SCIENTIFIC INQUIRY INTO
HYDRAULIC FRACTURING
IN THE NORTHERN TERRITORY

SUMMARY OF THE INTERIM REPORT

JULY 2017

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Front cover image: Central Australia Northern Territory. William Robinson. Source: Alamy Stock Photo.

Purpose of this summary document

On 14 July 2017, the Scientific Inquiry into Hydraulic Fracturing of Unconventional Reservoirs in the Northern Territory **(the Inquiry)** released an Interim Report, which is available on the Inquiry's website at www.frackinginquiry.nt.gov.au

The Interim Report sets out the work undertaken by the Inquiry to date in assessing the impacts and risks associated with any potential onshore unconventional shale gas development in the Northern Territory (**NT**). The report explains the method by which the Inquiry proposes to gather and then assess the evidence relevant to the issues that have been identified and discussed with the public. Where appropriate, the Interim Report makes some preliminary assessments about the likelihood of some of those risks eventuating as well as the methods to mitigate the risks. Finally, the report describes the future work of the Inquiry that will be undertaken prior to the release of its draft Final Report by the end of the year.

This document summarises each of the chapters in the Interim Report. Where further information is required, including references, the Interim Report should be referred to.

Executive summary

The following is an extract from the executive summary:

> *'The anxiety, if not hostility, surrounding fracking was on display during the first round of community consultations held by the Inquiry. Overwhelmingly, the message received from the people who attended these meetings was that fracking was not safe, was not trusted and was not wanted in the NT. "We want no Government humbug here", was the response from one member of the public in Maningrida.*
>
> *Having said this, it should be recognised that these are not universally held views. Many groups and individuals have expressed the opinion to the Inquiry that properly regulated and adequately safeguarded, the onshore extraction of shale gas by hydraulic fracturing could be beneficial to the Territory, creating employment opportunities and raising much-needed revenue.*
>
> *The ultimate task of this Inquiry is not to recommend to the Government that it retain or lift the moratorium presently in place—that is a matter for the Government. Rather, the work of the Inquiry is to, based on the most current and best available relevant scientific data and literature, assess the environmental, social, cultural and economic risks associated with hydraulic fracturing for shale gas in the NT. In doing so, the Inquiry must sort fact from fiction and weigh up claim and counter-claim in making its assessments and in formulating its recommendations. As one community forum participant in Yuendumu stated, "We've been told a lot of things from both sides. There's a lot of misinformation. We just want you to give us the truth".'*

Chapter 1 Purpose of the Inquiry

The purpose of the Inquiry is found in the Inquiry's Terms of Reference, which are available on the Inquiry's website at www.frackinginquiry.nt.gov.au. While limited to onshore unconventional shale gas only, the Terms of Reference are nevertheless broad in their scope. They require the Panel to assess and determine:

- *the nature and extent of the risks associated with hydraulic fracturing of onshore unconventional shale reservoirs and its associated activities on the environmental (aquatic, terrestrial and atmospheric), social, cultural and economic conditions of the NT;*
- *whether these risks can be mitigated to an acceptable level;*
- *if they can, by what methodology or methodologies these risks can be mitigated; and*
- *whether the existing regulatory framework is sufficient to implement these methodologies, and if not, what changes need to be made.*

This is not the first inquiry the NT has held into hydraulic fracturing. This Inquiry differs from its predecessors, however, by reason of its scope (it is wider) and its mandate to consult widely.

Chapter 2 Work of the Inquiry to date

Panel meetings

Since the Inquiry was constituted on 3 December 2016, the Panel has formally met on five occasions.

Interstate visits

The Panel has undertaken one interstate visit to South Australia (**SA**) to consult with officers of the Energy Resources division of the South Australian Department of State Development concerning the regulatory framework governing conventional and unconventional onshore gas development in that state. Consultation also occurred with the Nuclear Fuel Cycle Royal Commission Consultation and Response Agency, to discuss models of community engagement.

On 1 and 2 February 2017, the Panel travelled to Moomba in SA to conduct a two-day site visit of Santos Ltd's operations in the Cooper Basin.

Consultation

The Inquiry has a strong mandate to consult with Territorians about their views on the development of an onshore unconventional shale gas industry in the NT. The first stage of the Inquiry's community consultation and engagement program commenced in March 2017, following the release of the Inquiry's Background and Issues Paper (**Issues Paper**) on 20 February 2017.

To understand the views of the community on hydraulic fracturing and whether the Issues Paper correctly identified the risks of hydraulic fracturing for onshore shale gas, the Inquiry invited public comment and submissions and held a series of public hearings and community forums across the NT.

Over 290 submissions were received. All submissions are available to view on the Inquiry's website.

The Inquiry held a total of 37 public hearings in Alice Springs, Katherine, Tennant Creek and Darwin between 6 and 10 March 2017. The purpose of the hearings was to provide a formal avenue for stakeholders, organisations, businesses or any registered person or group to make a maximum 30-minute presentation to the Panel. The hearings were recorded and live-streamed on the Inquiry's website, which was viewed by more than a thousand people, including people in Canada, the US, Ireland, the UK, Hungary, Spain and Switzerland.

More than 1,000 people attended the Inquiry's community meetings. Registration was not required for the meetings, which were informal information and engagement sessions designed to encourage active discussion and participation by those who attended. These meetings took place in the following urban centres and regional communities: Alice Springs, Tennant Creek, Katherine, Darwin, Humpty Doo, Gapuwiyak, Nhulunbuy, Ngukurr, Borroloola, Daly Waters, Mataranka, Timber Creek, Wadeye, Hermannsburg, Yuendumu, Maningrida and Elliott.

The Inquiry also had an online feedback form on its 'Have your say' website page, and hard-copy feedback forms were available at community meetings. A total of 181 feedback forms were received.

Chapter 3 Evidence and risk assessment methodology

Evidence relied upon

In addition to their own expertise, the Panel is also taking into account the following to assess the impacts and risks associated with onshore unconventional shale gas development:

- *international and domestic literature, including Dr Allan Hawke's 2014 and 2015 reports entitled Report of the Independent Inquiry into Hydraulic Fracturing in the Northern Territory and Review of the Northern Territory Environmental Assessment and Approval Processes and Dr Tina Hunter's reports entitled Regulation of Unconventional Gas Resource Development in the Northern Territory and Review of the Draft Petroleum (Environment) Regulations and independent assessment of the Regulations against best practice regulation of environmental aspects arising from petroleum activities involving ground disturbance;*
- *all written submissions, letters and emails received by the Inquiry;*

- *oral submissions and feedback from the community during the Inquiry's initial round of consultations; and*
- *the views expressed in the online and hard copy 'Have Your Say' feedback forms.*

A comprehensive bibliography of the literature the Panel has considered so far and a complete list of the submissions provided to the Inquiry to date is listed in the Interim Report.

Unless indicated otherwise, all written submissions, letters and emails received by the Inquiry have been, and will continue to be, in the interests of fairness and transparency, published on the Inquiry's website.

Methodology and assessment of risk

The Panel will identify, collect, analyse and distil the available scientific evidence concerning each of the risks and issues it has identified (see Appendix 1 of the Interim Report for the revised list of risks and issues). The Panel will then assess the risks by determining whether the likelihood and consequence of an impact occurring is either 'Low', 'Medium' or 'High'. Once this assessment is made, it will be possible to determine the resultant risk, which will be either 'Low', 'Medium' or 'High', as depicted in the risk matrix below.The Panel's risk assessment framework has been modified from the NT Government's risk assessment framework in the Explanatory Guide to the *Petroleum (Environment) Regulations 2016* (NT).[1]

Following the risk assessment, the Panel will determine the mitigation measures that are available to reduce the levels of risk to acceptable levels. Some of those mitigation measures are identified in the Interim Report.

Risk matrix

		Likelihood		
		(L) The likelihood of the impact occurring is < 1%	**(M) The likelihood of the impact occurring is between 1 – 10%**	**(H) The likelihood of the impact occurring is > 10%**
Consequence	(H)	M	H	H
	(M)	L	M	H
	(L)	L	L	M

Chapter 4 Summary of discussions at community forums and the revised list of issues

The Issues Paper identified the issues the Panel considered to be the main issues arising from the development of an onshore unconventional shale gas industry in the NT. The Panel sought feedback from Territorians about those issues and about any other concerns the community had about hydraulic fracturing of onshore unconventional shale gas reservoirs. The feedback is summarised below.

Water: the primary and most consistently raised issue across all community forums was the potential impact of any onshore unconventional shale gas industry on water resources (surface water and groundwater) in the NT, both in respect of human use and dependent ecosystems.

Regulatory framework: the adequacy of the regulatory framework governing any onshore unconventional shale gas industry in the NT was a key concern for participants at the community forums. The Panel observed the community's lack of faith in the current regulatory framework to adequately, or in some instances, at all, protect the environment from the risks inherent in any onshore unconventional shale gas industry as well as a general distrust in the NT Government to make decisions in the best interests of the community.

Land: the concerns expressed during the community forums in relation to land were related to the following issues: loss of landscape amenity values, loss of habitat for wildlife, the spread of weeds, land contamination and the potential impact on stock movement as a result of roads, pipelines and well pads.

Air: the contribution of any onshore unconventional shale gas industry to climate change was a major issue for a significant number of participants. It was noted that shale gas is a fossil fuel and that its extraction, production and use cause greenhouse gas emissions (carbon dioxide and methane) that contribute towards climate change.

Aboriginal people and their culture: the potential impact of any onshore unconventional shale gas development on Aboriginal people and their

1 Northern Territory Government. (2016). Petroleum (Environment) Regulations, an explanatory guide. Available at < https://nt.gov.au/__data/assets/pdf_file/0005/295907/em-petroleum-environment-regulations.pdf>.

culture was raised by traditional Aboriginal owners, members of the Aboriginal community and by many non-Aboriginal people. Most were worried that any development would irreversibly disturb and damage country for future generations.

Social impacts: the most frequently raised potential adverse social impacts that an onshore shale gas industry might have on local communities related to rapid increases in population, conflict in the community between those for and against gas development, an influx of fly-in fly-out workers and the negative impacts of a 'cash splash' (a rapid injection of money into the community).

Public health: the key issues relating to public health included water contamination by hydraulic fracturing fluids, flowback and produced water, release of fugitive emissions, dust, impacts on climate change, the risk of spills along transport routes, the risk of road trauma and impacts on mental health and wellbeing.

Land access: access to land for the purposes of exploration and extraction of shale gas was a significant issue, particularly for Aboriginal people and pastoralists. Pastoralists and native title holders do not have a right to refuse access to their property for petroleum activities, which was a matter of considerable anxiety.

Economic impacts: there was a significant amount of scepticism expressed about the true value of any economic benefit created by shale gas development, especially in terms of employment, public revenue generation and royalties. There was a strong belief that those who bore the risks of the development would not receive the benefits. Many participants considered that investing in onshore unconventional shale gas, rather than in renewable energy, would result in an opportunity cost to the community and to the Government and that the Government should not be '*investing in a declining industry*'. Some stakeholders were concerned that the industry might have an adverse impact on other industries such as tourism, pastoralism, horticulture and agriculture, especially on the clean and green image of the NT.

Chapter 5 Shale gas development and management

Differences between conventional and unconventional gas

'Unconventional' gas is found in relatively impermeable source rocks, where the gas has been trapped where it was formed. This is different from 'conventional' gas, which has migrated from its original source rocks into more porous, permeable rocks and has then been trapped under a seal of impermeable rocks. Unconventional gas includes coal seam gas (**CSG**) (found in coal seams), shale gas (found in shale rocks) and tight gas (found in sandstone). Irrespective of whether it is conventional or unconventional, natural gas is composed mainly of methane—up to 98%—with varying amounts of other trace gases such as ethane, propane, butane and other hydrocarbons. From a consumer's perspective, unconventional gas is all but identical to conventional sources of natural gas.

Extraction of conventional and unconventional gas

Conventional gas can typically be developed with a limited number of wells due to the accumulation of the hydrocarbons in a confined area with well-connected pore spaces within the rock that enable effective drainage from strategically placed wells. The gas will flow to the surface under its own pressure driven by a water table (or aquifer) underneath a pressurised gas cap.

By contrast, the source rocks that hold unconventional gas have much lower porosity (that is, the void spaces between the grains that make up the rock are very small) and much lower permeability (that is, the interconnectedness of the pore spaces to allow the gas to move through the rock is very low). In order to extract unconventional gas, it is necessary to increase the level of porosity and permeability. This is termed 'artificial stimulation' and generally involves hydraulic fracturing.

Site and well management considerations

The matters that regulators and industry must consider in connection with unconventional shale gas development are summarised below.

Site infrastructure: during drilling and hydraulic fracturing, there is a concentration of heavy equipment on site along with large stockpiles of drilling supplies and hydraulic fracturing materials. In most cases, however, the final footprint of the wells and surface facilities is much smaller than the original drilling footprint.

Well integrity: there is evidence to indicate that well integrity has been an issue for the onshore shale gas industry, however, recent technological improvements in the design and construction of shale wells has resulted in a considerably improved performance in the integrity of modern wells when compared to earlier wells and legacy wells.

Decommissioning: following the production lifecycle of a well (typically 20 to 50 years), the wellhead is removed and the steel casing is filled with cement at various intervals, including the perforated zone, the middle of the well bore and down to a distance of about 30 metres below the surface. Fluid with an appropriate density is placed between the cement plugs in order to maintain adequate pressure in the voids between the plugs.

Water use: shale gas extraction requires the use of large quantities of water, which may be obtained from local surface or groundwater sources or

transported to the site from outside the region and typically stored in large, above-ground ponds. Typical water volumes used are around 1–2 ML for well drilling and approximately 1–2 ML for each hydraulic fracturing stage. For a well that has 20 hydraulic fracturing stages, around 40 ML of water is used.

Wastewater production and composition: three main sources of wastewater are produced during the shale gas extraction process:

- **water:** *in drilling mud used to drill the initial well bore;*
- **flowback water:** *water that is returned to the surface in the first few weeks to months after hydraulic fracturing has occurred; and*
- **produced water:** *water from the shale layer produced over the lifetime of the well.*

Management and reuse of flowback and produced water: flowback water is typically stored initially in open, lined surface ponds that may be constructed on the land surface or excavated below ground level. In the United States (**US**), there has recently been a move towards storing flowback water in special-purpose, above-ground tanks.

Reuse of wastewater: reuse (recycling) of wastewater can reduce, but not eliminate, the amount of fresh water needed for hydraulic fracturing since the volume of flowback water from a single well is generally small compared to the total volume needed to fracture a well. The Panel has sought information on the potential for petroleum companies to use less high-quality groundwater by reusing some of the treated or untreated wastewater.

Reinjection of wastewater: aquifer reinjection is being increasingly restricted because of concerns with potential for groundwater contamination and induced seismicity.

Seismicity: there is now evidence from the US and the United Kingdom (**UK**) that earthquakes may occur during hydraulic fracturing near fault lines and that larger scale earthquakes have occurred during the reinjection of wastewater into the ground.

Subsidence: sinkholes are unlikely to occur as a result of hydraulic fracturing of onshore shale reservoirs in the NT because of the large vertical distance between the shale layer and the surface (several thousand metres), a distance over which the intervening rocks should compensate for any cavities produced by hydraulic fracturing. This contrasts with CSG operations, where a substantial proportion of the original void volume is removed as produced water and there is a real possibility of subsidence given the closer proximity to the surface.

Chapter 6 Shale gas in Australia and the Northern Territory

Australia is believed to have substantial prospective shale gas resources, with the NT estimated to have more than a third of the total resources in rocks at depths of between 1,500 and 4,000 m below the surface. Almost 70% of this is thought to occur in the Beetaloo Sub-basin of the McArthur Basin, which is considered to be the main target for any future development in the NT (**Figure 1**). In recent years, exploration has focussed predominantly on the Beetaloo Sub-basin, which has received around 50% of the total $505 million of exploration investment since 2010. Noting the long lead time from exploration to development of shale gas resources, these figures suggest that the most likely area for shale gas development in the foreseeable future (five to 10 years) would be the Beetaloo Sub-basin.

Chapter 7 Water

Effective water management will be crucial to the potential development of any unconventional onshore shale gas industry in the NT. This involves first ensuring that water is used at a sustainable level, and second, ensuring that surface and groundwater quality is maintained. The Inquiry has reviewed and summarised the available information relating to NT water resources, the production and composition of wastewaters produced by the hydraulic fracturing process, and the management, treatment and possible reuse of these wastewaters. The Beetaloo Sub-basin is used in the Interim Report as a case study for a preliminary analysis of water resources and water use because it is the most prospective area in the NT for shale gas development, and, importantly, it is the region where the best information is available.

Water requirements

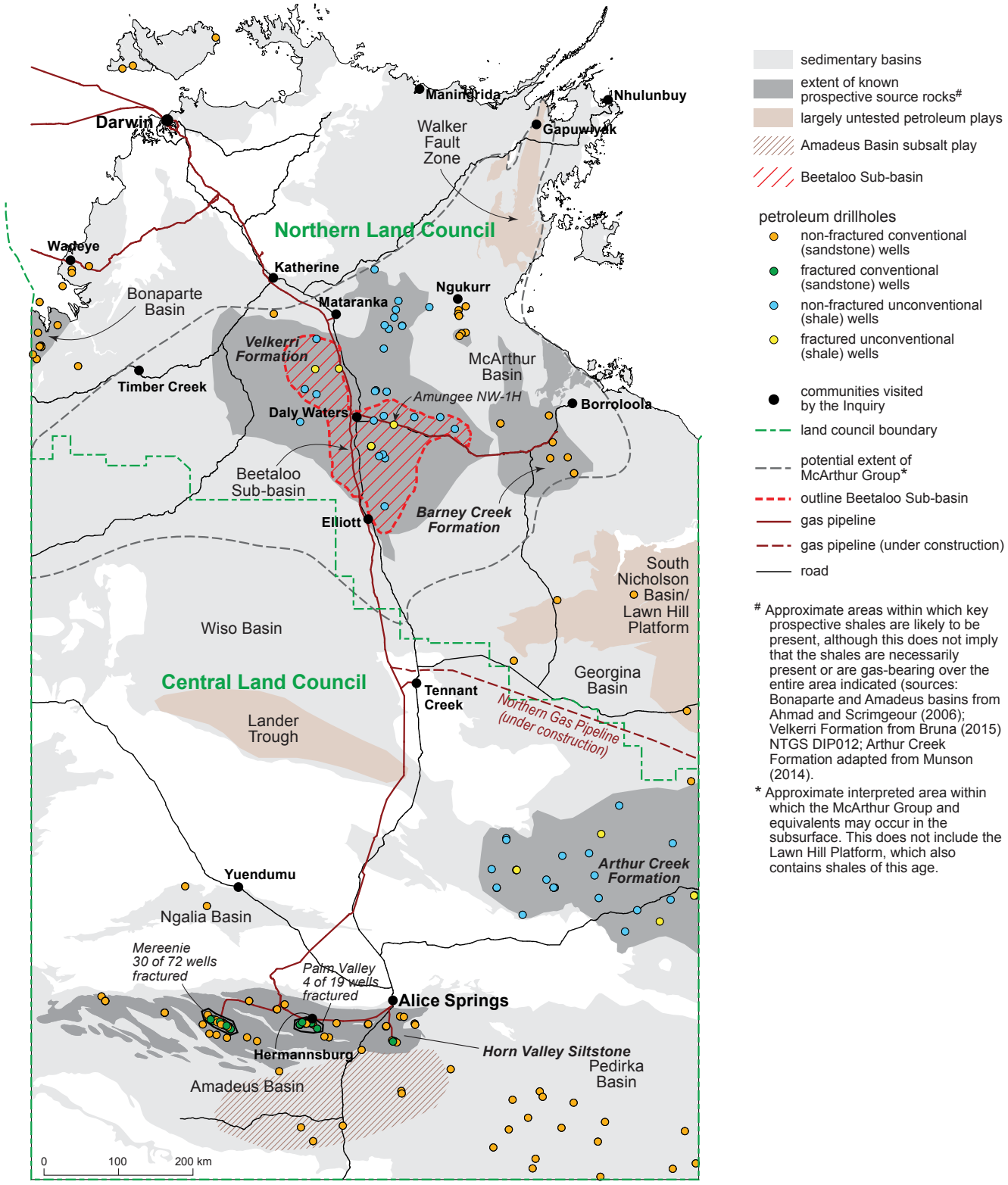
Typically, 1–2 ML of water is required for well drilling and for each hydraulic fracturing stage. The actual volume used in a particular location will depend on the length of the horizontal well and the number of fracturing stages. The Panel has estimated that a development scenario comprising 1,000 to 1,200 hydraulically fractured wells,[2] which is considered a feasible development scenario in the Beetaloo Sub-basin, will require an average of 2,500 ML/y (up to 5,000 ML/y at peak demand) of water, or a total of 20,000 to 60,000 ML from the aquifer system over 25 years.

Impact on surface water supply

The Panel's preliminary assessment is that the impact of onshore shale gas operations on surface water supply in semi-arid (such as the Beetaloo Sub-basin) and arid areas of the NT is relatively low.

2 The estimates provided by Origin, Pangaea and Santos suggest that the combined developments over the next 25 years could result in between 1,000 and 1,200 wells associated with around 150 pads.

Figure 1: Petroleum wells in the NT showing extent of known prospective source rocks. Source: Department of Primary Industry and Resources.



Approximate areas within which key prospective shales are likely to be present, although this does not imply that the shales are necessarily present or are gas-bearing over the entire area indicated (sources: Bonaparte and Amadeus basins from Ahmad and Scrimgeour (2006); Velkerri Formation from Bruna (2015) NTGS DIP012; Arthur Creek Formation adapted from Munson (2014).

* Approximate interpreted area within which the McArthur Group and equivalents may occur in the subsurface. This does not include the Lawn Hill Platform, which also contains shales of this age.

NORTHERN TERRITORY GOVERNMENT

Figure 1 shows the potential shale gas-bearing areas in the NT. The grey areas show the extent of known prospective shale gas source rocks; that is, rocks that are considered to have the necessary prerequisites for shale gas occurrence and for commercial development. The taupe areas are those that are considered to have the potential prerequisites for shale gas to occur but that have not been tested through drilling. **Figure 1** also shows petroleum wells that have been hydraulically fractured in the Northern Territory.

There are no permanent surface water resources (rivers, streams, lakes and waterholes) in the Beetaloo Sub-basin. The Panel's preliminary view is that the use of surface water for shale gas operations should be prohibited in arid and semi-arid zones. Further consideration will be given to the use of surface water for onshore shale gas operations in northern areas of the NT.

Impact on groundwater supply

The Panel received a number of submissions suggesting that the estimated volumes referred to above (2,500 to 5,000 ML/y) represent a very small percentage of the sustainable yield from the Cambrian Limestone Aquifer (**CLA**) in the Beetaloo Sub-basin. However, there appears to be little consensus on the actual sustainable yield of the aquifer. For the northern section of the Beetaloo Sub-basin (Mataranka to Daly Waters), the Panel is aware of estimates for the sustainable yield (recharge rate) that range from 100,000 ML/y to 330,000 ML/y. From a regional perspective, the use of up to 5,000 ML/y from the groundwater system is a relatively small proportion (<5%) of the suggested recharge rate of 100,000 to 330,000 ML/y. The Panel has no estimate for the recharge rate of the CLA in the southern part of the Beetaloo Sub-basin (around Elliott) but expects it to be considerably less than the above figures because of the lower rainfall in this region. The Panel intends to seek further information from the Government on recharge rates in the southern part of the Sub-basin and will make an assessment of the environmental impact of taking water for use in hydraulic fracturing in the draft Final Report.

Water quality

Connectivity between the shale formation and overlying aquifers

There is a low risk that groundwater can be contaminated as a result of induced connectivity between hydraulically fractured shale formations and overlying aquifers given the large distance between the shale formations and the overlying aquifers (between 1,000 and 2,000 m) as well as the low permeability of the intervening strata. The risk of connectivity increases, however, if there is a fault between the shale formation and the aquifer, and the Panel has committed to seek further clarification on the likelihood of existing faults, how they can be avoided and how the potential impacts of any naturally occurring seismic activity can be managed.

Spills

There is a risk that groundwater and/or surface water will be contaminated as a result of spills of chemicals, flowback water or produced water. Most spills are related to the storage of water and materials in tanks and pits and in moving wastewaters in pipelines between equipment. The greatest incidence of spills is during the first three years of well life, which is the period when wells are drilled and hydraulically fractured. The Panel's view is that the likelihood of spills can be reduced with well-engineered wastewater containment facilities and existing management strategies. The Panel will obtain more information regarding leading industry practices. There is also the potential for evaporation ponds storing wastewater to overflow during high-intensity rainfall events. The Panel's preliminary view is that hydraulic fracturing should not be permitted during the wet season for this reason.

Reinjection of wastewater into deep reservoirs

Reinjection of wastewater into deep reservoirs is common overseas. In the US, around 93% of flowback and produced water has been injected into deep reservoirs. This practice has been associated with increased seismic activity. For this reason, the onshore shale gas industry in the US is now focussing on reusing wastewater for well drilling and hydraulic fracturing.

Reinjection of wastewater into aquifers

There are risks associated with the injection of wastewater into groundwater systems. Managed aquifer recharge is practised in many areas of Australia and overseas and involves the injection of water of compatible chemistry into aquifers. For this to occur, however, the receiving aquifer must have suitable permeability and structural integrity to receive injected waters, and the injected water must have a suitable chemical composition. The Panel's preliminary view is that the reinjection of wastewater into groundwater should be prohibited.

Leaky wells

There is a risk that groundwater will be contaminated as a result of leaky wells. Leaky wells can result from poor design, construction, operation and abandonment practices. The Panel's preliminary view is that the likelihood of this occurring is low provided that leading practice is adopted. It is standard practice for a well to be lined with multiple layers of piping (casing), with a specialised cement layer between each of the pipes and also between the outer pipe and the rock strata. Analysis of the literature shows the frequency of well failures has decreased markedly with modern methods of design and construction being used.

Changes in groundwater pressure

If water for hydraulic fracturing is sourced from groundwater, there will be a resultant decrease in groundwater pressure, which may result in neighbouring groundwater bodies flowing into that aquifer and possibly changing the water quality. There is a risk that the water quality and quantity in the aquifer could be adversely affected, but this risk can only be quantified with site-specific hydraulic modelling. The Panel's preliminary view

is that groundwater for use in hydraulic fracturing should not be permitted unless modelling of the local groundwater system is undertaken and clearly demonstrates that there will be no adverse impact on groundwater quality and/or quantity.

Chapter 8 Land

The NT is internationally renowned for its vast and often spectacular landscapes, many of which have outstanding wilderness values and represent an iconic part of outback Australia. The NT also has exceptional terrestrial biodiversity values, featuring a wide range of habitats and high levels of species diversity and endemism. The Panel has identified various land-related risks of any onshore shale gas development that will require mitigation if it proceeds.

Landscape amenity

There may be a risk that the development of the unconventional gas industry will have an adverse impact on the outback experience (for example, tourism) through infrastructure development (for example, the construction of pipelines and processing plants) and increased traffic, noise and light (from flaring). The Panel's preliminary view is that the consequences of amenity impact will be high if shale gas development significantly detracts from iconic wilderness values. The Panel's preliminary view is that there should be a statutory prohibition against conducting onshore shale gas activities in national parks, conservation reserves and other areas of high conservation significance (see **Figure 2**) as well as a specification of a minimum well pad spacing/density if development is permitted to occur.

Inadequate knowledge of biodiversity assets

The Panel is considering making a recommendation that onshore shale gas development should be excluded from all conservation reserves and sites of conservation significance. However, the locations of these areas have historically not been proclaimed on the basis of systematic evaluations of regional biodiversity assets, and therefore, it cannot be assumed that they are representative of broader regional biodiversity values. A well-developed understanding of biodiversity assets within prospective regions for onshore shale gas development, including through a strategic, basin-wide assessment of biodiversity values, should occur prior to development to minimise risk to biodiversity. Better information on the location of biodiversity assets is required to enable Government to identify areas where development should not occur.

Spread of weeds

Weed invasion in the NT has had a significant and widespread impact on ecosystems in the Territory. The spread of weeds usually occurs with extensive regional development, particularly associated with access corridors. In the Beetaloo Sub-basin, for example, proposed exploration and development could pass through areas affected by declared weeds such as bellyache bush, grader grass, parkinsonia, noogoora burr, rubber bush and gamba grass. The Panel's view is that there is a need for increased clarity around the regulation, compliance and enforcement of comprehensive weed management plans for all areas affected by or adjoining exploration and development areas. Weed management plans should include a requirement for baseline assessments as well as clear and enforceable implementation strategies to prevent the spread of weeds.

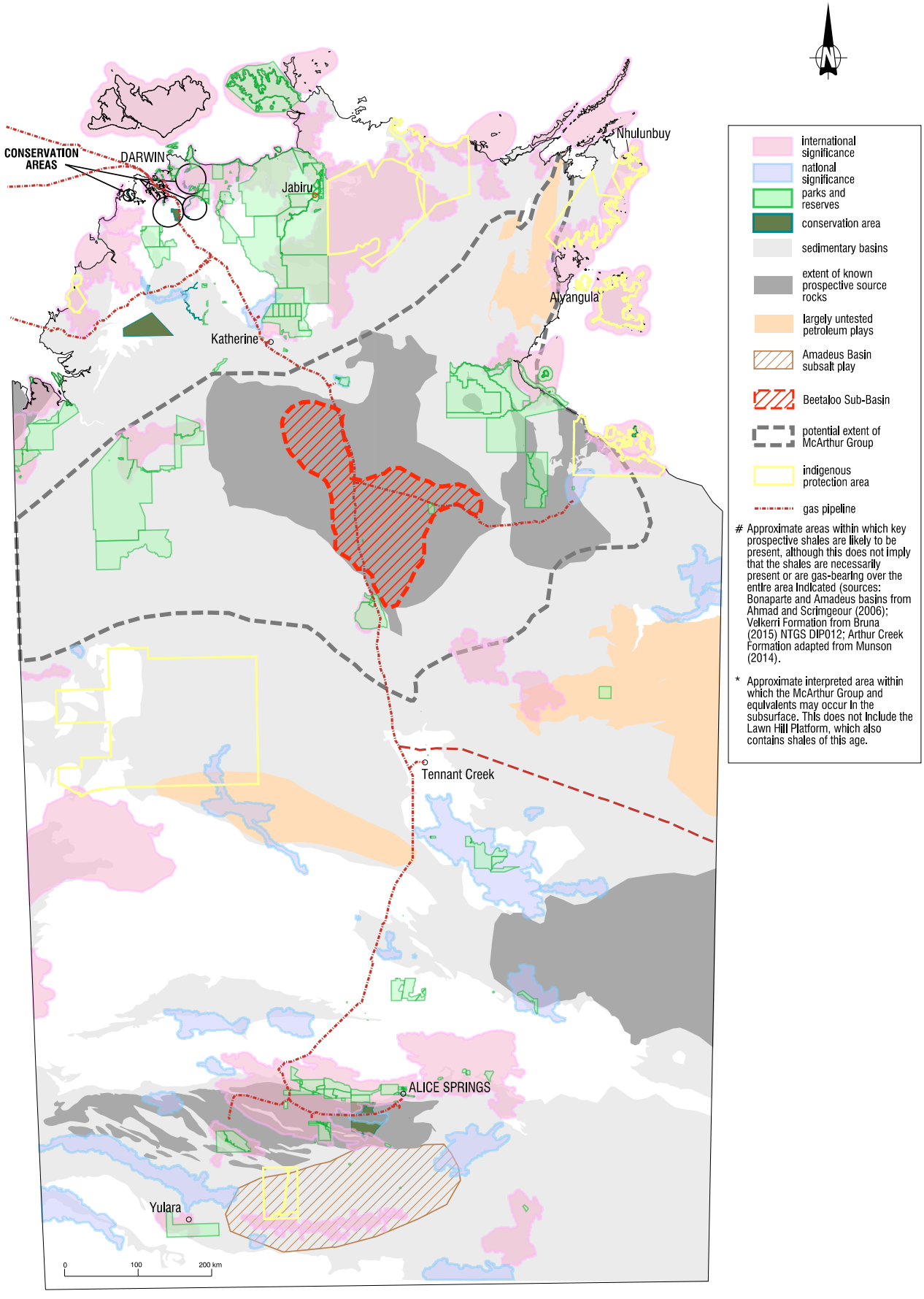
Changed fire regimes

Fire is a key ecological process in the tropical savannah landscapes of northern Australia (covering both the northern and central regions, including the Beetaloo Sub-basin), most of which are burnt every two to five years. Onshore shale gas development could potentially affect the frequency, timing and surface area extent of fire. This may be through increased ignitions because of increased human activity (acting to increase fire frequency) or through roads and pipelines acting as barriers to the spread of fire (acting to decrease fire frequency and surface area extent). The Panel's preliminary assessment is that the consequences of significantly altered fire regimes is high given the importance of fire as a driver of vegetation dynamics and greenhouse gas emissions, especially in higher rainfall regions. Should onshore unconventional shale gas development proceed, the Panel's view is that regional baselines for fire regimes should be established for the decade prior to commencement.

Habitat loss and fragmentation

Given that the onshore shale basins in the NT are almost entirely covered by native vegetation, development would involve substantial clearing. Based on submissions from Origin, Santos and Pangaea, industry forecasts are for well pad densities of one per 10–20 km^2 (equating to an average spacing between well pads of 3.2–4.4 km), which would require vegetation clearing of approximately 1.5–2.5% of the development area. In addition to the direct effects on the biota of cleared areas, such clearing would have especially pervasive edge and other fragmentation effects on uncleared vegetation because much of the clearing is linear (for example, pipelines and access roads). Impacts of habitat loss and fragmentation can be mitigated by minimising vegetation clearing by specifying well pad densities, rehabilitation and offsetting, including, for example, by funding local Aboriginal ranger programs for the management of weeds and fire.

Figure 2. Locations of conservation reserves and sites of conservation significance in relation to shale basins in the NT. Source: Department of Infrastructure, Planning and Logistics.



Chapter 9 Greenhouse gas emissions

In 2015, Australia signed the 'United Nations Framework Convention on Climate Change Paris Agreement', which has a goal of '*holding the increase in the global average temperature to well below 2˚C and above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5˚C*'. The Panel heard from many stakeholders who were concerned that development of the NT's shale gas reserves would compromise Australia's ability to reach these goals. This is because greenhouse gases (**GHG**), including methane and carbon dioxide, are emitted during the lifecycle of shale gas development.

GHG emissions during upstream development

Methane is the main GHG that is emitted during the upstream development of shale gas. Around 77% of upstream GHG emissions are from methane. Methane is considered to have a much greater climate impact than carbon dioxide. The Panel reviewed the scientific literature to determine the amount of methane emitted during shale gas operations. There was a great deal of variability, with some reports quoting methane emissions as low as 0.22% and others as high as 17% of total methane production.

GHG emissions associated with upstream shale gas development were mainly as the result of fugitive emissions during transport and distribution (26%), emissions from well completion (21%) and fuel combusted by processing compressors (12%).

The Panel noted that new standards introduced by the US Environmental Protection Agency (**US EPA**), which require reduced emission well completions for all new wells, have effectively reduced methane emissions in upstream development. The new standards include the use of plastic pipes and upgraded metering and monitoring systems. The US EPA reported that methane emissions have reduced from 2.27% in 1990 to 1.25% in 2015, in each case, of the total production volume.

If modern emission reduction technologies and practices employed in the US were replicated in Australia, the Panel considers that upstream methane emissions could be reduced to 2%.

GHG emissions during the lifecycle of shale gas development

To gain an understanding of the total GHG emissions released during the lifecycle of shale gas development, the Panel considered the GHG emissions at the upstream and downstream phases of development. Downstream emissions are the emissions resulting from burning natural gas (which is primarily methane along with some other hydrocarbons) for heat and electricity. Large amounts of carbon dioxide, another GHG, are released when natural gas is combusted, or burned. While methane dominates the upstream GHG emissions, carbon dioxide emissions dominate the lifecycle GHG emissions.

Noting that there is a great deal of variability in the literature, the Panel concluded that the lifecycle GHG emissions for shale gas-generated electricity is less than half of the emissions associated with coal-generated electricity.

The Panel is more focussed on ways to reduce methane emissions because the quantity of methane that is emitted during upstream development is more amenable to reduction, unlike carbon dioxide, which will ultimately be released when the natural gas is used at the end point. Methane also has a greater climate change impact than carbon dioxide.

Opportunities exist to ensure methane emissions are reduced by ensuring there is a strict regulatory framework in place. The Panel considers that baseline monitoring of GHG emissions will be essential to any onshore shale gas development. This will enable an understanding of the emissions that result from onshore shale gas development and emissions that result from other sources, including natural methane seepage, wetlands, landfills, sewage treatment facilities and livestock. The Panel considers that baseline measurements should commence at least 12 months prior to production to capture any seasonal variations in methane emissions and that monitoring of emissions should continue throughout the lifetime of any development.

Chapter 10 Public health

The Panel has evaluated the possible public health risks associated with onshore unconventional shale gas development in the NT. Public health impacts are generally measured in terms of adverse health changes in large exposed groups or populations. A conventional tool for assessing public health impacts from environmental sources is a Human Health Risk Assessment (**HHRA**). In order to conduct an HHRA, the following things must be known:

- *first, the toxicity of the chemicals of concern (**COC**); and*
- *second, potential pathways by which humans could be exposed to the chemicals.*

COC will most likely be those added to hydraulic fracturing fluid. Other COC would be those extracted from the shale formation, which are brought to the surface in formation and produced water. Other COC could be airborne chemicals, such as volatile organic carbon gases and vapours, diesel fumes associated with transport and drilling equipment, and airborne dusts generated by land-clearing and other activities.

Potential pathways include ingestion of contaminated drinking water or food; breathing in airborne gases, vapours or dusts; or direct

skin contact with soil or other contaminated media. There is strong evidence that proximity to unconventional gas activities is a crucial factor, with a survey of health effects showing that residents living beyond 0.8 km of wells had a lower incidence of a range of health effects than closer residents. This is not surprising since airborne, dust-borne and water-borne contamination would be expected to undergo dilution as it spreads away from the site of release, resulting in a lower potential for human exposure.

The Panel identified various potential risks to public health of shale gas development in the NT.

Contamination of aquifers

Where adequate toxicological information is available, the chemicals used in fracturing fluid appear to have low toxicity, and at the concentrations used in hydraulic fracturing fluid, ingestion would be unlikely to represent an acute health risk. As stated above, the Panel is still investigating the potential for contamination of drinking water aquifers if leakage of wastewater was to occur as a result of leakage from the well itself or from a spill. Further information is being sought on the likelihood that contaminated wastewater would seep through the soil profile and what dilution and dispersion would occur within the aquifer.

The COC found in flowback and produced water may be more of a health concern than the chemicals found in hydraulic fracturing fluid and include BTEX (benzene, ethylbenzene, toluene and xylenes), other volatile organic compounds and naturally occurring radioactive materials (**NORM**) extracted from hydrocarbon deposits. While concentrations of these COC may reach levels that would exceed health-based water quality guidelines, the dilution effect should substantially reduce these concentrations in an aquifer that was contaminated to a level that would not be of concern for exposure through ingestion.

The most likely pathways by which aquifers could be contaminated by chemicals used in hydraulic fracturing or that appear in formation or produced water are discussed above. The Panel's initial assessment is that any evaluation of human health risks associated with contamination of drinking water resources can only be meaningful if it is done on a site-specific basis.

Fugitive emissions and airborne chemicals

A number of scientific studies have addressed the potential public health impacts of volatile organic compounds and other airborne chemicals in dusts that may travel off site, and the Panel has summarised the variable findings of these studies in the Interim Report. The Panel has queried the applicability of the studies to the NT because of the much closer proximity of human habitation to gas fields in the studies, which would be very different from any development scenario in the NT which would occur in very remote locations.

Chapter 11 Aboriginal people and their culture

Aboriginal people make up most of the resident populations in the areas of the onshore shale gas basins in the NT. Aboriginal people are linked to their land (including water bodies) by their ancient traditions and the contemporary use of their land in accordance with those traditions. As a community, Aboriginal people must be able to maintain their cultural traditions relating to that land so that their ownership rights continue to be recognised, from one generation to the next. Aboriginal communities are therefore particularly vulnerable to degradation of the landscape and the natural systems it supports.

The need for good information and consultation

The Panel's preliminary view is that Aboriginal people have not yet been given enough information about the potential risks and benefits of hydraulic fracturing. It is imperative that accurate information be provided to the Aboriginal communities likely to be directly affected by development of the onshore shale gas industry well in advance of the development to ensure that the development will not pose a risk to Aboriginal people or their culture. Decisions made under native title and land rights legislation should not occur in the absence of full information about the nature and extent of future development.

Disruption of traditional cultural practices

The Panel's preliminary view is that consequences, or social costs, of development will be high if there is any disruption to traditional practices. For example, loss of the amenity value of a site used for the education of future generations could result in a feeling of powerlessness and failure being engendered in the traditional custodians of the site. The potential for this arises because of the direct personal responsibility Aboriginal people have for looking after their country.

The Panel is aware of cases in the NT where traditional owners have rejected development proposals because of their traditional beliefs about what lies beneath the ground. Aboriginal people consider that the rocks and minerals beneath the ground are an integral part of the observable features of sacred sites on the surface. The Panel notes that there is no basis under existing site protection legislation in the NT for Aboriginal custodians to prevent work on an underground rock formation, even if this is based on traditional Aboriginal beliefs, as long as the works do not affect any feature of the surface landscape. The definition of a sacred site, while broad, appears to

preclude this. The Panel has sought the views of land councils and the Aboriginal Areas Protection Authority on this issue.

It is the Panel's view that the laws protecting Aboriginal cultural heritage should be better integrated with legislation protecting the environment and regulating the petroleum industry.

Degradation of ecosystems central to traditional cultural practices

The Panel's preliminary view is that there should be a higher threshold test applied for the protection of natural ecosystems that have a strong cultural significance in addition to their ecological significance. The Panel notes that the current separate regulatory frameworks and departmental accountabilities for management of water quantity (flow allocation) and quality make it difficult to achieve this objective.

Chapter 12 Social impacts

Recent developments in the Australian onshore unconventional gas industry have created some adverse social consequences and have heightened concerns in some parts of the community about the development of the industry. The result has been a loss of trust by the broader public in the onshore unconventional gas industry. Because the footprint of a developed unconventional onshore shale gas industry in the NT is unknown, and because no two communities are the same and will respond to the risks and benefits associated with any such development in differing ways, the Inquiry went through a public tender process and commissioned Coffey Services Australia Pty Ltd (**Coffey**) to develop and implement a social impact assessment framework for a potential onshore unconventional shale gas industry in the NT. Coffey will apply this framework to the communities in and around the Beetaloo Sub-basin with the aim of understanding what the likely social impacts of any development of an onshore unconventional shale gas industry might be and whether and to what extent these impacts can be acceptably mitigated.

Chapter 13 Economic impacts

The potential economic benefits that might flow from the development of an unconventional onshore shale gas industry in the NT, in terms of jobs and additional revenue, must be considered against the potential adverse consequences of any such development. Among other things, there are concerns around the equitable distribution of royalties, the long-term sustainability of any jobs and growth created by the industry (the 'boom and bust' cycle of development) and the impact of the industry on existing industries such as tourism, agriculture, horticulture and pastoralism. During the consultations, the public wanted to know what, if any, were the real and enduring financial benefits to everyday Territorians of this industry if it was allowed to proceed. To answer these questions, the Inquiry went through a public tender process and commissioned economic consultants ACIL Allen Consulting Pty Ltd to provide realistic modelling on the matters set out in the scope of works.

Chapter 14 Regulatory reform

The design and implementation of a robust regulatory framework is the principal way in which the NT Government can facilitate the development of any onshore unconventional shale gas industry in a manner consistent with the principles of ecologically sustainable development (**ESD**) and in conformity with community expectations. Submissions to the Panel have indicated that the current system of governance for onshore unconventional gas development is deficient and needs to be strengthened to ensure these goals are met. The Panel agrees.

Operationalising the precautionary principle

The precautionary principle requires that where there is scientific uncertainty and the threat of serious or irreversible environmental harm, measures must be taken to avoid the threat of environmental harm. The Panel will be using the precautionary principle to assess each of the risks it has identified. Where appropriate, the Panel will recommend measures to ensure that environmental harm is avoided, including, for example, the use of 'no go zones' or 'restricted activity zones'.

No go zones

Most national parks, reserves and areas of high conservation value are currently not 'no go zones', which means those areas can be the subject of an application for a petroleum exploration permit. The Panel heard that, in addition to these areas, other areas should be included as 'no go zones', including agricultural land, sacred sites, cultural and tourism icons, towns and residential areas, and significant groundwater and surface water resources. The Panel will consider which of these areas should be declared 'no go zones' by taking into account the risk that the onshore shale gas industry may have on those areas.

Rehabilitation bonds

The long-term integrity of abandoned wells is a major issue for the community. Stakeholders were concerned about who had responsibility for the ongoing maintenance of abandoned wells and where responsibility would lie for maintenance and remediation in the event that a well degraded over time. The Panel was concerned about the transparency and methodology used to calculate rehabilitation bonds. The Panel will consider options to mitigate potential legacy issues associated with abandoned wells.

Minimum standards

The current regulatory framework in the Northern Territory is objective based, which means that gas companies must identify and achieve certain environmental outcomes for each activity that is proposed. While this is generally regarded as leading practice regulation because it encourages innovation, flexibility and best practice, the Panel will consider whether or not the regulatory framework should include some prescriptive requirements (for example, minimum well pad spacings or minimum well casing standards) to ensure minimum environmental standards are attained.

Regulator

The Panel noted the community's lack of confidence in the current regulator. There was a perception that the Department of Primary Industry and Resources is not independent from the industry, is not adequately resourced, and has a problematic record in relation to compliance and enforcement. The Panel will consider options to improve the structure, powers and resourcing of the regulator.

Access to justice

To improve decision-making and to maintain accountability and integrity in any developed onshore unconventional shale gas industry, review and appeal processes must exist to enable those directly and indirectly affected by a decision to allow this development to challenge that decision (for example, the granting of an exploration permit or the approval to drill for or extract shale gas). The Panel will consider options to ensure that those affected by a decision have appropriate access to justice.

Land access

The development of an unconventional shale gas industry in the NT has the potential to cause tension between those with rights and interests in the surface of the land, such as pastoralists and traditional owners, and those with rights to enter, explore for and extract gas from underneath the same land, that is, gas companies and operators. The Panel's preliminary assessment is that the land access regime needs to be improved, particularly with regard to pastoral leases. **Figure 3** below shows that most of the areas that are prospective for unconventional shale gas are on areas subject to native title rights and interests and pastoral leases.

Chapter 15 Future work of the Inquiry

The following additional activities are planned between now and the release of the draft Final Report.

Future interstate visits

A site visit to Queensland to visit CSG operations in that state (Chinchilla, Roma and Darling Downs) and to consult with the Queensland Gasfields Commission is planned for shortly after the release of the Interim Report. In addition, the Panel intends to travel to Canberra for briefings on climate change, energy security and the Australian Government Bioregional Assessment Program.

Visit to pastoral leases

The Panel will visit several pastoral leases, including those in and around the Beetaloo Sub-basin.

Consultation with Alberta Energy Regulator

The Chair, the Deputy Chair and other relevant Panel members will consult by telephone with the Alberta Energy Regulator in Canada. The purpose of this conference is to ascertain the regulatory framework within which the onshore unconventional gas industry operates in that province and to determine if there are measures from that jurisdiction that can be appropriately adapted and applied in the NT.

Next steps

As indicated in the Issues Paper, pursuant to the release of the Interim Report, a second round of public hearings and community consultations will take place. The public hearing schedule is outlined below:

Date	Location
31 July - 2 August 2017	Darwin
3 - 4 August 2017	Alice Springs
8 - 9 August 2017	Katherine
10 August 2017	Tennant Creek

Community consultations in remote communities will be held between 21 August and 1 September 2017.

It is anticipated that a draft Final Report will be published towards the end of the year and that the Final Report will be handed down by the end of 2017.

Further information

Further information about the Inquiry, including upcoming community visits, is available on the Inquiry's website: www.frackinginquiry.nt.gov.au

The Inquiry's contact information is as follows:

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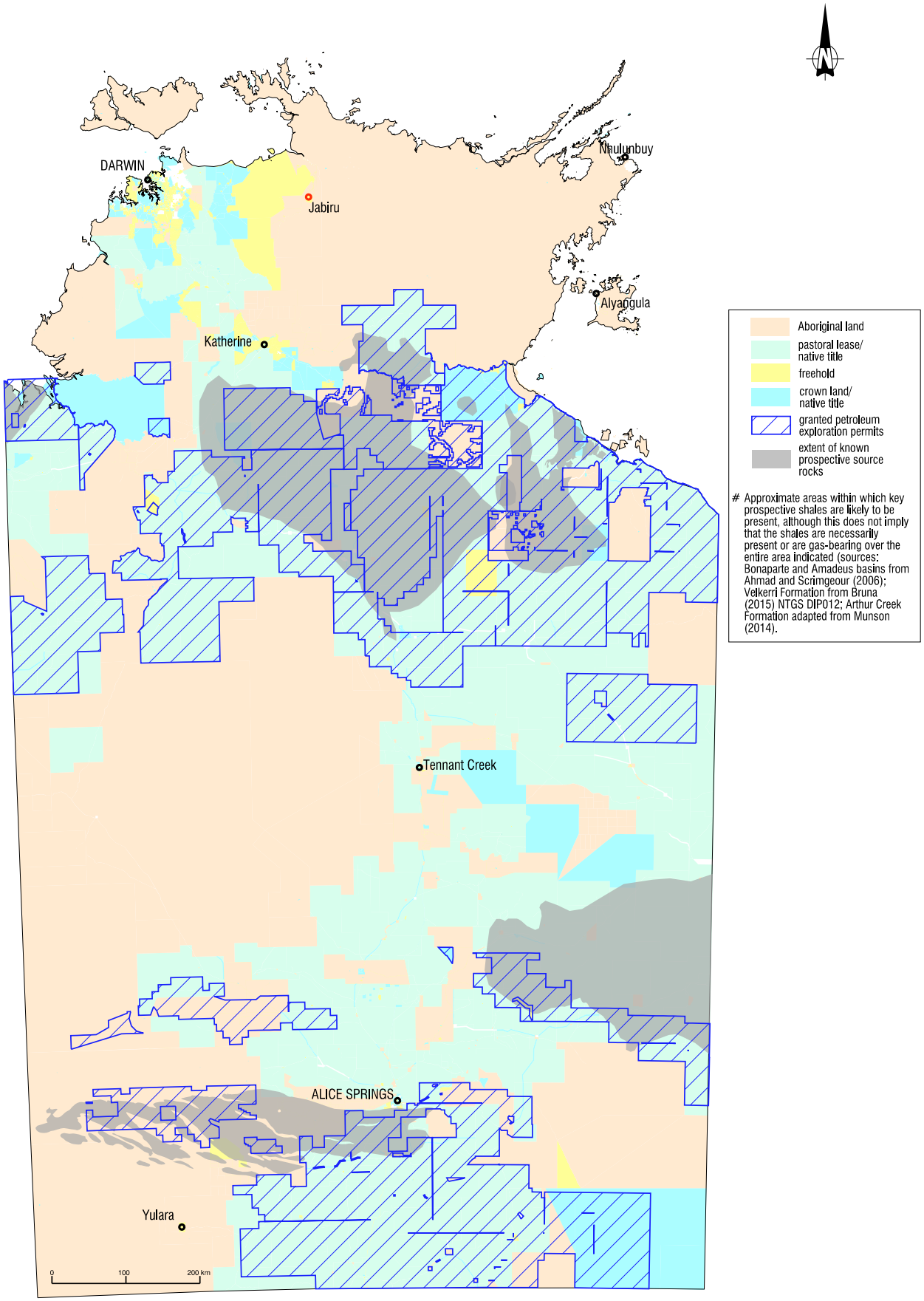
Figure 3: Pastoral leases and granted exploration permits. Source: Department of Infrastructure, Planning and Logistics.



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SCIENTIFIC INQUIRY INTO
HYDRAULIC FRACTURING
IN THE NORTHERN TERRITORY

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