Submission to the Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia.

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Author background and relevant expertise

I have been working in tropical agriculture and in particular the semiarid tropics which embraces much of the proposed Western Australia prospective sites for shale gas extraction for more than 45 years, employed by Government Research Organisations, Universities, International Agencies including the International Crops Research Institute for the Semiarid Tropics, and have undertaken consultations for the Consultative Group on International Agricultural Research, World Bank, FAO, UNDP,UNEP. AusAID, USAID, UKODA, GIZ, Rockefeller Foundation. I have been advising the Condamine Irrigators on the Darling Downs in their response to the Arrow Energy Surat Gas Project EIS, preparing a background report for a Land Court case and have coordinated three public forums on Gas and Mining Projects in Brisbane and Sydney which were attended by more than 1000 participants. My research is in soil science especially soil biology and plant nutrition, farming systems including forestry/agroforestry and animal production, and am currently involved in developing a probiotic for the live sheep export trade from Western Australia. I have published more than 170 peer reviewed papers, 14 book chapters and 30 consultancy reports.

My main concerns with fracking in the WA context are concerned with the

- Loss of good quality agricultural land
- Contamination of ground and surface water by noxious chemicals and gasses
- Atmospheric contamination by noxious gases and particles produced
- Very large requirement for water to frack
- Disposal of flow back water
- Induced Seismic events
- Capping wells appropriately at the end of their life
- Cost and expertise required for appropriate regulation of the industry by Government

I do not deal with these issues comprehensively but rather seek to use references to highlight how serious are the implications for WA. With all these issues the Precautionary Principle should prevail (Randall 2011; 2012), particularly in such a short term industry for WA, being made more so by the large production of gas in other countries, the questionable claim for its use as a transition hydrocarbon fuel particularly for electricity generation with the costs associated with renewable energy sources for electricity generation now less than new gas based systems. These concerns are addressed very thoroughly by the extensive examination of peer reviewed published literature in the latest 5th edition published in March 2018 of the publication (which comprises 266 pages and 1124 annotations/references) from which I cite important comment and conclusions that I trust will induce the panel to exam the whole document in detail :-

Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018, March). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (5th ed.) cited as PSR 2018. http://concernedhealthny.org/compendium/

P9-10 "*As is revealed in the Repository for Oil and Gas Energy Research, the database of literature maintained by PSE Healthy Energy, the number of peer- reviewed publications relevant to assessing the environmental, socioeconomic, and public health impacts of shale gas development doubled* *between 2011 and 2012 and then doubled again between 2012 and 2013. More than 90 percent of these publications have been published since January 2013, with nearly one-quarter of the now more than 1,300 available studies published in 2017 alone*." The hazards associated with shale gas extraction have taken time to measure and document hence the extraordinary explosion of publications in 2017 (Hays & Shonkoff 2016).

"*A growing body of peer-reviewed studies, accident reports, and investigative articles has detailed specific, quantifiable evidence of harm and has revealed fundamental problems with the entire life cycle of operations associated with unconventional drilling, fracking, and fracked-gas infrastructure. Industry studies, as well as independent analyses, indicate inherent engineering problems including uncontrolled and unpredictable fracturing, induced seismicity, extensive methane leakage, and* ***well casing and cement failures that cannot be prevented with currently available materials and technologies" (***P14 PSR 2018)***.***

Loss of good quality agricultural land.

GQAL in Australia and particularly WA is a very limited resource, circumscibed by rainfall and the availability of underground water, and soil quality. Thus it behoves society to protect this resource as once soils are degraded it often takes much beyond our lifetimes for them to recover not to mention the loss of food production capacity in the meantime. In this regard easements for access and gas gathering lines (c. 30m wide) and well head land area, and placement of wells and gas company easements in the path of agricultural equipment runs through the paddock, place an unacceptable burden on farm operations. Vehicle movements in the easement lines cause compaction and if the road contains aggregate this means that the easement is virtually unrecoverable. Recovery of land impacted by shale gas operations were not returned to pre-drilling conditions even after 25 to 50 years and requires intensive effort (Minnick et al 2015). The hard surface of the road affects movement of surface waters and proneness to erosion at the intersection of the road with the paddock soil.

The volume of water required for fracking (now estimated to be between 45 and 90 million litres per well (P 17 http://concernedhealthny.org/compendium) will place an extraordinary burden on the water resources (and road resources as this water will likely have to be trucked in) of much of WA where fracking is proposed particularly the Perth Basin. Already groundwater levels are falling and this amount of water required (more than two thirds not reusable) will be in direct competition with urban water supplies and agricultural use. Outside the tropical parts of Western Australia, climate change will result in even less rainfall and Perth water supply for example is already affected with the Perth Water Corporation well advanced in developing alternate and costly supplies mainly desalination plants and injection of sewage treated water into groundwater for later use (https://www.watercorporation.com.au/water-supply/our-water-sources/securing-perth-supply).

Contamination of ground and surface water by noxious chemicals and gasses

Contamination can occur from spills of fracking chemicals and returned fracking waste water, seepage from containment ponds if unlined or if the lining is punctured, pipe leaks and well failures. In the US "*Substantial evidence shows that drilling and fracking activities, and associated wastewater disposal practices, inherently threaten groundwater and have polluted drinking water sources, as confirmed by the 2016 final report of the U.S. Environmental Protection Agency (EPA) on the impacts of fracking on the nation's drinking water. Repudiating industry claims of risk-free fracking, studies from across the United States present irrefutable evidence that groundwater* *contamination occurs as a result of fracking activities and is more likely to occur close to well pads. In Pennsylvania alone, the state has determined that more than 300 private drinking water wells have been contaminated or otherwise impacted as the result of drilling and fracking operations over an eight-year period. As determined by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), the chemical contamination of some private water wells in Dimock, Pennsylvania posed demonstrable health risks, rendering the water unsuitable for drinking.* (P48 in http://concernedhealthny.org/compendium/).

Well failures regularly occur despite industry claims otherwise. They result because of cement casing faults (eg from faulty packing and because cement shrinks on drying) and even micron wide gaps and poor seals with the rock surrounding the well are a significant passage for fugitive methane emissions. The poorly sealed pipe joints, corrosion from salty wastewater, underground movements causing well casings to shear, also result in failures.

The 50 year integrity of wells is of course not yet known but is a substantial issue for the Inquiry to address. Schlumberger (2003) one of the world's largest specialist hydraulic fracturing companies reported that

"Leakage rates increased dramatically with age: about five percent of the wells leaked immediately; 50 percent were leaking after 15 years; and 60 percent were leaking after about 30 years."

In the Pennsylvania Marcellus Shale, of the 6,000 wells drilled since 2013, six to ten percent of them leaked natural gas with the rate increasing over time, and of the 1,3266 wells drilled in 2012, well failures occurred in 120 (8.9%) (Ingraffea 2013).

Isotope analysis indicates that drinking well contamination of VOCs and methane is occurring from fracking activity. The US EPA (2016) $29 million study confirmed that fracking caused substantial contamination of water resources in the USA. Further as the PSR Report states (P48, PSR 2018) contamination occurs with *"heavy metals, radioactive elements, brine, and volatile organic compounds (VOCs and BTEX), which occur naturally in deep geological formations and which can be carried up from the fracking zone with the flowback fluid. As components of the fracking waste stream, these toxic substances also pose threats to surface water and groundwater. A 2017 study found that spills of fracking fluids and fracking wastewater are common, documenting 6,678 significant spills occurring over a period of nine years in four states alone. In these states, between 2 and 16 percent of wells report spills each year. About 5 percent of all fracking waste is lost to spills, often during transport."*

Atmospheric contamination by noxious gases and particles produced

Methane fugitive emissions are the norm from gas wells because of the inability to block and cap gas escape from wells, and often gathering pipes. Well pressure disturbances and separation of water from gas often require venting and flaring of methane which then contributes to atmospheric pollution. Noxious, cancer forming VOCs and benzene from the shale are contained in these emissions and contribute to health problems, extensively documented in the US shale case (eg Stone 2017 and P48, P266 PSR 2018). CSG production in SE Queensland is closely linked with increases in asthma hospital admissions (McCarron 2018). Recently increasingly high levels of atmospheric ethane, an ozone contributing compound have been determined as resulting from shale gas production in the US (Kort et al 2016). This ozone stays near the ground surface and is linked to respiratory problems, eye irritation and crop damage.

Extensive helicopter surveys of more than 8000 wells in the US using an infrared camera, found that the levels of methane and VOCs varied in an unpredictable fashion from site to site, were much larger than previous inventories and that some wells were superemitters, leaking more than 200 cubic feet of methane and VOCs per hour (Lyon et al 2016).

Very large requirement for water to frack

As mentioned earlier, for current drilling systems for shale which extend the horizontal wells and fracking sites over several kilometres, 45 to 90 million litres are required for each well. When this is multiplied by the number of wells needed to be dug to make the site an economic venture (currently calculated at a minimum of 1000 wells and this depends on how well they flow gas!), a very large amount of water is needed for any shale gas venture. This requirement competes with other uses, and WA is not endowed with large groundwater reserves that could be readily and equitably used for this purpose. The number of truck loads required to transport this water into the well head and the fracked wastewater return away is very large indeed and affects all who are in the vicinity of these road networks which will become particle ridden from road dust and diesel produced particles both PM2.5 and 10, which are cancer inducing.

Road infrastructure degradation is an inevitable consequence. Further, spills from the transport of the wastewater are a continuing source of ground and surface water contamination in the US.

"*Given the fact that on average 1235 one-way truck trips delivering fracturing fluid and proppant are required to complete an unconventional well, the potential to transport invasive plant propagules is significant"* (Barlow et al 2017). In SE Queensland utilities going off road carried up to 397 weed seeds, 81% of which were exotic ie not from Queensland and 66% not from Australia, so that it is imperative that the wash down facilities for vehicle transport actually remove weed seeds (Khan et al 2017; Bajwa et al 2018). Current washdown facility instructions in Queensland are inadequate for removing weed seeds and a washdown period of 15 min is required for adequate removal from a utility (Khan 2012).

Can one imagine that trucks moving water to fracking sites will wait this long for their washdown which will take much longer as a truck is much bigger than a utility! Weeds have been introduced onto farms by vehicle movement by CSG operators. Will regulations adequately protect farmers and the environment in general from invasive weeds introduced by UG truck movements?

Disposal of flow back water

Apart from the danger of transport spills mentioned above, a major problem is how to dispose of the fluid in a way that is by its very nature damaging to the receiving environment and can contain toxic materials sustainably into the future as many of the compounds are slow to degrade over time from microbial or chemical reactions. In the US materials injected into aquifers or voids have been shown to migrate and are hence not contained and can contaminate streams, drinking water and farming irrigation wells (eg Dechert 2014; Alawattegama et al 2015). With current horizontal drilling extending more than 3 km, the fluid injections easily reach 60 million litres per well. Such reinjection causes buckling of the earth's surface in the US, observed from space with much potential for seismic disturbances (Coglan 2016).

The treatment of fracking wastewater needs to be very carefully regulated and as in the US the required inspections of the treatment facilities by Government Inspectors must be paid for by the UG companies.

Surface evaporation ponds are not a viable option, as even if they are lined, the plastics eventually degrade and the containment of toxic salts over time is thus obviated, releasing very large amounts of contaminants into the environment and thereby capable of migrating to aquifers and agricultural soils and other land based ecosystems. Such ponds have been banned in Queensland for this very reason. Strict regulation for the dam build for temporary holding ponds is required to prevent leaks. Even if reverse osmosis systems were capable of removing sufficient levels of these contaminants for the water to less harmful, the waste salt material removed still has to be disposed of.

This is a major unresolved issue for CSG in Queensland where the current proposal by the "We Kando Pty Ltd" company is to initially dump a million tonnes of salty sand and RO salt (4.5Million tonnes) in pits very close to the Darling catchment Stockyard Creek but with an approval for 15million tonnes showing the magnitude of the salt disposal problem with gas mining!

Induced Seismic events

Drilling deep into the earth and fracking can induce seismic activity that can be dangerous and destructive. In Australia the drilling and fracking into granite rocks in the Geodynamics "hot rocks" project in the Cooper Basin, Central Australia led to more than 4,000 earthquakes and induced ARENA to withdraw funding. Different components of the UG process can induce seismic events. The Human-Induced Earthquake Database **http://inducedearthquakes.org/** managed from Durham University in the UK lists 45 projects showing that earthquakes were induced by UG mining activity. Fracking can affect fault lines with even slight movement leading to pathways opening to aquifers above or strata below as well as freeing up gas, the objective of the fracking. Extraction of the water in the shale gas layer can also lead to earth movement as in the US where it is visible from space. While seismic assessments from the ground surface add to the knowledge of the geological formations, they cannot identify minor faults in the deep shale layers being drilled. In the one shale gas well drilled for Origin in the Amungee NW-1H Velkerri B shale pool in the Beetaloo Basin in the NT a deformation occurred midway in the horizontal section and as a result out 12 projected fracking stages the distal 6 were unable to be fracked and another which was attempted also did not frack (Origin 2017 https://frackinginquiry.nt.gov.au/submission-library?a=452658). In Canada, the fracking process itself has been linked to earthquakes as significant as magnitude 4.4. Reinjection of fracking waste fluids into ground strata has resulted in earthquakes in the US and Canada. *"In addition to direct pore pressure effects, deformations due to fluid flows ("poroelastic effects") play an important role in generating earthquake activity. Elevated risks for earthquakes can persist years after fracking waste is injected underground.*" (p132, PSR 2018; Barbour et al 2017). Such induced seismic activity can affect infrastructure such as large dams whose very weight can themselves cause seismic activity and the extra activity induced by the injections of fracking wastewater nearby may trigger a much larger and dangerous event.

Recent research by Fiona Mullen (2017) around the wells dug in the Perth Basin for UG exploration showed that for the Cadda Terrace with three shale gas wells *"In a strike slip environment fractures are more likely to propagate vertically"* (p98) enabling the contamination of overlying deep aquifers, and movement of salt upwards from other high salt aquifers. Such faults are not necessarily detected by on ground seismic tests and are likely to be common across the three different sites in Cadda Terrace in the Perth Basin. Fiona Mullen's states "*In conclusion, unconventional gas exploration permits have been issued throughout the south west of Western Australia without adequate appraisal of the risk to deep aquifers in the context of climate change. Based on work conducted by CSIRO and BOM, the south west of WA can expect a 20% reduction in rainfall by 2030 from the 1990 baseline."* These low salinity deep aquifers are used for agriculture and scheduled to supply Perth with 48 gigalitres/year. This water use would be in direct conflict/competition with any water required by the UG industry for fracking. Surely this gives pause for thought about the need for, and outcome from, a UG industry relying on fracking water.

Capping wells appropriately at the end of their life

Because metal well casings erode over time, and cement shrinks on drying and degrades over time, capping wells with cement, as is the common industry practice, so that they do not continue to pollute the environment is well nigh impossible. Current capping by cement in the CSG fields in Queensland is not proving adequate and bentonite is being trialled by the Coal Seam Gas Centre at the University of Queensland (https://ccsg.centre.uq.edu.au/ ; https://ccsg.centre.uq.edu.au/article/2017/05/ccsg-team-receives-175000-grant-bentonite-project). This illustrates that this industry is prepared to use processes that are known to damage the environment in the end often when the company has moved on or gone bankrupt. Checks on wells that are capped should be mandatory over time by Government (or Government accredited) inspectors paid for by the UG company. Under current practice these capped wells will continue to release fugitive emissions adding a great deal green house gas contamination of the earth's atmosphere.

Cost and expertise required for appropriate regulation of the industry by Government

Mitigation of the risks involved in UG require appropriately detailed and comprehensive Regulations that instigate processes and data gathering that are required for an integrated land use and maintenance of environmental integrity planning process by Government. Such planning processes need to be transparent with opportunities for input by community as well as developer stakeholders at each stage of consultation regarding the development or land use change. Such an appropriately devised planning process would then lead to a consensus indicating when a particular development such as UG can occur and under what conditions. This would reduce the requirements to be addressed in an EIA and avoid the use by developers of volume of words produced in an EIA as a process to perplex/confuse assessors both in Government and the general public stakeholders.

Landholders including Government (eg National Parks and leasehold land) and Native Title Land Holders need to be fully informed of the processes that the UG companies are planning to undertake and to have the option of refusing to allow such operations on the land they are stewards of, as occurs in the USA.

As well as technical competence of the drilling companies, the major issue in ensuring damage to the environment is minimised, is appropriate Government regulation and adequate technical staff capacity to assess mandated self reporting by the UG companies of "incidents" and the data from any required regular monitoring of the well integrity, water and contaminant movement and methane fugitive emissions. Self reporting needs to be quality controlled by continuing Government inspections of the facilities and the companies event recording books. As well as staff capacity to *assess and regulate* EIS issues and reports from the shale gas companies, the WA Government also needs the costly and difficult to obtain expertise to *monitor* the shale gas and oil field operations.

The cost to Government of managing an UG development in order to fulfil its fiduciary obligations towards the environment and its citizens is considerable. Such costs need to be underwritten by the companies undergoing such development either as a direct payment for the cost of undertaking required activities, undertaking the activities themselves in a regulated manner, or through an appropriate royalty level to cover Government monitoring costs (including the devising of appropriate rules and regulations, and auditing of OUG company and Government monitoring reports) as in the US.

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