appea the voice of australia's oil and gas industry

Submission

March 2018

Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia 2018

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2. Executive Summary

"The evidence is not there that it's dangerous. In fact, the evidence is that, if properly regulated, it's completely safe" Australia's Chief Scientist, Dr Alan Finkel (ABC Lateline, 27 January 2015)

- The Independent Scientific Panel Inquiry is Australia's 14th inquiry or review into hydraulic fracturing in recent years and the second such inquiry in Western Australia in the last five years. All these inquiries have confirmed that, with appropriate regulation and good industry practice, hydraulic fracturing is safe.
- Since 1949, hydraulic fracturing has been used to produce oil and gas from millions of wells across the world. Hydraulic fracturing has been used, without incident or environmental harm, in more than 1,500 wells in Australia. The process was first used in Western Australia in 1958; to date, more than 600 wells in the state have been stimulated. Hydraulic fracturing is also used in geothermal energy projects and to improve the output of water bores.
- Industry practices have been steadily refined over these decades of safe operations to eliminate or minimise potential risks. Potential risks are well understood by industry and are addressed effectively by industry practices as well as regulation.
- Research and innovation ensure continuous improvement in industry performance. Research agencies such as the CSIRO have extensive programs investigating social, economic and environmental aspects of the industry. No other industry in Australia has been the subject of such exhaustive study.
- Regulation of the industry in WA has developed over 50 years and, since 2011, has been assessed by an independent review, a whole of government cross-agency assessment and a two- years-long parliamentary inquiry. State regulation has been comprehensively tested and found fit for purpose.
- Developing onshore gas in Western Australia will deliver local, State and global benefits – economic and environmental. The most direct beneficiaries will be remote regional communities which urgently need economic development. Gas powers the state economy: employing about 20,000 people, sustaining an $8 billion local supply chain, and generating about $900 million in royalties and other taxes. On-call gas-fired generation stabilises the electricity grid by providing on-call energy to back up intermittent renewables. The regional demand for gas is steadily rising as countries seek to cut their emissions and address the air quality problems responsible for almost 3 million premature deaths a year.
- APPEA recognises that people – especially host communities – are seeking honest, factual information on hydraulic fracturing. The industry accepts its responsibility to engage, respectfully, with communities to address their concerns. Over the last decade, the industry has moved to a new, far higher standard of community consultation and transparency.
- The industry trusts that balanced, independent analysis from the Independent Scientific Panel Inquiry will contribute to a more informed public debate.

This submission provides an industry-wide perspective on the Inquiry's Terms of Reference. It should be read in conjunction with submission from APPEA member companies.

3. Introduction

APPEA welcomes the opportunity to provide an industry-wide perspective to the 2017-18 inquiry into hydraulic fracturing in Western Australia.

APPEA trusts that the Inquiry will improve public understanding of the facts about hydraulic fracturing in the state and across Australia.

A vast, growing body of independent scientific research has analysed the issues raised in the inquiry's terms of reference.[1] The evidence is clear – with sound regulation and good industry practice, shale and tight gas resources can and are being developed safely in Australia. After decades of operating experience and numerous research studies, the potential risks are well understood by industry and governments.[2]

On the other side of the ledger, the benefits of onshore gas development in Western Australia are equally clear. Development will deliver economic benefits to regional communities – jobs, infrastructure, and additional income for land owners. Royalty and other tax payments will help fund State government services. New gas supply into the domestic market will strengthen competition and energy security.

Should onshore gas be exported as liquefied natural gas (LNG) – or enable the export of more offshore gas as LNG – it would contribute to cutting global emissions by displacing coal and would help prevent some of the almost 3 million premature deaths a year caused by poor air quality in countries such as China and India.

3.1. About APPEA

The Australian Petroleum Production & Exploration Association (APPEA) is the peak national body for representing the oil and gas exploration and production industry. It has 60 full member companies comprising oil and gas explorers and producers in Australia. APPEA members account for an estimated 98 per cent of Australia's petroleum production. APPEA also represents more than 140 associate member companies providing goods and services to the oil and gas industry. For more information, see www.appea.com.au. APPEA has prepared this submission in concert with interested onshore member companies as listed in the table below.

Table 1: Interested onshore member companies contributing to the APPEA submission

Company	Region	Basin
AWE Limited	Mid West	Perth
Norwest Energy	Mid West	Perth

[1] Cook, P, Beck, V, Brereton, D, Clark, R, Fisher, B, Kentish, S, Toomey, J and Williams, J (2013). *'Engineering Energy: Unconventional Gas Production.'* Australian Council of Learned Academies (ACOLA), www.acola.org.au.
[2] A host of potential issues – public health, cumulative impacts, fugitive emissions, groundwater impacts – are covered in detail in publications by ACOLA, the International Gas Union and International Energy Agency.

Whitebark Energy	Mid West	Perth
Buru Energy	Kimberley	Canning
Finder Shale Limited	Kimberley	Canning
Mitsubishi Australia	Kimberley	Canning
Beach Energy	Mid West	Perth

3.2. WA's Oil and Gas Sector

Since the 1960s, Western Australia's economy has been built on local supply of competitively priced natural gas. Today, gas is the dominant fuel for electricity generation (accounting for 43% of generation in the south west interconnected system[3]), an essential feedstock for many manufacturers and, of course, the source of a massive, world-class LNG export industry.

More than 100 oil and gas fields have been developed in Western Australia. Most of these fields are offshore in the North West Shelf, with modest production from onshore conventional wells.

While development has been focused on offshore resources, Western Australia also has substantial onshore shale and tight gas resources. These reserves may be twice the size of known offshore resources. Recent advances in industry technology (including hydraulic fracturing) have made commercial development of these resources feasible.

The state's most prospective shale gas resources are clustered in three broad areas: the Kimberley and the East Pilbara (both in the Canning Basin) and the Mid West (in the Perth Basin). There are other potential resources in the Carnarvon and Officer Basins. These resources are untested for prospectivity or production[4]. The Department of Mines, Industry Regulation and Safety (DMIRS) estimates WA's sedimentary basins hold about 80 per cent of Australia's discovered natural gas resources, despite being one of the world's least-explored areas[5].

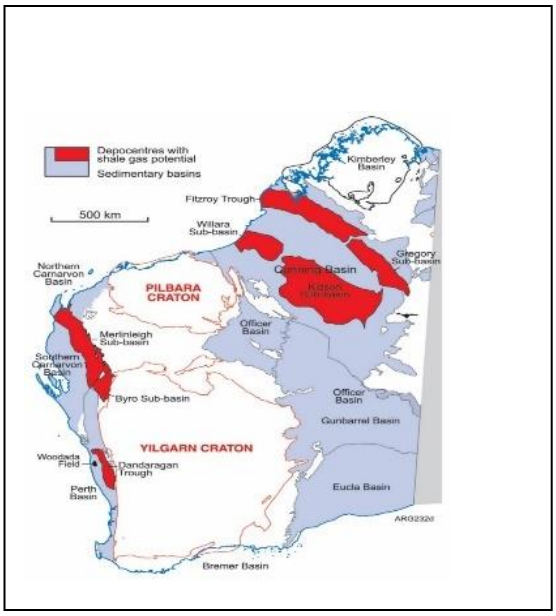
Western Australia is estimated to contain 8 trillion cubic meters (280 trillion cubic feet) of potential natural gas from shale and tight rocks. These resources are in the Kimberley, east Pilbara and Mid West regions (in the Canning and Perth Basins)[6]. DMIRS has estimated 39,140 billion cubic metres (Gm3) (or 1,381 Tcf) gas initially in place (GIIP) resources of shale and tight gas. Of this, about 29,900 Gm3 (1,054 Tcf) are in the

[3] AEMO (2017), WA Gas Statement of Opportunities.
[4] Department of Mines and Petroleum, *Western Australia's Petroleum and Geothermal Explorer's Guide: 2014 Edition*, September 2014, p18
[5] Department of Mines and Petroleum, *Western Australia's Petroleum and Geothermal Explorer's Guide: 2014 Edition*, September 2014, p18.
[6] Department of Mines, Industry Regulation and Safety, *Shale and tight gas exploration in Western Australia*, available at http://www.dmp.wa.gov.au/Petroleum/Shale-and-tight-gas-exploration-19990.aspx
[7] Geoscience Australia (2016) Coal Seam, Shale and Tight Gas in Australia: Resources Assessment and Operation Overview 2016 http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/UPR%20Unconventional%20Resources%20Report%202016_0.pdf

Canning Basin (Kimberley and East Pilbara regions); 6,540 Gm3 (232 Tcf) are in the Northern Perth Basin (Mid West region); and 2,700 Gm3 (95 Tcf) are in the Northern Carnarvon Basin (onshore).[7]

Since 2005, 24 exploration wells have been drilled to find shale and tight gas resources in Western Australia[8]. Hydraulic fracturing was subsequently used on eight of these wells to test the capacity of the reservoir to generate commercial gas flows. The fracturing programs were approved by DMP, in consultation with the Environmental Protection Authority (EPA), with strict regulatory requirements to avoid environmental harm.

Given the importance of natural gas to Western Australia, continued access to secure, reliable and competitively priced energy is critical[9].



PERTH BASIN

The northern Perth Basin has a long history of oil and gas operations. Its first exploration well was drilled in 1961, and the first oil and gas discovery was at the Yardarino-1 well in 1964. Natural gas was first produced for sale from the Dongara gas field in October 1971.

Since then, about 20 commercial oil and gas fields have been developed in the region. This has required field exploration, seismic surveys, and exploration and development drilling. More than 300 wells have been drilled and infrastructure and gas pipelines have been developed – with no significant environmental impacts. Today, oil and gas operations are conducted on several sites, employing local staff and contractors and contributing to the local community, as well as to Western Australia more broadly.

CANNING BASIN

In 2011 and 2013, US Energy Information Administration reports identified the Canning Basin as having more than 225 TCF of recoverable shale gas based on the Goldwyer Formation play alone. The Australian

[8] Geoscience Australia, Coal Seam, Shale and Tight Gas in Australia: Resources Assessment and Operation Overview 2016 – Upstream Petroleum Resources Working Group Report to COAG Energy Council, November 2016. Accessed via: http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/UPR%20Unconventional%20Resources%20Report%202016_0.pdf

[9] 'Strategic Energy Initiative: Energy 2031', Public Utilities office (2012), http://www.finance.wa.gov.au/cms/uploadedFiles/Public_Utilities_Office/WAs_Energy_Future/Strategic_Energy_Initiative_Energy2031_Final_Paper.pdf

Council of Learned Academies confirmed this assessment and calculated a further 38 TCF of recoverable shale gas in the Laurel Formation.

Since 2010, Buru Energy has carried out hydraulic fracturing activities on three vertical petroleum exploration wells in the Canning Basin (Yulleroo-2 in 2010, Asgard-1 in 2015 and Valhalla North-1 in 2015) as part of the company's Laurel Formation tight gas project.

In 2015, Finder Shale's Theia-1 exploration well intersected a 70-metre oil and gas column in a shale reservoir (Goldwyer Formation) at a depth of 1,550 meters. Finder is planning to drill two more wells to test this hydrocarbon formation.

As of February 2017, more than 300 wells have been drilled in the Canning, and four active petroleum systems have been identified. But because of the basin's size and complexity it is still considered to be very underexplored. DMIRS has said that it may be "the least explored Palaeozoic basin in the world"[10].

4. History and Issues

4.1. History of Hydraulic Fracturing

Hydraulic fracture stimulation has been used in the international oil and gas industry since 1949. More than 2.5 million hydraulic fractures have been completed worldwide; about one million of those were undertaken for shale gas or oil.

In WA, more than 600 wells have been hydraulically fractured since 1958. Most of these were in conventional oil and gas wells on Barrow Island. On mainland Western Australia, hydraulic fracturing has been used seven times at the Dongara gas field in the Perth Basin (Mid West) since 1974. The most recent examples of hydraulic fracturing for tight and shale gas in Western Australia are listed below:

Table 2. History of Hydraulic Fracturing for Tight and Shale Gas in WA

FIELD	LOCATION	YEAR
Gingin Field	Gingin	1971
Whicher Range	Mid West	1982 (WR-3), 1997 (WR-1 & WR-4), 2003 (WR-5)
Warro	Mid West	2009 (W-3), 2011 (W-4), 2015 (W-5 & W-6)
Corybas	Mid West	2009
Yulleroo	Canning Basin	2010
Arrowsmith	Mid West	2012
Senecio	Mid West	2012
Woodada	Mid West	2012

[10] Department of Mines and Petroleum (2017) Summary of Petroleum Prospectivity: Canning Basin http://www.dmp.wa.gov.au/Documents/Petroleum/Petroleum-SummaryProspectivityCanningBasin2017.pdf

Asgard/Valhalla	Canning Basin	2015 (Asgard-1 and Valhalla North-1)

4.2. Hydraulic Fracturing Process

Hydraulic fracturing is undertaken to link the petroleum-containing pore spaces of a reservoir when they are not naturally connected, or when the connections are not great enough to produce commercial flows. The benefits of these fractures in terms of improved flows of oil and gas have long been understood. If a well is drilled and encounters natural fractures, a large proportion of the flow will come from the fractures that are hydraulically connected to the wellbore.

In many cases, artificial fracture stimulation is required to generate any flow at all. While other forms of reservoir stimulation are available, hydraulic fracturing is by far the most common technology used.

Hydraulic fracturing involves pumping proppant-laden fluid under high pressure into the reservoir rock through heavily-encased wells. The process produces fine fissures. The proppant (sand or ceramic beads) remains in the fracture to prop it open, which provides a pathway for the oil or gas to flow up the well.

Hydraulic fracturing in the Canning and Perth Basins has generally been used at depths of more than 2,000 meters below ground level. The volumes of fluid used are typically less than 1,500kL per fracture treatment. Fracture fluids and proppants are typically ~94% water, ~5% proppant and ~1% chemical additives.

4.3. Concerns associated with hydraulic fracturing

Concerns have been raised about the use of hydraulic fracturing in the extraction of shale gas and oil, but the weight of scientific evidence indicates the practice is safe.

HYDRAULIC FRACTURE PROPOGATION

Perhaps the concern raised most is that hydraulic fractures could create a pathway linking the gas- or oil-producing zone to a drinking water source.

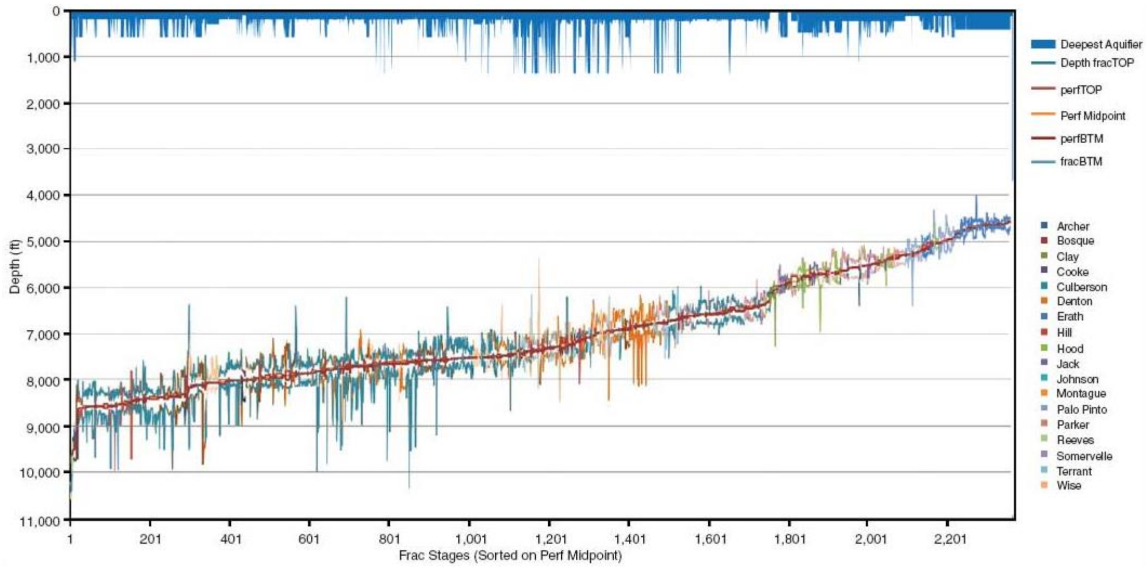
Recent studies by the CSIRO and other organisations have examined the possibility of hydraulic fracturing causing migration from deeper aquifers to shallow groundwater.

They concluded that there is little likelihood of hydraulic fracturing reaching a water resource when the vertical separation between the reservoir and the overlying aquifer is large and other natural pathways (such as faults or leaky wells) are absent.

CSIRO research also found that chemicals remaining underground after hydraulic fracturing are unlikely to reach people or ecosystems in concentrations that would cause concern. Natural dilution and degradation reduce concentrations to negligible levels. Risks are therefore likely to be very low.[11]

Research led by Durham Energy Institute indicates that there is a less than 1 per cent chance of a stimulated hydraulic fracture propagating upwards for more than 350m, and that the maximum recorded distance of such a fracture is less than 600m.[12] This is supported by the results of Buru Energy's Asgard-1 and Valhalla North-1 hydraulic fracturing program, which recorded a maximum fracture height of 151.5m[13].

Figure 1 - Separation of aquifers and maximum fracture propagation in the Barnett Shale region of Texas (listed by county)[14]



WELL DESIGN AND CONSTRUCTION

Before a well is drilled, it is carefully designed to make sure it meets the highest safety standards and can withstand the particular conditions such as pressure, corrosion, temperature and fluid flows.

Monitoring and maintenance programs are also undertaken over the life of the well, which is usually decades-long to ensure continued well integrity.

Several international standards guide good oil field practice in well construction[15] and these are required to be taken into account under the *Petroleum and Geothermal Energy Resources (Resource Management and Administration) Regulations 2015*.

Multi-disciplinary teams of petroleum professionals use several tools and processes to design a hydraulic fracture and guide its successful implementation. The design process involves several steps.

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[11] CSIRO (2017) Deeper Groundwater in CSG Extraction https://www.csiro.au/en/Research/Major-initiatives/Unconventional-gas/CSG-chemicals
[12] http://www.refine.org.uk/media/sites/researchwebsites/1refine/hydraulicfracturesrb/Hydraulic%20Fractures%20RB%202.0.pdf
[13] Buru Energy (2018). Buru Energy Submission to the Scientific Inquiry into Hydraulic Fracture Stimulation in Western Australia (Draft).
[14] 'Hydraulic Fracturing: The Process', FracFocus, http://fracfocus.org/hydraulic-fracturing-how-it-works/hydraulic-fracturing-process
[15] http://www.api.org/searchresults?search=well%20construction&page=1

Develop geological and geomechanical models

Geological models are developed based on information such as reservoir quality, mineralogical composition and petrophysical analysis of the target rocks. Geomechanical models are developed based on geomechanical data resulting from studies such as tight rock analysis to provide measurements and estimates of rock properties such as permeability, porosity and hydrocarbon saturation and estimates of the physical characteristics of the rocks at reservoir pressure such as brittleness. The geologist and reservoir engineer generate the models to determine and make inferences on which intervals of rock contain potentially moveable hydrocarbons and the likelihood of hydraulic stimulation being successful.

Confirm well integrity

Well pressure integrity is assured by pressure-testing the casing and well-head valves and in some instances this information may be supplemented with cement bond log data.[16]

Detailed planning

Based on the results of the geological and geomechanical studies and models and a number of other sources of information, particular intervals or rock are targeted for stimulation. The composition of treatment fluids to be used in the hydraulic fracturing operation is usually devised to contain the minimum amount of additives[17]. The fluids are tested with drilling cuttings or cores to ensure compatibility with the target rock. The geologist, "frac" engineer and reservoir engineer prepare a comprehensive operational plan that includes safety and environmental management plans and contingencies.

Monitoring execution to ensure alignment with design

Once the design has been finalised, the process is carefully managed on-site by verification through pressure testing and comparison of flow-back data with predictions derived from modelling[18]. During and after the fracture stimulation, on-site diagnostics data are monitored and the results of the hydraulic fracture program are evaluated and used to optimise subsequent operations by methods such as history matching with models.

WELL INTEGRITY

Controlling the gases and liquids as they are brought to the surface requires long-term well integrity.

The well must not only contain the petroleum products, it must also ensure that any subsurface rock layers and any related aquifers that it penetrates remain isolated from each other.

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[16] Crane, et al:"Fracturing Fluid Testing for Design Purposes and Regulatory Oversight in a Shale Gas Project," SPE 167107, 2013.

[17] Magill, D., Squires, S. T., Johnson, R. L., & Crane, B. (2013, November 11). Fracturing Fluid Testing for Design Purposes and Regulatory Oversight in a Shale Gas Project. Society of Petroleum Engineers. doi:10.2118/167107-MS

[18] Johnson, et al. "Utilizing Current Technologies to Understand Permeability, Stress Azimuths and Magnitudes and their Impact on Hydraulic Fracturing Success in a Coal Seam Gas Reservoir," SPE 133066, 2010.

Well integrity is also key to controlling any leakage of methane (i.e. fugitive emissions). Achieving this requires high standards of well design and construction.

Well construction ensures isolation of formations

Figure 2 - Well casings

The well is lined with multiple layers of pipe (called 'casing' or 'casing string' for longer sections). Interlocking casing strings back up the integrity of the well if one of the pipes fails.

Cement is pumped into the casing between the well and the rock, and between the various strings of casing. This isolates formations (including aquifers) from one another preventing flow between formations or inside the well itself.

There are usually four strings of casing: a conductor casing – to secure the near-surface section – soil and gravel - 8 $^{5}/_{8}$" diameter; a surface casing – generally set to isolate the deepest potable aquifer; an intermediate casing – from surface down to the base of weathered or weak strata – 6 $^{5}/_{8}$" diameter; and a production casing – down into the target formation – 4 ½" diameter. Actual casing sizes will depend on well and fracturing design.

Well cementing ensures well integrity

Cement is a critical component of well construction and cementing is a fully designed and engineered process. Cement is used in casing during well construction, and is used for plugging in well decommissioning. It can also be used to address production or perforation issues.

Cements used in well construction are highly engineered, specialised products, underpinned by decades of research. They are not the same as the cement used in traditional construction activities such as building and civil works. Special formulations and additives are used to customise cement to individual well conditions and provide increased resistance to: gas migration; naturally occurring chemical ions; acidic environments; carbon dioxide; high temperatures; sulphate; and mineral acids (King, 2012).

Figure 3 - Well casing and cement

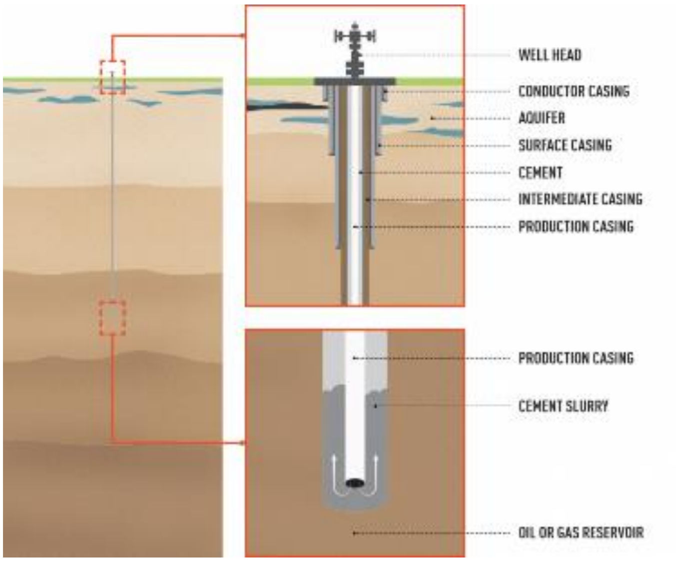
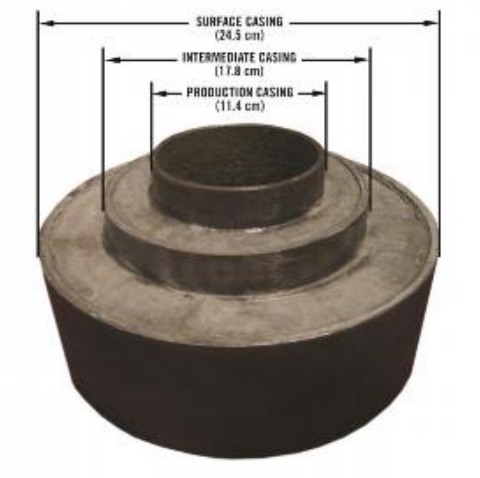


Figure 4 - Multiple pipe casings and cement



Well failure is very rare

The terms "well barrier failure" and "well integrity failure" have sometimes been misunderstood or misrepresented. In nearly all instances, a "well failure" refers to a failure of *one* of the multiple barriers in the well which ensure that gas and/or fluids passing through the well do not enter the environment. One barrier failing may reduce the integrity of the well but does not mean a loss of containment. Failed barriers can be restored (e.g. by re-working the well).

Studies indicate that wells are extremely unlikely to have barrier or well integrity failures when constructed according to modern standards.[19]

The US has one of the world's longest histories of oil and gas production, and the most extensive well database. Its Ground Water Protection Council examined more than 34,000 wells drilled and completed in Ohio between 1983 and 2007, and more than 187,000 wells drilled and completed in Texas between 1993 and 2008. The Texan wells included more than 16,000 horizontal shale gas wells with multi-staged hydraulic fracturing stimulations. The data[20] shows only 12 incidents in Ohio related to failures of (or erosions to) casing or cement – a failure rate of 0.03%. In Texas, the failure rate was only about 0.01%. Obviously zero is the aim, but this is still a very low percentage considering the large number of wells drilled.

[19] Stone CH, Eustes AW, and Fleckenstein WW, *A continued assessment of the risk of migration of hydrocarbons or fracturing fluids into fresh water aquifers in the Piceance, Raton, and San Juan Basins of Colorado. SPE-181680-MS.* In Society of Petroleum Engineers Annual Technical Conference and Exhibition, p 50, 2016b.

[20] Kell, S. (2011), State Oil and Gas Agency Groundwater Investigations and their Role in Advancing Regulatory Reforms: A Two-State Review: Ohio and Texas, Ground Water Protection Council, fracfocus.org/sites/default/files/publications/state_oil__gas_agency_groundwater_investigations_optimized.pdf

A recent review by King and King (2013) of data from 253,090 Texan wells found only 4 in every 100,000 (0.004%) wells built to modern standards have a loss of well integrity, compared to 0.2% for older wells.

The Queensland Gasfields Commission has released some information on well integrity in that state[21]. It found that cementing 'failure' rate after testing, remediation, and follow-up has been zero. The risk of a subsurface breach of well integrity is assessed to be very low to near zero.

In 2015, the Western Australia Department of Mines and Petroleum (DMP) surveyed 1,035 non-active wells (both offshore and onshore). It found that: "*the vast majority of petroleum and geothermal wells are drilled, completed, produced and decommissioned without any adverse environmental impacts*".[22] DMP found that, of the 953 petroleum wells surveyed, 9% have had production tubing failures and 3% have had production casing failures well away from aquifers which were still protected by the surface and conductor casings. There were no failures of surface or conductor casings.

Ensuring well integrity following decommissioning

Once a well has reached the end of its useful life, it must be decommissioned and remediated (the common industry term is 'plugged and abandoned'). This typically involves placing numerous cement plugs in the well bore, and removing all infrastructure at the surface.

A properly decommissioned well is very different to a producing well which needs regular measurement and monitoring. In remediating the well, the operator restores the integrity of the formation penetrated by the wellbore. This isolates permeable and hydrocarbon-bearing formations to protect underground resources, prevent future potential contamination of potable water sources and preclude surface leakage.

Modelling and analysis into well corrosion show that a properly designed and implemented well can last indefinitely. Yamaguchi, Shimoda, Kato, Stenhouse, Zhou, Papafotiou, Yamashita, Miyashiro & Saito (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 seals over a simulated period of 1,000 years. While the cement seals altered over time, the change after 1,000 years was small enough to conclude that cement will isolate CO_2 and upper aquifers for centuries.[23]

Cement plug integrity in carbon dioxide subsurface storage was also assessed by Van der Kuip, Benefictus, Wildgust & Aiken (2011)[24]. They noted that required plug lengths vary greatly between different regions, from a minimum of 15m in Alberta to 100m in some European countries, but in CO_2 storage only a few metres of cement might be affected in 10,000 years (CO_2 stored at high pressure is expected to be more aggressive than methane in corroding and degrading cement).

[21] Queensland Gasfields Commission (2016), Well Integrity. www.gasfieldscommissionqld.org.au/resources/gasfields/onshore-gas-well-integrity-in-qld.pdf
[22] S Patel, S Webster & K Jonasson, *Review of well integrity in Western Australia*, Petroleum in Western Australia, April 2015, p24
[23] Kohei Yamaguchi, Satoko Shimoda, Hiroyasu Kato, Michael J. Stenhouse, Wei Zhou, Alexandros Papafotiou, Yuji Yamashita, Kazutoshi Miyashiro, Shigeru Saito, *The Long-term Corrosion Behavior of Abandoned Wells Under CO2 Geological Storage Conditions: (3) Assessment of Long-term (1,000-year) Performance of Abandoned Wells for Geological CO2 Storage*, Energy Procedia, Volume 37, 2013, pp5804-5815, ISSN 1876-6102, www.sciencedirect.com/science/article/pii/S1876610213007467.
[24] M.D.C. van der Kuip, T. Benedictus, N. Wildgust, T. Aiken, *High-level integrity assessment of abandoned wells*, Energy Procedia, Volume 4, 2011, Pages 5320-5326, www.sciencedirect.com/science/article/pii/S1876610211007922.

DECOMMISSIONING AND REHABILITATION

Defined procedures and responsibilities for decommissioning petroleum wells exists in Western Australian petroleum legislation. Well decommissioning procedures isolate the subsurface formation for long term environmental protection. Decommissioning is intended to:

- Isolate and protect all freshwater zones from surface and subsurface ingress and egress ;
- Isolate all hydrocarbon bearing zones;
- Perpetually prevent leaks from or into the well; and
- Remove surface structures in order to rehabilitate landform to its former use.

(DMIRS, Closure and decommissioning - http://www.dmp.wa.gov.au/Petroleum/Closure-and-decommissioning-8667.aspx).

Legislative controls for decommissioning of onshore petroleum fields and facilities are primarily through the provisions of the *Petroleum and Geothermal Energy Resources Act 1967* and subsidiary regulations.

The default position requires the removal of all infrastructure unless companies can demonstrate the benefits of alternative options. Well Management Plans, Field Management Plans and Environment Plans address the environmental legislative requirements relating to decommissioning.

DMIRS released its Petroleum Decommissioning Guideline in October 2017. This guideline is intended to provide uniform regulatory guidance on the obligations as described in the relevant Acts and Regulations, of registered petroleum title holders preparing to engage in decommissioning activities[25].

An Environment Plan for decommissioning and rehabilitation must be submitted to DMIRS in advance of activities occurring. The Environment Plan must set rehabilitation completion criteria and associated measurable targets. Environmental monitoring may be required after decommissioning; this is determined in consultation with the regulator. The Environment Plan describes these commitments and ongoing regulatory reporting requirements.

Change in ownership of a production licence means the responsibilities of forward management of the licence will transfer to the new registered holders, jointly and severally, including all liabilities pertaining to decommissioning obligations. Any new registered holder must demonstrate the technical expertise and financial competency and assurances to comply with regulatory requirements for decommissioning.

The Environment Plan provides the avenue for detailed commitments that are appropriate to the nature and scale of the activity, including progressive remediation and rehabilitation.

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[25] Department of Mines, Industry Regulation and Safety, Petroleum Decommissioning Guideline, 2017. Accessed at: http://www.dmp.wa.gov.au/Documents/Petroleum/PET-DecommissioningGuideline.pdf

EMERGING TECHNOLOGY ("GREEN" FRACTURING FLUIDS AND GELLED LPG FRACTURING)

The types of chemicals used for hydraulic fracturing have changed substantially over the last twenty years. Most are environmentally benign and are found in many household products. Chemicals commonly used in hydraulic fracturing are available on the DMIRS website[26]. In accordance with Regulation 15(9) of the *Petroleum and Geothermal Energy Resources (Environment) Regulations 2012,* fracture fluid composition is fully disclosed in public Environment Plan summary documents and on many company websites.

Pioneers of new hydraulic fracturing methods in Alberta, Canada, have introduced a new method to eliminate water use. A gel made from propane (a naturally present hydrocarbon already naturally present underground) and a combination of relatively benign chemicals (such as magnesium oxide and ferric sulphate) has been used successfully in hydraulic fracturing 2,500 times in 700 US and Canadian wells[27].

Other initiatives include the development of "green" fracturing fluids such as Halliburton's CleanStim and Condor Friction Reduced Water System discussed further in section 5.4 below.

5. Regulatory Context

The regulation of most onshore oil and gas activities in Western Australia is governed by the *Petroleum and Geothermal Resources Act 1967* which is administered by the DMIRS. In addition, the various other pieces of legislation and agencies involved in regulation of hydraulic fracturing activities are specified in a *Guide to the Regulatory Framework for Shale and Tight Gas in Western Australia: A Whole-of-Government Approach*'[28]. The information is this section is consistent with the Panel's own report on the state of the regulatory framework.[29]

5.1. Petroleum and Geothermal Energy Resources Act 1967

The *Petroleum and Geothermal Energy Resources Act 1967 (PGERA)* has successfully managed petroleum activities for decades in Western Australia, including the use of hydraulic fracturing for over 50 years. A summary of legislation that applies to oil and gas activities, including environmental protection, safety, health and water legislation, is provided at Attachment 1.[30]

The *PGER (Environment) Regulations 2012* (referred to as the 'Environment Regulations') contain the provisions for environmental approvals for onshore oil and gas activities. The *PGER (Resources Management and Administration) Regulations 2015* articulate requirements for operators relating to well

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[26] Department of Mines and Petroleum, Petroleum information sheet – Chemicals used in hydraulic fracture stimulation. Available at: http://www.dmp.wa.gov.au/Documents/Petroleum/PD-SBD-NST-108D.pdf

[27] National Geographic, Gas Fracking? 5 Technologies for Cleaner Shale Energy, 2014. Available at: https://news.nationalgeographic.com/news/energy/2014/03/140319-5-technologies-for-greener-fracking/

[28] Department of Mines and Petroleum, *Guide to the Regulatory Framework for Shale and Tight Gas in Western Australia: A Whole-of-Government Approach 2015 Edition*, October 2015.

[29] Government of Western Australia, Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia 2017, The Regulatory Environment, 2017. Accessed via: https://frackinginquiry.wa.gov.au/sites/default/files/3_regulatory_environment.pdf. Viewed 27 February 2018.

[30] Including, amongst others, the Petroleum and Geothermal Energy Resources (Occupational Safety and Health) Regulations 2010, the Health Act 1911 and the Rights in Water and Irrigation Act 1914.

integrity, field development and data reporting. The Regulations are objective-based and risk-based. This encourages the adoption of leading practice environmental management systems and continuous improvement management strategies to ensure environmental impacts and risks are acceptable and reduced to ALARP.[31] This facilitates continuous improvement through ensuring environmental performance is monitored and maintained with the appropriate management controls and practices implemented as new technology and information becomes available.

The primary instruments for regulating petroleum activities are the Environment Plan, Safety Case, and Well Management Plan. These guide consultation across government agencies associated with the regulation of hydraulic fracturing. Continuous improvement and innovation of regulation and industry practice will ensure that the environment and safety remain at the forefront of risk management. In 2015, the Legislative Council's inquiry into hydraulic fracturing found that the former Department of Mines and Petroleum had assessed and strengthened its regulatory framework for onshore gas exploration.[32]

5.2. Whole-of-Government approach to shale and tight gas in Western Australia

Western Australia's regulatory framework is structured so that various agencies contribute to a holistic assessment of the impacts of activities and application of management strategies. Recognising the need to increase the visibility of this framework, in 2015, the DMP developed the *Guide to the Regulatory Framework for Shale and Tight Gas in Western Australia: A Whole-of-Government Approach*'[33]. This document clarifies the interaction between various agencies involved in regulating hydraulic fracturing.

Further formal interactions with DMIRS are articulated in agreements with the following agencies:

- Environmental Protection Agency Memorandum of Understanding
- Department of Environment Regulation Administrative Agreement
- Department of Parks and Wildlife consultation
- Department of Health Agreement
- Radiological Council Memorandum of Understanding
- Department of Water Administrative Agreement
- Department of Aboriginal Affairs Memorandum of Understanding
- Western Australian Planning Commission and the Department of Planning Memorandum of Understanding[34].

A number of agencies are involved in assessing and determining an activity proposal. It is important that this inquiry takes account of these interactions when considering the effectiveness of the regulatory

[31] Department of Mines and Petroleum, Guideline for the Development of Petroleum and Geothermal Environment Plans in Western Australia, November 2016. Accessed: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-177.pdf
[32] http://www.dmp.wa.gov.au/Documents/Petroleum/Report42-HydraulicFracturing_UnconventionalGas.pdf - Findings 2.
[33] Department of Mines and Petroleum, *Guide to the Regulatory Framework for Shale and Tight Gas in Western Australia: A Whole-of-Government Approach 2015 Edition*, October 2015.
[34] Department of Mines and Petroleum, *Guide to the Regulatory Framework for Shale and Tight Gas in Western Australia: A Whole-of-Government Approach 2015 Edition*, October 2015, pp 21-24.

framework. Further information on regulatory responsibilities across government, which builds on the materials released by the Independent Scientific Panel[35], is provided at Attachment 1.

The regulatory framework for shale and tight gas in Western Australia is aligned with a similar British model. In the UK, the Oil and Gas Authority is the lead agency for shale and tight gas – it issues Petroleum Exploration and Development Licenses and works with other agencies such as the Environment Agency, local authorities and the HSE Executive to assess the risk of activities. There is no specific or separate licensing regime for shale gas exploration that may involve hydraulic fracturing.[36]

5.3 Review of shale and tight gas regulation in Western Australia

An independent review of the regulatory framework was conducted in 2011 by Dr Tina Hunter, one of Australia's leading legal experts on petroleum legislation.[37]

This Review considered the state of Western Australia's regulations and their ability to manage tight and shale gas operations. It concluded:

> *"The Hon. Norman Moore, Minister for Mines and Petroleum, stated that WA has stringent regulatory processes in place to ensure that industry development of shale gas resources will be done so in a responsible and sustainable way. This assessment of the regulatory processes as sustainable and responsible is accurate. However, there are concerns regarding the integrity of the legislative framework that underpins the processes. In short, the legislative regime for resource and environment lacks legal enforceability, attributable to the absence of resource management regulations and environment regulations under the PAGERA"[38].*

Dr Hunter's recommended improvements to legal enforceability were addressed by establishing new regulatory instruments[39]. These measures increased the requirements on petroleum operators, for example in relation to reporting (which is used by DMIRS to monitor industry performance) and a requirement for full public disclosure of hydraulic fracturing chemicals on the DMIRS website.

5.4 The Commonwealth's approach to developing unconventional gas resources

The Australian Government has taken a lead role in developing a strategic framework for the responsible development of an unconventional gas industry, with annual reports to the COAG Energy Council on the progress of implementation[40]. It has worked to improve gas markets; engage communities in understanding that risks and environmental impacts can be managed; build confidence that community needs and expectations will be properly considered; and set up an industry growth centre, National Energy Resources Australia.

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[35] Government of Western Australia, Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia 2017, The Regulatory Environment, Viewed 27/02/2018, Accessed via: https://frackinginquiry.wa.gov.au/background-papers.
[36] United Kingdom, Department of Energy and Climate Change, *Onshore oil and gas exploration in the UK: regulation and best practice: England*, December 2013, pp 6-7.
[37] Dr Tina Hunter, University of Queensland, *Regulation of Shale, Coal Seam and Tight Gas Activities in Western Australia*, July 2011.
[38] Tina Hunter Review p4
[39] Dr Tina Hunter, University of Queensland, *Regulation of Shale, Coal Seam and Tight Gas Activities in Western Australia*, July 2011.
[40] http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/GSS%20Implementation%20Plan%20-%20revised%20Aug%202017.pdf)

APPEA supports the collaborative efforts being undertaken to extend the CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA) across Australia. This successful model can supplement the efforts of regulators and operators to build community confidence by providing independent research.

GISERA provides quality-assured scientific research and information to communities living in gas development regions focusing on social and environmental topics including: groundwater and surface water, biodiversity, land management, the marine environment, human health impacts and socio-economic impacts. Its governance structure is designed to ensure full research independence and transparency of research outputs.

5.5 Western Australian Parliamentary Inquiry

After two years of investigation, the Western Australian Legislative Council's Environment and Public Affairs Committee delivered the results of its *Inquiry into the Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*[41] in 2015.

The Committee made 51 findings and 12 recommendations, including that hydraulic fracturing poses negligible risk to underground aquifers or seismic events. The report broadly supports the regulatory framework in Western Australia for hydraulic fracturing activities[42].

These findings align with many other Inquiries and Reports that concluded the risks associated with hydraulic fracturing can be managed effectively.

Outlined below are industry responses to the recommendations made by the Parliamentary Inquiry most relevant to the terms of reference of the current scientific inquiry[43]:

Recommendations	Industry Response
Recommendation 9: Resource companies in Western Australia be encouraged to explore the recycling of wastewater during hydraulic fracturing operations, where practicable.	Where practicable, industry operators conserve water. For example, flowback fluid is reused in hydraulic fracturing to reduce the amount of water obtained from groundwater sources. Case studies in this submission illustrate this.

[41] Legislative Council Western Australian, Thirty-Ninth Parliament, *Report 42 Standing Committee on Environment and Public Affairs: Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015.

[42] The following findings support regulatory and policy direction and are relevant to this Inquiry: Finding 2, Finding 3, Finding 9, Finding 11, Finding 12, Finding 13, Finding 15, Finding 16, Finding 22, Finding 23, Finding 24, Finding 26, Finding 28, Finding 29, Finding 30, Finding 31, Finding 32, Finding 33, Finding 34, Finding 35, Finding 36, Finding 37, Finding 38, Finding 39, Finding 40, Finding 42, Finding 45, Finding 46, Finding 50.

[43] As obtained from the Legislative Council Western Australian, Thirty-Ninth Parliament, *Report 42 Standing Committee on Environment and Public Affairs: Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015

	There is an additional benefit to operators in reusing flowback water, as it reduces the volume of flowback water requiring disposal.
Recommendation 10: Baseline monitoring of aquifers and the subsequent publication of this data be a mandatory condition of all approvals for hydraulic fracturing operations in Western Australia.	Baseline monitoring of groundwater is a pre-requisite and industry standard practice for hydraulic fracturing and associated activities. Baseline groundwater monitoring undertaken by industry is guided by the *Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry Guidelines*[44] jointly developed by DMIRS and Department of Water.
Recommendation 12: Any future consideration of hydraulic fracturing for unconventional gas in Western Australia be based on established facts, ascertained through baseline data and monitoring, with a view to strengthening the industry's social licence to operate.	Industry operators collect baseline data and undertake monitoring on various environmental aspects such as land, air, water and social surrounds under various legislative mechanisms. This baseline data not only helps industry better understand the local environment to tailor appropriate operational and management practices, but also provides Government Departments with local information that may not be already known.

5.6 The Northern Territory Inquiry into Hydraulic Fracturing

The Draft Final Report[45] of the Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory was released on 12 December 2017. The Chair of the Inquiry, Hon. Justice Pepper noted:

> *"The overall conclusion of the Report is that risk is inherent in all development and that an onshore shale gas industry is no exception. However, if the recommendations made in this draft Report are adopted and implemented in full, those risks may be mitigated or reduced – and in many cases eliminated altogether – to acceptable levels having regard to the totality of the evidence."*[46]

The Report contains over 30 draft recommendations relating to regulation in the Northern Territory (NT). While recommendations are specific to the NT, many reflect existing best practice in jurisdictions such as

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[44] Department of Mines and Petroleum and Department of Water, Guidelines for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry, August 2016, Viewed 27 February 2018. Accessed via: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-040.pdf

[45] See: https://frackinginquiry.nt.gov.au/inquiry-reports/draft-final-report

[46] https://frackinginquiry.nt.gov.au/news/community-update-26

Western Australia and South Australia. For example, the recommendation to incorporate well integrity and resource management into subordinate regulations aligns with Western Australia's framework.

APPEA has consistently supported a similar approach in the NT, including with the introduction of the NT's *Petroleum (Environment) Regulations 2016*. This transferred environment-specific measures from prescriptive schedules into the new Regulations. Additional changes included introduction of ecologically sustainable development (ESD) principles; a requirement to publish summary environment plans and chemicals; and, enhanced stakeholder engagement and transparency.

APPEA's responses[47] to the Report and subsequent individual responses from our members, in particular from Origin[48] and Santos[49], accept or support with clarification the overwhelming majority of the Inquiry's recommendations. However, a few recommendations, on the basis of the evidence considered, go beyond what industry considers to be best practice and cause industry significant concern. These are primarily recommendations that are either too prescriptive or open up NT petroleum activities to potentially frivolous and vexatious legal challenge. Industry responses address these recommendations and, where appropriate, suggest amendments to improve their practical implementation.

As with Western Australia's experience, the NT has maintained a process of continuous improvement for the regulatory framework, with the current effort focused on two stages.

- Stage 1 reforms environmental impact assessments and introduces an environmental approval to be issued by the Minister for Environment and Natural Resources. This stage is also changing the Northern Territory Environment Protection Authority Act to improve the accountability of the NT EPA and to further define its role in the environmental management system.
- Stage 2 will transform the Waste Management and Pollution Control Act into an Environmental Protection Act, including provisions of the Mining Management Act. This stage will also consider and address duplication in the environmental management system.

Reforms to the NT's environment protection framework are expected to incorporate many of the features of Western Australia's framework, including those relating to matters such as water extraction.

5.7 Opportunities for regulatory reform

A risk-based regulatory framework for petroleum activities in Western Australia encourages continuous improvement in order to reflect contemporary regulatory standards and community expectations.

Opportunities for refinement exist in categorising petroleum operations into high, medium and low-risk activities based on the levels of operational and environmental risk. Under such an approach, high-risk activities would be subject to greater scrutiny (assessment, audits et al) than low-risk petroleum activities. The South Australian regulator has adopted this approach for petroleum activities. This would allow the regulator to focus its efforts on activities with higher risks.

Standard approaches or procedures may also be developed for activities undertaken using standard industry approaches with known risks. These standard approaches would be similar to the reference cases concept currently being developed by NERA to help the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) enhance transparency in assessment processes and

[47] See submissions #623 and #1251 available at: https://frackinginquiry.nt.gov.au/submission-library
[48] See submissions #544 and #1248 available at: https://frackinginquiry.nt.gov.au/submission-library
[49] See submissions #629 and #1249 available at: https://frackinginquiry.nt.gov.au/submission-library

reduce the regulatory and consultation burden. For example, reference cases could be developed for low-risk activities such as airborne surveys and applied regionally. Published reference cases would provide increased transparency regarding environmental risks and mitigation measures.

Onshore operators in WA would also support the compulsory collection of groundwater monitoring data before and after hydraulic fracturing is undertaken.

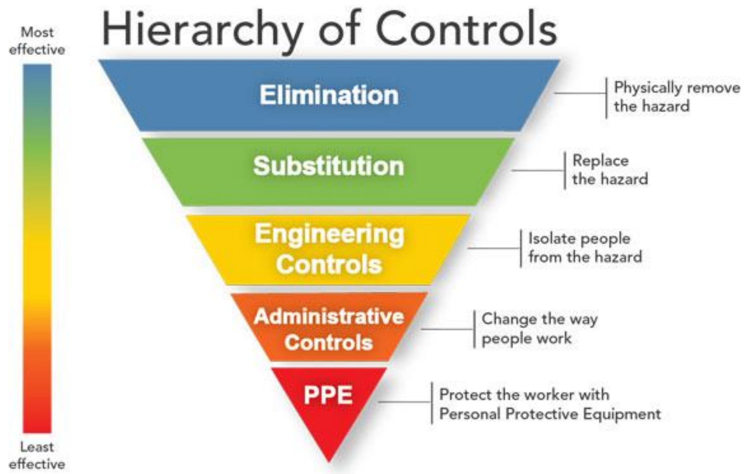
Monitoring programs should be undertaken in accordance with the DMIRS-DWER Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry, August 2016.

6 Potential Impacts and Mitigation

All industries have impacts and risks, although management practices can vary. Western Australia's oil and gas industry has a mature understanding of management practices that facilitate safe and responsible activities.

The 'Hierarchy of Controls' system – used across many industries to determine how to implement feasible and effective control solutions – is a common component of oil and gas risk mitigation. As noted by the US Centre for Disease Control, "the idea behind this hierarchy is that the control methods at the top of graphic are potentially more effective and protective than those at the bottom. Following this hierarchy normally leads to the implementation of inherently safer systems."[50]

Figure 5 - Hierarchy of Controls Pyramid[51]



This hierarchy framework is used to ensure that risks are managed to a level that is as low as reasonably practicable (ALARP) and acceptable in line with regulatory (legislative, policy and guidance) requirements and industry best practice. The primary aim is to eliminate where possible, or minimise the potential for environmental impacts over the duration of the activity.

Systems to mitigate risk are detailed in a company's Environment Plan (EP), in line with the requirements under the Environment Regulation which are described in the DMIRS '*Guideline for the Development of Petroleum and Geothermal Environment Plans in Western Australia 2016*'.[52]

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50 https://www.cdc.gov/niosh/topics/hierarchy/
51 https://www.cdc.gov/niosh/topics/hierarchy/
52 http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-177.pdf

The Environment Plan must detail the method and outcomes of a comprehensive environmental risk assessment, including the sources of risk and their associated impacts for both planned (routine) activities and unplanned (accident/incident) events. This must include accounting for worst-case scenarios, to ensure that management controls are capable of addressing accidents, incidents and emergency response. The Environment Plan is used to detail the controls to be used to manage any residual risk. The regulator will assess the Environment Plan and approve the activity if the risk management approach and the activity impacts are deemed acceptable.

Once an EP has been approved, making an operational change requires submitting a revised Environment Plan to DMIRS for approval. Changes to an activity may be needed because of equipment availability, seasonal variations, and approval conditions or other reasons.

This section provides an overview of the potential impacts of hydraulic fracturing and management systems applied to mitigate risk to ALARP and acceptable levels.

A detailed summary of legislation and specific management measures is provided at Attachment 1.

6.1 Key points

In summary, the key points made in this section are as follows.

Land:

- Effective industry management practices are applied to reduce the potential impacts on land to a level acceptable by the regulator.
- Hydraulic fracturing and associated activities do have potential impacts to land, as do all other industries.
- Oil and gas industry technology and practices have significantly evolved over the years, ensuring the industry meets safe and responsible resource development objectives.
- Research undertaken by oil and gas companies contributes to an improved understanding of the local environment.

Air:

- Effective industry management practices are used to reduce the potential impacts to air to levels considered acceptable by the regulator.
- Hydraulic fracturing and associated activities have potential impacts do exist, as do all other industries.
- Oil and gas industry technology and practices have significantly evolved over the years, ensuring the industry meets safe and responsible resource development objectives.

Water:

- Conserving and protecting groundwater and surface water is a high priority in all oil and gas activities.
- All surface activities that could potentially affect water resources are regulated and controlled.
- Studies and decades of experience show the risk of groundwater and surface water contamination is very low.

- When a well reaches the end of its life, it is decommissioned (plugged and abandoned). This is done to a high standard to ensure long-term containment and isolation from geological formations.53
- Oil and gas industry technology and practices have significantly evolved over the years, ensuring the industry meets safe and responsible resource development objectives.

Social surrounds:

- Effective industry management practices are used to reduce the potential impacts on social surrounds to a level acceptable by the regulator and the local community.
- Hydraulic fracturing and associated activities have potential impacts, as do all other industries.
- Oil and gas industry technology and practices have significantly evolved over the years, ensuring the industry meets safe and responsible resource development objectives.
- Stakeholder consultation and engagement is not only a legislative requirement but is recognised by industry as an important aspect of oil and gas operations.
- Hydraulic fracturing and associated activities are unlikely to induce significant seismicity.

6.2 Land impacts

TERRESTRIAL ENVIRONMENT

While exploration permits can cover large geographic areas, the actual footprint of an activity is relatively small.

The industry aims to minimise adverse environmental impacts to terrestrial ecosystems by conserving and protecting – and, where the opportunity exists, enhancing – the biodiversity values and water resources.

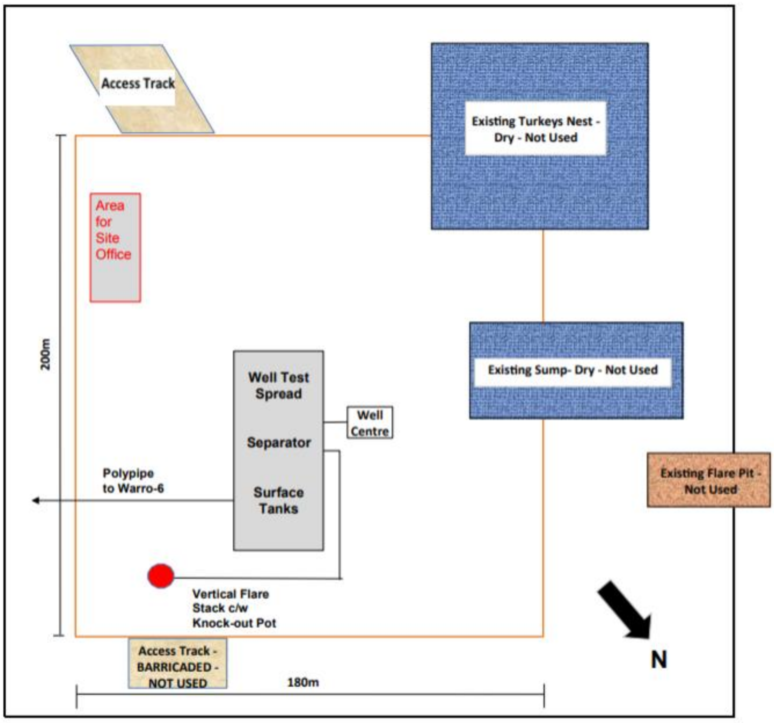
Where potential impacts are identified, appropriate mitigation measures and/or offsets are implemented. These measures seek to protect high biodiversity values and reduce risks and potential impacts to acceptable levels across the diverse terrestrial, aquatic, coastal and marine ecosystems.

Industry estimates that a well pad, including pipeline connections and access roads, is likely to disturb an area of approximately 14 hectares (0.14km^2). Based on a forecast of about eight well pads within a development area, Buru Energy estimates the total disturbance over the life of a project is approximately 100 hectares[54].

A typical site layout for a drilling operation in the Mid West is illustrated below.

[53] Report into the shale gas well life cycle and well integrity, CSIRO. December 2017.
[54] Buru Energy (2018). Buru Energy Submission to the Scientific Inquiry into Hydraulic Fracture Stimulation in Western Australia (Draft).

Figure 6 - Site layout for a Mid West operation[55]



Impacts to the terrestrial environment are addressed in the Environment Plan. In some cases, additional approvals are required, including from multiple agencies. A significant focus of the Environment Plan is the Oil Spill Contingency Plan (OSCP). The OSCP identifies the potential sources of spills of oil and other hazardous materials and provides worst-case scenarios to ensure the management practices applied are capable of managing a major spill incident.

The oil and gas industry uses a host of mitigation measures and practices to minimise and/or eliminate risks of activities affecting terrestrial ecosystems. Examples of industry practices have been provided below in Attachment 1. Generally speaking, existing cleared areas will be utilised if available. If clearing of activity areas is required, it will be limited to the area operationally required as clearing a larger area would carry a higher cost (with no operational benefit).

As an example of industry practice ensuring impacts are minimised, cleared areas that are no longer required for operational purposes are progressively rehabilitated to a state agreed with the landholder. Rehabilitation strategies are typically based on assisted natural regeneration, which combines natural regeneration from locally collected native seed and soil, to enhance germination success.

Once hydraulic fracturing activity is complete, the majority of equipment is removed from the site. This reduces the size requirements of the well site from around 6 hectares down to around 3 hectares.

[55] https://ace.dmp.wa.gov.au/ACE/Public/PetroleumProposals/ViewPlanSummary?registrationId=59982

BIODIVERSITY

Western Australia is a unique environment and home to many significant flora and fauna species. Companies are required to identify these species before commencing oil and gas activities. As mentioned above, where possible, vegetation clearing is avoided or at least kept to the minimum required for operational needs.

The operator undertakes baseline flora and fauna studies of the proposed area. This is done to guide planning of the activity, to avoid areas where priority species and rare flora exist (when necessary). Appropriate management practices are implemented to minimise overall impacts on biodiversity.

These baseline studies are developed using desktop and on-ground flora and fauna investigation of the proposed well sites and access tracks, and are undertaken by suitably qualified and experienced environmental scientists.

The clearing permit approval process for petroleum activities is the same that applies to other land development applications and proposals such as clearing for agriculture, urban development, infrastructure, and mining.

This information informs development of the Environment Plan for the activity, including detailed assessment of biodiversity and appropriate management practices. Management practices adopted by industry operators will vary depending on location and presence of flora and fauna species.

Given the unique environment at locations of oil and gas activities across Western Australia, Environment Plans are developed by industry and assessed by the regulator on a case-by-case basis to determine the acceptability of the proposed management practices for a specific location. An Environment Plan will not be approved unless the entire plan is deemed acceptable by the regulator.

Case study – Buru Energy Ltd: Bilbies in the Yulleroo Region[56]

The greater bilby (*Macrotis lagotis*) is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act* 1999 and the *Biodiversity Conservation Act* 2016, and is known to inhabit the Yulleroo region in the Canning Basin. In 2012, Buru Energy recognised that little was known about bilbies in the Canning Basin and began collecting information on the presence of bilbies in the Yulleroo area.

Given the lack of ecological information for the bilby in the Canning Basin, to inform risk assessments as well as generally, Buru Energy then supported a PhD project as Murdoch University on the disturbance ecology of the greater bilby. The PhD project was undertaken between February 2014 and December 2017 and collected fundamental ecological information for bilbies in the Canning Basin.

The project also involved collaboration with Traditional Owner ranger groups to ensure knowledge regarding bilbies is directly passed on to these groups.

[56] Buru Energy, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan, Revision 4, Document number HSE-PLN-017, 6 June 2014.

Buru Energy placed no restrictions on publication of the results to ensure that the results of the study are available to all stakeholders. The PhD thesis provides important ecological information that will be critical for understanding the response of bilbies to natural and anthropogenic disturbance and minimising impacts of our activities and those of other landholders on bilbies. The PhD thesis[57] was submitted for review in December 2017 and accepted with minor revisions in March 2018.

In addition, a fine-scale monitoring program was implemented to detect any project-attributable impacts on bilby burrows. Fine-scale monitoring involves sampling over weeks and is effective for detecting short term impacts on a fine spatial scale. The studies found no evidence that Buru's activities had impacted the bilby population.

BENEFICIAL USE

Companies are committed to working with landowners to minimise disruption and maximise coexistence, including by locating operations in areas of least impact. Many companies use sensitivity mapping and landscape management guidelines to plan the location of infrastructure, taking into account the landscape's biodiversity values.

Operators engage with landowners to understand the existing land uses, the timing of these activities and their potential interactions with petroleum operations. This engagement with landowners is used to guide operational plans and minimise impacts on the property.

Landowner agreements set boundaries on farming and petroleum activities to help minimise operational impacts and to ensure compliance with work, health and safety legislation. These agreements typically outline requirements such as closure of gates, adequate fencing around well sites to prevent fauna access, quarantine and weed control programs.

As part of land use discussions, landowners and operators discuss rehabilitation and related issues, such as post-activity land use, the desired condition of the land, and any beneficial use of infrastructure. Often landowners request that some infrastructure aspects installed by the operator remains after rehabilitation (for example, water bores, well pads/hard stands) so it may be used for future needs. Where there is no specified requirement, the operator will return the land to the pre-disturbed state.

Ongoing consultation between the landowner and industry is standard industry practice; APPEA member companies use it to minimise impacts to landowners.

WA Land Access Model Agreement

Petroleum titleholders typically engage with affected groups to plan their activities. Under the *Petroleum and Geothermal Energy Resource Act 1967*, oil and gas companies operating Western Australia must:

- negotiate with identified Native Title bodies;
- notify landowners and lessees of proposed activities;
- gain the written consent of private landowners; and

57 Dawson, S.J. (2017) Disturbance of ecology of the greater bilby (*Macrotis lagotis*). PhD Thesis, School of Veterinary and Life Sciences, Murdoch University (submitted).

- provide compensation for private landowners.

APPEA has worked with WA Farmers, Pastoralists and Graziers Association of WA, and Vegetables WA to develop a supplementary land access model agreement. This framework accommodates the rights and priorities of both farmers and explorers operating in the Mid West.

6.3 Air Impacts

GREENHOUSE GAS EMISSIONS

Increased use of hydraulic fracturing presents a major opportunity to reduce greenhouse emissions.

Natural gas produces energy that is cost-effective and lower in emissions. Gas-fired power generation can be matched with solar and wind plants to provide cleaner energy into the grid when the sun is not shining or the win is not blowing.

In Queensland, the development of the gas industry along with the associated power infrastructure to service it now means the solar plants can be set up in regional Queensland and piggyback off this same power infrastructure and therefore connect them to the grid, ultimately making solar more viable. In the US, rising shale gas production has had an enormous impact, cutting emissions and boosting the economy as industry and consumers switched from coal to gas.

Measurement of emissions

The onshore gas industry across Australia, including Western Australia, measures, reports and accounts for all of its greenhouse gas emissions, through the *National Greenhouse and Energy Report Act 2007* (NGER Act), which established the National Greenhouse and Energy Reporting Scheme (NGERS)[58], and associated *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (NGER Determination)[59].

The NGER Determination provides methods and criteria for calculating greenhouse gas emissions and energy data under the NGER Act and the *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines* (NGER Technical Guidelines)[60]. These are designed to assist reporters to understand and apply the NGER Determination. The NGER Technical Guidelines outline calculation methods and criteria for determining greenhouse gas emissions, energy production, energy consumption and potential greenhouse gas emissions embodied in natural gas.

Emissions from all stages of onshore production, supply and use are reported by the Department of the Environment and Energy (DOEE) in Australia's *National Greenhouse Accounts*[61]. Estimates of fugitive

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[58] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/nger for more information. NGERS is administered across Australia, including in the Northern Territory, by the Clean Energy Regulator. For information about the Regulator's administration of NGERS, see www.cleanenergyregulator.gov.au/NGER/About-the-National-Greenhouse-and-Energy-Reporting-scheme.
[59] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/nger/determination for more information.
[60] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/nger/technical-guidelines for more information.
[61] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/tracking-emissions for more information.

emissions of methane during onshore gas extraction activities are based on facility level data submitted by companies through NGERS which include fugitive emissions from gas exploration, production and processing, venting and flaring. The emissions estimation methods used in the *National Greenhouse Accounts* are subject to independent review each year by an external Expert Review Team selected by the United Nations Framework Convention on Climate Change (UNFCCC)[62].

DOEE reviews these emissions estimation methods to take account of the latest developments in Australia and overseas. In undertaking these reviews, DOEE consults with stakeholders in Australia, and monitors scientific developments and technical improvements to other countries' emissions reporting methodologies.

Improvements to the measurement and reporting on greenhouse gas emissions from onshore gas development, including in relation to fugitive emissions, have been the focus of ongoing work by DOEE and CSIRO since 2012.

This work has led to the publication of numerous reports, based on both desktop and field research, which in turn have further refined the emissions factors used in NGERS and its reporting framework.

As part of this work program, five key reports have been released:

- *Review of literature on international best practice for estimating greenhouse gas emissions from coal seam gas production*, August 2012[63]: Pitt & Sherry reviewed international best practice in methods for the estimation of fugitive emissions from coal seam gas (CSG) extraction.
- *Review of methods for the estimation of greenhouse gas emissions from diffuse sources associated with unconventional gas fields*, August 2013[64]: Pitt & Sherry conducted a literature review of methodologies that can be used to determine fugitive emissions from diffuse sources associated with CSG and other unconventional gas fields, and to assess the potential for using these methodologies for regulatory perspective in Australia.
- *Field Measurements of Fugitive Emissions from Equipment and Well Casings in Australian Coal Seam Gas Production Facilities*, June 2014[65]: over 18 months in 2013 and 2014 DOEE and CSIRO measured fugitive emissions associated with leakage from CSG facilities and well casings. CSIRO concluded in the report that the range of fugitive emission leakage measured was consistent with the emission factor currently used in the NGERS methodology for estimating emissions from equipment leaks.

[62] See unfccc.int/documentation/documents/advanced_search/items/6911.php?priref=600009533#beg for a copy of the most recent UNFCC report for Australia.
[63] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/review-of-literature-coal-seam-gas-production for more information.
[64] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/review-methods-unconventional-gas for more information.
[65] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/csg-fugitive-emissions and www.appea.com.au/media_release/csiro-report-points-to-environmental-benefits-of-csg for more information.

- *Methane emissions from CSG well completion activities*, May 2017[66]: the aim of this study was to measure fugitive methane emissions from well completion and workover activities at both hydraulically fractured and non-fractured wells to help develop Australian-specific emission factors for these operations. The study found fugitive emissions from well completion events in CSG fields are significantly lower than is currently provided for in the National Greenhouse Gas Inventory (NGGI).

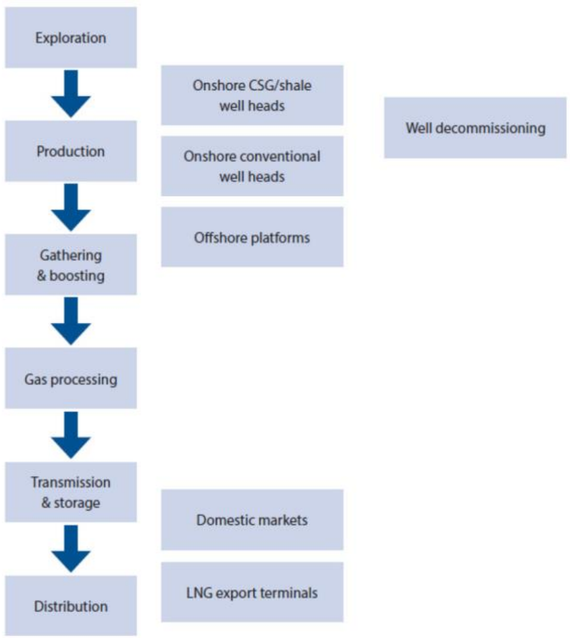
- *Update on recent empirical evidence on fugitive emissions from the gas industry*, June 2017[67]: DOEE has supported empirical research into fugitive emissions of methane from Australian CSG fields since 2013. The estimation methods used for Australia have been updated in light of this new evidence for Australian CSG fields. DOEE has also updated estimation methods for Australia drawing from recent relevant US experience where gaps in the Australian data exist.

Estimation methods used for Australia have been updated in light of new evidence for Australian CSG fields and the new evidence of emissions from US gas systems more generally. The new estimation method updates for the NGGI mainly concern the treatment of leakages. Few updates were implemented for the estimation of emissions from equipment vents or from flaring activity for this inventory.

The changes to the treatment of leakages stemmed from the separation of gas production processes identified by the IPCC Guidelines into new sub-categories used by the US EPA. Further, more explicit, methods have been provided that identify emissions from more components of the gas supply chain.

The major sub-categories of fugitive emission sources are highlighted below.

Figure 7: Emission estimation segments for the gas supply chain



Source: Department of the Environment and Energy (2017)

[66] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/methane-emissions-csg-well-completion-activities and www.appea.com.au/media_release/low-methane-emissions-from-csg-well-completions-new-csiro-report more information.
[67] See www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/fugitive-emissions-update for more information.

Most relevant for the Inquiry, DOEE's report concludes the "*new methods have led to emission estimates for Australia that are broadly consistent with outcomes reported for the United States by the US EPA, while also taking into account data from Australian empirical evidence and industry conditions." (Update on Recent Empirical Evidence on Fugitive Emissions - Page 10)*.

The DOEE has noted that there are now available numerous national 'top-down' studies based on satellites, flux towers and aircraft measurements for the US that broadly support the US EPA inventory estimate prepared using 'bottom up' emission factor approaches of around **1.4%** loss of gas throughput. The estimate for Australia, using data from the NGGI – that incorporated updated methodologies in 2017 – and supported by CSIRO research, is **0.5%**, much lower than the US.

Emissions limits are set for the onshore (and offshore) gas industry through the Emissions Reduction Fund (ERF) Safeguard Mechanism.

The Emissions Reduction Fund safeguard mechanism, set out in the *NGER* Act, sets baselines for facilities emitting over 100,000 tonnes of carbon dioxide-equivalent greenhouse gas emissions (100kt CO_2-e) each year, and requires emitters to keep emissions under those baseline levels[68]. Baselines are set by the Clean Energy Regulator.

All of Australia's major onshore gas facilities, offshore gas facilities and LNG facilities are covered by the ERF's safeguard mechanism. Under the safeguard mechanism, a full list of facilities for which baselines have been established is publicly available from the Clean Energy Regulator's website[69].

Similarly, any onshore gas facility in Western Australia that emitted over 100kt CO_2-e per year would be covered by the ERF safeguard mechanism and, under the safeguard mechanism, would have a baseline set by the Clean Energy Regulator that it may not exceed.

AIR POLLUTANTS

The available evidence indicates that the potential risks to public health from exposure to the emissions associated with shale gas extraction are low.

Air quality is an important consideration across all phases of a petroleum activity. For instance, building new roads may contribute to increased levels of dust or other particulate matter and facilities and equipment also generate emissions.

Fugitive emissions from natural gas exploration and production discussed above are also relevant to air quality. All of the above potential impacts are considered and mitigated through applied industry practices to eliminate or minimise these impacts to acceptable levels.

[68] See www.environment.gov.au/climate-change/emissions-reduction-fund/about/safeguard-mechanism for more information. The ERF safeguard mechanism is administered by the Clean Energy Regulator. See www.cleanenergyregulator.gov.au/NGER/The-safeguard-mechanism for more information about the Regulator's administration of the mechanism.

[69] See www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/Safeguard-baselines-table for more information.

CASE STUDY – LAUREL FORMATION TIGHT GAS EXPLORATION PROGRAM

During Buru Energy's 2015 frac program, AECOM undertook preliminary air quality monitoring[70]. This involved collecting air samples upwind and downwind of hydraulic fracturing operations. It detected methane at levels only marginally higher than the global average – comparable to what would be found about 200 meters from a cattle feedlot or within 5km of a landfill.

According to Public Health England, available evidence indicates that the potential risks to public health from exposure to the emissions associated with shale gas extraction are low[71].

In 2016, CSIRO completed a report for the NSW Environment Protection Authority into air emissions from gas development in that state. It found ambient emissions concentrations were low and, with certain exceptions, in the range expected for the particular source and the location or processes in that environment[72].

In Australia, particulate matter[73] load naturally fluctuates due to airborne dust, sea salt, and smoke from bushfires. Motor vehicles and off-road engines such as generators, mining, earthmoving equipment and ships are the main source of human-generated particulate matter in Australia. Particles less than 10 micrometres in diameter (one-thousandth of a millimetre) pose health concerns because they can be inhaled and can accumulate in the respiratory system. The use of natural gas results in very low emissions of nitrogen oxides and sulphur dioxide and generates virtually no emissions of mercury, particulates or other solid waste.

The industry measures and accounts for all its emissions, including any fugitive emissions associated with its activities. Operators in Western Australia are legislatively required to provide the regulator with quarterly emissions and discharges reports for each activity. The annual environmental report and/or end of activity report submitted to the regulator also provides information on emissions and discharges, including fugitive emissions data.

CASE STUDY - LATENT WARRO GAS FIELD HYDRAULIC FRACTURING[74]

Atmospheric and soil flux studies

To establish baseline surface gas readings and determine whether there are areas of elevated gas readings due to natural causes, Latent Petroleum, with CSIRO and the University of Western Australia, undertook a widespread soil geochemistry sampling project and installed a long-term soil gas detector at the Warro site.

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[70] Buru Energy (2016). *TGS End of Activity Report* (HSE-REP-094). Revision 1, July 2016.

[71] Public Health England, 2014, *Review of the Potential Public Health Impacts of Exposures to Chemical and Radioactive Pollutants as a Result of the Shale Gas Extraction Process*, A Kibble, T Cabianca, Z Daraktchieva, T Gooding, J Smithard, G Kowalczyk, N P McColl, M Singh, L Mitchem, P Lamb, S Vardoulakis and R Kamanyire.

[72] Day, S., Tibbett, A., Sestak, S., Knight, C., Marvig, P., McGarry, S., Weir, S., White, S., Armand, S., van Holst, J., Fry, R., Dell'Amico, M., Halliburton, B., Azzi, M. (2016). *Methane and Volatile Organic Compound Emissions in New South Wales*. CSIRO, Australia.

[73] Particulate matter refers to everything in the air that is not a gas and is the term for particles found in the air, including dust, dirt, soot, smoke and liquid droplets.

[74] Latent Petroleum Pty Ltd, Hydraulic Fracture Stimulation Monitoring at Warro Project – Mid West, WA, 2018.

This work did not detect any areas of anomalous soil gas readings. The lack of methane also suggests that hydraulic fracturing work at Warro has not rejuvenated any gas migration from natural near-surface faults.

The CSIRO also recorded atmospheric gas levels of methane. Once again, no anomalous readings were recorded.

These results provide valuable baseline information and demonstrate that even though well and fracturing activities had taken place (at Warro-3 and 4) there had been no discernible impact on the soil or atmospheric gases. Latent's submission to the Inquiry Panel provides a detailed analysis of the field results (refer to Appendix C of the Latent submission).

6.4 Water impacts

This section details potential environmental impacts to groundwater, surface water, water quality, and beneficial use.

QUALITY

Groundwater conservation and protection is a priority. Oil and gas wells are designed to standards with multiple failsafe levels of protection that keep all fluids and gas within the well bore. Companies also focus on well integrity management systems, safe handling and use of chemical additives and extensive environmental monitoring.

Maintaining well integrity throughout the life of operations is critical to safety and environmental protection. Wells are routinely inspected and subjected to maintenance operations. The industry regularly monitors wells and remedies any wells that are not functioning to the required standards.

All surface activities that could potentially affect water resources (such as drilling, construction and transport) are strictly regulated and controlled. The use of chemicals and materials on the surface is not unique to the oil and gas industry. Comprehensive regulation and risk management is in place to ensure these chemicals are properly managed.

GROUNDWATER

Independent scientific evaluation has concluded that impacts on groundwater are more likely to occur from surface spills, overflows of containment ponds/tanks or leaks of produced water than from hydraulic fracturing[75]. Mitigating impacts to land from hydraulic fracturing and associated activities also requires taking account of transport, storage and handling of chemicals and other hazardous substances, spillage or leaks of flowback water, soil compaction, and a number of other factors.

[75] https://gisera.csiro.au/more-information/frequently-asked-questions/what-is-shale-gas-in-australia/

A recent report by the CSIRO found that chemicals remaining underground after hydraulic fracturing are unlikely to reach people or groundwater dependent terrestrial ecosystems in concentrations that would cause concern. The impact of any chemicals is therefore likely to be very low[76].

The risk of drilling or fracture stimulation fluids contaminating aquifers is very low because:

- Hydraulic fracturing fluids are 90 to 98 per cent water and sand with only a small proportion of additives.
- Most additives used in hydraulic fracturing fluids are benign.
- The few additives that could, in theory, present a risk to human health or the environment would need to be discharged in large quantities, over a long period, to reach concentrations that could affect the much larger volumes of water present in aquifers. This would require an exceptional failure of preventative measures to occur and continue undetected over a protracted period.
- Thick layers of impermeable rock separate aquifers and oil and gas reservoirs. This isolates the fracture zone from aquifers.

Based on current technology, geological data (including thousands of metres of sealing rock between aquifers and the fracture stimulation targets) and site-specific evaluations and risk assessments, planning can ensure there is very little risk of fracture propagation leading to contamination of shallow aquifers.

Generally, the risks of aquifer contamination from chemicals are assessed on three levels:

1: Concentration and toxicity

Even in the very unlikely event of uncontrolled release of hydraulic fracturing fluid from a petroleum well, the low concentration of chemicals components in the fluid and their overall toxicity would ensure the potential impact on a water source would be minimal.

2: Likelihood that the chemicals remain in the ground

For fracture stimulation operations, 40 to 60 per cent of the stimulation fluids are returned to surface during flowback operations. Fluids not returned typically include proppant (i.e. sand) that is placed within the fractures or organic compounds that become bound within the rock. Over the life of a gas well – which may be decades – the pressure gradient towards the well ensures that any trace chemical additives that may be freed up over time are swept to the well and up to the surface for proper processing.

Further, many of the chemicals used in hydraulic fracturing fluids are readily biodegradable, meaning that they will not persist in the formation for long.

3: Managing stimulation fluid distribution

The volume of stimulation fluid is carefully calculated and monitored to ensure it remains near the well. Typically, there are substantial distances (typically thousands of metres of rock) between a fracture and any

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[76] CSIRO (2017) Deeper groundwater hazard screening for chemicals used in coal seam gas extraction - Overview , http://www.environment.gov.au/system/files/resources/370d0bcd-8fe2-436f-88d7-1c3361ef8cd5/files/deeper-groundwater-hazard-screening-research-overview.pdf

sensitive aquifers, such as those used for domestic or agricultural purposes. This can be monitored (e.g. with seismic technology to verify the models for fluid travel.

The chemicals used in hydraulic fracturing are commonly occurring and used for many applications other than oil and gas extraction[77]. In five technical papers, the CSIRO found that residual chemicals remaining underground after hydraulic fracturing are unlikely to reach people or ecosystems in concentrations that would cause concern. Therefore risks are very low.

Chemical use was one of the key issues examined by the WA Parliamentary Inquiry[78]. The Parliamentary Inquiry made the following recommendations regarding chemicals usage:

- "the Government ban the use of benzene, toluene, ethylbenzene and xylene during any hydraulic fracturing operations"
- "the Department of Mines and Petroleum's policy of public disclosure of chemicals used in any hydraulic fracturing activity be formalised in subsidiary legislation".

Public disclosure of chemicals in hydraulic fracturing has been a regulatory requirement since 2012. All companies voluntarily disclose this information at the time of EP lodgement, beyond the minimum regulatory requirement to make this information publicly available at time of approval[79]. Disclosure requirements, outlined in the DMIRS *Chemical Disclosure Guideline*[80], include toxicity and concentration, material safety data sheets, mass fraction (percentage) in the fluid system and Chemical Abstracts Service Registry Number. DMIRS assesses the environmental risk of these chemicals on a case-by-case basis as part of the EP assessment process. The volume of chemicals used depends on the depth and length of the drill hole, the number of fracture stages, rock chemistry, the required fluid characteristics and other factors.

On the rare occasion that use of BTEX chemicals (benzene, toluene, ethylbenzene and xylene) is sought for an activity, a detailed chemical risk assessment must be provided to the regulator in accordance with the DMP Environmental Risk Assessment of Chemicals used in WA Petroleum Activities Guideline[81].

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[77] Department of Environment. What does fracking fluid contain? http://www.environment.gov.au/system/files/pages/2d9f9167-3826-4d59-8be5-67c8c731fb59/files/what-does-fracking-fluid-contain-factsheet.pdf. In December 2017, the Australian Department of Environment and Energy (DoEE) and the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) released an assessment of chemicals associated with coal seam gas extraction in Australia. This study examined the risks to health and the environment from surface (above-ground) chemical spills. The NICNAS assessment focusses on what it describes as "worst-case" scenarios, which are highly-implausible and assume that all the safety and handling precautions required by law are not used. The NICNAS assessment found the most significant potential risk to public health and the environment was exposure to chemicals after a large-scale transport spill, a risk facing any industry that uses chemicals. The chemicals used for hydraulic fracturing in the CSG industry accounts for less than one hundredth of one per cent of chemicals transported by road in Australia. Extensive regulation of heavy vehicle movements and chemical storage already minimises the risks identified.

[78] Legislative Council Western Australian, Thirty-Ninth Parliament, *Report 42 Standing Committee on Environment and Public Affairs: Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015.

[79] Chemical disclosure requirements are set in the Petroleum and Geothermal Energy Resources (Environment) Regulations 2012 in regulation 15(9) which requires:

The implementation strategy (of and Environment Plan) *must include details of any chemicals or other substances that may be –*

(a) in, or added to, any treatment fluids to be used for the purposes of drilling or hydraulic fracturing undertaken in the course of the activity; or

(b) otherwise introduced into a well, reservoir or subsurface formation in the course of the activity.

[80] Department of Mines and Petroleum, Chemical Disclosure Guideline, Version 2: August 2013. Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-178.pdf

[81] Department of Mines and Petroleum, Environmental Risk Assessment of Chemicals used in WA Petroleum Activities Guideline, Version 1a, August 2013. Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-165.pdf

Ongoing research and development is one component in the industry's continuous improvement in environmental sustainability. One example of this is Halliburton's 'CleanStim AUS' fluid system, which is made entirely from ingredients sourced from the food industry[82].

Ecotoxicity assessments of the Halliburton CleanStim and Condor Friction Reduced Water System were commissioned by Buru Energy, and were undertaken by Ecotox Services Australia. These ecotox tests were undertaken on the juvenile rainbowfish (*Melanotaenia splendida splendid*). Rainbowfish were chosen for the test as they are common in freshwater areas of the Fitzroy River and other Kimberley catchments which assisted with Buru Energy's community engagement.

Both fracture fluids were determined to have extremely low toxicity. For the CleanStim chemical mixture, the fish were unaffected at concentrations of up to 200 mg of the chemicals per litre of water (i.e. the EC_{50} was >200 mg/L, and the NOEC was 200 mg/L). Condor's Friction Reduced Water System was found to have an EC_{50} of 7,100 mg/L and a NOEC of 6,300 mg/L. Under the NICNAS rating system[83], any material with an EC_{50} >100 mg/L and a NOEC >1 mg/L is classified as very slightly toxic, which is the lowest toxicity rating in Australia. Both chemical systems are therefore significantly less toxic than the lowest toxicity rating in Australia.

Further, an environmental chemical risk assessment undertaken in accordance with DMP (DMIRS) guidance found that none of the CleanStim chemicals form carcinogens or teratogens; are not persistent in the environment; and do not bioaccumulate. The risk assessment concluded that the chemical constituents were readily biodegradable or consumed downhole[84].

APPEA recognises the importance of transparency around chemical use. APPEA supports the public release of chemical information as stated in the APPEA Code of Practice for Hydraulic Fracturing[85] and in APPEA's submission to the previous WA Inquiry into hydraulic fracturing[86].

Guideline 4 *Use of Chemicals in Hydraulic Fracturing* of the APPEA Code of Practice for Hydraulic Fracturing contains the following guidance to minimise the use of chemicals, provide clear and accurate information on chemicals that may be used, and promote safe and responsible use of chemicals:

- fluids with the lowest toxicity to be used in hydraulic fracturing, and the concentrations used will be the minimum required to facilitate effective operations
- details of all fluids to be used during hydraulic fracturing operations, including information on actual usage and fluid recovery will be provided to DMP (DMIRS)
- information will include relevant Material Safety Data Sheets and National Industrial Chemical Notification and Assessment Scheme registration details and will be subject to the protections of proprietary or commercially sensitive information available under these schemes

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82 Submission 106 from Halliburton Australia Pty Ltd, 4 October 2013, p5. Available at: http://www.hallibutron.com/en-US/ps/stimulation/fracturing/cleanstim-hydraulic-fracturing-fluid-system.page.

83 Commonwealth of Australia (2013). NICNAS Handbook—a guide for importers and manufacturers of industrial chemicals in Australia. Available at: http://www.ag.gov.au/Copyright/Pages/default.aspx.

84 Buru Energy, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan, Revision 4, Document number HSE-PLN-017, 6 June 2014, p52.

85 APPEA, *Western Australian Onshore Gas: Code of Practice for Hydraulic Fracturing*.

86 Submission 104 from Australian Petroleum Production and Exploration Association, 3 October 2013, Appendix 3.

- operators will support the public release of this information. This will include working with DMP through APPEA to develop a standard process including consideration of a website service such as FracFocus Chemical Disclosure
- all chemicals used for hydraulic fracturing operations will be handled and stored in accordance with appropriate international standards organisations standards, relevant material safety data sheets and state regulatory requirements.

SURFACE WATER

A recent study by the Commonwealth Department of Environment and NICNAS found that "the stringent protective measures imposed by state and territory and Commonwealth governments for industry… significantly reduce the likelihood of potential harm" from chemicals used in drilling and hydraulic fracturing."[87]

Generally, the prevention of impacts on surface water focusses on preventing (and containing) spills of chemicals, fracturing fluid, flowback fluid and any other hazardous substances. The management of water and chemicals at surface is not unique to the oil and gas industry and also features in the mining, agriculture and transport industries.

Hydraulic fracturing operations use water, fracturing fluids, chemical additives and drilling muds, and produces flowback water and drill cuttings. These materials are typically stored in tanks or lined pits to isolate them from soils and shallow groundwater zones.

Industry best practice is to minimise the amount of these materials on site; to contain them as fully as possible; to reuse or recycle to the greatest extent feasible, and responsibly dispose of any residual materials in accordance with regulatory requirements.

Waste management practices are included in the project specific Environment Plan. Many operators also develop detailed waste management plans or procedures covering the handling, treatment and disposal of waste. Industry best management practices are applied to avoid contaminating water supplies, watercourses and bodies of standing water.

QUANTITY

Water management is one of the most significant areas of focus for onshore oil and gas operations.

Australian Bureau of Statistics data shows the volume of water used by the oil and gas industry is considerably lower than in many other sectors, including agriculture and power generation[88]. This data shows that, in 2015-16, an estimated 16,132 gigalitres (GL) was consumed.

The broad extractive industry sector (i.e. mining, mineral processing, oil and gas) accounted for approximately 4 per cent (661GL) of water consumption in 2015-16. The oil and gas industry used 26GL or 0.16 per cent of total Australian water consumption (see Figure 3).

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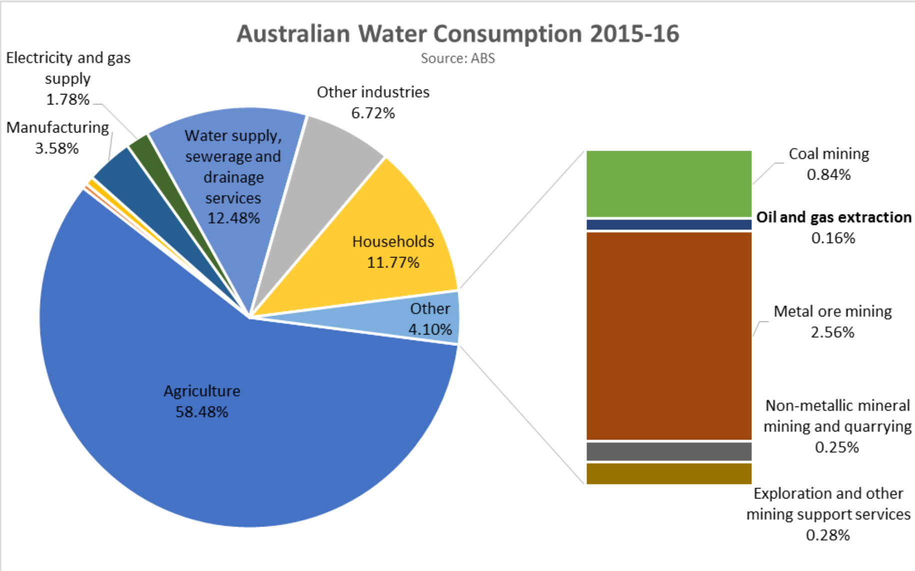
[87] Department of Environment, (2017) National Assessment of Chemicals, p11 http://www.environment.gov.au/system/files/resources/03137f85-1bea-46a4-b9e7-67d985b4aeb5/files/national-assessment-chemicals-overview.pdf

[88] Australian Bureau of Statistics, (2017) *4610.0 Water Account 2015-16.* www.abs.gov.au

Figure 8 - Water consumption by Industry and Disaggregated Mining Sector, 2015-16 (%).



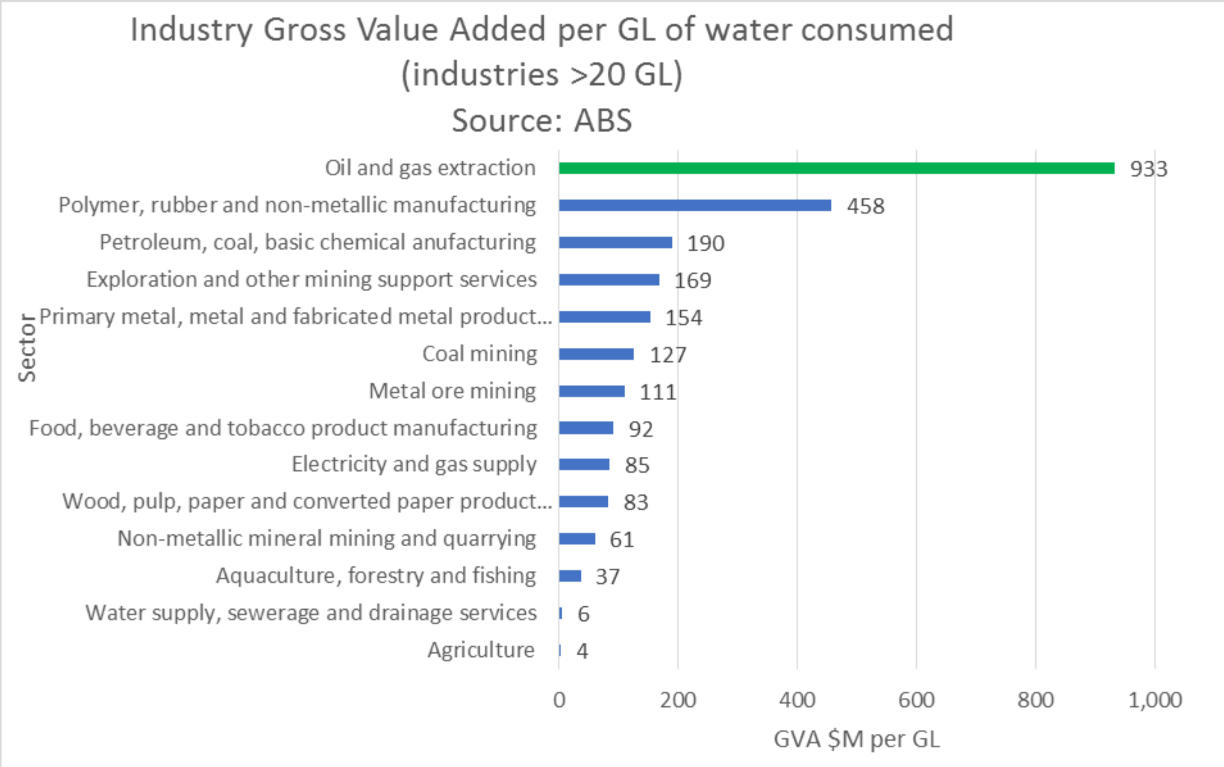
The amount of water used in hydraulic fracturing varies depending on resource and the amount of stages required. An example of quantities required for a fracture treatment is illustrated in the case study below.

The source of water for hydraulic fracturing is an important consideration for industry, particularly in new and remote field locations. Water used in petroleum operations in Western Australia is licenced under the *Rights in Water and Irrigation Act 1914* as administered by the Department of Water and Environmental Regulation (DWER).[89] DWER allocates water use via licences within the sustainable volume available for a groundwater resource. For example, DWER has determined that the Canning-Kimberley groundwater areas has an allocated limit of over 300 GL/year[90], of which less than 10% is currently allocated to various users.

The Australian Bureau of Statistics finds that every gigalitre of water consumed by the oil and gas industry generates over $933 million of value, which is relatively high compared to other industries.

[89] Western Australian Government (2016), Water and the shale and tight gas industry https://www.water.wa.gov.au/__data/assets/pdf_file/0020/7841/109620.pdf
[90] DoW (2014). Water resources inventory 2014: Water availability, quality and trends. Department of Water, WA.

Figure 9 - Industry Gross Value Added per GL of water consumed[91]



CASE STUDY – LATENT PETROLEUM WARRO GAS FIELD HYDRAULIC FRACTURINGWATER MONITORING AND USAGE[92]

Latent Petroleum (now Whitebark Energy) has a detailed understanding of the water resources in its area of operation, as a result of studies to understand the local hydrology and any risk factors, which was updated in 2014 (provided at Appendix A).

The study concluded that *"there will be no impact on the upper Yarragadee groundwater flow system from hydraulic stimulation, provided the well integrity is maintained. Effects of groundwater extraction on the Parmelia aquifer are indicated to be minor and restricted to the project area. Similarly, any leakages from water storages would be localised and could be controlled and contained using a recovery bore or bores"*.

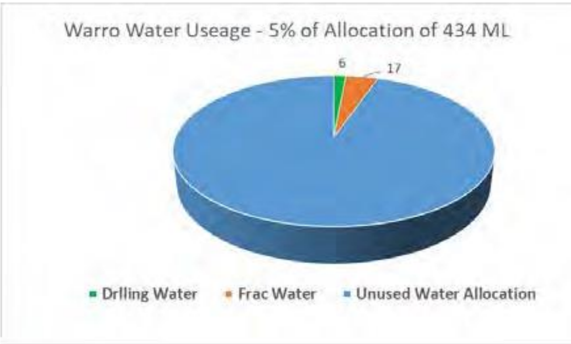
All water used by the Warro project has been extracted from near-surface aquifers under a water licence provided by the Department of Water.

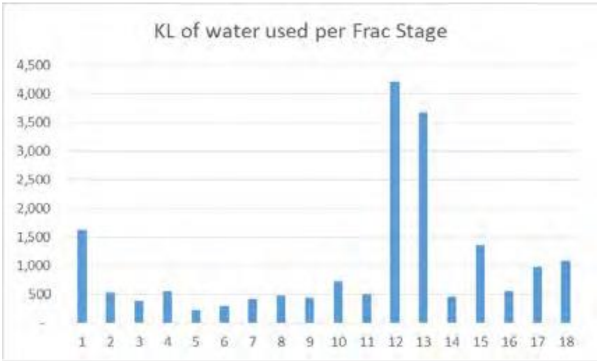
[91] Australian Bureau of Statistics (2007), *An Experimental Monetary Water Account for Australia*, Cat. No. 4610.0.55.005, August

[92] Latent Petroleum Pty Ltd, Hydraulic Fracture Stimulation Monitoring at Warro Project – Mid West, WA, 2018.

Since inception the project has used 23ML of bore water compared with the 430 ML allowed under the water licences.

The average water use has been 0.5ML per fracture stage, with a maximum for any one fracture stage being 4.2ML, as illustrated below:



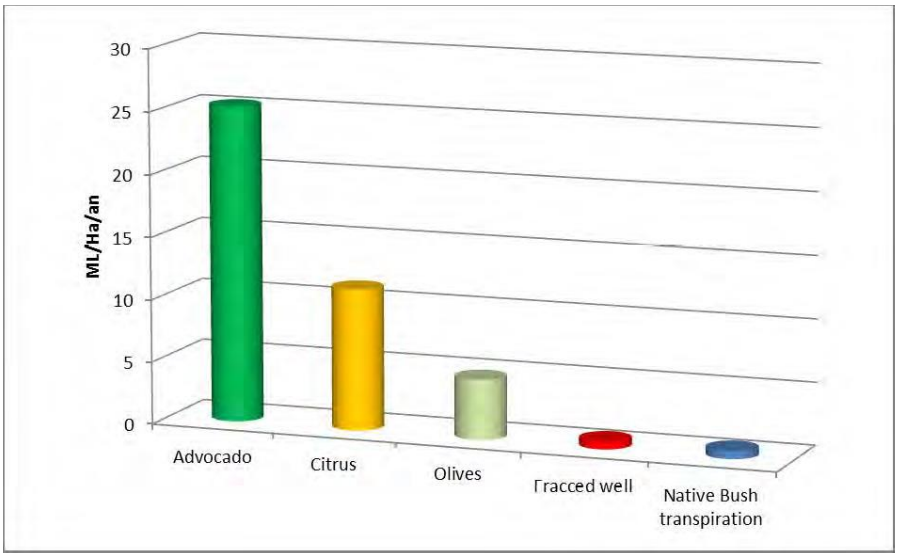


The following information on water usage was sourced by Latent Petroleum from the Department of Agriculture and Food's, *Identification of high quality agricultural land in the Mid West region: Stage 1 – Geraldton Planning Region*, Second edition, Resource management technical report 386:

- Perth Basin wells to date have used 0.2 – 8ML each.
- USA examples quote 12-15ML each shale gas well.
- Olympic pool = 2.5ML or Backyard pool = 0.5ML
- Total Perth Basin Water Allocation = 216,600ML/yr.
- Geraldton Region = 80,920ML/year.

A comparison of Latent's water use with other water use activities and allocations in the area:

- Fracturing water used approx. 6ML/well. (<3 Olympic swimming pools).
- Each development well will extract gas from 20ha area and use ~0.3ML/Ha to fracture reservoir (once-off).
- Average agricultural usage of 10-12 ML/ha/annually or 200ML per equivalent well location.
- District Water Allocation – 23,000 ML.
- Warro Water Allocation – 20 ML.



The company has monitored water quality at its sites since 2009 to ensure a robust understanding of any potential changes resulting from activities. Latent regularly sampled local and regional bores and analysed them to identify any changes in chemistry. The results were reported quarterly to DMIRS and the DoW. While there were seasonal variations in water quality, none of the samples showed any anomalous readings associated with the hydraulic fracturing activities.

The presence of boron and barium are usually strong indicators of any issues with the hydraulic fracturing process, as both are used in drilling and hydraulic fracturing. No significant change in the levels of either mineral was observed.

The company has questioned the classification of aquifers in the Warro area. The existing approach has been to treat any geological formation that can yield useful quantities of water as an aquifer. However, a large proportion of the Yarragadee is not a viable water source for most purposes, due to excessive depth and/or salinity. A water resource assessment approach, in line with the resource definition approach applied to mineral and petroleum industries, would bring more discipline and scientific rigour to identifying aquifers of interest.

Because well integrity has been identified as an important factor in protecting the aquifers, it is important to understand the intense efforts undertaken to ensure this is achieved. While protecting aquifers is important, it is equally important to ensure drilling, fracturing and testing activities of a well are safe. Industry experience accumulated from more than 100 of activities years has resulted in robust techniques that are rigidly applied in WA. As an example, the approach used at Warro is set out in an appendix to Whitebark's submission.

BENEFICIAL USE

Beneficial use of water is regulated through legislation and regulatory arrangements.

Before beginning an activity, the operator must obtain a water abstraction license in accordance with the *Rights in Water and Irrigation Act 1914*. This license sets limitations on water abstraction and use to protect Western Australia's water resources and promote the sustainable and efficient use of water.

The Department of Water and Environment Regulation administers this Act. An existing Administrative Agreement between DMP (now DMIRS) and DoW (now DWER) triggers a referral of an Environment Plan for an operation that may affect groundwater. In such cases, both departments assess the EP.

6.5 Social surrounds

A key determinant of social wellbeing is economic opportunity and the ability to earn a living. Increased economic growth can cause changes that affect the wellbeing of communities.

Companies address social impacts from oil and gas activities as part of operational planning. As the Inquiry Panel in the Background and Issues Paper has recognised, there are many such factors to consider.[93]

The Environment Regulations require stakeholder and community engagement. The operator must undertake adequate consultation with relevant authorities, interested persons and organisations. Industry recognises the importance of effective engagement in identifying and addressing concerns, as well as building and maintaining positive relationships with key stakeholders.

APPEA and industry support the *Principles of Stakeholder Engagement* as described in the DMIRS *Guideline for the Development of Petroleum and Geothermal Environment Plans in Western Australia*[94]. These are:

- Communication – open, accessible, clearly defined, two-way, appropriate.
- Transparency – open, agreed and documented processes and outcomes of engagement.
- Collaboration – mutually beneficial outcomes.
- Inclusiveness –communities and stakeholders must be appropriately involved early in the process and remain involved throughout.
- Integrity – establishment and fostering of mutual trust and respect.

Stakeholder engagement must begin before the development of the Environment Plan as it is an important factor for inclusion in the development of the EP. The EP must provide evidence of consultation and the resolution of issues and concerns.

Such evidence includes timing of consultation and engagement; contacts; and details of the issues and concerns raised and how these were addressed. The EP must also detail ongoing consultation and engagement to be undertaken over the duration of the activity. Operators maintain records of consultation prior to, during and post development and implementation of the Environment Plan. This not only serves as an accurate record to present to the regulator, but ensures operators are meeting the commitments agreed upon with stakeholders and the community.

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[93] Scientific Inquiry into Hydraulic Fracture Stimulation in Western Australia, Background and Issues Paper, 3 November 2017. Available at: https://frackinginquiry.wa.gov.au/sites/default/files/Scientific%20Inquiry%20into%20Hydraulic%20Fracture%20Stimulation%20in%20WA%20-%20Background%20Paper%20-%203%20November%202017.pdf

[94] Department of Mines and Petroleum, Guideline for the Development of Petroleum and Geothermal Environment Plans in Western Australia, November 2016. Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-177.pdf

Social surrounds are also taken into account by generating employment opportunities associated with activities and company engagement in local communities. The following case study provides an example of local community involvement in the Mid West.

CASE STUDY – LATENT WARRO GAS FIELD HYDRAULIC FRACTURING[95]

The Warro Joint Venture in Western Australia's mid-west region has a high level of community engagement. Community engagement began in 2008, before increased community concerns about the unconventional gas industry had been roused. Engagement with local Aboriginal groups started early in the project in 2009, culminating in a Native Title Agreement with the Yued People in 2013.

The Warro Joint Venture sought to involve the local community in the project. It supported the local school in educational projects, employed local people as part of its own workforce, and used local firms to provide equipment and supplies.

This involvement has added more than $3.8 million into the local economy and spent more than $54 million with Western Australian-based companies (over half the project's total expenditure).

The Warro Joint Venture has also provided many opportunities for site visits. From an early stage, the local community's views were canvassed and wherever possible accommodated. For example, local traffic needs were prioritised, particularly during school times when the project's operational vehicles were prohibited from using the roads.

ABORIGINAL HERITAGE

The industry has great respect for Aboriginal people's cultural values and the importance they place on the landscape, ecosystems, flora and fauna.

In addition to legislated requirements, detailed, comprehensive and transparent agreements with Aboriginal Traditional Owners can include specific provisions to protect cultural values and practices. Industry practices that manage risks to cultural heritage and connection to country have been addressed in Attachment 1 below.

Shale and tight gas exploration companies working with Traditional Owners in Western Australia have prioritised engagement with Aboriginal communities. As projects move from exploration to commercial development, Traditional Owners will be key beneficiaries of the onshore petroleum industry.

One company with close links to Aboriginal communities is Buru Energy (operating in the Canning Basin).

One of Buru's first major initiatives was to relinquish a significant portion of its exploration tenements in the Roebuck Bay area near Broome to the Yawuru Traditional Owners in 2011.

This was done to ensure that the Yawuru People could exercise their traditional roles as the custodians of Roebuck Bay without intrusion from oil and gas exploration.

In relinquishing the tenement area, Executive Director Eric Streitberg said the company's relationship with the community was founded on a respect for traditional country, culture and values.

[95] Latent Petroleum Pty Ltd, Hydraulic Fracture Stimulation Monitoring at Warro Project – Mid West, WA.

Since then, Buru has developed a comprehensive program involving:

- Indigenous training;
- Commitments to operations training and employment (if the projects proceed on a commercial basis);
- Cross cultural training;
- Heritage protection;
- Support for independent expert advice;

The input isn't confined to mandated consultation periods, but is part of an ongoing two-way flow of information. For more detail, see the following case study.

CASE STUDY – BURU ENERGY LTD[96]

Buru's comprehensive engagement program with Traditional Owners established a participatory process that encompasses Traditional Owner values and heritage, as well as ongoing community engagement. Buru maintains a strong and valued working relationship with Aboriginal groups demonstrated through:

- Heritage Protection Agreements for exploration activities.
- Conducting heritage surveys before starting work on Traditional Owners' land.
- Keeping the relevant communities and groups informed of exploration activities.
- Engaging appropriate Traditional Owners as cultural monitors during ground-disturbing field activities.

Heritage approval has been obtained through conducting field heritage surveys with the relevant Native Title groups, and searches of the Department of Planning, Lands and Heritage's Register of Aboriginal sites to ensure activities do not adversely impact the Aboriginal heritage values of an area or interfere with Aboriginal heritage sites.

During its 2015 fracture program, Buru Energy was able to provide significant training and employment benefits to the local Yungngora and Warlangurru Tradtional Owners (see case study in Section 6).

AMENITY AND AESTHETIC ENJOYMENT

In Australia, there is no established technical procedure for measuring the significance of changes to the landscape and visual impacts, and individual and community values vary greatly in this respect. Companies consider visual amenity in detailed planning processes by considering the sensitivity of the landscape or scenery and the magnitude of change expected as a result of the development.

Oil and gas activities vary in nature and therefore require different equipment and infrastructure over the progression of the exploration and development process. Equipment is therefore temporary until the production phase is reached when more permanent infrastructure is built. Through each phase of the process, continuous consultation and engagement is used to minimise impacts on amenity and aesthetics.

A landscape's sensitivity refers to the extent to which changes can be made without adverse effects on its character. Sensitivity varies according to the type of development proposed and the nature of the

[96] Buru Energy, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan, Revision 4, Document number HSE-PLN-017, 6 June 2014, p104.

landscape, including its inherent landscape value and the type of the proposed change. The magnitude of change affecting a landscape depends on the nature, scale and duration of the change.

Operations in remote areas usually have a relatively low impact on amenity because there are few local people. For activities in or near more populated areas, companies seek input to help determine the best location of equipment and infrastructure to minimise impacts on amenity and aesthetic values.

Truck noise and increased road traffic also affect land use, visual amenity and other forms of enjoyment. These aspects are considered in planning operations in consultation with stakeholders and the community to minimise potential impacts. In some cases special arrangements are made with the local council to minimise the impacts on road traffic and access, and noise monitoring of operations is undertaken to ensure noise remains within approved levels. Applied industry practice examples have been provided below in Attachment 1.

The impacts on amenity identified by the Inquiry panel in the Background and Issues Paper[97] on Amenity and Aesthetic enjoyment such as increased noise and dust, increased light, loss of visual amenity, and damage to recreational sites, are all common aspects addressed on a case-by-case basis within an Environment Plan. Industry operators have adopted controls to manage these aspects. Attachment 1 below provides examples of how these potential impacts are appropriately managed.

PUBLIC SAFETY

The oil and gas industry places a high priority on the safety of our workforce and the communities in which we operate. Detailed planning goes into developing work programs and practices that emphasise safety and health.

Many legislative safety requirements must be met before starting any activity and additional ongoing requirements must be met for the duration of the activity. DMIRS administers safety legislation relevant to hydraulic fracturing and associated activities as listed below:

- *Petroleum and Geothermal Energy Resources Act 1967*
- *Petroleum and Geothermal Energy Resources (Occupational Safety and Health) Regulations 2010*
- *Petroleum and Geothermal Energy Resources (Management of Safety) Regulations 2010*
- *Dangerous Goods Act and regulations may also apply to petroleum operations.*

The above legislation requires a Safety Case and Safety Management System to be approved by the regulator and applied on site. The objective of these documents is to protect the safety of personnel on site, who are the most experienced to the operations. In doing so, this largely ensures the safety of the wider community from project risks. The Safety Case and Safety Management System assessment is undertaken on a case-by-case basis as per the process of an Environment Plan assessment.

Additional safety legislative requirements may also apply depending on the location and type/nature of the activity to be undertaken.

[97] Scientific Inquiry into Hydraulic Fracture Stimulation in Western Australia, Background and Issues Paper, 3 November 2017. Available at: https://frackinginquiry.wa.gov.au/sites/default/files/Scientific%20Inquiry%20into%20Hydraulic%20Fracture%20Stimulation%20in%20WA%20-%20Background%20Paper%20-%203%20November%202017.pdf

As identified by the Inquiry Panel, road transport must be considered and addressed for each activity. Driving-related incidents are one of the largest risks for oil and gas operations. All companies operating land transport, or providing services involving land transportation, have management systems covering areas such as training, risk management and new road development. Usually, this training is mandatory for employees. Industry also invests heavily in road infrastructure to facilitate safe and sustainable access to sites. One example of this is provided in the case study below.

CASE STUDY – IVMS

In -vehicle monitoring systems (IVMS), or driver behaviour monitoring systems, are used to manage road safety in Western Australia (for example Barrow Island) and Queensland. These electronic devices record information about driver behaviour and vehicle use, such as date, time, speed, acceleration, deceleration, G-force and seat belt use. Data is sent back for real-time management. IVMS can also include fixed speed settings, whereby any vehicle speed exceeding would automatically trigger driving exception. Company policies are developed around the use of these systems and can result in dismissal when policies are breached. Not only does this system act as a safety mechanism, it aids in reducing impacts to fauna through speed monitoring and detection.

PUBLIC HEALTH

Although not specified as an aspect of social surrounds in the Inquiry Panel papers, APPEA considers public health to be an important matter for consideration in this Inquiry. The industry takes the health and safety of its employees and local communities very seriously.

Natural gas has been used widely for decades used in households all over Australia with no evidence that it is a health risk. In previous Inquiries, strong concern on chemical use impacts to public health has been raised. As noted in the 2014 Hawke Report to the NT Government[98] "chemicals used during hydraulic fracturing generally pose a low environmental risk, providing that leading practice is applied to minimising surface spills and managing flowback water after fracturing." Chemicals used in fracturing fluids are found in processed food and a range of household products. These chemicals are routinely used in many other industries and generally at higher concentrations.

The 2014 Hawke Report[99] stated that the greatest environmental risk from drilling and fracturing chemicals appears to be surface contamination from spills or accidents during the transport and storage of large quantities of chemicals in their concentrated form before fracturing. Risks to water quality and health risks

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[98] Hawke, A. (2014), *Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory*, https://frackinginquiry.nt.gov.au/__data/assets/pdf_file/0008/387764/report-inquiry-into-hydraulic-fracturing-nt.pdf
[99] Hawke, A. (2014), *Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory*, https://frackinginquiry.nt.gov.au/__data/assets/pdf_file/0008/387764/report-inquiry-into-hydraulic-fracturing-nt.pdf

associated with fracturing fluid chemicals may be minimised by strictly managed storage and handling (as per Material Safety Data Sheets), strict controls to ensure well integrity, and management of waste water after it is returned to the surface. Cross contamination is unlikely in shale and tight gas deposits which are located deeper underground (more than 2000 meters) and aquifers are a significant distance away.[100]

Chemical handling controls applied are common to many mining and other industrial processes, with well-developed regulation and guidelines, and the risks are not unique to unconventional gas extraction or hydraulic fracturing. Examples of best practice industry management controls applied to prevent incidents of surface contamination are provided in Attachment 1 below.

SEISMICITY

Microseismic events are tiny earthquakes that are too small to be felt by humans. They are the result of rocks suddenly breaking or slipping along zones of weakness within the earth's crust[101].

Research completed on seismicity in Western Australia during hydraulic fracturing demonstrates it is unlikely that hydraulic fracturing activities will cause any significant environmental impacts as presented below. Research on seismicity through microseismic monitoring is undertaken by industry operators and forms a commitment within the EP when undertaking hydraulic fracturing activities. This includes undertaking baseline seismicity monitoring of the activity area. For example, Buru Energy undertook a microseismic monitoring program for the Laurel Formation Tight Gas Pilot Exploration Program[102], which included 18 months of baseline monitoring.

Before and during hydraulic fracturing, surface and acoustic receivers were deployed in an array around the petroleum well. The acoustic receivers were connected to the microseismic office using a radio array. The layout of the acoustic receivers allowed the propagation of fractures to be observed in real-time, as well as monitoring for induced seismicity. Recorded microseismic events were of insufficient magnitude to be felt at surface or cause any hazards[103].

Baseline and monitoring during activities allows an operator to monitor the impacts of hydraulic fracturing, including any associated seismicity. Current evidence from this program is that seismic activity is not significantly increased as a result of hydraulic fracturing. There has been increased occurrence of seismic events associated with oil and gas activities (induced seismicity) in the US, particularly Oklahoma[104]; but these events are mostly related to the reinjection of wastewater into disposal wells[105] .

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[100] 'Hydraulic fracturing in the onshore gas industry and drinking water', Government of Western Australia Department of Health (2016). See http://ww2.health.wa.gov.au/Articles/F_I/Hydraulic-fracturing-in-the-onshore-gas-industry-and-drinking-water.
[101] The University of Western Australia, Microseismicity in South Western Australia, Accessed via: http://www.dmp.wa.gov.au/Documents/Community-Education/UWA_Passive_Seismic_Pamphlet.pdf
[102] Buru Energy, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan, Revision 4, Document number HSE-PLN-017, 6 June 2014.
[103] Buru Energy (2016). *TGS End of Activity Report* (HSE-REP-094). Revision 1, July 2016.
[104] United States Geological Survey webpage 'Induced Earthquakes'. Last Accessed 15 February 2018. Available at: https://earthquake.usgs.gov/research/induced/myths.php.
[105] Murray, K. E. (2013). State-scale perspective on water use and production associated with oil and gas operations, Oklahoma, U.S. Environmental Science and Technology Vol 47(9): 4918–4925, doi: 10.1021/es4000593.

CASE STUDY – LATENT WARRO GAS FIELD HYDRAULIC FRACTURING[106]

Latent Petroleum (now Whitebark Energy) has undertaken hydraulic fracturing at the Warro tight gas field in the Perth Basin since 2009. Several field monitoring programs were undertaken during this time, including measuring the extent of fractures created underground and associated seismicity. The work undertaken has been provided as a case study below.

Summary of the outcomes

- Modelling accurately predicted the fractures created;
- Field measurements showed that they were locally constrained and stayed within the target zones 4,000 m below the surface; and
- There is no discernible change in seismicity during or after fracture stimulation.

Extent of Fractures

For both commercial and environmental reasons, the operator must understand the extent of any fractures created in a well. All hydraulic fractures must be constrained within the target zones to ensure the reservoir is productive. The extent of fractures can be measured directly using downhole tools or estimated using seismic techniques.

Before attempting any fracture stimulation, all well data is incorporated into a computational simulation to predict where the fractures will go. These models use rock petrophysical and geo-mechanical data combined with assumptions about perforation intervals, proppant size and density, pumping rates and volumes, fluid properties (such as viscosity and breaking capacity) and fluid volumes to predict the geometry of fractures in the target zones.

Before the main phase of the fracture stimulation, the computer simulation predictions are tested via field experiments using a diagnostic fracture injectivity test (DFIT), which is a very small-scale fracture. The DFIT results are used to calibrate the computation simulations before starting fracture stimulation.

Downhole measurements at Warro used temperature logging and inert traceable ceramic proppant (NRT) to show where fluid and proppant had been place in the rocks and, by association, where the fractures are located. Temperature logging uses the cooling effect that fracturing fluid emplacement has on the rocks, while the traceable proppant is detected using neutron logging.

During the main fracture stimulation stage, the pressure and rate responses are carefully monitored and varied and/or fine-tuned to optimise fluid and proppant emplacement. Following the stimulation, each zone is logged to determine the height of the fractures. All the information obtained during the fracture emplacement is incorporated into the computation simulations to generate a new calibrated model as a check that can also be used to guide the parameter selection for the next stimulation stage.

Seismic mapping of fractures can been done via downhole geophones placed close to the target zones in a nearby deep well and/or using surface or near surface geophones usually in a widely spaced array. Due to the wide well spacing and excessive depth of the gas reservoir, during the fracture stimulation at

[106] Latent Petroleum Pty Ltd, Hydraulic Fracture Stimulation Monitoring at Warro Project – Mid West, WA.

Warro-5 and 6, Latent used three surface-based methods to detect and locate fractures using surface or near surface detectors. These were:

- Sets of geophones at varying depths in three 100m boreholes
- Patches of geophones at six widely spaced locations around the field
- Single geophone stations buried 1m below the surface.

The data from these systems were supplemented with data from an infield seismometer.

This work was supervised by the University of Western Australia working in conjunction with Seismology Research Centre, which provides seismic monitoring services in the Perth Basin. The data recordings obtained during the fracture simulation work at Warro-5 and 6 were sensitive enough to detect waves breaking on the coastline more than 60km away. They showed that the creation of fractures was imperceptible at surface (i.e. ML approximately < -1.0).

In addition, long-term monitoring before and after the fracture stimulation work showed conclusively that there had been no change in the intensity or frequency of the area's background seismicity.

The most significant seismic event occurred in 2011, 12km east-northeast of Warro and 16km below the surface. This event had no correlation with any activities at Warro and no change in seismicity has been recorded at or near the Warro project (which has drilled four wells and conducted 18 stages of hydraulic fracturing).

Conclusion

The Warro Gas Project shows that:

- Computational simulations provide a reliable guide on the scale and position of fractures.
- As new information is gained from rock properties and the well response to fractures, it is important to recalibrate the computational simulations.
- Physical measurements confirm that the fractures behaved as predicted and the growth of the fractures vertically was well constrained.
- No perceptible seismic events were observed at Warro during and after the fracturing work.
- Soil geochemical measurements did not detect any anomalous readings.
- Well integrity practices ensure the protection of the aquifer systems.
- Water monitoring of nearby water bores has not detected any changes in water chemistry that could be associated with several years of hydraulic fracturing.

7 Operational Case Studies

7.1 Canning Basin – Laurel Formation

Buru Energy Ltd is a West Australian-based oil and gas company operating in the Canning Basin. The Canning Basin is predominantly rangeland ecosystems, with low-intensity cattle grazing the dominant land use. There is very little infrastructure present across much of the Canning Basin. Isolated homesteads, tracks, fence lines, cattle yards and water bores are the only infrastructure outside the towns and away from the highway.

The Canning Basin holds a large potential gas resource in the Laurel Formation, about 2,000 m to 5,000 m below surface[107]. Exploration to date has defined large contingent gas resources in the Yulleroo region (on the western side of the basin), and in the Asgard/Valhalla region (on the eastern side of the basin).

Three wells have been hydraulically fractured in the Canning Basin – Yulleroo-2 in 2011, and Asgard-1 and Valhalla North-1 in 2015. During these hydraulic fracturing programs, Buru Energy was the nominated operator and Mitsubishi Corporation was its joint venture partner.

Hydraulic fracturing at Yulleroo-2 was undertaken before hydraulic fracturing became an issue of public concern. As such, it was treated as a routine petroleum operation with routine environmental monitoring. Buru Energy's 2015 hydraulic fracturing program was undertaken in an environment with much greater scrutiny and involved more thorough stakeholder consultation and extensive environmental monitoring. Therefore, the 2015 hydraulic fracturing program provides an ideal case study for the Canning Basin.

During the program, seven zones in the Asgard-1 well were hydraulically fractured and four zones in the Valhalla North-1 well were hydraulically fractured. Following the hydraulic fracturing, well intervention and flowback operations were undertaken to test the Laurel Formation.

WATER QUALITY

Buru Energy implemented a comprehensive groundwater monitoring program during the 2015 program. This was designed in consultation with the Department of Water, the University of Western Australia and expert hydrogeologists. Monitoring of groundwater occurred at numerous locations on each well site, prior to, during and following the hydraulic fracturing and flowback operations.

All water quality results – made publicly available on Buru Energy's website[108] – demonstrated no impact of hydraulic fracturing on groundwater.

WATER USE

Buru Energy anticipated water use of approximately 50ML per well during the 2015 program, which is less than 0.02% of the sustainable yield of the Canning Basin and was licensed under the *Rights in Water and Irrigation Act 1914*[109].

Buru Energy used significantly less than this amount and groundwater level monitoring did not detect any aquifer drawdown as a result of the water use[110].

AIR QUALITY

[107] Buru Energy Ltd, Onshore gas WA, viewed 22 February 2018, https://www.buruenergy.com/canning-basin/gas/
[108] Buru Energy Ltd, 2015 Pilot Frac Program, viewed 22 February 2018, https://www.buruenergy.com/2015-tight-gas-pilot-exploration-program/
[109] Buru Energy Ltd, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan Summary Document, viewed 22 February 2018, https://ace.dmp.wa.gov.au/ACE/Public/PetroleumProposals/ViewPlanSummary?registrationId=45145
[110] Buru Energy Ltd, Laurel Formation Tight Gas Pilot Exploration Program (TGS) End of Activity Report – Asgard 1 and Valhalla North 1 Exploration Wells (HSE-REP-094).

Specialists from AECOM undertook air quality monitoring during the well stimulation phase at Asgard-1. The monitoring detected methane levels marginally above global background concentrations, which are equivalent to levels 200m downwind of a cattle feed lot or within 5km of a landfill site.

MICROSEISMICITY

To understand background microseismic activity in the Canning Basin, Buru Energy commissioned Hasting Micro-Seismic Consulting to undertake a monitoring program. The Canning Basin was determined to be "seismically quiet". The two arrays detected 19 regional and seven local events; none of these were related to petroleum activities[111].

A microseismic array was also set up for the 2015 program to monitor induced fractures and respond to any induced seismicity.

During operations, microseismic events greater than a certain magnitude (determined from collected baseline data) were deemed attributable to the hydraulic fracturing operations. As the acoustic receivers were located in an array, the location of microseismic events could be determined.

Fracture stimulation was not associated with any significant microseismic events. The recorded microseismic events were of insufficient magnitude to be felt at surface and did not exceed thresholds that might cause hazards to the well or at the surface.

COMMUNITY

Compared to other parts of Western Australia, the Kimberley region is economically disadvantaged. Unemployment rates are around 12%, approximately double the state-wide rate[112]. Economic disadvantage and associated social problems are often most apparent in remote Aboriginal communities[113].

Buru Energy's comprehensive community engagement program in the Kimberley region has focused on key stakeholders, particularly Traditional Owners. Before the 2015 hydraulic fracturing program, Buru Energy made independent information available to the Traditional Owners to ensure they were fully informed about the fracturing activities. Subsequently during operations, Buru Energy had excellent engagement with the community. Senior members of the nearby Noonkanbah Aboriginal community delivered cultural inductions; 33 workers from Noonkanbah worked on the program for more than 13,500 hours of work[114]; and 15 Noonkanbah community members also received training as part of the program in areas such as security and machinery operations.

7.2 North Perth Basin – Woodada Gas Field

AWE Limited is an Australian-based energy company operating in the northern Perth Basin in WA's Mid West region. The northern Perth Basin has a long history of oil and gas operations and hosts some significant oil and gas discoveries[115].

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[111] Hasting Micro-Seismic Consulting (2013). Yulleroo and Valhalla Passive Seismic Monitoring Report, Days 166 to 329. Report to Buru Energy. February 2013.

[112] KDC (2015). 2036 and Beyond: A Regional Investment Blueprint for the Kimberley. Kimberley Development Commission. V 2.0. July 2015.

[113] WA Country Health Service (2013). Kimberley – population and health status. Government of Western Australia.

[114] Buru Energy Ltd, TGS Fact Sheet – Community: Training, Employment and Contracting, viewed 22 February, https://www.buruenergy.com/wp-content/uploads/5.-TGS-Training-Employment-and-Contracting_FINAL.pdf

[115] AWE, AWE Limited: Submission to the Environment and Public Affairs Committee – "Inquiry into the implications for Western Australia of Hydraulic Fracturing for Unconventional Gas", p7.

AWE's Woodada gas field is near the town of Dongara, about 360km north of Perth. Woodada was first discovered in June 1980 and production began in May 1982. In December 1987, the area surrounding the field was declared as Lake Logue Nature Reserve. The field is currently shut in for care and maintenance but has produced 52.9 billion standard cubic feet of gas (about 1.5 billion cubic meters of gas).

AWE has identified shale gas targets about 900m below the Woodada gasfield. Between 2009 and 2012, AWE drilled and hydraulically fractured three – Corybas-1, Woodada Deep-1 and Senecio-2. Across these three wells eight separate zones, some targeting shale gas, were hydraulically fractured. There has been no evidence of aquifer contamination in the Perth Basin from these operations.

The Woodada Deep well shows how hydraulic fracturing can be conducted safely and efficiently in onshore Western Australia. AWE undertook baseline studies of water and air quality before hydraulic fracturing to compare against post-hydraulic fracturing results.

In mid-2012, AWE successfully hydraulically fractured two zones at Woodada Deep-1, targeting the Middle Caryngima (2,370 to 2,425 meters) and Upper Caryngima (2,283 to 2,330 meters) shale formations.

AWE engaged third-party consultants Gemec Environmental Consultants to conduct water quality monitoring and advise on potential groundwater contamination risks. Gemec analysed water obtained from the fracturing fluid flowback ponds, as well as water from two existing water bores and three purpose-designed monitoring stations at varying distances from the Woodada Deep-1 well head. These monitoring bores accessed the Yarragadee formation 20 to 286 meters below ground surface. The ponds at Woodada Deep-1 are double-fenced and double high-density polyethylene-lined to prevent leakage into groundwater. Gemec's analysis concluded:

> *"… comparison of the data against previous groundwater monitoring events indicates that the hydraulic fracture stimulation operations have had no discernible influence on groundwater conditions in the vicinity of the WDA1 (Woodada Deep-1) site. No chemical of potential concern was identified that had the potential to present a risk of harm to the environment".*

In a similar study at AWE's Senecio-2 well, Gemec concluded:

> "*There are no chemicals of potential concern present in the groundwater samples. Comparison of the data against previous Groundwater Monitoring Events indicates that the hydraulic fracture stimulation operations have had no discernible influence on groundwater conditions in the vicinity of the Senecio-2 site*".

WATER USE

AWE was licensed to extract 32,000kL of water from a superficial aquifer to hydraulically fracture its Woodada Deep-1 well, but it used less than 5,00kL. In comparison to other users, AWE represented less than 0.034% of total annual use from a total allocation for all users of the superficial aquifer of 14,600,000kL. If AWE undertook hydraulic fracturing of a horizontal well for commercial production, the amount of water used would be about 20,00kL.

AIR QUALITY

AWE contracted Gemec Environmental Consultants to monitor, test and report on air quality around the fracturing fluid retention ponds. Gemec installed the sampling equipment and undertook an independent analysis of the chemical characteristics of the vapour emissions. The readings were conducted immediately after hydraulic fracture flowback fluids were deposited in the retention pond and about three months later. The concentrations reported at the Woodada Deep site are considered minor when compared to those reported at the reference locations (including a remote rural area, an industrial centre with high traffic density, refuelling a car at a service station). Gemec concluded:

> *"Given the generally minor to trace concentrations reported at or marginally above the limit of reporting, the vapour emissions emanating from the flowback fluid contained in the retention pond do not present an adverse risk to native fauna in the vicinity. The wind dispersion factor would further reduce concentrations away from the immediate vicinity of the retention pond. In a human health context, a comparison of the benzene, toluene, ethylbenzene and xylene concentrations reported during the sampling programme and those reported in various settings indicate that the concentrations reported at the Woodada site are negligible and do not pose an adverse risk to human health".*

The table below, shows the low levels of BTEX compounds in groundwater at AWE's Woodada-Deep 1 well in the Perth Basin[116]. Levels of BTEX in air quality testing were minor when compared to levels found in remote rural areas or industrial areas.

Table 3: Results of BTEX levels from nominated reference sites at the Woodada-Deep 1 well location[117]

	Compound			
Location	Benzene	Toluene	Ethylbenzene	Xylenes
Woodada Deep-1	0.51	0.59	1.01	0.22
Remote rural area	**0.2 - 16**	**0.5 – 260**	**0.2 – 1.6**	**<0.1 – 3**
Industrial centre with high traffic density	Up to **349**	Up to **1,310**	Up to **360**	Up to **775**
Refuelling a car at a service station	Up to **10,000**	Up to **9000**	-	-

Notes: concentrations reported in micrograms per cubic metre (μ/m³)

MICROSEISMICITY

Woodada Deep

AWE contracted Pinnacle (a Haliburton company) to undertake microseismic testing during the hydraulic fracturing operation of Woodada Deep-1. Pinnacle was primarily contracted to undertake hydraulic fracturing efficiency diagnostics to maximise completion efficiency and production economics for future hydraulic fracturing programs at Woodada Deep-1 and/or future wells. The testing also provided valuable information on the scale and location of microseismic events from hydraulic fracturing that can be used to interpret the safety of hydraulic fracturing.

Pinnacle reported three significant observations:

1. The shallowest mapped event was 700 meters in vertical distance away from the base of the closest known saline aquifer (Lesueur Sandstone). Given the distance between the aquifer and fracturing zone, no aquifer contamination from hydraulic fracture fluid is likely (the Lesueur Sandstone is 1,186 – 1,485 meters deep and saline, and is not used for human/stock consumption).

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[116] Submission 113 from AWE Limited, 7 October 2013, pp10-14.
[117] Submission 113 from AWE Limited, 7 October 2013, Table 2, p13

2. All events showed seismic moment magnitude between -3.0 and -1.9 which is typical for hydraulic fracture treatments. The smallest moment magnitude that can be felt by a person at surface is around 2.0 – 3.0. Each unit in moment magnitude is 30 times larger than the one before. Therefore, the largest events detected during the fracture stimulation at Woodada Deep-1 are about 27,000 times smaller than the smallest size of event that could be detected at surface. This is 729 million times smaller than the 1989 Newcastle earthquake, which is the smallest known earthquake in Australia to have caused fatalities.
3. No linear "out of zone" features in mapped events with abnormally high moment magnitude. It is likely that all events were contained within the targeted Carynginia section.

The Warro-3 and Warro-4 wells

The Warro tight gas field lies in a faulted anticline in the northern Perth Basin. Hydraulic fracturing at the Warro-3 and Warro-4 wells intersected deep-seated faults and natural fractures in the Warro field. During hydraulic fracturing, a review of the drilling and stimulation management practices outlined in the approved well management and environment plans confirmed the well processes would effectively manage the activities despite the faults and natural fractures.

No changes to the plans were deemed necessary, but to improve the penetration efficiency of the stimulation fractures Latent Petroleum located Warro-5 and 6 distant (>1km) from faults delineated by the 3D seismic (acquired after Warro-4). The company also placed additional seismic detection equipment in the field for monitoring purposes (with the assistance of the University of Western Australia), but no seismic activity could be detected at surface or in shallow boreholes before, during or after well operations. This demonstrates the approach taken by operators is robust and safe and during field activities; when unexpected encounters – such as intersecting a fault during hydraulic fracturing – occur the systems enable rapid adaptation.

Latent has worked with the assistance of CSIRO to determine if natural gas seepages exist at the surface and to establish if hydraulic fracture stimulation events have affected the natural fault and fracture systems. No gas seepages were identified. Latent Petroleum has concluded: *"in the Warro area, where a strong compressional stress regime is in force, fracture stimulation activities can be carried out safely and without any unintended consequences".*

Faults are fractures in a rock in which one side has been displaced relative to the other. In measuring the horizontal or vertical separation, the "throw" of the fault is the vertical component of the dip separation and the "heave" of the fault is the horizontal component.

Faults do not continue ad infinitum. As a rule of thumb the centre of a fault may be about one-tenth of the fault length in the vertical or horizontal dimension. The end of the fault (the tip) may grow as the fault moves. This normally happens in small jerks – such sudden displacements are earthquakes.

The fault surface is composed of crushed rock, surrounded by fractured rock in the block on each side. Geophysical methods are required to identify faults, with seismic reflection the most effective[118].

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[118] Buru Energy, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan, Revision 4, Document number HSE-PLN-017, 6 June 2014, p 76.

An assessment on the risk of fault reactivation during hydraulic fracturing of shale gas reservoirs from the US Department of Energy Berkley Science Laboratory (Rutqvist et at 2013[119]) considers that:

- Faults in gas bearing shales are likely to have low permeability, as otherwise the gas would have escaped over geological time.
- If faults were permeable, they would be active and critically stressed and in such a case, only a seismic slip might occur and, because of ductile slip, the permeability would not change considerably.

The Berkley scientists concluded that the possibility of hydraulically induced fractures at great depth causing activation of faults and creation of a new flow path that can reach shallow groundwater resources (or even the surface) is remote (Rutqvist et al, 2013[120]). The US Environmental Protection Agency found that fault reactivation due to hydraulic fracturing would likely occur on small distances of a few metres (US EPA, 2012).

[119] Rutqvist R, Rinaldi A, Cappa F, Moridis G (2013). Modeling of Fault Reactivation and Induced Seismicity During Hydraulic Fracturing of Shale-Gas Reservoir. Journal of Petroleum and Science Engineering. Accessed at: http://www2.epa.gov/sites/production/files/2013-12/documents/fault-reactivation.pdf (referenced from: Buru Energy, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan, Revision 4, Document number HSE-PLN-017, 6 June 2014).

[120] Rutqvist R, Rinaldi A, Cappa F, Moridis G (2013). Modeling of Fault Reactivation and Induced Seismicity During Hydraulic Fracturing of Shale-Gas Reservoir. Journal of Petroleum and Science Engineering. Accessed at: http://www2.epa.gov/sites/production/files/2013-12/documents/fault-reactivation.pdf (referenced from: Buru Energy, Laurel Formation Tight Gas Pilot Exploration Program (TGS14) Environment Plan, Revision 4, Document number HSE-PLN-017, 6 June 2014).

ATTACHMENT 1 – Management of Environmental Impacts Associated with Hydraulic Fracturing

This section describes environmental regulatory, policy and guidance controls, and examples of practices applied by industry to manage the potential environmental impacts when undertaking hydraulic fracturing and associated activities.

Details were obtained from member companies and publicly-available sources, including Environment Plan summaries publicly available on the DMIRS website.[121]

It is important to note that the below information may not cover all potential environmental impacts associated with every hydraulic fracturing activity or associated activities. Project specific risk assessments ensure all environmental risks are assessed and addressed as part of the Environment Plan process.

Regulatory Instruments Relating to Hydraulic Fracturing

- *Aboriginal Heritage Act 1972*
- *Australian Heritage Council Act*
- *Bushfires Act 1954*
- *Biodiversity Conservation Act 2016*
- *Biosecurity and Agriculture Management Regulations 2013*
- *Biosecurity and Agriculture Management Act 2007*
- *Conservation and Land Management Act 1984*
- *Contaminated Sites Act 2003*
- *Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2004*
- *Department of Mines and Petroleum Chemical Disclosure Guideline*
- *Department of Water: Water Quality Protection Notes*
- *Dangerous Goods Safety (Road and Rail Transport of Non-Explosives) Regulations 2007.*
- *Environment Protection and Biodiversity Conservation Act 1999*

[121] https://ace.dmp.wa.gov.au/ACE/Public/PetroleumProposals

- *Environmental Protection Act 1986*
- *Environmental Protection (Noise) Regulations 1997*
- *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*
- *Environmental Protection (Controlled Waste) Regulations 2004*
- *Environmental Risk Assessment of Chemicals 2013*
- *EPA Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia (Guidance Statement 51)*
- *EPA Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (Guidance Statement 56)*
- *Guideline for the Development of Petroleum and Geothermal Environment Plans in Western Australia 2016*
- *Guidelines to the Petroleum and Geothermal Energy Resources (Resource Management and Administration) Regulations 2015*
- *Guideline for the Development of an Onshore Oil Spill Contingency Plan 2016*
- *Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry 2016*
- *Heritage of Western Australia Act 1990*
- *Land Administration Act 1997*
- *Land Drainage Act 1925 (Note: this Act was repealed by the Water Services Legislation Amendment and Repeal Act 2012 s. 198(a) (No. 25 of 2012) as at 18 November 2013).*
- *Local Government Act 1960*
- *Native Title Act 1993*
- *Occupational Safety and Health Act 1984*
- *Petroleum and Geothermal Energy Resources Act 1967*
- *Petroleum and Geothermal Energy Resources (Environment) Regulations 2012*
- *Petroleum Decommissioning Guideline 2017*
- *Plant Disease Act 1914*
- *Plant Diseases Regulations 1989*
- *Rights in Water and Irrigation Act 1914*
- *Soil and Land Conservation Act 1945*
- *Wildlife Conservation (Rare Flora) Notice 2012*

Industry Instruments Relating to Hydraulic Fracturing

In addition to the above legislation, a number of Codes of Practice, Guidelines and Standards are applied when undertaking hydraulic fracturing and associated activities. These include:

- APPEA Code of Practice for Hydraulic Fracturing 2011.
- APPEA Code of Environmental Practice – provides guidance on objectives to be achieved when managing environmental impacts associated with petroleum exploration and production.
- AS/NZ 1546.3 – on-site domestic wastewater treatment units – Aerated wastewater treatment systems
- AS/NZS ISO 31000:2009 Risk Management – *Principles and Guidelines*
- HB 203:2012 *Managing Environment-related Risk*
- American Petroleum Institute Standards – constitute good practice. Include:
    - API HF1 *Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines*.
    - API HF2 *Water Management Associated with Hydraulic Fracturing*.
    - API HF3 *Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing*.
    - API Standard 65 Part 2 *Isolating Potential Flow Zones During Well Construction*.
    - API RP 51R *Environmental Protection for Onshore Oil and Gas Production Operations and Leases*.
- IEA Golden Rules – The International Energy Agency released its *Golden Rules for a Golden Age of Gas* on 29 May 2012. This document sets principles to allow governments, industry and other stakeholders to address environmental and social impacts during the life cycle of shale gas wells.
- UK Onshore Shale Well Guidelines – Supplement the Oil and Gas UK Guidelines and were developed to cover areas unique to shale and gas wells and high-volume fracturing operations.

- International Agreements – including:
    - Japan-Australia Migratory Bird Agreement
    - China-Australia Migratory Bird Agreement
    - Republic of Korea-Australia Migratory Bird Agreement
    - Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
    - Ramsar Convention on Wetlands

Industry Management Practices Relating to Hydraulic Fracturing

POTENTIAL ENVIRONMENTAL IMPACTS TO LAND

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
TERRESTRIAL ENVIRONMENTAL QUALITY	
Contamination of the terrestrial environment caused by: • Spillage of chemicals used (concentrated or dilute/ mixed). • Spillage of flowback water. • Spillage of produced liquid hydrocarbons.	• APPEA Code of Practice for Hydraulic Fracturing 2011. • APPEA Code of Environmental Practice • American Petroleum Institute Standards • AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines • HB 203:2012 Managing Environment-related Risk • Dangerous goods stored in accordance with Dangerous Goods Safety Regulations. • Segregation of dangerous goods. • Self-bunding (double skinned) storage tanks.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Spillage of other hazardous materials.	• Refuelling and transfer procedures • Vehicle and mobile equipment refuelling undertaken within impermeable lined and bunded designated refuelling areas. • Stationary machinery and equipment refuelling undertaken using a mobile tanker with drip trays. • Manning of refuelling operations at all times. • Spill kits located at refuelling stations and contain suitable equipment to allow immediate containment and clean-up of spills. • Storage of substances in accordance with MSDS. • Appropriate storage of hazardous substances. • Handling of hazardous substances by suitably trained personnel and in accordance with procedures or Job Hazard Analysis (JHA). • Daily site inspections including inspections of stored materials and integrity of bunding. • Containment, clean-up and remediation of a spill undertaken in accordance with the Company spill response plan. • Site personnel trained in the implementation of the oil spill contingency plan and emergency response plan. • Emergency drills and response exercises undertaken to test adequacy of processes and competency of personnel. • Incident reporting. • Certified equipment utilised. • Maintenance of vehicles and equipment. • Characterisation of flowback water to confirm low toxicity. • Monitoring of flowback water. • Baseline, operational and post-operational groundwater monitoring. • Analysis of drill cuttings for radiation levels. • On-site radiation meter. • Disposal of NORMs at licenced waste facility. • Maximise reuse of flowback water in subsequent hydraulic fracturing activities. • Reinjection of flowback water into the target formation.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
	• Ongoing monitoring of groundwater quality • Operational controls such as: • Pressure kickouts and pop-off valves to prevent exceedances in design pressures. • Double isolation barriers on fracture stimulation equipment. • Immediate shutdown monitoring systems (high and low pressure systems). • Exclusion zone around high pressure pumping area during operations. • Pressure testing of equipment prior to conducting activity. • Activities limited to hardstand area. • Use of metered closed loop flowlines. • Prevent double handling of hazardous materials. • Maintain only hazardous substances required on site with minimal excess stock.
• Indirect impacts to the health of people, plants and animals.	• Avoidance of clearing where possible. • Where clearing is required, the appropriate clearing permits are obtained prior to any site works. • Access is limited only to the activity area. • Fencing or marking of the activity area to alert personnel of activity area. • Quarantine management procedure in place where required. • Vehicle, machinery and equipment wash down or blow down facility where required (e.g. to prevent the spread of weeds, pests or dieback). • Use of dedicated vehicles for transport to and from site. • Quarantine certification of equipment entering the site. • Maintenance of quarantine records/logs. • Externally sourced gravel certified as weed free. • Pre-start checks of vehicles and machinery. • Daily inspections • Site personnel to have appropriate PPE including respiratory protection where appropriate.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Soil erosion, sedimentation or compaction. • Alteration of surface water flow.	• Topsoil stockpiled not greater than 3 meters high to prevent erosion and loss. • Maintenance of access track, well site and camp site. • Restricted access of vehicles and personnel to existing tracks, well site, and camp site. • Regular site inspections. • Repair of localised soil erosion or sedimentation where required.
• Contamination of the terrestrial environment caused by inappropriate waste disposal (incl. sewage).	• Waste managed and monitored in accordance with company procedure. • Storage of waste in dedicated, labelled containers. • Chemical drums to be stored in bunded storage areas. • Disposal of all waste at a licensed waste disposal facility. • Waste transported by a licensed waste contractor. • Waste records maintained. • Sewage appropriately stored on site. • Licenced was contractor to transfer sewage to appropriately licensed disposal facility. • Waste water treatment system on site to comply with Australian Standards.
• Fauna entrapment in ponds, excavations etc.	• Fauna egress (e.g. ladder, rope, matting) placed in ponds and other areas where fauna may not be able to escape without assistance. • Capping of unused pipe on site. • Fencing and gating of site perimeter. • Small hole fencing around the base of perimeter or infrastructure fencing to prevent smaller fauna entry. • Fencing of ponds and other infrastructure that could potentially trap fauna. • Closed gates.
• Ignition of bushfire (from flaring, machinery, equipment etc.). • Pollution caused by fire impacting operations.	• Maintenance of fire breaks. • Flaring kept to a minimum. • Closed loop flare system. • Shutting in of well. • Horizontal flare pit. • Vehicle and personnel access limited to access tracks, camp site and drill pad.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
	• Eliminate or reduce fire ignition sources. • Site inductions – address fire aspects. • Firefighting equipment available at well site and camp site. • Personnel trained to use firefighting equipment. • Designated smoking areas. • Consultation and liaison with local fire emergency services. • Monitoring bushfires in the region (e.g. via Sentinel Hotspots). • Lightning detection systems. • Smoking restricted to designated smoking areas.
• Inadequate decommissioning and rehabilitation	• Approved decommissioning plan in place prior to decommissioning activities taking place. • Rehabilitation plan approved by the regulator and in accordance with landowner agreements. • Removal of unused and excess equipment, infrastructure, chemicals and other site materials not required. • Progressive rehabilitation where possible. • Ongoing rehabilitation monitoring to ensure rehabilitation is successful.
BIODIVERSITY	
• Habitat loss or fragmentation from clearing of drill pads, roads and pipelines • Loss of local population of conservation significant species.	• Where required, clearing of vegetation is limited. • Clearing permit obtained prior to any site disturbance. • Areas of significant habitat are avoided with an adequate buffer zone in place. • Vehicle and personnel access limited to the activity area. • Appropriate fencing and/or marking provided to identify the activity area. • Fire detection equipment and lightning detection system installed, tested and monitored. • Firebreaks inspected and maintained in accordance with local shire requirements. • Smoking restricted to designated smoking areas. • Firefighting equipment located at on site with personnel adequately trained to use.
Death or injury of native fauna caused by:	• Compliance with operator or site Travel Management Procedure. • Lighting kept to a minimum required for safe operations with lighting facing inwards. • Well maintained and muffled equipment and machinery.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Uncontrolled vehicle access. • Vehicle strike. • Attraction of feral animals.	• Adequate fauna egress paths implemented, regularly inspected and maintained. • Adequate fencing of water holding facilities. • Disused pipes are stored with both ends capped to prevent fauna entry. • Off-road driving prohibited. • Prohibited driving at dusk and at night. • Adherence to speed limits. • Appropriate speed limit signage provided on site. • Minimisation of vehicle movement through the use of shared vehicles or bus to and from site. • Crew changes scheduled at appropriate times. • Fauna awareness signs displayed. • Site induction – environmental awareness. • Site surveys and awareness of fauna. • Minimal light spill outside camp and well site boundaries. • Inwards facing, and minimum safety lighting requirements. • Fencing of well site boundaries and water retention ponds. • Fauna egress paths installed in water retention ponds. • Grating over cellar to prevent fauna entrapment. • Capping of excess pipe or equipment. • Boundary fencing and gating of well site and water retention ponds. • Waste management – lidded bins, bins kept closed, removal of waste offsite by licensed waste contractor.
Increased noise and light from operations due to: • Well site machinery – pumps, generators, camp site. • Vehicle movement.	• Short duration of loud operations. • Low noise level operations. • Noise monitoring. • Distance from residences. • Well maintained and muffled vehicles, equipment and machinery. • Security and safety lighting in centre of well site. • Low light levels at perimeter of well site and camp site. • Lighting intensity from flare will attenuate over short distance at ground level. • Low light sources used at camp (no floodlights).

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Operational lighting • Flaring	• Internally lit walkways at campsite. • Inwards facing lighting.
Spread of weeds and pests due to: • Vehicles, machinery and personnel movements. • Uncontrolled access.	• Company quarantine management procedures. • Landholder quarantine procedures. • Restriction of access only to existing access tracks, well sites and camp sites. • Quarantine log books. • Washdown/blowdown facilities. • Site inductions (including weed identification). • Use of "clean" material on site (e.g. gravel). • Daily site inspections. • Weed management program. • Identification and avoidance of dieback areas.
• Degrading or restricting access to land that would have been used for other productive purposes including agriculture.	• Rehabilitation and closure planning and approvals obtained. • Consultation with the landowner to agree to state of the land post activity. • Removal of unnecessary equipment, machinery, chemicals from site. • Limited access to site via existing access track. • Minimise site size for operational and safety needs. • Progressive rehabilitation. • Baseline studies to record pre-disturbance state of the land.
BENEFICIAL USE	
• Degrading or restricting access to land that would have been used for other productive purposes including agriculture.	• Rehabilitation and closure planning and approvals obtained. • Consultation with the landowner to agree to state of the land post activity. • Removal of unnecessary equipment, machinery, chemicals from site. • Limited access to site via existing access track. • Minimise site size for operational and safety needs.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
	• Progressive rehabilitation. • Baseline studies to record pre-disturbance state of the land.

POTENTIAL ENVIRONMENTAL IMPACTS TO AIR

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
GREENHOUSE GAS EMISSIONS	
• Release of a significant amount of greenhouse gases.	• Gas from separation process of produced water release via cold vent system – least impact to environment.
DUST	
• Vehicle and equipment use.	• Dust control measures. • Dust monitoring. • Track and drill site maintenance. • Minimise vehicle, equipment and machinery movements.
AIR POLLUTANTS	
• Release of gases from wells into air	• Reduced emissions completions[122] – minimises methane and other VOC. • Couplings and flow lines for flow-back reticulation system pressure tested for leaks.

[122] IPIECA, *Green Completions*, 2014. Available at: http://www.ipieca.org/resources/energy-efficiency-solutions/units-and-plants-practices/green-completions/

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Fugitive emissions	• Gas reticulation system from flow-back monitored for gas leaks. • Monitoring of water retention ponds for hydrocarbon build up. • Radiation monitoring of flowback water. • Air quality monitoring.
• Fumes from drilling equipment and road traffic.	• Maintenance of equipment in accordance with manufacturer's specifications to ensure exhaust and fumes are minimised. • Records of equipment servicing or repair maintained on site. • Preventative maintenance system maintained and complied with for example, routine maintenance such as changing of filters is completed within the PM system. • Minimise vehicle and equipment use. • Verification of equipment maintenance. • Recording and reporting greenhouse gas emissions. • Air quality baseline and operational continuous monitoring.
Impact on the health of people, plants and animals.	• Daily site inspections to identify any leaks or equipment failings. • Appropriate signage of site. • Prevention of site access by fencing and gates. • PPE for workers and visitors.

POTENTIAL ENVIRONMENTAL IMPACTS TO WATER

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
QUALITY - GROUNDWATER	
Contamination of groundwater caused by: • Leakage of wells due to a failure in well integrity or	• Hydrogeological models. • Baseline, operational and post-operational groundwater monitoring. • Pre-commissioning checks – safety and process checks to ensure ready for commissioning. • Pre-fracture subsurface modelling and design engineering to manage fracture height and length. • Leak testing – use of water for testing prior to the introduction of hydrocarbons. • 24/7 monitoring of an active well or facility, with alarms to alert of any failure and enable shut down.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
degradation over the life of the well. • Spillage of flowback water. • Spillage of chemicals used (concentrated or dilute/ mixed). • Spillage of produced liquid hydrocarbons. • Spillage of other hazardous materials. • Inappropriate waste disposal (incl. sewage).	• Monitoring of pH levels of flowback water to required threshold value. • Testing of flowback water to inform disposal options; recycling and reusing flowback fluids where practicable. • Well integrity (Multiple casing and cement forming barriers; Cement bond logging; Well pressure testing; Well flow and system inspection for leaks and function). • Low toxicity hydraulic fracturing fluid from food industry with rapid biodegradation. • Real time monitoring of anomalous pressure changes during the activity and rapid shutdown of pumping in accordance with company procedure (including thresholds for ceasing operations). • Daily site inspections to identify any leaks or equipment failings. • Maintenance of 0.5 meter freeboard in all water storage/holding facilities on site. Where the risk of reaching freeboard exists and unfavourable weather risks overtopping, operators will manage the water to prevent overtopping such as trucking of water off site by an appropriately licenced waste contractor to an appropriately licenced waste disposal facility. • Dangerous goods transported in accordance with Dangerous Goods Regulations. • Company travel management procedure. • No or minimal driving at night. • Appropriate speed limits assigned to access tracks, with clear signage. • Job Hazard Analysis process.
• Contamination of groundwater caused by induced connectivity between hydraulically fractured shale and aquifers (i.e. fracture growth beyond targeted fracture zone, migration of methane and other contaminants up natural or induced faults).	• Geological risk review as part of planning process. • Microseismic monitoring program. • Real time monitoring of anomalous pressure changes during the activity. • Rapid shutdown of pumping in accordance with Company procedures (includes thresholds for ceasing operations).

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Contamination of groundwater caused by reinjection of treated water.	• Re use of water where possible. • Reinjection into the same reservoir. • Real time monitoring of anomalous pressure changes during reinjection activity and rapid shutdown of pumping in accordance with Company procedures (including thresholds for ceasing operations).
QUALITY – SURFACE WATER	
• Contamination of surface water caused by: • Spillage of chemicals, flowback water or other hazardous substances. • On-site spills resulting from the overtopping of water storage tanks due to extreme weather events. • Spills from the transportation of chemicals. • Impact on the health of people and terrestrial aquatic plants and animals.	• Daily site inspections to identify any leaks or equipment issues and general site compliance. • Leak testing with water or on equipment free of hydrocarbon. • Containment of leak test water and appropriate disposal or reuse where possible. • Vehicles to travel in accordance with the operator/site travel management procedures. • Operational activities that pose spill risk undertaken in bunded area or with adequate drip trays. • Facility shut in triggers for oil in water storage levels. • Company or site waste management procedure implemented. • Dangerous and hazardous good stored within appropriately bunded areas. • Labelling of dangerous goods in accordance with regulations and MSDS. • Company or site refuelling procedure implemented. • Machinery, vehicles and equipment well maintained in accordance with manufacturer's specifications. • Oil Spill Contingency Plan followed in the event of a spill. • 500 mm freeboard maintained in water storage ponds (turkey's nest, evaporation ponds). • Water levels in storage tanks monitored with appropriate equipment. • Bunds inspected following high rainfall events to maintain required bunding capacity. • Periodic well integrity testing and inspection and appropriate maintenance/rectification procedures (Leak-off Testing; Formation Integrity Testing). • Monitoring of Bureau of Meteorology forecasts and warnings. • Maintenance of 0.5 meter freeboard in all water storage/holding facilities on site. Where the risk of reaching freeboard exists and unfavourable weather risks overtopping, operators will manage the water to prevent overtopping such as trucking of water off site by an appropriately licenced waste contractor to an appropriately licenced waste disposal facility.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
	Dangerous goods transported in accordance with Dangerous Goods Regulations.
QUANTITY	
• Reduction in the quantity of groundwater available caused by the amount of water required for the fracturing process. • Impact on plant and animal habitats through a decrease in water availability	• All water use within licensed limits set by the Department of Water and Environmental Regulation (DWER). These limits are allocated within the sustainable yield of the relevant aquifer. • Metering and recording of water use and reporting to DWER on an annual basis. • Use only of water amounts required. • Reuse of water throughout the process. • Reinjection of water. • Recycled fracture fluid system between subsequent fracture stages (saves approximately 50% in quantity of groundwater used).
BENEFICIAL USE	
• Competition for water or loss of utility due to contamination.	• Controls as per Quality – Groundwater and Quantity above.

POTENTIAL ENVIRONMENTAL IMPACTS TO SOCIAL SURROUNDS

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
ABORIGINAL HERITAGE	
Damage to sites of cultural significance caused by: • Uncontrolled vehicle/ personnel access.	• Vehicle and personnel activity limited to the bounds of the activity area. • No clearing where possible. Heritage monitors present when clearing is required. • Heritage surveys undertaken to identify cultural heritage areas. • Land access agreements with Traditional Owners in place prior to commencement of activities. • Environment and Cultural/heritage awareness inductions and training. • On-going communication with Traditional Owners.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Groundwater drawdown.	
• Loss of bush tucker or bush medicine.	• Controls as per Terrestrial Environmental Quality above.
AMENITY AND AESTHETIC ENJOYMENT	
• Increased noise and dust from construction, operation and transport.	• Short duration of loud operations. • Low noise level operations. • Noise monitoring. • Distance from residences. Well maintained and muffled vehicles, equipment and machinery.
• Increased light from construction and operation.	• Distance from residences. • Security and safety lighting in centre of well site. • Low light levels at perimeter of well site and camp site. • Lighting intensity from flare will attenuate over short distance at ground level. • Low light sources used at camp (no floodlights). • Internally lit walkways at campsite. • Inwards facing lighting.
• Loss of visual amenity arising from infrastructure. • Flaring. • Facility lighting. • Operational noise.	• Use of existing infrastructure where possible. • Fit for purpose infrastructure only on site. • Consideration of location of infrastructure to minimise visual impact to the community.
• Damage to recreational sites.	• Controls as per Terrestrial Environmental Quality above.
PUBLIC SAFETY	

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Transport accidents	• Company Travel Management Procedure. • Obey Western Australian Road Laws. • Qualified and licenced contractors and staff employed. • Reporting of all accidents and near misses.
• On-site accidents	• Clear and appropriate signage on site and access tracks. • Fencing installed to limit access to site. • Sites are located at acceptable distance from residences. • Driving not allowed or avoided during dusk hours. • Approved Emergency Response Plan. • Fatigue management guideline/plan implemented. • Fit for work policy applied.
OTHER LAND USES	
• Disturbance to local landholders.	• Ongoing consultation with stakeholders including advanced notification of new or unexpected activities. • Compliance with the operator/site Travel Management Procedure. • Appropriate dust suppression methods applied. • Night time operations are limited where possible with the majority of operations undertaken in daylight hours. • Appropriate compensation agreed with the landholder. • Rehabilitation undertaken to the satisfaction of the landholder. • Monitoring of air quality to ensure levels are managed in accordance with legislative requirements. • Continued regular communication with Councils, Traditional Owners, Groups, pastoralists. • Vehicle and personnel access limited to camp site, well site and access tracks. • Complaints register.
Disturbance to livestock caused by: • Movement of vehicles and machinery.	• Vehicle and personnel access limited to camp site, access track and well site. • Fencing in place. • Well site gates to remain closed when not in use.

POTENTIAL ENVIRONMENTAL IMPACT	INDUSTRY PRACTICE (EXAMPLES ONLY)
• Installation/ alteration of gates and fencing • Access to public roads, access tracks and well site.	• Third-party gates are left as found (open/closed). • Regular consultation with relevant pastoral stations.
SEISMICITY	
• Induced seismic events that impact local infrastructure and safety. • Minor ground movements impacting on local environment. • Minor ground movements damaging property or impacting on public safety.	• Company procedures to identify monitoring and management measures for microseismic activity (e.g. thresholds for ceasing operations). • Baseline monitoring of naturally occurring microseismic events prior to activities commencing. • Microseismic monitoring during operations. • Real time surface monitoring for anomalous pressure changes during activities.

ATTACHMENT 2 – Petroleum Activities in Western Australia – Regulatory Reform 2011-2018

2011

- DMIRS commissioned an independent review of WA regulatory framework (Hunter Review). This review identified:
  - WA regulatory framework is robust but opportunities for improvement were identified
  - Recommended improving legal enforceability of regulations
- EPA released EPB No. 15 – Hydraulic fracturing of gas reserves
- APPEA Code of Practice for hydraulic fracturing in WA was released
- State Government Interagency Working Group was established to coordinate a whole of government approach for the regulation of fracking

2012

- In response to Hunter Review, new PGER (Environment) Regulations 2012 were released. These provided increased transparency and enforceability for petroleum activities in WA
- Regulations also strengthened obligations on industry in relation to water use, management and chemical disclosure

2013

- End of transition period for PGER (Environment) Regulations.
- Chemical Disclosure Guideline was released outlining requirements for full disclosure of down-hole chemicals
- WA Parliamentary Inquiry into hydraulic fracturing commenced

2014

- WA Parliamentary Inquiry progressed
  - Submissions received
  - Public hearings held
  - International and WA site visits undertaken
- EPA released EPB No. 22 – Hydraulic fracturing for onshore natural gas from shale and tight rocks.
- EPB No. 22 provided further guidance on the circumstances under which the EPA would regulate proposals that involve hydraulic fracturing.

2015

- WA Parliamentary Inquiry report published. Overall, the inquiry determined that hydraulic fracturing in Western Australia poses negligible risk to the environment and with careful regulation can be undertaken safely
- 'Guide to Regulatory Framework for Shale and Tight Gas in WA – A Whole of Government Approach' published by DMIRS. This outlined the role of respective state government agencies in regulating hydraulic fracturing.
- PGER (Resource Management and Administration) Regulations 2015 released

2016

- Interagency MOUs signed and further guidance released to complement "whole of government framework for regulating shale and tight gas' including:
  - Interagency MOUs signed between (DMP & EPA, DMP & DoW, DMP & DSD
  - Overview of Guide to Regulatory Framework released by DMP
- Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry jointly released by DMIRS & DWER

2017

- Change of government
- PGER (Hydraulic Fracturing) Regulations released. Regulations included a ban on fracking in metropolitan, Peel and South West region and moratorium in remainder of state
- Independent Scientific Inquiry into fracking announced
  - Scope and terms of reference released
  - Panellists appointed for inquiry
  - Background and issues papers released via inquiry website

2018

- Independent Scientific HFS Inquiry underway
  - Public meetings in Perth and key regions
  - Call for written submissions addressing terms of reference
  - Report due August 2018

ATTACHMENT 3 – Western Australian Regulatory Agencies

DEPARTMENT OF MINES, INDUSTRY REGULATION AND SAFETY (DMIRS) – FORMERLY DEPARTMENT OF MINES AND PETROLEUM

DMIRS is the state's lead agency for regulating minerals and energy resources in Western Australia and ensuring that safety, health, and environmental practices meet high standards and are consistent with relevant State and Commonwealth legislation, regulation and policies[123].

Legislation administered by DMIRS applicable to the oil and gas industry includes:

- *Petroleum and Geothermal Energy Resources Act 1967*
- *Petroleum Pipelines Act 1969*
- *Environmental Protection Act 1986* (Delegated Authority for native vegetation clearing)
- *Petroleum (Submerged Lands) Act 1982*
- *Dangerous Goods Safety Act 2004*
- *Occupational Safety and Health Act 1984*.

Subsidiary legislation administered by DMIRS provides for safety, environment and resources requirements, including:

- Environment Regulations – contains the provision for an Environment Plan and Oil Spill Contingency Plan as a part of the Environment Plan to be approved for each activity at each stage before starting.
- Safety Regulations – contains the provisions for a Safety Management System and Safety Case.
- Resource Management and Administration Regulations – contains the provisions for a Well Operations Management Plan and Field Development Plan.

Guidance material provided by DMIRS to assist with understanding environmental and resource legislative requirements for legislation administered by the Department includes:

- Guideline for the Development of Petroleum and Geothermal Environment Plans in Western Australia[124]

[123] The Government of Western Australia, *Guide to the Regulatory Framework for Shale and tight Gas in Western Australia – A Whole-of-Government Approach*, 2015 Edition, Table 1, p 15.
[124] Department of Mines and Petroleum, Guideline for the Development of Petroleum and Geothermal Environment Plans in Western Australia, November 2016, Accessed 27 February 2018. Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-177.pdf

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- Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry[125]
- Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry – Information sheet for landholders[126]
- Guideline for the Development of an Onshore Oil Spill Contingency Plan[127]
- Guideline for Preparing Annual Reports[128]
- Guideline for Petroleum Measurement and Quantity Determination[129]
- Guidelines to Petroleum and Geothermal Energy Resources (Resource Management and Administration) Regulations 2015 and Petroleum (Submerged Lands) (Resource Management and Administration) Regulations 2015[130]
- Petroleum Decommissioning Guideline[131]

Numerous other guidance material regarding oil and gas industry requirements and activities is available on the DMIRS website.

APPEA supports the development of DMIRS guidance material to support clarification of the complex and robust legislative framework administered by DMIRS in Western Australia. Transparency of this information provides the general public with insight into the significant requirements the oil and gas industry must meet before starting an activity.

Oil and gas activities are only undertaken once all relevant approvals are obtained. All petroleum proposals submitted to DMIRS are developed and assessed on a case-by-case basis in accordance with the risk-based regulatory approach. This enables a tailored approach that implements the management practices that are most suited for the proposed activities' circumstances. It also means industry can apply new technology and take a continuous improvement approach to performance and management.

[125] Department of Mines and Petroleum and Department of Water, *Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry*, August 2016, Accessed 27 February 2018. Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-040.pdf

[126] Department of Mines and Petroleum and Department of Water, *Guideline for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry – Information sheet for landholders*, August 2016, Accessed 27 February 2018. Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-042.pdf

[127] Department of Mines and Petroleum, *Guideline for the Development of an Onshore Oil Spill Contingency Plan*, July 2016, Accessed 27 February 2018, Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-203.pdf

[128] Department of Mines and Petroleum, *DMP Guideline for Preparing Annual Reports*, January 2014, Accessed 27 February 2018. Available at: http://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-187.pdf

[129] Department of Mines and Petroleum, *Guideline for Petroleum Measurement and Quantity Determination*, August 2017, Accessed 27 February 2018. Available at: http://www.dmp.wa.gov.au/Documents/Petroleum/PD-RES-GDL-103D%20(WEB).pdf

[130] Department of Mines and Petroleum, *Guidelines to Petroleum and Geothermal Energy Resources (Resource Management and Administration) Regulations 2015 and Petroleum (Submerged Lands) (Resource Management and Administration) Regulations 2015*, September 2016, Accessed 27 February 2018. Available at: http://www.dmp.wa.gov.au/Documents/Petroleum/PD-SBD-ADM-180D.pdf

[131] Department of Mines, Industry Regulation and Safety, Petroleum Decommissioning Guideline, October 2017, Accessed 27 February 2018. Available at: http://www.dmp.wa.gov.au/Documents/Petroleum/PET-DecommissioningGuideline.pdf

APPEA and industry will continue to work with DMIRS to ensure regulation of the oil and gas industry is effective, robust and efficient and achieves positive environmental outcomes.

ENVIRONMENTAL PROTECTION AUTHORITY (EPA)

One of the Environmental Protection Authority's (EPA) primary roles is to assess the environmental impacts of, and make recommendations to the Minister for Environment on proposals that may have a significant impact on the environment[132]. The EPA maintains a watching brief on developments in hydraulic fracturing in Western Australia, other Australian jurisdictions and overseas, and provides advice to DMIRS and other organisations[133]. It also assesses the cumulative environmental impacts of strategic proposals[134]. The EPA can also override the issue of a decision-making authority or proponent to not refer a proposal for assessment[57].

The EPA considers that a number of the potential impacts of hydraulic fracturing are similar to those associated with many other types of proposals, including land clearing, water abstraction, the release of greenhouse gas emissions and impacts related to noise and dust generation. The EPA does not consider hydraulic fracturing to be unique in its potential impacts and will '*consider such impacts associated with proposals involving hydraulic fracturing in the same way as other proposals*'[135]. The former EPA Chairman, Dr Paul Vogel, said: "…we identified that there are going to be other issues – cumulative impacts and risks – that will need to be managed over time. But the industry is a nascent one and we are in good shape to manage the issues and risks associated with that activity"[136].

Some of the factors the EPA considers in determining if a proposal is likely to have a significant effect on the environment include:

- values, sensitivity and quality of the environment which is likely to be impacted;
- extent (intensity, duration, magnitude and geographic footprint) of the likely impacts;
- consequence of the likely impacts (or change);
- resilience of the environment to cope with the impacts or change;
- cumulative impact with other projects;
- level of confidence in the prediction of impacts and the success of proposed mitigation;
- objects of the Act, policies, guidelines, procedures and standards against which a proposal can be assessed;
- presence of strategic planning policy framework;

[132] Submission 117 from Environmental Protection Authority, 25 March 2014, p 1.
[133] Legislative Council Western Australia, *Thirty-Ninth Parliament Report 42 Standing Committee on Environment and Public Affairs Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015
[134] Environmental Protection Authority, *Environmental Protection Bulletin No. 22: Hydraulic fracturing for onshore natural gas from shale and tight rocks*, December 2014, p 3.
[135] Environmental Protection Authority, *Environmental Protection Bulleting No. 22: Hydraulic fracturing for onshore natural gas from shale and tight rocks*, December 2014, p 3.
[136] Dr Paul Vogel, Chairman, Environmental Protection Authority, *Transcript of Evidence*, 31 March 2014, pp 4-5.

- presence of other statutory decision-making processes which regulate the mitigation of the potential effects on the environment to meet the EPA's objectives and principles for EIA; and
- public concern about the likely effect of the proposal, if implemented, on the environment[137].

By March 2014, the EPA had considered six proposals for hydraulic fracturing and in each case, determined that the environmental impacts were '*not so significant to warrant formal environmental impact assessment under the Act*'[138]. Recognising concerns in some parts of the community about whether hydraulic fracturing has significant impacts, the EPA issued the Environmental Protection Bulletin on 'Hydraulic fracturing for onshore natural gas from shale and tight rocks'[139].

The Final Report of the Standing Committee on Environment and Public Affairs found 'that the Environmental Protection Authority's process of assessing proposals according to the Environmental Protection Act 1986 is well-established and satisfies the legislative requirements of section 38 of the Act and its role as an advisory agency to the Minister for the Environment[140]'. The Standing Committee also found that the EPA 'has a mature understanding of its statutory obligations…[141]'. APPEA and industry support the Standing Committee's assessment of the EPA and believe the EPA is effective in its determinations in regulation of the oil and gas industry.

DEPARTMENT OF WATER AND ENVIRONMENTAL REGULATION (DWER)

The Department of Water and Environmental Regulation (DWER) was formed in July 2017 from the previous Department of Water (DoW), Department of Environment Regulation (DER) and the Office of the Environmental Protection Authority (OEPA). The Department of Water previously identified its primary role regarding hydraulic fracturing as regulating water access approvals for groundwater or surface water resources[142].

In August 2015, DMP and DoW entered into an administrative agreement for onshore petroleum and geothermal activities in the State to 'facilitate ongoing collaboration and cooperation

[137] Western Australian Government Gazette, No. 223, *Environmental Impact Assessment (Part IV Divisions 1 and 2) Administrative Procedures*, 7 December 2012, p 5944.
[138] Submission 117 from Environmental Protection Authority, 25 March 2014, p 2. Attachment A to EPA's submission contains details of all shale and tight gas referrals since 2011.
[139] Environmental Protection Authority, *Environmental Protection Bulletin No. 22: Hydraulic fracturing for onshore natural gas from shale and tight rocks*, 17 December 2014.
[140] Legislative Council Western Australia, *Thirty-Ninth Parliament Report 42 Standing Committee on Environment and Public Affairs Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015, Finding 9.
[141] Legislative Council Western Australia, *Thirty-Ninth Parliament Report 42 Standing Committee on Environment and Public Affairs Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015, Finding 10.
[142] Submission 115 from Department of Water, 15 October 2013, p 3.

between the two departments'[143]. The Standing Committee on Environment and Public Affairs Final Report concludes in Finding 12: '*that whilst the agreement between the Department of Water and Department of Mines and Petroleum is primarily administrative in its content, it is a positive development in the interagency regulation of the unconventional gas industry in Western Australia*'[144].

Finding 13 from the Standing Committee's Final Report states: *'there are sufficient safeguards and water source protection policies in place to protect Public Drinking Water Source Areas in Western Australia without the introduction of a 1.5km buffer zone between water source areas and unconventional gas activity'*[145].

Industry operators are required to consult with 'relevant authorities and interested persons and organisations[146]' before starting an activity. This information must be provided in the Environment Plan for a proposed activity to obtain approval. Where appropriate, DWER is consulted as a relevant authority and organisation by the industry operator direct during the development of an Environment Plan. Feedback on the proposal from DWER is addressed in the Environment Plan and submitted to DMIRS. On submission to DMIRS, where the proposal triggers the Administrative Agreement between DMIRS and DWER (DoW), DMIRS will also refer the proposal and consult with DWER prior to issuing approval of an Environment Plan.

Further, the industry licensing branch of DWER (formerly DER) is relevant to hydraulic fracturing operations when works approvals or licences are required under Part V of the *Environmental Protection Act 1986*. The applicability of Part V of the Act depends on the oil and gas volumes proposed to be produced.

The EPA services branch of DWER (formerly OEPA) supports the EPA by undertaking environmental impact assessments, developing relevant policies, and monitoring compliance.

DEPARTMENT OF HEALTH, WESTERN AUSTRALIAN

WA's Department of Health developed and released the *Hydraulic fracturing for shale and tight gas in Western Australian drinking water supply areas: Human Health Risk Assessment* in June 2015, to address community concerns about the introduction of hydraulic fracturing to assist extraction of natural gas reserves in Western Australian shale and tight rock[147]. The document provides a review of recent investigations into hydraulic fracturing and the potential to impact

[143] Department of Water and Department of Mines and Petroleum, *Administrative Agreement between the Department of Mines and Petroleum and Department of Water for onshore petroleum and geothermal activities in Western Australia*, 5 August 2015, p 2.
[144] Legislative Council Western Australia, *Thirty-Ninth Parliament Report 42 Standing Committee on Environment and Public Affairs Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015, Finding 12.
[145] Legislative Council Western Australia, *Thirty-Ninth Parliament Report 42 Standing Committee on Environment and Public Affairs Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas*, November 2015, Finding 13.
[146] Petroleum and Geothermal Energy Resources (Environment) Regulations 2012, regulation 11(f) – '*for the requirement mentioned in regulation 17(1)(b) – demonstrates that there has been an appropriate level of consultation with relevant authorities and interested persons and organisations'*.
[147] 'Hydraulic fracturing for shale and tight gas in Western Australian drinking water supply areas: Human Health Risk Assessment', Government of Western Australia Department of Health (2015). See http://ww2.health.wa.gov.au/~/media/Files/Corporate/Reports%20and%20publications/PDF/Hydraulic-Fracturing-HHRA-18June%202015.pdf

public health using Australian and International experiences with a specific focus on the potential impacts to drinking water supplies.

The outcomes of the Health Risk Assessment have determined that hydraulic fracturing of shale gas reserves in Western Australia can successfully be undertaken without compromising drinking water sources when under the right conditions. This conclusion has been drawn from the following reasoning:

- shale and tight gas reserves are at depths of considerable distance below potable ground water sources, and
- risks of hydraulic fracturing to drinking water sources can be well managed though agreed industry and engineering standards, best practice regulation, appropriate site selection, and monitoring of the drinking water source.

The Standing Committee on Environment and Public Affairs states in the Final Report '*the Department of Health's Hydraulic fracturing for shale and tight gas in Western Australian drinking water supply areas: Human Health Risk Assessment is an important document in informing the public debate about hydraulic fracturing'*.

This Health Risk Assessment forms one component of the whole of government approach supported by APPEA and industry.

WESTERN AUSTRALIAN INTERAGENCY WORKING GROUP

The Interagency Working Group was established to resolve significant concerns related to shale and tight petroleum resources in Western Australia such as water management and regulation, environment management and regulation, and land access. The Working Group also provides a forum for the sharing of information with particular focus on the DMIRS as lead agency, informing other agencies on the following matters:

- Updates on new proposals
- Updates on new policies and reforms
- Major developments and changes in other state or national jurisdictions
- Other relevant activities.

The Interagency Working Group has achieved outputs including the whole-of-government shale and tight gas regulatory framework[148] and the Government response to the first Western Australian Parliamentary Inquiry into shale and tight gas.

The Science Needs Working Group's was established to review available scientific research, identify gaps and prioritise research to be undertaken to determine the environmental effects of shale and tight gas development; and to recommend practicable ways to minimise any adverse effects and protect the environment. Achievements of this Working Group include the northern Perth Basin baseline environmental characterisation by CSIRO, and the in-house modelling study of impacts from hydraulic fracturing fluid injection on deep aquifers.

[148] The Government of Western Australia, *Guide to the Regulatory Framework for Shale and tight Gas in Western Australia – A Whole-of-Government Approach*, 2015 Edition,