NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

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File Ref: TRIM No.
Your Ref:

The Hon Justice Rachel Pepper
Chair
Hydraulic Fracturing Taskforce
GPO Box 4396
DARWIN NT 0801

Dear Justice Pepper

RE: DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES SUBMISSION TO THE SCIENTIFIC INQUIRY INTO HYDRAULIC FRACTURING IN THE NORTHERN TERRITORY

The Department of Environment and Natural Resources (DENR) appreciates the opportunity to provide a submission to the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, in response to the Background and Issues Paper released in February 2017 (Issues Paper).

You have also expressed an interest in water allocations in Katherine in response to submissions and concerns regarding the allocation and management of the water resources in the region. Detail on the sustainable yield, water allocations and their management are provided as an attachment for your consideration.

Should you need further clarification or information on this submission please contact [redacted].

Yours sincerely

JOANNE TOWNSEND
A/Chief Executive Officer

17 May 2017

DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

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

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NORTHERN TERRITORY GOVERNMENT

Contents

1 Introduction

The Department of Environment and Natural Resources (DENR) is responsible for the provision of advice and support for sustainable development of the Territory's natural resources and conservation of its unique native flora and fauna through the administration of a number of Acts. The Department has focused its comments on matters relating to water resources, biodiversity and the Northern Territory Government's environmental reform agenda.

2 Water Resources in the Northern Territory

The Northern Territory covers approximately 1.35 million square kilometres extending 1600 km from north to south, and 900 km from east to west. The climate ranges from arid or semi-arid in its southern and central regions, while in the north its climate is tropical and subject to monsoonal influence. The rainfall across the Northern Territory is distributed in a gradational pattern from north to south with approximately 2000 mm annually on the Tiwi Islands on the coast, to 150mm in the Simpson Desert. A large diversity of environments exist with tropical savannah and monsoon rainforests across the Top End, to the sand dune landscapes of the Simpson Desert in the south-east.

A seasonal monsoonal cycle profoundly influences the Northern Territory environment and lifestyle. During the hot wet season months between December and April, Top End aquifers recharge and native flora and fauna flourish. Whilst monsoonal rain brings the threat of flood to rivers across the whole of the Territory, it also presents the opportunity for billabongs and waterholes to refresh. While many river systems in the Northern Territory are ephemeral, the perennial systems are maintained by discharging groundwater systems. Towards the end of the dry season, groundwater systems deplete, awaiting replenishment from the next monsoonal cycle.

With the exception of the Darwin and Palmerston region and Katherine, the Northern Territory is reliant on groundwater. Groundwater accounts for 90% of all of the Northern Territory water supplies, a much higher proportion than any other jurisdiction in Australia. 78 towns and communities across the NT are serviced with reticulated water supply – most are solely reliant on groundwater, while others use surface water and groundwater conjunctively. Approximately half of the Northern Territory's land area is under pastoral lease, and with approximately 1.8 million head of cattle, the industry represents a significant user of groundwater resources.

The Northern Territory is featured by a mosaic of ancient rock types and weathered rock aquifer systems. Most are limited in extent. However, the large groundwater basins including the Daly, Georgina and Wiso Basins in the central region, the Amadeus Basin to the south and west of Alice Springs and the Great Artesian Basin in the south-east corner are prominent over a large part of the Northern Territory. These basins have large storage capacities. However, only the Daly Basin is seasonally recharged by monsoonal rainfall. For the other (arid zone) basins, recharge in episodic and dependent on infrequent large rainfall events.

The Daly and Roper Rivers are recognised as two key freshwater systems in the Northern Territory representing important and accessible tourist and recreational fishing destinations. These rivers are perennial and are groundwater fed from the Daly, Georgina and Wiso Basins. Other large perennial surface water systems including the Goyder, Koolatong, Cato and Liverpool Rivers in Arnhem Land represent important sources of food and have cultural significance to Aboriginal people.

The Northern Territory currently supports a diverse range of industries from aquaculture, agriculture, resources and energy and tourism. All have a reliance on water resources. Many high yielding aquifers within the Northern Territory are close to full allocation against the contingent allocations prescribed in the Northern Territory Water Allocation Planning Framework. However, actual usage is still significantly less than the consumptive allocations of the resource.

Groundwater and surface water resources in a number of specific areas such as Alice Springs, Darwin Rural, Douglas Daly, Katherine and Mataranka are recognised as being under pressure from resource development. Effective water resource planning in these areas is essential to achieve sustainable water

management and effective and equitable water allocation.

Management of water is vested in the crown and the Northern Territory Government is responsible for ensuring water resources are sustainably managed. The *Northern Territory Water Act 1992* is the primary legislation which provides for the investigation, allocation, use, control, protection, management and administration of water resources. DENR manages the day to day operational aspects of the Act including conducting water resource investigations, monitoring compliance, preparing water allocation plans and administrating licences and permits. The Act is overdue for review and the need to modernise the Act to meet contemporary and projected water resource management needs has been raised by industry advocates and environmental groups alike.

In 2006, the Territory Government agreed to the provisions and objectives of the National Water Initiative (NWI). The NWI establishes a national policy approach to water resource management, setting key principles by which Australia manages, measures, plans for, prices, and trades water.

2.1 Water Allocation Planning Framework

The Northern Territory Water Allocation Planning Framework (at Attachment A) applies to water resources within and outside water allocation plan areas. The Framework, sets out how water is to be allocated between consumptive and non-consumptive beneficial uses and is based on the principle that water should be allocated to non-consumptive beneficial uses (e.g. environmental and cultural values) as a matter of priority, and once this allocation is set, remaining water can be allocated to consumptive beneficial uses (e.g. agriculture, public water supply).

The Framework establishes contingent allocations for non-consumptive and consumptive uses where scientific research on environmental and/or non-consumptive cultural water requirements is not available, while allowing for alternative allocations to be set where there is scientific research that can be used as a basis for that allocation. The Daly River is the only river in the Northern Territory that has this directly related scientific research which quantifies minimum dry season river flow rates in cumecs at key sites on the river that are needed to maintain water dependent ecosystems identified through a suite of research projects funded by the then Environmental Flows Initiative. This means that these nominated environmental flow requirements are always prioritised to ensure the water flows needed to protect and maintain water dependent species and ecosystems.

Members of the Expert Scientific Panel into Hydraulic Fracturing in the Northern Territory have expressed interest in water allocations in the Katherine region. Attachment B provides an overview of the application of the Northern Territory Water Allocation Planning Framework in the water resources in the region, including the Daly River Environmental Flow requirements[1], as well as the allocations by resource.

2.2 Water Control Districts and Water Allocation Plans

Under the Water Act, the Minister can declare Water Control Districts (WCDs). Water Allocation Plans (WAPs) can then be declared within the Water Control District. WAP's are developed in consultation with community and technical groups and outline how a resource (e.g. a river and/or an aquifer) is to be managed. They set out the objectives, rules and strategies, and monitoring and performance indicators for managing the water resource to maximise environmental, economic, social and cultural outcomes. WAPs set limits to the availability of water assigned to each beneficial use, and define rules for managing licences and water trading.

[1] Erskine WD, Jolly P and Smith I, July (2004), Environmental Water Requirements of the Daly River: Revision of Recommendations of Erskine et al. (2003), based on Daly Regional Water Allocation Workshop held in Darwin on 5 May 2004, Report 30/2004D, Department of Infrastructure, Planning and Environment, Natural Resources Division, Palmerston NT.

WCDs and WAP areas reflect the regions where the NTG has identified existing or future pressure on water resources and, following risk assessment, determined that management plans are required.

Maps of WCDs and WAPs areas in the Northern Territory are outlined at: https://nt.gov.au/environment/water/water-control-districts. Information relating to each of the Water Allocation Plans is available on the DENR webpage: https://denr.nt.gov.au/land-resource-management/water-resources/water-allocation-plans.

2.3 Water Resources and unconventional gas exploration and production

There has been ongoing discussion about the impact of hydraulic fracturing on water resources, both the volume of water used by mining proponents and the risk of contamination of water from induced connectivity, surface spills or flow back of chemicals into aquifers. In addition there are potential risks regarding contamination of groundwater resulting from the poor design and operation of wells and subsequent deterioration and failure of those wells decommissioned over time.

2.4 Water Assessment

To enable effective planning for water resource development and environmental protection, the Controller of Water Resources is responsible for undertaking a continuous program for the assessment of water under the Water Act.

The Northern Territory is underlain by numerous aquifers. The groundwater systems of the Top End vary from those in the arid central and southern regions. The monsoonal climate ensures that most Top End aquifers are recharged every year in the wet season, resulting in groundwater of very low salinity. In the southern two thirds of the Territory (south of Larrimah), known as the semi-arid and arid zones, surface water resources are virtually non-existent and groundwater in this area receives minimal recharge. The definition of sustainable yield changes in the arid zone to allow the effective extraction of the resource over a defined period.

The lack of recharge also means that groundwater in the arid zone is commonly of poor quality, brackish to saline, with high concentrations of ions such as fluoride and nitrate.

As part of its ongoing water assessment program, the Water Resources Division of DENR has undertaken various assessments of the Territory's water resources across all areas of the Northern Territory. This information is publicly available and varies from broad scale aquifer mapping to detailed water assessments and the development of integrated ground and surface models. As identified in the issues paper, the Territory's known most prospective shale gas resources are confined to the following areas - the Beetaloo Sub-basin of the MacArthur Basin, the Arthur Creek Formation in the Southern Georgina Basin and the Horn Valley Siltstone in the Amadeus Basin.

The Water Resources Division has collated the available information and reports for the Daly, Wiso and Georgina Basins which overlie the Beetaloo Sub-basin and surrounds. This information includes water resource assessments, modelling reports, geophysical reports and bore completion reports. It has been undertaken to a depth of 400 meters given the development focus to date on agriculture, horticulture and urban and community water supply and in consideration that extraction beyond this is not considered economic for those purposes. This information will be published in June 2017 and available at https://denr.nt.gov.au/land-resource-management/water-resources/water-publications

While there is good availability of data and developed models in water control districts and plan areas, and in more populated areas of the Northern Territory, this information becomes more limited outside of those areas. Across Northern Territory Government agencies there is relevant data, as well as data held by current and prospective proponents, which would significantly add to, and extend, the information available.

2.5 Water Availability

The volume of water required for hydraulic fracturing varies depending on the design of the well (vertical or horizontal) and the number of stages, depending on the fracturing process. Estimates of water demand are in the order of 2 to 2.5 mega litres per stage, with a vertical exploration well comprising 1 or 2 stages and longer horizontal development wells comprising around 10 stages (resulting in estimated water use of between 2.5 and 25 mega litres) which would be predominantly drawn from groundwater.

There has been public commentary about the availability of groundwater to meet these activities, particularly in areas where there is high level of competition for water resources from other beneficial users and use. Preserving the security of existing licenced water users when assessing and determining water allocations is a factor in determining if a licence should be granted by the Controller of Water Resources; and an important principle to be maintained in water allocations and water planning generally as a means to ensure community and business certainty. This should provide some assurance to existing licenced water users and water users in water allocation plan areas that their licence entitlements are prioritised in any future licence decisions. The limitation on this assurance are extractions outside of a Water Control District and drawing water from bores equipped to produce less than 15 L per second.

Map 1 – *NT Water Control Districts, Water Allocation Areas, Prospective Source Rocks and Beetaloo Sub Basin* (Attachment C) shows the areas of high prospectively for unconventional gas reserves across the Northern Territory[2] against water allocation plan areas. Water allocation plan areas are areas of high competition for, and use of, the available consumptive pool, including its licencing and use for agriculture, industry, horticulture, tourism and other business enterprises as well as public water supply.

Water allocation plan areas are currently, or will be in the next 12 months, subject to a water allocation plan under the *Water Act*. Given the range of high value existing use for the available consumptive pool in these plan areas, access for unconventional gas exploration could not be granted without demonstrable evidence of the availability of water and certainty that extraction could maintain both the quality and quantity of water for non-consumptive and consumptive use.

In reference to Map 1, it is notable that area of greatest interest for unconventional gas exploration in the Top End, the Beetaloo Sub-basin, lies to the south-west of the Katherine Tindall Water Allocation Plan area.

Limestone aquifers of the Cambrian aged Wiso, Daly and Georgina Basins overlie much of the Beetaloo Sub-basin. An exception is an area in the north of the Sub-basin, from Bloodwood Downs to Avago Stations where the limestone lies above the watertable and does not form an aquifer. Unconventional gas wells in this area will not intersect any significant groundwater resource. Furthermore, the vertical distance between the base of the limestone aquifers and the potential gas producing zones is generally greater than 600 metres across the Sub-basin. The intervening formations include thick mudstones that do not transmit groundwater.

The proposed Tindall Mataranka-Daly Waters Water Allocation Plan area includes a small area of the northern Beetaloo Sub Basin. Limestone aquifers in this plan area are largely used for stock watering, and for horticulture in the vicinity of Mataranka.

With reference to the remaining areas of prospectively, the other area of overlap is the Amadeus Basin and a small part of the Alice Springs Water Allocation Plan area. A key consideration in assessing water impacts of unconventional gas in the Amadeus Basin would be impact on existing users and groundwater dependant ecosystems, proximity between unconventional gas activity and other water users and any evidence of connectivity between water resources in the area.

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[2] Map 1 has been developed using the mapping undertaken by the Northern Territory Geological Survey, Department of Primary Industry and Resources, December 2016, and mapping of Water Allocation Planning Areas and Water Control Districts, Department of Environment and Natural Resources, September 2016.

2.6 Water Allocations

Water planning is an important mechanism to assist Government and the community to determine water management and allocation decisions to meet productive, environmental and social objectives.

The principle reference for determining water resource allocations is the Northern Territory Water Allocation Planning Framework (see Attachment A). The Framework determines that setting water allocations for non-consumptive use (i.e. environment and cultural benefits) is the first priority, with allocations for consumptive use made subsequently within the remaining available water resource. It also determines that all available scientific research directly related to environmental and other public requirements will be applied in setting allocations.

The *Water Act* by virtue of Section 7 exempts mining and petroleum activities from licence and permit requirements prescribed in the Act. The management of water demand from mining and petroleum activities through water allocation planning, and licensing is an election commitment by the Northern Territory Government for implementation next year. While mining and petroleum activities have been included in the water allocation planning processes where they coexist, and there is information sharing on water requirements and water management between the Department of Primary Industries and Resources (DPIR) and DENR, there is limited public visibility on water allocations and use by the mining and petroleum industry compared to other water users.

The Northern Territory Government has committed to mining and petroleum industries being subject to the same licence and permit requirements as all other water users. This includes making water extraction licence applications available for public comment through the requirement to publish a Notice of Intention to make a Water Licence Decision, and making any reasons for the decision to grant or not to grant a licence public through a Statement of Decision by the Controller of Water Resources. The licence entitlement and source of water would also be published through the Licence Registry and on the Public Water Portal.

As part of assessing a licence request the preservation of the reliabilities of the entitlements of existing licence holders and the application of the Northern Territory Water Allocation Planning Framework, would apply.

As stated earlier, proponents whose activities fall outside of a water control district and who have a bore equipped to extract less than 15 L per second are already exempted from licence and permit requirements, by virtue of a declaration of exemptions. This exemption applies to all types of water use outside of the water control district and would continue to apply to mining and petroleum activities, unless the exemption was removed and/or the Act was amended.

The primary beneficial uses for groundwater extractions in the Northern Territory are for potable water supplies, stock and domestic bores, industrial purposes (including mining and petroleum activities) and agricultural use. With the exception of mining and petroleum use the groundwater resources which best meet these needs are referred to as fresh water with a salinity of less than 1,000 milligrams per litre as Total Dissolved Solids (TDS), which are generally located less than 500 metres deep. Where possible, water used for hydraulic fracturing stimulation should be sourced from brackish to saline (>3,000 milligrams per litre TDS) groundwater systems usually found at levels generally at depths below 500 metres, to avoid competition with demand for potable domestic and agriculture use, and the water used efficiently through the adoption of good industry practices for recovery and reuse of flow back water.

2.7 Well integrity and risk of contamination of aquifers

There has been public comment through this Inquiry and other reviews around the protection of aquifer systems from contamination from the deterioration and failure of decommissioned wells over time.

Key concerns for the protection of groundwater resources are ensuring that:

- exploration and well drilling and fracturing proposals clearly identify the presence of aquifers;
- well construction techniques protect the integrity of the aquifer;
- hydraulic fracturing does not result in damage to the aquifer;
- well abandonment and rehabilitation works provide long term protection; and
- Pre and post activity monitoring considers the hydrogeology of an aquifer system and is designed to identify emerging evidence of any changes (ie very early warning).

In order to address these concerns, it is critical that an adequate hydrogeological investigation is undertaken to inform minimum construction requirements and risks; and to establish baseline information as the basis for the design of any subsequent monitoring program.

The monitoring program must consider the identification of the likely down-gradient areas within an aquifer and cover a sufficient time period and intensity of sampling, such that if contamination was to occur, any contaminant plume would be intercepted by a sampling regime. The baseline monitoring information should also include assessment of surrounding areas to enable comparisons to be drawn.

The integrity of the well must be guaranteed for the long term which raises the issue about who bears the responsibility for a deteriorating well which has been abandoned. Consideration of proportional security measures through provision of bonds or guarantees would address any potential legacy issues.

It should be noted that the current construction standard for petroleum wells in the Northern Territory exceeds construction standards for water bores which are set in accordance with the *Australian Minimum Bore Construction Requirements*.

2.8 Risk of ground and surface water contamination from flowback and produced water and spills.

An environmental challenge in accessing shale and tight sand gas is the relatively poor quality flowback water from hydraulic fracturing stimulation and produced water, where the produced water from the target formations is typically of high salinity incorporating naturally occurring radioactive materials, dispersed oil and soluble organic compounds.

Management actions to protect ground and surface water (as well as other environmental assets) from contamination would typically include secure temporary storage on site and considerations for reinjection, treatment and/or removal from site. Under current regulatory arrangements DPIR has on-site responsibility for regulating this aspect of water management including protection of the environment from hydraulic fracturing stimulation activities and production. DENR carries off-site regulatory responsibility for this aspect of water and associated waste management.

Overall, the volume of flowback water resulting from the hydraulic fracturing process is comparatively small compared to other and its regulation off site would be managed using the *Water Act* if environmentally acceptable off site discharge to a waterway was proposed and/or the *Waste Management and Pollution Control Act* for the off-site transport, storage, treatment and disposal of wastes listed under that Act.

Under the Government's environmental reform commitments, as articulated in its *Healthy Environment, Strong Economy* policy, the current demarcation between the environmental regulation of activities occurring on and off-site will be removed. This is expected to deliver improvements in the environmental management of petroleum activities.

3 Biodiversity

Gas and petroleum extraction including hydraulic fracturing activities may potentially have an adverse impact on the Territory's aquatic systems and biodiversity, including groundwater dependent ecosystems. The impact of chemical spills, excessive land clearing and fragmentation of native vegetation, contamination of groundwater and indirect impacts associated with land surface disturbance (such as spread of weeds and promotion of deleterious fire regimes) are all risks associated the development of gas wells and particularly larger gas fields with many well heads.

While surficial biodiversity impacts associated with the development of an individual well are likely to be minor due to the small area of disturbance, the cumulative impacts resulting from the development of potentially a large number of wells over a gas field need to comprehensively assessed, and adequately monitored. DENR recognises that the risk of cumulative impacts of vegetation clearing and habitat fragmentation is not an issue that is isolated to shale gas extraction and hydraulic fracturing. The intention of the Governments current environmental regulatory reform program is to look at a broad range of activities and issues to be captured under the environmental assessment/approval process which would include cumulative impacts of vegetation clearing and habitat fragmentation.

Ensuring that onsite environmental risks are minimised, and that safeguards to ensure that individual wells are not established in areas with locally high value for significant biota or ecosystems, can be managed through a rigorous Environment Management Plan (EMP) process, particularly where EMPs are submitted to the Northern Territory Environment Protection Authority (NT EPA) as Notices of Intent (NOI). In determining whether further environmental impact assessment is required NTEPA seeks comment from DENR, which provides its comments on all aspects of the agency's responsibility, including weed management, land clearing, soil conservation, native flora and fauna and water resources.

Subterranean biodiversity including stygofauna is extremely poorly known within the Northern Territory. It may be reasonable to assume that if construction of wells and hydraulic fracturing is managed so as to avoid impacts on aquifers then risks to subterranean biota are also minimised, but this assumption warrants further testing.

4 Environmental Reform Commitments

The Northern Territory Government has committed to a comprehensive environmental regulatory reform program. The program is aimed at removing duplication and inconsistency, streamlining processes and improving community confidence in the environmental management system by transferring all environment and enforcement activities, including those associated with petroleum activities, to DENR and the NT EPA.

The regulation of all water extractions, use and storage and all wastewater discharges by mining and petroleum activities are currently regulated by DPIR under the *Petroleum* Act and *Mining Management Act*.

Through the program DENR, in conjunction with other relevant agencies including DPIR, will undertake a comprehensive review of the capacity of the existing regulatory system to appropriately manage and minimise the impacts of waste water discharges and other waste and pollution sources on water resources and to improve the system. Removal of the demarcation between on and off petroleum lease waste, pollution and waste water management, will enable more holistic environmental management and provide improved environmental outcomes.

Amendments to the *Water Act* to capture any surface water storage works, surface water extractions, groundwater extractions and water bore drilling associated with mining and petroleum activities will bring these activities in line with all other beneficial users.

Separately the transparency of EMPs is being increased by making these public and improving mechanisms for the enforcement of breaches of environmental obligations.

Following the finalisation of previous review/reports undertaken by successive Northern Territory Governments since 2011 - including the Hawke Reports I and II and the Hunter Reports I and II - the Petroleum (Environment) Regulations and the Schedule of Onshore Petroleum Exploration and Production Requirement Guidelines were developed. This new legislation was the first step in improving the regulatory framework for hydraulic fracturing.

Future design of the regulatory framework for hydraulic fracturing will be informed by the outcome and recommendations of this Inquiry.

NORTHERN TERRITORY WATER ALLOCATION PLANNING FRAMEWORK

All available scientific research directly related to environmental and other public benefit requirements for the water resource will be applied in setting water allocations for non-consumptive use as the first priority, with allocations for consumptive use made subsequently within the remaining available water resource.

In the absence of directly related research, contingent allocations are made for environmental and other public benefit water provisions and consumptive use. These are explained below.

Top End (northern one third of the Northern Territory)

Rivers

At least 80 per cent of flow at any time in any part of a river is allocated as water for environmental and other public benefit water provision, and extraction for consumptive uses will not exceed the threshold level equivalent to 20 per cent of flow at any time in any part of a river.

In the event that current and/ or projected consumptive use exceeds the 20 per cent threshold level, new surface water Licences will not be granted unless supported by directly related scientific research into environmental other public benefit requirements.

Aquifers

At least 80 per cent of annual recharge is allocated as water for environmental and other public benefit water provision, and extraction for consumptive uses will not exceed the threshold level equivalent to 20 per cent of annual recharge.

In the event that current and/ or projected consumptive use exceeds the 20 per cent threshold level, new groundwater Licences will not be granted unless supported by either directly related scientific research into groundwater dependent ecosystem/ cultural requirements, or in the absence of such research, hydrological modelling confirming that total groundwater discharge will not be reduced by more than 20 per cent.

Arid Zone (southern two thirds of the Northern Territory)

Rivers

At least 95 per cent of flow at any time in any part of a river is allocated as environmental and other public benefit water provision, and extraction for consumptive uses will not exceed the threshold level equivalent to five per cent of flow at any time in any part of a river.

In the event that current and/ or projected consumptive use exceeds the threshold levels of five per cent for river flow, new surface water Licences will not be granted unless supported by directly related scientific research into environmental other public benefit requirements.

Aquifers

There will be no deleterious change in groundwater discharges to dependent ecosystems, and total extraction over a period of at least 100 years will not exceed 80 per cent of the total aquifer storage at start of extraction.

In the event that current and/ or projected consumptive use exceeds the threshold levels of 80 per cent of the consumptive pool for aquifers, or groundwater discharges to groundwater dependent ecosystems are impacted, new groundwater Licences will not be granted unless supported by directly related scientific research into groundwater dependent ecosystem/cultural requirements.

Water Allocations in the Katherine Region.

There are three aquifers in the Katherine Region for which Water Allocation Plans are required. A map of the plan areas is included (Figure 1). The Water Allocation Plan for the Tindall Limestone Aquifer, Katherine has been declared (refer denr.nt.gov.au/water allocation plans). The Water Allocation Plans for the Oolloo Dolostone Aquifer and the Tindall Limestone Aquifer, Mataranka to Daly Waters are both in development. Water Advisory Committees have been established for all three of these plan areas.

Dry season river flows of the Daly River and its tributaries are dependent on the groundwater discharge from the Tindall Limestone Aquifer and the Oolloo Dolostone Aquifer.

Dry season river flows of the Roper River are dependent on groundwater discharge from the Tindall Limestone Aquifer and other smaller scale aquifers that contribute groundwater flows to tributaries within the catchment.

These aquifers support environmental, cultural and spiritual values as well as a variety of industries including cattle production, horticulture, forestry, Indigenous enterprises, fishing and tourism. The water sources are also used for public water supply and stock and domestic use.

Water availability for these resources varies from year to year because the Sustainable Yield varies from year to year. Water Extraction Licences are issued with Security Levels and inter-annual variability in the Sustainable Yield of the resources is managed through annual announced allocations which set annual extraction limits for every water extraction licence to ensure that environmental water requirements are met.

The table below shows the volumes of the Consumptive Pool for each of the planning areas, and the volume of water that has been allocated.

Aquifer		Consumptive Pool (ML/year)	Maximum licenced entitlements	Estimated Stock and Domestic and other small volume groundwater uses
Tindall Limestone Aquifer, Katherine		38,391	35,377	1,300
Oolloo Dolostone Aquifer		89,200	89,436	1,406
Tindall Limestone Aquifer, Mataranka to Daly Waters	Mataranka Zone	25,940	25,400	540
	Larrimah to Daly Waters Zone	40,000	225	Not estimated

Water Allocation Rules

The following rules have been applied in allocating surface water and groundwater between consumptive and non-consumptive beneficial uses within each plan area. These rules are also applied during each annual announced allocation. A map of the reporting locations is included (Figure 2).

Tindall Limestone Aquifer, Katherine

Under the Water Allocation Plan for the Tindall Limestone Aquifer, Katherine, the proportion of water preserved for the environment varies from year to year, depending on whether the year is very dry, dry or normal to wet:

a) During very dry years, 87% of the groundwater discharging into the Katherine River is reserved for environmental and other river-based public benefit outcomes whilst 13% is available for extraction. Very dry years are years for which modelling predicts that the flow in the Katherine River at Low Level (G8140222) on November 1 will be less than or equal to 0.6 m^3/sec.

b) During dry years, 80% of the groundwater discharging into the Katherine River is reserved for environmental and other river-based public benefit outcomes, whilst 20% is available for extraction. Dry years are years for which modelling predicts that the flow in the Katherine River at Low Level (G8140222) on November 1 will be less than or equal to 1 m^3/sec.

c) During normal to wet years, 70% of the groundwater discharging into the Katherine River is reserved for environmental and other river-based public benefit outcomes whilst 30% is available for extraction. Normal to wet years are years for which modelling predicts that the flow in the Katherine River at Low Level (G8140222) on November 1 will be greater than 1 m^3/sec.

Oolloo Dolostone Aquifer

The environmental water requirements applied to all water allocation decisions in the Daly Catchment downstream of Wilden Station (G8140536) on the Katherine River set maximum limits of change in flow at three river monitoring sites along the Daly River in accordance with recommendations made by Erskine et al (2004). The combined effect of all groundwater and surface water extractions should not reduce natural flows in the Daly River:

(a) at Dorisvale Crossing gauge station G8140067 by
(i) >8% whenever natural flow is ≤6.2 cubic metres per second; or
(ii) >20% whenever natural flow is >6.2 cubic metres per second

(b) at Oolloo Crossing gauge station G8140038 by
(i) >8% whenever natural flow is ≤12 cubic metres per second; or
(ii) >20% whenever natural flow is >12 cubic metres per second

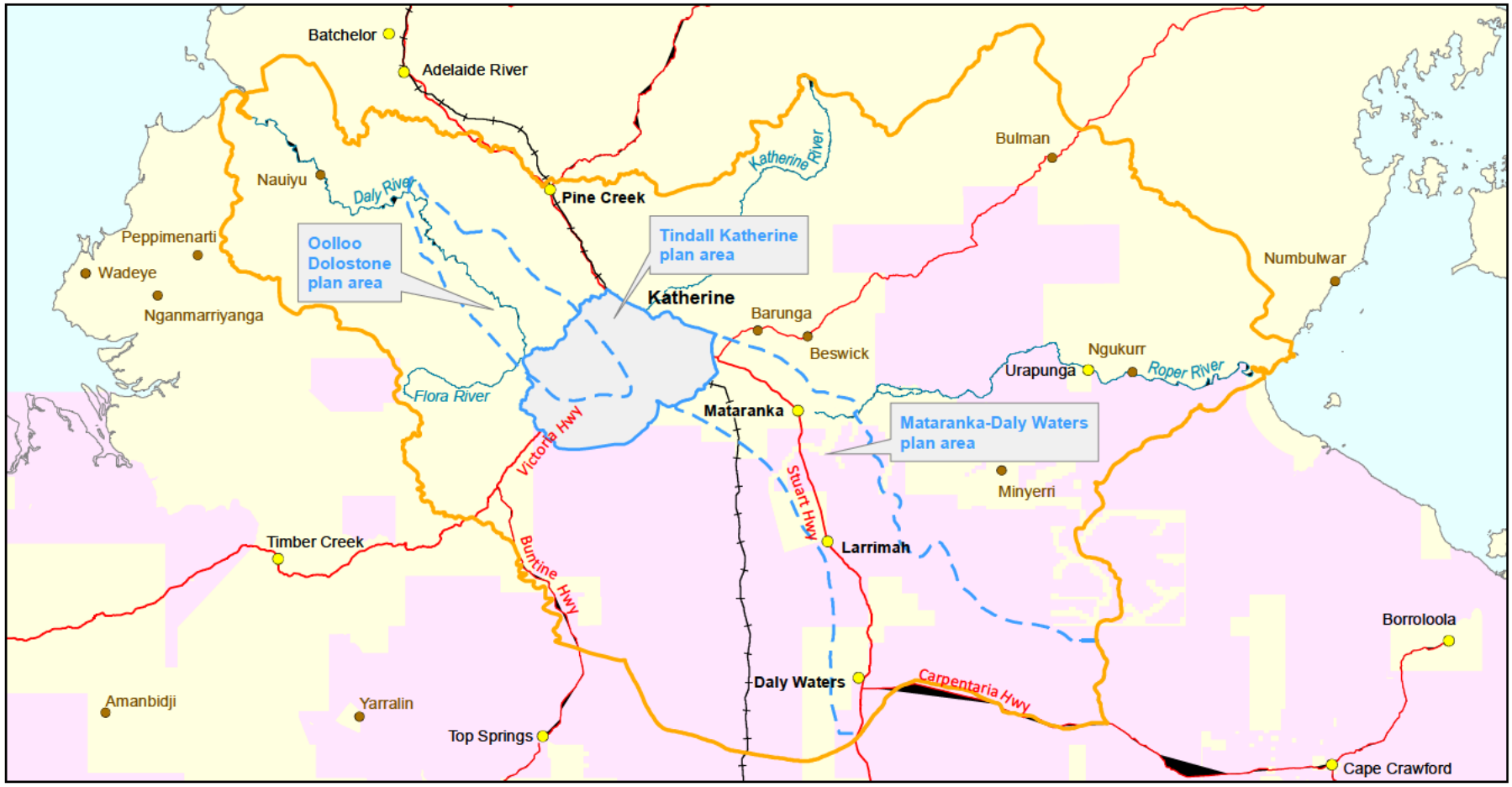
(c) at Mount Nancar gauge station G8140040 by
(i) >8% whenever natural flow is ≤12 cubic metres per second; or
(ii) >20% whenever natural flow is >12 cubic metres per second

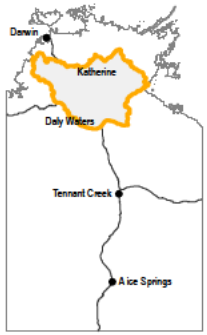
Tindall Limestone Aquifer, Mataranka to Daly Waters

In accordance with the contingent allocations specified by the NT Water Allocation Planning Framework, and in the absence of scientific information to set site specific environmental flow requirements, the Environmental Water Requirements applied to all water allocation decisions in the Roper River set maximum limits of change in flow as follow:

a) Not more than a 20% change in predicted flow at Bitter Springs (RN034230)
b) Not more than a 20% change in predicted flow at Rainbow Springs (RN035796)
c) Not more than a 20% change in predicted flow at Elsey National Park (G9030176)
d) Not more than a 20% change in predicted flow at Elsey Homestead (G9030013)
e) Not more than a 20% change in predicted flow at Red Rock (G9030250)

Water allocation decisions outside water allocation plan areas also take account of the contingent allocation rules set out by the NT Water Allocation Planning Framework.





km 0 20 40 60 km

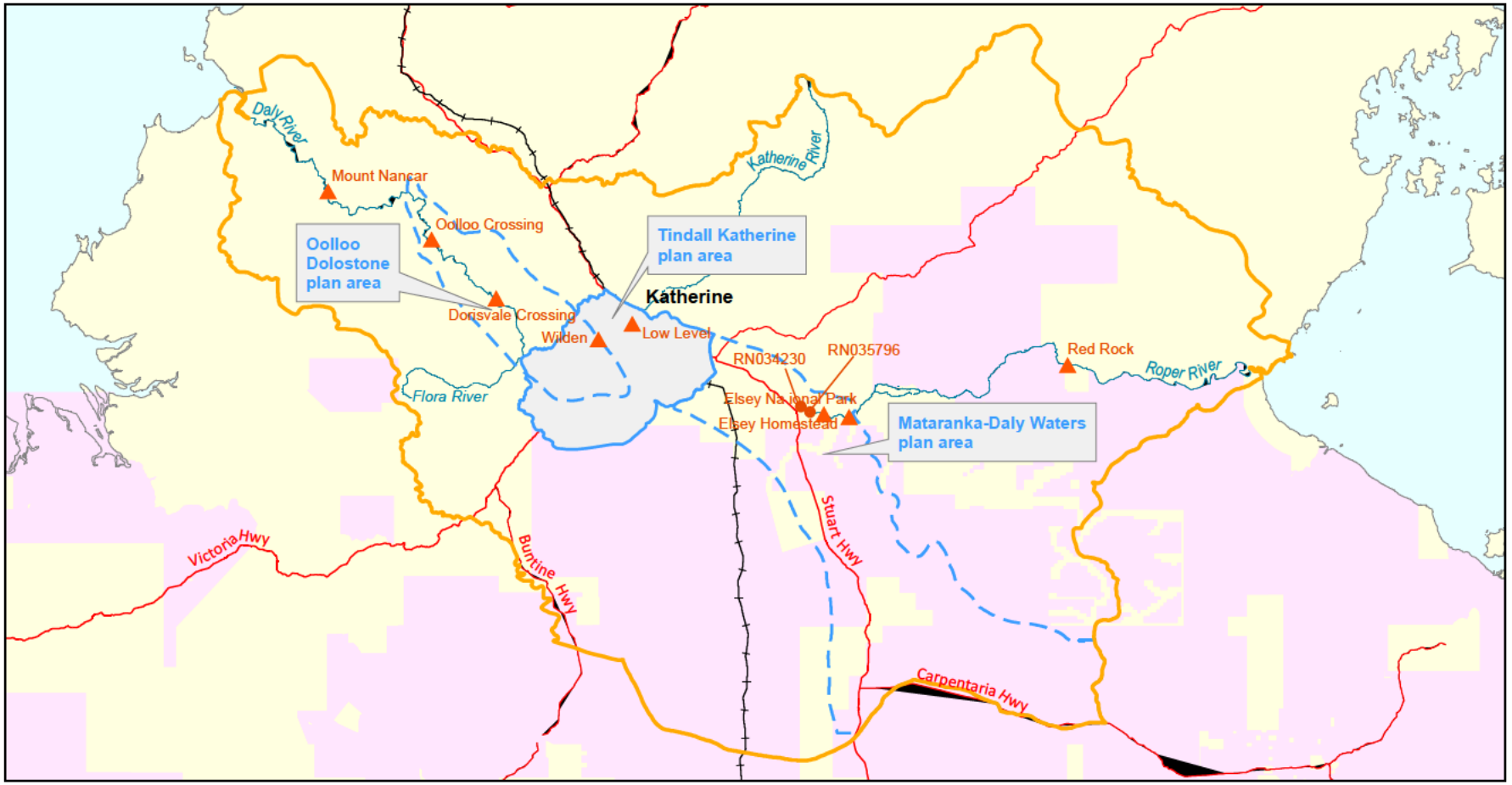
Daly-Roper Water Control District
Draft, Water Allocation Plan Area
Declared, Water Allocation Plan Area
Petroleum Exploration Permits - Granted

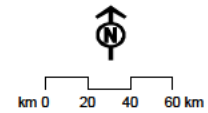
Data Source
WAPA boundaries: Water Resources Division
Department of Environment and Natural Resources (DENR)
Cadastre, Roads, Towns:
Department of Infrastructure, Planning and Logistics
Exploration areas: Department of Primary Industry and Resources
Rivers: © Commonwealth of Australia (BoM) 2014

Figure 1
Katherine Region
Water Allocation Planning Areas

Map created 10 May 2017
Department of Environment and Natural Resources

NORTHERN TERRITORY GOVERNMENT





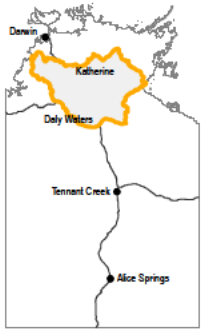


Figure 2
Katherine Region
Water Allocation Planning
Reporting Locations

Map created 10 May 2017
Department of Environment and Natural Resources

Data Source
WAPA boundaries: Water Resources Division
Department of Environment and Natural Resources (DENR)
Cadastre, Roads, Towns:
Department of Infrastructure, Planning and Logistics
Exploration areas: Department of Primary Industry and Resources
Rivers: © Commonwealth of Australia (BoM) 2014

Daly-Roper Water Control District
Draft, Water Allocation Plan Area
Declared, Water Allocation Plan Area
Petroleum Explora ion Permits - Granted

NORTHERN TERRITORY GOVERNMENT

References

Erskine WD, Jolly P and Smith I, July (2004), Environmental Water Requirements of the Daly River: Revision of Recommendations of Erskine et al. (2003), based on Daly Regional Water Allocation Workshop held in Darwin on 5 May 2004, Report 30/2004D, Department of Infrastructure, Planning and Environment, Natural Resources Division, Palmerston NT.

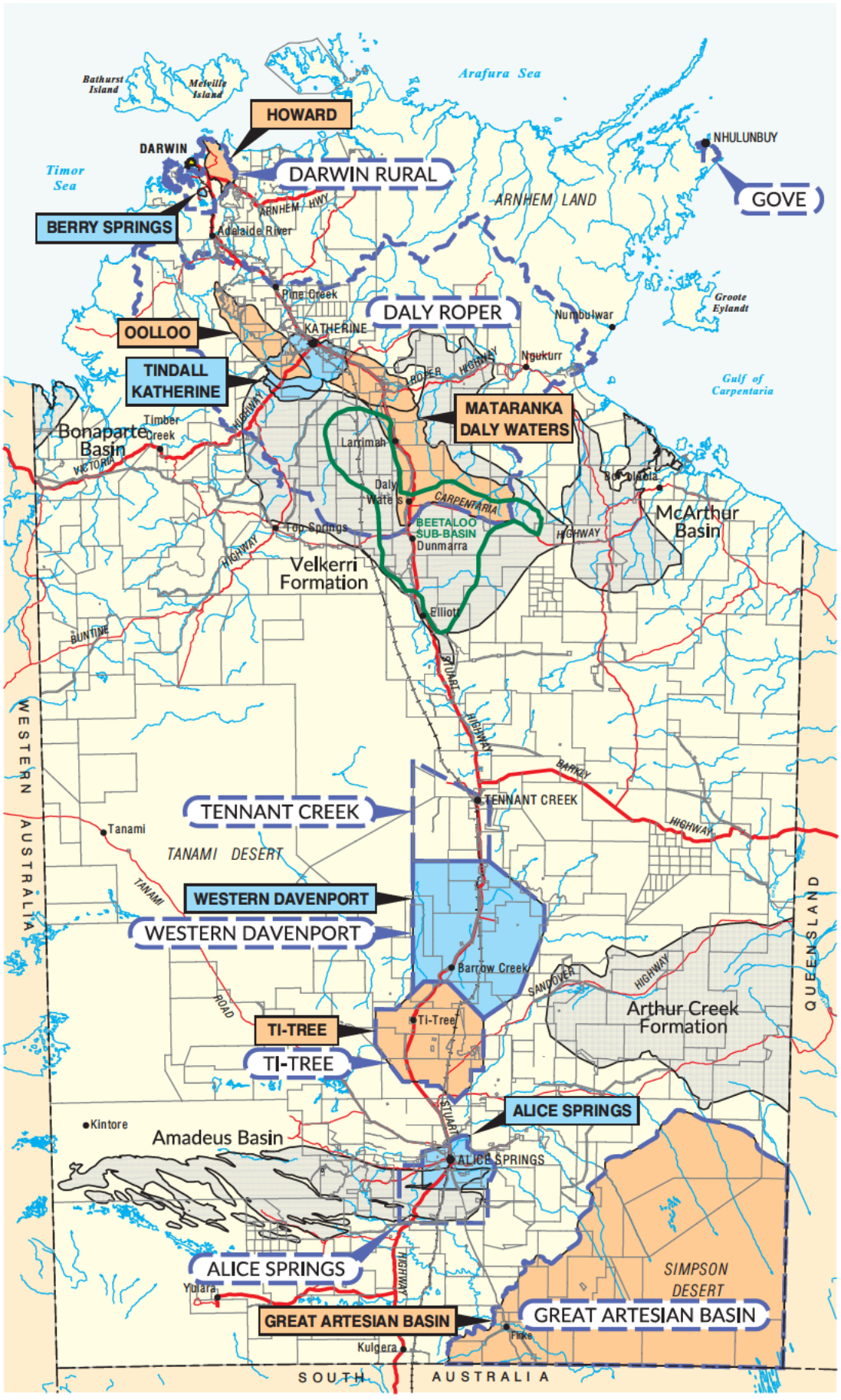
Bruwer, Q. & Tickell, S.J. (2015). Daly Basin Groundwater Resource Assessment – North Mataranka to Daly Waters, Department of Land Resource management, Water Resources Report Number 20/2015D

Water Allocation Plan for the Tindall Limestone Aquifer, Katherine 2016-2019, Document No: 08/2016D

Terms and Definitions

Sustainable Yield	The volume of groundwater that can be extracted from an aquifer on a sustained basis without impairing water quality or causing environmental damage.
Consumptive Pool	The volume of water available for allocation to consumptive beneficial uses after considering the water requirements of the environment.
Water Entitlement	A volume of water that may be extracted from an aquifer through either a licenced entitlement or a stock and domestic entitlement.
Maximum Entitlements	The volume of water that has been allocated to consumptive beneficial uses.
Announced Allocation	A portion of a licence entitlement volume that can be taken in a year, announced annually in May. Applied in systems where the volume of water that can sustainability be taken from the aquifer varies from year to year.
Security Level	Represents the order in which Annual Announced Allocations are applied to licence holders, e.g. in years when a less than 100% announced allocation is required, Low Security licence allocations are reduced first, then medium security licences and finally high security licences, as is required to meet objectives for minimum change in river flow.

NT WATER CONTROL DISTRICTS, WATER ALLOCATION AREAS, PROSPECTIVE SOURCE ROCKS & BEETALOO SUB-BASIN



NORTHERN TERRITORY OF AUSTRALIA

Water Control Districts are areas declared where there is a need for enhanced management for the sustainability of groundwater reserves and river flows.

Within a Water Control District a bore construction permit is required, water allocation plans can be developed and water extraction licences are required unless there is a specific exemption in place.

Water Allocation Plans aim to ensure the equitable sharing of available water between users, to protect the environment and ensure the long term sustainability of the water resource.

They usually occur in regions where there are competing demands for water, there is risk from water use to significant environmental values or a need to manage the whole system (surface water and groundwater resources) due to their significant inter connection.

NORTHERN TERRITORY GOVERNMENT

For further information contact:
Dept. of Environment and Natural Resources
Water Resources Division
P: 08 8999 4455
E: waterresources@nt.gov.au
Web: denr.nt.gov.au
Goyder Centre, Chung Wah Terrace
Palmerston

LEGEND

- Water Control Districts
- Declared Water Allocation Plans
- Water Allocation Plans in Progress
- Beetaloo Sub Basin
- Prospective Source Rocks

GENERAL FEATURES

- Primary Road
- Secondary Road
- Railway
- State Border
- Watercourse

May 2017
File: NT_Water-Control-Districts-Allocation-Areas_PSR_BSB
Drawing Ref: DENR2017028

kilometres 0 100 200 300 400 kilometres

Projection Lamberts Conformal Conic
Standard Parallels 23°20'00"S & 12°40'00"S
Horizontal Datum GDA 94

GDA

Joanne Townsend
Department of Environment and Natural Resources
PO Box 496
PALMERSTON NT 0830

By email: [redacted]

Dear Ms Townsend

RE: SUBMISSION TO THE SCIENTIFIC INQUIRY INTO HYDRAULIC FRACTURING IN THE NORTHERN TERRITORY

The Inquiry panel thanks The Department of Environment and Natural Resources (DENR) for its submission on 18 May 2017.

The Inquiry Panel has the below queries following the reading of DENR's submission.

Please provide a response by Wednesday 24 May 2017 as the Inquiry Panel is preparing its Interim Report and seeks the below for its understanding.

Recharge rates

- Please provide information on the recharge rates of the Cambrian Limestone Aquifers in the Beetaloo Basin, particularly differentiating between recharge rates in the north and south of this Basin.
- How does DENR determine these recharge rates and what is the uncertainty in the estimates?

Groundwater dependent ecosystems (GDE)

- Please list the GDE's known to exist in the Beetaloo Basin (exclude those to the north of the Basin (e.g. Daly River, Roper River system).
- Are Newcastle Waters and Lake Woods regarded as groundwater dependent ecosystems?

Water availability (Submission p6)

- It is noted that bores producing less than 15 L/s (i.e. 1.3 ML/d) are excluded from requiring a water licence. Is there no time condition on this figure? Does this also apply to a potential bore field of say 5 bores producing water for hydraulic fracturing, where each could be producing less than 15 L/s? Such a bore field could produce around 65 ML/d.

- Does DENR have any data on the amount of drawdown (and its lateral extent) that could occur as a result of a bore field of say 3-4 bores all pumping at say 10 L/s over a 60 day period?
- What would the recovery rate for this drawdown be?

General

- What is the difference between 'sustainable yield' and 'consumptive pool' (Submission Attachment B, p6)?

Thank you in advance for your Agency's cooperation.

Yours sincerely

THE HON JUSTICE RACHEL PEPPER
Chair

22 May 2017

Please direct all correspondence regarding the Scientific Inquiry into Hydraulic Fracturing to:
Hydraulic Fracturing Taskforce
GPO Box 4396, Darwin NT 0801
T 08 8999 6573
E fracking.inquiry@nt.gov.au
W frackinginquiry.nt.gov.au

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

Chief Executive Officer
Goyder Centre
25 Chung Wah Terrace
PALMERSTON NT 0830

Postal Address
GPO Box 496
PALMERSTON NT 0831

[redacted]

File Ref:
TRIM No. DLR2014/0080-0001

The Hon Justice Rachel Pepper
Chair
Hydraulic Fracturing Taskforce
GPO Box 4396
DARWIN NT 0801

Dear Justice Pepper

RE: REQUEST FOR ADDITIONAL INFORMATION TO THE DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES SUBMISSION TO THE SCIENTIFIC INQUIRY INTO HYDRAULIC FRACTURING IN THE NORTHERN TERRITORY

In response to a request from Mr James Pratt of your office on 22 May 2017 requesting additional information on the Department of Environment and Natural Resources submission, we have prepared the attached Addendum to our original submission.

Should you require any further clarification on the Addendum or our submission in general please contact this office.

Yours sincerely

JOANNE TOWNSEND
Chief Executive Officer

Date: 24 May 2017

Addendum 1
Department of Environment and Natural Resources Submission to the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory

Request for Additional Information by the Hydraulic Fracturing Taskforce on 22 May 2017

Recharge rates

Please provide information on the recharge rates of the Cambrian Limestone Aquifers in the Beetaloo Basin, particularly differentiating between recharge rates in the north and south of this Basin.

Northern Beetaloo Basin

In the area east of the Stuart Highway, a groundwater assessment has been undertaken which presents the understanding of the recharge process occurring (ref: Bruwer and Tickell, 2015 Water Resources Report Number 20/2015D). This is based on observed groundwater level data from between Katherine and Mataranka, and southward to Daly Waters. Monitored groundwater level data to the west of the Stuart Highway (ie. the Sturt Plateau region) indicates that the response pattern is similar from east to west across this region.

The recharge to the groundwater system represents a transition between the regimes of Top End aquifers typically evidenced as seasonally oscillating water levels, and the episodic recharge regimes generally across the arid zone. The reason is that recharge through the shallow soil profile will only occur once the matric potential of (dry) soils is satisfied and the soil matrix becomes saturated. Generally, in the central and arid zones of the NT, the threshold equates to about 700mm seasonal rainfall. The average annual rainfall in the vicinity of Larrimah is 713mm.

Observed groundwater levels in the Cambrian aquifer overlying the North Beetaloo Basin characterise this part of the system as seasonally responsive but muted. The increasing levels measured since the commencement of monitoring in the late 1990's indicate accumulation in the groundwater store due to the much higher than average wet period experienced since the late 1990's.

Southern Beetaloo Basin

The Southern Beetaloo Basin south of Daly Waters, underlies the aquifers of the Cambrian aged Georgina Basin. These aquifers are in the Anthony Lagoon Formation at shallow depth (generally <200m) which confine the deeper Gum Ridge Formation (Tindall Limestone) aquifers below it (approx. between 200m and 800m). The Gum Ridge Formation subcrops at shallow depth only around the margins of the Georgina Basin. That means that any recharge occurring in this area is received only by the uppermost groundwater system.

There is currently no groundwater level monitoring in either of the Cambrian Aquifers of the Georgina Basin. Hence, there is no knowledge of the behaviour and response to seasonal or event based recharge to the Anthony Lagoon Formation aquifers. Any inference of recharge in the Gum Ridge (Tindall Limestone) Formation basin is made through assessment of groundwater quality data and water isotope analysis which indicate fresher and younger groundwater on the western margin of the basin (approximately parallel to the Stuart Highway).

How does DENR determine these recharge rates and what is the uncertainty in the estimates?

For the area north of Daly Waters, the quantification of recharge is approached using three different methodologies as described in the Water Resources Report Number 20/2015D mentioned above. Two methods are empirical approaches based on Chloride Mass Balance and a general Water Balance. The third uses a modelled approach in which the recharge component is extracted. All three methods arrive at a similar order of magnitude estimate for áverage' annual recharge.

The level of uncertainty has not been quantified. However, the assessment of recharge using three different approaches confirms that recharge processes are active and provides a reasonable level of confidence that the recharge amount is within the calculated order of magnitude.

Groundwater dependent ecosystems (GDE)

Please list the GDEs known to exist in the Beetaloo Basin (exclude those to the north of the Basin (e.g. Daly River, Roper River system).

The Department does not have any data on potential GDEs in the area underlain by the Beetaloo Basin. Generally, groundwater levels are beyond the reach of terrestrial vegetation types, and there are no known discharge areas from either the Anthony Lagoon or Gum Ridge Formations.

Are Newcastle Waters and Lake Woods regarded as groundwater dependent ecosystems?

No. The groundwater level in this area is greater than 30m depth, and so there is no connection to these surface water systems.

Water availability

It is noted that bores producing less than 15 L/s (i.e. 1.3 ML/d) are excluded from requiring a water licence. Is there no time condition on this figure? Does this also apply to a potential bore field of say 5 bores producing water for hydraulic fracturing, where each could be producing less than 15 L/s? Such a bore field could produce around 65 ML/d.

There is no time limit on delivery of less than 15L/s from a bore outside a water control district beyond which a water extraction licence is required. The exemption applies to

individual bores and, consequently, no matter how many bores may constitute an operational bore-field, provided each bore does not provide more than 15L/s, then a water extraction licence is not required for the operation of the bore-field.

Does DENR have any data on the amount of drawdown (and its lateral extent) that could occur as a result of a bore field of say 3-4 bores all pumping at say 10 L/s over a 60 day period?

There is data available to provide approximate representation of the hydraulic nature of the aquifer systems overlying the Beetaloo Basin. The calculations below have been made using simple analytical equations assuming the aquifer is homogeneous and isotropic, and may be represented with the hydraulic parameters as stated. The bore field is assumed to be configured in a square pattern with bores at each corner and 1.5 km apart.

There are three possible sources of groundwater that occur in confined and unconfined conditions:

a) Anthony Lagoon Aquifers (usually unconfined);

b) Gum Ridge Formation Aquifers (unconfined); and

c) Gum Ridge Formation Aquifers (confined).

a) If water is sourced from unconfined Anthony Lagoon Aquifers

- The transmissivity (T) is 530 m2/d
- The specific yield (Sy) is 2%

The drawdown would extend 1.8kms from each corner of the bore field. At 1km away from each bore, the drawdown would be 0.2m. The greatest drawdown of 1.9m would occur at each bore.

(b) If water is sourced from unconfined Gum Ridge Formation Aquifers

- The transmissivity (T) is 1100 m2/d
- The specific yield (Sy) is 4%

The drawdown would extend 1.9kms from each corner of the bore field. At 1km away from each bore, the drawdown would be 0.08m. The greatest drawdown of 0.9m would occur at each bore.

(c) If water is sourced from confined Gum Ridge Formation Aquifers

- The transmissivity (T) is 1100 m2/d
- The storage coefficient (S) is 0.001%

The drawdown would extend 10.4kms from each corner of the bore field. At 1km away from each bore, the drawdown would be 0.7m. The greatest drawdown of 0.9m would occur at each bore.

What would the recovery rate for this drawdown be?

Theoretically, full recovery will be achieved in 60 days.

General

What is the difference between 'sustainable yield' and 'consumptive pool' (Submission Attachment B, p6)?

There is no difference between these two terms for a water resource that is at less than or equal to full allocation - the consumptive pool (all licensed and unlicensed extractions) is managed so that it does not exceed the sustainable yield of the water resource. In an over-allocated system, however, the consumptive pool exceeds the sustainable yield.

References

Bruwer, Q. and Tickell, S. J., (2015). Daly Basin Groundwater Resource Assessment - North Mataranka to Daly Waters, Department of Land Resource Management, Water Resources Report Number 20/2015D.

SCIENTIFIC INQUIRY INTO
HYDRAULIC FRACTURING
IN THE NORTHERN TERRITORY

Joanne Townsend
Department of Environment and Natural Resources
PO Box 496
PALMERSTON NT 0830

By email [redacted]

Dear Ms Townsend

RE: SUBMISSION TO THE SCIENTIFIC INQUIRY INTO HYDRAULIC FRACTURING IN THE NORTHERN TERRITORY

The Inquiry panel thanks the Department of Environment and Natural Resources (DENR) for its submission on 18 May 2017.

The Inquiry Panel has an additional query following the reading of DENR's submission.

Please provide a response by Monday 29 May 2017, as the Inquiry Panel is preparing its Interim Report and seeks the below for its understanding.

Can the Department provide information on the possible impact on the Katherine water supply (8,000 ML/y) from a shale gas development in the Beetaloo Basin (assume in the area close to Daly Waters (involving Pangaea, Origin & Santos)) of say 2,000 wells using an average of around 5,000 ML/y drawn from the Cambrian Limestone Aquifer over a period of 25 years? (This water use might be as high as 10,000 mL/y for a period of 10 years during the 25 year period).

Thank you in advance for your Agency's cooperation.

Yours sincerely

THE HON JUSTICE RACHEL PEPPER
Chair
24 May 2017

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

Chief Executive Officer
Goyder Centre
25 Chung Wah Terrace
PALMERSTON NT 0830

Postal Address
GPO Box 496
PALMERSTON NT 0831

[redacted]

File Ref:
TRIM No. DLR2014/0080-0001

The Hon Justice Rachel Pepper
Chair
Hydraulic Fracturing Taskforce
GPO Box 4396
DARWIN NT 0801

Dear Justice Pepper

RE: REQUEST FOR ADDITIONAL INFORMATION TO THE DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES SUBMISSION TO THE SCIENTIFIC INQUIRY INTO HYDRAULIC FRACTURING IN THE NORTHERN TERRITORY

In response to your correspondence of 24 May 2017 requesting the Department of Environment and Natural Resources provide further information with respect to its submission of the 18 May 20147, we have prepared the attached Addendum 2 to our original submission.

Should you require any further clarification on the Addendum or our submission in general please contact this office.

Yours sincerely

JOANNE TOWNSEND
Chief Executive Officer

Date: 26 May 2017

Addendum 2
Department of Environment and Natural Resources Submission to the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory

Request for Additional Information by the Hydraulic Fracturing Taskforce on 24 May 2017

Request

What is the possible impact on the Katherine water supply (8,000ML/y) from a shale gas development in the Beetaloo Basin (assume in the area close to Daly Waters (involving Pangaea, Origin & Santos) of say 2,000 wells using an average of around 5,000ML/y drawn from the Cambrian Limestone Aquifer over a period of 25 years?

Response

Exploration Permit Areas

Various consortiums which include the companies of Origin, Santos and Pangaea are title holders for the leases overlying most of the Beetaloo Sub-basin.

Pangaea holds EP167 and EP168 which extends approximately from the Stuart Highway to the Buntine Highway, and from as far north as Mataranka to the south as far as Elliott. These exploration permit areas cover the north Beetaloo Basin. The north Cambrian aged Wiso Basin which hosts the limestone groundwater system overlies this area.

Origin holds EP98, EP117 and EP76 and Santos EP161 in the southern Beetaloo Basin. The Georgina Basin, which hosts Cambrian Limestone aquifers in the Anthony Lagoon and Gum Ridge Formations, overlies these exploration permit areas.

Katherine Water Supply

Katherine water supply is largely drawn from the Donkey Camp Pool on the Katherine River. This is a surface water source. A large proportion of the river flow is spring fed from the 17 Mile Creek system. The springs emanate from the Cretaceous aged sandstones on the Muruwal Plateau at the southern edge of Nitmiluk National Park. There is no connection of the sandstone with the aquifers overlying the Beetaloo Sub-basin and therefore no impact would occur to this water source.

A water supply borefield provides a small proportion of Katherine's water supply. This borefield sources groundwater from the Tindall Limestone Aquifer (TLA) of the Daly Basin. Although the Daly Basin is in hydraulic connection with the Georgina and Wiso Basins, the groundwater flow regimes within each system are separate entities. The groundwater of the TLA in the vicinity of Katherine discharges in the Katherine River, whilst groundwaters of the Georgina Basin discharge in the Roper River.

Groundwaters of the Wiso Basin discharge to the Flora River. Therefore, any groundwater extractions occurring in the Georgina and Wiso Basins will not have any impact on the TLA around Katherine.

Groundwater Extraction in the Beetaloo Sub-basin

Water Resources report 20/2015D (Bruwer and Tickell, 2015) provides the assessment of a modelling scenario for a borefield extraction of 40,000ML/y in an area to the east of Larrimah (ref: Chapter 4). This analysis shows that under a 40,000ML/y extraction regime, the impact on flow in the Roper River as measured at gauging station G9030176 near Mataranka Homestead will only exceed 20% after about 50 years. Further downstream at gauging station G9030013 at Elsey Homestead, the effects on flow will not exceed 20% at any time within the 115 year modelling period.

References

Bruwer, Q. and Tickell, S. J., (2015). Daly Basin Groundwater Resource Assessment - North Mataranka to Daly Waters, Department of Land Resource Management, Water Resources Report Number 20/2015D.