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Honourable Justice Pepper
Scientific Inquiry into Hydraulic Fracturing
Northern Territory

Dear Justice Pepper

Re: Submission to the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory

Thank you for the opportunity to make a submission to the Inquiry. I write from my position as Director at The University of Queensland (UQ), Centre for Coal Seam Gas. The Centre conducts and coordinates research on technical and social challenges associated with the development of CSG onshore in Queensland. It was founded in December 2011 and is funded by The University of Queensland the four main CSG industry proponents in Queensland. The Centre supports research across more than 15 different UQ schools and centres and all research is subject to the University's research integrity and ethics policies and procedures (www.ccsg.centre.uq.edu.au).

I recognise that the Inquiry Panel released a comprehensive Interim Report on 14 July 2017 and that the panel has consulted widely e.g., public hearings and a program of formal meetings with government agencies in other jurisdictions, research institutions and community organisations. This included meeting with researchers from the Centre for Coal Seam Gas on 17 July 2017 and this submission now provides additional information.

I note that concerns regarding groundwater issues were dominant in the Interim Report. As we discussed at the meeting on 17 July, we consider that the three key elements of effectively managing groundwater resources in a region of unconventional gas development include understanding the following:

1. Natural variability in water quality across the Basin and over time—collating and analysing historical groundwater records (including naturally occurring hydrocarbon occurrences) and continuing to build this dataset over time.

2. The quantity of groundwater used for all different purposes—metering this wherever possible and combining this with the use of emerging geospatial estimating methodologies.

3. The key recharge areas in the Basin (volumes of water, processes and pathways) —measuring recharge and adopting monitoring techniques that are suited to the characteristics of key recharge sites.

Within this, we also note that, in the case of Queensland and other jurisdictions overseas, the early, *pre-development* estimates of water abstraction by industry have been systemically and significantly over-estimated by industry and third parties alike. This is a combination of understandable regulator prudence, industry conservatism and academic and other 'worse case' analyses.

The attached table provides a summary of research projects managed through the Centre for Coal Seam Gas and findings/outcomes that are relevant to the risks identified in the Panel's Background and Issues Paper released in February 2017.

As you and the panel are aware, a large number of Parliamentary Inquiries or government commissioned reviews into hydraulic fracturing and associated aspects of the unconventional gas industry have been conducted since 2012, both in Australia and internationally. I have observed these review processes and read the resulting reports with interest. Based on these reviews I believe that the following comments are worth noting:

- There is by and large a reasonable understanding of the general hazards associated with the development of the onshore gas industry. There is also good understanding of the strategies and techniques that can be used to minimise and mitigate the environmental and social impacts of the industry. There is a good opportunity to learn from practices in other locations in order to adapt this knowledge to the circumstances in the Northern Territory.

- Many reviews have found that there is no current scientific evidence that supports a blanket moratorium on hydraulic fracturing. Importantly though, these reviews do agree that a robust regulatory framework is required to effectively manage hydraulic fracturing processes. To emphasis one point, research at UQ Business School (Stakeholder trust in the CSG industry) suggests that public trust in regulator capability is critical to perceptions of this 'robustness'.

- Within this wider body of review work, it would seem that understanding how best to engage and communicate risks, benefits and trade-offs in a contentious arena might require a new look!

There seems to be broad agreement across several, highly respected reviews, including the extensive ACOLA review, that the hazards are (or can be) understood and that the hydraulic fracturing process can be effectively managed through a robust and well-resourced regulatory system. However, this has clearly not resulted in a uniform political response even between States within a given country. The evidence is the same and the

laws of physics and chemistry generally don't change at State boundaries, perhaps something else is at play.

It is apparent that the panel has already reviewed many peer-reviewed journal articles regarding hydraulic fracturing. I would recommend that the panel also consider searching the OnePetro database for additional material if this has not been done to date. This specialist database, which is managed by the Society of Petroleum Engineers, includes a wide range of peer reviewed and non-peer reviewed technical literature for the oil and gas industry written by both practitioners and academics. It will include publications that do not always feature in other scientific databases. While much of this material is highly operational in nature, three review papers, written by a respected, senior industry experts are considered to be sound pieces of work:

King, G. E. (2012, January). Hydraulic fracturing 101: what every representative, environmentalist, regulator, reporter, investor, university researcher, neighbor and engineer should know about estimating frac risk and improving frac performance in unconventional gas and oil wells. In *SPE hydraulic fracturing technology conference*. Society of Petroleum Engineers. SPE- 152596

King, G. E., & King, D. E. (2013). Environmental risk arising from well-construction failure--differences between barrier and well failure, and estimates of failure frequency across common well types, locations, and well age. SPE Production & Operations, 28(04), 323-344. SPE-166142.

King, G. E., & Valencia, R. L. (2014, October). Environmental risk and well integrity of plugged and abandoned wells. In *SPE Annual Technical Conference and Exhibition*. Society of Petroleum Engineers. SPE-170949-MS

It could of course be argued that these papers are not 'independent' of industry, however I would recommend judging them on content and merit rather than by association. Note that the recent publication "*The Extensive review of shale gas environmental impacts from scientific literature (2010–2015)*" (Costa et al 2017), did not reference this material. The amount of published material in this domain has grown enormously in the last few years, such that our researchers and PhD students have a real challenge in staying current. In addition to the King papers above, our researcher Mr Dave Campin, who is researching regulatory responses to hydraulic fracturing, high-grades the following for your interest:-

Broomfield, M. 2013. Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe. (in European Commission DG Environment AEA/R/ED57281).

Fisher, Kevin, Norm Warpinski. 2012. Hydraulic fracture height growth: real data (in SPE Production and Operations February 2012: 1-12).

Zoback, Mark, Saya Kitasei, Brad Copithorne. 2010. Addressing the environmental risks from shale gas development (in Worldwatch Institute Briefing Paper 1).

For further information on regulation of hydraulic fracturing and well integrity, I would also recommend key chapters (including some by UQ-CCSG authors) in a very recent book "*Handbook of Shale Gas Law & Policy*" edited by Dr Tina Hunter, who I believe is known to the inquiry.

Finally, I would like to confirm that the Centre for Coal Seam Gas is available to provide further information on any issue of interest to the panel and in particular our professors of petroleum engineering can assist with scientific information on many petroleum engineering and hydraulic fracturing topics.

Yours sincerely

Professor Andrew Garnett
Director – UQ Centre for Coal Seam Gas

Summary of UQ Centre for Coal Seam Gas research relevant to the risk themes identified by The Scientific Inquiry into Hydraulic Fracturing in the Northern Territory

Risk Themes	CCSG project	Findings/Product
Water • Quality • Quantity • Aquatic ecosystems and biodiversity • Amenity values • Public health • Aboriginal people and their culture • Economic • Cumulative risk	3D Water Atlas for the gasfields https://wateratlas.net/	The 3D Water Atlas project developed an online data portal that provides public access to all publicly available groundwater data for the Surat Basin in combination with a (static) geological model. The portal provides 3D visualisation of both geological and groundwater data and access to detailed water bore records. A range of automated analytical tools are also available. The Atlas allows users to easily 'see' the considerable natural variability in water chemistry between geological layers, and across the basin. The database structure, visualisation software and analytical tools can be applied to other geological models and groundwater data sets to provide similar portals for other basins. A free model is available to the public, and CCSG member companies have access to additional technical features and their own company groundwater data through a special login.
	Recharge estimation in the Surat Basin	Current recharge estimates which constrain groundwater impact models probably do not do a good job and may underestimate recharge rates in key areas. This project aims to improve understanding of spatial and temporal distributions of groundwater recharge in the Surat Basin. The literature review documented recharge estimation methods used globally, reviewed the methods that had already been applied to the basin (and the results) and identified the potential for improving methods of recharge estimation for this basin. New data is being gathered at 3 sites to improve conceptual models and groundwater flow modelling inputs.
	Characterisation of current groundwater uses in the Surat and Bowen Basins	A significant amount of groundwater use in the Surat Basin is un-metered, predominantly that used for stock and domestic (S&D) purposes. This abstraction is used in ground water models to help estimate long term impact, however the quantity and spatial distribution of this groundwater abstraction were not well understood. This study developed new statistical and empirical modelling techniques to produce probabilistic estimates of groundwater extraction for non-CSG uses. The new statistical modelling framework gives a more complete understanding of the uncertainty inherent in any estimate of groundwater bore extraction than existing methods. While the study was specific to the Surat Basin, the reports detail the types of

		additional data and range of statistical methods that can be used to improve modelling performance for any Basin.
	Salt Compression and recrystallization	Salt is a waste product of the coal seam water treatment process. While overall salt volumes being produced are significantly lower than initial predictions, final waste disposal or beneficial use options are still being explored. UQ research developed a new salt compression technique to be applied at landfill sites, which have the potential to significantly reduce the waste volumes. This technique is also likely to make the salt more stable. The technique has been through laboratory tests, but has not been through field trials. The companies are still determining final salt management strategies.
	Mitigation of silica-associated scaling in CSG water treatment facilities	The physical mechanisms for scaling of water treatment membranes are now better understood and allow for changes to be made in pre-treatment in areas depending on natural variability. This project aims to improve the effectiveness of pre-treatment infrastructure to support the operation of reverse osmosis treatment plants. This is expected to reduce chemical waste and increase water recovery.
Well integrity is suggested as an additional value under the Water theme	Well Integrity Modelling	Simple modelling has shown that if the steel casing of CSG wells become damaged (e.g. via corrosion) underground or the cement around them develops micro-channels, the predominant mode of flow is very, very low rate. Furthermore, flow is of groundwater from the aquifers into the well and not gas from wells into the aquifers. Flow into the well causes the well to stop flowing gas.
Limited research in to the aquatic ecosystems and biodiversity has been completed in Australia. The Centre is aware of the following studies: 1. Healthy HeadWaters Coal Seam Gas Water Feasibility Study: the reports on aquatic ecosystems and biodiversity are found here: https://www.dnrm.qld.gov.au/water/catchments-planning/healthy-headwaters/coal-seam-gas-water-feasibility-study/activity-4 2. ARC Linkage Project: Salty gas: the ecological risk of saline effluents from coal seam gas and other hydrocarbon resources. http://appliedecology.edu.au/project/salty-gas-the-ecological-risk-of-saline-effluents-from-coal-seam-gas-and-other-hydrocarbon-resources-arc-lp/		
Land • Terrestrial ecosystems and biodiversity • Soil health	Impact of CSG extraction on biodiversity	This project (completed 2013) noted little previous scientific research into the impacts of the Australian CSG industry on biodiversity. Limited research had been conducted overseas (primarily in USA), which found that a range of measurable ecological impacts had been identified at local and regional scales and were potentially cumulative. The major impacts identified as important to the Queensland context were potential fragmentation of habitat and increased potential for invasion by pest/weed species.

• Amenity values • Aboriginal people and their culture • Economic • Proppant • Cumulative risk	Interactions of CSG development with agriculture	While the land taken out of production by CSG may be small (typically <2%), some landholders are spending significant amounts of extra time in dealing with CSG companies. This project surveyed 47 landholders and undertook detailed on-farm visits to investigate the impacts (positive and negative) of CSG development on agricultural businesses. This research also identified delays in rehabilitation of easements as a factor negatively affecting farm productivity and profitability.
	Plugging wells with bentonite and other expansive clays	Field trials so far have shown that special clay plugs can seal old wells very tightly. Lab tests show that they are gas-tight and very hard to dislodge. This research aims to develop an alternate well decommissioning technology, based on the use of bentonite plugs rather than cement as the filling material. The bentonite plug technology is expected to deliver 'self-healing' plugs with better long-term sealing performance than cement. Also, bentonite is cheaper than concrete and could present a more cost-effective solution.
Air • Public health • Climate change • Amenity values • Cumulative risk	Plugging wells with bentonite and other expansive clays	The bentonite technology (above) has the potential to reduce fugitive emissions from decommissioned wells including old coal bores.
Public health • Drilling & fracking chemicals • Hydrocarbons & BTEX • Radioactive substances • Mental health and wellbeing • Diesel fumes • Physical safety • Cumulative risk	A research agenda on potential environmental and population health impacts from the CSG industry	There is "a lack of clear evidence" of the environmental and public health impacts of unconventional gas extraction both locally and internationally. This may be because there have been no long term, comprehensive population based studies of the public health impacts of unconventional natural gas operations. A scoping study completed in 2013 reviewed available scientific literature. The report discussed public health studies, symptomatology and environmental stressors, epidemiological evidence, mental health, water, hydraulic fracturing, pollution of aquifers, surface discharges of produced and waste water, air quality, dust and pollutants in soil, and traffic. A research strategy incorporating the following elements was developed: a) Environmental health source data – collection and mapping (aiming to systematically gather and synthesise data on CSG-related emissions and map them spatially and demographically to support further analysis) b) Health data – collection of available health data, assessment of contaminant toxicity levels, review to identify any health effects consistent with contaminant levels and source locations/strengths.

		c) Pathways assessment – investigate any health effects identified in b) to identify possible pathways. The research would be very complex, would need to take place over several years and would require a lead role to be undertaken by Queensland Health.
	Bowen Surat hydrocarbon systems analysis	Naturally occurring liquid and gaseous hydrocarbons occur widely in the basin at different levels and in different areas. Their location provides information about vertical pathways to flow. The Bowen/Surat Hydrocarbon Systems Analysis study developed a methodology for establishing baseline conditions regarding the deposition and migration of hydrocarbons in geological basins. This approach can assist in understanding the background flux of methane emissions prior to gas development. The methodology uses data from exploration and production activities, geological studies and hydrological monitoring.
	Applications of natural draft dry cooling towers in CSG production	Compressor equipment associated with CSG requires fans for cooling, which use energy and create noise. This recently commenced project is developing a silent, low or no power cooling system for use in the CSG gathering network. While the primary objective was initially reduction in energy consumption, the new design may significantly reduce noise emissions when compared with current infrastructure. The project is reviewing potential application to both large-scale compressors and wells.
Aboriginal people and their culture • Land ownership • Benefits • Culture, values & traditions • Community wellbeing • Aquatic and terrestrial ecosystems • Cumulative risk	Indigenous land use agreements scoping study	This scoping study (2013) found that most analysis of land use agreements occurred in the context of mining activities rather than gas extraction. Several recommendations are documented in *Aboriginal engagement and agreement-making with a rapidly developing resource industry: Coal seam gas development in Australia*.https://doi.org/10.1016/j.exis.2014.08.001

Social • Housing & rent • Insurance • Health services • Education • Infrastructure • Livelihoods • Long term benefits • Community cohesion • Crime • Employment • Business • Cumulative risk	Cumulative socio-economic indicators Socio-economic indicators maintenance & annual reporting	It is possible and useful to measure socio-economic impacts relating to many projects (cumulative impacts) over time using objective measures (indicators) agreed by communities. Done at town level, this enables a conversation around a common fact base. Housing, traffic, employment, business incomes, crime rates etc. *together* all help a fuller understanding of town-growth dynamics. The *Cumulative socio-economic indicators* project developed a methodology for working with communities, government and industry to identify agreed indicators of change. These indicators are mapped over time to provide information to all stakeholders regarding changes at a town level, providing more detailed understanding of local changes that the usual analysis at regional or state level. The project produced an online toolkit to assist other communities to compile data associated with the indicators identified in the study – https://boomtown-toolkit.org/. The study compiled and analysed data for a number of communities and produced town profile booklets for each location. Following review of this data, the researchers identified 3 key effects (cumulative impacts): a) Movement – significant movement of people into, out of, and around the region as well as shifts upward and downward in economic and social wellbeing b) Diversity – an increase in the diversity of businesses, market choices, livelihoods, buildings, and cultural backgrounds of people in the region c) Expectations – the processes underlying the distribution of benefits and burdens in the region, town-by-town and family-by-family, seemed to be only partly understood. This foundation work has continued in the *Socio-economic indicators maintenance & annual reporting* project. The project has developed an annual reporting website for the Queensland gasfields region (https://boomtown-indicators.org/) where indicator information on selected towns is regularly updated and analysed. Town profiles are reviewed annually and key topics identified through analysis are discussed in detail.
	Evaluation framework for SSP STEM programs in the Surat Basin	Government education policy aims to improve student performance in the science, technology, engineering and mathematics (STEM) disciplines because these areas are important in supporting innovation and productivity. Queensland CSG companies were supporting STEM programs in Surat Basin Schools as part of their social impact commitments. The STEM evaluation framework was developed to assist companies to monitor the effectiveness of these investments and inform decision making processes. UQ also applied the evaluation framework to investments made in 2015 and 2016 and reported findings to industry.

	Interactions of CSG development with agriculture	Easing burden on landholder time may be more important than compensation. This project identified that while CSG development on farmland may have minimal impacts on productivity, the extra burden on landholder time was significant and higher than foreseen. The public report will be released in the near future.
	SME Study – Economic trends & benefits	Companies above a certain critical size, well networked and forward looking seem to have done well in the CSG boom. Very small companies struggle with quick upturns and downturns. It is possible to categorise firms and provide advice on being more resilient. This project surveyed 400 firms regarding the performance of small businesses in Queensland towns affected by CSG development across 3 time periods (investment, transition to operations and estimated future performance). The analysis identified the key factors that influence performance in each period. The report documents these factors and provides recommendations for business owners and policy makers.
	Stakeholder trust in the CSG industry	Trust in organisations or whole sector arises from experience and perceptions of capability, capacity and benevolence (or alignment of interests). It is influenced by power balances and by how a regulator is perceived by community groups. Trust in the CSG industry is highly variable, with different segments of the community having significantly differing views. Researchers conducted in-depth interviews with 145 participants and also surveyed over 550 individuals representing 5 stakeholder groups (landholders, community members, regional leaders, regulators and industry employees). The research identified 11 drivers of trust and distrust in the CSG industry and analysed the responses from the different stakeholder groups. Findings are reported in APPEA Journal 56.
Economic • Distribution • Property values • Other industries • Energy security • Net impacts • Management • Cumulative risk	Cumulative socio-economic indicators Socio-economic indicators maintenance & annual reporting Interactions of CSG development with agriculture SME Study – Economic trends & benefits	As above. The Boomtown indicators website tracks a range of population, housing, employment, income, business and crime rate indicators on an annual basis. These indicators provide insight regarding the local impacts of changing development in a region. This range of indicators can be expanded if consultation identifies new requirements.

Land access • Consultation • Consent • Conditions • Compensation • Cumulative risk	Interactions of CSG development with agriculture	As above. The public agriculture report provides a summary of the landholder perspectives on a variety of issues including land access arrangements. Several of the Centre's technical projects are aimed at improving well performance and decreasing maintenance requirements. Research in these areas has the potential to i) decrease the number of wells required to extract the gas and ii) decrease the number of maintenance visits to on-farm infrastructure. Such outcomes have the potential to decrease the impacts on agricultural businesses.
Regulatory framework • Failure to protect the environment • Land access • Public health • Aboriginal culture and communities • Social impacts • Economic impacts • Compliance & enforcement • Complexity • Regulatory capture • Cumulative risk	Stakeholder trust in the CSG industry Interactions of CSG development with agriculture Cumulative socio-economic indicators Socio-economic indicators maintenance & annual reporting Regulatory approaches in the unconventional gas sector	As above Regulatory approaches to the onshore unconventional gas sector vary across jurisdictions. The emergence of public concern has seen some governments respond with regulatory reviews and significant reforms, while others have used existing frameworks with adjustment to address specific risks and impacts. The *Regulatory approaches in the unconventional gas sector* study reviewed the evolution of regulation in selected jurisdictions (in Canada, USA, Europe and Australia) with either a significant or developing unconventional gas industry. Increased community expectations for regulatory effectiveness, regulatory complexity, regulator capacity and the role of science were some of the themes addressed. In addition, an internal CCSG review of development conditions identified that there was a strong focus on environmentally protective conditions (due to the requirements of environmental protection legislation), which also served to be protective of public health.