be potentially trapped within the rock. Permeability is a measure of the level of interconnectivity between the pores and is an indication of the ease or difficulty encountered in extracting fluids from the rock, or injecting fluids into the rock. The higher the permeability the easier it is to produce gas or liquids from a rock.

Typically, the gas (and associated oil) in conventional reservoirs is found in sandstone, less commonly in limestone, with high porosity and high permeability. The depth, pressure and thermal history within a sedimentary basin defines whether oil or gas is likely to have been generated from the remains of ancient algal bacteria and plants, and then migrated within the basin; the structure of the basin determines whether generated oil or gas is likely to have been trapped. To date, most of the gas that has been produced, globally and in Australia, has been from conventional reservoirs. Oil and gas in conventional reservoirs has underpinned twentieth century economic and social development.

On the other hand gas and oil in unconventional reservoirs can be described metaphorically as the “high hanging fruit” which are gas or oil resources that are regionally pervasive, contained (as shown in Figure 1) within underground formations such as shale, low permeability sand (tight gas) and coal. The gas that is contained within coal is often referred to as Coal Seam Gas (CSG), Coal Seam Methane (CSM) or Coal Bed Methane (CBM).

Typically, oil and gas extraction from an unconventional reservoir requires specialised extraction technologies which have been developed to enhance production from conventional reservoirs (e.g. dewatering of coal seams for CSG and fracture stimulation for shale gas and tight gas).

Fracture stimulation (commonly referred to as “fracking”) is a technology used to induce fractures and fissures in rock, providing paths with increased permeability for fluid flow within hydrocarbon reservoirs. Firstly, the cemented steel casing is perforated using specialised downhole perforation guns. Water is then pumped down the well under high pressure, passing through the perforations into the target reservoir zone to create or enlarge fractures in the rock. Viscosity modifying agents (such as guar gum) and other chemical additives are then added in low concentration to enable proppants, typically sand or ceramic beads, to be carried from the surface to the underground zone to ‘prop’ the newly created fractures open and prevent them from closing up after pressure is released. This allows the trapped oil or gas to flow through the induced fracture system to the production well.

Additional general information on what unconventional reservoir development entails can be found in Information Sheet P11 on the DSD-ERD website[41].

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[40] Engineering Energy: Unconventional Gas Production A Study of Shale Gas in Australia, Final Report: ACOLA http://acola.org.au/PDF/SAF06FINAL/Final%20Report%20Engineering%20Energy%20June%202013.pdf

[41] https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/ISP11.pdf

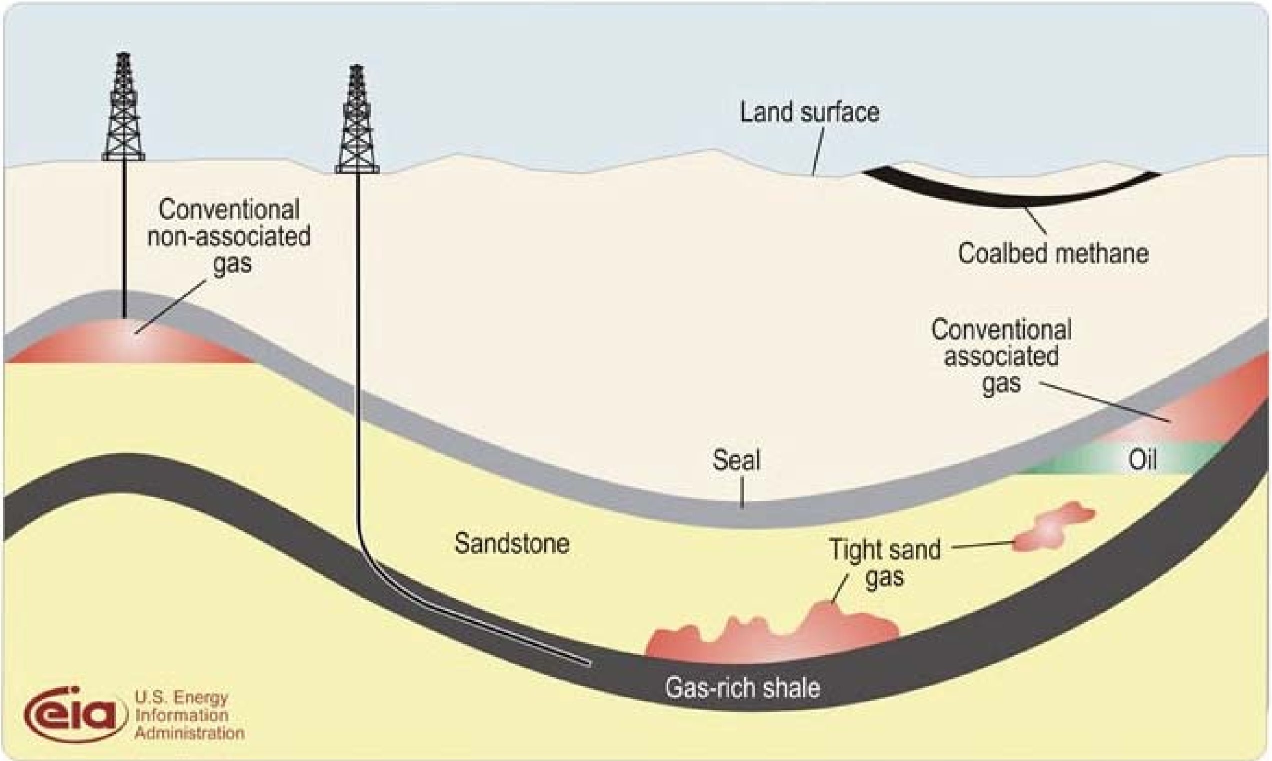

Figure 1 - Diagramatic representation of conventional and unconventional petroleum reservoirs – not to scale (from the US Energy Information Administration)

Appendix 2: Map of petroleum activity in South East of South Australia, since 1910 to present.