"What environmental, social, and economic impacts will hydraulic fracturing (fracking) for shale gas have on the Northern Territory?"

Literature Review

by Pauline Cass

10 May 2016

Figure 1. An aerial view of hydraulic fracturing for shale gas in Wyoming, USA. Source: Bagilet 2015.

Pauline Cass Email: territoryfun@yahoo.com.au

Table of Contents.

"What environmental, social, and economic impacts will hydraulic fracturing (Fracking) for shale gas have on the Northern Territory?"

Literature Review by Pauline Cass

10 May 2016

Introduction to the Northern Territory and Hydraulic Fracturing.

The Northern Territory of Australia has a total area of 1,349,129 square kilometres (Geoscience Australia n.d.) which is home to 244,500 people (Australian Bureau of Statistics 2015). The 'Onshore Petroleum Titles and Developments' map (Appendix 1), shows over 90% of the Northern Territory (NT) is currently either approved or under application for onshore oil and gas exploration and production (Styles 2016), with prospective onshore gas resource estimates of more than 200 trillion cubic feet (Department of Minerals and Energy 2015c, p. 3). Onshore gas is found in a variety of matrixes or plays, such as shale, tight sands, coal seam (CSG), and conventional plays, with each requiring different methods of extraction (Department of Economic Development, Jobs, Transport and Resources 2015). Shale gas is mostly methane, is colourless and odourless, and can be used in homes, industry, and to generate electricity (Santos Ltd 2016). The NT's onshore gas is predominantly shale gas trapped in shale rock, so will need hydraulic fracturing to extract it (Department of Minerals and Energy n.d; Hawke 2015, p. ii).

Hydraulic fracturing shale gas is a form of unconventional gas mining. It is also known as fracking, fraccing, hydrofracturing, hydrofracking, fractious stimulation, and onshore natural gas production. The term 'fracking' is used in this review to describe all aspects of the hydraulic fracturing processes and industry. Shale gas in the NT requires horizontal fracking (Figure 2), where a well is drilled down vertically for an average of 2.5 kilometres (Northern Territory Government 2016), before turning horizontally in the shale rock and continuing <2 kilometres (Northern Territory Government 2015c). The well is then cased and cemented (Northern Territory Government 2015b), before being perforated at the production site. Fracking fluid consisting of water, proppants and chemicals, is then injected in large quantities at high pressure to force and hold fractures open, stimulating gas flow, and resulting in vertical fissures which "can extend several hundred feet away from the wellbore" (EPA 2015b). The gas then flows to the surface where it is collected and processed (Figure 4). Compared to other gas types, shale's production rate declines rapidly once fracked, necessitating the constant drilling and fracturing of new wells to maintain a play's productivity (Cook et al. 2013, p. 23), often resulting in 'octopus' or multi-well pads (Figure 3).

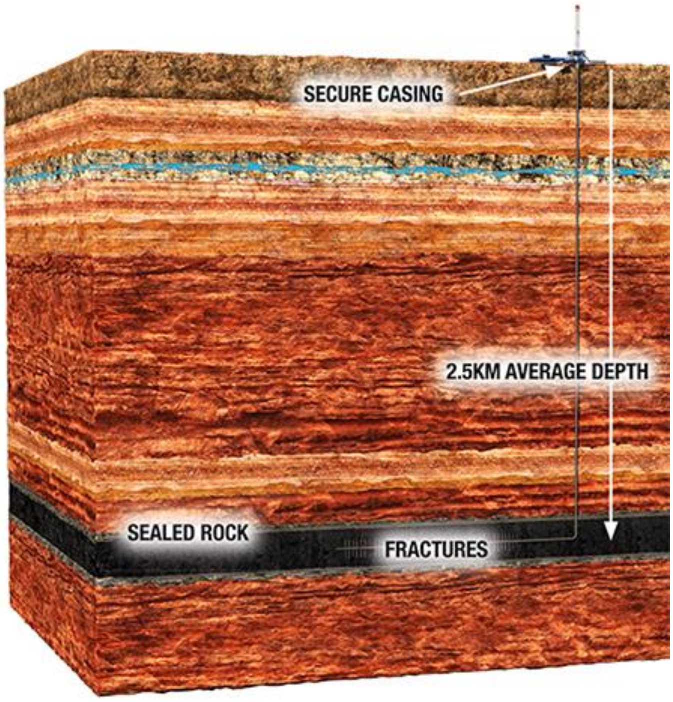


Figure 2. Diagram of horizontal drilling and hydraulic fracturing for shale gas.
Source: Northern Territory Government 2016.

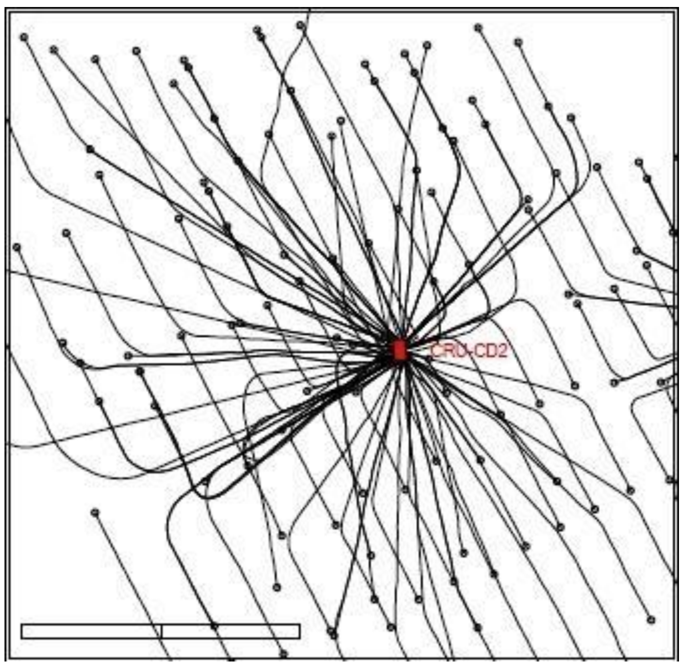


Figure 3. An octopused multi-well pad. The surface multi-well pad is shown in red with the wells (Black lines) radiating out underground. 2,000 acres of shale reservoirs can be fracked from one 7 acre pad. Source: Hicks 2012.

Situation Analysis:

Fracking is a divisive issue. Internationally, some countries like the USA (EIA n.d.) frack, though it is banned in some US States (Kaplan 2014); some like South Africa (Bagilet 2015) have a moratorium on fracking; while others such as Italy (DLA Piper 2016), Wales (Schaps 2015), and France (Members Research Service 2014, p. 5), have banned fracking due to environmental concerns. The Northern Territory Government (NTG) promotes and supports fracking as a clean energy (Jackson 2016). In 2015 it released the 'Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory' (Hawke Report), which states "This Inquiry's major recommendation, consistent with other Australian and International reviews, is that the environmental risks associated with hydraulic fracturing can be managed effectively subject to the creation of a robust regulatory regime" (Hawke 2015, p. x). The Hawke Report's finding that a moratorium is unjustified, despite over half the submissions calling for one (Hawke 2015, p. 46), was questioned by NT politicians (Manison 2015), lawyers (ABC News 2015), and environmentalists (Zillman 2015), and applauded by industry (Macdonald-Smith 2016; Curtain 2015).

2016 is a Territory election year and fracking has become a political issue. The current NTG (Country Liberal Party) asserts it will frack (Giles 2016), Territory Labour promises a moratorium if elected (Coates 2016), 1Territoy publicises they are 'anti-fracking' (Earley 2015), and an independent candidate has called for a fracking referendum (Bardon 2016a). There are numerous anti-fracking groups in the NT, such as Protect Arnhem Land, Don't Frack the Territory, Environment Centre NT, Arid Lands Environment Centre, and NT Frack Free Alliance, which has groups in many areas. A recent Mix FM Darwin survey found 89.1% of respondents opposed fracking (Woolfe 2016), and another poll in the NT News reported 83% of Territorians were concerned by the effects of fracking (Walsh 2016).

This literature review aims to inform NT stakeholders such as politicians, local businesses, Indigenous communities, and the general public about the impacts of unconventional gas mining for NT shale gas, and provide an extensive, relevant bibliography. It will investigate shale gas fracking literature, in order to answer the question 'What environmental, social, and economic impacts will hydraulic fracturing (Fracking) for shale gas have on the Northern Territory?'

Figure 4.

Santos' Moomba gas plant, South Australia, has approximately 5,600 kilometres of pipelines and flowlines, field boost compressors, and 24 oil and gas satellite facilities.

Source: Foster & McGee 2015

Literature Review:

Impacts of Hydraulic Fracturing for Shale Gas in the NT.

This literature review will explore fracking impacts pertinent to the Northern Territory, using recent Australian peer-reviewed literature whenever possible. There is a plethora of information available on horizontal hydraulic fracturing for shale gas, with many international and national government and private sector inquiries, discussion panels, scientific reports, scientific journals, websites, magazine and newspaper articles, and anecdotal reports on social media. A recently published literature review (Hays & Shonkoff 2016) found 685 peer-reviewed scientific papers addressing the impacts of fracking had been published between 2009 and 2015.

Figure 5. 3600 kilometres of seismic lines cleared in preparation for fracking operations near Broome, WA. Source: Frack Free Kimberley Community 2016

Figure 6. Well pads, access roads, pipeline corridors and other fracking infrastructure in Green River Valley, Wyoming, USA. Source: Hoffman 2012.

Environmental Impacts:

The Hawke Report (2015) found environmental impacts can potentially result from many shale gas fracking processes but that the risks can be managed with robust regulations. The Australian Academy of Technological Sciences and Engineering’s (ATSE) submission to the Hawke Inquiry (Finkel 2014, p. 2) warns that if management is inadequate, the NT’s ecosystems, sedimentary basins, water resources, and landscapes may be detrimentally impacted.

The key environmental findings of the European Parliament’s study ‘Impacts of Shale Gas and Shale Oil Extraction on the Environment and on Human Health’ were:

• Unavoidable impacts are area consumption due to drilling pads, parking and manouvering areas for trucks, equipment, gas processing and transporting facilities as well as access roads. (Figures 5 & 6)

• Major possible impacts are air emissions of pollutants, groundwater contamination due to uncontrolled gas or fluid flows due to blowouts or spills, leaking fracturing fluid, and uncontrolled waste water discharge. (Figures 10 & 11)

• Fracturing fluids contain hazardous substances, and flow-back in addition contains heavy metals and radioactive materials from the deposit. (Appendix 2)

• Experience from the USA shows that many accidents happen, which can be harmful to the environment and to human health. The recorded violations of legal requirements amount to about 1-2 percent of all drilling permits. Many of these accidents are due to improper handling or leaking equipments. (Appendix 3)

• Groundwater contamination by methane, in extreme cases leading to explosion of residential buildings, and potassium chloride leading to salinization of drinking water is reported in the vicinity of gas wells. (Figures 7 & 8)

• The impacts add up as shale formations are developed with a high well density (up to six wells per km^2). (Tables 1 & 3)

(Lechtenböhmer et al. 2011)

In 2013 the European Commission Directorate-General for Environment commissioned environmental risk assessments for both individual wells, and multiple installation's cumulative effects, for each stage of shale gas well development. The results are shown in Table 1 and demonstrate that risks to water, air and biodiversity increase with multiple wells.

Table 1. Summary of shale gas well environmental risk assessments for an individual site and cumulative sites. This table demonstrates that risks to air, water and biodiversity increase with well accumulation.

Environmental Aspect	Site identification and preparation	Well design drilling, casing, cementing	Fracturing	Well Completion	Production	Well abandonment and post-abandonment	Overall rating across all phases
Groundwater Contamination Individual Site	Not Applicable	Low	Moderate – High	High	Moderate – High	Not Classifiable	High
Groundwater Contamination Cumulative	Not Applicable	Low	Moderate – High	High	High	Not Classifiable	High
Surface water Contamination Individual Site	Low	Moderate	Moderate – High	High	Low	Not Applicable	High
Surface water Contamination Cumulative	Moderate	Moderate	Moderate – High	High	Moderate	Not Applicable	High

Water Resources Individual Site	Not Applicable	Not Applicable	Moderate	Not Applicable	Moderate	Not Applicable	Moderate
Water Resources Cumulative	Not Applicable	Not Applicable	High	Not Applicable	High	Not Applicable	High
Release to Air Individual Site	Low	Moderate	Moderate	Moderate	Moderate	Low	Moderate
Release to Air Cumulative	Low	High	High	High	High	Moderate	High
Risk to Biodiversity Individual Site	Not Classifiable	Low	Low	Low	Moderate	Not Classifiable	Moderate
Risk to Biodiversity Cumulative	Not Classifiable	Low	Moderate	Moderate	High	Not Classifiable	High
Seismicity Individual Site	Not Applicable	Not Applicable	Low	Low	Not Applicable	Not Applicable	Low
Seismicity Cumulative	Not Applicable	Not Applicable	Low	Low	Not Applicable	Not Applicable	Low

Adapted from: Broomfield 2013.

Fracking Chemicals:

The Northern Territory Government (2015c) tells us fracking requires "pumping a mixture of sand, water and a low concentration of chemicals (up to 3%)" into a well. 3% sounds innocuous until the volume of water used is considered. It is unclear which chemicals will be used in the NT (Department of Minerals and Energy n.d.). Appendix 2 summarises the fluids and particles used in hydraulic fracturing fluid in Australia. Elsner & Hoelzer (2016) discuss the over 1,000 reported fracking substances used in America and found they range from non-toxic to extremely toxic (deadly).

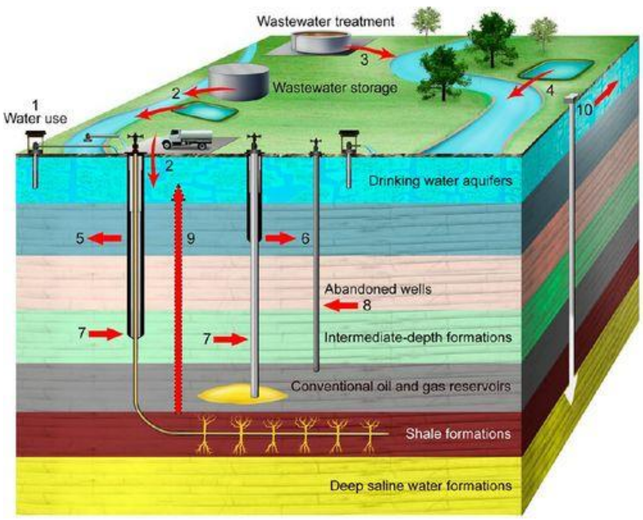
Water:

The main concern people have with fracking is its impacts on water (Hawke 2015, p. 31). Water resource impacts include contamination and depletion (Table 1). Shale gas production uses a higher input of water than CSG production, but it also creates less waste water (Australian Council of Learned Academies 2013, p. 2). A shale gas well can use over 10 million litres of water to frack (Grafton 2012, p. 16).

The media often shows flammable water as examples of water contamination (Figures 7 & 8). Osborn et al. (2011, p. 8172) found "methane concentrations in drinking water wells increased with proximity to the nearest gas well" and were "a potential explosion hazard" in active fracking areas. Drilling fluids, flow back fluids, fracking chemicals, and naturally occurring contaminants migrating into drinking water and rivers due to fracking have also been found (Broomfield 2012). Fracking fluids containing heavy metals and acids have harmed Kentucky fish species (Papoulias & Velasco 2013). Wildlife and animals suffer similar impacts to humans (Centre for Biological Diversity, n.d.; Kelly 2011). 'Fracking Can Contaminate Drinking Water' (Vaidyanathan 2016), explains why older reports refuted fracking caused water contamination. Figure 9 demonstrates possible sources of water contamination from fracking shale gas.

Figure 7. Tap water on fire after water contamination from fracking. Source: Beament 2015.

Figure 8. CSG fracking is blamed for methane in the Condamine River. Source: Water Career 2016.



Schematic illustration (not to scale) of possible modes of water impacts associated with shale gas development reviewed in this paper: (1) overuse of water that could lead to depletion and water quality degradation particularly in water-scarce areas; (2) surface water and shallow groundwater contamination from spills and leaks of wastewater storage and open pits near drilling; (3) disposal of inadequately treated wastewater to local streams and accumulation of contaminant residues in disposal sites; (4) leaks of storage ponds that are used for deep-well injection; (5) shallow aquifer contamination by stray gas that originated from the target shale gas formation through leaking well casing. The stray gas contamination can potentially be followed by salt and chemical contamination from hydraulic fracturing fluids and/or formational waters; (6) shallow aquifer contamination by stray gas through leaking of conventional oil and gas wells casing; (7) shallow aquifer contamination by stray gas that originated from intermediate geological formations through annulus leaking of either shale gas or conventional oil and gas wells; (8) shallow aquifer contamination through abandoned oil and gas wells; (9) flow of gas and saline water directly from deep formation waters to shallow aquifers; and (10) shallow aquifer contamination through leaking of injection wells.

Figure 9. Potential sources of shale gas fracking impacts on water.
Source: Avner et al. 2014, p. 8337.

Irreversible water impacts include: depleting fossil aquifers (eg. Australia's Great Artesian Basin), large volume water extraction causing aquifer compaction, artesian aquifers losing pressure, fracking creating new connections between aquifers, groundwater contamination, and loss of biodiversity and groundwater-dependent ecosystems (Nelson 2012, p. 31).

Air Pollution:

Sources of air pollution associated with fracking, including methane, are illustrated in Figure 12. Styles (2014) found that flaring gas containing high percentages of hydrogen sulfide results in SO_x emissions which affects local and regional air quality, and Tumuluri et al. (2016) found acidic gases produced by fracking, including CO_2, SO_2, and NO_x, have adverse environmental and health effects. Fracking air pollutants and their health impacts are described in Table 2.

Figure 10. Venting shale gas containing toxic H_2S, Franklin, Texas. Source: Wilson 2012.

Figure 11. Shale gas flare, burning off excess gas, Nordheim, Texas. Source: Tedesco & Hillier 2014.

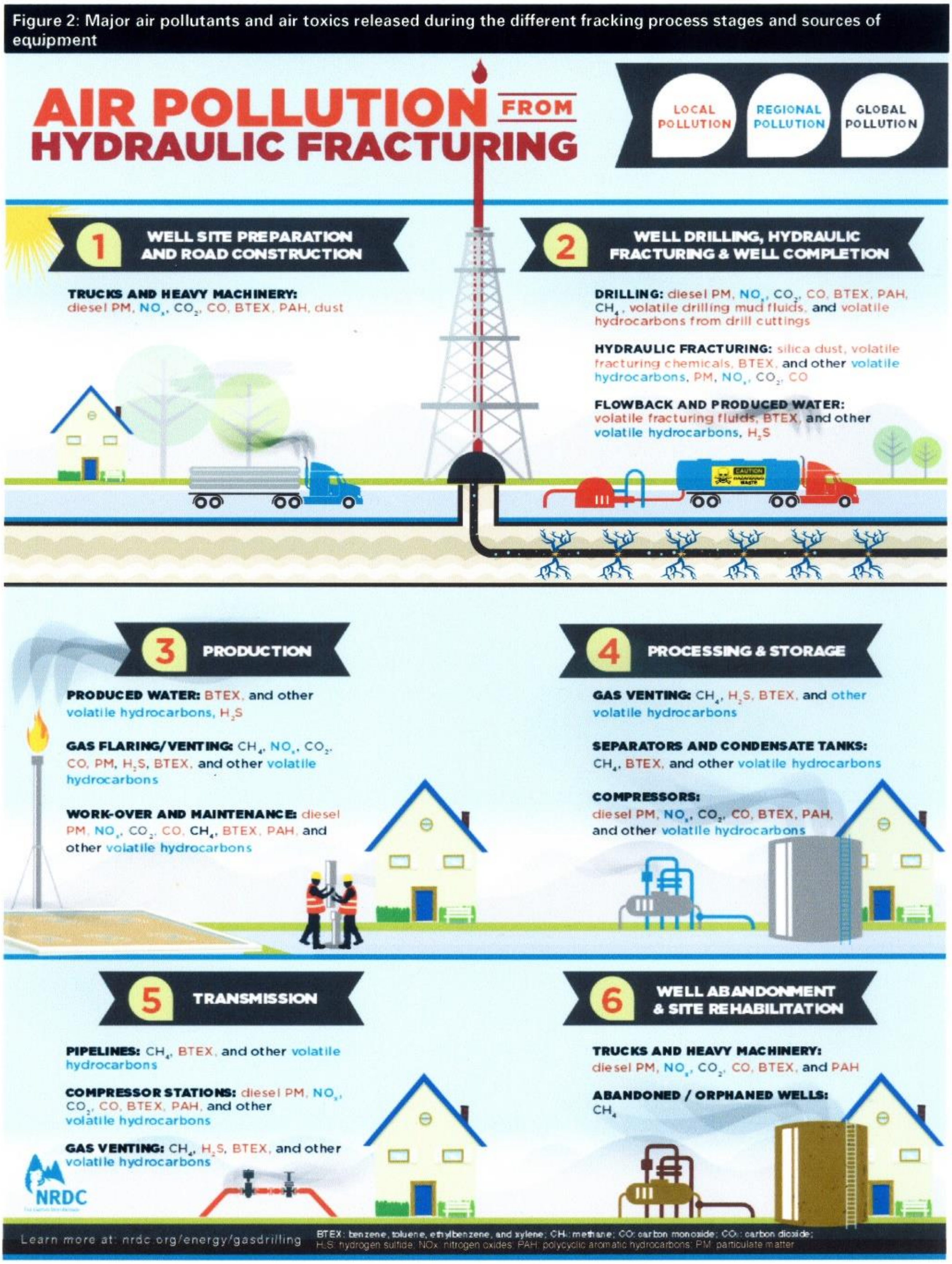


Figure 12. The major air pollutants released during the different stages of fracking. Source: Srebotnjak & Rotkin-Ellman 2014.

Table 2. The Health Impacts of Air Pollution from Hydraulic Fracturing.

<table>
<tr><th colspan="2">Air Pollutant Type</th><th>Affected Body Organ/System</th><th>Carcinogen</th></tr>
<tr><td colspan="4">Particulate Matter (PM)</td></tr>
<tr><td colspan="2">Diesel PM</td><td>Respiratory system; Cardiovascular system</td><td>✓</td></tr>
<tr><td colspan="2">PM_{10} and smaller *</td><td>Respiratory system; Cardiovascular system, Dermal</td><td></td></tr>
<tr><td colspan="4">Volatile Organic Compounds (VOCs)</td></tr>
<tr><td rowspan="4">B
T
E
X</td><td>Benzene</td><td>Immune system; Blood; Foetal development, Neurologic System</td><td>✓</td></tr>
<tr><td>Toluene</td><td>Brain and nervous system; Respiratory system; Foetal and child development;
Reproductive system</td><td></td></tr>
<tr><td>Ethylbenzene</td><td>Foetal and child development; Liver; Kidney; Endocrine system; Auditory system</td><td>✓</td></tr>
<tr><td>Xylene</td><td>Brain and nervous system; Foetal and child development</td><td></td></tr>
<tr><td colspan="2">Other VOCs
(incl. Formaldehyde, Methanol)</td><td>Immune system; Respiratory system; Brain and nervous system; Dermal; Liver; Kidneys; Endocrine system; Foetal and child development</td><td>✓</td></tr>
<tr><td colspan="4">Other Air Pollutants</td></tr>
<tr><td colspan="2">Hydrogen sulphide (H_2S)</td><td>Respiratory system; Dermal, Pulmonary system, Brain and nervous system; Gastrointestinal system</td><td></td></tr>
<tr><td colspan="2">Nitrogen oxides (NO_x)</td><td>Pulmonary, Respiratory system</td><td></td></tr>
<tr><td colspan="2">Ozone (O_3)</td><td>Respiratory system; Cardiovascular system</td><td></td></tr>
<tr><td colspan="2">Carbon Monoxide (CO)</td><td>Neurologic, Reproductive system</td><td></td></tr>
<tr><td colspan="2">Respirable Silica</td><td>Respiratory system; Kidneys; Immune system</td><td>✓</td></tr>
<tr><td colspan="2">Polycyclic aromatic hydrocarbons (PAHs)</td><td>Immune system; Reproductive system; Brain and nervous system; Foetal and child developmental effects</td><td>✓</td></tr>
</table>

* PM_{10} : particulate matter of 10 micrometres or smaller in diameter.
Adapted from: Srebotnjak & Rotkin-Ellman 2014; & Spear 2015.

Climate Change:

Methane (CH_4) is 84 times more damaging to the atmosphere than CO_2 for the first twenty years after its release (Climate and Clean Air Coalition n.d.; EDF n.d.). Venting methane into the atmosphere during fracking contributes greatly to greenhouse gas emissions (Figure 10). Gas flaring (Figure 11) also accelerates climate change, though it releases 28-84 times less methane than venting (Styles 2014). The US EPA is proposing to limit methane release from fracking due to climate change concerns (EPA 2015a; EDF n.d.).

Seismic Activity:

A Miami University, Ohio study has directly linked hydraulic fracturing to earthquakes (Skoumal et al. 2015). Waste water injection from fracking has also been linked to seismic activity (Walsh & Zoback 2015). Oil and gas operations have been tied to earthquake surges in eight US states, including, Arkansas, Kansas, Ohio, Oklahoma and Texas (Kuchment 2016).

Oklahoma's earthquakes have dramatically risen since 2008 (Figure 13) when Oklahoma increased its oil and gas production (Rusinow n.d.). Studies have also found fracking wells have caused earthquakes in Canada (Hirji 2016).

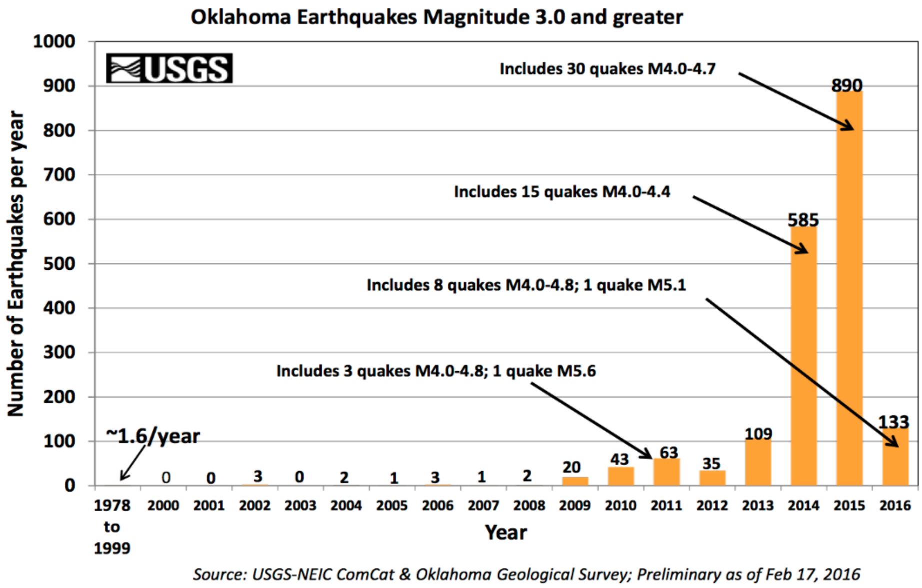


Figure 13. Oklahoma's earthquake incidence has increased dramatically since 2009. 2016 only includes January and early February figures. Source: USGS 2016.

Socio-Economic Impacts:

Lifestyle:

Fracking has many social impacts on communities. The most influential in rural towns being demographic change, with an influx of single males employed by the fracking industry, mostly as fly in - fly out (FIFO) workers (Hawke 2015, p. 63), and an exodus of families (Everingham et al. 2013, p. 40).

Fracking impinges on people's lifestyles. Numerous US communities are reliant on bottled drinking water provided by the fracking companies, as their water supplies have been contaminated or depleted by fracking (Jerolmack & Berman 2016; O'Connor 2014). They "shower with the windows open, to prevent a build-up of explosive gas", and some have had their "water wells explode" (Fenton 2016). Territorians rely on bore water so this is a serious concern.

National Geographic (Dobb 2013) describes "Streets clotted with noisy, exhaust-belching … trucks. More crime, more highway accidents, more medical emergencies. People on fixed incomes forced to move because they can't afford steep rent hikes. Overtaxed water and sewer systems. Prostitution…". Then there's the noise, lights, odours, dust, traffic, and other excessive nuisances (Goldberg et al. 2015; Nicholson 2014).

Landowners have no legal right to refuse a gas company access to their land if it owns the mineral rights (Dairy Australia 2015). This impacts privacy and ability to conduct routine activities (Figure 14). The 'Lock the Gate Alliance' has become a vocal, anti-fracking movement, nationally attracting and uniting a diverse range of people concerned about fracking issues. Members' voice concerns, which are shared internationally, such as environmental impacts, health, climate change (de Rijke 2013, p. 2), social dynamics, and people's rights to protect their water, land and livelihoods from fracking (Figure 20).

Broomfield's (2013) risk assessments commissioned by the European Commission Directorate-General for Environment are shown in Table 3. They demonstrate that traffic, noise, visual, and land-take impacts increase with multiple wells (Figures 14 & 15).

Table 3. Risk Assessment Results for an Individual Site and Cumulative Risks. This shows the risks and impacts of fracking increase with multiple (cumulative) wells, especially in regards to traffic and land-take.

Environmental Aspect	Site identification and preparation	Well design drilling, casing, cementing	Fracturing	Well Completion	Production	Well abandonment and post-abandonment	Overall rating across all phases
Traffic Individual Site	Low	Low	Moderate	Low	Low	Not Applicable	Moderate
Traffic Cumulative	High	High	High	Moderate	Low	Not Applicable	High
Noise Impacts Individual Site	Low	Moderate	Moderate	Not Classifiable	Low	Not Applicable	Moderate – High
Noise Impacts Cumulative	Low	High	Moderate	Not Classifiable	Low	Not Applicable	High
Visual Impact Individual Site	Low	Low	Low	Not Applicable	Low	Low – Moderate	Low – Moderate
Visual Impact Cumulative	Moderate	Moderate	Moderate	Not Applicable	Low	Low – Moderate	Moderate
Land-Take Individual Site	Moderate	Not Applicable	Not Applicable	Not Applicable	Moderate	Not Classifiable	Moderate
Land-Take Cumulative	Very High	Not Applicable	Not Applicable	Not Applicable	High	Not Classifiable	High

Adapted from: Broomfield 2013.

Figure 14. Land-take, air pollution and visual impacts of shale gas fracking in North Dakota, USA. Source: Dawson 2014.

Figure 15. Visual, noise, air pollution, and traffic impacts. Fracking truck traffic in Watford City, North Dakota. Source: Lee 2013.

Health:

Risks for neurological and respiratory problems, and birth defects increase with proximity to active wells (Spear 2015). New York State banned fracking after ‘A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development’ identified significant health risks (Zucker & Dreslin 2014; Kaplan 2014). ‘Symptomatology of a Gas Field - An independent health survey in the Tara rural residential estates and environs’ (McCarron 2013) ‘found a pattern of symptoms which is extremely concerning’ (p. 1). Berke discusses fracking toxicology and its serious health effects (Berke 2016). Wildlife and domestic animals also suffer these health issues (Centre for Biological Diversity, n.d.; Kelly 2011). Figure 16 illustrates the health effects associated with fracking chemicals, and Table 2 addresses air pollution health impacts.

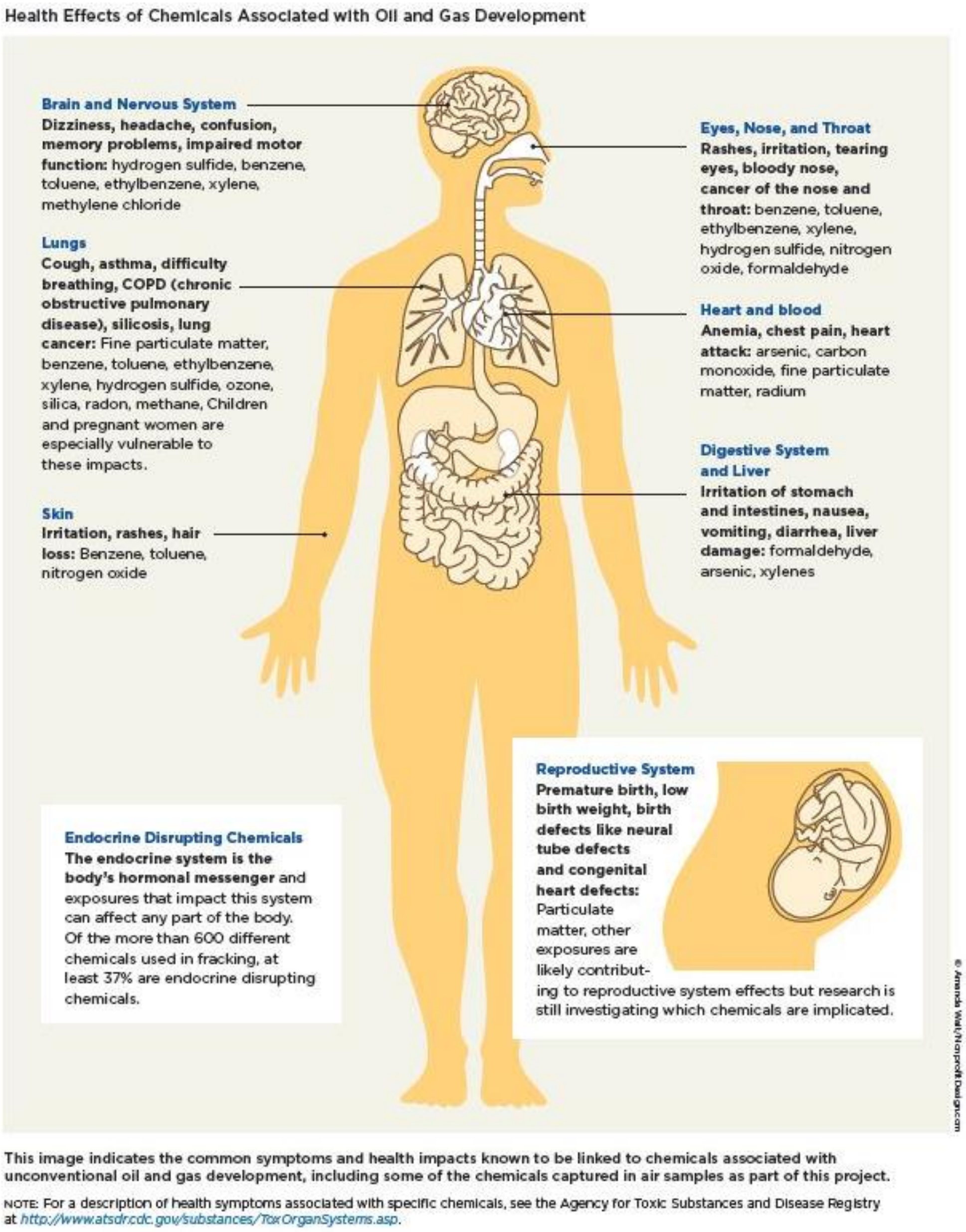


Figure 16. Health effects of chemicals associated with fracking. Source: CEH 2013.

Local Economy:

The Australian Business Review and Wall Street Journal have been reporting the risks of fracking (Berke 2016; Hutchinson 2015; Dawson 2014; de Rijke 2013). Land-take, water contamination, water depletion, air pollution, and health effects will likely be detrimental to the tourism, real estate, agriculture, horticulture, aquaculture, fisheries, crocodile, and manufacturing industries in the NT. A reduction of production in these industries can lead to a decrease in exports, and increased imports and food prices (GISERA 2013). NT tourism currently attracts over 1.5 million tourists each year (Tourism NT 2016), a reduction in tourist numbers will greatly affect many small businesses.

Initially, hotels, motels, bakeries, restaurants, car sales, and coach charters will flourish as a result of fracking, but many other small businesses will perish. “There’s more small businesses for sale at the moment in Roma than almost any town in western Queensland. And they can’t sell.” (Everingham et al. 2013, p. 40). This is partly due to the exodus of families (GISERA 2013) and influx of single, male, FIFO workers, and exacerbated by the difficulties in retaining staff as small businesses can’t compete with the wages offered by fracking companies (Everingham et al. 2013, p. 39; GISERA 2013).

The NTG tells us fracking “will create more jobs, boost the economy, improve local infrastructure and could lead to cheaper electricity which in turn stimulates further business activity” (Northern Territory Government 2016b). While this may initially be true during the short term, establishment phase, the CSG experience in Queensland shows employment and expenditure in mining is now declining (Figure 17), and up to 50% of mining town homes are now selling at a loss (Hutchinson 2015).

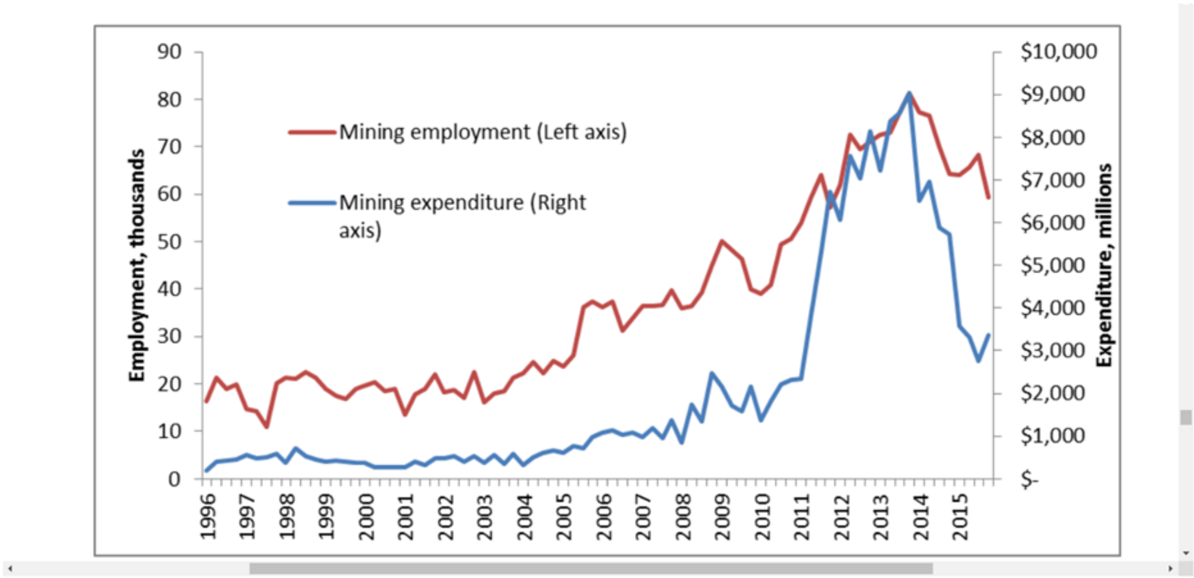


Figure 17. Mining expenditure and employment is declining in Queensland. Source: Swann et al. 2016, p. 41.

Economics and Legalities:

Fracking is labelled as petroleum mining and controlled by the Northern Territory Petroleum Act (AustLII n.d.b; EDONT n.d.). Gas pipelines are regulated under the Northern Territory Energy Pipelines Act (AustLII n.d.a; EDONT n.d.). Litigation against fracking companies is on the rise in the US. (Goldberg et al. 2015; Nicholson 2014). This trend is now occurring in Queensland with the Nothdurft family challenging QGC and four other respondents in the Brisbane Land Court, seeking compensation for fracking impacts under Queensland's Petroleum and Gas Act (Smail 2016).

The NTG has “cut the red tape” for oil and gas corporations by “Reforming as necessary, the Northern Territory Government’s regulatory and other practices” to "accelerate land access and approvals processes" (Department of Minerals and Energy n.d.b, p. 21).

The NTG also lowered “the cost of assessing the prospectivity of Northern Territory gas resources” for fracking corporations by committing “nearly $8 million over four years to specifically target improved knowledge about the Territory’s shale gas resources. The CORE program, totalling $23.8 million, is the largest investment to support the exploration industry made by a Territory Government" (Department of Minerals and Energy n.d.b, p. 17). The NTG is also financing an elaborate advertising campaign (Figure 18), and $800 million to construct a gas pipeline from Tennant Creek to Mount Isa (Giles n.d.).

A Deloitte Access Economics report for the Australian Petroleum Production & Exploration Association (APPEA) modelled a “success scenario” which found “the cumulative addition to GSP over the two decades from 2020 to 2040 would be about $17 billion, and government coffers would collect an extra $680 million” based on the most ambitious future demand predictions from the Australian Energy Market Operator (AEMO) (Aikman 2015).

America’s oil and gas corporations are struggling, with “at least 15 companies” having their credit cut, and lenders preparing to lose billions of dollars on oil and gas loans (Loder & Klein 2016).

Accidents Happen:

There have been 43 pollution incidents which threatened or caused ‘serious environmental harm’ reported to the NT EPA since 11 May 2006 (NT EPA 2016), see Appendix 3. Interestingly, the copper concentrate spill at East Arm Wharf, Darwin Harbour (Ascend 2015, p. 105), and water contamination incidents at McArthur River Mine (Bardon 2016b) are not listed. This does not foster confidence that the NTG can successfully manage fracking risks if proposed unconventional shale gas plans were to eventuate.

The Hakwe Report (2015, p. 85) acknowledges that robust regulatory regimes can not fully prevent accidents from occurring, stating “the risks cannot be reduced to zero and some areas of uncertainty remain, particularly the very long-term integrity of wells”. Appendix 4 has several images of shale gas fracking accidents from America and Canada.

Potential Limitations of This Literature Review:

The high proportion of literature detailing negative impacts of fracking in this review led to concerns of author bias. This review's findings are supported by Hays and Shonkoff's, 'Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015' (2016, p. 1) which found:

- 84% of public health studies contain findings that indicate public health hazards, elevated risks, or adverse health outcomes;
- 69% of water quality studies contain findings that indicate potential, positive association, or actual incidence of water contamination; and
- 87% of air quality studies contain findings that indicate elevated air pollutant emissions and/or atmospheric concentrations. (Hays & Shonkoff 2016, p. 1)

The prevalence of recent scientific evidence decrying unconventional gas maybe due to the development of new testing methods (Vaidyanathan 2016), and fracking impacts being accumulative (Broomfield 2013), so only becoming documented now.

Figure 18. Northern Territory advertisement. Oil & Gas it's for the future.
Source: Northern Territory Government 2015d

Figure 19. Tanker trucks hauling water and fracking fluids line up near a gas flare in Williston, North Dakota. Source: Berke 2016

Figure 20. 16 April 2016, Our Land is Our Life March in Katherine, NT.
Source: Don't Frack the Territory 2016

Conclusion:
What environmental, social, and economic impacts will hydraulic fracturing (Fracking) for shale gas have on the Northern Territory?

This literature review discovered onshore shale gas is a multibillion dollar industry, which booms and busts, and comes at great cost and risk to the environment and general public.

Hydraulic fracturing for gas is opposed by the majority of people in the NT. With over 90% of the Northern Territory granted or under application for unconventional gas mining it will potentially impact everyone in some way. Fracking poses a very real threat to the people, places and activities we love, and risks our health, lifestyles and livelihoods. These are things which money can not replace.

Tax payer funded advertising designed to influence the public into accepting unconventional gas extraction, portrays onshore natural gas as a clean energy. This review found that the land clearing, infrastructure, machinery, water usage, chemicals required, waste water produced, and gases leaked during fracking debunk this claim.

Scientific evidence shows horizontal hydraulic fracturing for shale gas poses many environmental risks, some with irreversible consequences, and each new report further confirms this. Fracking has destroyed aquifers and rivers through contamination and over extraction, killing wildlife, fish, and aquatic ecosystems. It has caused air pollution, health issues and seismic activity, and it contributes to climate change by releasing greenhouse gases such as methane. Countless reports list these risks, including the 'Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory', which concluded that the risks can be managed by regulation. While regulation might offer some protection, accidents do occur. Human error, mechanical failure, unforeseen circumstances, waste water ponds flooding, trucks of fracking fluid crashing, wells leaking, and well heads catching fire, can and have happened. And the repercussions can be catastrophic for the affected area and its inhabitants.

Clean water is critical for economic growth, public health, and the environment. Our aquifers, lakes and rivers provide water for households, irrigation for crops, water for livestock, support our crocodile industry, and our pristine waterways attract over 1.5 million tourists and fisherman to the Northern Territory each year. Our agriculture, horticulture, aquaculture, real estate and tourism industries will be impacted if our water is accidently contaminated or depleted.

These industries are also impacted by the resources and infrastructure required by the gas industry. Employees leave their local jobs to go work for mining companies. Frack pads and production water ponds require large areas of land. Pipelines and roads require land clearing which will deter tourists who come to see the untamed wilderness of the outback, not a gas field with heavy truck traffic or polluted hot springs. Fracking risks these industries, the revenue they generate, and the jobs they provide.

At the conclusion of this literature review we must ask ourselves, is fracking worth the risk? Just because we can do something, doesn't mean we should. We can live without gas but we can't survive without clean air and water. This review suggests that the Northern Territory Government ceases spending tax payers' money to support and promote an industry which is detrimental to Territorians, and that it hold a referendum on fracking. In view of the mounting legitimate health and environmental concerns, this review highly recommends that the Northern Territory Government immediately declares an indefinite moratorium on the unconventional mining of shale gas.

References (Bibliography).

ABC News 2015, *Hydraulic fracturing gets go ahead in Northern Territory as Tasmania extends ban by five years,* Australian Broadcasting Corporation, viewed 1 May 2016,

http://www.abc.net.au/news/2015-02-26/hydraulic-fracking-gets-go-ahead-in-nt/6266772

Aikman, A 2015, *Shale gas could bring millions to Northern Territory*, The Australian, 6 May 2015,

http://www.theaustralian.com.au/news/shale-gas-could-bring-millions-to-northern-territory/news-story/24cb7538a8a90c3f94d01b1045d52ad5

Ascend Waste and Environment 2015, *The Health and Environmental Impacts of Hazardous Wastes: Impact Profiles*, Department of Environment, Australian Government, viewed 7 May 2016,

http://www.environment.gov.au/system/files/resources/bc0e52ba-8f78-4ce1-83b4-4910f4a1f0e9/files/hazardous-waste-impacts.docx

AustLII n.d.a, *Northern Territory Consolidated Acts: Energy Pipelines Act*, AustLII, viewed 7 May 2016,

http://www.austlii.edu.au/au/legis/nt/consol_act/epa185/

AustLII n.d.b, *Northern Territory Consolidated Acts: Petroleum Act*, AustLII, viewed 7 May 2016,

http://www.austlii.edu.au/au/legis/nt/consol_act/pa137/

Australia Pacific LNG n.d., *What is Coal Seam Gas?,* Australia Pacific LNG, viewed 2 May 2016,

http://www.aplng.com.au/home/what-coal-seam-gas

Australian Bureau of Statistics 2015, *Australian Demographic Statistics – Sep 2015*, Australian Bureau of Statistics, viewed 21 April 2016,

http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0

Australian Council of Learned Academies 2013, *Engineering Energy: Unconventional Gas Production – Report Summary*, Office of the Chief Scientist, Australian Government, viewed 2 May 2016,

http://www.chiefscientist.gov.au/wp-content/uploads/shalegas-recommendationsFINAL.pdf

Avner, V, Jackson, R, Warner, N, Darrah, TH & Kondash, A 2014, 'A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States', *Environmental Science and Technology*, American Chemical Society Publications, vol. 8, p. 8337, viewed 4 May 2016,

http://sites.nicholas.duke.edu/avnervengosh/files/2011/08/EST-Review-on-hydraulic-fracturing.pdf

Bagilet, V 2015, *Fracking in South Africa: an alternative to coal?*, South African Institute of International Affairs, viewed 2 May 2016,

http://www.saiia.org.za/opinion-analysis/fracking-in-south-africa-an-alternative-to-coal

Bardon, J 2016a, *Delia Lawrie wants NT fracking referendum when voters head to polls*, ABC News, viewed 2 May 2016,

http://www.abc.net.au/news/2016-04-19/delia-lawrie-wants-nt-fracking-referendum/7338904

Bardon, J 2016b, *The race to avert disaster at the NT's McArthur River Mine*, ABC, viewed 7 May 2016,

http://www.abc.net.au/radionational/programs/backgroundbriefing/the-race-to-avert-disaster-at-the-nts-mcarthur-river-mine/7159504

Beament, E 2015, 'Earthquake expert issues warning over dangers fracking could increase seismic activity in UK', *The Daily Mirror,* MGN Ltd, viewed 3 May 2016,

http://www.mirror.co.uk/news/uk-news/earthquake-expert-issues-warning-over-6408414#

Berke, J 2016, 'We're finding out more and more about the worrisome link between fracking and health', *Business Insider Australia*, viewed 7 May 2016,

http://www.businessinsider.com.au/fracking-fluids-are-seriously-toxic-201http://www.businessinsider.com.au/fracking-fluids-are-seriously-toxic-2016-1?r=US&IR=T

Bounds, A 2015, UK: *Lancashire County Councillors turn down Cuadrilla's fracing "because of the impact of traffic on rural roads, which would endanger lives." In Alberta, frac endangerment of families continues, without oversight or law enforcement*, Ernst v. EnCana Corporation, viewed 5 May 2016,

http://www.ernstversusencana.ca/uk-lancashire-county-councillors-turn-down-cuadrillas-fracing-because-of-the-impact-of-traffic-on-rural-roads-which-would-endanger-lives-in-alberta-frac-endangerment-of-families-continues-w

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*, European Commission DG Environment, viewed 9 April 2016,

http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf

Brown, B 2016, *Crews Responded to Large Fracking Operation Fire in Grady County*, NewsOn6.com, viewed 7 May 2016,

http://www.newson6.com/story/30959461/crews-responded-to-large-fracking-operation-fire-in-grady-county

CEH 2013, *Study Documents Air Pollution Risks from Fracking*, Center for Environmental Health, viewed 6 May 2016,

http://www.ceh.org/study-documents-air-pollution-risks-fracking/

Centre for Biological Diversity n.d., *Fracking Threatens California's Wildlife*, Centre for Biological Diversity, viewed 6 May 2016,

http://www.biologicaldiversity.org/campaigns/california_fracking/wildlife.html

Climate and Clean Air Coalition (CCAC) n.d., *CCAC Oil & Gas Methane Partnership*, United Nations Environment Programme (UNEP), viewed 5 May 2016,

http://www.unep.org/ccac/Initiatives/CCACOilGasInitiative/CCACOilGasMethanePartnership/tabid/794017/Default.aspx

Coates, N 2016, *Fury over possible NT fracking moratorium: potential for legal action*, ABC Rural, viewed 2 May 2016,

http://www.abc.net.au/news/2016-03-09/fury-over-possible-fracking-ban-partner-could-take-legal-action/7233738

Cook, P, Beck, V, Brereton, D, Clark, R, Fisher, B, Kentish, S, Toomey, J & Williams, J 2013, *Engineering Energy: Unconventional Gas Production, A study of shale gas in Australia*, Australian Council of Learned Academies (ACOLA), viewed 1 May 2016,

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

CORE (Creating Opportunities for Resource Exploration) 2016, *Onshore petroleum titles and developments*, Department of Mines and Energy, Northern Territory Government, viewed 21 April 2016,

http://www.core.nt.gov.au/Content/File/InvestmentAlert/Petroleum.pdf

Curtain, C 2015, *Community support in Northern Territory shifting in favour of onshore oil and gas developments according to industry*, ABC Rural, viewed 2 May 2016,

http://www.abc.net.au/news/2015-12-17/community-support-in-nt-shifting-in-favour-of-onshore-oil-gas/7038208

Dairy Australia 2015, *Unconventional Gas Mining: Land access and farmers' rights*, Dairy Australia Ltd, viewed 6 May 2016,

http://www.dairyaustralia.com.au/~/media/Documents/Environment%20and%20Resources/Coal%20Seam%20Gas%20mining/Fact%20sheet%20-%20land%20access%20and%20rights.pdf

Dawson, C 2014, 'North Dakota's Latest Fracking Problem', *The Wall Street Journal*, Dow Jones & Company Inc, viewed 5 May 2016,

http://www.wsj.com/articles/north-dakotas-latest-fracking-problem-1404170442

Department of Economic Development, Jobs, Transport and Resources 2015, *Types of Onshore Gas*, Victoria State Government, viewed 1 May 2016,

http://onshoregas.vic.gov.au/about-onshore-gas/types-of-onshore-gas

Department of Minerals and Energy n.d., *Oil and Gas Fact Sheets: What's the difference between Coal Seam Gas, Shale Gas and Tight Gas*, Northern Territory Government, viewed 1 May 2016,

http://www.nt.gov.au/d/Minerals_Energy/oilandgas/factsheet/fs02-diffence-between-gasses.html

Department of Minerals and Energy n.d.b, *Oil and Gas Industry Development Strategy*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/__data/assets/pdf_file/0003/195591/Oil-Gas-INDUSTRY-Strategy.pdf

Department of Minerals and Energy 2015, *Oil and Gas Industry Development Strategy Summary*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/__data/assets/pdf_file/0004/195592/Oil-Gas-Strategy-Summary.pdf

Department of Minerals and Energy 2016, *Onshore petroleum titles and developments*, Northern Territory Government, viewed 21 April 2016,

http://www.core.nt.gov.au/Content/File/InvestmentAlert/Petroleum.pdf

Department of Minerals and Energy n.d., Blank page - no chemicals listed, Northern Territory Government, viewed 2 May 2016,

http://www.nt.gov.au/d/Minerals_Energy/?header=Chemicals%20used%20in%20Hydraulic%20Fracturing

de Rijke, K 2013, 'Coal Seam Gas and Social Impact Assessment: An Anthropological Contribution to Current Debates and Practices', *Journal of Economic and Social Policy*, vol. 15: Iss. 3, Article 3, viewed 5 May 2016,

http://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1250&context=jesp

DLA Piper, Novelli, F, Zamberletti, P & Maroncelli, G 2016, *Italy - Law & Practice*, Chambers & Partners, London, viewed 1 May 2016,

http://www.chambersandpartners.com/guide/practice-guides/location/271/8073/2298-200

Dobb, E 2013, 'Bakken Shale Oil: The New Oil Landscape', *National Geographic*, viewed 5 May 2016,

http://ngm.nationalgeographic.com/2013/03/bakken-shale-oil/dobb-text

Earley, B 2015, *Policies*, 1 Territory Party, viewed 2 May 2016,

http://1territory.party/policies/

EDF n.d., *Methane: The other important greenhouse gas*, Environmental Defense Fund, New York, viewed 5 May 2012,

https://www.edf.org/methane-other-important-greenhouse-gas

EDONT n.d., Overview of mining laws, Environmental Defenders Office (NT) Inc, viewed 20 April 2016,

http://edont.org.au/factsheets/overview-mining-laws/

EIA n.d., *Natural Gas*, U.S. Energy Information Administration, viewed 2 May 2016,

https://www.eia.gov/naturalgas/

Elsner, M & Hoelzer, K 2016, 'Quantitative Survey and Structural Classification of Hydraulic Fracturing Chemicals Reported in Unconventional Gas Production', *Environmental Science and Technology*, American Chemical Society, viewed 9 April 2016,

http://pubs.acs.org/doi/abs/10.1021/acs.est.5b02818

EPA 2015a, *Proposed Climate, Air Quality and Permitting Rules for the Oil and Natural Gas Industry: Fact Sheet*, United States Environmental Protection Agency, viewed 1 May 2016,

https://www3.epa.gov/airquality/oilandgas/pdfs/og_fs_081815.pdf

EPA 2015b, *The Process of Hydraulic Fracturing*, United States Environmental Protection Agency, viewed 1 May 2016,

https://www.epa.gov/hydraulicfracturing/process-hydraulic-fracturing

Everingham, J, Collins, N, Rodriguez, D, Cavaye, J, Vink, S, Rifkin, W & Baumgartl, T 2013, *Energy resources from the food bowl: an uneasy co-existence. Identifying and managing cumulative impacts of mining and agriculture*, Centre for Social Responsibility in Mining, The University of Queensland, Brisbane, viewed 1 May 2016,

https://espace.library.uq.edu.au/view/UQ:326236/UQ326236.pdf

Fenton, J 2016, 'Coal seam gas industry's solution to underground pollution is to bury the proof', *The Sydney Morning Herald,* viewed 5 May 2016,

http://www.smh.com.au/comment/coal-seam-gas-industrys-solution-to-underground-pollution-is-to-bury-the-proof-20140227-33m4t.html

Finkel, A 2014, *Inquiry into Hydraulic Fracturing in the Northern Territory*, Australian Academy of Technological Sciences and Engineering (ATSE), viewed 9 April 2016,

http://www.hydraulicfracturinginquiry.nt.gov.au/public_submissions_aatse1_20140529.pdf

Foster, F & McGee, B 2015, 'The Future Economy', *CityMag*, Solstice Media, viewed 5 May 2016,

http://citymag.indaily.com.au/commerce/business-profile/future-economy/

Frack Free Kimberley 2016, Image of seismic line clearing 44 kilometres from Broome, Facebook, viewed 27 April 2016,

https://www.facebook.com/724120277661637/photos/a.724140027659662.1073741829.724120277661637/1062814320458896/?type=3&theater

Geoscience Australia n.d., *Area of Australia - States and Territories*, Australian Government, viewed 21 April 2016,

http://www.ga.gov.au/scientific-topics/national-location-information/dimensions/area-of-australia-states-and-territories

Giles, A 2016, *Guiding principles set out how oil and gas industry should operate in the Territory*, Chief Minister of the Northern Territory, viewed 2 May 2016,

http://chiefminister.nt.gov.au/media-releases/guiding-principles-set-out-how-oil-and-gas-industry-should-operate-territory

Giles, A n.d., *NT announces Jemena to build gas pipeline to east coast*, Chief Minister of the Northern Territory, viewed 6 May 2016,

http://www.chiefminister.nt.gov.au/media-releases/nt-announces-jemena-build-gas-pipeline-east-coast

GISERA 2013, *Rural change as a result of coal seam gas developments and the associated economic impacts*, Gas Industry Social & Environmental Research Alliance (GISERA), viewed 26 April 2016, http://www.gisera.org.au/publications/project_factsheets/rural_change_factsheet.pdf

Goldberg, HM, Williams, MS & Cours, D 2015, 'It's a Nuisance: The Future of Fracking Litigation in the Wake of Parr V. Aruba Petroleum, Inc.', *Virginia Environmental Law Journal*, vol. 33, no. 1, viewed 6 May 2016,

http://www.velj.org/uploads/1/2/7/0/12706894/3._goldberg_williams_cours.pdf

Grafton, Q 2012, 'Chapter 1. Challenges and Opportunities for Australian Unconventional Gas Production', in CEDA (ed.), *Australia's Unconventional Energy Options*, Committee for Economic Development of Australia, Melbourne, pp. 13-26, viewed 5 May 2016,

http://adminpanel.ceda.com.au/FOLDERS/Service/Files/Documents/15347~cedaunconventionalenergyfinal.pdf

Hanson, S 2012, 'Tanker Truck Flips, One Hurt', *The Intelligencer*, Wheeling News-Register, viewed 5 May 2016,

http://www.theintelligencer.net/page/content.detail/id/573873/Tanker-Truck-Flips--One-Hurt.html?nav=515

Hawke, A 2015, *Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory*, Northern Territory Government, Darwin, viewed 21 April 2016,

http://www.hydraulicfracturinginquiry.nt.gov.au/docs/report-inquiry-into-hydraulic-fracturing-nt.pdf

Hays, J & Shonkoff, S 2016, 'Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015', *PLoS ONE,* vol. 11, no. 4, viewed 1 May 2016,

http://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0154164#abstract0

Hicks, B 2012, 'Multi-Well Pad Will Sink OPEC', *Energy and Capital*, viewed 2 May 2016,

http://www.energyandcapital.com/articles/multi-well-pad/2892

Hirji, Z 2016, 'Many Man-Made Earthquakes in Western Canada Can Now Be Linked to Fracking', *Inside Climate News*, viewed 7 April 2016,

http://insideclimatenews.org/news/30032016/earthquakes-fracking-western-canada-oil-gas-drilling-usgs-oklahoma

Hutchinson 2015, 'Boom and bust puts mining town homes on the skids', *The Australian Business Review*, viewed 8 May 2016,

http://www.theaustralian.com.au/business/property/boom-and-bust-puts-mining-town-homes-on-the-skids/news-story/71ba9c9fd10399fa4c5075247cedd0e8

Jackson, V 2016, *Petroleum Opportunities*, Department of Mines and Energy Northern Territory Government, viewed 1 May 2016,

https://minerals.nt.gov.au/__data/assets/pdf_file/0016/260521/EPNT14-3.pdf

Jerolmack, C & Berman, N 2016, 'Fracking Communities', *Public Culture*, vol. 28, no. 2, pp. 193-214, Duke University Press, viewed 5 May 2016, http://publicculture.dukejournals.org/content/28/2_79/193.full

Kaplan, T 2014, 'Citing Health Risks, Cuomo Bans Fracking in New York State', *The New York Times*, viewed 8 April 2016,

http://www.nytimes.com/2014/12/18/nyregion/cuomo-to-ban-fracking-in-new-york-state-citing-health-risks.html?_r=0

Kelly, S 2011, *Environment: The Trouble with Fracking*, National Wildlife Federation, viewed 5 May 2016,

https://www.nwf.org/News-and-Magazines/National-Wildlife/Animals/Archives/2011/Trouble-with-Fracking.aspx

Kuchment, A 2016, 'Drilling for Earthquakes', *Scientific American*, viewed 7 April 2016,

http://www.scientificamerican.com/article/drilling-for-earthquakes/

Lechtenböhmer, S, Altmann, M, Capito, S, Matra, Z, Weindrorf, W & Zittel, W 2011, *Impacts of Shale Gas and Shale Oil Extraction on the Environment and on Human Health*, European Parliament Directorate General for Internal Policies, viewed 4 May 2016,

http://www.europarl.europa.eu/document/activities/cont/201107/20110715ATT24183/20110715ATT24183EN.pdf

Lee, M 2013, 'Oil Boom: Bakken truck traffic has N.D. counties scrambling to fix roads', *EnergyWire*, E&E Publishing, LLC, viewed 5 May 2016,

http://www.eenews.net/stories/1059988537

Loder, A & Klein, JX 2016, *Oil Drillers Feel the Pain as Banks Slash Their Credit Lines*, Bloomberg, viewed 4 May 2016,

http://www.bloomberg.com/news/articles/2016-04-12/oil-drillers-feel-the-pain-as-banks-slash-their-credit-lines

Macdonald-Smith, A 2016, 'Gas entrepreneurs bet on Beetaloo Basin as Australia's answer to US shale', *The Sydney Morning Herald*, viewed 2 May 2016,

http://www.smh.com.au/business/energy/gas-entrepreneurs-bet-on-beetaloo-basin-as-australias-answer-to-us-shale-20151231-glxgwy.html

Manison, N 2015, *Hawke Report Highlights Need for Moratorium*, Territory Labor, viewed 2 May 2016,

http://www.territorylabor.com.au/Stay-Updated/Media-Releases/PostId/250/hawke-report-highlights-need-for-moratorium

McCarron, G 2013, *Symptomatology of a gas field - An independent health survey in the Tara rural residential estates and environs*, Dr Geralyn McCarron MB BCh BAO FRACGP, viewed 7 April 2016,

http://www.ntn.org.au/wp/wp-content/uploads/2013/05/Symptomatology-of-a-gas-field-An-independent-health-survey-in-the-Tara-rural-residential-estates-and-environs-April-2013.pdf

MEF n.d., *Cause and Contributing Factors of Failure of Temporary Pipe and Flowline Connections at Fracking Sites*, Metropolitan Engineering Consulting and Forensics, viewed 6 May 2016,

https://sites.google.com/site/metropolitanforensics/cause-and-contributing-factors-of-failure-of-temporary-pipe-and-flowline-connections-at-fracking-sites

Members Research Service 2014, *Shale gas and EU energy security*, European Parliament, viewed 1 May 2016,

http://www.europarl.europa.eu/RegData/etudes/BRIE/2014/542167/EPRS_BRI(2014)542167_REV1_EN.pdf

Nasti, C 2013, *Habitat: Bad News/Good News for Longleaf Pines*, Passport to Texas, viewed 5 May 2016,

http://passporttotexas.org/2013/11/page/3/

Nelson, R 2012, 'Chapter 2. Unconventional Gas and Produced Water', in CEDA (ed.), *Australia's Unconventional Energy Options*, Committee for Economic Development of Australia, Melbourne, pp. 27-40, viewed 5 May 2016,

http://adminpanel.ceda.com.au/FOLDERS/Service/Files/Documents/15347~cedaunconventionalenergyfinal.pdf

Nicholson, BR 2014, *Analysis of Litigation Involving Shale & Hydraulic Fracturing*, Norton Rose Fulbright, Texas, viewed 6 May 2016,

http://www.nortonrosefulbright.com/files/20140101-analysis-of-litigation-involving-shale-hydraulic-fracturing-104256.pdf

Northern Territory Government 2015a, *About Natural Gas*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/about-natural-gas

Northern Territory Government 2016b, *Benefits for Territorians*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/benefits

Northern Territory Government 2015b, *Exploration and Production*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/key-facts/fact-sheets/fact-sheet-exploration-and-production

Northern Territory Government 2015d, *Oil and Gas it's for all of us*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/media/oil-and-gas-its-for-all-of-us

Northern Territory Government 2015c, *Oil and Gas Production*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/exploration/oil-and-gas-production

Northern Territory Government 2016, *Onshore Gas and Environmental Safety*, Northern Territory Government, viewed 1 May 2016,

https://onshoregas.nt.gov.au/media/onshore-gas-and-environmental-safety

NT EPA 2016, *Duty to Notify Incident Reports - Section 14 - Incidents Reported*, Northern Territory Environment Protection Authority, viewed 7 May 2016,

http://www.ntepa.nt.gov.au/waste-pollution/compliance/incidents#reported

O'Connor, L 2014, *California Community Relying on Bottled Water May Be Grim Preview of Things to Come*, The Huffington Post Australia Pty Ltd, viewed 5 May 2016,

http://www.huffingtonpost.com.au/entry/california-groundwater-shortage_n_5731830.html?section=australia

Osborn, SG, Vengosh, A, Warner, NR & Jackson, RB 2011, 'Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing', *PNAS*, vol. 108, no. 20, pp. 8172–8176, viewed 26 April 2016,

http://www.pnas.org/content/108/20/8172.full.pdf

Papoulias, DM, Velasco, AL 2013, 'Histopathological analysis of fish from Acorn Fork Creek, Kentucky exposed to hydraulic fracturing fluid releases', *Southeastern Naturalist*, Eagle Hill Institute, viewed 7 April 2016,

https://pubs.er.usgs.gov/publication/70047892

Rusinow, J n.d., *What's Causing Those Oklahoma Earthquakes*?, Jeff Rusinow, viewed 5 May 2016,

http://www.jeffrusinow.com/data/

Santos 2016, *Shale Gas*, Santos Ltd, viewed 1 May 2016,

https://www.santos.com/what-we-do/production/natural-gas/shale-gas/

Schaps, K 2015, *Wales Votes Against Shale Gas Fracking*, Reuters, viewed 1 May 2016,

https://uk.finance.yahoo.com/news/wales-votes-against-shale-gas-190742367.html

Sierra Club's West Virginia Chapter 2011, *Welcome to West Virginia Sierra Club*, Sierra Club, viewed 6 May 2016,

http://marcellus-wv.com/

Skoumal, RJ, Brudzinski, MR & Currie, BS 2015, 'Earthquakes Induced by Hydraulic Fracturing in Poland Township, Ohio', *BSSA*, Seismological Society of America, viewed 5 May 2016,

http://www.bssaonline.org/content/early/2015/01/01/0120140168.abstract

Smail, S 2016, *Queensland farming family launches bid for compensation over impact of gas wells*, ABC News, viewed 9 April 2016,

http://www.abc.net.au/news/2016-03-29/queensland-farming-family-launch-compo-bid-against-csg-company/7282478

Spear, S 2015, 'Report Shows How Fracking Industry's Failure to Follow Regulations Impacts Human Health', *EcoWatch*, viewed 6 May 2016,

http://ecowatch.com/2015/01/27/fracking-industrys-failure-regulations/

Srebotnjak, T & Rotkin-Ellman, M 2014, *Fracking Fumes: Air Pollution from Hydraulic Fracturing Threatens Public Health and Communities*, NRDC, viewed 5 May 2016,

https://www.nrdc.org/sites/default/files/fracking-air-pollution-IB.pdf

Styles, G 2014, 'Bakken Shale Gas Flaring Highlights Global Problem', *Pacific Energy Development*, PEDEVCO Corporation, viewed 9 April 2016,

http://www.pacificenergydevelopment.com/blog/bakken-shale-gas-flaring-highlights-global-problem

Styles, P 2016, *Labor conference should support Northern Territory economy and onshore gas development*, Northern Territory Government Newsroom, viewed 9 April 2016,

http://newsroom.nt.gov.au/mediaRelease/18280

Swann, T, Ogge, M & Campbell, R 2016, *Jobs Growth in Queensland: Trends and prospects*, The Australia Institute, viewed 6 May 2016,

http://www.tai.org.au/sites/defualt/files/Ogge%20Swann%202016%20QLD%20Jobs%20Growth%20FINAL%20w%20Cover%20v2.pdf

Tedesco, J & Hillier, J 2014, *Up in Flames, a four part investigation*, San Antonio Express-News, viewed 5 May 2016,

http://www.mysanantonio.com/news/local/article/Up-in-Flames-5704385.php#photo-6756883

The Aspen Times 2013, *Colorado flooding triggers oil spills, shutdowns*, Swift Communications, Inc, viewed 6 May 2016,

http://www.aspentimes.com/news/8203303-113/oil-flooding-spills-colorado

Tourism NT 2016, *Quickstats Report: Year Ending December 2015*, Northern Territory Government, viewed 10 April 2016,

http://www.tourismnt.com.au/~/media/files/corporate/research/quick-stats-ye-december2015_northern-territory_australia.ashx

Tumuluri, U, Rother, G & Wu, Z 2016, ‘Fundamental Understanding of the Interaction of Acid Gases with CeO2: From Surface Science to Practical Catalysis’, *Industrial and Engineering Chemistry Research*, American Chemical Society, viewed 9 April 2016,

http://pubs.acs.org/doi/abs/10.1021/acs.iecr.5b05014

URS Australia Pty Ltd 2014, *Hydraulic fracturing (‘fraccing’) techniques, including reporting requirements and governance arrangements, Background review*, Department of the Environment, Australian Government, viewed 7 April 2016,

http://www.environment.gov.au/system/files/resources/de709bdd-95a0-4459-a8ce-8ed3cb72d44a/files/background-review-hydraulic-fracturing_0.docx

USGS 2016, *Oklahoma Earthquake Information*, U.S. Geological Survey, US Department of the Interior, viewed 5 May 2016,

http://earthquake.usgs.gov/earthquakes/states/?region=Oklahoma

Vaidyanathan, G 2016, ‘Fracking Can Contaminate Drinking Water’, *Scientific American*, viewed 7 April 2016,

http://www.scientificamerican.com/article/fracking-can-contaminate-drinking-water/

Vengosh, a Lauer, N & Harkness, J 2016, *Contamination in North Dakota Linked to Fracking Spills*, Nicholas School of the Environment, Duke University, North Carolina, viewed 3 May 2016,

https://nicholas.duke.edu/about/news/ContaminationinNDLinkedtoFrackingSpills

Walsh, C 2016, ‘84 per cent fear fracking’, *NT News*, News Corp Australia, viewed 2 May 2016,

http://www.ntnews.com.au/business/84-per-cent-fear-fracking/news-story/e8982524e976e4b69a74096f45641bbb

Walsh, FR & Zoback, MD 2015, 'Oklahoma's recent earthquakes and saltwater disposal', *Science Advances*, vol. 1, no. 5, viewed 5 May 2016,

http://advances.sciencemag.org/content/1/5/e1500195.full

Water Career 2016, *Dramatic Gas Clip in QLD Call to Action*, CareerSpot Pty Ltd, viewed 3 May 2016,

http://www.watercareer.com.au/news/dramatic-gas-clip-in-qld-call-to-action

Wilson, S 2012, *Merry Fracking Christmas: Venting Sour Gas in Booger, Texas*, texassharon.com, viewed 5 May 2016,

http://www.texassharon.com/2012/12/25/merry-fracking-christmas-venting-sour-gas-in-booger-texas/

Woolf, K 2016, *Do you feel environmental standards are being met when it comes to fracking?,* Mix 104.9 Darwin, viewed 9 April 2016,

http://www.mix1049.com.au/katie-home/latest-from-katie/48881-do-you-feel-environmental-standards-are-being-met-when-it-comes-to-fracking

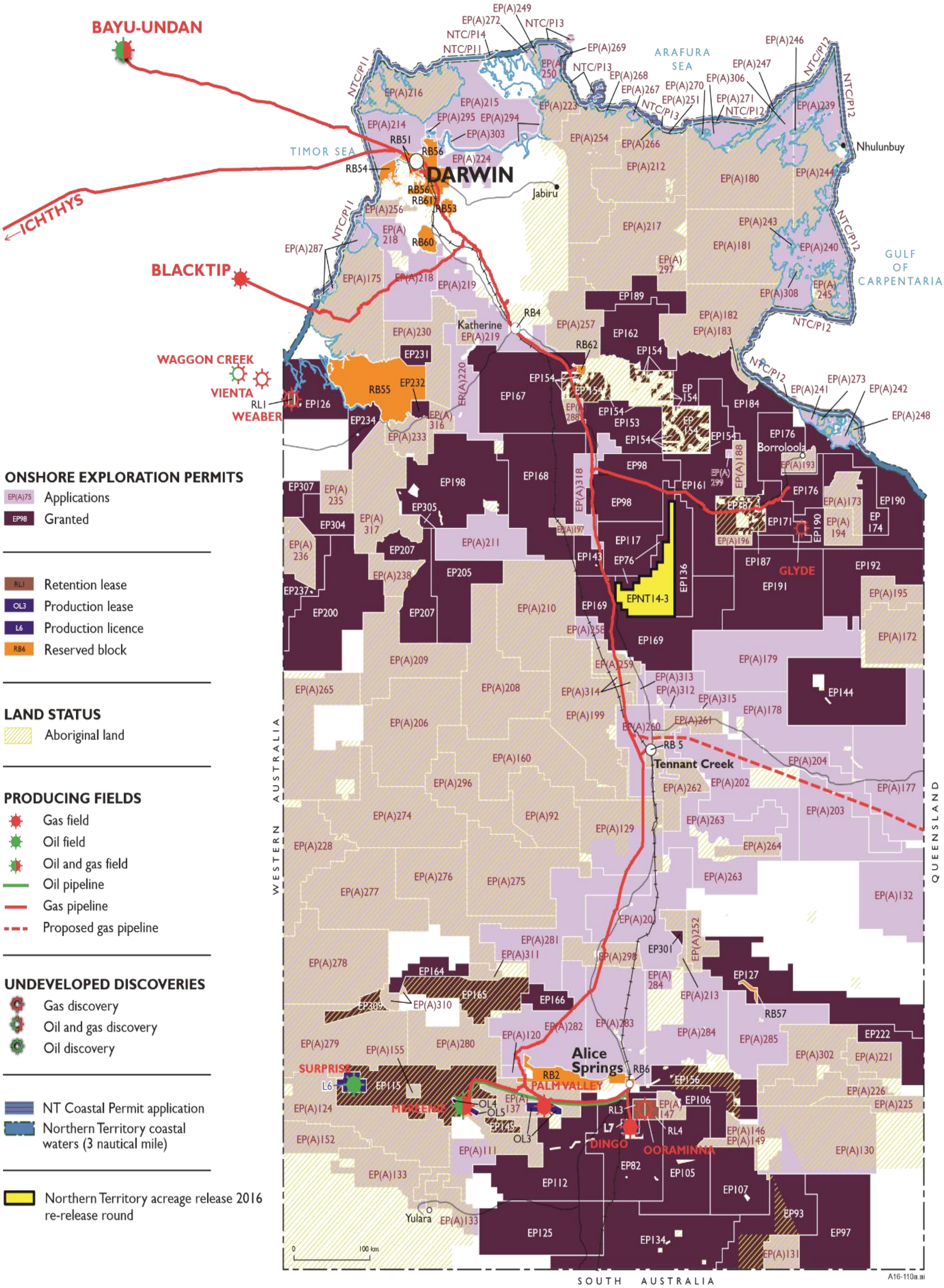
Zillman, S 2015, *No NT fracking moratorium needed: Report*, Fairfax Media, viewed 1 May 2016,

http://www.macleayargus.com.au/story/2925110/no-nt-fracking-moratorium-needed-report/

Zucker, H & Dreslin, S 2014, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development*, New York State Department of Health, New York, viewed 6 May 2016,

http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

Appendix 1. NT Onshore Petroleum* Titles and Developments Map.



*The term ‘Petroleum’ on this map also includes Hydrocarbon materials such as shale gas.

Source: CORE (Creating Opportunities for Resource Exploration), Department of Mines and Energy 2016

Appendix 2. Hydraulic Fracturing Chemicals.

Appendix 2 Table. Summary of the fluids and particles used in hydraulic fracturing fluid in Australia.

Injected substance	Purpose	Products used	Notes
Water	Fractures the coal when injected under high pressure	Bore water, farm pond water or groundwater previously extracted from coal seams is often used	Volume of water required is ~0.2 to 1.3 ML per well (USEPA 2011)
Proppant	Keeps the fractures open once the high pressure fluid is removed	Sand Resin-coated sand Ceramics Bauxite (aluminium ore)	The latest technology advances in proppants include high strength ceramics and sintered bauxite
Acid	Dissolves calcite in the coal prior to fracturing	Hydrochloric acid Muriatic acid Acetic acid	Not all wells require this treatment because coal seams do not always contain calcite
Gelling agent or Clay stabilisers	Increases the viscosity of the fluid, to allow more proppant to be carried into fractures	Guar gum Starches Cellulose derivatives Polydimethyldiallylammonium chloride (Claytrol) Tetramethylammonium chloride (Claytreat 3C)	Not all hydraulic fracturing uses a gel; gel-free fracturing is termed 'slickwater'
Crosslinker	Increase the viscosity of gelling agents	Borate salt Ethyl glycol Isopropanol Disodium octaborate tetrahydrate Boric acid Boric oxide	There are different crosslinkers for different gelling agents

Injected substance	Purpose	Products used	Notes
Biocide	Limits or prevents growth of bacteria that could damage the gelling agent	Glutaraldehyde 2,2-Dibromo-2-cyanoacetamide (DBNPA) Tetrakis(hydroxymethyl)phosphonium sulfate (THPS, Magnacide 575) bronopol (2-bromo-2-nitropropane-1,3-diol) Sodium hypochlorite Sodium thiosulfate Boric acid Caustic soda	The natural polymer gelling agents are good food for bacteria so they encourage bacterial growth - biocides kill these bacteria
pH buffer	Keeps the pH of the fluid in a specified range	Acetic acid Sodium hydroxide Potassium carbonate Sodium carbonate,	Required for the stability of crosslinked polymers
Breaker	Chemically break the bonds of the gel in order to reduce the viscosity back to that of water	Hydrogen peroxides Sodium persulfate Diammonium peroxidisulphate	Only required if a gel is used
Corrosion scale inhibitors		Aloe resin n,n-dimenthyl formamide Methanol Nonyl phenol	
Friction reducers	Reduce fluid surface tension	Oxyalkylated alcohol	
Other additives	Includes foamers, gel stabilisers, clay stabilisers, preservatives, surfactants	Terpenes and terpenoids Sweet orange oil Polyacrylamide Alcohols n,n-dimenthyl formanide Citric acid Ammonium bisulfite Ethylene glycol Potassium chloride	Operators in NSW and Queensland are required to disclose a full list of additives prior to hydraulic fracturing

Source: URS Australia Pty Ltd 2014, p. 26.

Appendix 3. NT Pollution Incidents threatening or causing 'serious environmental harm'.

Section 14 Incident Reports received by the NT EPA since May 2006 are provided below.

NOTE: All notices/licences/reports issued under previous Department/Agency names are valid and are available throughout the NT EPA website. http://www.ntepa.nt.gov.au/waste-pollution/compliance/incidents#reported

Date	Incident	Lot Information	Address
08 April 2016	GEMCO *Stormwater Discharge*		Alyangula Groote Eylandt
16 March 2016	GEMCO *Stormwater Discharge*		Milner Bay, Alyangula Melville Island NT
14 March 2016	Power and Water Corporation - Remote Operations *Diluted Treated Effluent Overflow*	Lot 580 Townsite of Angurugu	Angurugu - Sewer ponds, infiltration basin 1
21 Feb 2016	Cleanaway Darwin *Used Lube Oil spill from Tank*	Lot 5725 Hundred of Bagot	875 Stuart Highway, Holtze
04 Feb 2016	Power and Water Corporation - Remote Operations *Diluted Treated Effluent Overflow*	Lot 580 Townsite of Angurugu	Angurugu - Sewer ponds, infiltration basin 2
20 Jan 2016	Teras Australia *Discharge into Aspley Straight*		Port Melville Project Area, Melville Island NT
20 Jan 2016	GEMCO *Stormwater Discharge*		Milner Bay, Alyangula Groote Eylandt
07 Jan 2016	Power and Water Corporation - Remote Operations *Sewage Overflow* - combination of raw sewage and partially treated sewage	Lot 580 Townsite of Angurugu	Angurugu - Sewer Pump Station 1
27 Dec 2015	Vista Gold *Mt Todd Mine Retention Pond Overflow*		Mt Todd Mine Jatbula Road, Katherine
22 Dec 2015	GEMCO *Stormwater Discharge*		Milner Bay, Alyangula Groote Eylandt
17 Dec 2015	Power and Water Corporation - Remote Operations *Sewage Overflow*	Townsite of Angurugu	Angurugu - Sewer ponds, infiltration basin 1
01 Dec 2015	Power and Water Corporation - Remote Operations *Sewage Overflow*	Lot 580 Townsite of Angurugu	Angurugu - Sewer Pump Station 1

Date	Incident	Lot Information	Address
12 Nov 2015	Northline Pty Ltd *Nitric acid leak*	5963 Hundred of Bagot	14 Dawson Street, East Arm
27 July 2015	Northern Australian Beef Limited *Ground containing listed waste.*	Lot 4 Hundred of Cavenagh Section 5410, Hundred of Strangways	270 Blyth Road Livingstone 2660 Stuart Highway, Livingstone
12 May 2015	Teras Australia *Diesel Spill*	NT Portion 1644	Port Melville Accommodation Village Melville Island. Tiwi Islands
16 March 2015	McArthur River Mine *Air Pollution - unplanned fire*		McArthur River Mine site
16 Feb 2015	BHP Billition Manganese Australia *Stormwater Discharge*		Milner Bay, Alyangula, Groote Eylandt
15 Feb 2015	BHP Billition Manganese Australia *Stormwater Discharge*		Milner Bay, Alyangula, Groote Eylandt
14 Feb 2015	BHP Billiton Manganese Australia *Stormwater Discharge*		Milner Bay, Alyangula, Groote Eylandt
10 Feb 2015	BHP Billiton Manganese Australia *Stormwater Discharge*		Milner Bay, Alyangula, Groote Eylandt
13 Dec 2014	NT Police, Fire and Emergency Services, Berrimah *Oil Spill*	section 6349 Hundred of Bagot	cnr Berrimah road and Export Drive, East Arm
18 Feb 2014	Power and Water Corporation *Discharge of untreated effluent at the Darwin Botanical Gardens*		Gardens Road, The Gardens, Darwin
16 Feb 2014	WDR Iron Ore Pty Ltd *Vehicle in River. Potential for diesel and oil impacts*		Roper Bar Mine Site
13 Feb 2014	WDR Iron Ore Pty Ltd *Uncontrolled Discharge*		Roper Bar Mine Site
12 Feb 2014	WDR Iron Ore Pty Ltd *Uncontrolled Discharge*		Roper Bar Mine Site
24 Jan 2014	John Holland Pty Ltd *Leachate water leak, Shoal Bay Landfill*	Lot 3952 Town of Sanderson	Shoal Bay Waste Depot
9 Aug 2013	McArthur River Mining Pty Ltd *Trailer roll over carrying MRM concrete*		

Date	Incident	Lot Information	Address
24 May 2013	Asphalt Co Australia Pty Ltd *Accidental Fire igniting tyres*	Lot 4490 Hundred of Bagot	66 Syrimi Road Tivendale
22 Feb 2013	Vista Gold Pty Ltd *Uncontrolled discharge*		
18 Oct 2012	Ichthys LNG Pty Ltd *Hydraulic Fluid Leak, Blaydin Point*		
11 Sept 2012	Territory Alliance *Emulsion Spill*		
10 Aug 2012	Department of Defence - Larrakeyah *Ruptured Fuel Tank*		
7 Dec 2011	Power and Water Corporation *Pine Creek Substation*		
23 Mar 2009	Patrick Stevedores Darwin *Acid spill, East Arm Wharf*		
2009	Perkins - Diesel Spill		
2009	Diesel Spill - Black Point		
10 Sept 2008	Peanut Company of Australia *Diesel Spill, Taylors Park, Katherine*		
2 Mar 2008	Darwin RAAF Base *Dispersal of Aqueous Film Forming Foam*		
4 Feb 2008	Parmalat Australia Ltd *Raw milk loss to sewer, Bishop Street, Woolner*		
7 Feb 2007	ORICA Australia Pty Ltd *Cyanide spill near Renner Springs*		
14 Jul 2006	Power and Water Corporation *Fuel spill, Ron Goodin Power Station, Alice Springs*		
27 Jun 2006	BP Australia Pty Ltd *Diesel spill, Roper Hwy, between Mataranka and Ngukurr*		
11 May 2006	BP Australia Pty Ltd *Diesel and Avgas spill, Buchanan Hwy (300km south of Katherine)*		

Source: NT EPA. Accurate at 7 May 2016.

Appendix 4. Accidents Happen: Images.

Pressurized lines being improperly connected or being hammered on while under pressure cause 'production fluid spills' Source: MEF n.d.

Large Fracking Operation Fire in Grady County, Oklahoma.
Source: Brown 2016

2011 Gas well blowout. It burned acres of forest in remote Village Creek State Park, Texas.
Source: Nasti 2013

Shale well, West Virginia.
Source: Sierra Club's West Virginia Chapter 2011

A truck hauling fracking lubricant, smashed through guardrails, trees and into a creek, leaking fracking fluid into the creek. West Liberty, West Virginia. Source: Hanson 2012

A fracking tanker accident and spill in the town of Fox Creek, Alberta, Canada.
Source: Bounds 2015

2013, Weld County Colorado. Floods inundated hundreds of fracking wells causing contamination.
Source: The Aspen Times 2013

Scientists inspect a fracking spill in North Dakota.
Source: Vengosh, Lauer, Harkness 2016